105 A) ILUMINACION INTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES

Del 17 al 28 de octubre de 1994

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105 A) ILUMINACION INTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES

Del 17 al 28 de octubre de 1994

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105 A) ILUMINACION INTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES
Del 17 al 28 de octubre de 1994.

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Iztacalco, Méx.D.F.

15. Pedro Rodríguez

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Tel.

16. Ing. J. Félix Roque Romero
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18 Fidel Rosales Monroy
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DIVISION DE EDUCACION CONTINUA
CURSOS ABIERTOS
ILUMINACION INTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES
Del 17 al 28 de octubre de 1994.

FECHA	HORARIO	TEMA	PROFESORE
LUNES 17 OCT.	17:00 A 18:00 HRS.	APERTURA EVALUACION INICIAL	ING. CARLOS GARCIA R.
	18:00 A 21:00	LUZ Y COLOR TERMINOLOGIA	ING. ERNESTO MENDOZA
MARTES 18	17:00 A 19:00	BALASTROS	ING. ERNESTO MENDOZA
	19:00 A 21:00	LAMPARAS	ING. ALFREDO BADILLO
MIERCOLES	17:00 A 21:00	CONTROL DE LUZ FOTOMETRIA SELECCION DE LUMINARIOS	ING. JOSE LUIS BONILLA
JUEVES 20	17:00 A 21:00	NIVELES DE ILUMINACION CALCULO DE ILUMINACION	ING. CARLOS GARCIA R.
VIERNES 21	17:00 A 21:00	CALCULO DE ILUMINACION EJERCICIO DE ILUMINACION	ING. CARLOS GARCIA R.
LUNES 24	17:00 A 21:00	ARQUITECTURA DE LA LUZ ILUMINACION DE HOTELES	ARQ. ENRIQUE QUINTERO
MARTES 25	17:00 A 21:00	ILUMINACION COMERCIAL EJEMPLO DE ILUMINACION	ARQ. ENRIQUE QUINTERO
MIERCOLES 26	17:00 A 21:00	ILUMINACION DE OFICINAS EJEMPLO DE APLICACION	ING. JAIME GALINDO
JUEVES 27	17:00 A 19:00	ILUMINACION DE IGLESIAS Y MUSEOS ILUMINACION DE BANCOS Y LIBRERIAS	ARQ. ENRIQUE QUINTERO
	19:00 A 21:00	ILUMINACION INDUSTRIAL	ING. CARLOS GARCIA R.
VIERNES 28	17:00 A 19:30	AHORRO DE ENERGIA EN INSTALACIONES DE ILUMINACION	ING. CARLOS GARCIA R.
	19:30 A 20:00	EVALUACION	
	20:00 A 20:45	MESA REDONDA	
	20:45 A 21:00	CLAUSURA	

*rgd.

EVALUACION DEL PERSONAL DOCENTE

CURSO: ILUMINACION INTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES
FECHA: Del 17 al 28 de octubre de 1994.

CONFERENCISTA	DOMINIO DEL TEMA	USO DE AYUDAS AUDIOVISUALES	COMUNICACION CON EL ASISTENTE	PUNTUALIDAD
ING. CARLOS GARCIA R.				
ING. ERNESTO MENDOZA				
ING. ALFREDO BADILLO				
ING. JOSE LUIS BONILLA				
ARQ. ENRIQUE QUINTERO				
ING. JAIME GALINDO				

EVALUACION DE LA ENSEÑANZA

ORGANIZACION Y DESARROLO DEL CURSO	
GRADO DE PROFUNDIDAD LOGRADO EN EL CURSO	
ACTUALIZACION DEL CURSO	
APLICACION PRACTICA DEL CURSO	

EVALUACION DEL CURSO

CONCEPTO	CALIF.
CUMPLIMIENTO DE LOS OBJETIVOS DEL CURSO	
CONTINUIDAD EN LOS TEMAS	
CALIDAD DEL MATERIAL DIDACTICO UTILIZADO	

ESCALA DE EVALUACION: 1 A 10

1.- ¿LE AGRADO SU ESTANCIA EN LA DIVISION DE EDUCACION CONTINUA?

SI	NO

SI INDICA QUE "NO" DIGA PORQUE.

2.- MEDIO A TRAVES DEL CUAL SE ENTERO DEL CURSO:

PERIODICO EXCELSIOR		FOLLETO ANUAL		GACETA UNAM		OTRO MEDIO	
PERIODICO EL UNIVERSAL		FOLLETO DEL CURSO		REVISTAS TECNICAS			

3.- ¿QUE CAMBIOS SUGERIRIA AL CURSO PARA MEJORARLO?

4.- ¿RECOMENDARIA EL CURSO A OTRA(S) PERSONA(S)?

SI		NO	

5.- ¿QUE CURSOS LE SERVIRIA QUE PROGRAMARA LA DIVISION DE EDUCACION CONTINUA.

6.- OTRAS SUGERENCIAS:

DIVISION DE EDUCACION CONTINUA
CURSOS ABIERTOS
ILUMINACION INTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES
Del 17 al 28 de octubre de 1994.

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CURSO: ILUMINACION INTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES
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CONFERENCISTA	DOMINIO DEL TEMA	USO DE AYUDAS AUDIOVISUALES	COMUNICACION CON EL ASISTENTE	PUNTUALIDAD
ING. CARLOS GARCIA R.				
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ARQ. ENRIQUE QUINTERO				
ING. JAIME GALINDO				

EVALUACION DE LA ENSEÑANZA

ORGANIZACION Y DESARROLO DEL CURSO	
GRADO DE PROFUNDIDAD LOGRADO EN EL CURSO	
ACTUALIZACION DEL CURSO	
APLICACION PRACTICA DEL CURSO	

EVALUACION DEL CURSO

CONCEPTO	CALIF.
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PERIODICO EL UNIVERSAL		FOLLETO DEL CURSO		REVISTAS TECNICAS			

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4.- ¿RECOMENDARIA EL CURSO A OTRA(S) PERSONA(S)?

SI		NO	

5.- ¿QUE CURSOS LE SERVIRIA QUE PROGRAMARA LA DIVISION DE EDUCACION CONTINUA.

6.- OTRAS SUGERENCIAS:

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DIVISION DE EDUCACION CONTINUA

CURSOS ABIERTOS.

ILUMINACION INTERIOR:

PRINCIPIOS, DISEÑOS Y APLICACIONES.

B A L A S T R O S.

ING. ERNESTO MENDOZA.

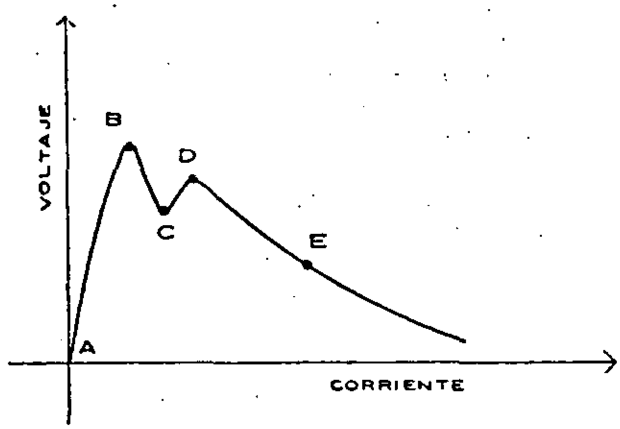
Palacio de Minería Calle de Tacuba 5 Primer piso Deleg. Cuauhtémoc 06000 México, D.F. APDO. Postal M-2285
Teléfonos: 512-8955 512-5121 521-7335 521-1987 Fax 510-0573 521-4020 AL 26

EL BALASTRO

Finalidad: El transformador de alta reactancia de dispersión.

Tipos de Balastros.

El fenómeno de la descarga eléctrica en gas es un fenómeno complejo, y la gráfica siguiente nos da idea del comportamiento de las cargas cuando se lleva a cabo el fenómeno.



La información que se puede obtener de la gráfica y que nos interesa exponer, se encuentra entre los puntos D y E que es la región de operación normal de la lámpara fluorescente.

En esta parte de la gráfica se ve que habiéndose superado el voltaje Vx el gas presenta una región de resistencia negativa, y en donde la corriente eléctrica a través del gas crece teóricamente hasta el infinito.

Es debido a ésto que se justifica la existencia de los balastros, que son dispositivos que sirven primordialmente para -- mantener la corriente eléctrica a través de la lámpara, en un rango de valores, que permiten a la lámpara operar satisfactoriamente y sobre todo protegerla de la destrucción.

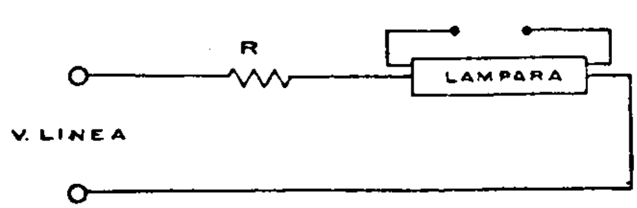
El vocablo balastro se deriva de la palabra inglesa "ballast" que significa lastre.

De acuerdo a la definición que la norma CCONNIE - 16.2 1 tiene, el balastro, "es un dispositivo que, por medio de inductancias, capacitancias, o resistencias, solas o en combinación, - limita la corriente de lámparas fluorescentes al valor requerido para su operación correcta y también, cuando es necesario -

suministra la tensión y corriente de arranque, y en el caso de balastros para lámparas de arranque rápido, suministra la tensión para calentamiento de los catódos".

En principio, un balastro puede ser cualquier elemento que limita la corriente, como por ejemplo, una resistencia, una capacitancia, una inductancia ó una combinación de los elementos anteriores.

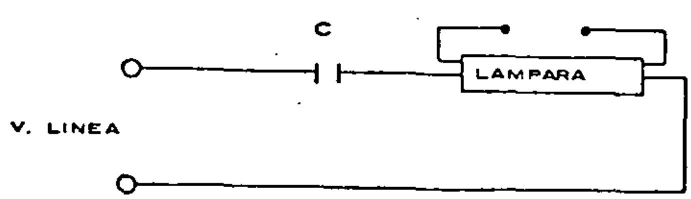
El hecho de usar lámparas fluorescentes obedece a que su eficiencia lumínica es mayor que las incandescentes debido a que éstas últimas emiten un gran porcentaje de radiación en la región infrarroja es decir en forma de calor; entonces si nosotros usamos un balastro a base de resistencias, lo que logramos es crear pérdidas, y no tiene caso usar una lámpara fluorescente que es incluso más cara, si la eficiencia del conjunto balastro-lámpara es parecida a una incandescente.



El usar un balastro a base de capacitancias no es económico debido a las bajas frecuencias de transmisión de energía -- que se utilizan comunmente (50 ó 60 Hz), además de que la forma de onda de la corriente de la lámpara se deformaría - notablemente, creando picos que dañarían a la lámpara .

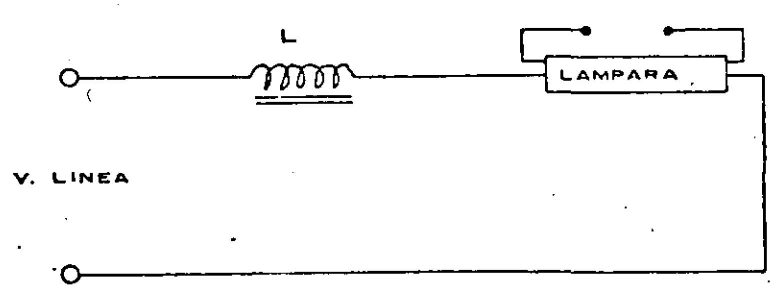
En otras palabras, se necesitarían valores altos de capaci tancia para poder proporcionar a la lámpara una corriente- nominal de operación muy deformada.

Sin embargo el capacitor resulta ser buen balastro desde - 400 Hz en adelante.



El tipo restante de balastro es una "reactancia inductiva". También conocida como inductancia, inductor, o bobina de choque.

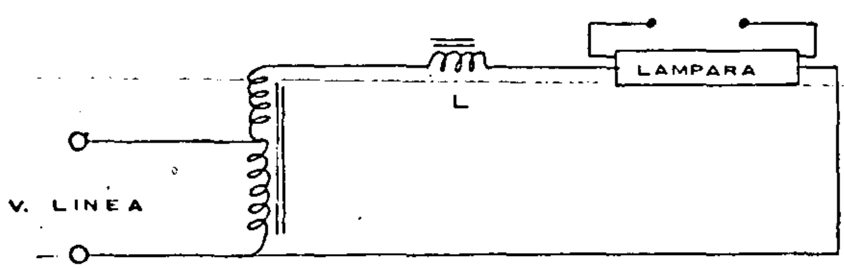
De los tipos de balastros antes mencionados, éste es sin duda el más satisfactorio y el más económico, y en la actualidad casi todos los balastros están formados por inductancias, o combinaciones de éstas con capacitancias.



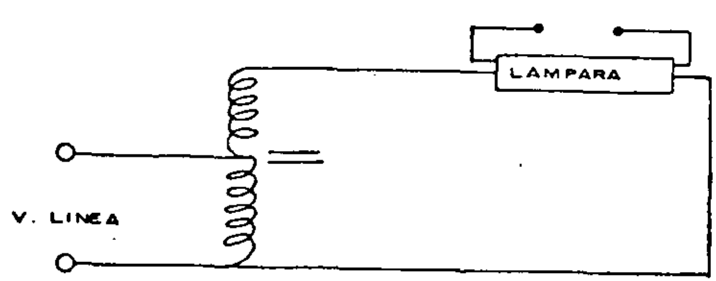
INDUCTANCIA SERIE

EL AUTOTRANSFORMADOR DE ALTA REACTANCIA DE DISPERCION

Los circuitos mostrados anteriormente, funcionan en redes de alimentación cuyo voltaje es mayor que el voltaje mínimo de encendido de la lámpara, sin embargo cuando éste último es superior al de línea, se necesitaría, además de la inductancia serie, un transformador o autotransformador que elevara la tensión hasta un valor suficiente para encender la lámpara tal como se muestra en la siguiente figura:

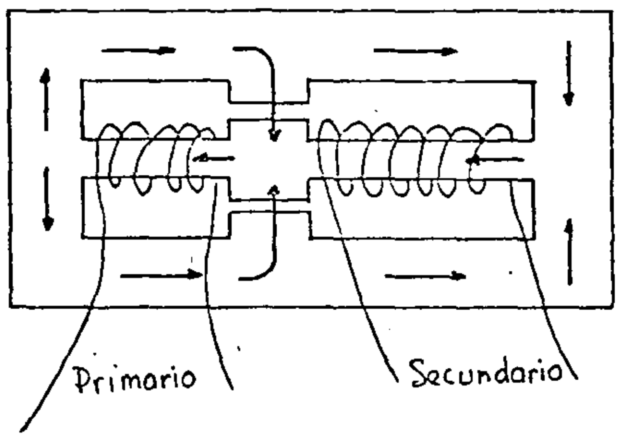


Esta combinación es completamente satisfactoria eléctricamente; aunque excesivamente costosa. Probablemente el avance técnico de más significación en el campo de la fabricación de balas -- tros para lámparas fluorescentes y en general para lámparas - de descarga eléctrica en gases, fué el desarrollo de los balas tros "autotransformadores de alta reactancia de dispersión" - que son las que se utilizan actualmente. Dicho de forma ele - mental, el balastro autotransformador de alta reactancia combi na los elementos del circuito de la Fig. (autotransfor mador y bobina de choque) , en un solo núcleo, lo que disminu - ye el tamaño y costo, y aumenta la eficiencia del circuito. Es te tipo de balastro se muestra esquemáticamente en la siguiente figura.



AUTOTRANSFORMADOR ALTA REACTANCIA

En la figura se muestra la estructura del núcleo de acero y de los devenados, así como las trayectorias de las Líneas Magnéticas.



DIBUJO ESQUEMATICO

Nótese en la figura que el autotransformador de alta reactancia tiene 2 devenados, uno primario y otro secundario, separados mediante entrehierros magnéticos.

En un transformador ordinario tendríamos ambos devanados uno encima del otro, ya que en este caso resulta importante que todo el flujo magnético que produce el devanado primario pase a través del devanado secundario. Al embobinar ambos devanados uno encima del otro se logra ésto fácilmente. Sin embargo en un - autransformador de alta reactancia, al tener separados mediante entrehierros los devanados primario y secundario, intencionalmente obligamos que parte del flujo magnético creado por - el devanado creado por el devanado primario, pase a través de- los entrehierros, y no pase a a través del devanado secundario. Esta alta dispersión del flujo magnético creada a propósito, manifiesta su efecto en forma de una reactancia inductiva parásita en serie con el circuito secundario y es precisamente esta - reactancia inductiva la que controla la corriente eléctrica a - través de la lámpara.

TIPOS DE BALASTROS

En resumen, para poder iniciar la descarga eléctrica en un tubo fluorescente, se necesitan 2 condiciones:

1. Que exista entre sus extremos un voltaje igual o mayor que el mínimo necesario especificando por el fabricante de lám paras.

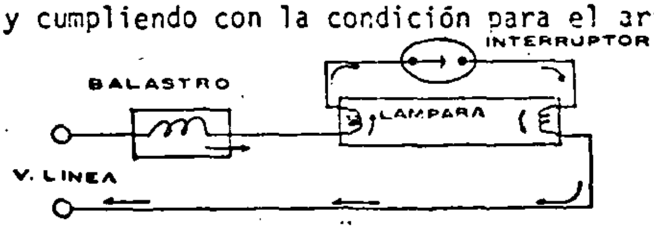
2. Que sus cátodos tengan al momento de arranque disponibles - electrones libres.

Esta segunda condición se puede lograr de tres formas diferen- tes y da lugar a la división de las lámparas y de los balas -- tros en tres tipos de encendido.

a) Encendido Precalentado
b) Encendido rápido
c) Encendido instantáneo

a) Encendido Precalentado:

Se conecta un interruptor térmico entre dos terminales - opuestas entre dos terminales opuestas de las lámparas, de tal manera que cuando está frío (el interruptor) - se pone en corto circuito, y origina que una corriente- circule a través de los cátodos de la lámpara calentan- dolos y cumpliendo con la condición para el arranque; -

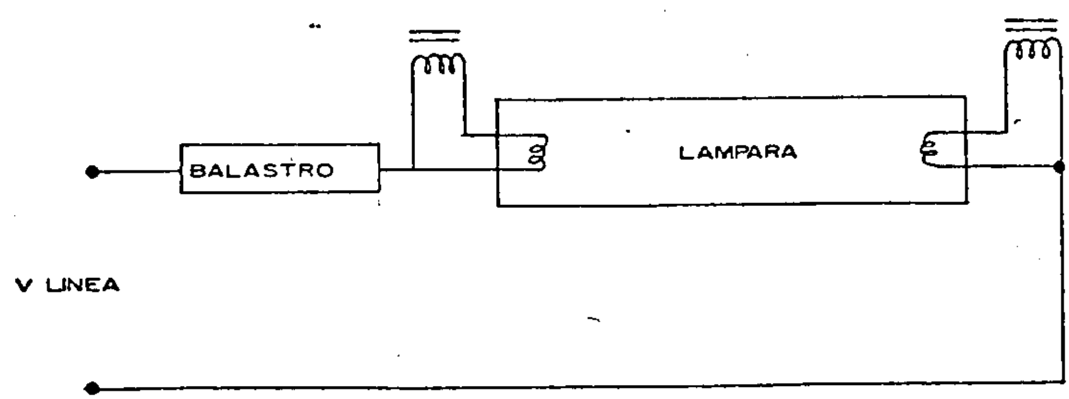


ENCENDIDO PRECALENTADO

un instante después se abre el interruptor térmico (cebador o arrancador) presentándose las dos condiciones necesarias -- para el encendido.

b) Encendido Rápido

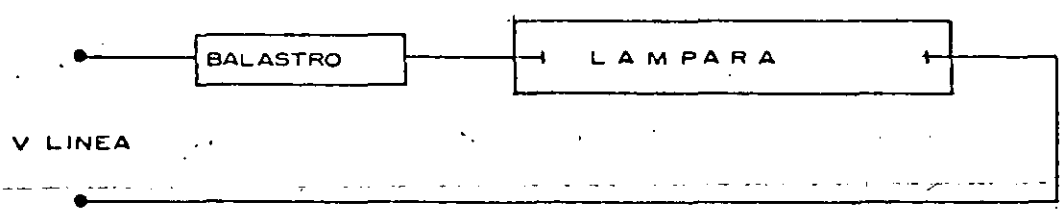
En el encendido rápido, devanados auxiliares proporcionan calentamiento contínuo a los cátodos mediante la aplicación de un voltaje pequeño en los mismos, con lo cual se tiene la nube electrónica disponible, y con la aplicación de un voltaje mayor al mínimo necesario se cumplen las condiciones para el encendido



ENCENDIDO RAPIDO

c) Encendido Instantáneo

En el encendido instantáneo se tienen disponibles los electrones en los cátodos por efecto de campo; ésto es que, para este tipo de encendido se amplía un voltaje en los extremos de la lámpara los suficientemente alto, como para que los electrones del material emisivo de los cátodos sean literalmente arrancados, y empiecen a viajar hacia el cátodo contrario iniciando la descarga eléctrica a través del gas.



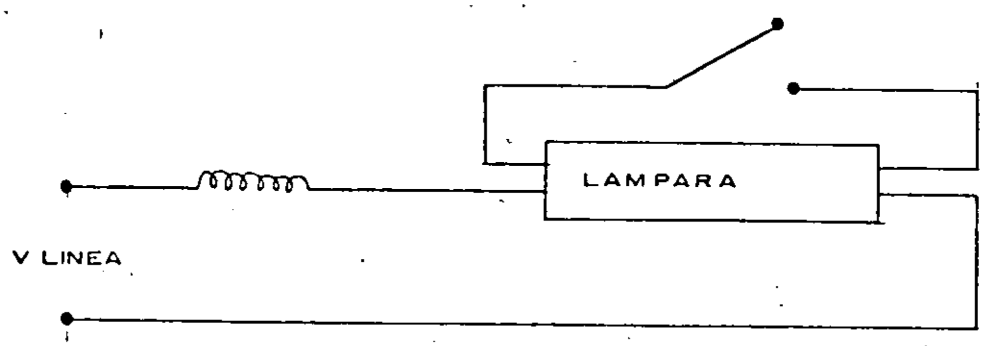
ENCENDIDO INSTANTANEO

Cada tipo de encendido presenta ventajas y desventajas sobre los otros, sin embargo todos tienen campo de aplicación, y por lo mismo mercado.

Ahora por el tipo de circuito que utilizan, los Balastros -- tienen otra división, a saber:

Principales Circuitos

a) El circuito más sencillo, es la inductancia serie o bobina de choque.

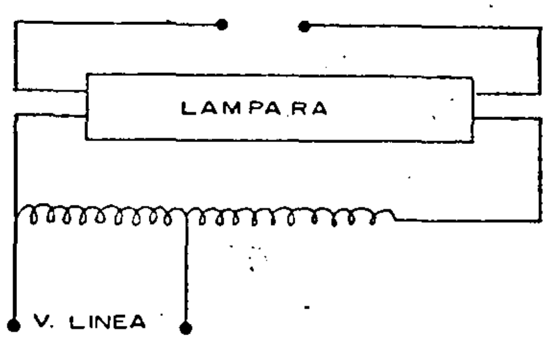


Se usa en líneas de alimentación cuyo voltaje excede el voltaje mínimo de encendido de la lámpara. Para el caso alto factor, se le agrega un capacitor en paralelo con la línea.

Normalmente se usa en encendido precalentado exclusivamente, aunque se puede utilizar también en encendido instántaneo.

b) Le sigue el circuito autotransformador de alta reactancia, que se usa en los casos en donde el voltaje mínimo de encendido es mayor que el voltaje de línea; usualmente son bajo factor, para alto factor, se utiliza un capacitor -

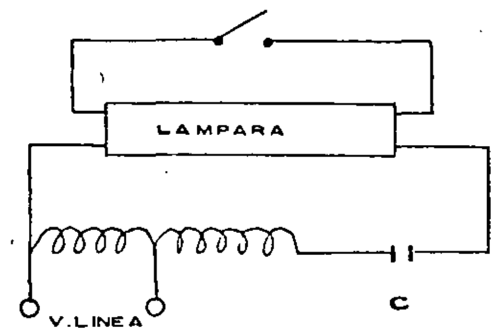
en serie con una inductancia, como se ve en líneas punteadas en el diagrama. Se usa en encendido precalentado, encendido rápido e instantáneo bajo factor de potencia. En este tipo de circuito, la regulación de la corriente de lámpara, se logra mediante la reactancia de dispersión exclusivamente



ALTA REACTANCIA

c) El tercer tipo de circuito es el autotransformador autorregulado; es de alto factor de potencia, y siempre tiene el capacitor en serie con la lámpara. Se usa en todos los balastros de encendido rápido alto factor, y en los de encendido instantáneo alto factor para una sola lámpara.

En este circuito, la combinación de la capacitancia en serie - con la reactancia inductiva de dispersión, proporciona una mejor regulación en la corriente del secundario, que el circuito anterior



BALASTROS H. I. D.

LAS LAMPARAS DE DESCARGA DE ALTA INTENSIDAD (H. I. D.), TAMBIEN SE COMPORTAN COMO LAS LAMPARAS FLUORESCENTES YA QUE PERTENECEN AL MISMO GRUPO DE LAMPARAS DE DESCARGA ELECTRICA EN GAS, POR LO TANTO TAMBIEN ES VALIDO EL RAZONAMIENTO ANTERIORMENTE EXPLICADO SOBRE LA JUSTIFICACION DE LA EXISTENCIA DE BALASTROS H. I. D.

LAS PRINCIPALES LAMPARAS H. I. D. SOBRE CUYOS BALASTROS HABLAREMOS SON :

1.- VAPOR DE MERCURIO
2.- ADITIVOS METALICOS
3.- VAPOR DE SODIO ALTA PRESION
4.- VAPOR DE SODIO BAJA PRESION (*)

(*) SE INCLUYE ESTA LAMPARA, AUNQUE ESTRICTAMENTE HABLANDO NO PERTENECE AL GRUPO H. I. D.

ESTAS LAMPARAS TIENEN COMPORTAMIENTOS DIFERENTES ENTRE SI, Y CON RESPECTO A LAS LAMPARAS FLUORESCENTES, Y UNO DE LOS ASPECTOS DONDE HAY MAYOR DIFERENCIA ES EN EL ARRANQUE.

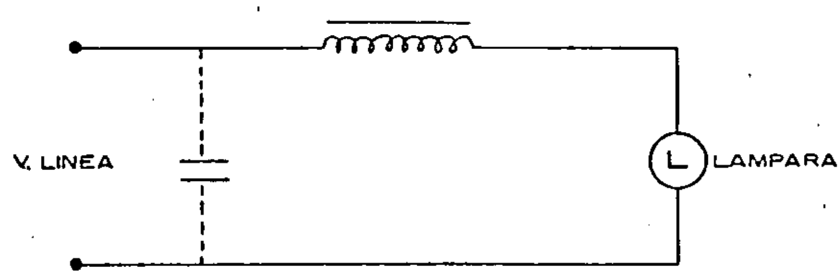
2..

AUN ASI, SUS BALASTROS TIENEN ASPECTOS EN COMUN, DE TAL MANERA QUE A CONTINUACION DESCRIBIREMOS EN FORMA GENERAL SUS CIRCUITOS :

I.- BALASTROS ATRASADOS :

SU NOMBRE SE DEBE A QUE EN LA FORMA DE ONDA EN LA LAMPARA, LA CORRIENTE VA ATRASADA RESPECTO AL VOLTAJE.

A ESTA CATEGORIA PERTENECEN LAS INDUCTANCIAS SERIE O "BOBINAS DE CHOKE" Y LOS AUTOTRANSFORMADORES DE ALTA REACTANCIA



INDUCTANCIA SERIE

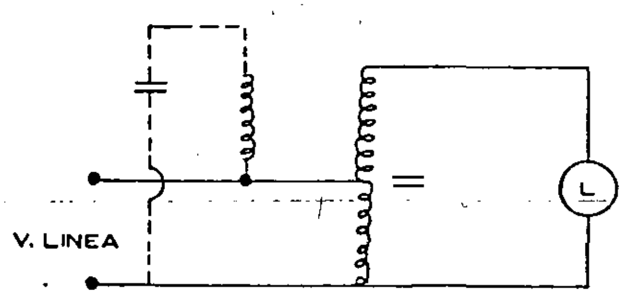
LA INDUCTANCIA SERIE ES EL BALASTRO MAS SENCILLO, Y SE UTILIZA PARA LAMPARAS CUYO VOLTAJE DE ENCENDIDO ES MENOR QUE LA TENSION DE LINEA.

NORMALMENTE ES DE BAJO FACTOR DE POTENCIA, Y SI SE

REQUIERE UN ALTO FACTOR, SE AGREGA UN CAPACITOR EN PARALELO CON LA LINEA.

SU REGULACION DEJA MUCHO QUE DESEAR Y SU CORRIENTE DE ENCENDIDO ES MAYOR QUE LA CORRIENTE NOMINAL DE OPERACION, POR LO QUE DEBE TOMARSE ESTO EN CUENTA PARA EL CALCULO DE LAS PROTECCIONES DE CIRCUITO.

EL VOLTAJE DE EXTINCION (VOLTAJE DE LINEA AL CUAL SE APAGA LA LAMPARA) ES ALTO, PROVOCANDO QUE SE APAGUE LA LAMPARA SI EXISTEN VARIACIONES FUERTES EN LA TENSION DE LINEA.



AUTOTRASFORMADOR ALTA REACTANCIA

EL AUTOTRANSFORMADOR DE ALTA REACTANCIA PERMITE ENCENDER UNA LAMPARA A CUALQUIER TENSION DE LINEA.

SI SE REQUIERE ALTO FACTOR DE POTENCIA, SE LE AGREGA UN CAPACITOR Y UNA INDUCTANCIA EN PARALELO CON LA LINEA COMO SE VE EN LA FIGURA.

SU REGULACION SIGUE SIENDO MALA COMO LA DE LA INDUCTANCIA SERIE (± 5% V LINEA ± 12% W LAMP.): SU CORRIENTE DE ENCENDIDO ES MENOR QUE LA CORRIENTE NOMINAL DE OPERACION, Y SU VOLTAJE DE EXTINCION TAMBIEN ES ALTO.

EN GENERAL, ES NECESARIO MENCIONAR QUE ESTOS BALASTROS ATRASADOS SON LOS MAS ECONOMICOS Y LOS QUE PROVEEN LAS CARACTERISTICAS DE OPERACION MENOS BUENAS.

II.- AUTOTRANSFORMADORES AUTORREGULADOS

EN EL MERCADO NACIONAL SE LES CONOCE COMO "AUTOTRANSFORMADORES AUTORREGULADOS" Y EN ESTADOS UNIDOS DE NORTEAMERICA SE LES LLAMA AUTOTRANSFORMADORES DE POTENCIA CONSTANTE (C. W. A.).

EL CONTAR CON UNA CAPACITANCIA EN COMBINACION CON UNA INDUCTANCIA PROVEE AL CIRCUITO DE MEJOR CONTROL SOBRE LA OPERACION DE LA LAMPARA.

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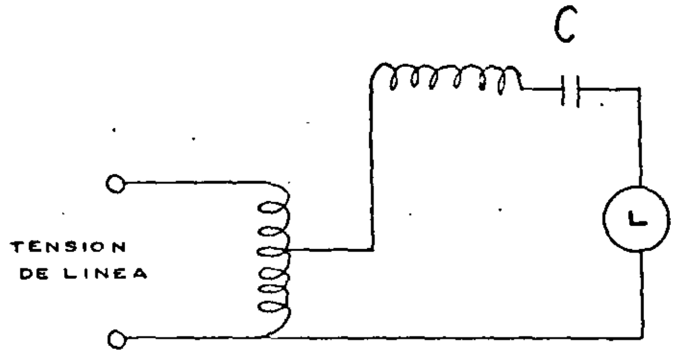


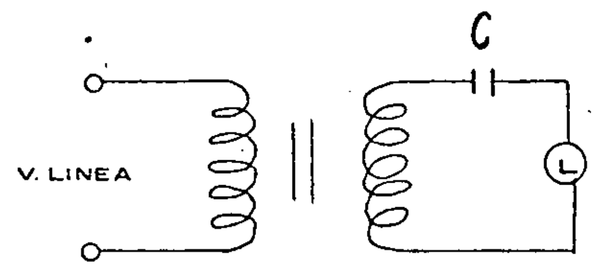
AUTOTRANSFORMADOR
AUTORREGULADO

EN ESTE CIRCUITO, QUE SIEMPRE SERA DE ALTO FACTOR DE POTENCIA, LAS CARACTERISTICAS EN GENERAL SON MEJORES QUE EN LOS CIRCUITOS ATRASADOS; SU REGULACION ES MEJOR (± 10% V LINEA ± 5% W LAMP.), SU CORRIENTE DE ENCENDIDO O ARRANQUE ES MENOR QUE LA CORRIENTE NOMINAL DE OPERACION, Y SU VOLTAJE DE EXTINCION ES MENOR QUE EN LOS CIRCUITOS ATRASADOS.

III.- TRANSFORMADORES DE POTENCIA CONSTANTE

ES EL MEJOR DE LOS BALASTROS, SU PRINCIPAL CARACTERISTICA DESDE EL PUNTO DE VISTA CIRCUITO, ES QUE NO EXISTE CONEXION ENTRE EL PRIMARIO Y EL SECUNDARIO AISLADO.

LA VENTAJA QUE SE DERIVA DE ESTA CONDICION ES SEGURIDAD PARA EL USUARIO.



TRANSFORMADOR DE POTENCIA CONSTANTE

POR OTRA PARTE LA REGULACION DE ESTE BALASTRO ES LA MEJOR DEL MERCADO YA QUE PARA UNA VARIACION EN TENSION DE LINEA DE ± 13% SE OBTIENE UNA VARIACION EN LA POTENCIA DE LAMPARA DE ± 2%, RAZON POR LA CUAL SE LES HA ASIGNADO EL NOMBRE DE TRANSFORMADORES DE POTENCIA CONSTANTE.

RESPECTO A LA CORRIENTE DE LINEA DURANTE EL ENCENDIDO, ES MENOR QUE LA CORRIENTE NOMINAL DE OPERACION, Y SU VOLTAJE DE EXTINCION ES TAN BAJO, QUE PRACTICAMENTE NO EXISTEN PROBLEMAS DE LAMPARAS APAGADAS POR VARIACIONES SEVERAS EN LA TENSION DE LINEA.

1.- BALASTROS PARA LAMPARAS DE VAPOR DE MERCURIO.-

SUS CIRCUITOS SON EXACTAMENTE LOS DESCRITOS ANTERIORMENTE, ES DECIR :

I.- ATRASADOS

II.- AUTOTRANSFORMADOR AUTORREGULADO

III.- TRANSFORMADOR DE POTENCIA CONSTANTE

2.- BALASTROS PARA LAMPARAS DE ADITIVOS METALICOS.-

LAS LAMPARAS DE ADITIVOS METALICOS REQUIEREN BALASTROS CON CARACTERISTICAS UN POCO DIFERENTES A LOS DE VAPOR DE MERCURIO, PRINCIPALMENTE PORQUE DESPUES DE CIERTO TIEMPO DE HABER ENCENDIDO LA LAMPARA, SE PRESENTA UN ESTADO DE BAJA CONDUCTANCIA EN EL ARCO ELECTRICO QUE EL BALASTRO DEBE SER CAPAZ DE SOPORTAR PROPORCIONANDO MAYOR ENERGIA DE LA NORMAL PARA MANTENER ENCENDIDA LA LAMPARA. ESTE FENOMENO SE CONOCE COMO "REIGNICION"

EL CIRCUITO APROPIADO, DE LOS DESCRITOS ANTERIORMENTE ES EL :

II) AUTOTRANSFORMADOR AUTORREGULADO.

EXISTEN ALGUNAS LAMPARAS DE ADITIVOS METALICOS QUE PUEDEN OPERAR EN ALGUNOS TIPOS DE BALASTROS DE VAPOR DE MERCURIO.

ESTAS LAMPARAS TIENEN UN CIRCUITO DE ARRANQUE ESPECIAL INTEGRADO QUE BASICAMENTE ES UN DOBLADOR DE VOLTAJE QUE FUNCIONA EN COMBINACION CON EL CAPACITOR DEL BALASTRO, POR LO QUE SOLO PUEDE OPERAR EN BALASTROS DE POTENCIA CONSTANTE O EN AUTOTRANSFORMADORES AUTORREGULADOS.

SIN EMBARGO, ES NECESARIO HACER NOTAR QUE TANTO LA VIDA COMO LOS LUMENS PRODUCIDOS SON MENORES, QUE SI SE UTILIZARA UN BALASTRO DE ADITIVOS METALICOS.

3.- BALASTROS PARA LAMPARAS DE VAPOR DE SODIO ALTA PRESION.-

A DIFERENCIA DE LOS TIPOS ANTERIORES DE LAMPARAS QUE

9.

PARA EL ARRANQUE CUENTAN CON UN ELECTRODO AUXILIAR EN EL TUBO DEL ARCO, LA LAMPARA DE V. S. A. P. POR TENER UN TUBO DEL ARCO MUY DELGADO NO PUEDE ALOJAR ESTE ELECTRODO DE ARRANQUE.

POR ELLO, LOS BALASTROS DE V. S. A. P. CUENTAN CON UN CIRCUITO AUXILIAR QUE GENERA PULSOS DE ARRANQUE DE APROX. 3,500 VOLTS, CON EL UNICO OBJETO DE ENCENDER LA LAMPARA.

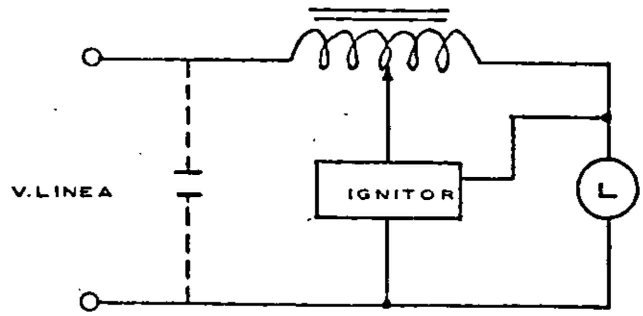
ESTE DISPOSITIVO DENOMINADO IGNITOR ESTA CONSTITUIDO DE ELEMENTOS SEMICONDUCTORES, Y ESTA CONECTADO AL CIRCUITO COMO SE VERA EN LAS FIGURAS SIGUIENTES :

LOS CIRCUITOS DISPONIBLES PARA ESTAS LAMPARAS SON APROX. LOS DESCRITOS ANTERIORMENTE CON ALGUNAS VARIACIONES, AUNQUE SU MODO DE OPERACION SEA DIFERENTE.

I) CIRCUITOS ATRASADOS.-

SOLO EXISTE LA INDUCTANCIA SERIE

10.

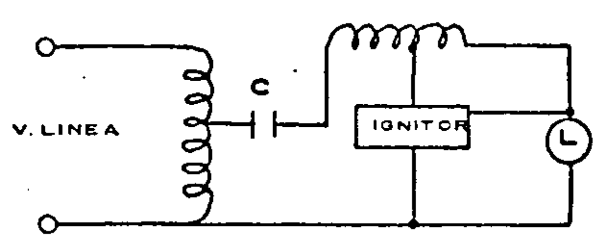


INDUCTANCIA SERIE

II) AUTOTRANSFORMADOR ADELANTADO - REGULADO .-

ES EL EQUIVALENTE DE LOS AUTORREGULADOS PARA LOS 2 TIPOS ANTERIORES DE LAMPARAS.

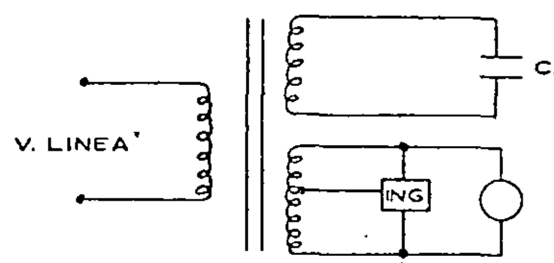
SE LE LLAMA ADELANTADO PORQUE LA CORRIENTE VA ADELANTADA AL VOLTAJE EN LA LAMPARA.



CIRCUITO ADELANTADO - REGULADO

III) CIRCUITO ATRASADO-REGULADO.-

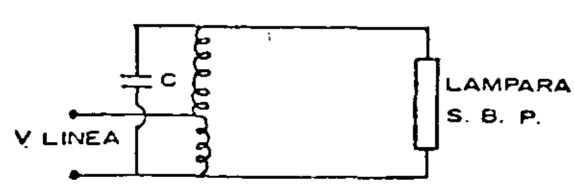
ES EL EQUIVALENTE A LOS CIRCUITOS DE POTENCIA CONSTANTE ANTES DESCRITOS.



CIRCUITO ATRASADO REGULADO

4.- BALASTROS PARA LAMPARAS DE SODIO DE BAJA PRESION.-

POR LAS CARACTERISTICAS PROPIAS DE ESTA LAMPARA, REQUIERE NECESARIA Y UNICAMENTE DE UN BALASTRO TIPO "ATRASADO", POR LO QUE EL UNICO CIRCUITO EXISTENTE A LA FECHA ES EL : AUTOTRANSFORMADOR ALTA REACTANCIA, CON ALTO FACTOR DE POTENCIA.



CIRCUITO ALTA REACTANCIA PARA S.B.P.

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA
CURSOS ABIERTOS

ILUMINACION INTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES

ILUMINACION COMERCIAL

ARQ. ENRIQUE QUINTERO LOPEZ

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Lighting Merchandising Areas[1]

SECTION 8

New lighting techniques, equipment and more efficient light sources present the lighting designer with the tools to meet the challenge of the ever changing requirements of the merchandising world and the spiraling cost of energy.

Sophisticated consumers and the general lack of trained sales personnel make it essential to present merchandise under lighting that will aid in sales and a reduction in merchandise returns.

Consideration should be given to the quality, quantity and effectiveness of light on the task or displayed merchandise that will contribute to a pleasant and secure environment in which to do business.

OBJECTIVES OF MERCHANDISE LIGHTING

There are three primary objectives of lighting merchandising areas: to attract the customer, to initiate purchases and to facilitate the completion of the sale (and minimize returns).

Lighting to Attract the Customer. The first step in the merchandising process is to attract the customer to the merchandise and merchandising space. Light attracts. The quantity, quality, and effect of the light reaching the merchandise and the appearance of the area—show window or store interior—are determining factors in the effectiveness of the sale of the merchandise.

Lighting to Initiate the Purchase. Buying decisions start when the customer is visually intrigued. The actual purchase is not accomplished until the customer can visually evaluate the merchandise and read labeling through adequate illumination.

Lighting to Complete the Sale. Adequate lighting at the point of sale is necessary to complete the transaction. It should enable sales personnel to quickly and accurately perform their sales duties, such as: registering sales, preparing sales slips, reading prices and packaging.

There are numerous factors which must be considered in the lighting design for merchandising spaces to achieve the above objectives. In general, these fall within four design considerations: appearance of the space and occupants, appearance of the merchandise and graphics, merchandising operation and methods, and physical and environmental aspects of the space and merchandise. See Section 1 for a general discussion of lighting design.

LIGHTING DESIGN CRITERIA

The fundamental factors affecting the appearance of merchandising spaces, sale of merchandise and performance of tasks are: brightness and brightness distribution produced by luminance and luminance ratios; merchandise or task size, contrast, color, form and texture; and time for viewing.

Factors in Seeing Merchandise

There are four fundamental factors that affect visibility—the size of the details to be seen, contrast against their background, the amount of time available for viewing, and the luminance of the details and their background.

Size. The size of things to be seen varies considerably. As size increases, visibility in-

NOTE: References are listed at the end of each section.

Fig. 8-5. Currently Recommended Illuminances for Merchandising Areas

Areas or Tasks	Description	Type of Activity Area*	Illuminance**	
			Lux	Foot-candles
Circulation	Area not used for display or appraisal of merchandise or for sales transactions	High activity	300	30
		Medium activity	200	20
		Low activity	100	10
Merchandise† (including show-cases & wall displays)	That plane area, horizontal to vertical, where merchandise is displayed and readily accessible for customer examination	High activity	1000	100
		Medium activity	750	75
		Low activity	300	30
Feature displays†	Single item or items requiring special highlighting to visually attract and set apart from the surround	High activity	5000	500
		Medium activity	3000	300
		Low activity	1000	150
Show windows				
Daytime lighting				
General			2000	200
Feature			10000	1000
Nighttime lighting				
Main business districts-highly competitive				
General			2000	200
Feature			10000	1000
Secondary business districts or small towns				
General			1000	100
Feature			5000	500

* One store may encompass all three types within the building

High activity area — Where merchandise displayed has readily recognizable usage. Evaluation and viewing time is rapid, and merchandise is shown to attract and stimulate the impulse buying decision.

Medium activity — Where merchandise is familiar in type or usage, but the customer may require time and/or help in evaluation of quality, usage or for the decision to buy.

Low activity — Where merchandise is displayed that is purchased less frequently by the customer, who may be unfamiliar with the inherent quality, design, value or usage. Where assistance and time is necessary to reach a buying decision.

** Maintained on the task or in the area at any time

† Lighting levels to be measured in the plane of the merchandise

The recommended levels in Fig. 8-5 are intended as a guide. Current practice indicates a strong trend to variations in illumination for different kinds of stores and for various departments within a store. These considerations, plus those of competition, need for distinctive effects, store design, etc., may make it desirable to vary the levels at specific locations over the values shown.

Where merchandise is displayed in one location and appraised in another (such as taking items out of a showcase to show a customer) it is desirable not to exceed a 3-to-1 ratio in illuminances between the two locations.

During the day, reflections in the glass of show windows determine the levels needed to enable customers to see through them effectively. Higher or lower values than recommended may be desirable, depending on such considerations as severity of reflections, reflectance of merchandise and backgrounds, and illuminances in competitive store windows.

For illuminance recommendations relating to sales transactions and tasks in service or support areas, see Fig. 2-2.

Energy

The basis for lighting energy conservation in the design and operation of merchandising facilities is described in IES (ASHRAE) standards for new and existing buildings.[2] These standards identify a process to determine the power budget for each total store building, which is the upper limit of power to be used by the lighting systems to be energy efficient. This process does not restrict the lighting system design or operation, since it only establishes a limit which can be utilized as desired. Beyond establishing a power budget, the standards also identify methods of achieving energy conservation through an energy management program. See Section 4 for the budget procedure and energy management programs. These apply to the entire building and exterior spaces. The following energy management considerations apply specifically to the merchandising spaces.

In looking for ways to more efficiently utilize energy, the objectives of merchandise lighting as stated earlier should be firmly kept in mind to avoid inappropriate decisions which while producing the desired energy efficiency might lead to ineffective merchandising results. On the other hand energy evaluations may produce ways to improve the quality of the illumination, lower operating costs, as well as lower energy use.

Lighting Requirements. Merchandise lighting levels in Fig. 8-5 are measured in the plane in which the merchandise is displayed. A frequent check should be made because of the flexibility of space use, changing displays and display planes and if levels are higher than recommended a reduction is encouraged.

The type of activity area initially selected from Fig. 8-5 should be reevaluated to determine if the category description is still accurate. In some cases rearrangement of store space may have resulted in different usage (*e.g.*, from medium to low activity) and illuminance may then be accordingly reduced.

Ratios between illuminance on displays and illuminance in customer appraisal location should be determined. If ratios exceed the recommended 3-to-1, levels should be reduced to fall within the recommendation.

Light Sources (Lamps and Ballasts). A periodic review of sources being used and a familiarity with new types is advised to determine if more efficient types may be substituted. In evaluating the efficacy of lamps consideration should be given to not only lumens per watt but also to candlepower because of application situations where small displays requiring special emphasis are lighted from distant luminaire locations. Color rendition of merchandise is also of importance in selecting light source substitutions and may be a deciding factor in changing from one light source family to another, or within one category.

Luminaire Layout and Control. Each time displays are changed the lighting system should be checked for appropriate aiming angles to obtain full benefit on the merchandise. Specific highlighting units not required for the changed display should be removed if mounted on a track or other flexible installation, or shut off if part of a permanent installation.

Consideration should also be given to controlling the lighting system so that a low level of lighting may be provided for nighttime security surveillance purposes, *e.g.*, perimeter lighting or a portion of the general lighting. Frequently a low level on a wall at the rear of a store will be sufficient to provide a view into the store and silhouette any intruder.

Area Surfaces. Lighter finishes should be used for greater utilization of reflected light, but excessive luminance ratios should be avoided, keeping in mind the suitability of background surfaces for the merchandise.

Maintenance Program. Coordination between maintenance and display personnel is important so that equipment is maintained (lamped, cleaned, positioned) to produce efficient display lighting solutions.

Operating Procedures. Accent and display lighting is for customers—to attract and aid in appraisal of the items presented. It should therefore be turned off during hours of non-use by customers, including cleaning periods.

Entrances and windows require a higher illuminance in daytime because of daylight competition than at night when surrounded by a lower ambience. It is recommended that levels in both areas be reduced during evening hours of operation.

Space Utilization. Consideration should be given to the use of the space so that the most energy efficient lighting solutions may be achieved. For example, spill light from feature displays may be sufficient for delineating circulation areas without the necessity of providing separate aisle lighting systems.

LIGHTING SYSTEMS CONSIDERATION

Both daylight and electric lighting systems are used in merchandising areas, but each has its own specific characteristics and considerations.

Daylighting

In open-front stores, or where there may be windows, or skylights, it is necessary to avoid large differences in luminance between daylighted areas and interior areas illuminated to recommended levels. This may be accomplished by controlling the daylight, rather than by increasing the level of electric illumination.

The amount and distribution of daylight received in store interiors depends on the orientation and total area of windows, their light transmission properties, and the relationship of the window height to the room width. See Section 7 of the 1981 Reference Volume.

Comfortable seeing conditions in merchandising areas result from careful consideration of the types of glass used in windows, the method and degree of shading the windows, and the reflectance values of the area surfaces.

Draperies, shades, baffles or louvers should be used for windows in areas where sky luminance or sunlight becomes uncomfortable or glaring to persons within. Horizontal or vertical overhangs outside the windows can eliminate glare from direct sunlight. Sales personnel should be oriented so that bright windows are not within the normal field of view, and shadows are not cast on reading material.

Electric Lighting

Light Sources. For merchandising applications, there are three basic types of light sources in use today: incandescent filament, fluorescent and high intensity discharge. Each light source type has certain advantages, and the proper selection will depend upon the particular requirements of the installation, the economics, and perhaps some personal preference of the system designer or owner. See Section 8 of the 1981 Reference Volume for a discussion and data on light sources.

Incandescent Filament Lighting. The chief advantages of incandescent filament lighting are its low initial cost, good color rendering properties, and good optical control capabilities. Disadvantages are shorter lamp life and lower lamp efficacy (lumens per watt) as compared to the other light sources. Included in the family of incandescents are the tungsten-halogen lamps, having a much better light output maintenance characteristic and longer lamp life than standard incandescent filament lamps, and low voltage lamps having good beam control. In addition, both the tungsten-halogen and low voltage lamps can be compact in physical size and of a shape that results in small luminaires.

Fluorescent Lighting. Many merchandising areas are illuminated with fluorescent light sources. A fluorescent lighting system provides higher lumens per watt, long lamp life, and good color rendition depending on lamp color selection. For indoor applications, louvers and prismatic or diffusing covers are desirable for use with fluorescent luminaires to provide lamp protection as well as maximum shielding. Essentially a tubular light source, fluorescent lighting may be controlled to some extent; however, it is difficult to control the distribution of light emitted lengthwise from the lamp.

High Intensity Discharge Lighting. The family of high intensity discharge lamps includes mercury, metal halide and high pressure sodium. Although each of these lamp types has its own specific characteristics, they have the following characteristics in common: long lamp life and high luminous efficacy when compared with incandescent lamps; compact source size, which allows for good optical control; and a time delay and slow build-up of light output when the lighting system is first energized or when there is a power interruption. Because of this delay characteristic, it is essential to include incandescent or fluorescent lighting.

In areas where color rendition is important, improved-color phosphor-coated mercury lamps are recommended rather than clear mercury lamps. It should be noted, however, that phosphor-coated lamps provide medium to wide beam spreads. In comparison to mercury lamps, the metal halide lamp provides higher luminous efficacy, but has a shorter life. These lamps also have good color rendition.

The high pressure sodium lamp has a higher luminous efficacy than the metal halide lamps and an excellent light output maintenance characteristic. Color acceptability is fair, but all colors are recognizable with these lamps. High pressure sodium lamps are used primarily for outdoor lighting.

Luminaires. No one lighting system can be recommended exclusively. Each system has qualities that may match the requirements for a given situation. The first consideration, however, should allow the customer to see efficiently and without distraction to produce sales; the second should be the appearance of the installation within the architectural and decorative design of the store.

Among the factors that affect the selection of a luminaire are:

1. The type of light source to be used.
2. The illumination performance that it will provide such as light distribution.
3. The proper luminance ratios for appearance and efficiency.
4. The structural factors and materials used.
5. The effectiveness of heat dissipation.
6. The modular size.
7. The appearance.
8. The quality of product.
9. The economics.

Two luminaires may have the same general appearance, but differ in performance. Comparisons using distribution curves and data from photometric tests obtained by qualified testing laboratories are the effective way to determine if the luminaires will provide equivalent lighting results.

Acoustical and Thermal Factors

Today's store frequently requires integration of lighting with acoustical and thermal aspects. Acoustical treatment of ceiling surfaces can be incorporated in the majority of stores. The reflectance of the acoustical material is important to the lighting scheme.

Heat from light sources and luminaires can have a great effect on the air conditioning and heating systems in merchandising areas. Air handling luminaires—supply, return, heat removal—may be effectively used in merchandising areas as part of the comfort control system and may also improve the efficiency of the lighting system. See Section 2.

Economics

The total cost of a lighting system is the sum of owning and operating charges. While initial investment may in some cases be a dominant factor in selecting specific luminaires or lamp types, there are capital expenses (amortization, interest, taxes, and insurance) that also should be considered. See Section 3.

Maintenance

All lighting systems depreciate in light output with the passage of time. See Section 4. Lighting equipment and room surfaces should be well maintained if reasonable efficiency and appearance are to be obtained, and consideration should be given to the accessibility of luminaires for cleaning and relamping in high mounting areas.

Fading, Bleaching and Spoilage

When the merchandiser displays a product, the color stability of merchandise should be considered. Not all products have the same color stability and products fade or change chemical composition because of varying environmental reasons.

Fading of merchandise may be caused by exposure to high illuminances for extended periods of time. Other factors that could contribute to fading are duration of environmental exposure, spectral distribution of radiation, moisture, temperature, chemical composition of merchandise, saturation of dye in merchandise, and composition of weave of fabrics. See Section 19.

LIGHTING INTERIOR SPACES

Merchandising Spaces

Merchandising spaces can be conducive to initiating and completing sales transactions. Each of the following factors should be considered in the design and lighting for merchandising spaces:

1. Type and characteristics of merchandise.
2. Location of merchandising area within the store.
3. Ambient illuminance in adjacent areas.
4. Size and shape of space.
5. Surface reflectances, colors and textures.
6. Flexibility requirements.
7. Size and location of graphics.
8. Method of display—racks, gondolas, counters, etc.
9. Method and location of sales transactions.
10. Location of merchandise displays, including feature displays.
11. Traffic patterns.

Lighting Methods for Merchandising Spaces

Once the type of store, class of merchandise to be handled, and clientele desired are determined, the lighting should be designed in keeping with their character. The lighting design should consider all surfaces in the customers' fields of view. Merchandise should dominate the scene.

There are three basic approaches to the lighting of merchandise areas in stores—the general pattern system, the specific system and the flexible system. Each system should have supplemental lighting to attract attention to featured displays, to influence traffic circulation and to create added interest.

General Pattern System. The general pattern system employs a pattern of luminaires to provide general lighting with or without display lighting throughout the sales area without regard

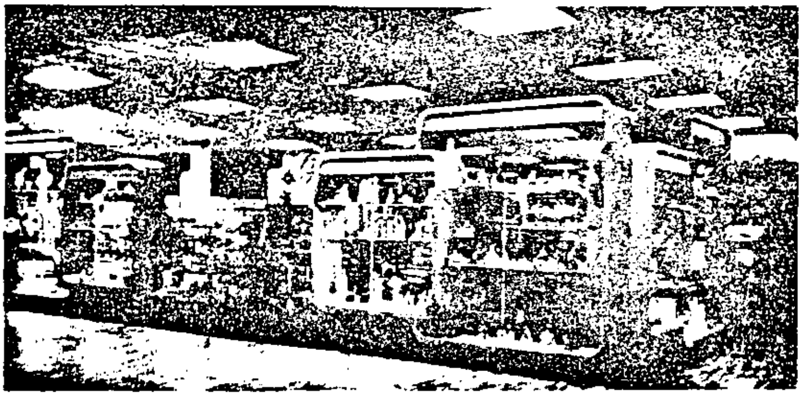


Fig. 8-6. Fluorescent and incandescent luminaires used in a general pattern system.

to the location of the merchandise (see Fig. 8-6). The system should include switching or dimming controls for flexibility of space use and for efficient energy utilization. If neither display lighting nor switching or dimming controls are used, there will be a lack of area emphasis on focal points.

Specific System. The specific system employs a layout of luminaires determined by the location of the merchandise displays (store fixtures, showcases, gondolas, etc). It is tailored to emphasize the merchandise and delineate sales areas (see Fig. 8-7).

Flexible System. The flexible system employs a pattern of electric outlets of continuous or individual type for nonpermanent installation of luminaires. These may be wired for multiple circuit application and/or control.

This system may be used for general pattern lighting or for specific lighting and offers the added advantage of interchangeability of luminaire types to create lighting tailored to the merchandise display.

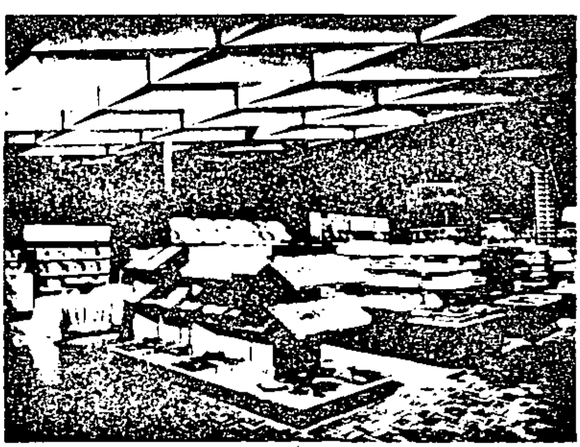


Fig. 8-7. Specific lighting systems relate to the merchandise displays. They may be concealed as shown here to avoid competing with the merchandise. Flexibility may be an additional desirable feature of the system.

Feature and Supplementary Lighting

Lighting on vertical displays and wall cases, because of the favorable viewing angle, is important because these are prime profit centers. The proper balance of general or specific and feature and supplementary lighting is dependent on the type of merchandise, methods of presentation and type of store. Certain portions of the merchandising area should be given special consideration as to the most effective supplementary lighting methods to attain the lighting results desired. Each must receive individual consideration in lighting design, selection of lighting equipment and illuminances. Specific consideration should be given to placement and aiming the light sources at angles to prevent direct and reflected glare from reaching the eyes of customer and sales personnel. The following is a discussion of those merchandising areas that will generally require supplementary lighting.

Counter Lighting. Counter lighting is a form of accent lighting in which merchandise on the tops of counters, or point of sale at counter tops, receives three to five times the circulation area illuminance. This is usually accomplished with high intensity directional downlight equipment.

Lighting at Mirror. Lighting at the mirror is important because shoppers finally appraise hats, dresses, shoes, cosmetics and hairdos in terms of color, fit and how well the personality is complemented. When a buyer appraises wearing apparel, the face is generally observed first. The following factors should be considered when lighting mirrors:

1. The face should be softly lighted with light sources that flatter skin tones, and from a direction that minimizes harsh lines. Overhead lighting directed toward hair can add sheen and color.
2. The sales item should be adequately lighted over its entirety.
3. The lighting should be of a quality consistent with the illumination under which the merchandise will be worn—*i.e.*, outdoors for beach and sportswear, indoors for evening wear.

Light sources can be used to direct light into the mirror and then back onto the subject if the source brightness cannot be seen by the customer. It is possible with fixed viewpoint to control the lighting, especially in fitting rooms or special selling alcoves. Side lighting can be used and confined directly to the garment, especially in departments where there are coats and furs. In the case of triplicate mirrors, such lighting can be reflected from the wing mirrors. Controlled downlighting can also be used effectively in confined selling spaces such as fitting rooms. The reflectance, color and illumination of the background are important. See Fitting Rooms, page 8-12.

Showcase Lighting. Another element for emphasis in merchandise lighting is to call attention to merchandise displayed in showcases. Generally, showcase lighting is three times the illuminance required for circulation area lighting. Fluorescent lamps may be employed for a continuous line of light, and to minimize the heat created in enclosed spaces. The major objective of showcase lighting is to attain maximum light on merchandise without obstruction from lighting equipment; therefore, small-diameter lamps are generally preferred. Despite the general use of fluorescent lamps, incandescent filament "showcase" lamps are frequently used for more acceptable color rendition. They show merchandise as it will be worn or seen in warm light and may create sparkle for the display of jewelry, glassware and other similar merchandise. For a curved or irregular case, cold-cathode tubing can be bent to conform to the shape of the case. See Fig. 8-8.

Modeling Lighting. The form and texture of merchandise may be more apparent through the use of directional lighting supplementing the general diffuse lighting needed for the over-all effect. However, light should not be directed too obliquely, since objectionable shadows may be cast.

Wall Case Lighting. Wall case lighting can be considered in three categories: (1) the freestanding vertical display mounted against a wall; (2) the encased, open-front, wall-mounted display; and (3) the glass-door, wall-mounted display case.

Accent lighting of the freestanding vertical display offers the greatest freedom in expression to the lighting designer. It may be accomplished by flush, surface-mounted or suspended adjustable luminaires, strategically located to produce highlights and shadows to create a three-dimensional display. Colored lamps in lieu of clear lamps may further dramatize or call attention to the displayed merchandise.

The open-front, wall-case display follows the lighting methods of the freestanding vertical displays. The system should be planned to project light within the encased area. In this type of display, added flexibility of design can be accomplished by using adjustable units installed at strategic points at angles that avoid veiling reflections around the outer edge of the case or within the encased area.

Display cases with glass doors present a different problem—namely, the merchandise displayed behind the glass panel is obscured by surface reflections from the glass. Since this becomes virtually a show window problem, the best way to overcome annoying reflections is to increase the lighting level within the case. Spotlighting can accomplish this; however, extended periods could cause fading.

Rack Lighting (Clothing). Rack lighting should be designed to attract customers and for easy evaluation of the merchandise. Racks located in large, cased wall areas may have concealed baffled light sources above racks. Where linear light sources are used, the color should

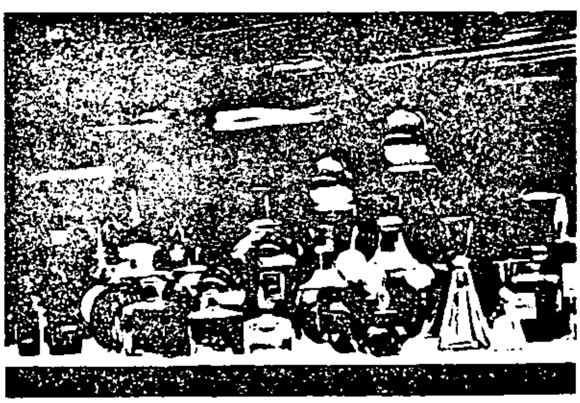


Fig. 8-8. Fluorescent sources beneath diffusing material produce a transilluminated display for a cosmetic counter showcase. Perfume bottles appear to glow and float.

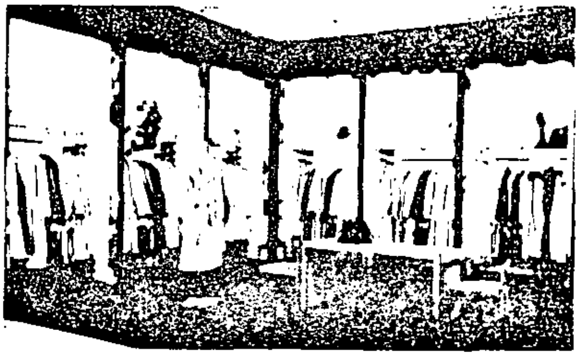


Fig. 8-9. A uniform wash of light over the length of the hanging garments facilitates customer evaluation of the item and eases the task of reading pertinent data on tags. Fluorescent sources are housed here in the top of the wall case.

render color in the same way as the ambient lighting in the fitting rooms. The lighting system chosen should be one that fully illuminates the articles of clothing from the standpoint of color and texture. A lighting level should be provided that will permit quick and discerning customer selection (see Fig. 8-9).

In the open rack areas, flush or surface-mounted adjustable ceiling downlights should be directed obliquely onto the displayed merchandise. The lighting level on the clothing should be greater than that of the general or ambient lighting of the aisles between racks. In the aiming of the downlights, caution must be exercised to avoid directing the light beam into the eyes of customers viewing clothing on the opposite side of the rack or at adjacent racks. The use of louvers, baffles or lenses helps to alleviate this situation.

Perimeter Lighting. Perimeter lighting is an asset to a store environment, contributing to a sense of pleasantness and adding to the visibility and visual impact of displays at the walls (see Fig. 8-10).

Other Store Spaces

In addition to the lighting consideration for merchandising areas, attention should be given to those for other spaces utilized by customers and/or store personnel. The following is a list of those spaces:

1. **Fitting Rooms**. The selling potency of fitting rooms is of tremendous importance. This is where the final, critical decision to buy is made. Every effort should be made to hold and motivate the customer to complete the sale. The lighting systems in these small spaces should create a feeling of relaxed security and pleasant anticipation.

Background finishes should be matte, simple and light in color to avoid color distortion or distract from merchandise.

Light sources should be compatible in color rendering with those in the selling space to insure that initial customer attraction to the merchandise is continued when a close personal evaluation is made.

Careful choice and placement of overhead luminaires will add to the vibrancy of color, en-

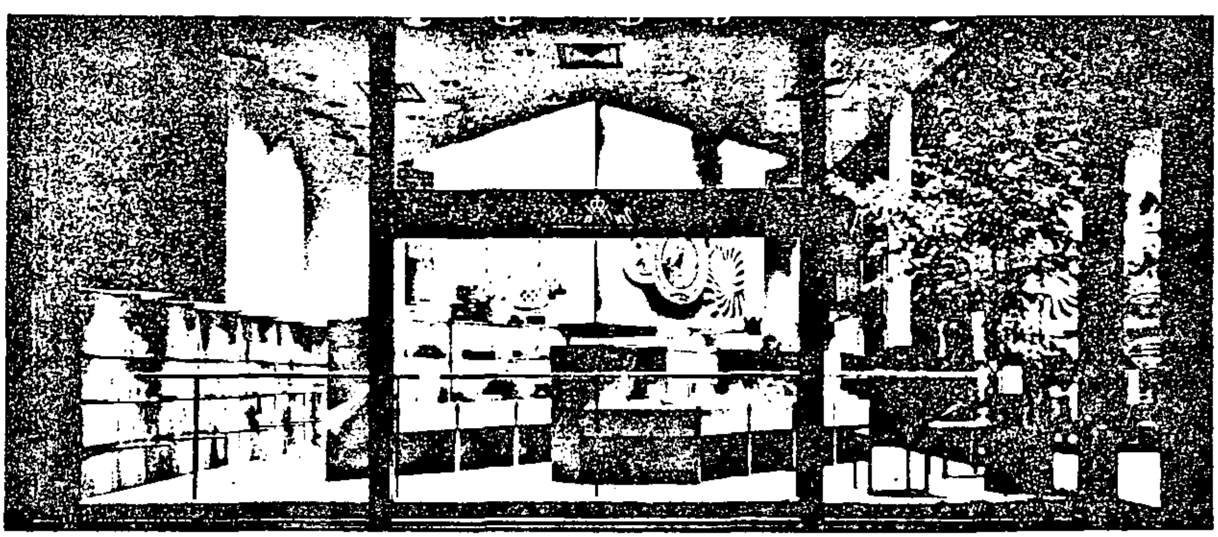


Fig. 8-10. A store, seen from the outside, utilizing perimeter lights to produce vertical surface luminances for attraction and to overcome potential veiling reflections in the windows.

Fig. 8-11. Exterior lighting of a large department store to attract and lead the customer to the entrance.

hancement of texture, sheen or glitter of hair and materials, and create modeling effects. Lighting at the mirror should be used to compliment and soften facial shadows. Vertical illumination should extend far enough down to enable customer to easily evaluate full-length garments. See page 10-5.

2. **Alteration Rooms.** Sewing and Pressing tasks are involved.
3. **Stock Rooms.** Methods of storage shelves, bins, racks, etc.
4. **Wrapping and Packaging.** Sample displays, wrapping and boxing are involved.
5. **Toilets, Washrooms, and Locker Rooms.** Lighting at mirror, sanitary maintenance, lounge facilities, and locker lighting are important.
6. **Offices.** See Section 5.
7. **Food Service Facilities.** See Section 7.
8. **Escalators, Elevators, and Stairways.** Safety, traffic pattern and use, graphics, and emergency provisions are important.

EXTERIOR SPACES

The role of outdoor lighting at stores and shopping centers is numerous and varied; it should attract customers to the center and then to specific stores (see Fig. 8-11); identify key areas such as entrances, exits, parking and the various stores; facilitate safe passage of motorists and pedestrians on the grounds; contribute to effective security and surveillance of people and property, and visually unify the shopping area, providing a positive contribution to the visual environment. See Section 12.

When the potential customer arrives in the vicinity of the shopping center (or freestanding store) there is a pattern of progression to arrive at the point of purchase. Lighting plays a major role in leading the shopper from one zone to another and eases the identification process through each step—from locating the shopping center site, entrance to center, parking area and store (all vehicular circulation) to locating the store entrance, departments and finally the merchandise (all pedestrian circulation).

SHOW WINDOWS

The show window can be a powerful attraction, providing the link between the potential customer passing by and the merchandise within the store. Each of the following factors should be considered in the design of show-window lighting:

1. Type and characteristics of merchandise.
2. Location of show window—outdoor or enclosed mall area, urban or suburban, solo or shopping center.
3. Night and/or day use and associated ambient illuminances (see Fig. 8-5), including the nature of the competition.
4. Open back or enclosed.
5. Size and shape.
6. Contour and slant of show-window glazing—brightness from daytime and nighttime reflections.
7. Interior surface reflectances and colors.
8. Flexibility requirements.
9. Size and location of display graphics.

See Section 9 of the 1981 Reference Volume for calculation techniques.

REFERENCES

1. Committee on Merchandising Lighting of the IES: "Recommended Practice for Lighting Merchandising Areas." *Light. Des. Appl.*, Vol 6, p. 6, June, 1976.
2. *American National Standard, Energy Conservation in New Building Design.* ANSI/ASHRAE/IES 90-80, American National Standards Institute, New York. Proposed American National Standard, *Energy Conservation Existing Buildings—Commercial*, ASHRAE 100.3 (IES/EMS-4.3), American National Standards Institute, New York.

ILUMINACION DE APARADORES.

En los almacenes unos artículos son de mayor importancia que otros, pueden tener mayor margen de ganancia, pueden ser artículos de temporada ó de existencia regular.

En culquiera de los casos los artículos deben de presentarse de forma que impacten a la apreciación visual del comprador. El objetivo de la iluminación de es hacer que el comprador vea las mercancias claves.

Una iluminación de aparador buena proporciona variaciones en configuraciones brillantez que dan el enfasis visual necesario para atraer la atención hacia los artículos de atracción particular. También la iluminación adicional incrementa la visibilidad produciendo una apreciación rápida y exacta por medio de alta brillantez y distribución de luz favorable. En suma una iluminación de aparador buena enfatiza aquellas caracterfsticas de la mercancia que son especialmente atrayantes - pulido, atractivo, textura, forma, translucidez, etc. Finalmente la iluminación de aparadores añade interes a lo que de otra forma podría aparecer como una atmósfera sin atractivo.

Para lograr un grado significativo de impacto visual, el aparador iluminado deberá tener una brillantez de por lo menos el doble de los espacios que lo rodean. Conforme aumente el significado o importancia del aparador, la diferencia en brillantez, también deberá aumentarse, los aparadores clave deberán ser de 5 a 10 veces más brillantez que los espacios que los rodean. Ejemplo : Una tienda con un nivel de iluminación para la mercancia en general de 100 fc, deberá utilizar niveles de iluminación de 200 a 1000 fc para los aparadores.

Para añadir iluminación a las superficies verticales o a los artículos que son de atractivo especial, los almacenes de frente abierto, el factor que determina la iluminación de aparadores, no es la iluminación de los espacios adyacentes, sino las reflecciones producidas en la protección de vidrio. En este caso, los espacios más importantes del aparador deberán estar dentro del rango de 500 a 2000 fc., porque ellos están en el aparador.

El arreglo que se dé a la iluminación de aparadores se rige por la naturaleza de la mercancia y la forma en que se quiere presentar. El arreglo más común de iluminación de aparadores es el de de luz puntual, cuyo haz de luz direccional varía las cualidades de configuración, brillantez y acentúa la forma que no se logra con la iluminación general. Las lámparas fluorescentes también son útiles, en cornizas y doceles, ocultas en las repisas iluminadas y en los gabinetes iluminados, e instaladas en cabidades ocultas por table-- ros traslúcidos para producír un ambiente o medio de luz a las mercancias de alta reflectancias.

ILUMINACION PUNTUAL.

Las tablas de la página muestran las relaciones adecua-- das de potencia y espaciamiento para varios tipos de iluminación incandescente acentuada. No obstante que estos datos son útiles, en la mecánica del diseño de iluminación y en la elección de fuentes - de luz, no contemplan algunas consideraciones importantes en la iluminación puntual de aparadores.

La elección de lámparas y equipo de iluminación está basada -- parcialmente en las necesidades de iluminación, así como en la naturaleza del aparador y su ubicación en el almacén. Cuando un lugar fijo se establece para aparadores de decoración tal como el extremo de una góndola, un manequí de pedestal o un lugar de barra de fondo es deseable planear la iluminación en terminos de su atracción para un efecto visual mejor o en general, si las superficies principales de los aparadores son verticales, las luces puntuales deberán localizarce de tal forma que los ejes de los haces incidan en los pun-- tos importantes del aparador un ángulo con respecto a la vertical - de 25° a 30°. Esto asegura que son efectivas visualmente en la vertical con contornos naturales de sombras. También, este angulo de dirección evita la posibilidad de un deslumbramiento que moleste a las personas que se aproximen hacia aparador o transiten en áreas - cercanas a el. Las luces puntuales instaladas en la parte baja para dirigirlas hacia arriba deben de ser evitadas cuando sea posible, ya que produce efectos de desconfort visual.

No obstante que las luces puntuales dirigidas verticalmente -- son inadecuadas para la iluminación de superficies importantes en aparadores verticales, son de bastante utilidad para la iluminación de aparadores de importancia cubiertas de tapetes, y otros exhibidores cuyas superficies superiores pueden ser vistas por las personas. En los equipos de iluminación hacia abajo, es importante particularmente vigilar las reflexiones en los momentos que puedan ser molestos a las personas o producír velas en los objetos que se muestran. Por esta razón, la iluminación de vitrinas con luces verticales, usualmente se localizan dentro de la mitad del área de la vitrina --

que quede hacia el comprador. Algunas veces estos equipos con portalámparas ligeramente inclinados se utilizan para ayudar a posicionar las lámparas fuera de las zonas de reflexión y tengan el centro del haz hacia el centro de la cubierta de la vitrina.

Las herramientas más comunes para la iluminación puntual interior son las lámparas PAR y R. Sus ventajas principales son :

1.- Amplia variedad de equipo para alojarlos y de costo accesible o ecónomico.

2.- Amplia variedad de tamaños y potencias para satisfacer las necesidades de la mayoría de los aparadores, tanto en cantidades de luz como en áreas por iluminar.

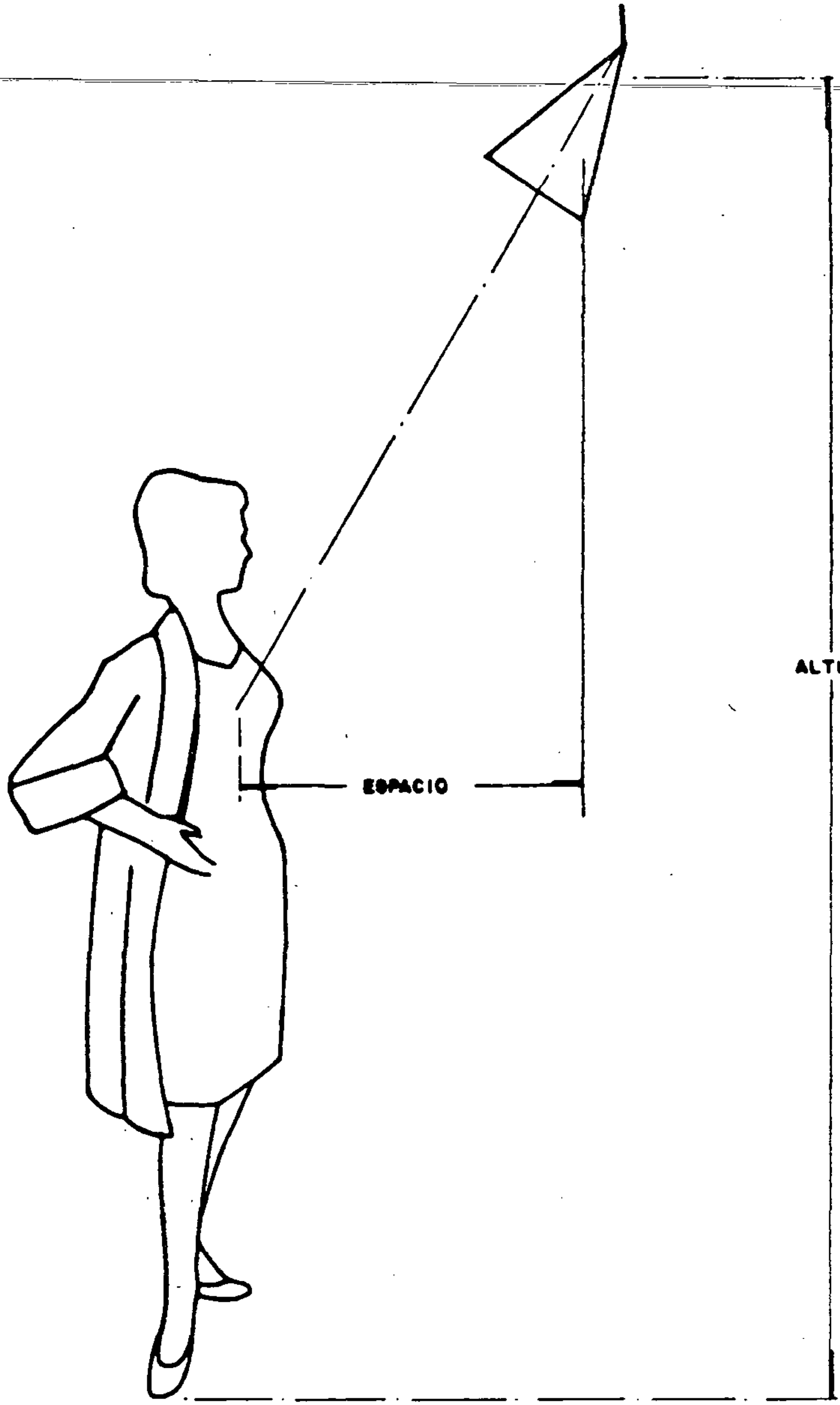
3.- Reflectores que no necesitan ajuste o limpieza.

4.- Vida útil larga.

Se recomienda utilizar hasta donde sea posible equipo fijo para la iluminación de aparadores, para asegurar que el equipo permanecerá enfocado adecuadamente sobre el aparador sin que de lugar a "puntos calientes", áreas obscuras o deslumbramientos para los ---- clientes que algunas veces encuentran equipo mal dirigido.

En casos donde los aparadores puedan variar ligeramente en tamaño o forma, y especialmente en casos donde la ubicación general - de los aparadores pueda cambiar frecuentemente, se necesita una flexibilidad mayor. Las luces puntuales ajustables, ya sean empotra-- das o sobrepuestas, pueden dirigir sus haces hacia las partes importantes del aparador. Este punto o detalle seguido se descuida re-- sultando que las luces no pueden ser dirigidas hacia las nuevas ubicaciones de los aparadores, perdiéndose mucho del atractivo visual, que pueda lograrse del aparador. Para estos casos, algunos de los sistemas de rieles electrificados deben ser considerados. Ellos -- permiten fijar las luces puntuales en cualquier punto deseado, con una planeación cuidadosa pueden adicionar flexibilidad y utilidad a los sistemas de iluminación de aparadores.

Esta tabla muestra las relaciones espaciamiento y la ilumina-- ción resultante para aparadores con iluminación puntual vertical. - Los datos se basan en orientaciones de cada lámpara con su eje del haz incidiendo en el objetivo 5 pies arriba del piso, con un ángulo de 30°. Los valores de iluminación son los obtenidos en un área pequeña en el centro de haz de luz sobre una superficie perpendicular al eje del haz.



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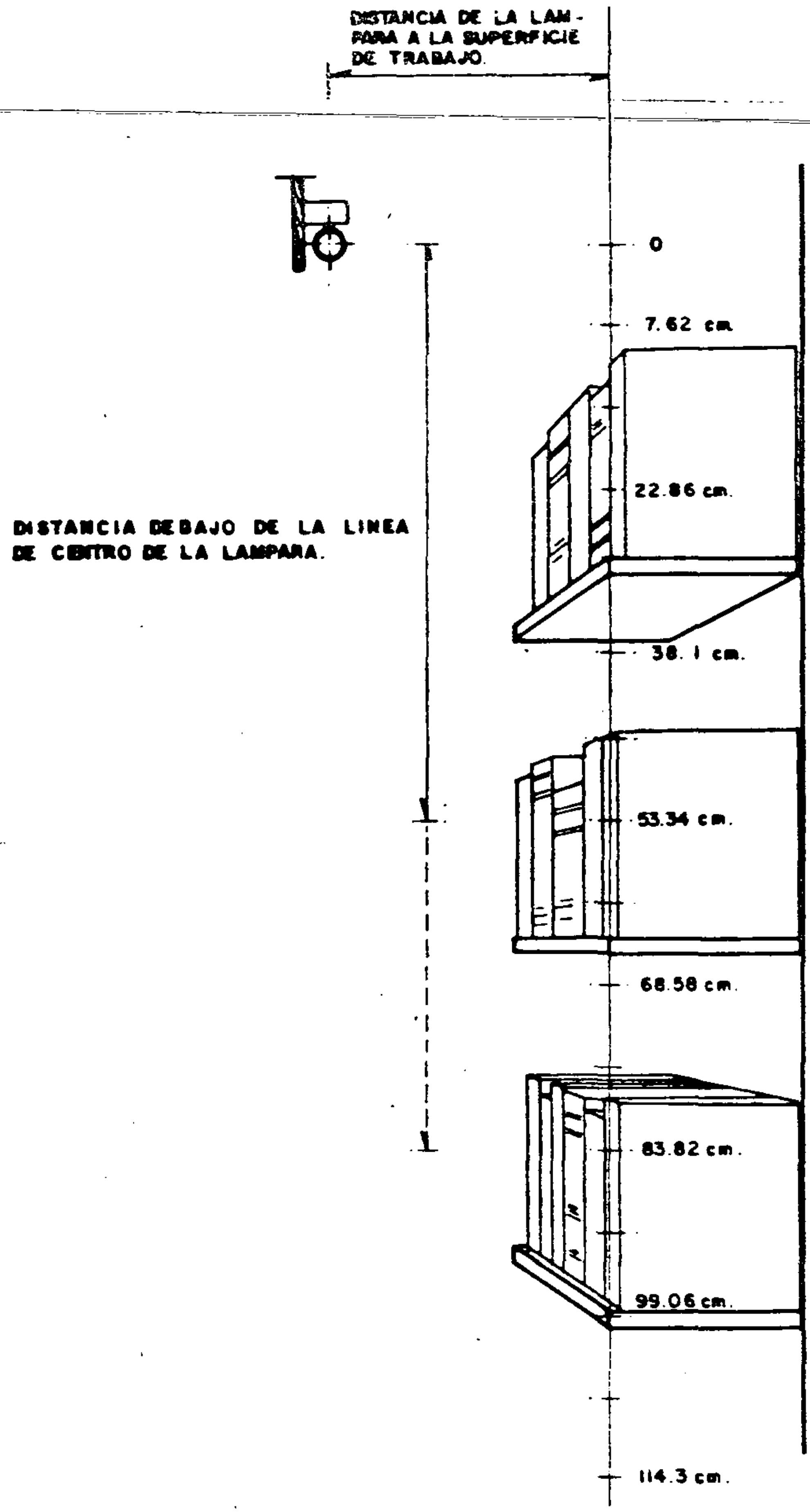
Las tiras luminosas son utilizadas más frecuentemente a lo largo de paredes para iluminar repisas y anaqueles decorados, pero también son eficientes en áreas centrales del almacen para iluminar gondolas o muestrarios similares con artículos de lujo o alto margen de utilidad.

Brillanteces más altas en las mercancias claves, es el objetivo de la iluminación con tiras continuas luminosas en los almacenes. También se utiliza para compensar las reducciones o carencia que resultan en ciertas áreas unicamente con la iluminación general.

La fuerza de atracción de las tiras luminosas usualmente es mucho menos dramática que la obtenida con iluminación puntual, y llama la atención desde distancia en el área total iluminada. Puntos de alta intensidad y las sombras son disminuidos más que con la iluminación puntual, ya que la dimensión de la fuente de luz es más grande y su brillantez es más baja.

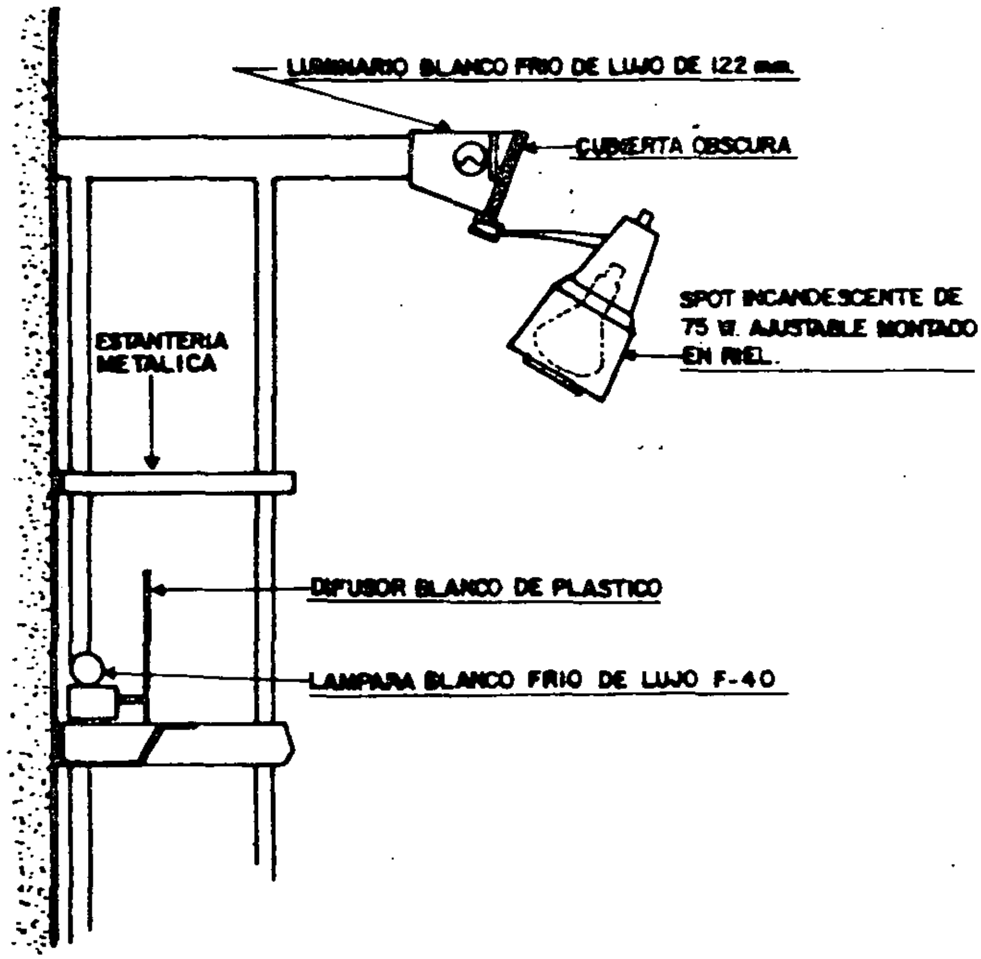
Alfunas guias de diseño para tiras luminosas se ilustran en los siguientes bosquejos y tablas. El montaje de las lámparas suficientemente separadas de la superficie vertical para producir una distribución de iluminación razonable es de importancia principal, si la tira luminosa está demasiado cerrada a la superficie por iluminar, la apariencia es de una alta brillantez en la parte superior, perdiendo uniformidad en el total del área iluminada, además de que aumenta la probabilidad de desvanecer los colores de las mercancias.


DISTANCIA DE LA LAMPARA A LA SUPERFICIE DE TRABAJO.
0
7.62 cm
22.86 cm.
DISTANCIA DEBAJO DE LA LINEA DE CENTRO DE LA LAMPARA.
38.1 cm.
53.34 cm.
68.58 cm.
83.82 cm.
99.06 cm.
114.3 cm.

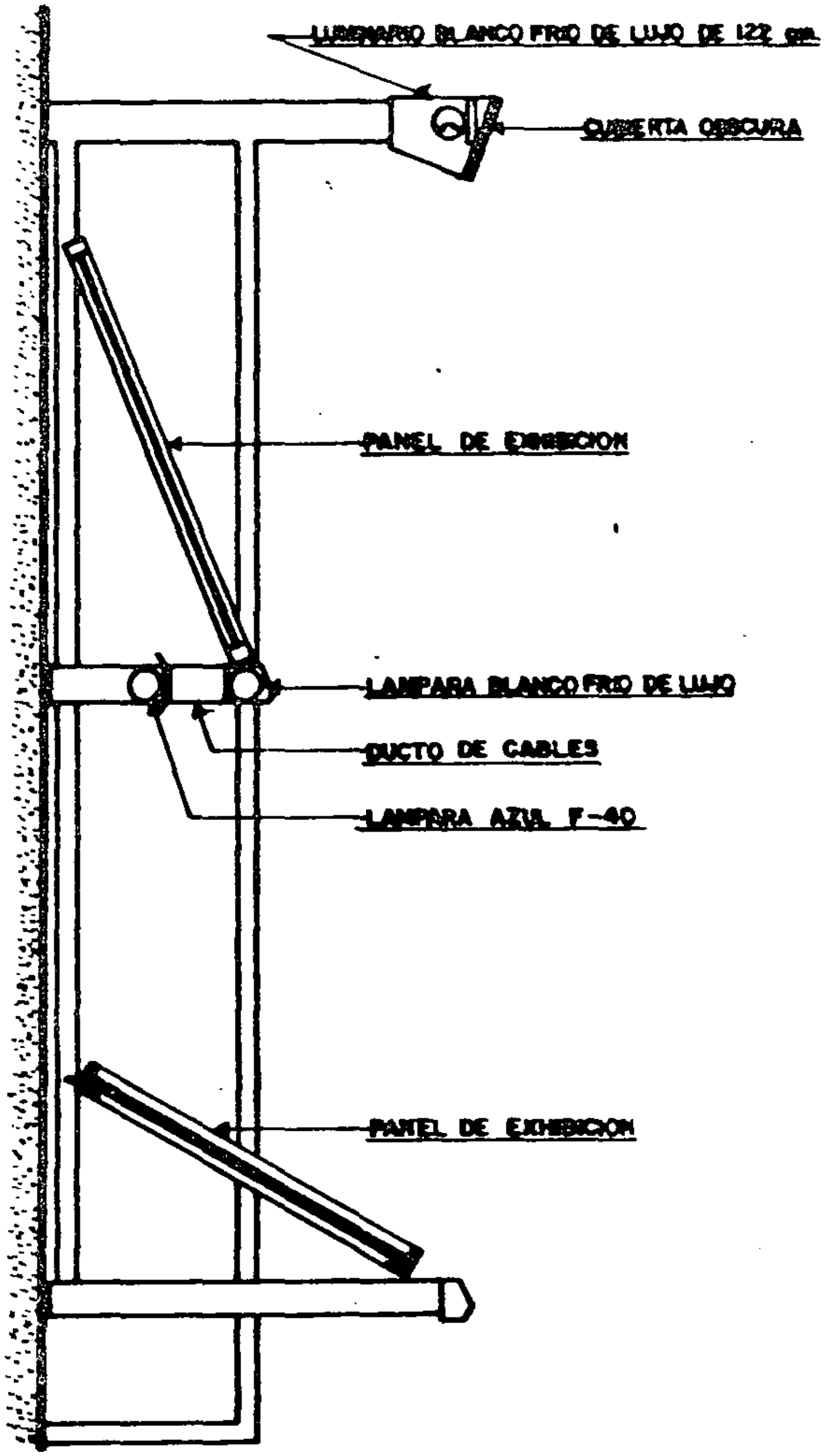
PIE CANDELAS MANTENIDOS EN LAS SUPERFICIES VERTICALES DE APARADORES.

La tabla y el diagrama muestran la iluminación mantenida, las superficies verticales obtenidas con tiras luminosas equipadas con lámparas fluorescentes blanco frío de lujo ó blanco cálido de lujo 40 Watts Slim Line T-12. Las superficies interiores de la línea - luminosa son pintadas de color blanco, se considera un factor de -- mantenimiento de 75 %. Los valores de iluminación disminuyen en -- los extremos de las líneas luminosas.

Distancia abajo de la línea de centro de lámparas.	Distancia de línea de centro de la lámpara a la superficie vertical.			
	15.24 cm.	22.86 cm.	30.48 cm.	45.72 cm.
7.62 cm.	1614 Lux	1076 Lux	828.5 Lux	538 Lux
22.86 cm.	645.6	699.4	664.6	516.5
38.1 cm.	236.7	344.3	398.1	398.1
53.34 cm.	107.6	182.9	236.7	279.8
68.58 cm.	75.3	107.6	139.9	193.7
83.82 cm.	43.4	75.3	96.8	129.1
99.06 cm.	32.3	43.4	64.5	96.8
114.3 cm.	21.5	32.3	53.8	75.3


LUMINARIO BLANCO FRIO DE LUJO DE 122 mm.
CUBIERTA OBSCURA
SPOT INCANDESCENTE DE 75 W. AJUSTABLE MONTADO EN RIEL.
ESTANTERIA METALICA
DIFUSOR BLANCO DE PLASTICO
LAMPARA BLANCO FRIO DE LUJO F-40

23-


LUMINARIO BLANCO FRIO DE LUJO DE 122 cm.
CUBIERTA OBSCURA
PANEL DE EXHIBICION
LAMPARA BLANCO FRIO DE LUJO
DUCTO DE CABLES
LAMPARA AZUL F-40
PANEL DE EXHIBICION

La iluminación de repisas o extrepaños con fuentes fluorescentes es de otra manera para obtener brillantez variada y aumentar el poder de atracción de los aparadores: La iluminación integrada a vitrinas normales y vitrinas refrigeradas cae dentro de esta categoría, lo mismo que la iluminación de repisas o entrepaños individuales en aparadores especiales o convencionales.

Se dispone de varios métodos para integrar la iluminación a los entrepaños. Los reflectores de vitrinas comerciales pueden sujetarse a los entrepaños, con los balastros localizados lejos, de tal forma que no interfieran la distribución de luz en el espacio por iluminar.

Los reflectores para vitrinas utilizan lámparas fluorescentes de diámetro pequeño, tal como las lámparas Slim-Line 42T6 y 64T6. Esto reduce el espesor necesario del extrepaño.

Lámparas y canaletas convencionales también pueden sujetarse en algunos extrepaños. Las lámparas deberán quedar bien ocultas para que no distraigan la atención del comprador, apartandola de las mercancias y para no disminuir el confort visual.

Puede también ser deseable utilizar muebles de entrepaños fabricados especialmente con su sistema de iluminación integrado. Por ejemplo, las lámparas pueden instalarse en el eje frontal de los entrepaños y los balastros sujetados a la pared. Este método reduce la resistencia necesaria para sujetar los entrepaños a los soportes de pared.

La iluminación de entrepaño convencional tiende a crear un énfasis pronunciado de superficie horizontal, con repeticiones, planos horizontales gruesos. Este énfasis puede ser cambiado a planos verticales modulares, utilizando entrepaños de vidrio delgado con lámparas fluorescentes sujetas a herrajes verticales existentes entre los compartimentos del aparador. Para obtener una eficiencia máxima con este arreglo, a las lámparas deben estar localizadas con una separación del frente del mostrador a un octavo de claro entre herrajes: así, para aparadores con claros de 48 pulgadas, las lámparas deberán estar separadas más de 6 pulgadas de las superficies frontales de los separadores.

En muchos almacenes, la iluminación fluorescente puede estar integrada a los aparadores, las lineas luminosas iluminan a la parte superior de las paredes y a la mercancia. Los entrepaños y vitrinas iluminadas en forma individual son detalles más localizados.

Tableros con iluminación por la parte posterior producen efectos impactantes con las mercancías transparentes y traslucidas.

En las aplicaciones que se muestran, las tiras luminosas utilizan lámparas Power Groove, montadas en canaletas de sección transversal pequeña, con balastros remotos. Se han hecho diseños de tiras luminosas con canaletas para contener los balastros, sujetos directamente a la estructura del entrepaño y con brazos soporte de portalámpara a una distancia apropiada desde la pared. Estos dos arreglos disminuyen la posibilidad de que la canaleta con balastro obstaculice la distribución de luz y también son arreglos que se pierden en el conjunto de la estructura de los aparadores.

La ilustración muestra un diseño sencillo de tablero luminoso que es el adecuado para instalarse en los aparadores existentes. También es de menor costo que tableros fabricados con el sistema de iluminación integrado y retiene mucho de la eficiencia visual de la mayoría de las unidades complejas. Para las mercancias presentadas por lotes, la no uniformidad de brillantez en un tablero como éste, no sería distrayente. La luz puntual esta sujeta a un riel eléctrico que permite relocalizar la unidad rápidamente para acentuar algún artículo en particular.

La ilustración nos muestra los medios para introducir color en las superficies de fondo de las mercancias, mientras que conserva un rendimiento de color favorable en los aparadores.

Una estructura de entrepaño como la mostrada se puede obtener haciendo variaciones pequeñas al angulo normal de entrepaños y al equipo de iluminación.

Algunas veces puede ser problema el calor producido o generado por los sistemas de iluminación de vitrinas y entrepaños. Para disminuir lo anterior las balastras pueden localizarse lejos ayudando a disminuir la carga de refrigeración en aparadores que necesitan ambiente frío no obstante el calor del balastro puede ser necesario para calentar a las lámparas en vitrinas refrigeradores.

Cuando artículos sensibles al calor son colocados en entrepaños iluminados la localización de temperaturas más altas en los extremos de las lámparas y arriba de los balastros puede ser demasiado y dañan algunos productos, botes de aerosol en particular, no deben ser mostrados en este tipo de exhibidores.

ILUMINACION PERIMETRAL.

El ambiente de tiendas se relaciona con la vista de superficies verticales alderedor del perímetro de la misma, y con superficies -- verticales dentro de ella. El sentido de espacialidad en la tienda y la apariencia de su decoración están influenciadas por la iluminación perímetral. La planeación cuidadosa ayuda a crear configuraciones brillantes que complementen al diseño y orden del departamento, dando al comprador una impresión favorable de la tienda.

En tiendas de aparador, las superficies superiores del interior de ellas constituyen una parte importante del campo visual a través de los escaparates. Las paredes de color brillante, iluminadas efectivamente para realzar su brillantez, ayudan a eliminar las reflexiones en el cristal, así los comprobadores pueden mirar dentro de la - tienda durante el día. De hecho, las paredes interiores de la tienda constituyen la "espalda" del aparador. Estas deben ser suficientemente brillantes para que la gente pueda ver facilmente dentro de la tienda. Esto requiere para iluminación sobre paredes de altas reflectancias de 100 a 200 pie-candela.

Parte del efecto de la apariencia de superficies de un cuarto - se produce por la iluminación general y por la exhibición. Si en la iluminación general se usan lámparas fluorescentes en conjunto con - una amplia distribución de luz, existirá mayor iluminación sobre las paredes, no así, si se usaran luces incandescentes bajas de distribución concentrada. Los exhibidores con reflectores, los nichos iluminados, los anaqueles, y los paneles luminosos también contribuyen a la apariencia de las superficies verticales de la tienda a una distancia, estas deben también ser consideradas como una característica de la iluminación perimetral.

La iluminación uniforme de superficies perimetrales es fácil de realizar con lámparas fluorescentes. Las luces superiores de línea colgante pueden ser efectivas en este aspecto. Frecuentemente, sin embargo, un sistema separado para iluminación de paredes puede ampliar la flexibilidad de diferentes tonos o colores a las mismas, -- creando un ambiente más interesante.

La brillantez no uniforme alderedor del perímetro de la tienda puede ser bastante interesante, añade individualidad a la apariencia y acentúa un rasgo de diseño particular ó un departamento. Las lámparas incandescentes, localizadas cerca de las superficies que ellas iluminan, son utíles para este propósito. Este modelo de iluminación variante, se acentúa aún más por la mayor atención dada a las texturas ó formas, en las superficies iluminadas.

La luz de color para uso en exhibidores posteriores y paredes pueden estar convenientemente logradas con lámparas fluorescentes ó incandescentes. La mayoría de los tamaños de lámparas fluorescentes se encuentran disponibles en varias clases de blanco y en un número de colores saturados. Las lámparas fluorescentes de color son mucho más eficientes que las incandescentes de color.

Las lámparas incandescentes de color incluyen diseños de bulbo convencional en wattages que oscilan entre los 10 y los 150, y en bulbos PAR y R-Shape para líneas de luz de color. La variedad de color adicional puede realizarse combinando luz de dos o más lámparas de color. Algunos comerciantes han empleado sistemas motorizados de atenuamiento para lograr un cambio gradual, sutil en el tono perimetral de la superficie sobre un ciclo de varios minutos.

LUZ Y DESVANECIMIENTO.

Algunos tipos de mercancía se desvanecerá el color debido a la exposición a la luz. En la mayoría de los casos, los desvanecimientos son resultado de la oxidación química de tintes y pigmentos; la luz actúa como un catalizador que acelera la reacción. (Una excepción importante es la decoloración de las carnes frescas en mostradores de autoservicio. El espacio no permite aquí, una discusión detallada, pero la investigación ha demostrado que la luz no tiene, ó tiene poco efecto en proporción del decoloramiento de la carne fresca, pero esa decoloración es resultado del crecimiento de bacterías superficiales). El número de factores que se involucran en cada situación de desvanecimiento es tan amplio que ninguna generalización acerca de proporciones en desvanecimiento parecen justificarse. El gran número de fábricas y sus tintes, tanto como las condiciones en el proceso de teñido hacen que la predicción del desvanecimiento en solo los textiles, casi imposible. Algunos artículos son notablemente luz - firme; otros tienen colores relativamente " fugitivos " que pueden cambiar fácilmente. La investigación recientemente conducida en Nela Park indica claramente que allí ha habido adelantos considerables en la firmeza de la luz de las fábricas comerciales, en los años recientes como resultado del aprovechamiento de fibras y tintes mejorados.

El método general de evaluación de las condiciones bajo las cuales el desvanecimiento toma lugar, es computar la "exposición" a la luz. La exposición es el producto combinado de la iluminación sobre el producto y el tiempo en que el producto es iluminado. Así que, - un producto de aparador bajo 100 pies-candela por 300 horas, ha tenido una exposición de 30,000 (horas-pie-candela (fc-hr); similarmente, un período de 30 horas bajo 1000 pies-candela, también representa 30 mil (pies-candela-horas) de exposición. La investigación reciente ha indicado que exposiciones iguales pueden no tener el mismo efecto de desvanecimiento, si toman lugar en diferentes niveles de iluminación. Eso es, 5 veces más iluminación, probablemente no producirá el mismo grado de desvanecimiento en un quinto del tiempo, si - bien es casi cierto que acelera el desvanecimiento en algún grado. - Sin embargo no ha habido suficiente investigación en suficientes y - diferentes materiales para clarificar la relación iluminación versus tiempo, más completamente de lo que se ha expuesto aquí. En pruebas de más de 100 muestras comerciales de fábrica, bajo 8 condiciones diferentes de iluminación, muchas de ellas resistieron más de ------- 1,000.000 fc-hrs. Sin desvanecimiento defectable, mientras algunas de ellas disminuyeron notablemente con 50,000 fc-hrs.

Una de las principales causas de desvanecimiento es la disposición de exhibidores y su iluminación en tal forma que se exagera la exposición en parte del artículo. Por ejemplo, muchos exhibidores - de ropa iluminados con línea colgante estan diseñados de tal manera que la lámpara fluorescente se encuentra a sólo unas cuantas pulgadas directamente arriba de los hombros del exhibidor (perchero). A esta distancia, la iluminación debe tener varios cientos de pies- -- candela sobre los hombros y de algunos artículos con colores fugitivos, puede esperarse que disminuyan con menos de 200 horas de exposición. La prevención de esta situación es, grandemente, un asunto de buen diseño de iluminación. Para iluminar efectivamente las superficies verticales de las prendas, la lámpara debería estar cuando menos a 9 pulgadas fuera de la superficie vertical; esta re-locación - reduce naturalmente la alta iluminación sobre el hombro, por tanto - disminuye la probabilidad de desvanecimiento, mientras que el mismo tiempo se mejora la efectividad de exhibición. Ejemplos similares - de diseños pobres se encuentran en muchas instalaciones de reflectores y estantes iluminados.

Los recursos eléctricos de iluminación difieren en distribuciones espectrales y en sus efectos sobre la apariencia de colores, pero las pruebas han demostrado que no existe diferencia significativa entre recursos razonablemente blancos en sus efectos en desvanecimiento.

Eso es, para la misma iluminación, el desvanecimiento es probable -- que ocurra en el mismo tiempo (ó igualmente que no ocurra) bajo iluminación incandescente ó fluorescente. La radiación ultravioleta de las lámparas fluorescentes es casi la misma en cantidad, que la - de incandescentes. Las pruebas muestran que filtrando el ultravioleta de los modernos colores blancos fluorescentes, no tiene efecto medible en las tasas de desvanecimiento. Cuando existe una proporción substancialmente mayor de onda ultravioleta larga ó media que ocurre con incandescentes ó fluorescentes por ejemplo bajo luz natural el - desvanecimiento de color ocurrirá más rápido con muchos géneros (textiles). La ilusión popular de que las lámparas fluorescentes son en particular causas severas de desvanecimiento de color, es a menido - originado por las experiencias con recursos de baja rendición de color. Los colores Deluxe alivian frecuentemente estos problemas. En otras situaciones, la deficiente iluminación de exhibidor arriba descrita es la causa; las fluorescentes son más señaladas, simplemente porque son aplicadas erróneamente más a menudo.

El manejo de artículos con colores transitorios, es un asunto - de intéres. Reducir la iluminación - no operando la iluminación de la vitrina, por ejemplo puede ser una solución parcial. Otro artificio efectivo es exhibir el producto, así el desvanecimiento que afecta, tomará lugar uniformemente sobre la superficie, en lugar de concentrarse en una pequeña área; esta es una de las ventajas secunda--rias que ha resultado con el cambio de las corbatas de caballero de las vitrinas con sólo los dobleces expuestos a los mostradores superiores donde toda la corbata es iluminada uniformemente en algunos - casos, su caja ó envoltura puede proteger de la luz, a casi todo el corbatín. En cualquier circunstancia, debe recordarse, que cual---- quier artículo que se decolora durante el período de cambios en la - tienda, es casi seguro que decolore si se expone mucho a la luz del día, ó al exterior ó cerca de una ventana; así, este puede ser un recurso posterior de queja por el cliente aún sí no se ha decolorado - en la exhibición.

En algunos casos, los requisitos de exhibición correcta, espe-- cialmente en escaparates, automáticamente resulta en exposición a la luz del día y a la luz eléctrica que causa pérdida de color inevitable. En estos casos lo que puede ocurrir, se descuentan normalmente como parte de gastos de exhibición ó publicidad.

ECONOMIA DE ILUMINACION EN TIENDAS.

Cuesta más iluminar una tienda con un sistema de iluminación ge neral, iluminación, de exhibidor e iluminación perimetral que reune el conjunto de objetivos expuestos en este proyecto, que aplicar un simple modelo de equipo de iluminación general de tubo desnudo, con un mínimo de iluminación perimetral y de exhibición. Una razón de la existencia de muchas instalaciones en iluminación es el alto costo de mejores iluminaciones, parece prohibitivo. La perspectiva ganada por un análisis de costos de iluminación en relación con las ventas a menudo justifica la buena iluminación al proyecto planeado. Es posible estimar exactamente los costos de dos sistemas de iluminación, y compararlos en términos de las ganancias de la tienda.

El incremento en el costo de mejor iluminación tendría que ser visualizado por el incremento del beneficio bruto. Este costo aumentado representa sólo una pequeña fracción de beneficio bruto. Por tanto, un incremento en las ventas, y el consecuente beneficio bruto, es suficiente para pagar el costo de una mejor iluminación. Un incremento del 10 % en ventas rinde una utilidad de 100 % sobre la inversión añadida en iluminación.

Para obtener el incremento de ventas que pagará por su costo aumentado, la iluminación moderna en tiendas ofrece las siguientes ventajas:

1.- Mejor iluminación hace posible decisiones de compra más rápidas y certeras sobre de todos los artículos de la tienda, a través del incremento de visibilidad de detalles.

2.- La iluminación escubierta reduce la molesta brillantez directa de las luces superiores y mantiene la atención del comprador sobre la mercancia. También crea un aspecto más terminado a la tienda.

3.- En exhibidor, la iluminación de relfector y la de localización posterior llama la atención hacia los artículos principales acentuando su forma y textura que añade una chispa a la atmósfera de la tienda.

4.- La iluminación perimetral hace que la tienda parezca más espaciosa y realza la decoración de la misma.

Muchos comerciantes han atribuído significativamente las mejores ganancias en ventas a la mejora en la iluminación (que se requiere para pagar por tales mejoras). Mientras que las estadísticas no pueden predecir exectamente los resultados para una tienda específica, las utilidades demostrables de la mejor iluminación y las módicas ventas requeridas para pagar por ella, argumentan fuertemente la cuidadosa consideración de la iluminación en el proyecto para nuevas tiendas ó para su remodelación.

Datos cuidadosamente reunidos de muchas tiendas muestran que la buena iluminación de exhibidor desemboca en aumento de ventas que oscilan del 10 al 20 %.

32-

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

CURSOS ABIERTOS

ILUMINACION INTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES

CONTROL DE LA LUZ Y FOTOMETRIA

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4 Control de la luz

Generalidades

Una vez obtenida la luz, mediante el manantial luminoso correspondiente, se presenta el problema de su control ya que, debido a su gran luminancia, la mayoría de manantiales luminosos existentes en la actualidad no realizan por sí mismos una distribución del flujo luminoso que permita su aplicación directa, sino que se hace necesaria la utilización de dispositivos que modifiquen o controlen la luz emitida por dichos manantiales luminosos.

La modificación de las características luminosas de un manantial luminoso, con vistas a una aplicación eficiente de luz emitida puede realizarse aprovechando uno o varios de los fenómenos físicos que se citan:

a) *Reflexión*
b) *Refracción*
c) *Absorción*
d) *Transmisión*
e) *Difusión*

Reflexión

Cuando una superficie devuelve la luz que incide sobre ella, se dice que *refleja* la luz. La reflexión de luz depende, esencialmente, de las siguientes circunstancias:

a) Condiciones moleculares de la superficie reflectante. Por ejemplo, una superficie lisa refleja mejor la luz que una superficie rugosa.

b) Angulo de incidencia de los rayos luminosos; ya veremos algo más adelante qué se conoce con el nombre de ángulo de incidencia.

c) Color de los rayos incidentes. La luz blanca se refleja mejor que la luz coloreada.

La *ley fundamental de la reflexión de la luz* dice (véase figura 24):

El ángulo de incidencia es igual al ángulo de reflexión.

Llamamos *ángulo de incidencia* al ángulo α que forma el rayo luminoso incidente con la vertical en el punto de incidencia cuando este rayo choca con la superficie, y *ángulo de reflexión* al ángulo β que forma el rayo luminoso, ya reflejado con la vertical en el punto de incidencia, cuando ese rayo luminoso, se aleja de la superficie.

Esta ley fundamental es solamente teórica. En la práctica se cumple solamente cuando la superficie sobre la que incide el rayo luminoso es absolutamente lisa y brillante como, por ejemplo, la de un espejo. En este caso, se habla de *reflexión dirigida* o, también de *reflexión especular.* Si se coloca una lámpara encendida sobre un espejo puede observarse en el espejo la imagen de la lámpara.

Cuando la superficie sobre la que incide el rayo luminoso es rugosa y brillante, por ejemplo, el papel couché, a cada rayo incidente (figura 25), corresponderán varios rayos reflejados, que cumplen sólo aproximadamente la ley fundamental de la reflexión. En este caso se trata de *reflexión semidirigida;* si situamos la lámpara como en el caso anterior, desaparece la imagen de la lámpara, que queda sustituida por una mancha de luz más brillante que el resto de la superficie.

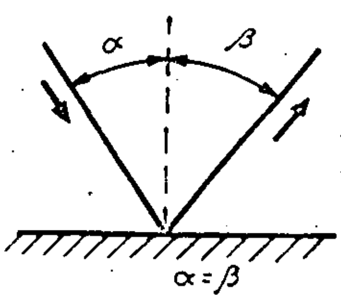

Fig. 24. — Figura ilustrativa de la ley fundamental de la reflexión de la luz.

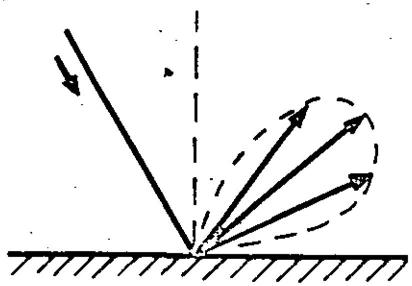

Fig. 25. — Reflexión semidirigida.

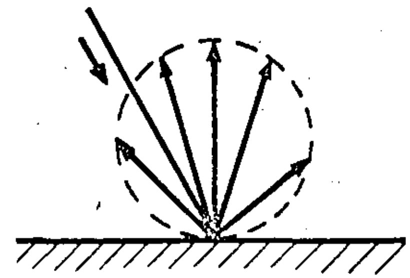

Fig. 26. — Reflexión difusa.

Finalmente, cuando la superficie es rugosa y mate, por ejemplo, un trozo de tela blanca, el rayo incidente (figura 26) se refleja por igual en todas las direcciones del espacio y, por lo tanto, no se cumple la ley fundamental de la reflexión. En este caso, se habla de *reflexión difusa;* en las mismas condiciones citadas en los párrafos anteriores, desaparece la imagen de la lámpara, porque, la luz incidente se dispersa en todos los sentidos.

La reflexión especular proporciona una luminancia máxima en la dirección del rayo reflejado y nula en las demás direcciones del espacio. La reflexión difusa proporciona una luminancia constante en cualquiera de las direcciones del espacio, aunque de menor valor que en el caso de reflexión dirigida.

Con la reflexión difusa se evita el efecto de *deslumbramiento,* que trataremos en un próximo capítulo, y que se aprecia cuando en el campo de la visión existen elementos luminosos cuya luminancia es mucho mayor que la de los elementos circundantes.

Otro efecto interesante de la reflexión difusa es que cualquier superficie reflectora aparece como un disco luminoso de igual luminancia en todas direcciones; es decir, que si iluminamos un disco y una esfera, ambos difusores y ambos de igual diámetro, el efecto visual será el mismo y los dos objetos — disco y esfera — aparecerán a nuestros ojos como discos. O, dicho de otra forma, con la reflexión difusa desaparece el efecto plástico. Ya volveremos sobre esta cuestión más adelante.

Refracción

La dirección de los rayos luminosos queda modificada al pasar de un medio a otro de diferente densidad; este fenómeno físico se llama *refracción.*

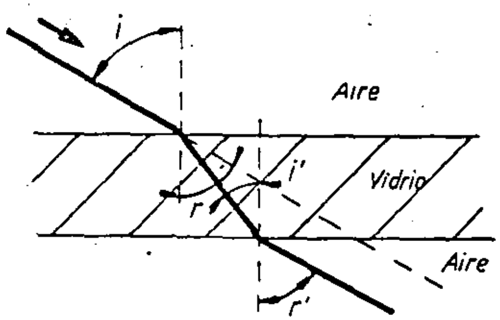

Fig. 27. — Figura ilustrativa de la ley fundamental de la refracción de la luz.

La *ley fundamental de la refracción* dice (véase la figura 27):

La razón de los índices de refracción de ambos medios es igual a la razón de los senos de los ángulos de incidencia y de refracción.

O, expresando esta ley en una fórmula matemática:

$$\frac{n_2}{n_1} = \frac{sen\ i}{sen\ r}$$

Naturalmente, llamaremos *ángulo de incidencia* al ángulo que forma el rayo luminoso con la vertical en el punto de incidencia, cuando dicho rayo choca con la superficie, y *ángulo de refracción*, al ángulo que forma el rayo luminoso con la vertical en el mismo punto de incidencia, cuando dicho rayo luminoso se aleja de la superficie. *Indice de refracción* es la relación entre la velocidad de la luz a través del aire y su velocidad, a través del medio o sustancia correspondiente; por lo tanto, el índice de refracción del aire es la unidad y cuando las sustancias son más densas que el aire, lo que es el caso más general, su índice de refracción es mayor que la unidad: lo que quiere decir — como era de suponer — que la velocidad de la luz es tanto menor cuanto mayor sea la densidad del medio que atraviesa.

Por lo tanto, si el primer medio es el aire, tendremos

$$n_1 = 1$$

y entonces

$$n_2 = \frac{sen\ r}{sen\ i}$$

Volviendo a la figura 27, supongamos, para fijar ideas que los dos medios son, respectivamente, aire y vidrio. Podemos observar que si hacemos pasar el rayo luminoso del aire al vidrio y de éste nuevamente al aire, este rayo luminoso, al pasar por segunda vez al aire seguirá también la ley fundamental de la refracción y su dirección será paralela a la del rayo incidente antes de pasar a través del vidrio; o sea que

$$Angulo\ i = Angulo\ r'$$
$$Angulo\ r = Angulo\ i'$$

Para terminar este parágrafo, en la tabla 4 expresamos los índices de refracción de algunos materiales empleados en luminotécnia.

TABLA 4. INDICES DE REFRACCIÓN

Material	Indice de refracción
Aire	1
Agua	1,33
Vidrio común	1,5 a 1,54
Cristal	1,56 a 1,78

Absorción

En el fenómeno de reflexión de la luz, no todo el flujo luminoso que incide sobre los cuerpos, se refleja; una parte de este flujo luminoso, queda absorbido en mayor o menor proporción según los materiales componentes de cada cuerpo. Por lo tanto, los fenómenos de reflexión y de absorción están íntimamente ligados.

La consecuencia más interesante del fenómeno de absorción es el color de los cuerpos. Si el cuerpo es de color blanco, quiere decir que al incidir sobre él la luz blanca, la refleja enteramente, sin haber absorción; por el contrario los cuerpos negros absorben por completo la luz blanca, sin haber réflexión y si es de color gris, parte de la luz blanca es reflejada y parte absorbida. Un cuerpo es, por ejemplo, de color rojo a causa de que absorbe todos los colores que componen la luz blanca, excepto el rojo, que refleja sobre esta cuestión volvemos más adelante, al hablar del color, en general, y de la luz coloreada.

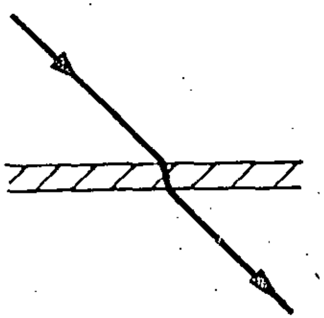

Fig. 28. — Transmisión dirigida.

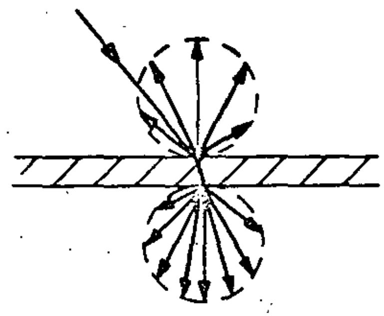

Fig. 29. — Transmisión difusa.

Transmisión

Al pasar los rayos luminosos a través de los cuerpos transparentes o traslúcidos, se dice que estos rayos han sido transmitidos.

La transmisión de la luz puede ser *dirigida* (figura 28) si el rayo luminoso sufre solamente la variación debida a la refracción normal; se consigue esta clase de transmisión utilizando cristales *claros* (es decir *transparentes*) y se produce intenso deslumbramiento debido a la gran luminancia de los rayos luminosos incidentes.

La transmisión de la luz se llama *difusa* (figura 29) cuando el rayo luminoso incidente queda dispersado al chocar con el material, de manera que quede iluminada uniformemente toda la superficie del cuerpo de que se trate; en la citada figura 29 se puede apreciar como una parte del flujo incidente se refleja con reflexión también difusa. Se puede conseguir una transmisión difusa utilizando cristales *opalinos, mateados*, etc..., es decir, cuerpos *traslúcidos*. En este caso, la luminancia es constante en todas las direcciones del espacio y el deslumbramiento es mucho menor que en el caso anterior.

Difusión

De este fenómeno ya hemos hablado en los parágrafos que hemos dedicado a la reflexión y a la transmisión de la luz. Debido a la rugosidad de la superficie que refleja — o en su caso que transmite — el flujo luminoso, éste se esparce en todas las direcciones del espacio; y a este fenómeno se le da el nombre de *difusión*. Podríamos añadir que una superficie perfectamente difusora tiene la misma luminancia

en cualquiera de las direcciones del espacio, o sea que sigue la ley de Lambert.

Relaciones entre reflexión, absorción y transmisión luminosas

Cuando se ilumina una superficie, una parte del flujo luminoso se refleja, otra parte atraviesa dicha superficie y queda absorbida por el cuerpo y, por fin, una tercera parte de la luz incidente se transmite a través del cuerpo. Esto quiere decir que los tres fenómenos — reflexión, absorción, transmisión — están íntimamente ligados y en todos los casos tendremos:

Flujo luminoso total = Flujo luminoso reflejado + Flujo luminoso absorbido + Flujo luminoso transmitido.

Hemos de tener en cuenta las siguientes consideraciones que, por otra parte, son de sentido común:

1. En los cuerpos opacos, el flujo luminoso transmitido es nulo. Pues la principal cualidad de los cuerpos opacos es, precisamente, que no dejan pasar la luz o, dicho de otra forma, que no transmiten la luz. Si lo hicieran, dejarían de ser opacos.
2. No existe, en ningún caso, cuerpos reflectantes puros. El cuerpo más reflectante que se conoce es la plata pulida, y aun en este caso, una parte del flujo luminoso queda absorbido por el cuerpo.
3. Según estas explicaciones, los cuerpos iluminados se convierten en fuentes luminosas secundarias o virtuales, y una parte del flujo luminoso que procede de estas fuentes virtuales puede percibirse visualmente: de esta manera es como las superficies iluminadas se hacen visibles directamente o por transparencia.

Ahora llamaremos

Φ_o = Flujo luminoso incidente o total
Φ_R = Flujo luminoso reflejado
Φ_A = Flujo luminoso absorbido
Φ_T = Flujo luminoso transmitido

Hemos visto anteriormente que

$$\Phi_o = \Phi_R + \Phi_A + \Phi_T$$

Llamaremos *factor de reflexión*, que simbolizaremos con la letra ρ, a la relación que existe entre el flujo reflejado y el incidente, o sea

$$\rho = \frac{\Phi_R}{\Phi_o}$$

Llamaremos *factor de absorción*, simbolizado con la letra α, a la relación entre el flujo absorbido y el flujo incidente, es decir

$$\alpha = \frac{\Phi_A}{\Phi_o}$$

Finalmente, llamaremos *factor de transmisión*, que designaremos con la letra τ, a la relación que hay entre el flujo transmitido y el flujo incidente; o sea

$$\tau = \frac{\Phi_T}{\Phi_o}$$

Se comprenderá fácilmente que, en todos los casos, los factores de reflexión, absorción y transmisión son inferiores a la unidad.

Si en la fórmula que expresa el valor del flujo total, multiplicamos y dividimos los tres términos del segundo miembro por Φ_o, tendremos:

$$\Phi_o = \frac{\Phi_R}{\Phi_o}\Phi_o + \frac{\Phi_A}{\Phi_o}\Phi_o + \frac{\Phi_T}{\Phi_o}\Phi_o$$

y, teniendo en cuenta las definiciones anteriores

$$\Phi_o = \rho\Phi_o + \alpha\Phi_o + \tau\,\Phi_o$$

Y si ahora dividimos los dos miembros por Φ_o, obtendremos:

$$1 = \rho + \alpha + \tau$$

Es decir, que la suma de los tres factores (reflexión, absorción y transmisión) es igual a la unidad. La tabla 5 expone los factores de reflexión, absorción y transmisión que corresponden a diversos materiales interesantes en Luminotecnia; en muchos casos, hemos indicado, además, el efecto resultante. Téngase siempre en cuenta que la absorción representa, en todos los casos, pérdida, por lo que deben utilizarse normalmente materiales de bajo factor de absorción, excepto en casos muy especiales (por ejemplo, iluminación decorativa).

TABLA 5. FACTORES DE REFLEXIÓN, ABSORCIÓN Y TRANSMISIÓN

Material	Factor de reflexión ρ	Factor de absorción α	Factor de transmisión τ	Observaciones
Superficie pintada castaña	0,1 — 0,5	0,9 — 0,5	0	Reflexión difusa
» » roja	0,1 — 0,35	0,9 — 0,65	0	» »
» » verde	0,1 — 0,6	0,9 — 0,4	0	» »
» » azul	0,05 — 0,5	0,95 — 0,5	0	» »
» » gris	0,2 — 0,6	0,8 — 0,4	0	» »
» » negra	0,04 — 0,08	0,96 — 0,92	0	Reflexión semidirigida
Vidrios y cristales				
Vidrio opaco negro	0,5	0,95	0	Reflexión dirigida
Vidrio opaco blanco	0,75 — 0,8	0,25 — 0,2	0	Reflexión difusa
Vidrio transparente claro (2 a 4 mm.)	0,08	0,02	0,9	Transmisión muy dirigida
» deslustrado al ext. (1,5 a 2 mm.)	0,07 — 0,20	0,06 — 0,17	0,87 — 0,63	Transmisión escasamente difusa
» deslustrado al int. (1,5 a 3 mm.)	0,06 — 0,16	0,05 — 0,07	0,89 — 0,77	Transmisión escasamente difusa
Vidrio opalino blanco (1,5 a 3 mm.)	0,30 — 0,55	0,04 — 0,08	0,66 — 0,36	Transmisión difusa
» » rojo (2 a 3 mm.)	0,01 — 0,05	0,92 — 0,93	0,04 — 0,02	» »
» » anaranjado (2 a 3 mm.)	0,05 — 0,08	0,85 — 0,86	0,1 — 0,06	» »
» » amarillo (2 a 3 mm.)	0,25 — 0,3	0,55 — 0,58	0,2 — 0,12	» »
» » verde (2 a 3 mm.)	0,08 — 0,1	0,83 — 0,87	0,09 — 0,03	» »
» » azul (2 a 3 mm.)	0,08 — 0,1	0,82 — 0,87	0,1 — 0,03	» »
Otros materiales				
Papel blanco	0,6 — 0,8	0,3 — 0,1	0,1 — 0,2	Reflexión difusa. Transmisión difusa
Pergamino sin colorear	0,48	0,1	0,42	» »
Pergamino amarillo	0,4 — 0,2	0,2 — 0,63	0,4 — 0,17	» »
Seda blanca (tupida)	0,28 — 0,38	0,01	0,61 — 0,71	Reflexión semidirigida. Transm. difusa
Seda de color (tupida)	0,2 — 0,1	0,11 — 0,86	0,54 — 0,13	» » »

LUMINARIO :

CARACTERISTICAS DE CONSTRUCCION :

Cualquier tipo de luminario es un conjunto armonioso que integra 4 aspectos :

1.- MECANICO.
2.- ELECTRICO.
3.- OPTICO.
4.- ESTETICO.

Y además debe satisfacer los siguientes puntos:

1.- Distribuir el flujo luminoso emitido por la lámpara para obtener resultados óptimos.

2.- Controlar el flujo luminoso de tal forma que la brillantez sea mínima, y con esto obtener un máximo confort visual.

3.- Tener propiedades mecánicas, eléctricas y ópticas que lo hagan adecuado para el propósito para el cual fué diseñado.

4.- Que la lámpara, el sistema eléctrico y óptico queden protegidos -- contra la acción de los agentes externos que se encuentran en el - medio ambiente que rodea al luminario y que pueden afectar la eficiencia del mismo.

El sistema óptico de un luminario puede estar compuesto por :

1.- REFLECTOR.
2.- REFRACTOR.

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El reflector es un elemento con la forma y cualidades ópticas adecuadas para dirigir el haz luminoso producido por la lámpara al área por iluminar. Para su funcionamiento utiliza los fenómenos de reflexión especular y reflexión difusa y puede ser fabricado en cristal liso ó prismático, aluminio anodizado mate ó brillante ó bien lámina de acero pintada en color brillante.

Pero sin importar el tipo de material el reflector debe tener un tratamiento contra la corrosión que garantize la óptima eficiencia el mayor tiempo posible, bajo cualquier condición de instalación.

Generalmente son de forma parabólica ó elíptica de acuerdo con la forma deseada del haz.

El reflector elíptico es más eficiente que el parabólico, pero produce un haz más abierto; el reflector parabólico, produce un haz más cerrado y uniforme pero menos eficiente. En la mayoría de los casos el reflector se fabrica combinando las dos formas para obtener una distribución más adecuada.

El refractor utiliza las leyes de refraxión de cuerpos transparentes y normalmente está fabricado en plástico ó vidrio.

Los ingredientes principales que forman el vidrio son : la arena silice; carbonato sódico, cal y borax, en adición con otros ingredientes menores. La proporción de cada uno de los componentes es conocida de tal manera que se lleva un estricto control de ellas, asegurandose así la calidad de los productos.

Una vez preparada la mezcla se mete en hornos en donde se funde para ser posteriormente vertida en los moldes.

El vidrio puede ser formado por varias técnicas, prensado, soplado ó centrifugado. Estas operaciones pueden ser realizadas por método manual ó por máquinas automáticas dependiendo del volúmen de producción.

Ya formada la pieza de vidrio pasa a otro horno para el proceso de templado, el cual elimina las tensiones internas, asegurando una buena resistencia mecánica.

El terminado del vidrio es muy variado y depende del método de fabricación.

La superficie del vidrio puede ser alterada con ácido, arena a presión (Sand Blast), púlido, pintado, ó teñido. Estas operaciones son usadas para mejorar la reflexión y tener mayor control de refraxión.

La función del vidrio en iluminación puede ser dividida en las siguientes categorías.

1.- CONTROL DE LUZ.
2.- PROTECCION DE LA LAMPARA.
3.- SEGURIDAD.
4.- DECORACION.

Estas funciones pueden ser combinadas para una aplicación en particular.

Las propiedades de transparencia, estabilidad de color y durabilidad del vidrio utilizado deben ser excepcionales, así como su maleabilidad para ser formado en prismas precisos.

Sin control de la materia prima la mayoría de los vidrios ó cristales pueden variar de color después de una larga exposición a la radiación ultravioleta de las lámparas comerciales ó del sol, por lo que los componentes utilizados deben ser cuidadosamente estudiados para obtener máxima estabilidad química, sin cambio apreciable de color.

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Dentro de los vidrios utilizados, podemos distinguir dos clases principalmente: el borosilicato ó resistente al choque térmico y el Hi-Stress ó de "alta resistencia mecánica".

VIDRIO BOROSILICATO.

La tendencia al uso de lámparas de mayor capacidad y el uso de lámparas de vapor de mercurio hizo que se desarrollara un vidrio con buenas propiedades mecánicas y térmicas, principalmente para uso intemperie.

Dicho vidrio está formado por borosilicato principalmente, el cual contribuye grandemente a reducir el coeficiente de expansión, haciendolo resistente a los cambios bruscos de temperatura.

HI-STRESS. (alta resistencia mecánica).

Todos sabemos que el cristal es muy resistente a la compresión, pero es relativamente débil a la tensión. Cuando un vidrio se quiebra, es debido a que el esfuerzo de tensión en este punto ha superado el punto de falla. Un vidrio ordinario sujeto a un choque mecánico se flexiona haciendo que la superficie que recibe el golpe se comprima y la opuesta sea sujeta a tensión, ocasionando en esta forma la ruptura.

La característica principal del vidrio Hi-Stress es que sus superficies están en constante compresión esto se logra con la adición de un tratamiento térmico especial. Cuando una hoja de Hi-Stress recibe un choque mecánico, la superficie opuesta experimenta una tensión pero como se encuentra en estado previo de compresión, el golpe debe ser suficientemente fuerte para superarla, antes de que la tensión empieze y vaya más allá del límite ocasionando la ruptura. Si ésta ocurriera la rápida descarga del esfuerzo compresivo hará que el cristal Hi-Stress se estrelle en pequeños pedazos.

Este tipo de cristal se utiliza en luminarios sujetos a golpes como son gimnasios, áreas peligrosas, instituciones penales, salas psiquiátricas, etc.

P L A S T I C O

El uso del plástico en alumbrado ha sido aumentado debido principalmente a su poco peso y a su resistencia mecánica.

Existe en el mercado varios tipos de plásticos con los cuales se elaboran difusores. Entre los más usuales encontramos el vinílico, poliestireno, acrílico y ultimamente el policarbonato.

La selección del tipo de plástico a utilizar en iluminación depende de las condiciones físicas y económicas en donde se vaya a usar.

El acrílico es el material más usado en la fabricación de difusores por :

* SU ESTABILIDAD EN COLOR.
* SU ALTO COEFICIENTE DE TRANSMISION.
* SU BUENA ESTABILIDAD DIMENSIONAL.
* SU RESISTENCIA AL IMPACTO.
* SUS CARACTERISTICAS INVARIABLES BAJO CONDICIONES NORMALES.

Además el acrílico resiste la lluvia, sol, calor, frío, etc. Y no es afectado por la mayoría de los gases industriales.

METODO DE MANUFACTURA.

Los diseños de lentes prismáticos pueden ser hechos por : rolado, extruidos ó inyectados a presión.

En alumbrado, la calidad y efectividad de un sistema óptico es -- tan bueno como sea el proceso mecánico que siga para producirlo.

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Por esto, la reproducción de lentes prismáticos requiere un proceso de alta presión como el de inyección, ya que solo de esta forma se tiene la presión suficiente para llenar el molde y la precisión necesaria para controlar la luz. Los productos deben estar hechos por este -- proceso, además de utilizar moldes adecuados para minimizar el flujo luminoso en la zona de 60° a 90° con respecto a la vertical ya que ahí es donde se pueden producir deslumbramientos molestos.

El exceso de brillantez en la zona de deslumbramiento de 60° a 90° con relación a la vertical disminuye la comodidad visual y es perjudicial a los ojos. Se ha demostrado por los investigadores científicos -- que la agudeza visual disminuye con el cuadrado de la brillantez directa en la zona de deslumbramiento. Los sistemas de rolado ó extrusión -- son procesos de relativa baja temperatura en los cuales el plástico --- suavizado pasa a travéz de rodillos-dados y es expuesto inmediatamente después a la temperatura ambiente.

Esto dá como resultado un producto con considerables esfuerzos internos en los prismas que hace que se deformen prematuramente además de irregularidad en su estructura prismática causando un control deficiente de luz, aumentando el deslumbramiento directo.

Existen en el mercado una gran variedad de diseños prismáticos, teniendo prismas de diferentes formas y diseños como son : piramidal de - base cuadrada, pentagonal, circular cónico, en forma de estría, etc. Todos ellos embutidos ó salientes.

De todos estos tipos de prismas, el más adecuado es el tipo circular cónico ya que es el único que nos garantiza un control sobre el rayo luminoso en los 360°.

Porta-lámpara: Es un elemento muy importante ya que su función además - de alimentar eléctricamente a la lámpara, debe darle un soporte mecánico adecuado para mantener a la lámpara en el foco óptico previamente -

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definido; en algunos casos el porta-lámpara no es suficiente para mantener la lámpara en posición. Sobre todo en zonas de mucha vibración, por lo que son necesarios soportes extras.

El gabinete ó carcaza proporciona protección contra la intemperie a la lámpara, balastro y demás partes de la unidad. Está compuesto por uno ó varios elementos los cuales deben tener resistencia a impactos - mecánicos, rigidez, resistencia a la corrosión y no deben ser deformados por elementos extraños ó por vibración.

Su forma, dimensiones y el material de fabricación deben corresponder al tipo de luminario y Watts de la lámpara, así como a la zona de - instalación, su diseño debe facilitar el mantenimiento y reemplazo de - la lámpara y además debe ser un cuerpo estético.

El montaje del luminario puede ser realizado con elementos integrales ó bien con elementos anexos como son postes, brazos, etc. Pero sin importar el elemento de montaje este debe ser diseñado para garantizar el fácil acceso al luminario.

Los luminarios se clasifican de acuerdo con el CIE (Comisión Internacional de Iluminación), por el porcentaje de luz emitida sobre y abajo de la horizontal (Fig. 1).

DIRECTA
SEMI DIRECTA
GENERAL DIFUSA
DIRECTA INDIRECTA
SEMI INDIRECTA
INDIRECTA

La forma de distribución puede variar dentro de los límites antes señalados, dependiendo del tipo de la fuente de luz y del diseño del - luminario; por lo que podemos también clasificarlos por el tipo de curva (Fig. 2).

ALTAMENTE CONCENTRADA	HASTA 0.5 ALTURA DE MONTAJE.
CONCENTRADA	DE 0.5 A 0.7
MEDIA	DE 0.7 A 1.5
EXTENSIVA	DE 1.5 A 4.5
SUPER EXTENSIVA	DE 4.5 A 12.0

Todas las anteriores pueden ser simétricas ó asimétricas.

En los sistemas de iluminación con equipo tipo directo se pueden usar todas las curvas descritas anteriormente. Este tipo de sistema de iluminación tiene muy alta utilización, pero se reduce bastante por la necesidad de minimizar el brillo, además no se recomienda en áreas pequeñas por que se presentan los problemas de brillo reflejado y sombras.

El sistema de iluminación semidirecto es utilizado básicamente en las mismas condiciones del directo, con la ventaja que la componente superior atenúa las sombras y mejora la relación de brillantez.

El sistema de iluminación directo-indirecto, debido a la poca emisión de luz en los ángulos cercanos a la horizontal reduce la brillantez en la zona de brillo directo (60° a 90°). Este sistema es mejor que el general difuso, pues este último distribuye la luz en todas direcciones careciendo de control de brillo. Los sistemas semidirectos e indirectos eliminan virtualmente las sombras ya que todo el techo ó estructura pueden funcionar como un reflector gigante. Para que esto pueda operar, es necesario que el techo y las paredes tengan alta reflectancia, ya que de otra forma la energía eléctrica para mantener el nivel de iluminación calculado se incrementa enormemente.

Dentro de las curvas super extensivas se encuentra toda una gama de distribuciónes, las cuales son utilizadas para el diseño de sistemas de alumbrado público.

En el diseño de estas curvas se toma una altura de montaje constante, por lo que es necesario tener diferentes distribuciones de luz para iluminar diferentes anchos de calles usando diferentes espacia-- mientos.

Las curvas para alumbrado público se pueden clasificar tomando - en consideración :

A.- SU CONTORNO DE DISTRIBUCION LATERAL.
B.- SU CONTORNO DE DISTRIBUCION VERTICAL.
C.- SU CONTROL DE LUZ SOBRE EL CONO DE MAXIMA INTENSIDAD.

La distribución lateral es aplicable para diferentes relaciones de anchos de calle a altura de montaje y se dividen en : (Fig. 3).

TIPO I	Cuando el cono de máxima potencia pasa a 1.0 A.M. sobre la línea perpendicular a la calle.
TIPO I	Cuatro vias. Igual pero con cuatro ramales.
TIPO II	Cuando el cono de máxima potencia pasa a 1.75 A.M. sobre - la línea perpendicular a la calle.
TIPO II	Cuatro vias. Igual pero con cuatro ramales.
TIPO III	Cuando el cono de máxima potencia pasa a 1.75 a 2.75 A.M.
TIPO IV	Cuando el cono de máxima potencia pasa a más de 2.75. A.M.
TIPO V	Es una distribución simétrica.

La distribución vertical es aplicable para diferentes relaciones de espaciamiento a altura de montaje y se dividen en :

DISTRIBUCION CORTA	4.75 A.M.
DISTRIBUCION MEDIA	4.75 A 7.5 A.M.
DISTRIBUCION LARGA	HASTA 12.0 A.M.

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Si tomamos en cuanta el control de luz sobre el cono de máxima - intensidad, los luminarios para alumbrado público se dividen en : --- (Fig. 4).

A.- CUTOFF

B.- SEMI CUTOFF

C.- NON CUTOFF

El luminario con curva tipo cutoff es designado así cuando las - candelas no exceden 2.5 % a un ángulo de 90° sobre la horizontal y -- 10 % a un ángulo de 80° sobre la horizontal. Esto se aplica a cual--- quier ángulo lateral alrededor del luminario.

El luminario con curva semicutoff es designado así cuando las -- candelas no exceden 5 % a un ángulo de 90° sobre la horizontal y --- 20 % a un ángulo de 80° sobre la horizontal.

Esto se aplica a cu al quier ángulo lateral alrededor del lumina-- rio.

El luminario con curva noncutoff no tiene ninguna limitación de emisión de candelas en cualquier ángulo.

CURVAS FOTOMETRICAS

La curva fotométrica de un luminario es una gráfica representati va de la emisión de luz del mismo, por lo cual es un elemento indis-- pensable en el diseño de cualquier sistema de alumbrado, es decir, el luminario de acuerdo con este dato debe ser aplicado de tal forma que llene las necesidades del proyecto, tales como nivel de iluminación, uniformidad sobre el plano de trabajo, altura de montaje, iluminación sobre superficies verticales, etc. Todas estas condiciones nos obli-- gan a utilizar las curvas fotométricas.

Es usual que los fabricantes de luminarios proporcionen esta cur va únicamente como un valor indicativo de la distribución de flujo, -

es decir, únicamente proporcionan el contorno de la curva (Fig. 5).

Esto en realidad no es ninguna ayuda, ya que no es una herra---- mienta de cálculo, es indispensable que únicamente se útilizen curvas con datos tabulados por el fabricante (Fig. 6). Los valores en la - columna central representan la potencia medida en candelas a los ángu los correspondientes, por lo cual son los únicos valores confiables - para el cálculo. Analizemos los elementos que normalmente incluye un reporte fotométrico.

1.- En la parte central, sobre un sistema de coordenadas polares se - encuentra dibujado el contorno de la curva. Esta es obtenida en el la boratorio, y como se dijo anteriormente es la representación gráfica del comportamiento del luminario.

Si la unidad tiene distribución simétrica solo necesitamos un so lo plano, pero si nosotros sabemos por adelantado que la distribución es asimétrica entonces necesitaremos curvas fotométricas en todos los planos principales para poder obtener la información del funcionamien to completo del luminario.

En la columna de la derecha, están las lecturas reales en lume-- nes con intervalos de 10° a partir de 0° hasta 180°. Con estos valo-- res es posible computar el rendimiento luminoso en lúmenes del lumina rio como un total del porcentaje de lúmenes emitidos por las lámpa--- ras, ó bien para cada zona en particular. Estos datos se encuentran - en la parte inferior izquierda.

Estudiarémos la emisión de flujo en las varias zonas tomando el punto 0° como punto de referencia. El porcentaje de flujo luminoso en la zona de 0°-180° nos dá el valor de la eficiencia total de la uni-- dad de iluminación.

El flujo de 90°-180° nos indica el porcentaje de la luz transmi- tida arriba de la horizontal; el porcentaje de 0° a 90° nos dá el flu jo luminoso transmitido hacia abajo de la horizontal. El flujo emitido en la zona de 0°-60° indica el porcentaje útil de flujo luminoso sobre el plano de trabajo. En áreas donde las unidades están montadas a relativamente bajas alturas, un mayor porcentaje del flujo en la zona 30°-60° llega a las paredes, de manera que para alturas de montaje medias (4.50 a 7.50 metros), solamente el flujo en la zona 0°-45° nos dá una indicación de la luz útil hacia abajo y para alturas de montaje mayores (más de 7.5 metros), debemos considerar únicamente el flujo en la zona 0°-30°, como luz útil. Es decir, en otras palabras, un reflector industrial de àlto montaje diseñado para alturas de 7.50 metros ó más, no es efectivo si produce un alto porcentaje de flujo luminoso en la zona arriba de los 30° del nadir o vertical.

La porción del flujo luminoso en la zona 60°-90° debe ser estudiada cuidadosamente porque ésta es la luz que llega a nuestros ojos directamente y nos produce deslumbramiento. Por ejemplo, es posible tener dos unidades con el mismo rendimiento lumínico útil pero con diferentes porporciones de flujo luminoso en la zona de deslúmbramiento y, por lo tanto, con una considerable diferencia en la cantidad de deslumbramiento directo.

En la parte inferior derecha se encuentran los lúmenes para cada zona.

Estos son obtenidos en laboratorios y son utilizados para conocer la emisión luminosa del luminario en diferentes zonas.

Por ejemplo tomemos la zona 0° a 10° tomamos la lectura de las candelas a la mitad de la zona 5° y multiplicamos este valor (10870 candelas) por la constante de zona 0°-10° (0.095) obteniendo 1032.65 lúmenes.

Este mismo procedimiento se utilizó para obtener la eficiencia del luminario anteriormente explicado.

Las unidades de iluminación deben ser diseñadas para usarse con espaciamientos perfectamente definidos para áreas interiores o exteriores y es importante no exceder el espaciamiento máximo para una altura de montaje dada, pues de otra manera no se obtiene una iluminación uniforme sobre el plano de trabajo.

Una unidad de iluminación debe de ser diseñada partiendo de la -- curva fotométrica de la distribución deseada y por esta razón, todas - las unidades de iluminación manufacturadas deben producir curvas de -- distribución muy aproximadas a las curvas fotométricas ideales a fín - de proporcionar una distribución lumínica adecuada.

A veces, es necesario evaluar una curva de distribución en fun--- ción de la extensión que abarca su flujo luminoso hacia abajo y no obs tante que esto es relativamente difícil para unidades diseñadas para - aplicaciones con espaciamientos muy grandes, existe una regla muy sim- ple para estimar la relación de "espaciamiento / altura de montaje", - de unidades típicas de iluminación interior. "Si la distancia angular en la curva fotométrica medida del 0° al punto donde la potencia lumi- nosa se reduce a la mitad del máximo es 17°, entonces la relación máxi ma de "espaciamiento / altura de montaje" es 0.5; para relaciones de - 1.0 y 1.5 respectivamente las distancias angulares del 0° a los puntos con mitad de potencia luminosa son 35° y 50°, esto se logra dividiendo esta distancia angular entre 34°".

Para usar esta simple regla vamos a suponer que tenemos una uni-- dad de iluminación cuya distribución es tan concentrada que el punto - con la mitad de potencia luminosa en bujías está a los 10°. Esto signi fica que esta unidad no debe espaciarse a más de 3 décimas de la altu- ra de montaje sobre el plano de trabajo para obtener una iluminación - horizontal uniforme sobre dicho plano.

Por otra parte si se desea espaciar las unidades de iluminación a una distancia igual a la altura de montaje, porque las condiciones de la instalación así lo requiere, entonces una curva de distribución cu- ya extensión angular sea extensiva proporcionará demasiada luz en las zonas superiores, la cual está sujeta a interferencias debido a mampá- ras, maquinaria, equipo, estibas de materiales, etc. Para un mejor di- seño, las unidades deben localizarse dentro de su máxima relación de - "espaciamiento-altura de montaje".

....14

Vamos ahora a resumir la técnica que emplearemos en analizar y - evaluar una curva fotométrica.

1.- Asegurarse que la curva tenga una escala numerada con valores de bujías.

2.- Asegurarse que el rendimiento lumínico de la lámpara de pruebas - esté indicando.

3.- Investíguese si la curva fotométrica representa la característica total lumínica de la unidad, en lugar de un plano específico únicamente.

4.- Investíguese la distribución del flujo luminoso especialmente en las zonas 0°-30°, 0°-45°, 0°-60°, 60°-90°, y 0°-180°.

5.- Cerciorece de que la curva fotométrica represente una unidad de - iluminación adecuada para el espaciamiento y altura de montaje de la instalación en cuestión.

6.- Cuando se trate de distribuciones concentradas ó asimétricas, investiguese la dirección de la potencia.

Vamos ahora a probar nuestra habilidad para analizar curvas fotométricas de varios tipos. En la 1a. hoja se ilustra una curva fotométrica de una unidad de iluminación del tipo esencialmente de distribución hacia abajo. (Prismpack 630). El flujo en las diversas zonas vemos que es del 69.1 % de rendimiento en la zona útil y solamente 1.1 en la zona de deslumbramiento.

No pasemos desapercibidas las pequeñas orejas de la curva que representa la componente luminosa hacia arriba y por lo tanto que ésta unidad dirige un 12.1 % de su rendimiento hacia el techo.

....15

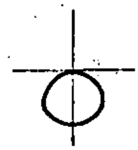
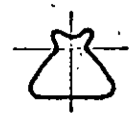
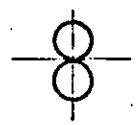
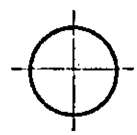
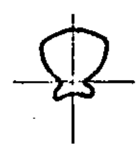
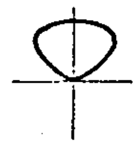
El punto de media potencia luminosa está a 25° aproximadamente -- indicando que la unidad puede ser espaciada 0.73 veces su altura de - montaje. La distribución luminosa es simétrica y es aparente que ésta es una curva fotométrica de una unidad de iluminación tipo directo, a decuada para la iluminación de fábricas, gimnasios, etc. En la 2a. se ilustran diferentes tipos de curvas, la 1a. curva es de una unidad -- con distribución asimétrica más bien concentrada (F-798). Es aparente que esta unidad es adecuada especialmente para la iluminación de su-- perficies verticales porque la distribución fotométrica en un plano - transversal dirige la mayor parte de luz hacia la superficie vertical y en el plano lateral la luz se difunde sobre la superficie vertical por iluminar. La 2a. curva ilustra una curva similar pero en este ca- so la fuente luminosa es una lámpara fluorescente (9012). Sin embargo debido a que las aplicaciones de iluminación son similares, las cur-- vas fotométricas deben ser necesariamente del mismo tipo, cualquiera que sea la fuente luminosa empleada. La 3a. curva ilustra una unidad con distribución asimétrica (C-824). Esta unidad se diseñó para la i- luminación específica de corredores y veremos si sus características fotométricas son adecuadas para este tipo de iluminación. La curva to mada a lo largo del corredor muestra que esta unidad tiene muy baja - potencia luminosa y por lo tanto muy baja brillantez en los ángulos - superiores, lo cual significa que la unidad será muy cómoda a la vis- ta de las personas que se aproximan a ella.

Usando nuestra regla sobre relaciones de espaciamiento vemos que el punto con mitad de potencia lumínica está a los 49°, lo cual indi- ca que la unidad puede ser espaciada una y media veces la altura de - montaje para obtener una iluminación horizontalmente, uniforme. La -- curva de distribución transversal al corredor muestra que hay una com ponente considerable de luz dirigida hacia las paredes laterales y -- también hacia el techo, lo cual es bueno para dar la impresión de una iluminación abundante. De lo anterior se deduce que esta curva de dis tribución fotométrica es ideal para una unidad de baja brillantez di- señada para iluminar el techo, las paredes y el piso de un corredor,- de acuerdo con la técnica más moderna.

....16

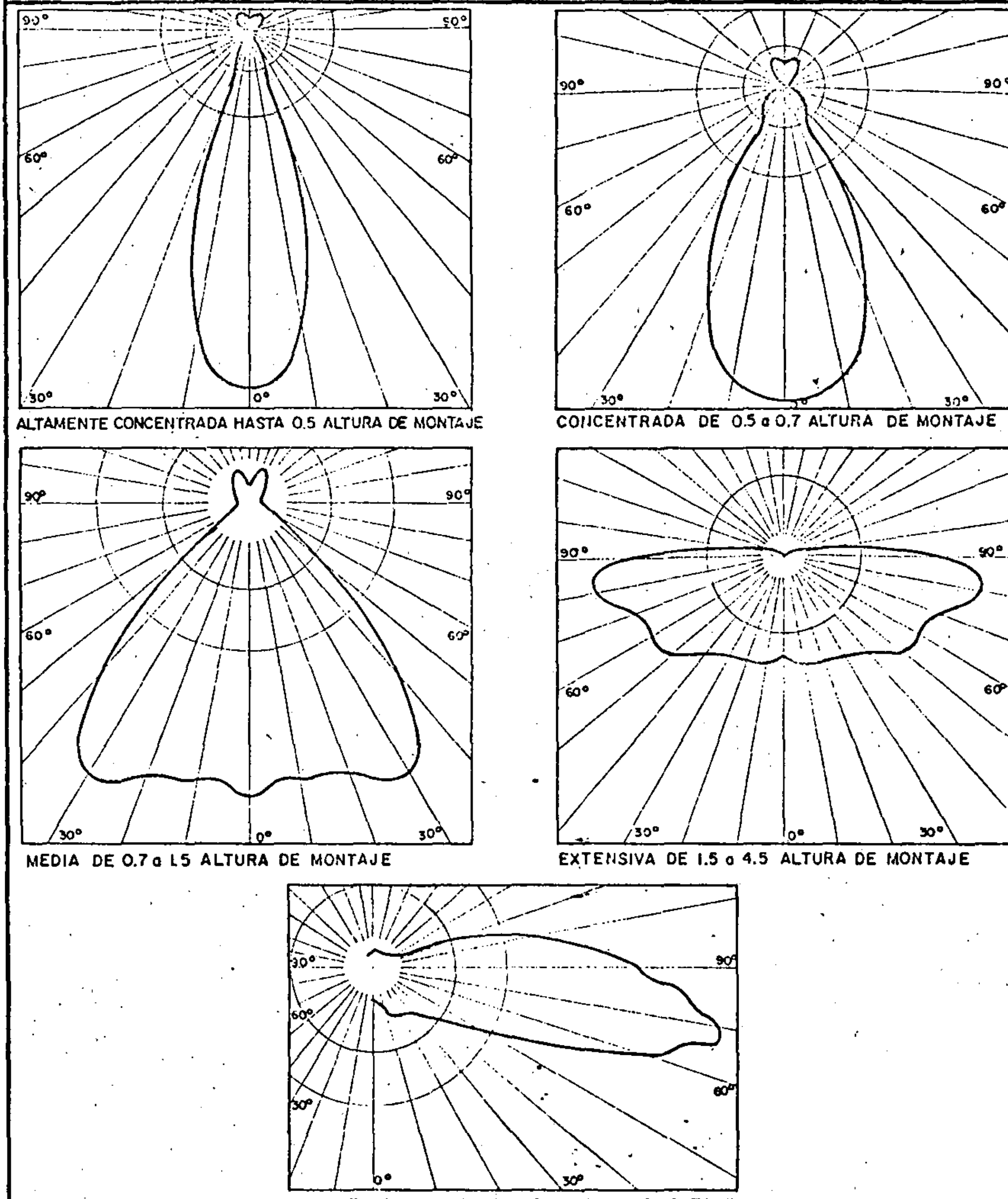
La siguiente curva muestra una distribución muy concentrada. Esta unidad es adecuada para alto montaje. El punto con mitad de potencia está a 18°, lo cual indica que la unidad puede ser espaciada a un poco más de 0.5 veces la altura de montaje. Los datos del rendimiento lumínico indican que un gran porcentaje del flujo está en zona 0-30 - (54.4 %), y una pequeña porción de la zona de deslumbramiento ----- (1.6 %), es interesante comparar la cantidad de lúmenes de esta unidad con la de la lámpara sola, la cual emite 21500 lúmenes, o sea -- 4301 lúmenes más que la unidad de iluminación, lo que nos da una eficiencia de 79.9 %.

Finalmente vamos a considerar una distribución muy interesante - en la última curva y nos preguntaremos si las características fotométricas de esta unidad son adecuadas para la iluminación de áreas exteriores cuando la unidad se monta sobre la pared de un edificio (415). Debido a su distribución concentrada en cierta dirección, el análisis se hará por medio del estudio de los valores de las potencias lumínicas principalmente. En la dirección vertical se vé claramente que la mayor parte de su rendimiento lumínico está en la zona entre los 70° y 80° de vertical. Sin embargo, la distribución lateral en el cono de los 75° (tomada a través de la máxima potencia luminosa), muestra que la mayor parte de la luz es dirigida en dirección opuesta al edificio con solamente una pequeña parte enviada hacia la fachada misma. No se espera que de una breve plática como ésta, convierta a todos ustedes en expertos fotométricos, pero yo confío que dada la atención y el interés que se han servido prestarme, ahora está ustedes capacitados para comparar curvas fotométricas e investigar las características lumínicas de las distintas unidades de iluminación, por medio de sus curvas fotométricas, aplicando las pocas reglas que he descrito en el -- curso de ésta plática.

CLASIFICACION	% DE LUZ RESPECTO A LA HORIZONTAL ARRIBA	ABAJO	DISTRIBUCIÓN DE POTENCIA LUMINICA
DIRECTA	0-10%	90-100%	
SEMI-DIRECTA	10-40%	60-90%	
DIRECTA INDIRECTA*	40-60%	60-40%	
GENERAL DIFUSA	60-40%	40-60%	
SEMI-INDIRECTA	60-90%	10-30%	
INDIRECTA	90-100%	0-10%	

* SOLO CLASIFICACION IES

Figura 1. CLASIFICACIONES CIE-IES.



ALTAMENTE CONCENTRADA HASTA 0.5 ALTURA DE MONTAJE

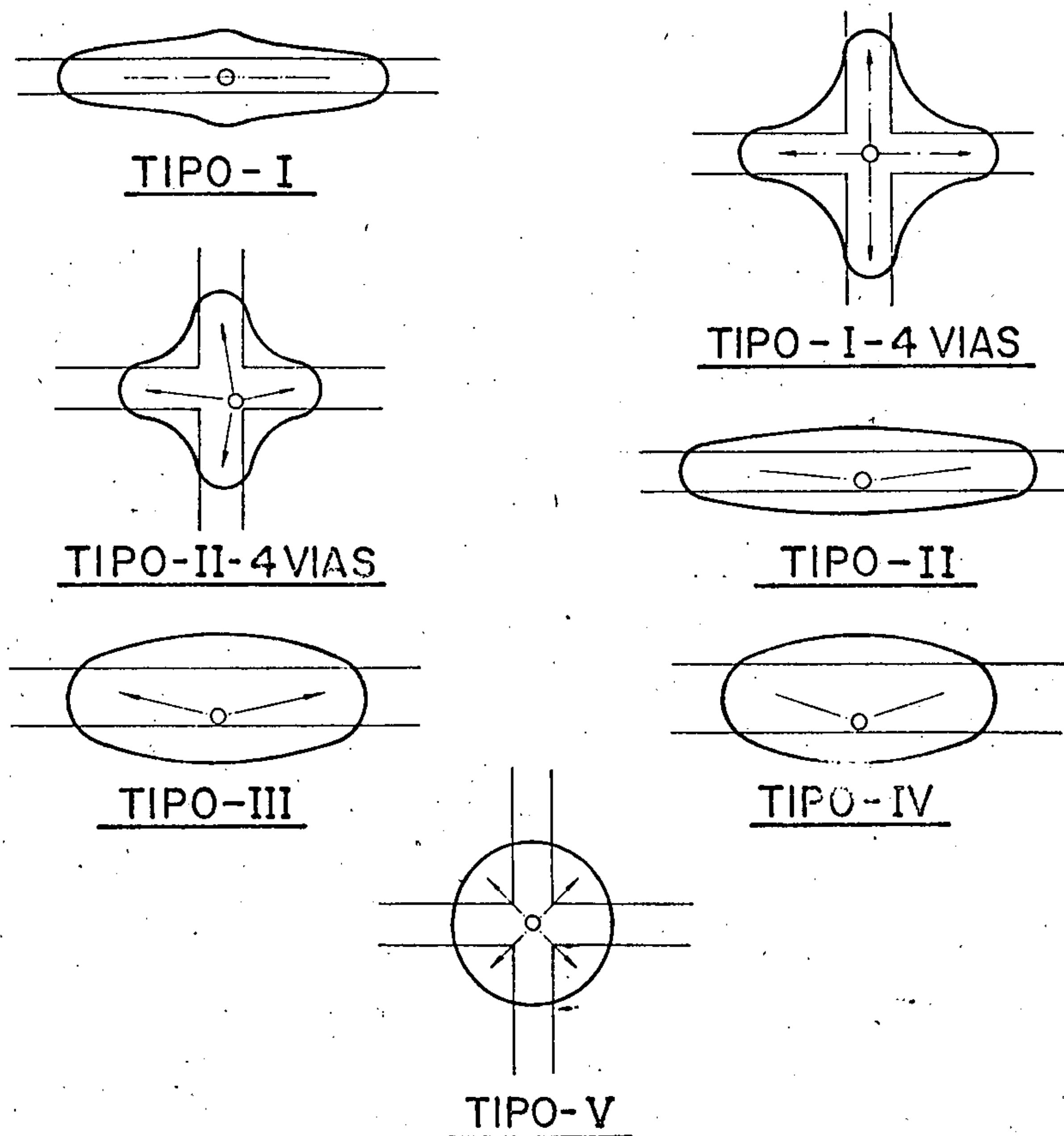
CONCENTRADA DE 0.5 a 0.7 ALTURA DE MONTAJE

MEDIA DE 0.7 a 1.5 ALTURA DE MONTAJE

EXTENSIVA DE 1.5 a 4.5 ALTURA DE MONTAJE

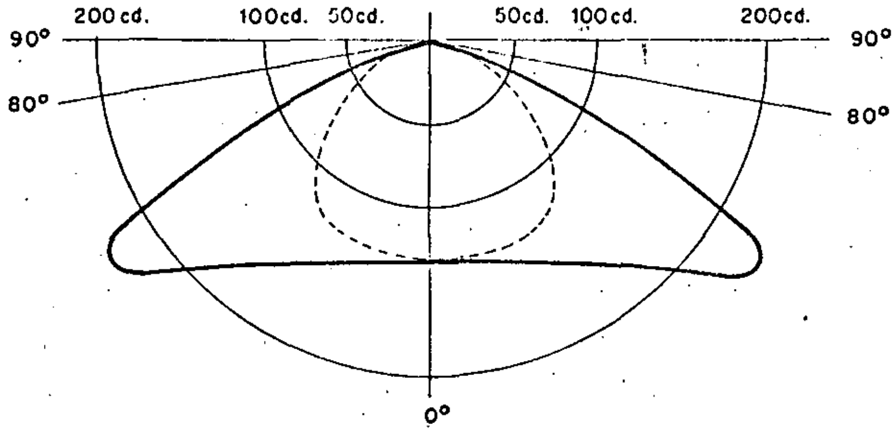
SUPER EXTENSIVA DE 4.5 a 12 ALTURA DE MONTAJE

FIG. 2 TIPOS DE CURVA.

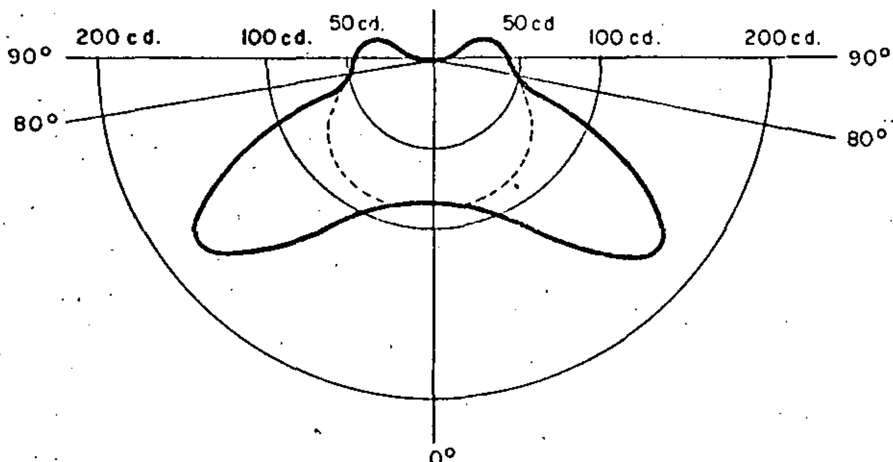


DESCRIPCION : TIPOS DE DISTRIBUCION LATERAL DE LUZ.

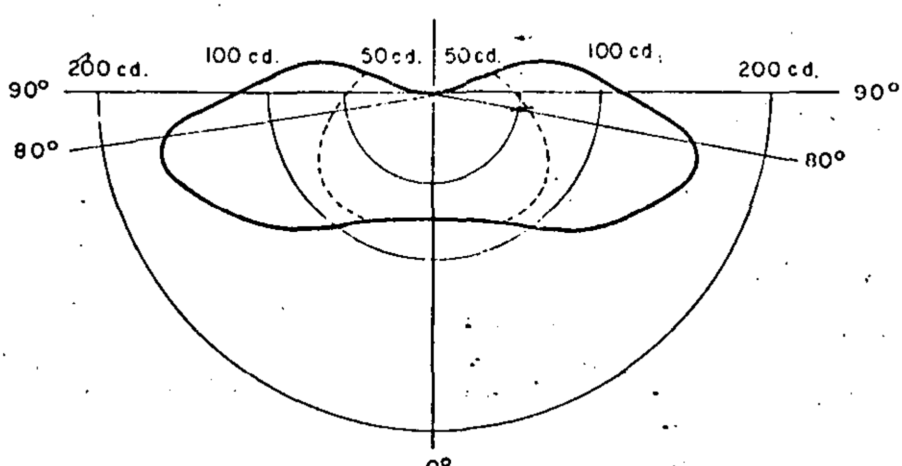
FIG. 3



a) CUT-OFF (HAZ RECORTADO)

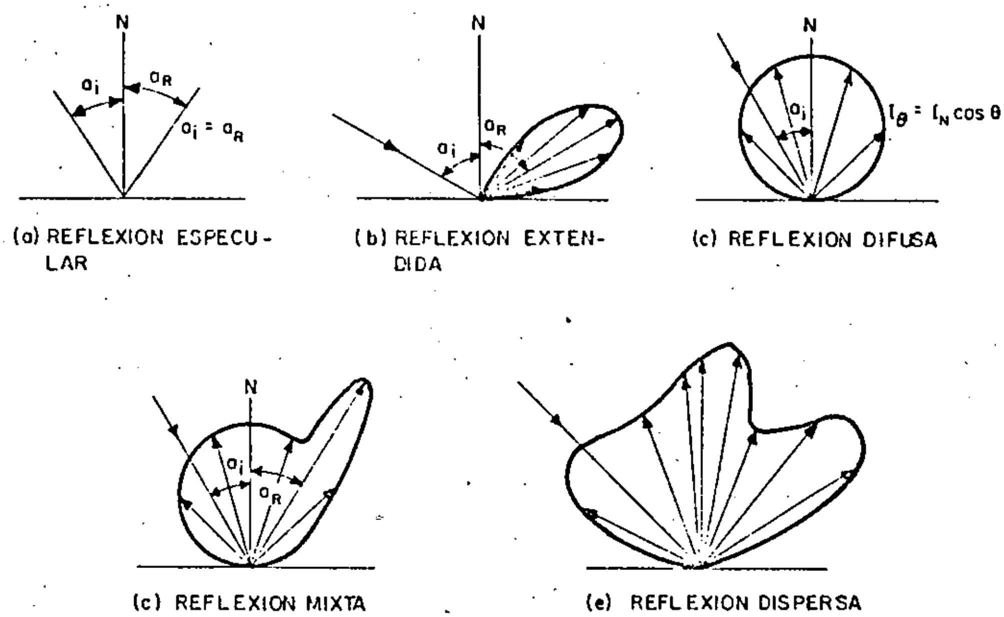


b) SEMI CUT-OFF (HAZ SEMI-RECORTADO)



c) NON CUT-OFF (HAZ NO RECORTADO)

Fig. 4

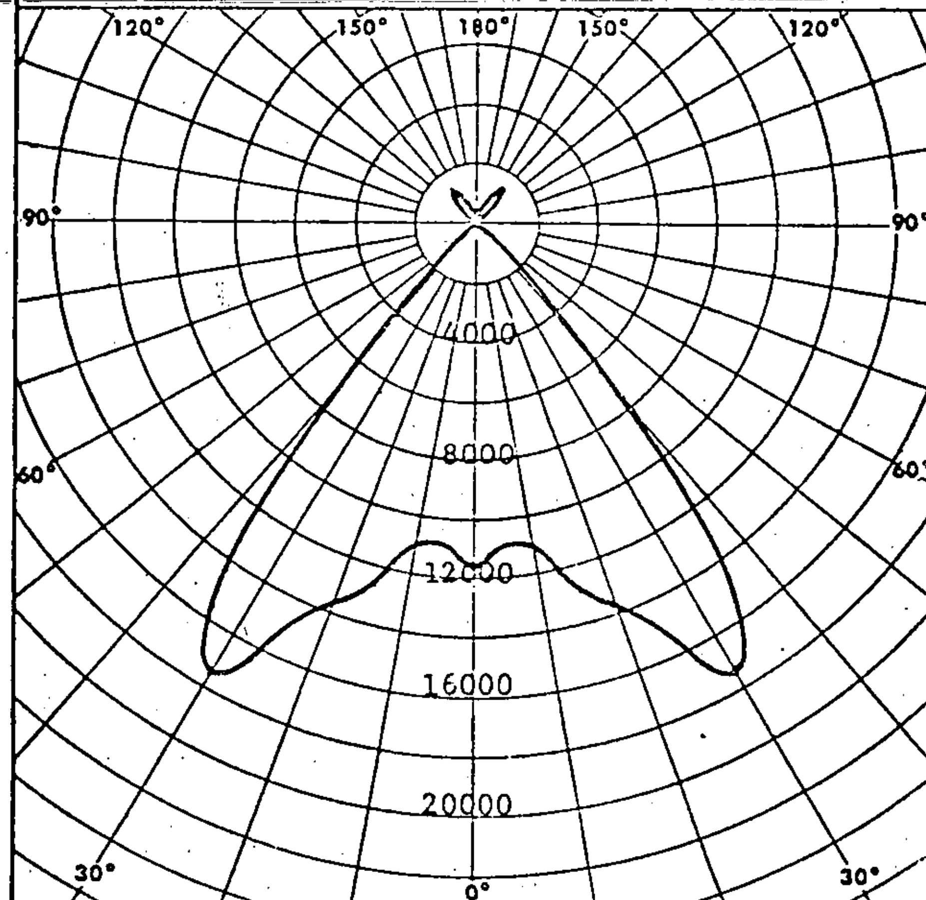


CONFIGURACIONES DE REFLEXION

Fig. 5

PHOTOMETRIC TEST REPORT

HOLOPHANE COMPANY, INC.
ENGINEERING CENTER
NEWARK, OHIO



Test of Holophane No. 635

Position of Lamp Light Center 2-3/8" below top of glass reflector

Remarks Unit tested with 400W. Multi-Vapor, Super-Hi and Metalarc Lamps. Candlepower and lumen values are average of the three tests on 31000 lumen basis

Lamp

Lumens	31000	**Amps.**	
Watts	400	**Volts**	
Bulb	BT-37	**Fil.**	

R.P.M. Lamp & Accessory - 50

Test Distance 25 Feet

Test Cell No. G-9

Tested by JRGreen

Certified by R Z Smith
Manager of Test Engineering

Distribution Data

Angle Degrees	Candle-power	Lumens
0	11680	
5	10870	1060
10	10950	
15	12690	3540
20	13660	
25	15200	7130
30	17520	
35	14300	8280
40	6410	
45	1865	1900
50	710	
55	365	370
60	205	
65	130	135
70	85	
75	55	65
80	45	
85	30	35
90	20	
95	30	30
105	40	45
115	50	50
125	295	265
135	985	765
145	1465	920
155	995	460
165	450	125
175	245	25
180	265	

Output Data

Zone Degrees	Lumens	% Total Lamp Lumens
0-45	21435	69.2
0-60	22280	71.8
60-90	235	.9
90-180	2685	8.7
0-180	25200	81.3

Date January 26, 19[illegible]

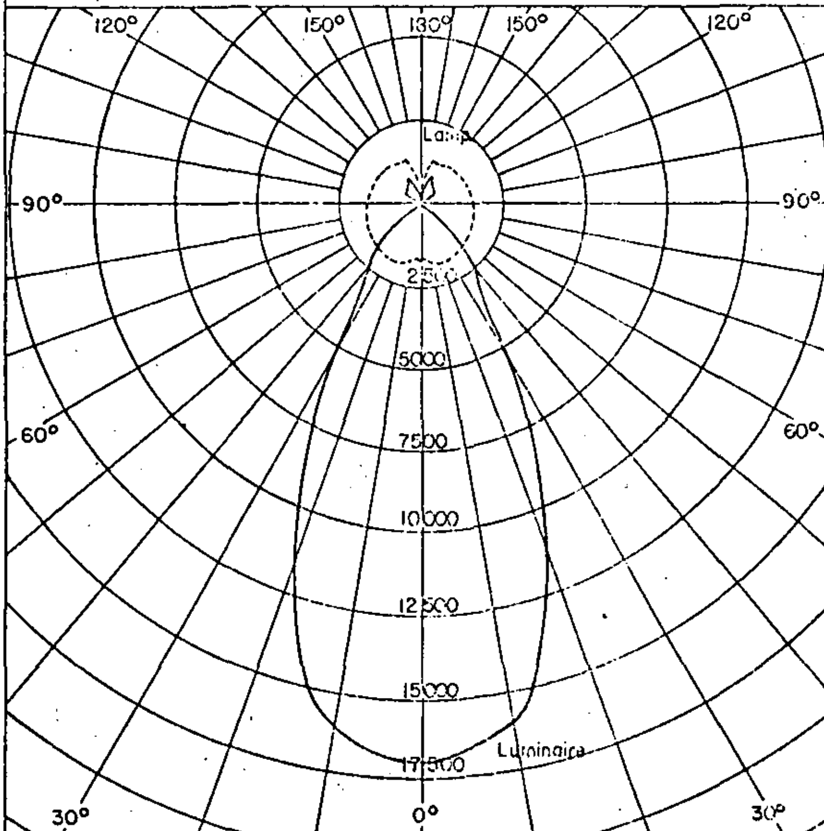
File

Test No. 21372

FIGURA 6 DATOS FOTOMETRICOS

PHOTOMETRIC TEST REPORT

HOLOPHANE COMPANY, INC.
ENGINEERING CENTER
NEWARK, OHIO



Distribution Data

Angle Degrees	Candle-power	Lumens
0	16950	
5	16600	1575
10	16050	
15	14200	3960
20	11600	
25	8320	3880
30	5290	
35	3110	2190
40	2430	
45	1960	1495
50	1385	
55	745	712
60	297	
65	102	141
70	65	
75	51	53
80	43	
85	39	42
90	29	
95	60	66
105	155	164
115	319	316
125	462	414
135	602	466
145	660	427
155	860	398
165	570	161
175	58	6
180	10	

Test of Holophane No. 630

Position of Lamp Light Center 2-9/16" below top of glass reflector

Remarks —

Lamp H33-IGL/C Mercury
Lumens 20000 Amps.
Watts 400 Volts
Bulb BT-37 Fil
R.P.M. Lamp and Accessory-50
Test Distance 25 Feet
Test Cell No. G-8

Output Data

Zone Degrees	Lumens	% Total Lamp. Lumens
0-30	9415	47.1
0-45	12418	62.1
0-60	13812	69.1
60-90	236	1.1
90-180	2418	12.1
0-180	16466	82.3

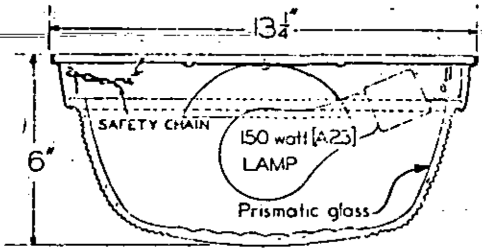
Date May 28, 1962

Tested by

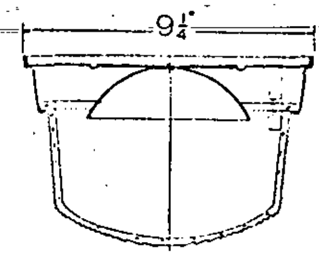
File

Certified by

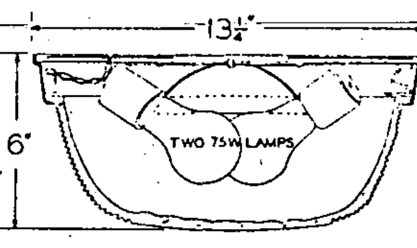
Test No. 19575



No. C-824
Longitudinal Section

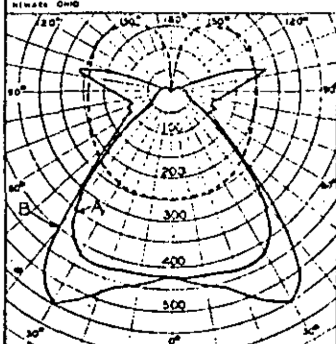


Lateral Section



No. C-824-2
Longitudinal Section

PHOTOMETRIC TEST REPORT
HOLOPHANE COMPANY, INC.
ENGINEERING CENTER
NEWARK, OHIO



Distribution Data

Angle Degrees	Candle-power A	Candle-power B
0	423	423
5	428	429
10	426	445
15	428	457
20	430	483
25	434	522
30	426	546
35	392	507
40	331	401
45	240	278
50	156	192
55	97	147
60	65	124
65	48	98
70	40	108
75	35	92
80	32	95
85	31	110
90	31	123
95	32	153
105	24	217
115	22	81
125	26	25
135	9	20
145	2	23
155		12

Test of HOLOPHANE No. C-824

Position of Lamp LIGHT CENTER 1⅞" BELOW TOP OF GLASSWARE WITH LAMP TILTED AS IN DRWG NO. D-757

Remarks A-VERTICAL DISTRIBUTION ALONG AISLE
B-VERTICAL DISTRIBUTION ACROSS AISLE

Lamp C, INSIDE FROSTED
Lumens 2650 Amps.
Watts 150 Volts 120
Bulb A-23-IF Fil CC-6
B.P.M. LAMP & ACCESSORY-0
Test Distance 10 FEET
Test Cell No. G-5

Output Data

Zone Degrees	Lumens	% Total Lamp Lumens

Date SEPT. 16, 1953
File D.O. 663
Test No. 17367 A & B

Tested by [signature]
Certified by R. L. Smith [signature]

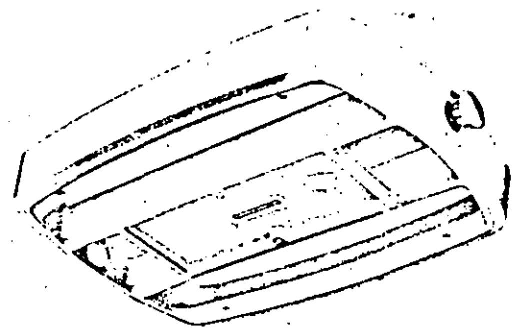
COEFFICIENTS OF UTILIZATION

ZONAL-FACTOR INTERFLECTANCE METHOD

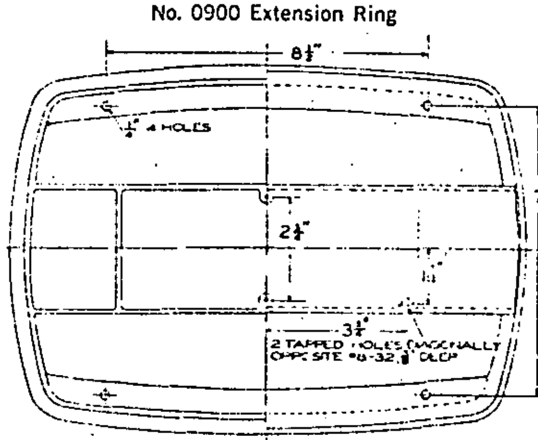
Floor		30%				10%			
Ceiling		80%		50%		80%		50%	
Walls		50%	30%	50%	30%	50%	30%	50%	30%
J	0.6	.27	.23	.25	.22	.27	.23	.25	.21
I	0.8	.34	.29	.31	.27	.33	.29	.30	.27
H	1.0	.39	.34	.35	.31	.37	.33	.34	.30
G	1.25	.44	.38	.39	.35	.41	.37	.37	.34
F	1.5								
E	2.0								
D	2.5								
C	3.0								
B	4.0								
A	5.0								

ROOM INDEX

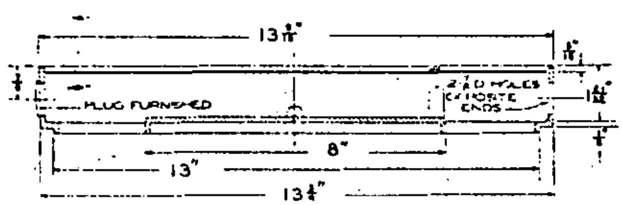
Corridor lighting unit. These room indexes are not generally found in areas using this type unit.



No. 0900 Extension Ring



FACE VIEW BACK VIEW



No. 0900 extension ring for No. C-824 luminaire when surface type wiring is required.

CATALOG DATA

Cat. No.	Lamps	Maximum Spacing Ratio	Dimensions in Inches Length	Width	Depth	Net Wgt. Lbs. Each
C-824	1-150 W. (A23) Inc.	1.5	13¼	9¼	6	6½
C-824-2	2-75 W. Inc.	1.5	13¼	9¼	6	6½
0900	Extension Ring for Surface Wiring.					2½

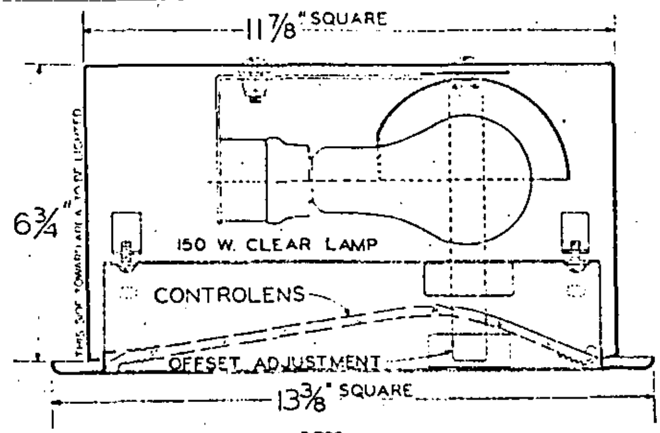
Unit is wired.

UNDERWRITER'S INSPECTED ELECTRIC FIXTURE LABEL

HOLOPHANE COMPANY, INC. • 1120 AVENUE OF THE AMERICAS, NEW YORK 36, N. Y.

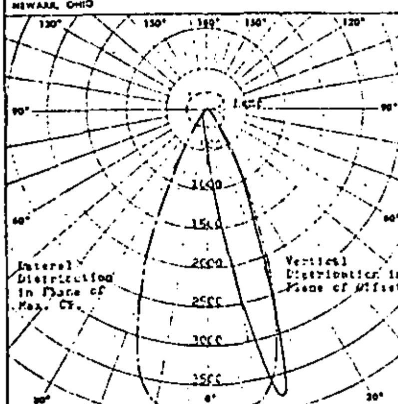
Printed in U.S.A. 5M—3-9-64

F-798 VERTICAL SURFACE LIGHTING UNIT



No. F-798

PHOTOMETRIC TEST REPORT
HOLOPHANE COMPANY, INC.
ENGINEERING CENTER
NEWARK, OHIO



Distribution Data

Angle Degrees	Candle-power Vert.	Candle-power Lat.
0	[illegible]	3770
2½	633	
5	945	3530
7½	1450	
10	2300	3790
12½	3265	
15	3780	2345
17½	3195	
20	2260	2245
22½	1665	
25	1235	1405
27½	1005	
30	751	624
32½	602	
35	375	234
40	154	110
45	126	73
50	98	57
55	79	46
60	64	42
65	53	34
70	44	
75	35	16
80	24	
85	12	3

Test of Holophane Nos. F-798

Position of Lamp: Light Center 4-1/4" above bottom of lens and offset 2-5/16"

Remarks

Lamp C, Clear
Lumens 2700
Watts 150
Bulb A-23
R.P.M.
Test Distance
Test Cell No.
Amps.
Volts 120
Fil. CC-6

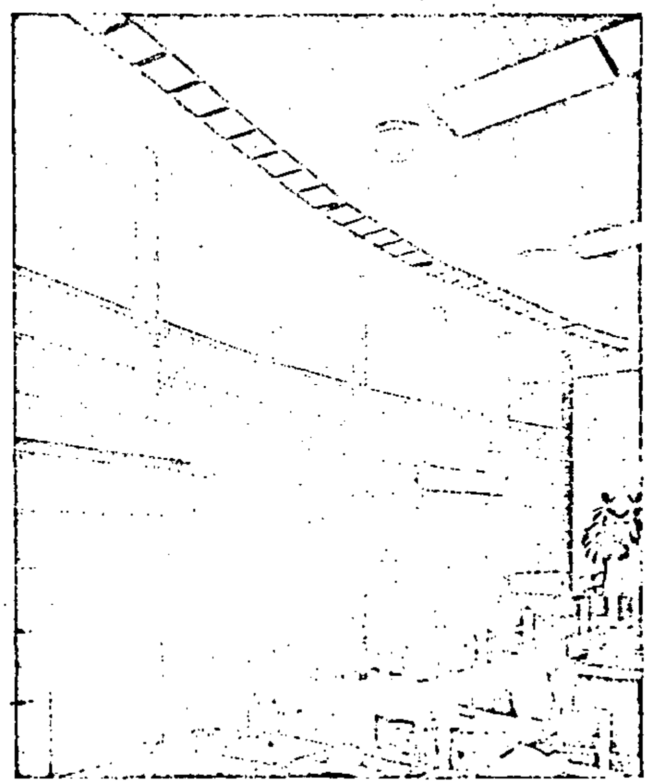
Output Data

Zone Degrees	Lumens	% Total Lamp Lumens

Date Oct. 31, 1960
File DO-861
Test No. 15956 & 2
Tested by
Certified by

Distribution Curve No. F-798

Solid Curve—Vertical Distribution in Plane of Offset
Dotted Curve—Lateral Distribution in Plane of Maximum Candlepower



F-798 carries Underwriters Inspected Recessed Fixture Label

CATALOG DATA

Cat. No.	Lamps	Roughing Box Length	Roughing Box Width	Roughing Box Depth	Face Plate Length	Face Plate Width	Framed Opening Length	Framed Opening Width	Net Wgt. Lbs. Each
F-798	1-150 W. Inc.	11⅞	11⅞	6¾	13⅜	13⅜	12⅛	12⅛	17

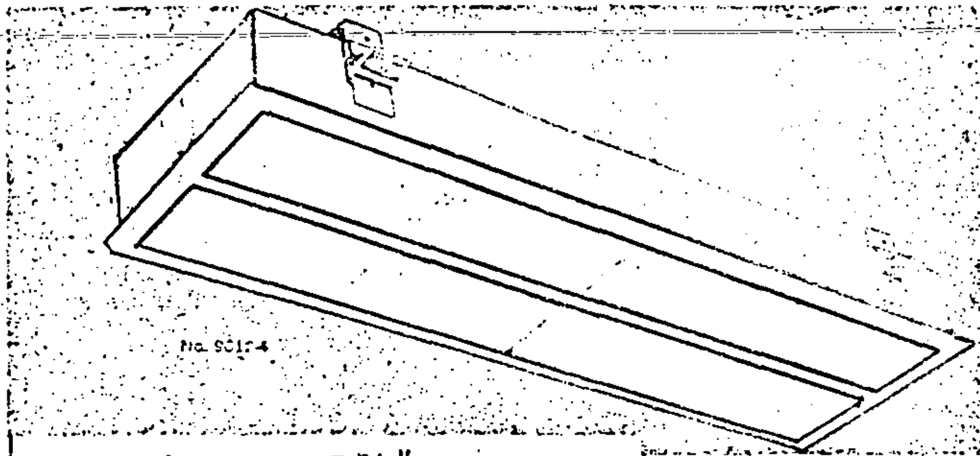
(Dimensions in Inches)

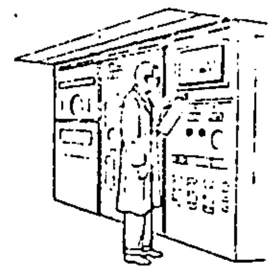
Plaster Flange No. 0251 for F-798 and No. 02097 — 4' Flexible Conduit/Connectors available on separate order.
Units are not wired.

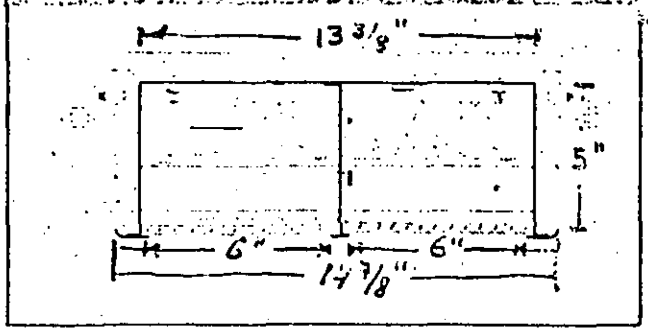
HOLOPHANE COMPANY, INC. • **1120 AVENUE OF THE AMERICAS, NEW YORK, N. Y. 10036**

PRINTED IN U.S.A. 8M-1-73

VERTICAL SURFACE FLUORESCENT 9012 SERIES

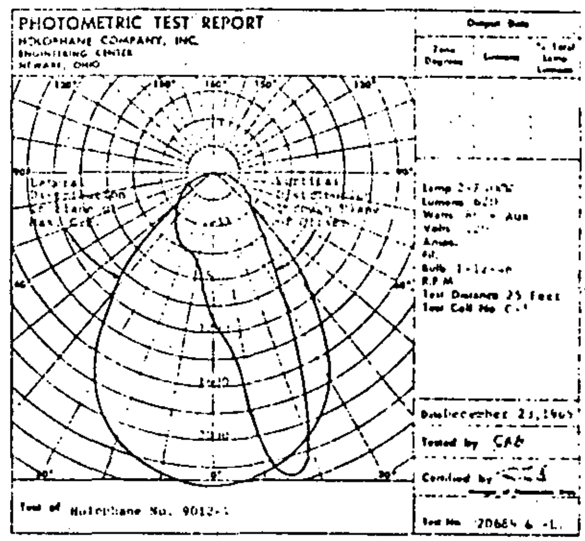






Vertical surface lighting requires specific distributions of light to assure maximum useful illumination and a minimum amount of light cast backward toward the eyes of the viewer. These Holophane products accomplish these results by prismatic lens action. They are available in either single or double width units, depending upon the level of illumination desired.

These units are completely recessed so that they virtually disappear from view. Housings and trim are of heavy gauge steel reinforced to assure rigidity and accurate alignment in continuous runs. The units can be mounted end to end without unsightly metal mullions. A universal yoke is provided which has a reversible bracket grip and conveniently located knock-outs. This assures flexibility for installation in all varieties of hung ceiling construction. Exterior parts are finished in pearl gray enamel to blend with adjacent ceiling construction. Prismatic CONTROLENS* are permanent in their light controlling properties. They require merely routine washing to restore initial efficiency and are removed simply by tipping and tilting for easy relamping of luminaire.



Underwriters Inspected Recessed Fixture Label

Cat. No.	Lamps	Dimensions in Inches: Recessed Portion Length	Recessed Portion Width	Recessed Portion Depth*	Face Flange Length	Face Flange Width	Net Wgt. Lbs. Each
9011-4	1-40 W. Fl. Rap. St. 1-100 W. Inc.	48⅛	6¾	5	49¼	8¼	34
9011-4 Add. Sect.		48	6¾	5	48	8¼	30
9012-4	2-40 W. Fl. Rap. St. 1-100 W. Inc.	48⅛	13⅜	5	49¼	14⅞	45½
9012-4 Add. Sect.		48	13⅜	5	48	14⅞	39½

*Units require 6¼" recessing depth where standard brackets are used.

Catalog designations end in a number that gives the nominal length of the complete unit in feet. Thus 9012-16 consists of one 9012-4 plus three added sections and has an over-all length of 16 feet ⅛ inches. Units are fused and wired. Standard voltage 110 v. to 125 v. Specify when other voltages are required. Plaster flanges are not furnished with these units.

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ESPECIFICACIONES

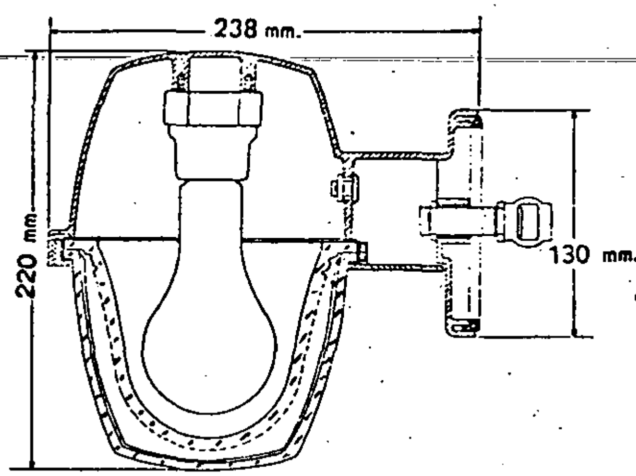
Este luminario es del tipo arbotante, está diseñado para instalarse con lámparas de 75, 100 y 150 Watts.

La parte metálica está hecha de aluminio fundido.

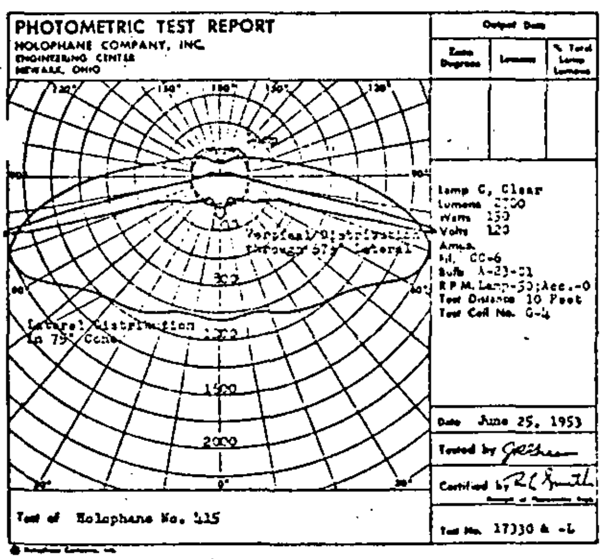
El refractor No. 4203 está formado por dos piezas de cristal transparente, cuyos prismas se combinan para proporcionar una iluminación del tipo super extensivo.

Este luminario esta diseñado para uso a la intemperie.

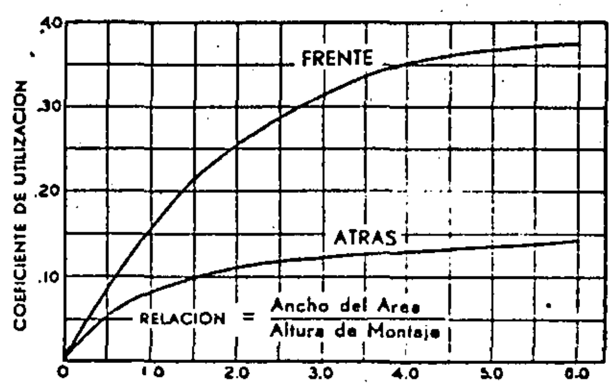
Espaciamiento máximo entre unidades para obtener una iluminación uniforme sobre el piso: 6 veces la altura de montaje que se tenga sobre dicho piso.



Corte transversal del arbotante No. 415 con dimensiones en mm.



Distribución Fotométrica del Refractor No. 4203 con lámpara de 150 W., bulbo claro. 2700 lúmenes



Curva de utilización

Iluminación media en Luxes sobre el Area Horizontal = Lúmenes Lámpara x Coeficiente Utilización / Espaciamiento x Ancho de Area en metros

Holophane*, S.A. de C.V.

S.I.C.-D.G.E.-4841

*Marca Reg. Julio 76 - 2 M.

No HM-16

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LUZ Y COLOR

AUTOR: ING. ALEX RAMIREZ
EXPOSITOR: ING. ERNESTO MENDOZA E.

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LIGHT and COLOR

People usually associate color with physical objects that are viewed in sharp contrast to their surroundings, such as beautiful flowers, multi-hued leaves in autumn, or with the pigment on an artist's brush as he attempts to recreate these impressions. But in addition to colored "things," color also is associated with overall visual impressions of the sky at sunset, fireworks on a summer night, the after-dark excitement of a carnival. Color in design, though, is often considered an integral part of textures and surfaces - walls, carpets, appliances, cars, etc. Color also is viewed as the intangible, mood-setting effect of colored lights.

Artists and building designers have a long tradition in the use of pigment colorants - a tradition that reaches back to the mineral and vegetable mixtures used to color the walls of caves. So people are accustomed to thinking of color in this sense. But the ability to manipulate color by controlling the characteristics of light sources is a relatively recent development - and this often is more difficult to comprehend and appreciate.

As explained throughout this book, color is not a property that is a physical part of the things we see - color is simply the effects of light waves bouncing off or passing through various objects. The color of a given object, then, is determined by several things: the characteristics of the light source under which it is viewed; and the way the object absorbs, transmits, or reflects the light waves striking it. Sometimes the effects of surroundings on the mind is a determining color factor, and, of course, the physical condition of the viewer's eyes are another important determining factor. However, only those light waves entering the eye from the object are technically responsible for what "color" is "seen."

Colors associated with objects can be changed in many ways - by changing the light source (such as from incandescent to fluorescent lamps), by adding light filters (such as wearing sun glasses), as well as by altering the makeup of the object itself. For example, to change an automobile color from red to blue, a different paint pigment is used - one that will reflect blue light waves while absorbing other colors of light waves. But colors can be changed by lights, too. If you have ever seen a red car parked under a clear mercury street lamp at night, you will have noticed that the car was easily mistaken for brown in color, for the clear mercury lamp, while very powerful in producing light, is practically devoid of red energy ... therefore, there were few red light waves available to reach the eye.

Since light and color are such integral parts of our everyday lives, the lamp design engineer is faced not only with designing lamps to give light to see by, but more importantly, he must design lamps which simultaneously appear white and render naturally the color appearance of familiar objects.

By explaining the fundamental principles of light and color, and how they are manipulated for practical application in schools, business, industry, and the home, it is hoped that some of the mystery and misunderstanding of this fascinating science may be removed.

2-

THE NATURE OF LIGHT

"Light" is a special, narrow range of electromagnetic energy. It is a special range because it alone can stimulate the two types of receptors within the eye which permit vision. Therefore, we call light "visible energy," even though we cannot see the energy itself.

[illegible]

Electromagnetic energy is only one form of energy known today. Other forms are thermal, chemical, kinetic, atomic, electrical, etc. Electromagnetic energy is also referred to as radiant energy because it exists only in the form of repeating wave patterns traveling in straight paths, as rays, in all directions from its source. So light, being a special form of radiant energy, also is called "visible radiant energy."*

Considering that energy cannot be destroyed - only changed from one form to another, and considering the physiological composition and functions of the eye, we can now understand that light is transformed from electrical energy to radiant electromagnetic energy within a light source, travels in a high-speed, high-frequency wave form, and becomes useful to man when a sufficient amount of it is transformed into chemical energy within the receptors of the eye.

There is a very broad spectrum of radiant, electromagnetic energy, of which light is but one narrow band. All radiant energy travels at the speed of 3×10^8 meters per second (186,000 miles per second) in air or in a vacuum. At one end of the spectrum are cosmic rays, and at the opposite end are electrical power waves. The individual types of radiant energy are identified by their particular ranges of frequencies, or number of wave cycles per second. The average wavelength of the shortest cycles of radiant energy known (cosmic rays) is 0.00001 nanometers. (One inch contains about 25.4 million nanometers. A nanometer is one thousand-millionth of a meter.) At the other end of the known spectrum of electromagnetic radiation are electric power waves — with an average wavelength of almost 5 million meters (3100 miles).

The spectrum of radiant energy waves we call light is very narrow, ranging from approximately 380 nanometers to 760 nanometers** (or from 15 to 30 millionths of an inch). Wavelengths shorter or longer than these do not stimulate the receptors in the eye. Beyond this range is darkness, for, while the eye may be exposed to many other wavelengths of radiant energy, they are not capable of initiating responses in the eye.

LIGHT SOURCES

The sun - and electric lamps, are considered light sources because they transform energy from another form into the radiant energy wavelengths which we call light. But these light sources also emit useful energy at wavelengths both shorter and longer than light waves. Ultraviolet energy - valuable for its germ-killing, suntanning, and photochemical properties, has wavelengths shorter than light waves; and infrared energy waves (often referred to as heat rays) are longer than light waves. All radiant energy, when absorbed, can be transformed into heat.

* Both the Electromagnetic Wave Theory and the Quantum Theory have been postulated as possible explanations for the phenomenon of radiant energy. While science has proven neither to date, the Electromagnetic Wave Theory provides the most direct explanation of radiant energy characteristics.

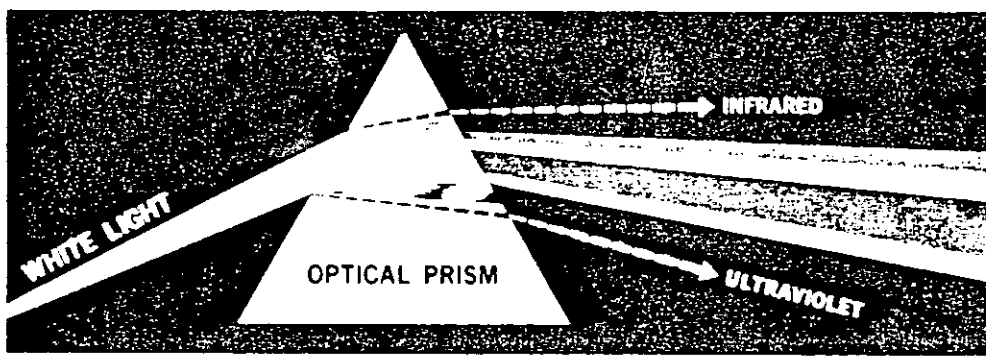
** Some authorities extend the visible to 780 nanometers. The effect on seeing of these longer wavelengths is very close to zero.

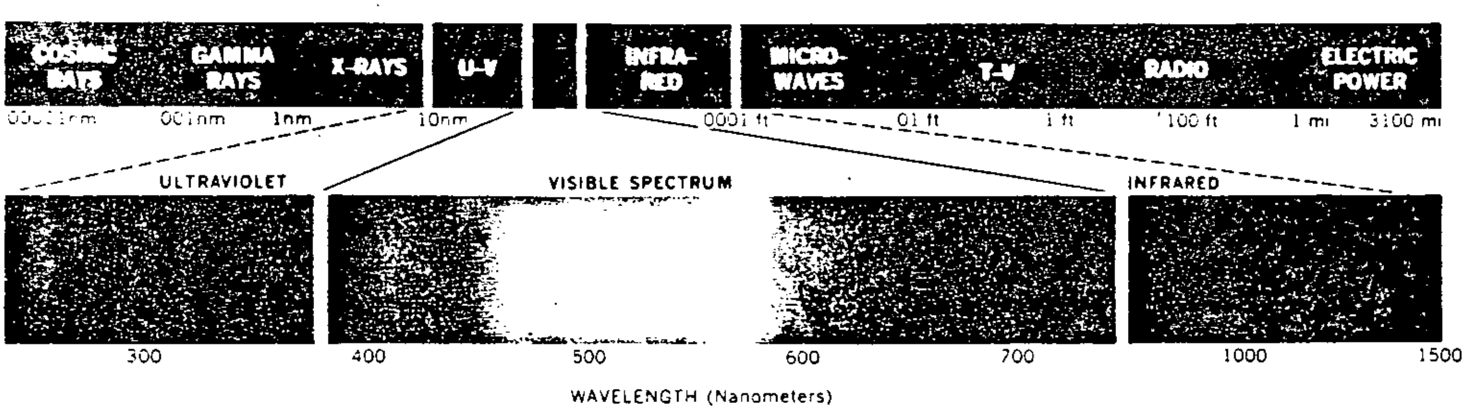
3-

A light source emitting radiant energy relatively balanced in all visible wavelengths will appear white to the eye. However, passing a narrow beam of white light through a prism of transparent material will spread and separate the individual wavelengths of visible energy so that the eye can distinguish between them - the resulting visual phenomenon is called a color spectrum. The normal eye will see three wide bands of blended color - violet, green, and red, with several narrower bands (blue, yellow, and orange) blended between the wider bands. The "color blind" eye will see only graduations of gray, or perhaps some of the colors and some gray - depending upon the extent of physiological impairment of the eye.

A lamp designer is more concerned with the cause of these wavelengths than he is with the names we have given them. However, it is vitally important that he know that wavelengths longer than 610 nanometers produce that effect we call "red" — and those between 440 and 500 nanometers are called "blue," and so on, in order to control both the appearance of light sources themselves and the effects light sources have on the appearance of colors in objects around us.

Representation of a prism bending rays of white light. The effect of the prism is to bend shorter wavelengths more than longer wavelengths — separating them into distinctly identifiable bands of color. The colors can be recombined into a beam of white light by accurately orienting a properly designed second prism to intercept the dispersed color light rays. Note that the prism also is useful for separating infrared and ultraviolet rays as well as visible rays.





THE NATURE OF COLOR

"Color" is a term which describes an *imbalance* of visible radiant energy reaching the eye from light sources and objects . . . imbalance being defined as any deviation from the *average* amount of energy at all wavelengths. Such deviations, or imbalance combinations, are almost incalculable in number - which accounts for there being so many "colors," or names, to describe the various "mixes" or combinations of visible energy.

WHAT COLOR IS

A colored light source radiates much more energy at some wavelengths than at others, and a colored object reflects or transmits some wavelengths more readily than others. In either case, there is an energy imbalance, occasionally to the point where some wavelengths actually are missing, in the mix that reaches the eye. Thus we see that color has both *qualitative* and *quantitative* characteristics. The qualitative characteristics refer to information on *what wavelengths* are present, while the quantitative characteristics refer to *how much energy* is present at *each* wavelength. The qualitative characteristics are a specification of *chromaticity*, and are termed *dominant wavelength* and *purity*. The quantitative characteristic is a specification of *luminance* - formerly called photometric brightness.

Dominant wavelength is the wavelength, or color, which *appears* to be most abundant. However, it need *not* be the wavelength which is *actually* the strongest in intensity, although both wavelengths are usually very near to each other.

Purity may be described as the *percentage* of color VS the *percentage* of white in any color.

To demonstrate that color is the result of an *imbalance* of visible radiant energy, consider two theoretical objects which both reflect half of the light from a perfectly balanced white light source. One reflects *half* of the energy at all wavelengths of the visible spectrum - it appears gray and produces no color sensation because *all* wavelengths are still present, though only half as intense. The other object reflects *all* the energy in *half* of the spectrum - say, the shorter wavelengths, from 380 nanometers to 570 nanometers - but *no* energy in the other half of the spectrum. This object will produce a strong color impression - blue, but only a secondary sensation that only half of the light source energy is being reflected. So it is apparent that color is *not* a result of any changes in volume of *total* radiant energy, but is a result of energy deficiencies at individual wavelengths.

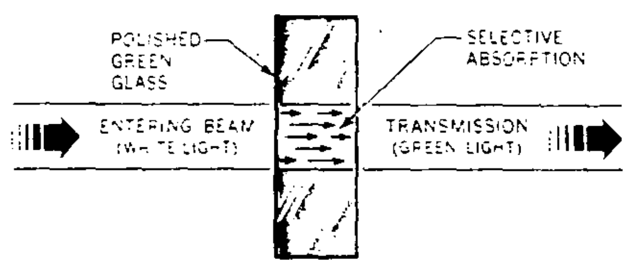
An extreme case of imbalance of light waves would be a *monochromatic* situation wherein only one color, or wavelength of visible energy, is present. The color perceived would be of the purest quality since no other wavelengths of energy (colors) are present to dilute its purity.

SEEING COLOR IN OBJECTS

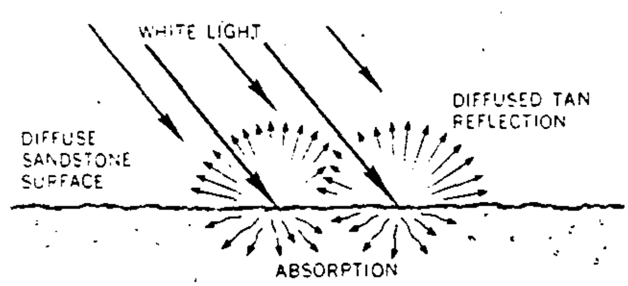
It is now apparent that without light there can be no colors, for colors are simply other names to describe the various mixtures of electromagnetic energy - which exists only in the transient state of radiation. And since colors are descriptions of dynamic, or moving, phenomena, they cannot also be physical properties of stationary objects. What, then, are colors in objects?

Colors we see in objects are, still the result of, waves of radiant energy that reach the eye - but *after* they have been *modified* in many ways by each object.

All physical objects have a modifying effect on light waves - reducing both the amount of energy and the types of light waves which reach the eye from the light source. Even the particles in the earth's atmosphere filter the sun's radiation before it reaches our eyes - which is a partial explanation for changes in the colors of the sky and clouds at sunset.



EXAMPLE OF SELECTIVE SPECTRAL TRANSMISSION



EXAMPLE OF SELECTIVE SPECTRAL REFLECTANCE

We call radishes "red," lemons "yellow," and pine trees "green" - in fact we have assigned color names to almost everything we come in contact with in our daily lives. That these objects appear to be the same colors under all lighting conditions is called "color constancy" - which simply means that those objects consistently reflect or transmit light waves only in a particular, narrow color range while absorbing all others. Water has no color constancy because it will reflect and transmit *all* light waves, hence, it appears to be whatever color is dominant in its surroundings.

The two fundamental ways in which objects and mediums modify the colors of light have already been mentioned — transmission and reflection, but objects and mediums usually are *selective* in how much energy, and at which wavelengths they will transmit or reflect light. The Selective Spectral Transmission diagram (p. 6) shows how a green glass filter will selectively absorb all wavelengths except green from a light beam passing through it, so that both the chromaticity and luminance of the transmitted beam are affected.

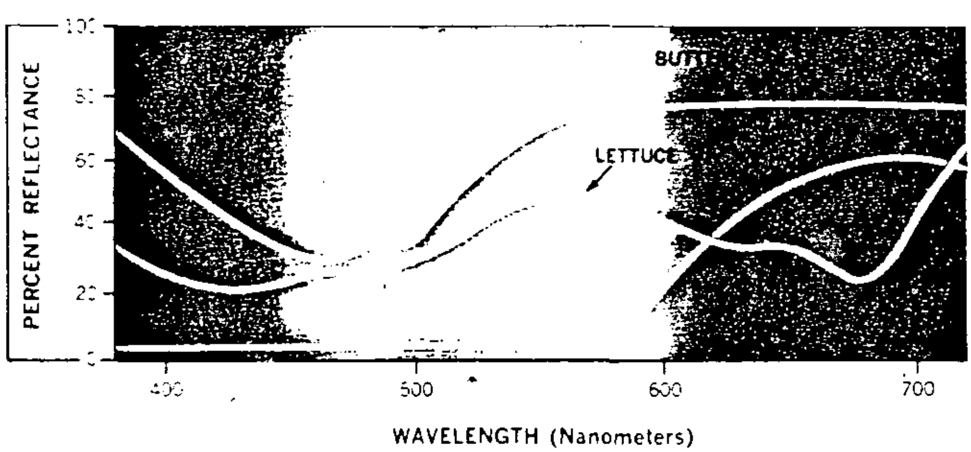
Just how much the color and intensity of the transmitted light is modified depends on the molecular composition of the materials through which the light passes. For example, in some colored lamps, coatings of colored pigments and dyes are used to selectively absorb unwanted wavelengths or colors and transmit the desired wavelengths. In other cases, the glass or medium itself is colored to achieve the same effect.

When light is evenly played on a diffuse (unpolished) surface, the effect is that light waves are reflected in all directions, but only after they have been modified by the absorption qualities of the surface. The result is that the surface then appears to have a color all its own . . . different from the color of the light source. But that is only because the surface has absorbed various amounts of various wavelengths of spectral energy. Sandstone is a highly diffuse material with relatively even spectral absorption qualities, hence, it appears tan in color throughout (see diagram, p. 6). A coat of paint on an object also has an evenly distributed quality of absorbing, and thus will evenly reflect whatever colors, or wavelengths of energy, that are not absorbed by the paint.

It is important to reiterate that since *all* light waves are modified in some way by *all* physical objects - that the *color* appearance of an object is determined by the mix and energy of light waves which *remain* intact to reach our eyes. Objects have a characteristic color only because of the way they selectively reflect or transmit or otherwise modify various wavelengths of light.

As shown in the reflectance chart below, butter appears "yellow" because it absorbs blue light and reflects a high percentage of all other colors. The resultant combination, or dominant wavelength, is yellow. Similarly, lettuce reflects light with wavelengths primarily in the 500 to 600 nanometer (green) range and absorbs most of the energy at other wavelengths. A tomato, then, is red only because it reflects radiant energy at 610 to 780 nanometers while absorbing most of the energy at other wavelengths.

But just as important to the apparent color of objects is the character of light waves being radiated onto the objects by the *light source*.

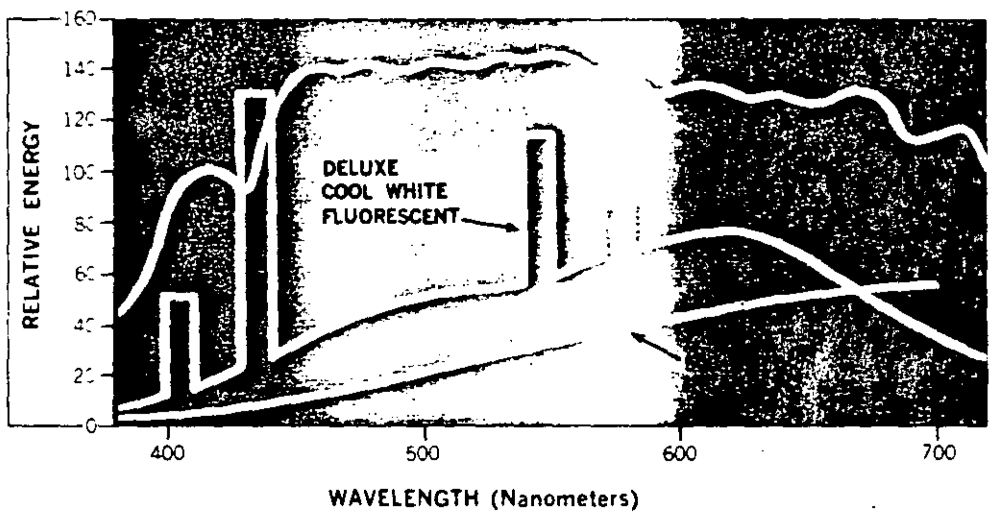


Colored light sources emit energy in selective wavelength bands, and "white" light sources generally emit energy at all visible wavelengths. But some light sources actually are deficient in energy at various wavelengths and *still* emit what is considered "white" light (see adjacent chart). This deficiency affects the perception of object colors (color rendition) and color differences, graying some colors while increasing the relative vividness of others.

There are "warm" sources such as all incandescent and some fluorescent lamps. These produce white light that tends to be strong in the red, orange, or yellow wavelengths. Conversely, there are "cool" sources such as clear mercury lamps and other fluorescent sources which produce white light that is strong in blue and green. Lighting a surface alternately with warm and cool lamps, then, will produce an apparent change in the perceived color of that surface, despite the fact that in both cases, so-called white sources are used. This effect is most pronounced if the changes are rapid, and the observer does not have time to adapt to the difference in whiteness.

Some light sources, of course, are deliberately made with only one color predominant, to achieve a specifically desired effect. For example, if a wall that appears white under a white light is lighted with a light source that is predominantly red, the wall will *appear* to be red because *only* red wavelengths of visible energy are present to be reflected from the wall toward the observer's eye. If the same white wall is lighted with green light, the wall will appear green.

As we have seen with the tomato example, lighting a red surface with a "white" light source will make the surface appear red - because only red wavelengths of light are reflected toward the observer's eye . . . all other wavelengths are absorbed. However, if the same tomato is lighted with a green light, it will appear much darker and essentially colorless (brownish gray) because there is *little red energy* in the *green light* to be reflected. The important point is that regardless of the characteristics of a surface finish, the eye cannot see colors from it that are not contained in the source of illumination.



THE PSYCHOLOGY OF COLOR

Up to this point we have treated color in the vernacular of the illuminating engineer or physicist. The definition given was: "Color" is a term which describes an imbalance of visible radiant energy reaching the eye from light sources and objects. And this definition is true - as far as it goes. But consider this definition - "Color" is a concept or human interpretation of the neural impulses transmitted to the brain from the normal eye when it is stimulated by various imbalances of visible radiant energy. This latter definition is not more true - it is just more complete - because it encompasses all three sciences involved: physics, physiology, and psychology. Paraphrased, color is a concept resulting from the interaction of light source, object, eye, and brain.

COLOR PERCEPTION

The process and mechanisms by which the brain "perceives" color, or any other concept, is not yet fully defined, but science and technology are being continually advanced toward that end. Perhaps someday we will understand how we think - "color" - but for the moment we are concerned with what is already established knowledge in the field of light and color.

The adjacent illustration demonstrates that the more complete definition of color as a concept is accurate when we consider that color does not exist independent of normal, color vision. As previously mentioned, the totally color-blind person cannot distinguish between various *wavelengths* of light - he can only distinguish between various *amounts* of light. To him there is no "color" - everything is either black or white or shades of grays in between. Most important is the fact that the physical light waves received by both a color-blind person - and by a person with normal color vision, are not changed by the *condition* of the receptors in the eyes of either person. Only the *concept* (perception or interpretation) of what is seen by each person is changed. Therefore, red, or any other color, is exclusively the mental *concept* resulting from the brain's interpretation of special visual stimuli.

COLOR ASSOCIATIONS

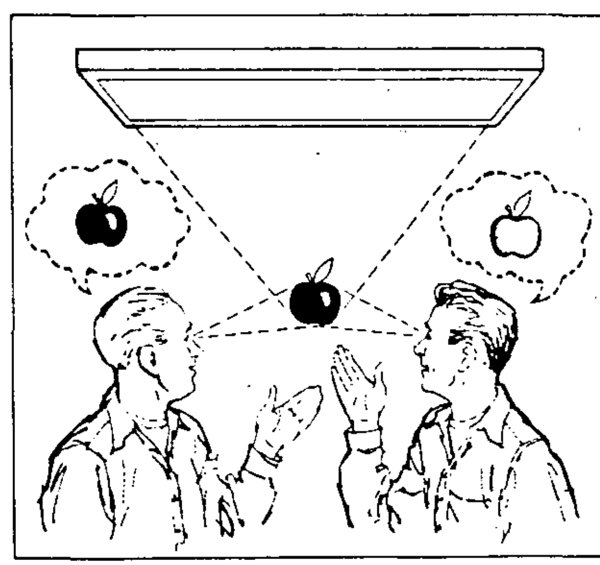
Now that we have brought color into the realm of the abstract concept, it immediately becomes a part of what we think about everything else - objects, situations, attitudes, moods, environmental conditions, etc. Color is unconsciously assimilated into all our impressions or concepts because our eyes are constantly supplying our brain with color information which is automatically associated with all other information on any given subject or situation.

Perhaps more than any other single element in design, people's reactions to color affect their individual preferences. But, some color reactions are universal. Certain colors, for example, are associated with certain moods. Reds, oranges, and yellows, are generally accepted as stimulating while blue, blue-violet, and violet are considered the least exciting.

People's reactions to the colors associated with materials do not always correspond to their reactions to the same colors associated with light. As a demonstration, the green in foliage is generally accepted as refreshing, cool, and undisturbing, so people have come to think of trees and shrubs as somewhat neutral or quiescent in effect; hence, green background materials in man-made objects are psychologically restful. But green in a light source is unnatural; and used alone, tends to produce a macabre or sinister effect.

Where the proper appearance of people is important, there is a strong unconscious preference for white light sources which are rich in red light; these lamps help impart a healthy, ruddy or tanned impression of the skin and flatter the complexion. There also are indications that people prefer warm light in areas where lower levels of illumination are involved, while cool light seems to be more acceptable for higher levels.

Where stronger, more saturated colors are involved, people generally agree that warm colors appear to advance, while cool colors recede and help support a feeling of spaciousness. In a more subtle sense, changes in the color of light appear to alter the moods of a space - the impressions associated with warm sunlight and cool shadows, the pinks and purples of a sunset; the similar restful qualities of the interior of a cathedral where light is tinted by stained glass windows; the gaudy, overstimulating effects of rapidly moving, colored carnival lights. People invariably feel the psychological impact of light and color without ever realizing that they do - or even analyzing the reasons for associating colors with moods



"It's red! . . . . No, it's dark! . . . . ."
"It is not - it's bright red! . . . Nope - medium dark!"

Color Is A Concept That Does Not Exist Independent Of Normal Color Vision.

COLOR VISION

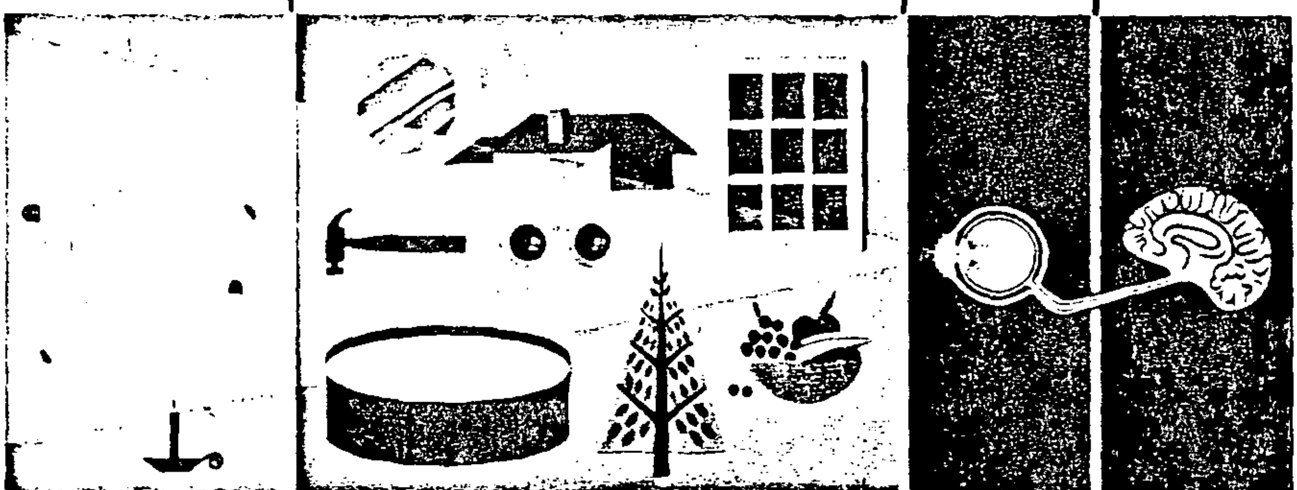
The diagram below briefly summarizes the ingredients in the process of seeing light and color. As we have seen in the preceding pages, it is a complex process involving physics, psychology, engineering, photometry, etc. - and now we come to the eye itself - physiology.

EYE FUNCTIONS

There are many theories to explain the phenomenon of color vision. The most easily understood is Young's three-component theory which assumes three kinds of light sensitive elements (cones) - each receptive to one of the primary colors of light - an extreme spectrum red, an extreme spectrum violet

SEEING LIGHT AND COLOR

GENERATORS — TRANSMITTERS (LIGHT SOURCES)	MODIFIERS AND RETRANSMITTERS (SECONDARY LIGHT SOURCES)	RECEIVERS — ENCODERS (EYES)	DECODER — INTERPRETER (BRAIN)

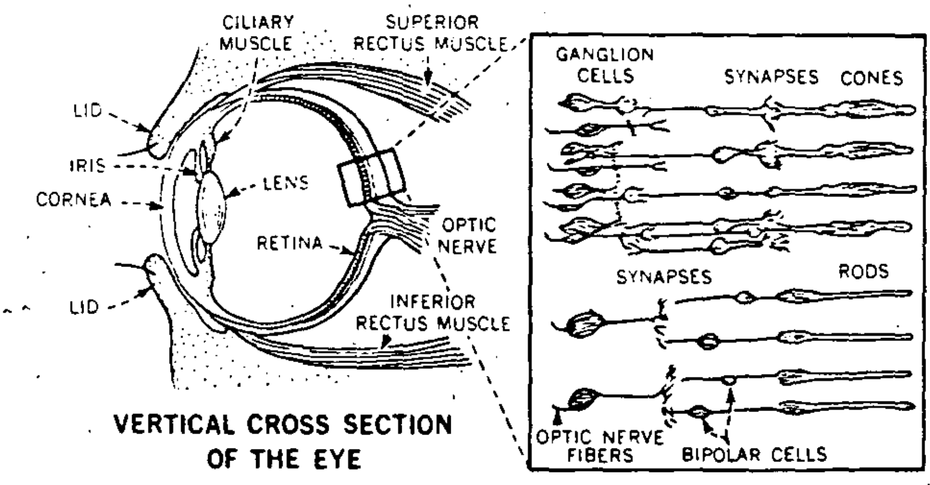


SUN, DISCHARGE LAMPS, FLUORESCENT LAMPS, INCANDESCENT LAMPS, OPEN FLAMES, ETC.	ATMOSPHERE, AIR, WATER, PLANETS, LENSES, WINDOWS, TREES — ALL NATURAL OR MANUFACTURED OBJECTS WHICH MODIFY LIGHT WAVES BEFORE THEY REACH THE EYE.	CORNEA, IRIS, LENS, RODS & CONES, OPTIC NERVES	ANALYSIS, IDENTIFICATION, ASSOCIATION, PERCEPTION

HOW THE EYE WORKS

Light waves enter the eye through the cornea which roughly focuses the pattern of waves on the foveal pit in the retina. The waves are fine-focused as they pass through the lens. The iris acts as a diaphragm which expands or contracts the pupil (opening in the iris to the lens), controlling the amount of light that is permitted to enter the eye.

The rods and cones are the ultimate receivers for individual parts of the image. They transform the received optical image pattern from radiant energy into chemical energy which energizes millions of nerve endings. The optical pattern then becomes a series of electrical impulses traveling within a very special group of nerves which connect to the optic nerve. The optic nerves (from both eyes) combine and transmit the selective impulses to the brain where they are interpreted.

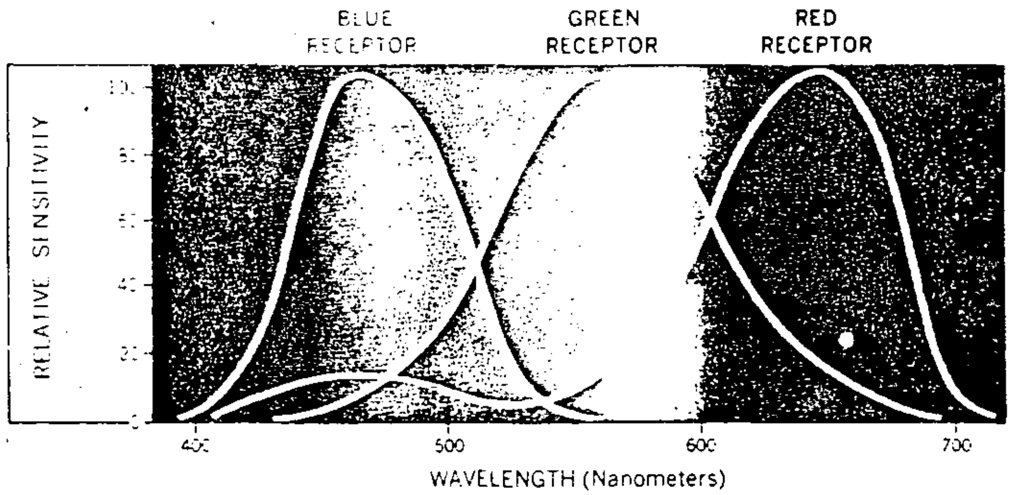


VERTICAL CROSS SECTION OF THE EYE

and an imaginary green (see adjacent sensitivity chart).

The cones in each eye number about seven million. They are located primarily in the central portion of the retina called the fovea, and are highly sensitive to color. People can resolve fine details with these cones largely because each one is connected to its own nerve end. Muscles controlling the eye always rotate the eyeball until the image of the object of our interest falls on the fovea. Cone vision is known as photopic or daytime vision.

Other light receptors, called rods, are also present in the eye - but they are not involved in color vision. Rods serve to give a general, overall picture of the field of view, and are receptive only to the quantity of light waves entering the eye. Several rods are connected to a single nerve end: thus they cannot resolve fine detail. Rods are sensitive to low levels of illumination and enable the eye to see at night or under extremely low lighting conditions. Therefore, objects which appear brightly colored in daylight when seen by the color-sensitive cones appear only as colorless forms by moonlight because only the rods are stimulated. This is known as scotopic or night vision.



Relative spectral response function of the cone mechanisms as postulated in Young's theory. Absolute sensitivities of the three receptor peaks are not necessarily equal.

DAY-NIGHT VISION

As the adjacent spectral sensitivity curves show, the eye is not equally sensitive to all wavelengths. In dim light particularly, there is a definite shift in the apparent brightness of different colors. This was discovered by Johannes von Purkinje. While walking in the fields at dawn one day, von Purkinje observed that blue flowers appeared brighter than red, while in full daylight the red flowers were brighter than the blue. This is now called the Purkinje effect and is particularly important in photometry - the measurement of light.

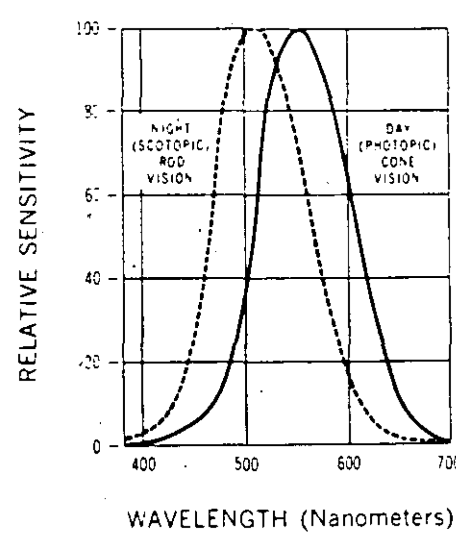
COLOR DEFICIENCIES

9-

The totally color-blind person cannot distinguish between color and quantity because the cones are either partially or totally impaired — only the rods are functioning. This person's eyes are only sensitive to luminance, or quantity of light. As a result, light sources appear as "brighter or dimmer," and objects appear as "lighter or darker."

A totally color-blind person has full appreciation of his surroundings - but in values of grays, much as a person with normal color vision has full appreciation of a color TV program which is viewed on a black and white TV set.

The most prominent type of color deficiency is known as Deuteranomaly - or red-green blindness, wherein the person sees yellows and blues normally, but has trouble differentiating reds and greens. Only about five percent of the male population has this deficiency, and only 0.38 percent of the females. An even smaller number of people - 0.003 percent males and 0.002 percent females, are totally color blind.

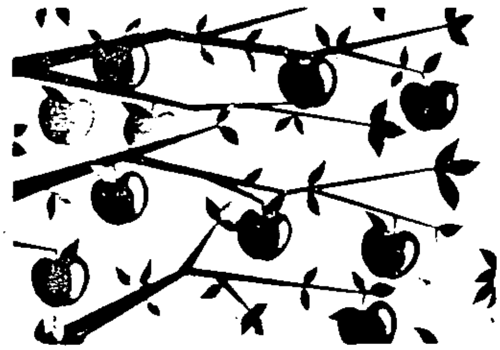


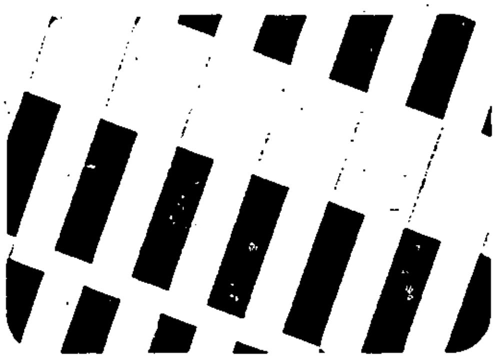
VISUAL ILLUSIONS

10-

"Now you see it — now you don't." The old magician's line about sleight-of-hand tricks is perhaps more applicable to tricks our eyes play on us with colors — in different arrangements, under different lighting, at different distances. To get the strongest visual reactions, cover all other illustrations on the pages when studying each illusion.

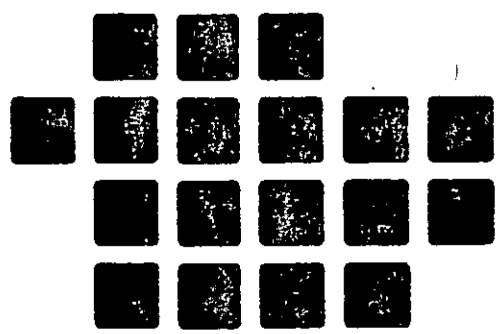
COLOR RECEPTION DEFICIENCIES. Non-functioning cones in the eyes of totally color-blind persons result in rod vision only - whereby everything is perceived in blacks, grays, and whites (right half of illustration) instead of in colors (left half of illustration). The values in the grays of the illustration match the combined chroma and values in the colors.

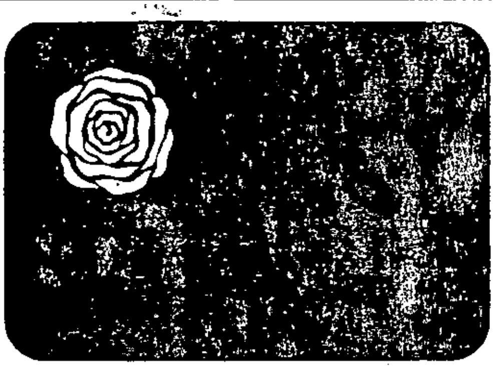




CHAMELEON EFFECT. Colors of medium value and chroma will appear to change in the direction of lighter, brighter colors - or darker, duller colors surrounding it. The blue bars in this illustration are all printed with exactly the same color of ink - but they appear lighter next to yellow, and darker next to black.

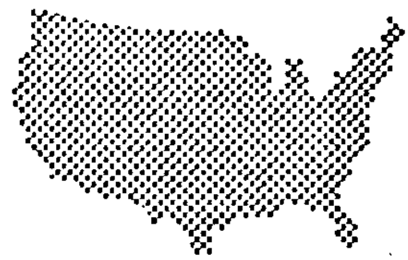
DISAPPEARING SPOTS. Stare at the color blocks and dancing spots will appear where the corners meet. But try to look at one of the spots and it fades away. What shape are the spots? Squares, circles, four-pointed stars?

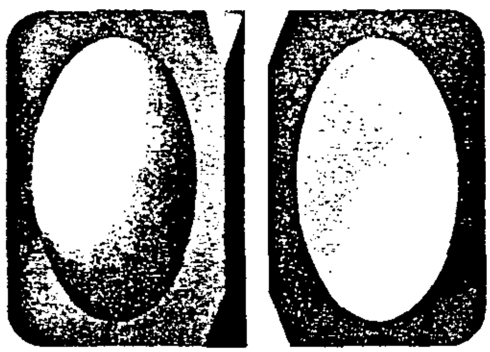




DAY-NIGHT VISION. Under good lighting conditions the red flower will appear brighter than the blue. If viewed for five to ten minutes in very dim light though, the red flower will almost disappear while the blue flower will stand out as a light gray. (Look one or two inches aside from the blue flower to see it more clearly since the rods (used for scotopic, or night vision) in the eye are most numerous in the retina just outside the foveal pit.)

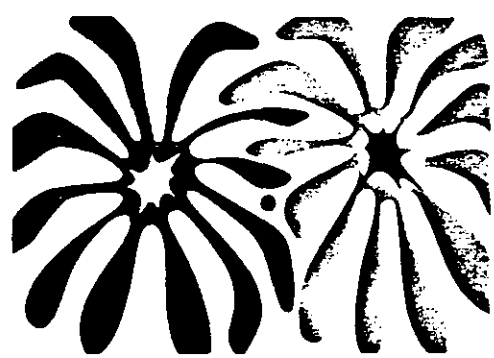
ADDITIVE SPATIAL FUSION. The green dot pattern in the shape of the United States will merge into a solid gray when viewed from a distance of 6 to 8 feet. At that distance the eye can no longer distinguish individual colors (yellow and green) and the phenomenon produced is "gray." This same phenomenon is used in all lithographic printing in this book.





ADVANCING AND RECEDING COLORS. Warm colors and light grays appear to advance toward the eye while cool colors and dark grays appear to recede. Since this phenomenon is related to day-night vision, both ovals in this illustration will appear as mounds when viewed for 5 to 10 minutes in very dim light.

COMPLEMENTARY AFTERIMAGE. To see red and white fireworks in a blue-violet sky, stare for 30 seconds at the black dot just below center — then look at the black dot in the white space below. Prolonged concentration on any colors will reduce eye sensitivity to them, and the reverse or complementary colors, remaining unaffected, will dominate the afterimage for a brief period until balance is restored.



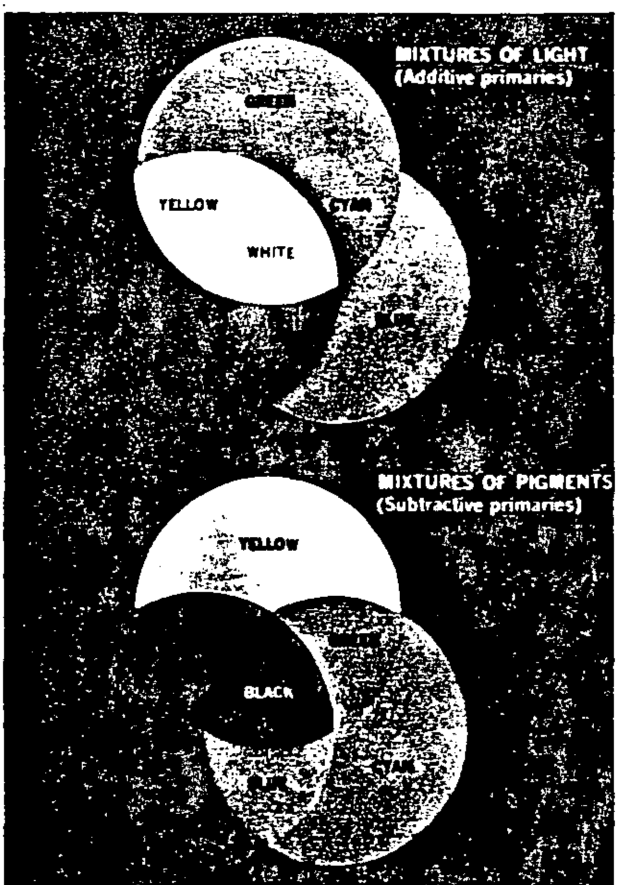
COLORIMETRY

12-

Colorimetry is the science of measuring and systematically designating colors. It is an important science, since precise systems of color measurement are required to identify, duplicate, and standardize the thousands of colors in use today - and many useful systems have been set up to organize and specify these colors. But before any of the systems can be described, it is essential to understand the relationship which exists between the primary colors of light and the primary colors of pigments.

PRIMARY AND SECONDARY COLORS

The primary colors of light (red, green and blue) can be added to produce the secondary colors of light - magenta (red plus blue), cyan (green plus blue), and yellow (red plus green). Thus, the colors of light are called "additive." A secondary color of light mixed in the right proportions with its opposite primary will produce white light. For example, a mixture of yellow and blue light will result in white light. Thus, yellow and blue are complementary colors of light - as are cyan and red, and magenta and green.



PRIMARY AND SECONDARY COLORS OF LIGHT AND PIGMENT

In pigments or colorants, however, a primary color is defined as one that subtracts or absorbs a primary color of light and reflects or transmits the other two. So the primary colors in pigments (sometimes called subtractive primaries) are magenta, cyan, and yellow - the secondary colors of light.

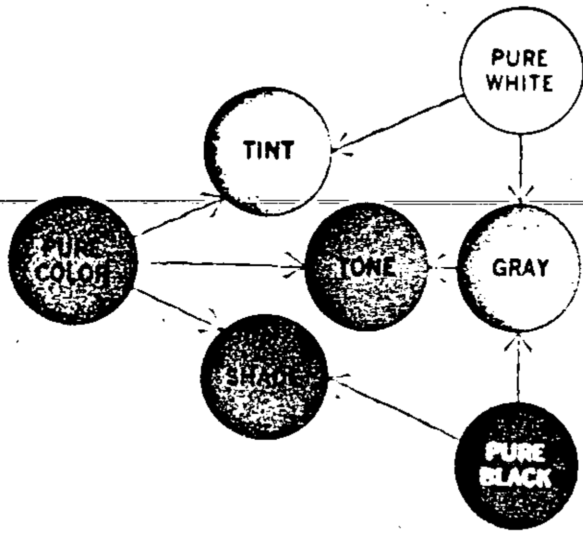
This subtractive nature of pigments is easily demonstrated by placing magenta, cyan, and yellow pigment filters over a source of white light (see adjacent illustration). Each of the pigment filters absorbs or subtracts one of the primary colors from the light. Where two filters overlap, one of the primaries of light is transmitted. For example, the yellow filter absorbs blue (transmitting red and green) and the magenta filter absorbs green (transmitting red and blue). Together, the filters transmit only red - having, in effect, subtracted the other two primary colors from the white light. Where the three pigment filters are superimposed at the center, all light is absorbed. Complementary pigment colors are the same as those in light - yellow and blue, cyan and red, magenta and green.

Color television reception is an example of the "additive" nature of light colors. On the interior face of the picture tube is applied approximately 100,000 triangular dot patterns of electron-sensitive phosphors - each triad consisting of one phosphor dot each that will radiate red light, blue light, and green light, respectively. In operation, all red-emitting phosphor dots in all triads are stimulated by electron pulses from an electron gun inside the picture tube which generates "red" pulses corresponding to "red" energy seen by the TV camera. Blue and green electron guns inside the picture tube stimulate the blue and green triad phosphors in the same manner.

The effect, viewed on the home color TV receiver, is that the three primary colors from the phosphors are "added" together and received by the color sensitive cones in the eye, and a full color image is perceived. Thirty successive image changes per second - in all three colors, complete the motion illusion in color television.

THE COLOR TRIANGLE

Although black and white pigments are not considered true colors, their addition to colored pigments produce tints, shades, and tones. The adjacent diagram illustrates the triangular relationship involved here - that adding black to a pigment color produces a shade, whereas adding white produces a tint. When gray (a mixture of black and white pigments) is added to a color pigment, a tone is produced.



13-

OSTWALD COLOR SYSTEM

Similar in arrangement to the Color Triangle is the Ostwald Color System which arranges lettered color chips in triangles and describes them in terms of purity, whiteness, and blackness (adjacent chart printed with permission of Container Corporation of America). The purest colors (or hues) contain no white or black pigments. The system as originally published divided the spectrum of colors into 24 basic numbered hues with 28 variations of each in lightness or darkness (tints, shades, and tones).

MUNSELL COLOR SYSTEM

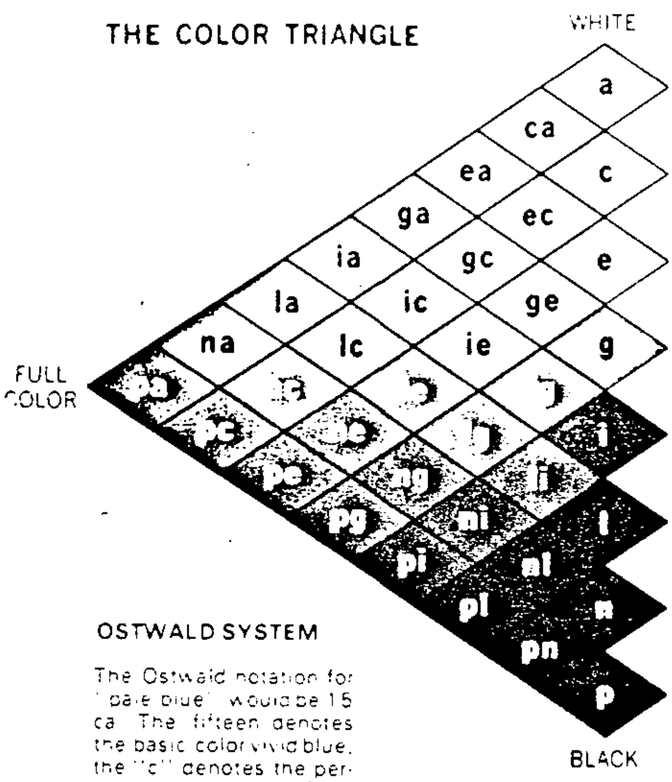
The Munsell system of color notation is based on a theoretical solid form - much like an irregular globe. The vertical axis is graduated into nine shades of gray - with black at the bottom as zero, and white at the top as ten (see adjacent illustration, printed with permission of the Munsell Color Company). The colors of the spectrum are divided into 20 basic hues which are represented as vertical pie sections of the solid with their purest colors located around the perimeter, or equator. The Munsell system also uses a set of coded, standardized color chips for each color. Variables in the Munsell system are hue, value, and chroma.

Hue is the classification of a color by which the eye sees it as red, blue, green, yellow, etc. A Munsell hue is designated by a single letter - R for red, G for Green, or pairs of letters, such as YG, for yellow-green.

Value (similar to the gray scale in the Ostwald System) indicates lightness or darkness of a color on a scale ranging from 0 for black to 10 for white. Thus, a color can be dark or light red, indicating a position in a light-to-dark scale. (Munsell value is approximately equal to the square root of the percent reflectance of the color.)

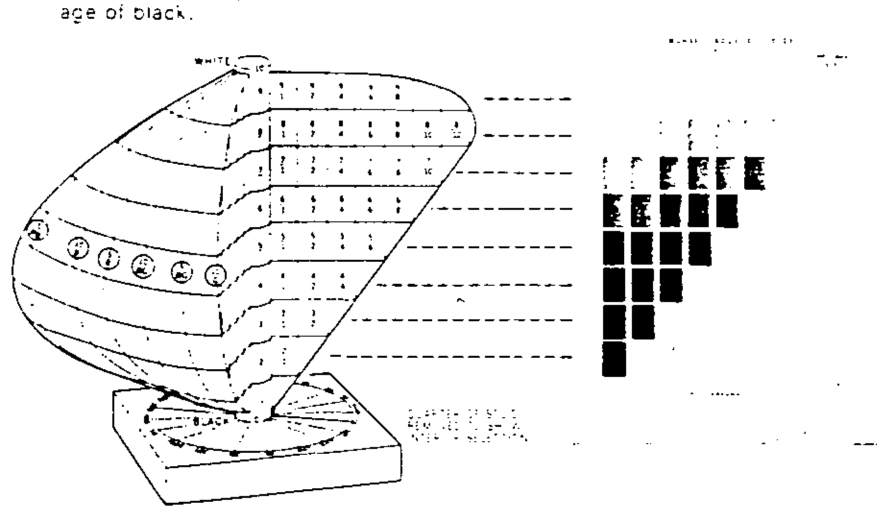
Chroma indicates the purity or saturation of the color, or conversely, its freedom from dilution. Chroma is indicated by a number preceded by a slant line, following the value notation.

THE COLOR TRIANGLE



OSTWALD SYSTEM

The Ostwald notation for "pale blue" would be 15 ca. The fifteen denotes the basic color vivid blue, the "c" denotes the percentage of white, and the "a" denotes the percentage of black.

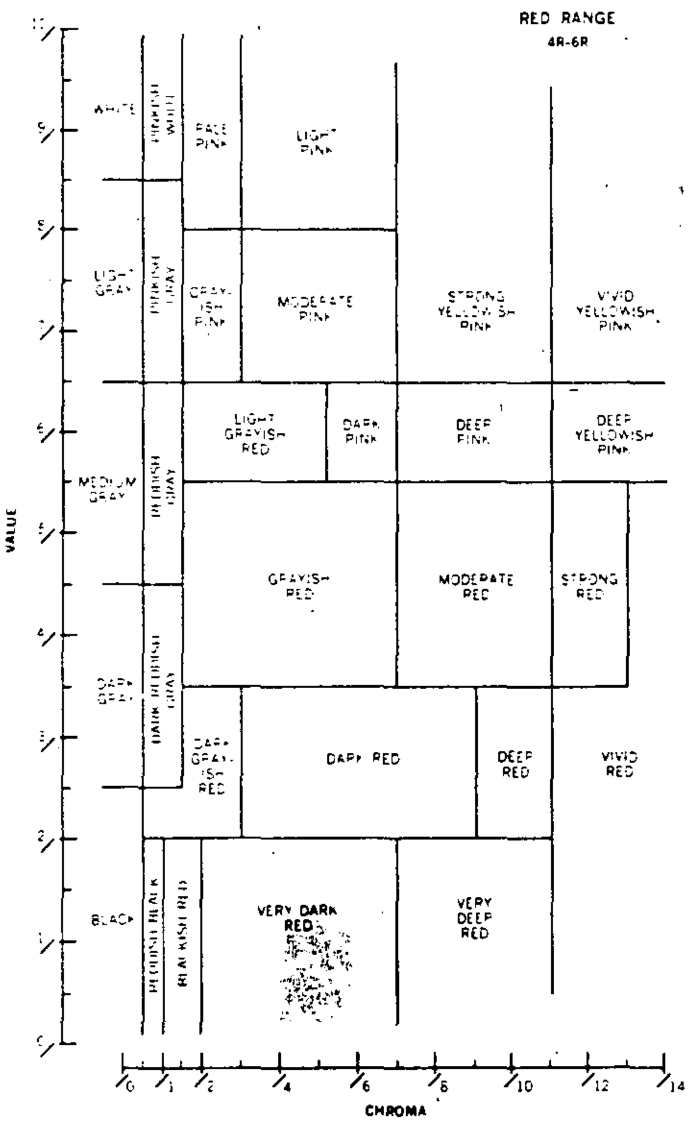


MUNSELL SYSTEM

Form of the Munsell color solid showing color notation scales for hue, value, and chroma and a sample color hue chart. A very greyed (low value) yellow would be identified by the notation 5Y 3 2.

ISCC-NBS COLOR SYSTEM

The Inter-Society Color Council - National Bureau of Standards (ISCC-NBS) has standarized 267 names for describing the colors of paint. Each name is matched to a color chip, with the boundaries of each name fixed with limits defined in the Munsell color notation system.



The following 28 basic hue names are used:

ISCC-NBS STANDARD HUE NAMES AND ABBREVIATIONS

Name	Abbreviation	Name	Abbreviation
red	R	purple	P
reddish orange	rO	reddish purple	rP
orange	O	purplish red	pR
orange yellow	OY	purplish pink	pPk
yellow	Y	pink	Pk
greenish yellow	gY	yellowish pink	yPk
yellow green	YG	brownish pink	brPk
yellowish green	yG	brownish orange	brO
green	G	reddish brown	rBr
bluish green	bG	brown	Br
greenish blue	gB	yellowish brown	yBr
blue	B	olive brown	OlBr
purplish blue	pB	olive	Ol
violet	V	olive green	OlG

Additional adverbs, and adjectives are used in combination with the above hue names to completely identify the. 267 basic color chips in the system. The additional modifiers are:

Light	Very	Strong
Medium	Grayish	Vivid
Dark	Moderate	Brilliant
Deep	Pale	

The adjacent chart illustrates the application of the ISCC-NBS color designation system as, applied to the Munsell notation for Red ranging from 4R to 6R.

C. I. E. COLOR SYSTEM

The C.I.E. color system was devised and adopted by the C.I.E. (Commission Internationale de l'Eclairage - the International Commission on Illumination) in 1931 and has since become an international standard for measuring, designating, and matching colors.

In the C.I.E. system, the relative percentages of each of the theoretical primary colors (red, green, blue) of a color to be identified are mathematically derived, then plotted on a Chromaticity Diagram as one chromaticity point. From the chromaticity point, the dominant wavelength and purity can be determined. All possible colors may be designated on the Chromaticity Diagram, whether they are emitted, transmitted, or reflected. Thus, the C.I.E.

system may be coördinated with all other color designation systems.

To specify the chromaticity of a color by the C.I.E. system it is first necessary to measure the color's spectrophotometric values (reflectance, emittance, or transmittance) at each wavelength. These values then must be weighted by the values of the three theoretical primaries (see adjacent chart), and the resultant computation will represent the amount of the theoretical primaries (red, green, and blue) needed to produce for the standard observer the color of the spectrum at that wavelength.

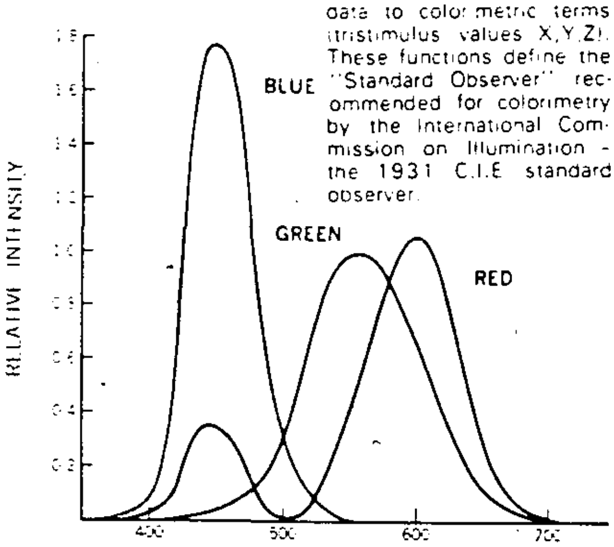
The sums of each of these calculated red, green and blue calculations are called the *tristimulus values* for that color. Tristimulus values are denoted by *capital* letters, X (for red), Y (for green), and Z (for blue). The Y (green) value also is that color's luminosity. The tristimulus values are then used to calculate the color's chromaticity *coordinates*.

A color's chromaticity coordinates represent the relative percentages of each of the primary colors present in a given color. *Lower case* letters are used to designate the coordinate values: x = red, y = green, and z = blue. The fractional values are easily computed from the tristimulus values, X, Y, Z, by the following equation:

$$\frac{X}{X + Y + Z} = x$$

By substituting Y and Z, respectively, in the numerator of similar equations, the chromaticity coordinates for green (y) and blue (z) may also be calculated. Since the coordinates represent fractional values, then the sum of x, y, and z will always equal unity, 1.0. The x, y values are plotted on the Chromaticity Diagram (see p. 18).

Weighted functions used to reduce spectrophotometric data to colorimetric terms (tristimulus values X,Y,Z). These functions define the "Standard Observer" recommended for colorimetry by the International Commission on Illumination - the 1931 C.I.E standard observer.



15- When the chromaticity coordinate values for x and y are plotted on the C.I.E. Chromaticity Diagram, the intersection point will be a graphic presentation of the chromaticity of the given color - in relation to the three theoretical primary colors of the diagram. Notice on the C.I.E. diagram on the following page that the point of equal energy (white) is located at .333 on the x (red) axis, and .333 on the y (green) axis. The chromaticity points for several fluorescent lamp colors are also shown on the C.I.E. diagram on the next page.

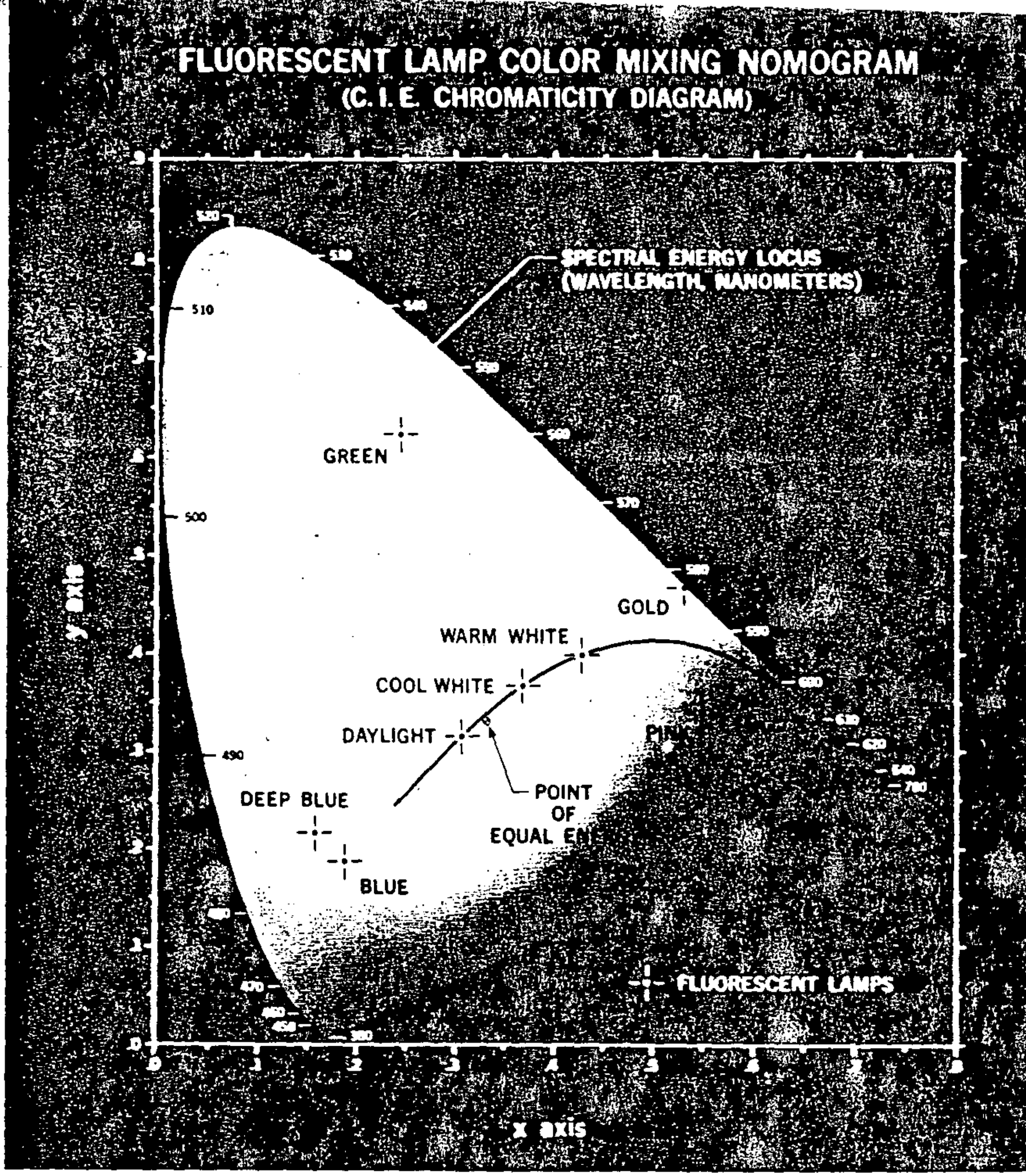
After the chromaticity point of a color has been located on the C.I.E. Chromaticity Diagram, it is a simple matter to derive that color's dominant wavelength and purity. A line drawn from the point of equal energy - through the color's chromaticity point - will *intersect* with the spectral energy locus *at the* dominant wavelength. And since the spectral energy locus represents 100% purity, and the point of equal energy represents 0% purity, then the distance between the point of equal energy and the chromaticity point - as a *ratio* of the distance between equal energy and the locus point - becomes the percentage of *purity* for the color to be identified.

The designation of a color on a C.I.E Chromaticity Diagram gives no information on the spectral energy *distribution* of the light source or object. (Even though the first inputs to the chromaticity formula are the energy at each wavelength, they are concealed as soon as they are averaged.) Therefore, identifying the percentages of the primaries in a color is not a complete color identification system since many different combinations of spectral energy mixtures can result in the same apparent color.

The present C.I.E system is, however, more accurate than both the Ostwald and Munsell systems because it specifies color on a physical basis - eliminating the need for human or subjective comparisons or judgments. The most complete measurement of color, then, would necessarily have to include the C.I.E. chromaticity, dominant hue, and purity data together with the spectral energy distribution data in order to pinpoint all key variables.

COLOR TEMPERATURE

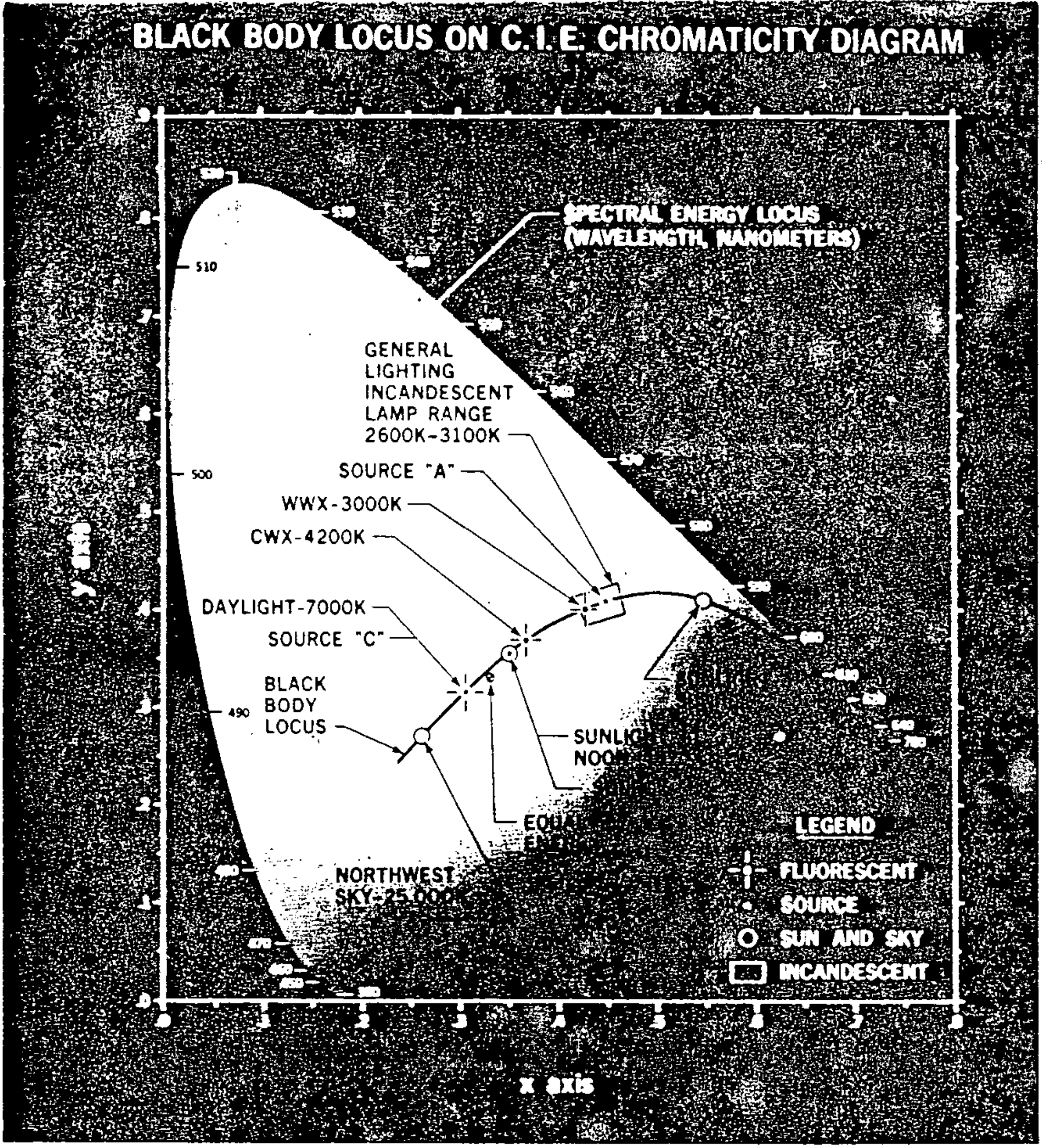
All objects will emit light if they are heated to a sufficiently high temperature. Also, as an object is raised in temperature, the color of the light emitted from it will change. An iron bar, for example, appears dull red when first heated, then red-orange, then white, and finally blue-white as it is heated hotter and hotter. In the same way, a tungsten filament in an incandescent lamp changes color when different voltages are applied. This phenomenon was studied by Max Planck in 1900 and is the basis for his law of blackbody radiators. This law, in essence, predicts the distribution of



thermal radiation as a function of temperature, and defines the upper limit of thermal radiation. A blackbody is defined as one which will absorb all radiation falling on it.

This law can be used to designate the relative color temperature of any heated object. A color temperature designation, applied to a light source, refers to the absolute temperature in degrees Kelvin of a theorectical blackbody or full radiator whose color appearance matches that of the source in question. Such a body is black at room temperature, red at 800K, yellow at 3000K, white at 5000K, pale blue at 8000K, and brilliant blue at 60,000K. Tungsten filament lamps used for general lighting have color temperatures in the 2600K to 3000K range. Low wattage lamps used where luminance is not too important operate at about 2000K. Such lamps as TV and studio floods operate in the 3100 - 3400K range, just short of the tungsten melting point of 3500K. In most cases, actual filament temperature is slightly lower than the apparent color temperature.

Technically, a "color temperature" designation can only apply to incandescent sources, and, as such, it is a specification of both the degree of whiteness and the spectral energy composition of the source. However, the term "apparent color temperature" is often used to specify the degree of whiteness of fluorescent lamps as well as sky light, mercury vapor lamps, etc.



Typical examples of "apparent color temperature" values are as follows:

Warm White (WW) and Deluxe Warm White (WWX) Fluorescent Lamps	3000K
Cool White (CW) and Deluxe Cool White (CWX) Fluorescent Lamps	4200K
White (W) Fluorescent Lamp	3500K
Daylight (D) Fluorescent Lamp	7000K
Sunlight at sunrise	1800K
Sunlight at noon	5000K
Sky - overcast	6500K
Sky - extremely blue (clear northwest)	25,000K

A few of these lamps are shown together with the blackbody locus on the adjacent C.I.E. Chromaticity Diagram.

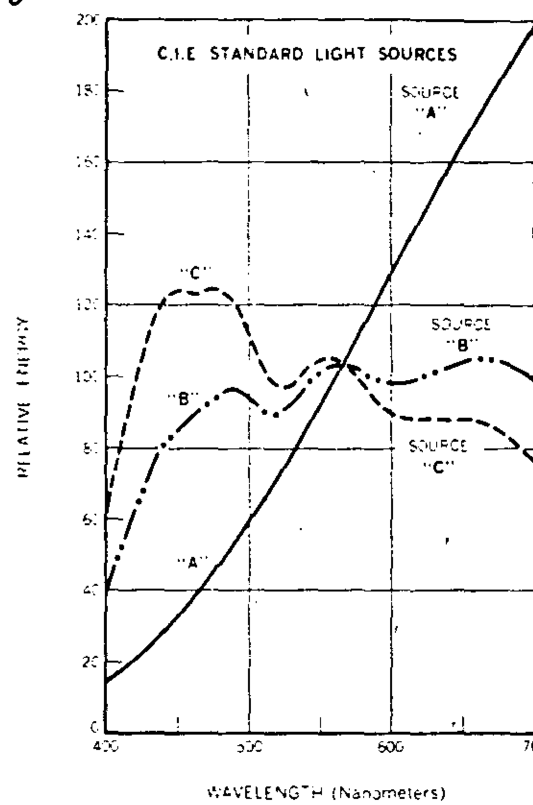
Unfortunately, the apparent color temperature designation for any light source does not give information on its specific spectral energy distribution. For example, Cool White and Deluxe Cool White lamps appear to be the same color but their spectral distribution curves are quite different and their effects on colored objects and materials are definitely different. The same limitation applies in using color temperature notations to specify sky light, mercury vapor lamps, etc.

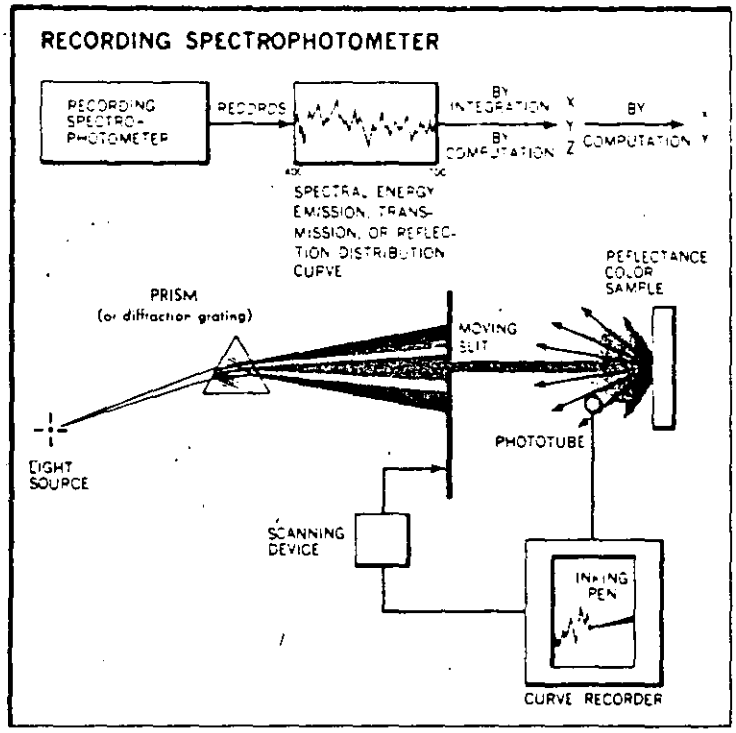
STANDARD LIGHT SOURCES

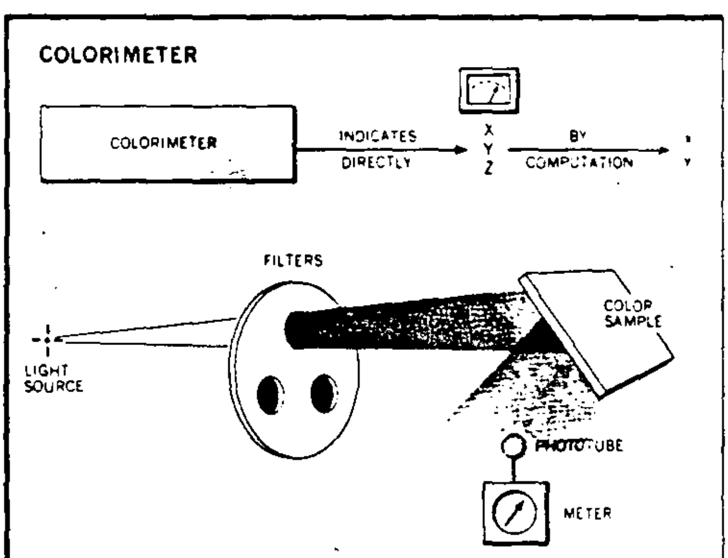
Three sources have been selected by the C.I.E. as standards for use in colorimetry. These sources are designated source A, B, and C. Calibrated lamps may be obtained from the National Bureau of Standards.

Source A is a tungsten filament lamp operating at 2854K. Source B utilizes a lamp having the spectral quality of source A in combination with a specified filter. The apparent color temperature of source B approximates that of noon sunlight (4870K). Source C is source A, the tungsten-filament source, but with a different filter. The filter and lamp combination produces a color quality which approximates daylight at 6770K.

The adjacent chart gives the relative spectral energy distribution of these three standard light sources.







COLOR MEASURING INSTRUMENTS

The two most common color measuring instruments in use today are the spectrophotometer and the colorimeter. Their operating principles are quite different, as illustrated on the adjacent diagrams.

The spectrophotometer gives the radiant energy at each unit wavelength across the entire visible spectrum, while the colorimeter gives only the sum of radiant energy for each primary. Spectral energy data from either may be used to calculate the C.I.E. chromaticity of a color, but it is obvious that the spectrophotometer calculations will be more accurate since the input data are more complete.

Spectral energy distribution curves from spectrophotometers are often used for color matching where high accuracy is essential. Conversely, colorimeters are not as accurate as spectrophotometers over broad ranges, but they are effective for general color matching — where minor color variations are immaterial. Colorimeters are quite accurate within narrow color ranges, though, and are often built into production color control operations.

Both devices will perform in either additive or subtractive modes, and thus will provid color measurements from similar light source or object colors.

WHITE LIGHT SOURCES

19–

The types of white light sources in use today vary greatly. Fluorescent, incandescent, and high intensity discharge lamps, as well as natural daylight are all thought of as sources of white light. But as we have seen in previous sections of this book, white lights are seldom what they seem - each varying significantly from others in spectral energy content - and all appearing white to the observer because of the synthesis function of the brain and psychological adaptation variations.

The goal of lamp designers has been to achieve good commercial sources of white light. The three criteria or requirements are 1) efficiency, or the most light per dollar, 2) color rendering, or the ability to make objects appear in their most familiar colors, and, 3) whiteness, or absence of color tints.

Continual research and development with light source materials has produced remarkable improvements in today's light sources, but, as yet, the perfectly balanced lamp has not been achieved. The best of lamps available are the results of compromises among the three prime criteria. The most efficient light sources known are deficient in color rendering capabilities. To improve color rendering, filters and coatings must be added - but they reduce the efficiency. And obtaining a lamp that "appears" white, can only be achieved by affecting both efficiency and color rendition. However, each type of light source has special advantages which are useful and important in different types of applications.

TYPES OF LIGHT SOURCES

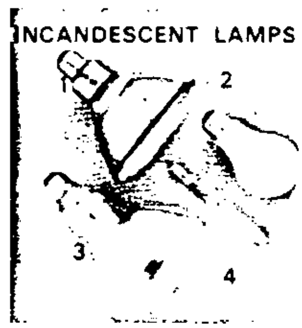
There are three basic types of light sources used today - incandescent, fluorescent, and high intensity discharge lamps. Incandescent lamps produce light by electrically heating high-resistance tungsten filaments to intense brightness.

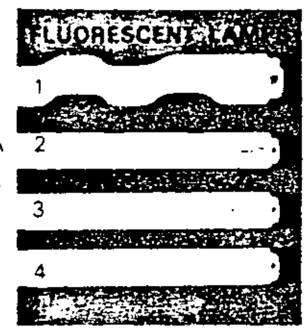
Fluorescent lamps produce light by establishing an arc between two electrodes in an atmosphere of very low pressure mercury vapor in a chamber (the glass tube). This low pressure discharge produces ultraviolet radiation at wavelengths which excite crystals of phosphor (the white powder) lining the tube wall. The phosphor fluoresces, converting ultraviolet energy into visible energy - light.

Mercury, Multi-Vapor*, and Lucalox* lamps are high intensity discharge types. They also produce light by establishing an arc between two electrodes but the electrodes are only a few inches apart - in opposite ends of a small, sealed, translucent or transparent arc tube. An arc of electricity spanning the gap between the electrodes generates heat and pressure much higher than in fluorescent lamps - high enough to vaporize the atoms of various metallic elements contained within the arc tube. This vaporization causes the atoms to emit large amounts of electromagnetic energy in the visible range.

The metallic element in mercury lamp arc tubes is mercury. In Multi-Vapor lamps, small quantities of sodium, thallium, and indium iodides are added to the basic mercury. In Lucalox lamps, sodium is the primary element but a small amount of mercury is added.

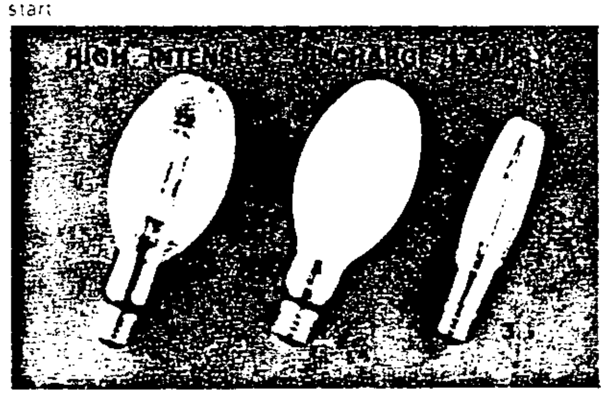
Incandescent general lighting lamps produce from 17 to 23 lumens[1] of light per watt of power consumed - depending on wattage, life, and physical design features. The bulk of the radiated energy from incandescent lamps lies in the invisible infrared region of the spectrum (see chart on next page). Typical white fluorescent lamps produce about 50 — 80 lumens per watt — depending on their size and type. Mercury lamps emit about 50 — 55 lpw, Multi-Vapor lamps about 80 — 90 lpw, and Lucalox lamps, the most efficient of all, over 100 lpw.





INCANDESCENT LAMPS: (1) Pressed glass "PAR" (parabolic aluminized reflector) weatherproof spot or flood. (2) General purpose A-line. (3) Blown glass (reflector) spot or flood. (4) 500-watt Quartzline*.

FLUORESCENT LAMPS: (1) Power Groove* high current rapid start. (2) High output rapid start. (3) Slimline instant start. (4) Standard 40-watt pre-heat rapid start.



HIGH INTENSITY DISCHARGE LAMPS: (1) Multi-Vapor. (2) Phosphor-coated mercury. (3) Lucalox lamp.

* Trademark of the General Electric Company.

[1] The lumen is the unit of luminous flux equal to the flux in or unit solid angle from a uniform point source of one candela.

20-

SPECTRAL ENERGY DISTRIBUTION

A graphic presentation of the energy emitted by a light source at each wavelength in the spectrum is called a spectral energy distribution (S.E.D.) curve. The S.E.D. data are derived through a spectroradiometer, and are usually adjusted to some common reference (such as output per lumen) to provide a basis of comparison among sources. The curves on the adjacent chart represent such data for one phase of natural daylight and for many of the most common general lighting sources.

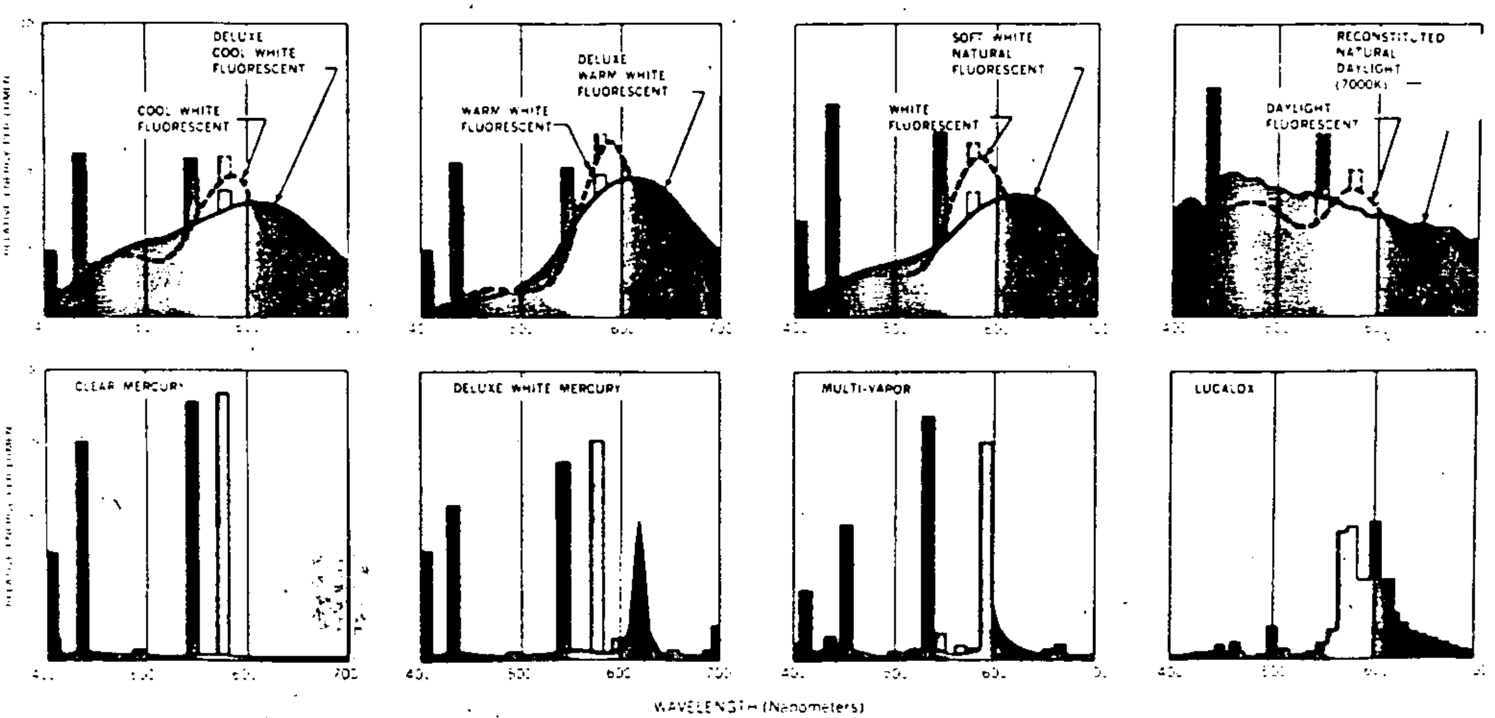
Incandescent lamps obey established physical laws of thermal emission: energy is distributed in a smooth curve beginning in the near UV range with very little deep blue radiation, increasing with wavelength into the deep red. Energy actually peaks in the near infrared. Data are shown for color temperatures common in general lighting lamps (3000K) and photoflood or studio lighting lamps (3400K). Because it has relatively more blue and less red energy, the 3400K source appears much "whiter" than the slightly yellowish general lighting lamps.

High intensity discharge lamps produce peaks of energy at specific wavelengths. These are determined by specific shifts in electron orbits within the atomic structure of the metal. Thus, energy is emitted in "resonance lines" that are different for each metal.

For clear mercury lamps, major resonance radiation occurs at 405, 436, 546, and 578 nanometers in the visible spectrum, and also at 253, 296, and 365 nanometers in the ultraviolet.

(The outer bulb of the mercury lamp absorbs most of the shortwave UV). Phosphor-coatings applied to the inside of the bulb absorb this ultraviolet, and radiate energy with continuous characteristics to improve the color of the clear mercury lamp, as in the Deluxe White lamp illustrated.

The Multi-Vapor lamp also contains mercury, but several metallic iodides (e.g., sodium, thallium and indium) have been added. The mercury resonance radiation is subordinate, and most of the



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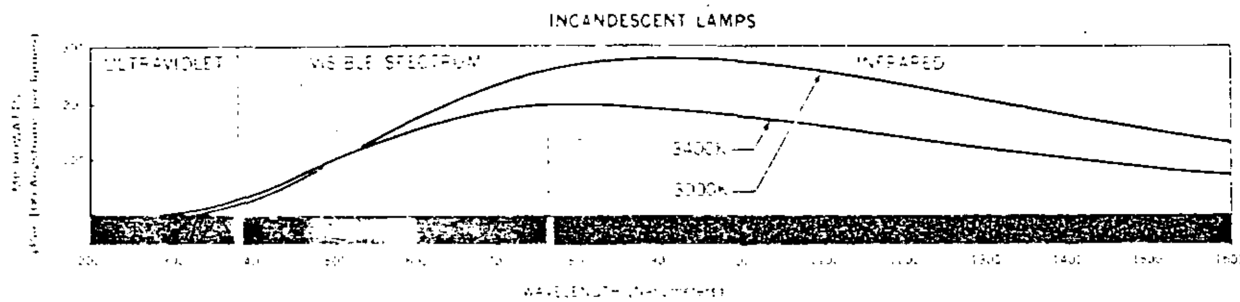


light comes from the four lines (410, 451, 535, and 590 nanometers) characteristic of the iodide additives. The spacing of the lines and relative energy of each in the Multi-Vapor spectrum yields whiter light and better color rendering than the clear mercury lamps.

The Lucalox lamp is basically a sodium arc. Sodium's normal resonance radiation is at 589 nanometers (actually, a "doublet" or two lines at 589 and 589.6, called the sodium "D" line). However, the temperatures reached in the Lucalox lamp's arc causes a remarkable reversal: The D-line radiation is absorbed, and the energy is re-radiated at shorter and longer wavelengths. This produces a relatively continuous S.E.D. curve with a dip at 589 nanometers. A small amount of mercury is also in the arc tube, and traces of the mercury lines are radiated.

In the fluorescent lamp, most of the arc radiation is at the 253.7 nanometer ultraviolet line, but phosphors selected for sensitivity to this UV line absorb and re-radiate the energy in various continuous spectra as shown. In addition, there is a small amount of radiation in the mercury resonance lines.

COLOR EFFECTS OF WHITE LIGHT SOURCES

Selecting a "white" light source on the basis of its color appearance or its color rendering* properties alone is rarely done for general lighting. Often, efficacy (lumen output per watt consumed) is a major consideration. Ease of shielding and directional control, as well as maintenance and over-all system economics also must be considered.

* The term color rendering with reference to light sources is a measure of the degree to which the perceived colors of objects illuminated by various light sources will match the perceived colors of the same object when illuminated by standard light sources, for specified viewing conditions. (These conditions include an observer with normal color vision who has adapted to the environment, illuminated by each source in turn).

Incandescent lamps generally are considered to have a slight edge over other lamps in color rendering - not because they render colors more naturally, but because through decades of usage they have come to be *considered* the norm. "Good" rendition is generally interpreted to mean the "familiar" appearance of familiar objects - and objects assume "familiar" colors only by being frequently seen under certain types of light sources (daylight or incandescent). If fluorescent lamps had come into wide usage before incandescents, it is possible that object colors would appear most "familiar" under them - instead of incandescents.

Color and color rendition are as much functions of individual preferences as they are functions of light sources. People are familiar with the color effects of daylight - which emphasizes cool colors, and equally familiar with the color effects of incandescent lamps - which accentuate warm colors. This obviously incongruous situation is compounded by the effects of memory, atmosphere, environment, and personal color preferences - to the point where "true colors" and "true color rendition" are very subjective at best. The choice of which lamps to use for which situations always will vary according to personal preferences. The color rendering properties of lamp types described on these pages may be of considerable aid, however, in pointing out to lamp users the *relative* color effects of white light sources.

Some lamps tend to "flatter" object colors - which is another way of saying they emphasize the dominant color of the object while deemphasizing complementary colors. For example, Warm White and Deluxe Warm White fluorescents and all incandescent lamps will bring out warm object tones;

the more efficient Warm White fluorescents lack the capability to bring out reds, but do emphasize other warm tones. The Deluxe Warm White is usually recommended for homes and other applications where illumination will be fairly low (50 fc or less) and the atmosphere will be primarily "social."

On the other hand, when a cooler atmosphere is desired, Deluxe White mercury, Multi-Vapor, and Cool White and Deluxe Cool White fluorescent lamps are most frequently used because they flatter the cool colors. This results in a crisper atmosphere which is usually related to higher illumination or more serious activity, as in offices, schools, industrial plants and many stores. With fluorescent, Deluxe Cool White is recommended for areas where color rendering is important.

Mercury lamps are completely satisfactory in their rendering of blacks, whites, and grays, but the scarcity of red and the concentration of blue, green, and yellow in a few narrow bands makes them poor sources for producing the familiar appearances of warm colors. However, recent years have seen improved color mercury lamps achieved by the addition of phosphor coatings. The most significant of these has been the Deluxe White phosphor, which yields color rendering fully as acceptable as that of Cool White, the most widely used fluorescent color.

The Lucalox lamp produces a sunny atmosphere where used—because of its greater amount of yellow and orange energy, and reduced blue. Although the current Lucalox lamp, like the Multi-Vapor lamp, is most frequently used where color rendering is secondary to efficacy, its pleasant golden-white color offers many new application opportunities for this powerful new light source. Prospects are promising for Lucalox lamps of much better color rendering capability.

LAMP SELECTION GUIDE

The table presented below is intended as a general guide to lamp selection - giving a few indications as to the color effects of the lamps on atmosphere, people, and objects.

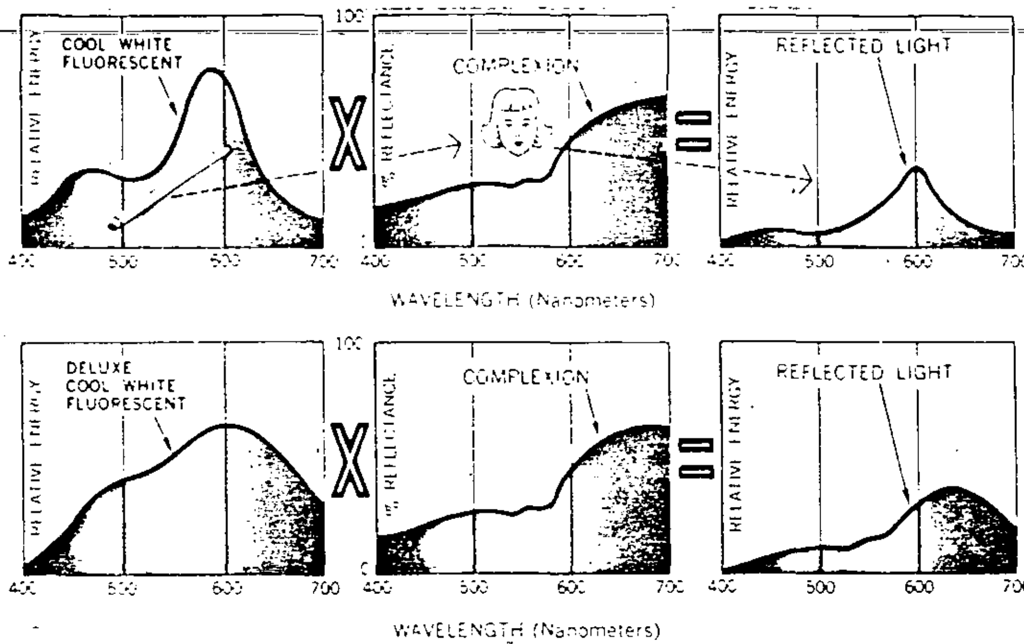
LAMP SEL

FLUORESCENT LAMPS

Lamp Names	Cool* White	Deluxe* Cool White	Warm** White	Deluxe** Warm White	Daylight	White	Soft White/Natural
Efficacy (Lumens/watt)	High	Medium	High	Medium	Medium-High	High	Medium
Lamp appearance effect on neutral surfaces	White	White	Yellowish white	Yellowish white	Bluish white	Pale yellowish white	Purplish white
Effect on "atmosphere"	Neutral to moderately cool	Neutral to moderately cool	Warm	Warm	Very Cool	Moderately warm	Warm pinkish
Colors strengthened	Orange, Yellow, Blue	All nearly equal	Orange, Yellow	Red, Orange Yellow, Green	Green, Blue	Orange, Yellow	Red, Orange
Colors greyed	Red	None appreciably	Red, Green Blue	Blue	Red, Orange	Red, Green, Blue	Green, Blue
Effect on complexions	Pale Pink	Most natural	Sallow	Ruddy	Greyed	Pale	Ruddy Pink
Remarks	Blends with natural daylight—Good color acceptance	Best overall color rendition; simulates natural daylight	Blends with incandescent light—poor color acceptance	Good color rendition; simulates incandescent light	Usually replaceable with CW	Usually replaceable with CW or WW	Tinted Source Usually replaceable with CWX or WWX

* Greater preference at higher levels. ** Greater preference at lower levels.

23-



How light source affects color appearance. The illustrations show how SED's of Cool White and Deluxe Cool White lamps are modified by reflectance of typical human complexion. Under the deluxe lamp, much more red is reflected to the eye. Result: A healthier, more natural appearance. This is true though CW and CWX lamps have approximately the same whiteness. Deluxe Warm White, which de-emphasizes blues somewhat, is even more flattering to complexions.

TION GUIDE

	INCANDESCENT	HIGH INTENSITY DISCHARGE LAMPS				
Lamp Names	**Filament****	**Clear Mercury**	**White Mercury**	**Deluxe White* Mercury**	**Multi-Vapor***	**Lucalox****
Efficacy (Lumens/watt)	Low	Medium	Medium	Medium	High	High
Lamp appearance effect on neutral surfaces	Yellowish white	Greenish blue-white	Greenish white	Purplish white	Greenish white	Yellowish
Effect on "atmosphere"	Warm	Very cool, Greenish	Moderately cool, Greenish	Warm, Purplish	Moderately cool, Greenish	Warm, Yellowish
Colors strengthened	**Red Orange Yellow**	Yellow Green Blue	Yellow Green Blue	Red Yellow Blue	Yellow Green Blue	Yellow Orange Green
Colors greyed	Blue	Red, Orange	Red, Orange	Green	Red	Red, Blue
Effect on complexions	Ruddiest	Greenish	Very pale	Ruddy	Greyed	Yellowish
Remarks	Good color rendering	Very poor color rendering	Moderate color rendering	Color acceptance similar to CW fluorescent	Color acceptance similar to CW fluorescent	Color acceptance approaches that of WW fluorescent

24-

COLOR RENDERING INDEX

The interpretation of the color rendering abilities of light sources has not been widely agreed upon in the illumination industry, and the resulting confusion among lamp users is understandably great. Additional confusion has been generated by claims of lamps which are said to duplicate sunlight, daylight or some other arbitrary comparison source. In 1965, an industry standard was adopted as a step toward establishing a uniform basis for determining the color rendering abilities of all light sources. This rating system is called the Color Rendering Index.

INDEX CONCEPT - The Color Rendering Index is a two-part concept. The first part establishes the real or apparent color temperature of a given light source on the CIE chromaticity diagram. If the color temperature of the given source is 5000K or less, then the reference or comparison source is that Planckian radiator of the nearest color temperature - or, if the color temperature of the given source is above 5000K, then the reference source is the nearest reconstituted daylight source. (Reconstituted daylight represents a series of mathematically derived curves representing the weighted average of daylight at a given color temperature measured at different locations, elevations, times, etc.) These Planckian radiators and reconstituted daylight curves then become the standard light sources against which to compare any given light sources.

The second part of the Color Rendering Index concept is establishing a *comparison* between a given light source and the reference light source - and denoting this comparison by an R factor, which is a ratio or percentage of how closely a given light source matches the color rendering ability of the reference light sources. The index for the R factor is based upon an arbitrary scale which places a specific Warm White fluorescent lamp at R=50, and the reference source at R=100. The reference source always has an R=100 since it means (theoretically) that it is the reference standard for each color point.

EXAMPLES - The industry standard Color Rendering Index denotation for a specific warm white fluorescent lamp is R=50 at 3000K. Color Rendering Indexes are listed below for some of the more popular current General Electric fluorescent lamps.

Lamp Color Name	Apparent Color Temperature	Color Rendering Index
Warm White	3000K	R = 52
Deluxe Warm White	2900K	R = 73
White	3500K	R = 60
Cool White	4200K	R = 66
Deluxe Cool White	4200K	R = 89
Sign White	5200K	R = 86
Daylight	7000K	R = 79

METHOD - Determining the Color Rendering Index, R, for any given light source requires precise spectroradiometric data. The spectral distribution curve must be determined for the given light source and its apparent color temperature calculated. In the approved method, eight arbitrary standard color samples are used and their apparent chromaticities - under the *reference* source - are calculated. A similar set of calculations under the given light source - will produce eight *different* apparent chromaticities. The differences between these two sets of data indicate the "color shift" of the given light sources in relation to the reference source. The final calculation results are then *averaged* to arrive at the Color Rendering Index, R.

INDEX LIMITATIONS - There are shortcomings in the Color Rendering Index rating which must be recognized to prevent its misuse. It will be noted in the calculation of R that each light source has a specific color temperature reference. Therefore, two light sources *cannot* be compared unless their reference is similar (within 100K to 300K of each other - depending on their location on the color temperature scale).

Also, it is important to note that two lamps may have the *same* reference source and Color Rendering Index - and still have drastic differences in their ability to render one or all colored materials identically - because the R is an *average* of the color rendering of *eight* or more specific colors - and better performance in some areas may be concealed in the average with poorer performance in other areas.

If the R is less than 90, these comparisons can be of questionable value since the *direction* of the color shift has been eliminated, and the *degree* of shift in some areas may be quite different for different sources.

Finally, it must be remembered that the Color Rendering Index is based upon arbitrary references (the Planckian radiator or reconstituted daylight). This choice is merely for convenience - and does *not* imply that the reference source is the *perfect* color rendering source.

INDEX ADVANTAGES - The Index will provide sufficiently meaningful information on the color rendering capabilities of lamps to be of significant value to the lamp industry and to users - providing that all of the restrictions mentioned above are adhered to.

COLOR MATCHING AND GRADING

Color matching is, as the term implies, a process by which fabrics or other colored materials are matched with other fabrics or with completely different materials. It is usually desirable to match such materials under lighting conditions identical to those under which the products are to be used or displayed.

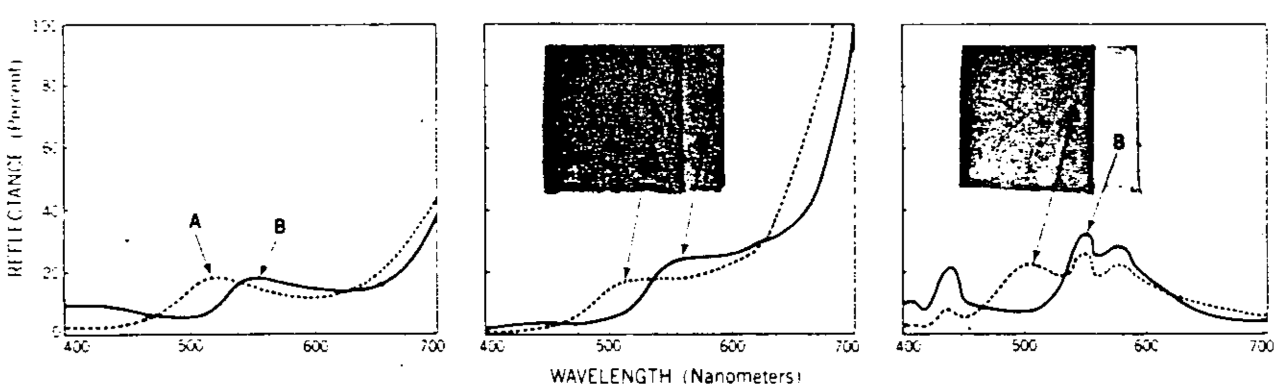
Color matching is done in various ways. An artist may begin with a pure pigment colorant, adding white, black, or other colors. A printer, on the other hand, may alter the size of the halftone dots to change the ink color tone in which the picture is printed, or add an additional dot pattern (screen) in a different color to change the final color.

Color grading and color shading are processes by which materials are divided into groups of colors or tints or shades. For example, batches of white chinaware in the process of being baked in a kiln may vary slightly in whiteness. A trained color shader can separate the products into several dozen different shades of white. This is important in the ceramics industry since complete table settings must be well matched.

Some objects may appear to be the same colors under a certain light source - and even have identical C.I.E. chromaticity specifications - while they are actually different in spectral composition. These colors are called metameric. If the light source is changed, however, the object color differences become readily apparent. Only color samples which have identical S.E.D. curves will continue to match under all light sources. The chart below illustrates the phenomenon of metamerism. Color matching of metameric colors also depends on the eyes of the viewer, since people differ considerably in the way they see colors which are complicated in this manner. The comparison and interpretation of the curves of metameric colors constitutes a complex phase of colorimetry.

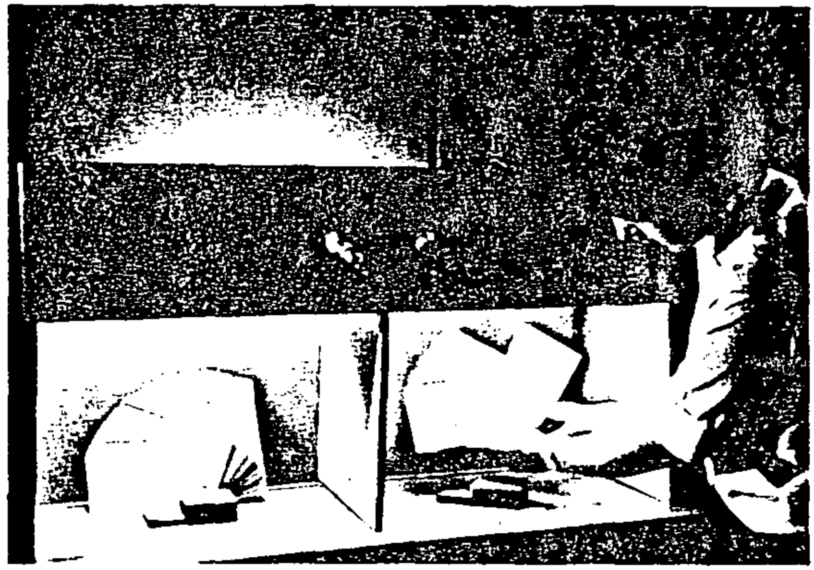
In the past the "ideal" light sources for color matching were thought to be the sun and sky, particularly because of their presumed color constancy. Actually, sunlight varies from about 1800K at sunrise to 5300K at noon. Sky light ranges from 7000K (uniform overcast) to 28000K for an extremely blue clear northwest sky. Because of these variations, sky light and sunlight are not the best of color matching sources.

When the exact light under which materials are to be seen is not known, or when the materials are suspected of being metameric, *two* light sources of *widely* different spectral character should be used - one at a time - to examine the samples. One of the two sources used should be predominantly blue in its spectral characteristics, such as daylight fluorescent lamp; the other should be predominantly red such as a tungsten filament lamp.



METAMERISM - Chart at left shows absolute spectral reflectance of two metameric wool samples (measured by Spectroreflectometer). The same samples under tungsten filament lamps (center chart) appear to be the same color. Under Daylight fluorescent lamps (chart at right), they exhibit noticeable mis-match of color.

26—



Color Booth — The color of an object is the result of the spectral characteristics of the light source, the reflectance characteristics of the material and the level of illumination used. A color booth which provides many different light source colors and varying levels of illumination can duplicate a proposed environment—and provide a dependable area for color selection. Color schemes should be selected under conditions duplicating those under which they will be used—to prevent unexpected color shifts or mismatches of color in actual use.

There are a few materials that fluoresce, or produce visible light, when irradiated by ultraviolet energy. For this reason, one inspection light source that is predominantly blue should be used - especially one that also contains enough ultraviolet radiation so that these fluorescent effects can be produced. The second light source - predominantly red - should not emit ultraviolet energy.

If it is not feasible to use two light sources for some particular color matching job, the best single source available today is the Deluxe Cool White fluorescent lamp, as this lamp has relatively balanced amount of energy in all portions of the spectrum. This means that all colors receive about the same treatment, without undue emphasis on any one portion of the visible spectrum.

If the color matching is confined to a particular color, as might be the case for a manufacturer of blue denim textiles, the best single source under these conditions is one that is essentially complementary in color to that of the product. For the blue denim, incandescent lamps would allow the color matcher to see more subtle differences in color than would be the case with most other types of illuminants.

For color-discrimination work where the grader carries the standard in his head, so to speak, it is most important that the illuminant match as closely as possible the source under which the grader was trained, and to which he is accustomed. He remembers his standard samples as he saw them under a particular illuminant. However, if it is not possible to train the grader, then the best source is the Deluxe Cool White fluorescent lamp.

For most types of color matching, 200 to 400 footcandles are probably adequate. When dealing with very dark colors, more than 1000 footcandles are desirable.

Color matching booths provide a controlled environment necessary for critical inspection of many objects. The interior should be matte finished in neutral tones - gray or white for objects having diffuse surfaces, black for those with specular or polished surfaces. Matte black eliminates masking reflections that would obscure the true color of the underlying pigment. In all cases, the neutral tones have little or no influence on the color of the object.

In addition to being graded for color, fabrics having shiny surfaces are inspected for uniformity and amount of sheen. For this purpose, the light source should be of high luminance, and should be carefully positioned so as to reveal any variation in the specularity of the material.

For critical color grading and matching, it is desirable to position the light source in such a manner that reflections of the source are directed away from the inspector. With three-dimensional objects, however, elimination of all reflected images of the source may not be possible. Therefore, a luminaire relatively large in area and uniform in brightness is the best choice for this application.

COLORED LIGHT SOURCES

The colors of light are commonly described in terms of hue, saturation, and brightness. Hue refers to the quality that can be described as red, green, etc. In everyday language, the word *color* is often used to mean *hue*. In the C.I.E. color system, it is the dominant wavelength. Saturation, like Munsell's Chroma, and C.I.E. purity, refers to the amount by which the light appears to differ from white - the strength or depth of the color. A deep red light, for example, is said to be of high saturation. Brightness is related to the apparent quantity of light, without regard to hue or saturation.

Most colored light sources, even those that appear highly saturated, are not truly monochromatic - that is, they emit a fairly wide band of wavelengths, often including small amounts of energy in other hue regions. The less saturated the color, the greater the content of other hues. (See adjacent spectral energy distribution charts.)

Yellow light is unusual in that a strong sensation of yellow may be produced either by monochromatic light of about 580-600-nanometer wavelength, or by mixture of red and green light covering about two-thirds of the spectrum (see adjacent spectral chart of yellow lamps). In fact, it is theoretically possible to have a light that appears yellow, but contains no energy at the wavelengths normally seen as yellow. (However, there are no practical light sources of this type.)

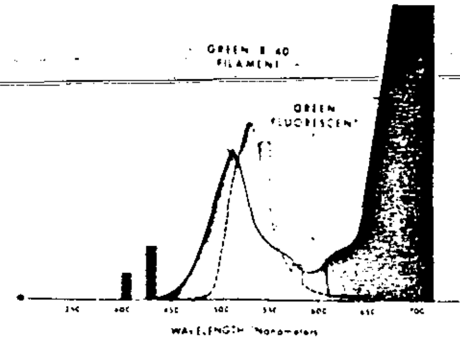
HOW LAMP COLORS ARE CHANGED

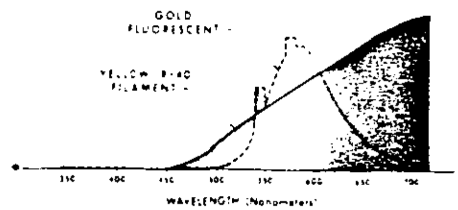
Colored light can be produced by starting with white light and filtering out or subtracting the undesired portion of the spectrum. A colored or filtered incandescent lamp uses this principle. Or colored light can be produced by a light source which generates only the desired portion of the spectrum - such as fluorescent lamps in which variations in phosphor produce varying colors of light.

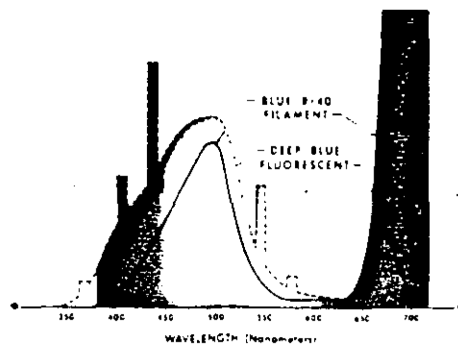
So-called natural colored incandescent lamps have bulbs of transparent colored glass. But the bulbs of most colored sign and decorative lamps begin as clear glass; then are coated with finely ground colored glass (vitreous glass enamel); and finally, they are fired to fuse the coating into a hard, colored enamel finish. The coatings contain a white pigment, as well as colored ones, for better diffusion of light. The tinted Coloramic® lamps are made in a similar manner.

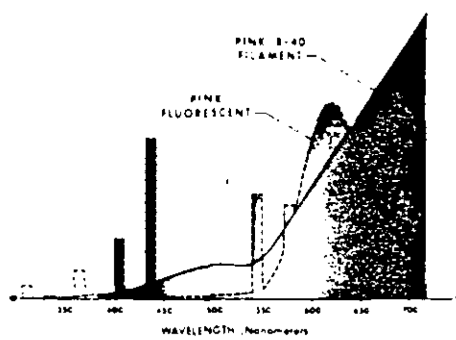
Lexan® color sign lamps have a transparent polycarbonate resin plastic coating. They offer more sparkle, greater brightness, and higher saturation for any given color. For instance, the blue and green Lexan-coated lamps are freer of red, and have a more distinct separation from each other. For this reason, the contrasts between warm and cool colors are also greater, such as between red and blue.

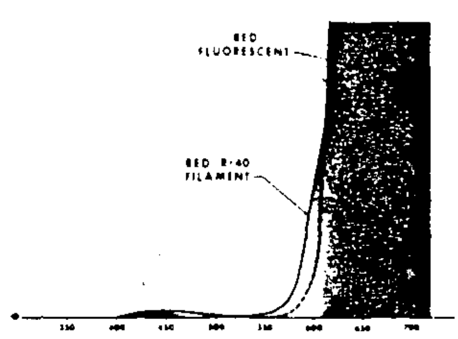
Colored reflector lamps (R-40's and R-30's) also have fired enamel finishes. But these colored glass coatings contain no extra diffusing material - to preserve the transparency so the light











28-

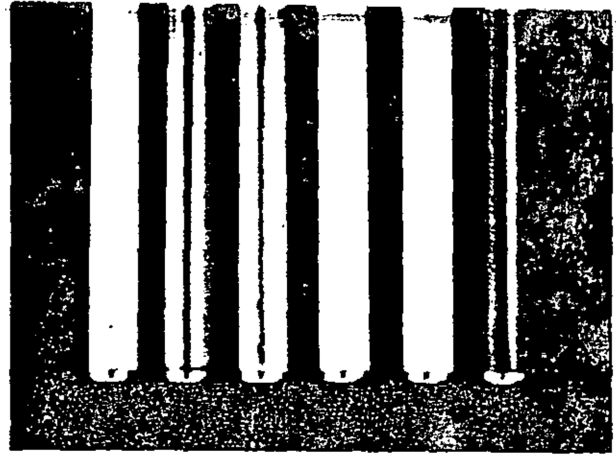
beam will not be broader than desired. The 100-watt PAR-38 lamps have a coating of dye-impregnated silicone plastic, similar to the Lexan-coated lamps. There are 150-watt PAR-38 red, amber, and yellow lamps with stained glass faces. In this case, a coloring material is applied to one side of the glass. The glass is then baked, causing the color to stain a thin layer of the cover plate.

Interference filters involve one or more very thin layers of selected materials deposited (in a vacuum chamber by evaporation techniques) as a film on a base material such as clear glass. The thickness of each layer is usually less than one wavelength of light. The filters make use of the optical principle of interference to pass a limited band of wavelengths. The center wavelength and spread of the transmitted band are determined largely by the thickness and number of layers in the film. However, unlike other filters, the wavelengths not transmitted are reflected, as from a mirror, rather than absorbed. Therefore, these filters stay relatively cool.

COLORED FILAMENT LAMPS: Representative sign, floodlighting, decorative, and display lamps.

Broad-band interference filters are often called dichroic (two-colored) because they transmit one part of the spectrum and reflect the other. Some PAR lamps make use of these filters - Cool-Beam lamps that separate much of the visible from the infrared wavelengths; and Dichro-Color lamps that use the interference principle to produce a full range of saturated colors.

Fluorescent lamps produce colored light by the use of special phosphors. These interior coatings convert the ultraviolet energy generated within the lamp to visible light of the desired wavelengths. In two colors (Deep Blue, and Red), colored filtering materials are added to the outside bulb wall to produce more saturated colors than can be produced by the phosphors. The gold fluorescent lamp, however, achieves its color by subtraction - since no phosphors emit primarily yellow light. A yellow filter coating on the inside of the tube absorbs the unwanted wavelengths from a warm white phosphor.



COLORED FLUORESCENT LAMPS: Reading left to right — green, deep blue, gold, pink, blue, and red.

Blacklight (BL) fluorescent lamps utilize a special phosphor that emits primarily near-ultraviolet energy with a small amount of visible blue light. But for many BL effects, even a small amount of visible light is undesirable. For these situations, BLB lamps - made of a special dark filter glass - transmit the near UV energy but absorb virtually all of the visible energy.

EFFICACY OF COLORED LIGHT SOURCES

Luminous efficacy is reduced whenever subtractive (filtering) techniques are used. To obtain any strong color with filament lamps, it is necessary to remove most of the light emitted by the filament. The more saturated the color, the lower the efficacy of the source-plus-filter combinations. Because it is necessary to remove the greatest amount of energy to obtain the correct hue, cool color lamps, such as blue, have the lowest efficacy of filament types. In the case of fluorescent lamps, the phosphors are usually selected to generate the desired hue — a substantially more efficient process.

The following table shows a comparison of the efficacy of fluorescent and filtered filament lamps producing colored light of approximately the same saturation.

Efficacy of Fluorescent and Filtered Filament Lamps Producing Colored Light of Approximately the Same Saturation

Hue	40-watt Fluorescent (Lumens per watt)	Filament* (Lumens per watt)
red	5	2-3
pink	28	6-8
yellow	55	10-12
green	100	1.5-2.5
deep blue	11	
blue	28	1-2
light blue	63 (Daylight color)	4-5

* Uncolored lamp assumed to be 16 lumens per watt

SOCIEDAD MEXICANA DE INGENIERIA DE ILUMINACION A.C.
CURSO FUNDAMENTAL DE ILUMINACION COMERCIAL E INDUSTRIAL;

"VISION Y DESEMPEÑO HUMANO"

Ponencia

DR. AGUSTIN SERRANO SANCHEZ

I: INTRODUCCION.

Quisiera antes de iniciar esta que será mi primera participación como Socio activo en la Sociedad Mexicana de Iluminación,agradecer a la mesa Directiva y a los organizadores de este Curso, el haberme invitado a colaborar en la realización del mismo, a lo que no podría haberme negado ni ahora ni en futuras oportunidades que se me brinden, ya que estoy plenamente identificado por años en la actividad docente y no obstante los esfuerzos que el enseñar implica, me resulta particularmente grato el compartir todo conocimiento o inquietud científica que desarrollada en mi siempre apreciada profesión.

Es mi deseo explícito en esta primera ocasión en que tengo el honor de presentarme ante Ustedes y dada la oportunidad de su amable atención, intréducirnos en los aspectos Biomédicos de la Iluminación,reinstalando al hombre,ser biopsico social como el verdadero centro de nuestras reflexiones y avances tecnológicos llegando,de ser posible a integrar lo que bien podriamos denominar como Ortoiluminación, es decir la Iluminación correcta para un desempeño laboral; escolar o recreativo optimo y saludable.

Espero que al termino del breve lapso de tiempo de que disponemos, lograr modificar las caras de natural extrañeza que este selecto grupo de Ingenieros y Tecnicos en Iluminación, muestran hoy al tener frente de sí, no a un conocido colega que hable su propio lenguaje tecnico sinó a un Médico y por añadidura Cirujano Oftalmologo, que conciente de su aparente intromisión en un terreno que no le compete, desea afirmar todo lo contrario y desea llegar a establecer un solido puente de comunicación entre nuestros respectivos campos de trabajo del que en forma recíproca obtengamos un enriquecimiento academico para los mismos.

Es un hecho costatable y lamentable nuestra real desvinculación. Ejemplos multiples podrían enumerase a este respecto tanto en el Ejercicio Médico como en el del Ingeniero o Técnico .

Nuestros acercamientos profesionales se limitan a ciertas anotaciones relativamente superficiales tanto en los libros de Iluminación como en los de Medicina y en los propios de la especialidad Oftalmológica. Interesante habrá de resultar el analisis de las causas de nuestra actual desvinculación y de sus posibles correcciones, asi como entender la necesidad de una mayor comunicación profesional. Tengo la firme convicción de que la Interdisciplinariedad es y será siempre una banda fronteriza fertil para el trabajo conjunto.

Esa extraordinaria y en muchos aspectos extraña manifestación dela energía Electromagnetica que es la Luz, nos vincula de manera conatural. El Ingeniero en Iluminación colocado al otro lado del puente, desarrolla los sofisticados sistemas de aplicación de los Emisores luminosos , mientras que de este lado del mismo puente radiante se encuentra el Médico Oftalmólogo cuya función explícita es la de preservar y optimizar con todos sus recursos terapeuticos al Receptor de dicha energía radiante, que es el complejo sentido de la Visión.

Resulta factible que nuestras jovenes ciencias al vincularse interdisciplinariamente, refuercen mutuamente sus argumentos para motivar no solo con razonamientos técnicos sino tambien con bases Biomedicas, a los industriales,comerciantes directivos escolares, administradores públicos y privados asi como público en general,-acerca de las reales ventajas no solo en el rendimiento laboral sino en la salud Psico-visual que representa el aceptar e implementar un programa aplicativo de Ortoiluminación.

Debo anticipar una disculpa si es que esta introducción resultase más extensa de lo habitual,guardo conciencia de ello, pero tengo al escribir las presentes lineas la sensación de estar escribiendo una de esas cartas especiales que van dirigidas al más apreciado de los amigos, que ha permanecido por mucho tiempo distante y al que en una sola hoja de papel se deja verter todo un mundo de vivencias e inquietudes no comunicadas. La disculpa resulta pertinente y necesaria ante un auditorio acostumbrado a un estilo distinto en el que formulas matematicas y ecuaciones hacen su aparición desde el mismo prologo. Tal ausencia matematica será manifiesta en mi escrito y no dudo que ello habrá de frustrar sus naturales inclinaciones concretas, pero es aquí justamente donde da pricipio el terreno de la interciencia .

Ahora sí Colegas Mios, Profesionales de la Luz... a construir el Puente...

II; MANEJO DE LUZ GALACTICA: PRECURSORES DE LA INGENIERIA DE ILUMINACION.

La serie de transparencias como apoyo visual a la presente ponencia, se inicia con un simbolo. El Vitral norte de esa extraordinaria muestra de la arquitectura gótica francesa que es la catedral de Notre Dame en Paris. He tratado con ello de representar una bella muestra del manejo cientifico-tecnico y artistico que de la Luz hacian gala, los que si se me permite calificaría de precursores a partir del siglo X de la Ingeniería de Iluminación, los Diseñadores-Constructores de Vitrales.

Proveniente de lejanas estrellas de nuestra Via Lactea, la Luz debe haber sensibilizado a los realizadores de catedrales Góticas con ideas tan elevadas como ellas mismas, ya que parecen erigirse para honrar a esa energía radiante proveniente de distancias colosales, como digno recinto,morada ultima a donde deberían llegar a descansar de su largo viaje los fatigados fotones.

Ante tales obras cabe suponer que dichos profesionales contaban ya con amplios y valiosos conocimientos acerca de la Luz, de su comportamiento físico en la Reflexión, Refracción,Difracción, asi como de Optica Geometrica y probablemnete de Optica Fisiologica inclusive. El dominio que exhiben de arte crometico asi como de la tecnólogia del vidrio complementaban las posibilidades para modificar la longitud de onda luminosa segun las exigencias que el diseño impusiera.

Para desgracia nuestra de ese Arte-Ciencia, no contamos con suficientes documentos, ya que concientes de su incalculable valor eran celosamente guardados y solo transmitidos verbalmente a un grupo autoseleccionado de familias, habiendose perdido en el tiempo.

Tratando de imitar a la naturaleza , el Hombre y su Ciencia han logrado desarrollar fuentes luminosas artificiales suficientemente utiles y en constante evolución, de las que se vale el moderno Iluminador , que asi como sus predecesores habrá de requerir un cúmulo de conocimientos acorde a la tecnología vigente.

III: Primero fué; HAGASE LA LUZ" ... más no resultó suficiente y...
Despues fué; VEASE LA LUZ" ... y entonces fue creada una función de tan alta estatura como la propia Luz... LA VISION.

En muy alta estima dbe tener la Naturaleza la captación de Fotónes provenietes l espacio galactico, para haber creado uno de los Sentidos que sin duda es uno de lo más complejos y desarrollados como es el de la Visión. Baste para ello detenerse a observar el asombroso diseño estatico-dinamico del globo ocular ya no solo de la especie humana sino de cualquier otra que se considere. Mecanismos automaticos de una increible eficiencia asi como detalles finos aún no comprendidos por la ciencia moderna son el sello inconfundible del perfecto diseñador, que ha pensado en todas las posibilidades fisiologicas y de ellas ha seleccionado la mejor como analizaremos a continuación de manera somera dadas las limitaciones de espacio y tiempo a que estamos sujetos, no sin antes invitar al lector atento a revisar con detalle la bibliografía recomendada en el presente escrito.

La Unidad Visual , como habremos de llamar al sistema se integra por varios elementos organofuncionales. Dos Globos Oculares que son en realidad procidencio extensión del propio cerebro, mismos que son los elementos Receptores de los quantos de luz y que se comportan en cierta forma como las antenas parabolicas de un radiotelescopio astronómico que al igual que los ojos han sido diseñados para la adecuada captación de ciertas longitudes de onda del amplio espectro electromagnetico, magnificación y transducción.

La Historia de la Medicina demuestra las grandes dificultades que se han presentado para dilucidar la estructura y función de los ojos y no es sino a pequeños saltos como cada centuria y en especial las ultimas de nuestra era han contribuido a integrar un concepto mas cercano al real. Curiosas resultan en verdad las antiguas concepciones del fenomeno visual. De ellas algunas resultan inquietantes aún en nuestros dias, como es el concepto egipcio de considerar al ojo como Emisor de una "energiá" con la cual se escudriñan los objetos y demás seres. Si bien esta concepción resulta sumamente interesante como lo atestiguan algunos estudios cientificos en centros neurofisiologicos de los Estados Unidos, los que al parecer explican ciertos fenomenos en la comunicación interpersonal, solo deben considerarse por ahora como preliminares.

Resulta ya clasico el simil entre el ojo y una cámara fotográfica, lo que nos da una idea gráfica del complejo mecanismo óptico qûe implica el fenomeno de "ver",sin embargo tal comparación no es justa si se obsreva la extraordinaria movilided y sincronismo binocular cuyo gobierno se encuentra en un centro cibernetico a nivel mesencefálico. Tal dinámica asi como la captacion de imagen en movimiento más nos permitiría hablar de un simil con el sistema de televisión.

De continuar la busqueda de una exacta equivalencia de nuestra extraordinaria Unidad Visual, con nuestros avances tecnológicos , tendriamos que representarla como una inexistente hibridación tecnológica que combinara ciertas caracteristicas de la cámara fotográfica, de la T.V. con un gobierno Cibernetico asi como elementos de la antena parabolica de un radiotelescopio y de resultar cierta la concepcion de la Unidad Visual como Emisora se tendrían que adicionar caracteristicas del mismo radar.

Como puede facilmente adivinar el lector, nuestro pretendida hibridación tecnológica queda muy por debajo de las reales ptencialidades de nuestro Sentido de la Visión.

Además del sistema Optico y del sistema Neurosensorial y Neuromotor que gobierna la motilidad binocular intra y extraocular, existe un sistema hidraulico de alta complejidad de cuya eficiencia dpendera el equilibrio entre la produccion de liquidos intraoculares y su correspondiente desalojo. La falla de este sistema conduce a la conocida enfermedad denominada Glaucoma en donde la Presión Intraocular supera las cifras normales de 10-20mm de Hg. que de no ser modificada favorablemente habrá de llevar inexorablemnete al paciente a la ceguera.

Si todos los sistemas se han orquestado adecuadamente, la luz proveniente de fuentes naturales o artificiales, habrá de concentrar la energía radiante en uno o varios puntos de la retina, en los que los fotones o cuantos de energía la transmitirán a los Fotoreceptores, los que a su vez y mediante diversos pasos bioquimicos de los pigmentos visuales (Rodopsina y pigmentos de los conos, todos relacionados con la Vitamina A) transduciendo de esta manera la energía lumínica en un debil impulso electrico el cual mediante diversos neurotransmisores serán procesados y codificados en la computadora retiniana que es el primer nivel de actividad cibernética . Dichos mensajes electricos seran enviados por la Via Visual hasta la segunda estación de procesamiento precortical que son los cuerpos geniculados. La tercera estación esta representada por la propia corteza visual en el lóbulo occipital asi como las areas corticales de asociación.

Sorprende en verdad lo intrincado del sistema cibernetico Visual, pero - más complejo aún resulta el fenomeno Psicofisico de la percepción Visual en la que simples señales electroquimicas llegan a conformar imagenes con un significado concreto tridimensional que permite asi mismo la integración de Formas, del espacio , el movimiento o inclusive de las más atrevidas abstracciones. En este terreno falta mucho por estudiar ya que el fenomeno Psico-cerebral de "ver" esta lejos de un perfecto entendimiento, asi como sus sus diversas interacciones con otros sitemas sensoriales, intelectivos ,afectivos y de memoria.

Debemos mantenernos bien informados y alertas ante el avance de la investición Biomédica y Psicofisica en esta área y de ser posible contribuir de alguna manera a su propio desarrollo. Esperemos que en el futuro cercano lleguemos a comprender con plena exactitud como influye la Luz en el comportamiento individual y colectivo y de como puede la calidad de la Iluminación influir en la propia calidad de vida asi como del desempeño humano.

IV: PRIORIDAD Y VULNERABILIDAD DE LA UNIDAD VISUAL.

Resulta interesante y significativo el hecho de que los ojos .y probablemente el resto de la Unidad Visual muestren una destacdada prioridad en la conformación del embrión de cualquer especie. Desde los primera semanas de gestación y ya se esbozan los acumulos caracteristicos de pigmento visual, que en el humano hacia el dia sesenta ya demuestra un alto grado de diferenciación morfológica.

El delicado camino de la morfogenesis ocular puede por desgracia verse desviado por un sinnumero de factores agresores que pueden conducir a la misma ausencia del organo , Anoftalmía, una falta de desarrollo; Microftalmía o bien graves t tornos oftalmicos como es la Ciclópia condición que impide la sobrevida pc los multiples defectos cerebrales asociados. Ejemplos de tales entidades médicas se han mostrado en la serie de trasparencias de apoyo.

Amplia es la gama de agentes agresores que en cualquier momento pueden dañar gravemente la Unidad Visual , conduciendole a la Amaurosis ó cancelación de la función receptora de quantos de luz. Ellos pueden ser de naturaleza traumática, Infecciosa-Parasitaria, Inflamatoria,Toxica,Degenerativa y neoplasica. Hasta el propio espectro electromagnetico provedor de la materia prima .de la visión que es la Luz y aún esta misma en ciertas condiciones y en determinada longitud de onda pueden provocar lesiones irreversibles en la vulnerable Unidad Visual.

La prioridad que la naturaleza ha otorgado al sentido de la Vista no se limita a la etapa Morfologica sino que se manifiesta en la Psicologica inclusive. Todas y cada una de las sociedades humanas aún las más primitivas ofrecen muestras de la alta representatividad que ha tenido siempre la Visión para el hombre. Ceremonias y rituales más o menos elaboradas hablan de una mezcla de respeto, magia y temor acerca de los ojos como puente entre la Obscuridad y la Luz.

Si el sufrimiento de un enfermo pudiese cuantificarse y compararse, no dudaría en colocar en primer termino el de aquel que se le ha planteado la necesidad imperiosa de extirparle uno o los dos ojos. El impacto psicologico-filosofico es de tal magnitud que no se limita al propio paciente sino a todo el nucleo familiar y perifamiliar., habiendose de requerir de cierta labaor de apoyo simultaneo.

De acuerdo a lo antes dicho bien podriamos concluir que si el ojo es una extension o exteriorización preferencial del cerebro y aquel se alimenta de luz ya se entenderá el por qué la Luz tiene una importancia Psicologica vital. Por no debemos conformarnos con dar solo "migajas" de luz a las escuelas y centro de labor, porque estaremos con ello mal nutriendo o inclusive aniquilando cerebros. Por extensión e imitando una frase popular se podría decir inquiriendo "Dime como es tu Iluminación y te dire quien eres"

V: " ORTOILUMINACION " : PUENTE ENTRE LA OFTALMOLOGIA Y LA LUMINOTECNIA.

Ante la ausencia de un termino que indicara o significara "Correcta Iluminación" me he permitido por esta ocasión y para el desarrollo de la presente ponencia integrar uno, mediante el empleo de un prefijo frecuentemente empleado en Medicina derivado del griego ORTHOS, que significa recto,derecho,correcto,normal.
Espero en el transcurso de futuras participaciones se me indique si en su terminología tecnica existe otro mejor y a la vez ofrecer los argumentos en favor de este termino que por principio, habrá de facilitar la integración en un cuerpo toda una serie de conceptos Biomedicos, ,Psicofisicos y tecnicos en favor de una Iluminación Sana, para el adecuado desempeño humano.

Uno de los curiosos imperativos de nuestra "civilización" y que en cierta forma ha dado pie para la aparición y desarrollo de la Luminotecnia es el de tratar de romper el perfecto ciclo de Iluminación natural Dia-Noche que se corresponde de manera estrecha con los ciclos circadianos que a su vez gobiernan el binomio Actividad-Reposo. El hombre, valiendose de los inumerables recursos de la Iluminación artificial le ha robado a la noche la mayor cantidad de horas que ha sido posible, fara fines laborales, escolares y recreativos. Como esta tendencia del humano parece continuar, el horizonte aplicativo de la Luminotecnia se magnifica con el tiempo.

Si el romper el ciclo natural es por sí mismo una grave infraccion a nuestra propia naturaleza, resulta un deber ineludible el impedir por todos los medios apropiados ~~el impedir~~ un mayor deterioro empleando fuentes de iluminación mal estudiadas o peligrosas, que lejos de crear un ambiente propicio se conviertan en un contaminante más de los muchos que por desgracia el hombre no conciente ha arrojado a su paso. Debemos exigir y autoexigirnos el debido cumplimiento no solo a normas y reglamentos de ingeniería de construccion y sanitaria, por desgracia siempre anticuados y obsoletos, sino mediante estudios cada vez más profundos tanto en la Psicofisiologia Sensorial aunados a los avances de la Tecnología llegar a establecer las especificaciones a que debe someterse todo recinto que haya de requerir de Iluminacion artificial y en donde el hombre centro de nuestras reflexiones deba ejecutar algun trabajo.

Existen evidencias de que el empleo de ciertas lamparas implica un riesgo potencial sobre todo en aquellas en que la banda espectral opera en una longitud de onda entre 280-320nm correspondiente al rango del U.V. En el año de 1974 en el mes de Noviembre una escuela pública de Maryland reportó lesiones dermicas y oculares en algunos de sus alumnos. La investigación reportó que la cubierta interior del cristal de cuarzo de las lamparas allí empleadas y que habitualmente limita el paso del U.V. estaba por alguna razón roto. En otro reporte de 460 personas lesionadas se encontró que una sola lampara defectuosa de Vapor de Mercurio afecto a 69 personas.

Si bien los anteriores son los primeros reportes publicados, deben existir un número mayor de observaciones que de ser conocidas ayudarían de manera importante a comprender la posible fisiopatología que implica una mala iluminación no solo en el daño directo de la Unidad Visual sino en algo más sutil y dificil de evaluar y cuantificar de como una iluminacion deficiente , de baja calidad o mal estudiada puede modificar el propio comportamiento del sujeto expuesto.

El campo ,los alcances y prospectiva de la Ortoiluminación son enormes y muy estimulantes. De su avance sostenido, a pesar de las inherentes adversidades en el nuestro y en otros medios, seremos nosotros los responsables, los que desde el punto de vista Médico o tecnico nos apasiona el estudio de esa intrigante y no pocas veces voluble energía radiante que es la Luz.

El espacio y el tiempo que nos rigen ha cerrado por ahora su ciclo y toca el punto de cerrar esta presentación cuyas aspiraciónes más filosoficas que tecnica espero hayan despertado su interés y que nos permitan tender lazos firmes que vinculen nuestras respectivas profesiones, que si bien las actividades de rutina habrán de ocupar el mayor tiempo, cuando contemos con ese tiempo preciado de que a veces disponemos, demos rienda suelta a nuestra creatividad y nos permitamos compartirla en esta desusada hibridacion de Médicos e Ingenieros, en favor de una máxima salud visual y de un desempeño humano más pleno.

Asi como dimos entrada a nuestra presentación exhibiendo esa real maravilla del arte gótico que es el Vitral Norte de Notre Dame en Paris, nos despedimos mostrando a ustedes el Vitral opuesto, igualmente rico en la capacidad de atrapar y acariciar la Luz .. .

DR. AGUSTIN SERRANO SANCHEZ

35

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FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA
CURSOS ABIERTOS
ILUMINACION INTERIOR PRINCIPIOS, DISEÑO Y APLICACIONES

TERMINOLOGIA

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I n t r o d u c c i ó n.

En las técnicas y procedimientos utilizados en Luminotecnia es frecuente - especialmente para el principiante - encontrarse con complicaciones al realizar tanto las evaluaciones preliminares como la determinación exacta de parámetros para el desarrollo de los diversos métodos de solución de los sistemas de iluminación.

Una de las principales causas de estas complicaciones es la carencia de fundamentos sólidos sobre Ingeniería Eléctrica en general y sobre Ingeniería de Iluminación en particular.

La adquisición de estos antecedentes se hace generalmente tediosa debido a la propia naturaleza árida y no pocas veces abstracta de las definiciones y conceptos fundamentales. El tratamiento para este estudio y en general para cualquier otro relacionado con alguna especialidad técnica o científica puede hacerse de tres diferentes maneras:

a) Como Fenómeno Físico
b) Como Modelo Matemático
c) Como Problema Ingenieril

A grandes rasgos, estos tratamientos consisten en:

a) Como Fenómeno Físico.- Se explican, mediante palabras y figuras, las relaciones entre los diferentes parámetros así como los fenómenos en que éstos intervienen. SE utilizan enunciados, definiciones y conceptos utilizando como apoyo analogías con otros fenómenos físicos más comunes y por tanto más fáciles de comprender. Como es obvio, se gana en tiempo, visión y facilidad de comprensión pero se está limitado en cuanto a las posibilidades de modificación y control del sistema.

b) Como Modelo Matemático.- Mediante las relaciones entre los parámetros básicos se establecen las ecuaciones - llamadas ecuaciones de estado del sistema - que predicen y/o explican el comportamiento exacto del sistema bajo diferentes condiciones. Sin embargo en este método es común sumergirse en un mar de complejas ecuaciones donde en ocasiones se corre el riesgo de perder parte de la aportación subjetiva del diseñador. Evidentemente, para usar este método se requiere de dos condiciones indispensdables: tiempo considerable y sólida formación matemática.

c) Como Problema Ingenieril.- Mediante la combinación de la clara comprensión del fenómeno físico y las ecuaciones fundamentales se establecen las bases que servirán para la solución del problema. Se utilizan sólo las matemáticas indispensables por ser insustituíble herramienta pero apoyadas por el criterio y visión ganados al analizar físicamente los fenómenos.

Es evidente que cada método tiene ventajas y desventajas. Por la naturaleza de este curso se tienen dos limitantes importantes: tiempo reducido y grupo heterogéneo. Por estas razones utilizaremos el tercer tratamiento ya que en él se combinan las ventajas de los dos anteriores sin desventajas apreciables.

TERMINOLOGIA Y UNIDADES DE ILUMINACION.

En Luminotecnia intervienen dos elementos básicos a considerar: la fuente productora de luz y el objeto a iluminar. Las unidades y magnitudes fundamentales empleadas para valorar y comparar las cualidades y los efectos de las fuentes de luz son las siguientes:

- FLUJO LUMINOSO (POTENCIA LUMINOSA)
- RENDIMIENTO LUMINOSO (EFICACIA)
- CANTIDAD DE LUZ (ENERGIA LUMINOSA)
- INTENSIDAD LUMINOSA
- ILUMINANCIA
- LUMINANCIA

A continuación describiremos brevemente cada uno de los anteriores conceptos:

FLUJO LUMINOSO

La energía transformada por los manantiales luminosos no se puede aprovechar totalmente para la producción de luz. Por ejemplo, una lámpara incandescente consume una determinada energía eléctrica que se transforma en energía radiante, de la cual sólo una pequeña parte es percibida por el ojo en forma de luz, mientras que el resto se pierde en calor (Fig 1).

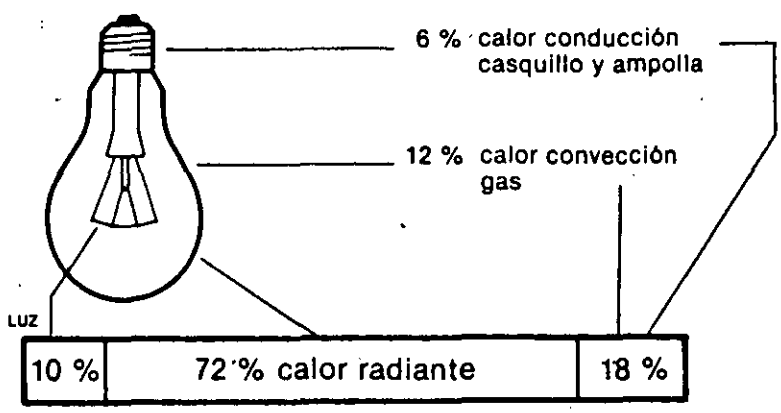


FIG 1.- TRANSFORMACION DE ENERGIA ELECTRICA PARA LA PRODUCCION DE LUZ EN UNA LAMPARA INCANDESCENTE.

A la energía radiante de una fuente de luz que produce una sensación luminosa se le llama Flujo Luminoso o Potencia Luminosa. El flujo luminoso se representa por la letra griega ϕ y su unidad es el LUMEN (lm). Un lumen es el flujo luminoso de la radiación monocromática que se caracteriza por una frecuencia f de valor 540×10^{12} Hertz y por un flujo de energía radiante equivalente a 1/683 watts. Un watt de energía radiante de longitud de onda de 555 nm en el aire equivale a 683 lm aproximadamente.

La medida del flujo luminoso se realiza en laboratorio por medio de un fotoelemento ajustado según la curva de sensibilidad fotópica del ojo a las radiaciones monocromáticas, incorporado a una esfera hueca a la cual se le da el nombre de esfera integradora de Ulbricht, y en cuyo interior se coloca la fuente a medir.

En la tabla siguiente se muestran algunas de las lámparas más usadas y su flujo luminoso característico.

Tipo de lámpara	Flujo luminoso lm
Efluvios	0,6
Vela de cera	10
Bicicleta	18
Incandescente Standard de 100 W	1.380
Fluorescente L 40 W/20 (Blanco frio)	3.200
Mercurio a alta presión HQL 400 W	23.000
Halogenuros metálicos HQI 400 W	28.000
Sodio a alta presión NAV-T 400 W	48.000
Sodio a baja presión NA 180 W	33.000
Magnesio AG 3B	450.000

TABLA I.- FLUJO LUMINOSO DE LAMPARAS COMUNES

EFICACIA O RENDIMIENTO LUMINOSO.

El rendimiento luminoso o eficacia luminosa de una fuente de luz, indica el flujo que emite la misma por cada unidad de potencia eléctrica consumida para su obtención.

El rendimiento o eficacia se representa por la letra griega ETA (η) y sus unidades son lúmenes por watt (lm/w):

$$\eta = \frac{\phi\ [\text{lm}]}{W\ [\text{watt}]}$$

Si se lograse fabricar una lámpara que transformara sin pérdidas toda la potencia eléctrica consumida en luz de una longitud de onda de 555 nm, esta lámpara tendría el mayor rendimiento posible, cuyo valor sería de 683 lm/w, pero como sólo una pequeña parte es transformada en luz, los rendimientos luminosos obtenidos hasta ahora para las distintas lámparas quedan muy abajo de este valor, presentando diferencias notables entre las mismas, como puede apreciarse en la TAbla II.

Por ejemplo, una lámpara incandescente estándar de 4o watts produce 440 lúmenes, por lo que tiene una eficacia de 11 lm/w. U na lámpara de sodio baja presión de 180 watts produce en cambio 3294 lúmenes por lo que tiene una eficacia de 183 lm/w.

Tipo de lámpara	Potencia nominal W	Rendimiento luminoso lm/W
Efluvios........................	0,3	2
Incandescente Standard 40 W/220 V	40	11
Fluorescente L 40 W/20 (Blanco frio).	40	80
Mercurio a alta presión HQL 400 W .	400	58
Halogenuros metálicos HQI 400 W .	360	78
Sodio a alta presión NAV-T 400 W. . .	400	120
Sodio a baja presión NA 180 W.....	180	183

TABLA II.- EFICACIAS PROMEDIO DE DISTINTAS LAMPARAS

Cabe aclarar que las eficacias de la Tabla II se refieren exclusivamente a las lámparas; para las lámparas de descarga como sistema completo incluyendo instalación y accesorios de conexión dichas eficacias pueden variar sustancialmente.

ENERGIA LUMINOSA O CANTIDAD DE LUZ.

De forma análoga a la energía eléctrica que se determina por la potencia eléctrica por unidad de tiempo, la cantidad de luz o energía luminosa se determina por la potencia luminosa o flujo luminoso por unidad de tiempo.

La cantidad de luz se representa por la letra Q y su unidad es el LUMEN_HORA (lm-h). Su fórmula es:

$$Q = \phi . t$$

Esta magnitud es importante en las lámparas de relámpago empleadas en fotografía, pues su valor es decisivo para la iluminación de la película. Debido al corto tiempo de la descarga, la cantidad de luz suele darse en lúmenes por segundo (lms). En la lámpara que emite una cantidad de luz de 2.1 lmh, esta magnitud por segundo será 2.1 lmh x 3600 seg ó 7560 lms.

También tiene interés conocer a efectos de cálculos económicos la cantidad de luz que emite una lámpara durante su vida. Una lámpara incandescente de 40 watts que emite un flujo luminoso de 440 lúmenes, durante su vida promedio de 1000 horas emitirá una cantidad de luz de 440,000 lmh. De este valor habrá que descontar la pérdida de flujo que se produce en el transcurso de su vida, ya que este valor no es constante.

INTENSIDAD LUMINOSA .

Este parámetro se entiende únicamente referido a una determinada dirección y contenido en un ángulo sólido w (Omega Minúscula). Al igual que a una magnitud de superficie corresponde un ángulo plano que se mide en radianes, a una magnitud de volumen le corresponde un ángulo sólido o estéreo que se mide en estéreorradianes.

El radián se define como el ángulo plano que corresponde a un arco de circunferencia de longitud igual al radio. El estereorradián se define entonces como el ángulo sólido que corresponde a un casquete esférico cuya superficie es igual al cuadrado del radio de la esfera (Figuras 2 y 3).

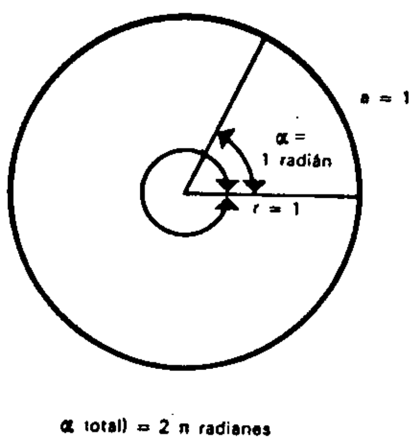


FIG 2.- ANGULO PLANO

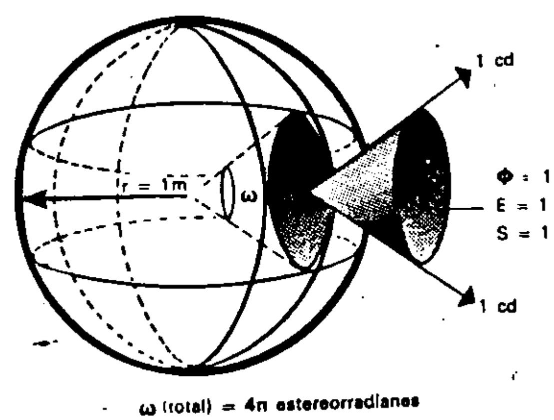


FIG 3.- ANGULO SOLIDO Y RELACION ENTRE FLUJO LUMINOSO, INTENSIDAD LUMINOSA E ILUMINANCIA.

La intensidad luminosa de una fuente de luz en una determinada dirección es igual a la relación entre el flujo luminoso contenido en un ángulo sólido cualquiera cuyo eje coincida con la dirección considerada y el valor de dicho ángulo sólido expresado en estereorradianes.

La Intensidad Luminosa se representa por la letra I y su unidad es la CANDELA (cd). Su fórmula es:

$$I = \frac{\phi}{w}$$

La candela se define como la intensidad luminosa de una fuente puntual que emite un flujo luminoso de 1 lumen en un ángulo sólido de un estereorradián:

$$cd = \frac{lm}{sr}$$

DISTRIBUCION LUMINOSA. CURVA FOTOMETRICA.

El conjunto de la intensidad luminosa de un manantial en todas direcciones constituye lo que se llama distribución luminosa. Las fuentes de luz utilizadas en la práctica tienen una superficie luminosa más o menos grande, cuya intensidad de radiación se ve afectada por la propia construcción de la fuente presentando valores diferentes en las distintas direcciones.

Con aparatos especiales se puede determinar la intensidad luminosa de un manantial en todas direcciones del espacio con relación a un eje vertical. Si representásemos por medio de vectores la intensidad luminosa de un mananatial en infintas direcciones del espacio, obtendríamos un cuerpo llamado Sólido Fotométrico (fig 4).

Haciendo pasar un plano por el eje de simetría del cuerpo luminoso se obtendría una sección limitada por una curva que se denomina Curva de Distribución Luminosa o Curva Fotométrica. Mediante la curva fotométrica de un manantial se puede determinar con exactitud la intensidad luminosa en cualquier dirección, dato necesario para los cálculos de iluminación.

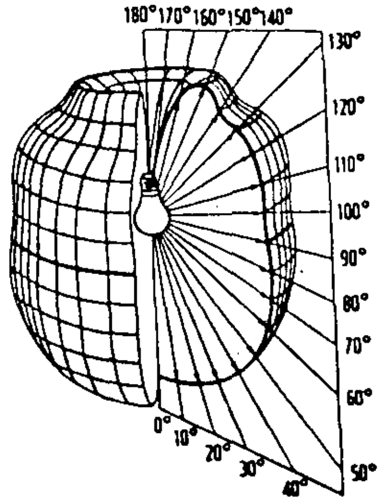


FIG 4.- SOLIDO FOTOMETRICO DE UNA LAMPARA INCANDESCENTE

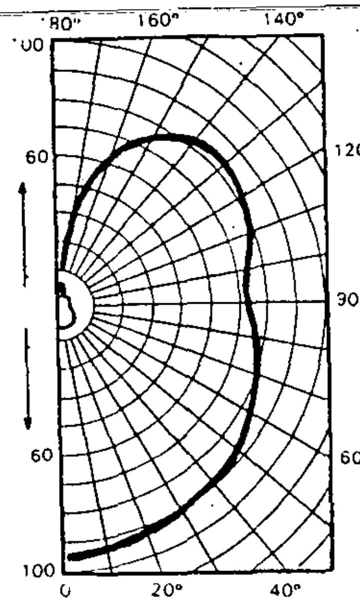
Las curvas fotométricas se dan referidas a un flujo luminoso de 1000 lúmenes y, como el caso más general es que la fuente de luz emita un flujo mayor, los valores de intensidad luminosa correspondientes se encuentran mediante una simple relación.

Por ejemplo, si una lámpara de mercurio de alta presión tiene un flujo luminoso de 23000 lúmenes, los valores de la intensidad luminosa deducidos de su curva fotométrica dada para 1000 lúmenes, habrá que multiplicarlos por el factor 23 hallado de la relación 23000/1000, para obtener el verdadero valor.

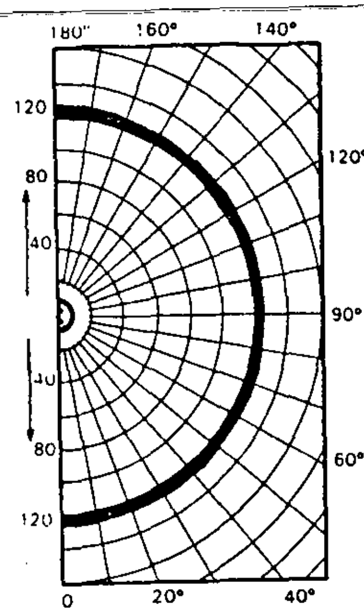
MEDIDA DE LA INTENSIDAD LUMINOSA.

La medida de la intensidad luminosa se realiza en el laboratorio por medio de aparatos especiales, de los cuales existen diversos modelos fundados en la Ley Inversa del Cuadrado de la Distancia -la cual se discutirá posteriormente- usando una luz patrón y otra desconocida, situadas una frente a otra en un mismo eje e interceptadas en una pantalla en la que se igualan las iluminaciones captadas en ambas caras de la misma mediante un objetivo apropiado.

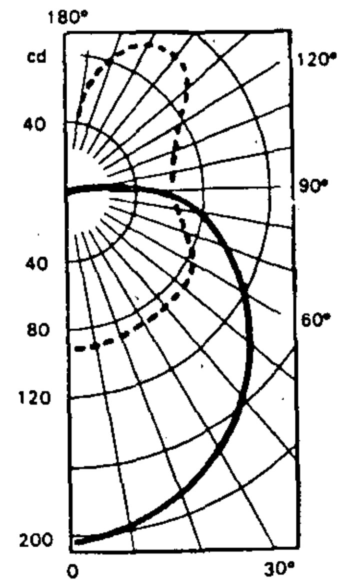
En las figuras 5, 6 y 7 se muestran las curvas fotométricas típicas de algunas de las lámparas más utilizadas.



(5)



(6)



(7)

FIGS 5,6,7.- CURVAS FOTOMETRICAS TIPICAS DE LAMPARAS COMUNES

5) LAMPARA INCANDESCENTE ESTANDAR
6) LAMPARA FLUORESCENTE
7) LAMPARA DE MERCURIO ALTA PRESION CON LUMINARIO

ILUMINANCIA.

La iluminancia o iluminación de una superficie es la relación entre el flujo luminoso que recibe la superficie y su extensión. Se representa por la letra E y su unidad es el LUX en el Sistema Internacional de Unidades. Su ecuación es:

$$E = \frac{\phi}{A}$$

De esta ecuación se deduce que cuanto mayor sea el flujo luminoso incidente sobre una superficie, mayor será la iluminancia, y que, para un mismo flujo luminoso incidente, la iluminancia será tanto mayor en la medida en que disminuya la superficie.

El lux, unidad de luminancia se define como la iluminación de una superficie de un metro cuadrado que recibe uniformemente repartido un flujo luminoso de un lumen (Fig 8).

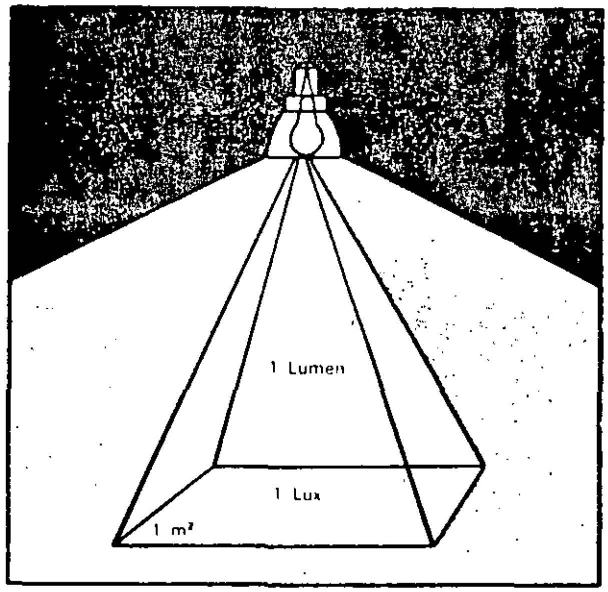


FIG 8.- UNIDAD DE LUMINANCIA. LUX.

$$LUX = \frac{1\ lm}{1\ m^2}$$

La iluminancia constituye un dato importante para valorar el nivel de iluminación que existe en una oficina, en la superficie de un recinto, en una calle, etc.

La medida de iluminancia se realiza por medio de un aparato denominado luxómetro, que consiste en una celda fotoeléctrica que, al incidir la luz sobre una superficie, genera una débil corriente eléctrica que varía en función de la luz incidente. Dicha corriente se mide con un miliampérmetro cuya escala está calibrada directamente en lux. La Tabla III muestra distintos valores aproximados de iluminancias.

T A B L A III

Mediodía de verano al aire libre, con cielo despejado	100,000 lux
Mediodía de verano al aire libre, con cielo cubierto	20,000 lux
Lugar de trabajo bien iluminado en un recinto interior	1,000 lux
Buen Alumbrado Público	20 - 40 lux
Noche de Luna LLena	0.25 lux
Noche de LUna nueva (Luz de estrellas)	0.01 lux

LUMINANCIA.

La luminancia de una superficie en una dirección determinada es la relación entre la intensidad luminosa en dicha dirección y la superficie aparente (superficie vista por el observador situado en la misma dirección).

La luminancia se representa por la letra L y su unidad es el NIT (nt) o candela por metro cuadrado (cd/m²); tiene un submúltiplo que es el STILB (sb) que es candela por centrímetro cuadrado (cd/cm²), empleado para fuentes con elevadas luminancias.

La ecuación que expresa la LUminancia es:

$$L = \frac{I}{S \cos \alpha}$$

donde: $S \cos \alpha$ es la Superficie Aparente

La Luminancia es máxima cuando el ojo se encuentra en la perpendicular a la superficie luminosa, ya que entonces el ángulo α es igual a cero y el coseno de α igual a uno, correspondiendo la superficie aparente a la real.

La luminancia puede ser directa o indirecta, correspondiendo la primera a los manantiales luminosos y la segunda a los objetos iluminados (Figuras 9 y 10).

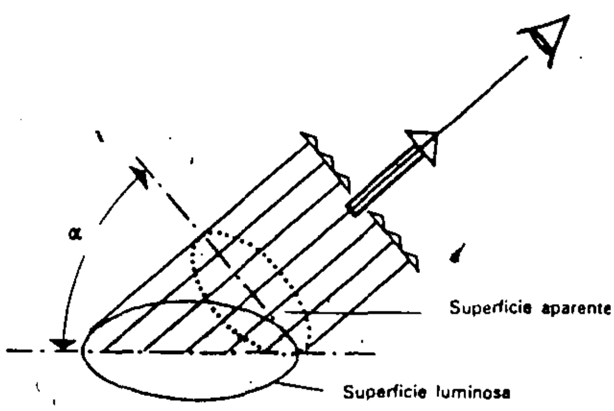


FIG 9.- LUMINANCIA DIRECTA DE UNA SUPERFICIE LUMINOSA.

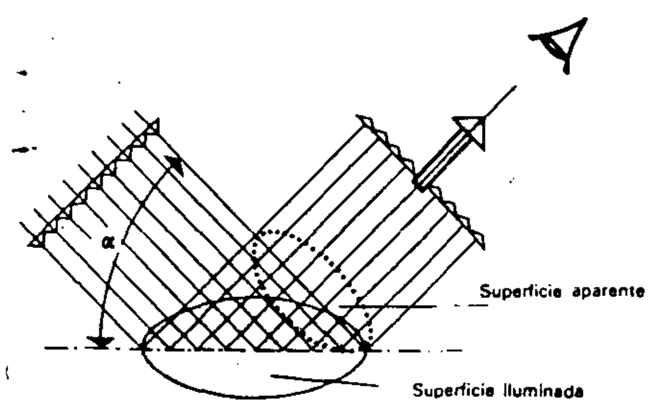


FIG 10.- LUMINANCIA INDIRECTA DE UNA SUPERFICIE ILUMINADA.

La luminancia es lo que produce en el órgano visual la sensación de claridad, pues la luz no se hace visible hasta que es reflejada por los cuerpos. La mayor o menor claridad con que vemos los objetos iluminados, depende de su luminancia. El libro y la mesa de la figura 11 tienen la misma iluminancia, pero se ve con más claridad el libro porque su luminancia es mayor que la de la mesa.

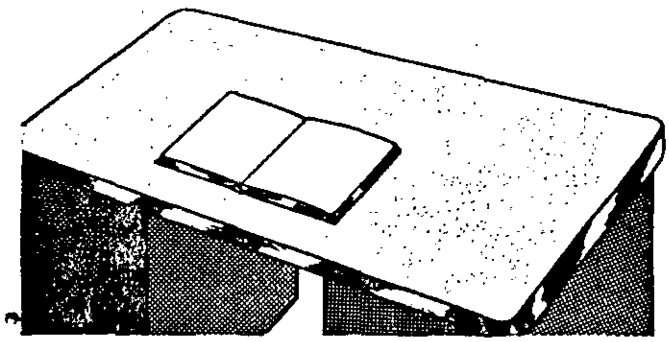


FIG 11.- DIFERENTES LUMINANCIAS DE DOS CUERPOS CON IGUAL ILUMINANCIA.

Ls percepción de la luz es realmente la percepción de diferencias de luminancias. Se puede decir, por lo tanto, que el ojo ve diferencias de luminancias y no de iluminación.

En la Tabla IV se dan algunos valores de luminancias.

T A B L A I V

Sol	150,000 cd/cm²
Cielo despejado	0.3 - 0.5 "
Cielo Cubiero	0.03 - 0.1 "
Luna	0.25 "
LLama de una vela de cera	0.70 "
Lámpara Incandescente Clara	100 - 200 "
Lámpara Incandescente mate	5 - 50 "
Lámpara Incandescente Opal	1 - 5 "
Lámpara Fluorescente L40W/20	0.75 "
Lámpara de mercurio a alta presión 400 W	11 "
Lámpara de Aditivos Metálicos 400 W	700 "
Lámpara de sodio a alta presión 400 W	500 "
Lámpara de sodio a baja presión 180 W	10 "
Papel Blanco con Iluminación de 1000 lux	250 cd/m²
Calzada de una calle bien iluminada	2 "

La medida de la luminancia se realiza por medio de un aparato especial llamado Luminancímetro o Nitrómetro, de construcción similar al luxómetro, del que igualmente existen diversos modelos.

SISTEMAS DE UNIDADES.

El sistema inglés de unidades tiende a desaparecer, por lo que en un futuro próximo todos los países utilizarán el Sistema Métrico, más propiamente llamado el Sistema Internacional de Unidades, abreviado SI. Las principales razones para adoptar el SI son las siguientes: 1) Su extenso uso en la mayor parte de los países del mundo, 2) Son las unidades primarias en el campo científico, y 3) La necesidad de uniformizar los campos de ciencia e Ingeniería.

En la Ingeniería de Iluminación sólo aquellos términos que involucran unidades de longitud o área se ven afectados por la conversión. Las unidades de lúmenes, candelas, estereorradianes y eficacia permanecen igual. Por lo tanto sólo las unidades de Luminancia e Iluminancia se ven afectados por esta conversión:

En el sistema Inglés la unidad de Iluminancia es el foot candle (fc) y equivale a un lumen por pie cuadrado, o sea:

$$fc = \frac{lm}{pie^2}$$

La conversión entre Footcandles y Lux se reduce a una simple conversión de pies cuadrados a metros cuadrados porque los lúmenes son comunes:

$$1 \text{ pie} = 0.3048 \text{ metros} \; ; \quad 1 \text{ pie}^2 = .0929 \text{ m}^2$$

$$1 \text{ footcandle} = \frac{lm}{pie^2} \cdot \frac{pie^2}{0.0929 \, m^2} = 10.7639 \text{ Lux}$$

$$\text{o también: } \frac{1 \text{ fc}}{10.76 \text{ lux}} = 1$$

En el Sistema Inglés la unidad de Luminancia es el foot-candle (fl) y equivale a una candela por pie cuadrado, o sea:

$$fl = \frac{cd}{pie^2}$$

La conversión entre footlamberts y Nits se reduce también a una simple conversión de metros cuadrados a pies cuadrados pero se debe incluir el valor :

$$fl = \frac{1}{\pi} \frac{cd}{pie^2} \frac{pie^2}{0.0929\ m^2} = 3.4262 \frac{cd}{m^2} = 3.4262\ Nits$$

$$\text{o también : } \frac{fl\ .\ m^2}{3.426\ cd} = 1$$

La relación entre candelas, lúmenes, estereorradianes y footcandles puede encontrarse fácilmente utilizando una esfera unitaria de 1 pie de radio con una fuente puntual uniforme de 1 candela en el centro de la esfera (Fig 12):

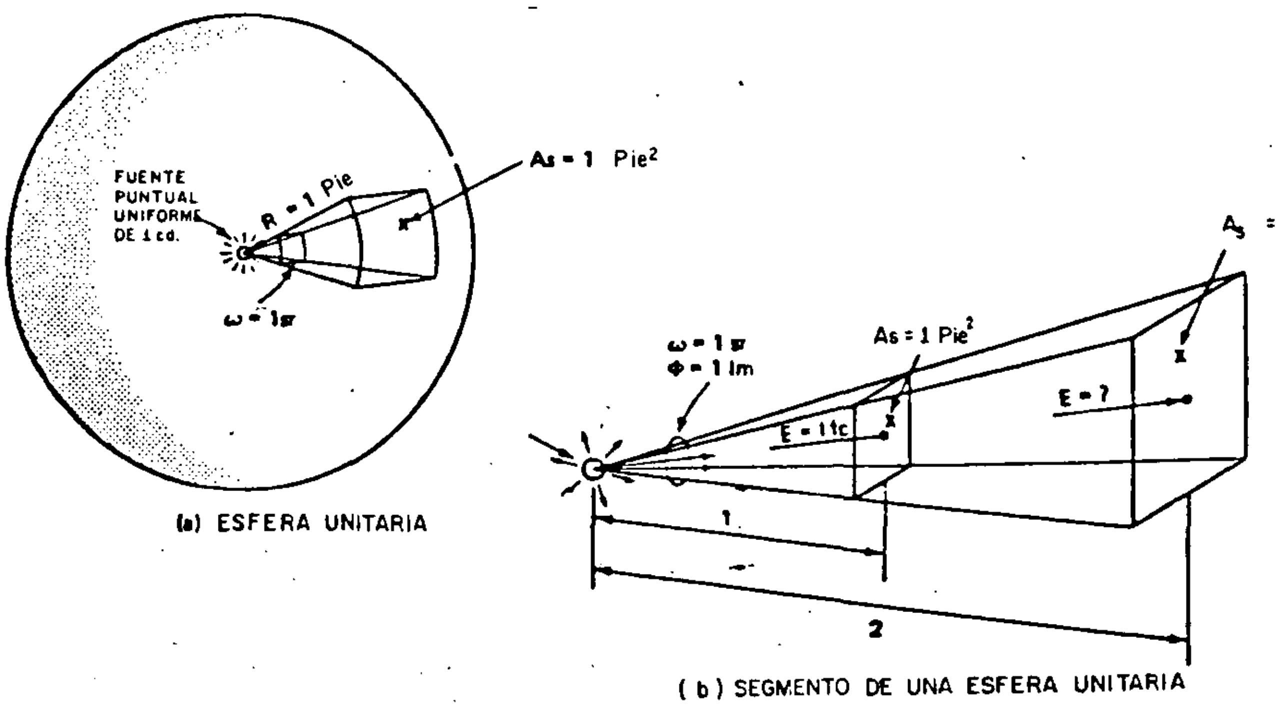


FIG 12.- ESFERA UNITARIA

Para un área de un pie cuadrado en la superficie, el ángulo sólido obtenido será un estereorradián (sr):

$$w = \frac{A}{R^2} = \frac{1 \text{ pie}^2}{1 \text{ pie}^2} = 1 \text{ sr}$$

La fuente puntual de una candela producirá un lumen an la unidad de ángulo sólido:

$$\phi = I\ w = cd\ .\ sr = lm$$

La iluminación producida en la superficie interior de la esfera será de 1 lm en un pie² o un footcandle:

$$E = \frac{\phi}{A} = \frac{1 \text{ lm}}{1 \text{ ft}^2} = 1 \text{ fc}$$

El área total de la superficie de una esfera es 4 R².Por lo tanto, el área total de la superficie de la esfera unitaria es 4π o 12.57 ft². Si el flujo luminoso de 1 lm llega a cada pie cuadrado, la fuente puntual uniforme produce un total de 4π lm o 12.57 lm.

Además de las unidades estudiadas hay otras que se usan regularmente. Algunas de éstas son las siguientes:

Cuando la intensidad luminosa está en candelas y el área está en pulgadas cuadradas, la unidad de luminancia es candelas por pulgada cuadrada, por tanto:

$$1 \text{ fl} = \frac{1 \text{m}}{\text{ft}^2} \cdot \frac{1}{\frac{\pi \text{ lm}}{\text{cd}}} = \frac{1}{\pi} \cdot \frac{\text{cd}}{\text{ft}^2} = \frac{1}{144} \cdot \frac{\text{cd}}{\text{pul}^2}$$

El número de footlamberts es igual a 1/144 veces el número de candelas por pulgada cuadrada, es decir:

$$\frac{1 \text{ fl}}{(1/144\pi)(\text{cd-pul}^2)} = \frac{144\pi.\ \text{pul}^2\ .\ \text{fl}}{1 \text{ cd}} = 1$$

Haciendo un análisis comparativo entre dos esferas unitarias para cada sistema de unidades, es decir una con radio de 1 pie y otra con radio de 1 metro se pueden comprobar varias_ de las relaciones encontradas (Fig13).

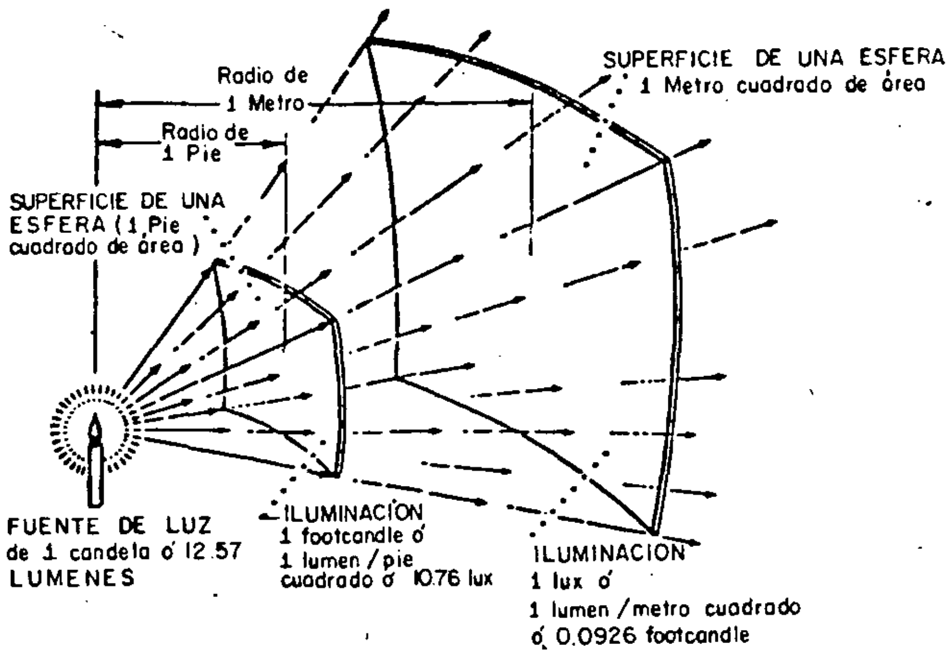


FIG 13.- UNIDADES DE ILUMINANCIA.

En la Tabla VI hacemos un resumen de las magnitudes y unidades luminosas fundamentales para los sistemas Inglés e Interna-- cional y en la Tabla V se incluyen algunos factores de conversión entre unidades comunes.

T A B L A V

pul	x	2.54	....	cm
pie	x	.3048	....	m
lux	x	m^2	....	lm
fc	x	pie^2	....	lm
fc	x	10.765	....	lux
cd	x	sr	....	lm
fl	x	452	....	cd/pul^2
fl	x	3.4262	....	Nits (cd/m^2)
cd/pul^2	x	1.55	....	Kcd/m^2

T A B L A   V I

RESUMEN DE LAS MAGNITUDES Y UNIDADES LUMINOSAS FUNDAMENTALES

MAGNITUD	SIMBOLO	UNIDAD	DEFINICION DE LA UNIDAD	RELACIONES
FLUJO LUMINOSO	ϕ	Lumen (lm)	Flujo luminoso de la radiación monocromática de frecuencia 540 x 10E12 HZ y un flujo de energía radiante de 1/683 watts.	$\phi = i \cdot w$
RENDIMIENTO LUMINOSO	η	Lumen/watt (lm/w)	Flujo luminoso emitido por unidad de potencia	$\eta = \phi/W$
CANTIDAD DE LUZ	Q	Lumen por segundo (lms) Lumen por hora (lmh)	Flujo LUminoso emitido por unidad de tiempo.	$Q = \phi \cdot t$
INTENSIDAD LUMINOSA	I	Candela(cd)	Intensidad luminosa de una fuente puntual que emite flujo luminoso de un lumen en un ángulo sólido de un estereorradián.	$I = \phi/w$
ILUMINANCIA	E	Lux (lx) footcandle (fc)	Flujo luminoso de 1 lumen que recibe una superficie de 1 m^2	$E = \phi/A$
LUMINANCIA	L	Nits(Cd/m^2) Stilb(cd/cm^2)	Intensidad luminosa de una candela por unidad de superficie.	$L = I/A$

LEYES FUNDAMENTALES DE LA ILUMINACION

• LEY DEL CUADRADO INVERSO DE LA DISTANCIA

Para una fuente luminosa, las iluminancias en diferentes superficies situadas perpendicularmente a la dirección de la radiación son directamente proporcionales a la intensidad luminosa del foco, e inversamente proporcionales al cuadrado de la distancia que las separa del mismo.

$$E = \frac{I}{d^2}$$

La ley del inverso del cuadrado de la distancia se cumple cuando se trata de una fuente puntual, de superficies perpendiculares a la dirección del flujo luminoso y cuando la distancia es grande en relación al tamaño del foco, se considera suficientemente aplicable, si la distancia es por lo menos cinco veces la máxima dimensión de la luminaria.

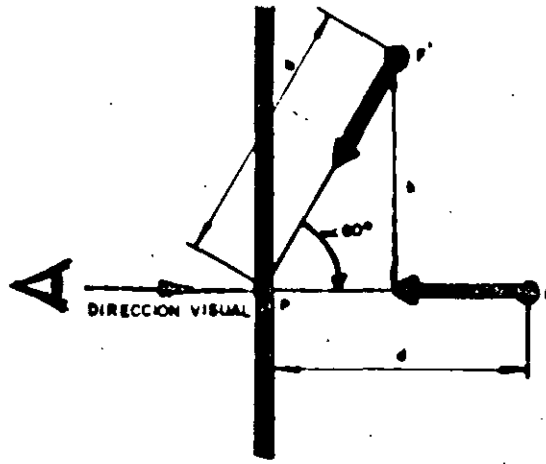
Según esta ley una fuente cuya intensidad luminosa es de 36 candelas, producirá sobre una superficie situada perpendicularmente a la dirección de radiación, a las distancias de 1, 2 y 3m, las siguientes iluminancias:

En la superficie a 1 m $E_1 = \frac{I}{d_1^2} = \frac{36}{1^2} = 36$ lux

En la superficie a 2 m $E_2 = \frac{I}{d_2^2} = \frac{36}{2^2} = 9$ lux

En la superficie a 3 m $E_3 = \frac{I}{d_3^2} = \frac{36}{3^2} = 4$ lux

LEY DEL COSENO

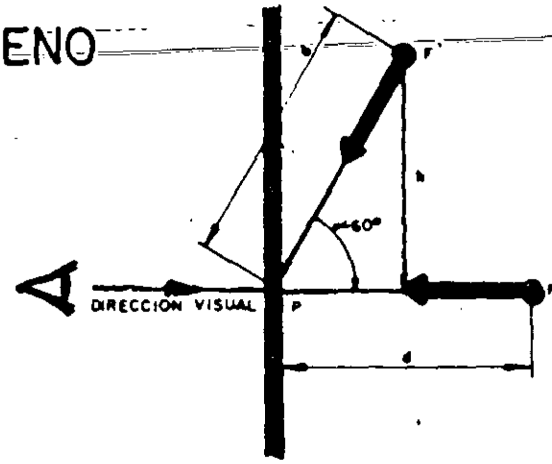


En el caso anterior la superficie estaba situada perpendicularmente a la dirección de los rayos luminosos, pero cuando forma con esta un determinado ángulo α, la fórmula de la ley del cuadrado inverso de la distancia hay que multiplicarla por el coseno del ángulo correspondiente cuya expresión constituye la llamada "Ley del coseno"

$$E = \frac{I}{d^2} \cos \alpha$$

La iluminancia en un punto cualquiera de una superficie es proporcional al coseno del ángulo de incidencia de los rayos luminosos en el punto iluminado.

LEY DEL COSENO



En la figura se representan dos fuentes F y F' con igual intensidad luminosa y a la misma distancia del punto P. A la fuente F con un ángulo de incidencia α igual a cero, corresponde un coseno 0° = 1 y produce una iluminación en el punto P de valor.

$$Ep = \frac{1}{d^2} \times 1$$

De la misma forma el F' con un ángulo $\alpha = 60°$, corresponde el cos 60° = 0.5, producirá en el mismo punto una iluminación de valor.

$$E'p = \frac{1}{d^2} \times 0.5$$

Es decir que $E'p = 0.5\,Ep$ o que para obtener la misma iluminación en el punto P, la intensidad luminosa de la fuente F' debe ser doble de la F.

En la práctica, generalmente no se conoce la distancia "d" del foco al punto considerado, sino su altura "h" a la horizontal del punto y al ser $\cos\alpha = \frac{h}{d}$ ∴ $d = \frac{h}{\cos\alpha}$, substituyendo este valor en la fórmula anterior, se obtiene la siguiente.

$$Ep = \frac{1}{h^2} \cos^3\alpha$$

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA
CURSOS ABIERTOS

ILUMINACION INTERIOR PRINCIPIOS, DISEÑO Y APLICACIONES

LAMPARAS

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3.3. FUENTES LUMINOSAS.

Las fuentes de luz (lámparas) que se utilizan actualmente -- para la iluminación artificial, pueden ser divididas en dos-categorias principales: Incandescentes y de descarga. Las -- lámparas del tipo de descarga pueden ser de alta ó baja presión. Las fuentes de descarga en baja presión son las fluorescentes y las de sodio en baja presión. Las lámparas de vapor de mercurio, aditivos metálicos y sodio alta presión son consideradas lámparas de descarga en alta presión.

Estas son las fuentes de luz más comunmente usadas en el campo de la Ingeniería de Iluminación. Cada fuente de luz será-descrita en términos de sus tres componentes primarios: (1)-Elemento productor de luz, (2) Bulbo y (3) Conexión eléctrica El capítulo esta dividido en dos secciones: (1) fuentes incandescentes, (2) fuentes de descarga

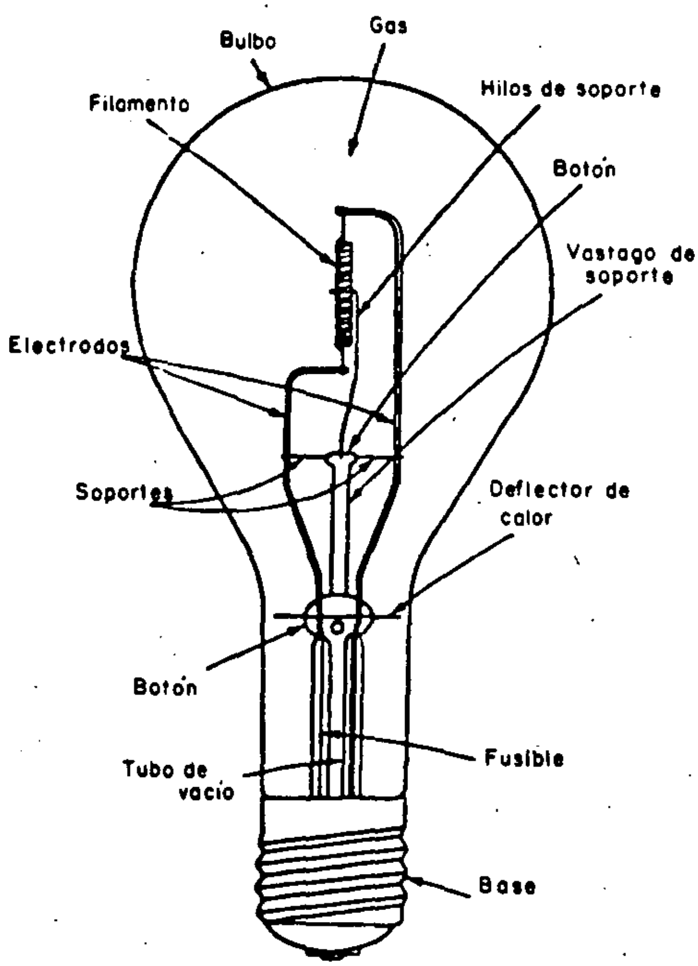


Figura 3-22 Lámpara Incandescente

3.3.1 FUENTES INCANDESCENTES.

3.3.1.1. LAMPARAS INCANDESCENTES ESTANDAR

Elemento productor de luz.

La luz es producida en la lámpara incandescente (figura - 3-22) calentando un hilo o filamento a altas temperaturas, lo cual causa que el conductor se haga incandescente. Lo- incandescente del hilo es resultado de la resistencia al- flujo de corriente eléctrica a través del conductor. El - tungsteno es usado como material para el filamento. Ningu na otra substancia es tan eficiente en convertir energía- eléctrica en luz en la base de vida y costo. El tungsteno tiene cuatro características importantes:

1.- Alto punto en fusión
2.- Baja evaporación
3.- Alta resistencia y ductilidad
4.- Características favorables de radiación

Las designaciones más comunes de letras para filamentos -- son "S", "C", y "R". Los filamentos bobinados son los más- eficientes y ampliamente utilizados en las lámparas encon- tradas en Ingeniería de Iluminación. La resistencia del -- tungsteno frío es baja, comparada con su resistencia opera cional: por lo que hay gran cantidad de corriente inicial- de encendido, en una lámpara fría.

Bulbo.

El bulbo o cubierta de vidrio es usado para evitar que el aire toque el filamento. Cuando el filamento se expone al aire la evaporación ocurre más rápido. El bulbo se llena con gas inerte de argón y nitrógeno para retardar la evaporación del filamento. Las lámparas con gas designadas tipo C son de 40 watts y mayores. Las lámparas de 25 watts y menos son lámparas en vacío, las cuales son designadas tipo B. Los bulbos también son designados de acuerdo a su forma (ver figura 3-23).

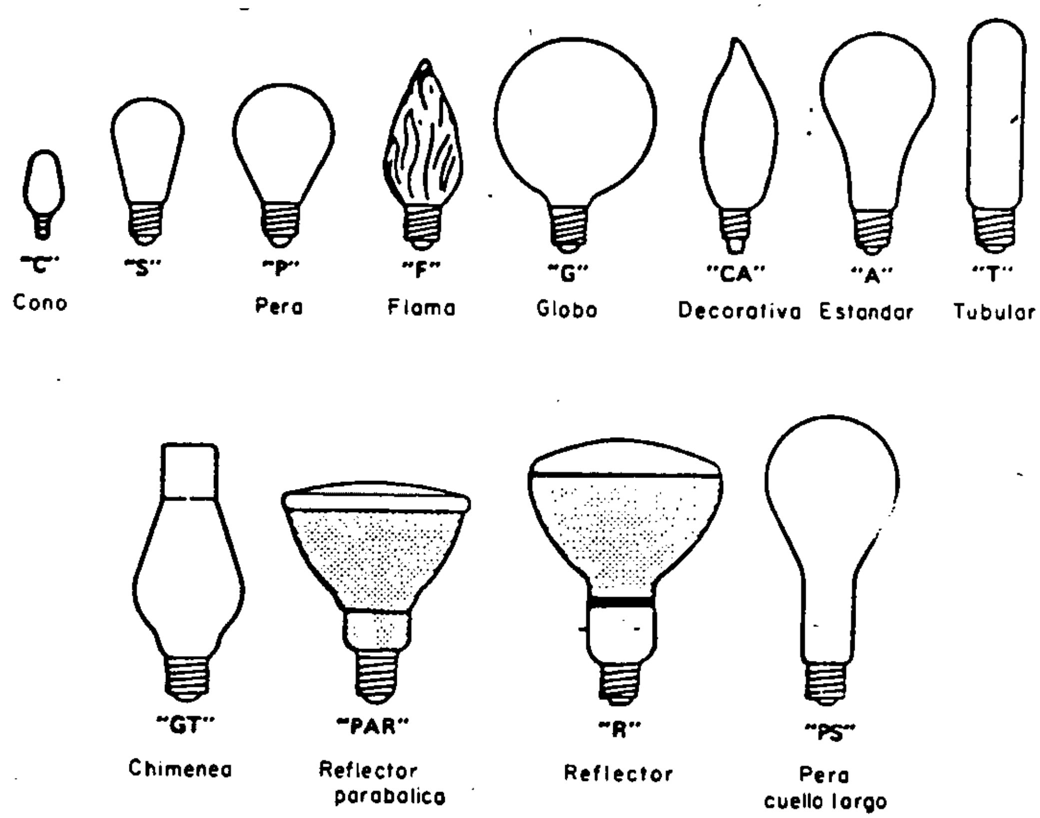


Figura 3-23 Formas de Bulbos de lámpara Incandescentes y de Tungsteno Halógeno.

Aparte de la designación con letras, los bulbos también tienen una designación numérica, la cual representa el diámetro del bulbo en octavos de pulgada. Por ejemplo, una designación A-19 indica un diámetro de 19/8" ó 2 3/8" de pulgada.

Los acabados de las superficies del bulbo pueden ser claro, esmerilado u opalino, de color o superficies interiores plateadas. Las lámparas normalmente en el mercado son las claras, esmeriladas u opalinas, blancas y plateadas, los bulbos de color pueden ser de vidrio en color natural, pintura exterior o filtros.

Conexión Eléctrica.

La base proporciona la conexión eléctrica, montaje y posicionamiento de la lámpara. Hay ocho tipos diferentes de bases. Las lámparas para servicio general de menos de 300 watts normalmente usan la base roscada mediana; de 300 a 500 watts las lámparas usan la base roscada mogul.

Características de Operación.

Variación de voltaje.- La variación del voltaje en una lámpara incandescente, arriba o abajo del voltaje nominal, --

afectará las características de la lámpara. Por ejemplo, si una lámpara para 120 volts nominales es operada a 125 volts (4% de incremento), la lámpara producirá 16% más lúmenes, 7% más watts, y 38% menos de vida. Una lámpara de 120 volts nominales operada a 115 volts (4% menos), proporcionará 13% menos lúmenes, 6% menos watts y 62% más vida (ver figura 3-24).

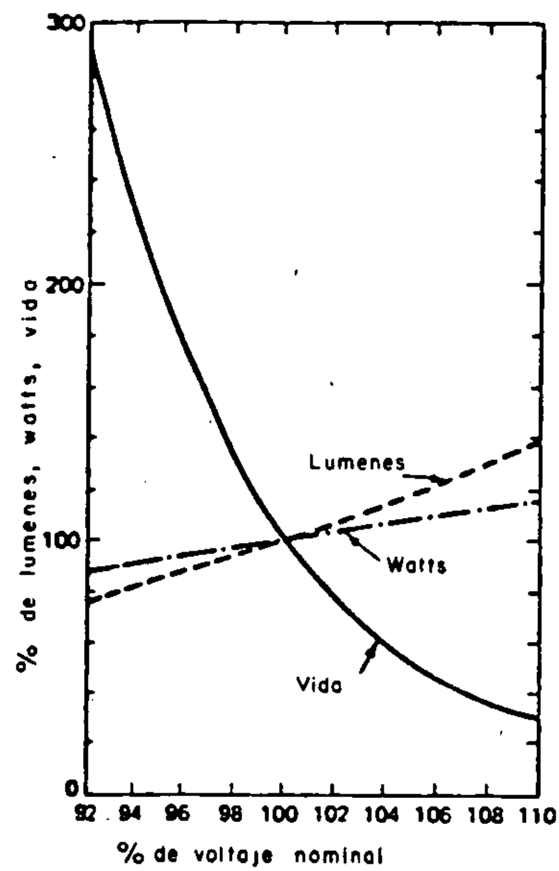


Figura 3-24 Efecto del Voltaje en la Emisión Lumínica y Vida de la Lámpara.

Depreciación de Lúmenes.- La resistencia del filamento aumenta con el tiempo debido a la evaporación, dando como resultado una disminución del diámetro del filamento. Este incremento en la resistencia del filamento, causa una disminución en los lúmenes, amperes y watts. Una reducción adicional en la salida de lúmenes es debida a la absorción de luz por el tungsteno depositado en la superficie interior de la lámpara (ver figura 3-25).

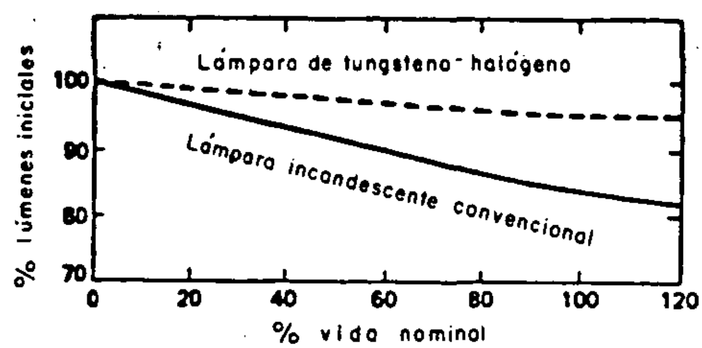


Figura 3-25 Depreciación de Lúmenes en las Lámparas Convencionales y de Tungsteno Halógeno.

3.3.1.2. LAMPARAS DE TUNGSTENO - HALOGENO.

Una deficiencia de las lámparas incandescentes normales - ha sido su mantenimiento de lúmenes a lo largo de su vida. Cuando el filamento se calienta, este se evapora lentamente y se deposita en la pared interior del bulbo. Esta capa de tungsteno entonces actúa como un filtro, absorviendo -- algo de luz y disminuyendo la salida de luz. Esto fué superado con el desarrollo de la lámpara de ciclo tungsteno -- halógeno, la cual también es llamada lámpara de cuarzo. La lámpara de tungsteno - halógeno contiene un halógeno como- el iodo de bromo y un gas de relleno. El búlbo está hecho- de cuarzo para soportar las altas temperaturas requeridas- por el ciclo para trabajar. A altas temperaturas, el tungsteno evaporado se asocia con una molécula de halógeno. En- vez de depositarse en las paredes del búlbo, la molécula - combinada de tungsteno halógeno retorna al filamento ca--- liente, liberando al halógeno para permitirle combinarse - con otra molécula de tungsteno evaporado.

Esta acción de limpieza minimiza el deposito de tungsteno-- en la pared del búlbo, y da como resultado un incremento - en la salida de lúmenes a través de la vida de la lámpara. En la figura 3-25 se muestra la salida de lúmenes de una -- lámpara incandescente normal y la de una lámpara de tungsteno - halógeno durante la vida de cada una de ellas.

El principal objeto al desarrollar la lámpara de tungsteno - halógeno fué el mantener la salida de lúmenes, pero se - hicieron otras mejoras. La vida de la lámpara aumentó un - poco, así como su eficacia. Para operar apropiadamente las lámparas de tungsteno - halógeno requieren de relativamente altas temperaturas, el filamento tuvo que ser compactado y el búlbo se hizo más pequeño. La fuente como es más - pequeña se acerca más a la fuente puntual ideal, necesaria para un buen control óptico.

La lámpara de tungsteno - halógeno es un tipo de lámpara - incandescente y por lo tanto es fácil de atenuar. Sin - -- embargo el atenuarla provoca una reducción en la temperatura de las paredes del búlbo, lo cual retarda la unión de - las moléculas de tungsteno - halógeno, dando como resultado un enegrecimiento de las paredes del búlbo y reducción- en la salida de los lúmenes de la lámpara. Cuando la lámpara es regresada a un nivel de temperatura suficiente, algo del tungsteno depositado en el búlbo es removido.

3.3.1.3. CARACTERISTICAS GENERALES DE OPERACION.

Eficacia y vida.

Una de las características m´as importantes de cualquier --

fuente de luz, es su habilidad para convertir la energía - eléctrica en energía luminosa. A esto se le conoce como -- eficacia de la lámpara. Las lámparas incandescentes tienen eficacias que andan en el orden de los 4 a los 24 lumenes/ Watt. Para propositos de comparación, a la lámpara incan-- descente se le asigna una eficacia de 20 lumenes/Watt.

El costo de la luz depende no solo de la eficacia, también depende de la vida de la fuente. Las lámparas incandescen- tes tienen una vida promedio de 1000 hrs., o sea alrededor de 5 meses con un período típico de encendido de 8 hrs. -- diarias (52 semanas/año x 6 dias/semana x 8 horas/día = - 2496 horas/año). La vida de la lámpara es función de va--- rios factores, incluyendo la forma del filamento y su so-- porte, el gas de relleno, los ciclos de encendido-apagado- y la potencia.

Características de color.

El sistema visual humano responde en forma diferente a las diferentes longitudes de onda de la radiación. Nuestra mente interpreta estas diferentes longitudes de onda como co- lor. Las fuentes de luz son importantes en la visión del - color ya que proporcionan la energía radiante y por lo tanto la respuesta al color. La distribución de las longitudes de onda emitidas por una fuente, es conocida como la distribución de potencia espectral (DPE).

La DPE de una lámpara incandescente se muestra en la figura 3-26

Note la tremenda cantidad de rojo o grandes longitudes de onda presentes; Esto es normal para una fuente que produce energía luminosa por calor. La DPE de la lámpara de iodo-cuarzo es similar a la de la lámpara incandescente pero contiene ligeramente más longitudes de onda corta (azul). Esto es resultado de las altas temperaturas de operación. Las lámparas incandescentes tienen un redimiento de color aceptable.

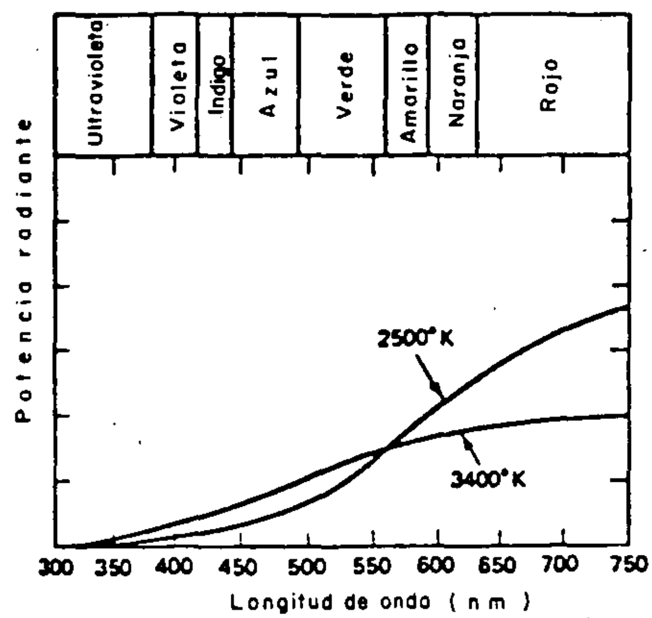


Figura 3-26 Distribución de Potencia Espectral de una Lámpara Incandescente.

Distribución de energía

La distribución de energía de una lámpara incandescente - se muestra en la figura 3-27

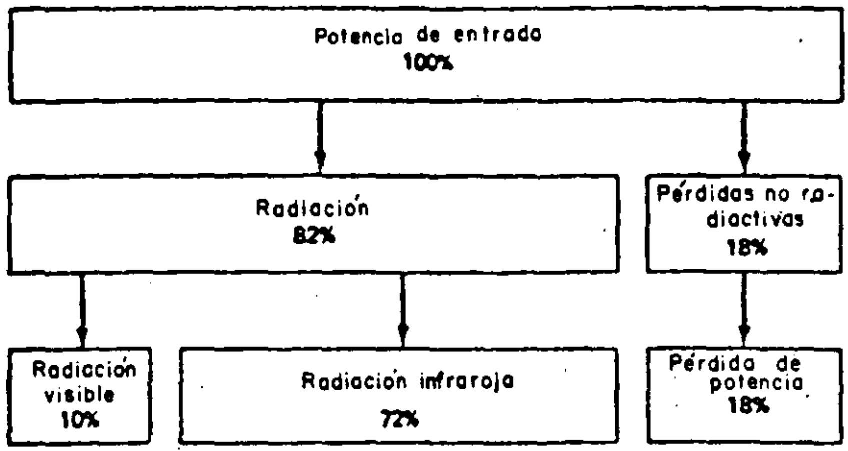


Figura 3-. Distribución de Energía de una Lámpara Incandescente.

3.3.1.4 RESUMEN.

A pesar de que las fuentes incandescentes tienen una vida corta y baja eficacia, tienen ventajas que las hacen ser- seleccionadas comunmente como fuentes de luz. Entre estas ventajas estan el bajo costo inicial de la lámpara y su - relativamente pequeño tamaño, lo que facilita dirigir la- salida de luz ya que se aproxima al modelo ideal de una -

fuente puntual. El rendimiento de color es aceptable. Algunas veces se selecciona un sistema incandescente debido a su facilidad y bajo costo para atenuarlo, lo cual es una consideración importante en muchos diseños.

Las lámparas ahorradoras de energía en el mercado, hacen uso de diferentes gases de relleno. Estas lámparas utilizan más el Kryptón que el Argón utilizado en las lámparas normales. El resultado es una disminución en la potencia consumida sin disminución de la eficacia. Como un beneficio adicional, la vida se incrementa. La lámpara incandescente es aún popular debido a su bajo costo. Las lámparas ahorradoras de energía cuestan alrededor de 10 veces más lo que cuesta una lámpara incandescente convencional.

3.3.2 FUENTES DE DESCARGA GASEOSA.

Las lámparas de descarga gaseosa son comparadas con un elemento de resistencia cero o de resistencia negativa. Cuando los aditivos dentro del tubo de arco se ionizan, la resistencia dentro del tubo de arco disminuye. Esto provoca que la resistencia se aproxime a cero, mientras que la corriente se aproxima a infinito.

$$I = \frac{E}{R} \qquad R \rightarrow 0, \qquad I \longrightarrow \infty$$

Sin un dispositivo que limite la corriente, los electrodos se destruirían en cuestión de segundos. Debido a lo anterior, todas las fuentes de descarga gaseosa requieren de un balastro.

Un balastro es un dispositivo eléctrico que sirve para tres funciones primarias:

1.- Limita la corriente (característica de elemento de resistencia cero).

2.- Proporciona el voltaje de encendido.

3.- Proporciona corrección del factor de potencia.

El balastro actúa como un autotransformador para proporcionar el voltaje de encendido. Por lo tanto, contiene devanados que provocan una carga de reactancia inductiva. La reactancia inductiva causa un defasamiento entre las ondas de corriente y voltaje, el cual es corregido con la adición de un capacitor en el balastro. El balastro se describirá con más detalle al final de este capítulo.

Posición de operación.- Las lámparas de descarga gaseosa son usualmente sensibles a la posición de operación. El Ingeniero debe tener precaución al seleccionar las lámpa--

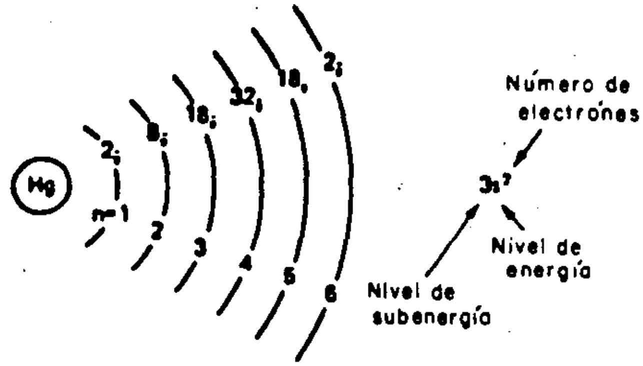
ras, ya que si se operan en una posición diferente de la especificada, estas pueden cambiar su salida de lúmenes, su vida y sus características de color. Algunas lámparas pueden explotar o implotar si no se instalan correctamente. Se deben consultar las especificaciones del fabricante para obtener información de la posición de - - operación. Las letras típicas para designar la posición- de operación son:

BU:	base arriba	BD-HOR:	Base abajo a horizontal
BD:	base abajo	VER-BU:	Vertical a base arriba
BU-HOR:	base arriba a horizontal	VER-BD:	Vertical a base abajo
		HOR:	Horizontal solamente

3.3.2.1 FUENTES DE DESCARGA GASEOSA DE BAJA PRESION.

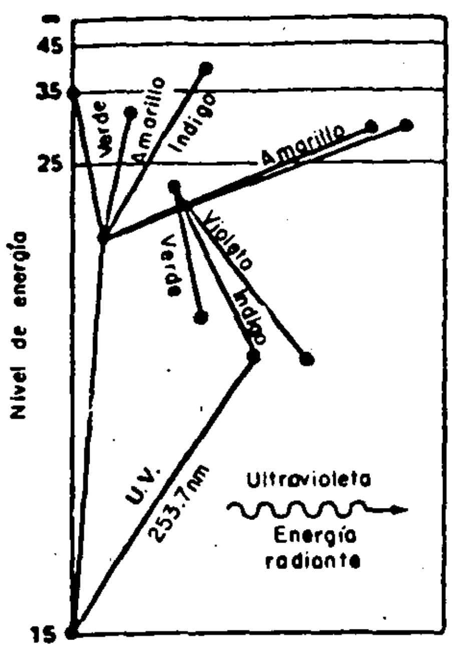
Lámparas fluorescentes.

La primera instalación importante de lámparas fluorescentes fué hecha en los años de 1938 - 1939 en la féria mundial - de Nueva York. Las lámparas fueron instaladas en racímos -- verticales en las astas, a lo largo de la avenida de las -- banderas. En la figura 3-28 se muestra un esquemático de la lámpara fluorescente.

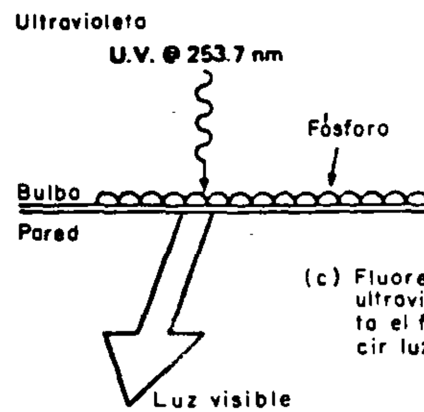


$Hg(1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 4p^6, 4d^{10}, 4f^{14}, 5s^2, 5p^6, 5d^{10}, 6s^2)$

(a) Atomo de Mercurio.



(b) Nivel de energía.



(c) Fluorescencia.- Energía ultravioleta radiante, ex ta el fósforo para prod cir luz visible.

Figura 3-28 Esquemático de la Operación de una Lámpara Fluorescente.

Elementos productores de luz.- La lámpara fluorescente -- requiere de tres elementos o componentes para producir luz visible: (1) electrodos, (2) gas y (3) fósforo.

Electrodos (cátodos).- Los electrodos son los dispositivos emisores. Actualmente se utilizan 2 tipos de cátodos. El cátodo caliente es un filamento de tungsteno con doble o triple arrollamiento, cubierto con un oxido de tierra alcalina que emite electrónes cuando se calienta. Los electrónes son emitidos a una temperatura aproximada de 900°C. Los electrónes están sujetos a un voltaje mayor, emitiendo electrónes a 150°C aproximadamente. El cátodo caliente es el tipo de electrodo más comunmente usado en lámparas fluorescentes, para la mayoría de las aplicaciones. Por lo tanto, no se describirán las lámparas de cátodo frío.

Gases.- Una pequeña cantidad de gotas de mercurio se coloca en el interior del tubo fluorescente. Durante la operación de la lámpara, el mercurio se vaporiza a una presión muy baja. A esta baja presión, la corriente fluyendo a través del vapor provoca que el vapor radíe energía, principalmente a una sola longitud de onda en la región ultravioleta (253.7 nm) del espectro. La presión del mercurio es regulada durante la operación, por la temperatura de la pared del bulbo.

La lámpara también contiene una pequeña cantidad de un gas raro altamente purificado. Los más comunes son el Argón y- el Argón-Neón, pero algunas veces también se utiliza el -- Kryptón. El gas de ioniza rápidamente cuando se aplica un- voltaje suficiente a la lámpara. El gas ionizado decrese - rápidamente su resistencia, permitiendo que la corriente - fluya y el mercurio se vaporize.

Fósforo.- Este es el recubrimiento químico en la pared interior del bulbo. Cuando el fósforo es excitado por radiación ultravioleta a 253.7 Nanómetros, este produce luz visible por fosforecencia. (ver figura 3-28). Es decir, la - luz visible de una lámpara fluorescente es producida por - la acción de la energía ultravioleta en el recubrimiento - de fósforo dentro del bulbo.

Envolvente.- El bulbo es el envolvente de vidrio que con-- tiene los gases y proporciona una superficie a la cual pue de aplicarse el fósforo . Los bulbos se designan de acuerdo a su forma, diámetro y color (ver figura 3-29). Por ejem plo, T-12 indica una forma tubular (T) y un diámetro de -- 1 1/2 pulg. (12 representa el diámetro en octavos de una - pulgada: 12/8 = 1 1/2 pulg).

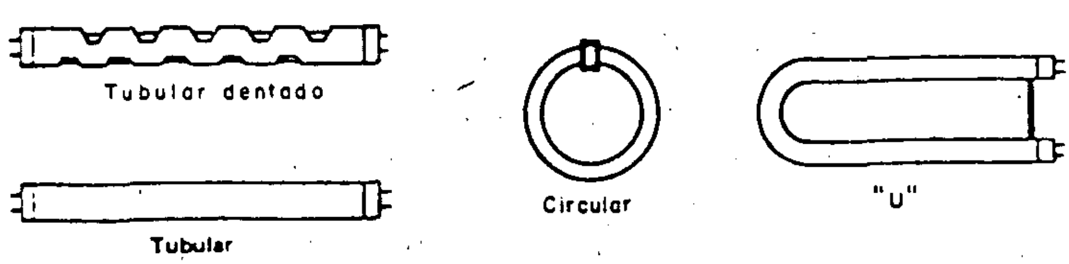


Figura 3-29 Formas de Tubos Fluorescentes.

Conexión eléctrica.- La base proporciona la conexión eléctrica entre la lámpara y el soquet y sirve como soporte -- y alineamiento de la lámpara. Hay tres tipos de bases asociadas con las lámparas fluorescentes:

1.- Doble alfiler (miniatura, media, mogul): Se usa - en todas las de precalentamiento y la mayoría de- lámparas de arranque rápido.
2.- Doble contacto embutido: Se utiliza en las lámpa-- ras de alta emisión y Power Groove. Su propósito- es proteger a los usuarios del alto voltaje en -- los contactos.
3.- Contacto sencillo: Usado en lámparas de arranque - instantáneo.

Características de color.- El color de una lámpara fluorescente depende del recubrimiento de fósforo en la pared interna del bulbo. La curva de Distribución de potencia Es-- pectral consiste en dos componentes:

(1) una porción continua, y (2) una línea de espectro. Las líneas o barras en la curva DPE representa la luz visible- que es generada directamente por el arco de mercurio; la - porción contínua es debida a la acción de la energía ultra

violeta en el fósforo. La DPE de una lámpara fluorescente puede ser cambiada modificando el tipo de mezcla de fósforo usados en el recubrimiento de las lámparas. Hay seis lámparas fluorescentes blancas en el mercado (ver figura 3-30).

CW: Blanco frío

WW: Blanco cálido

W: Blanco

CWX: Blanco frío de lujo

WWX: Blanco cálido de lujo

D: Luz de día

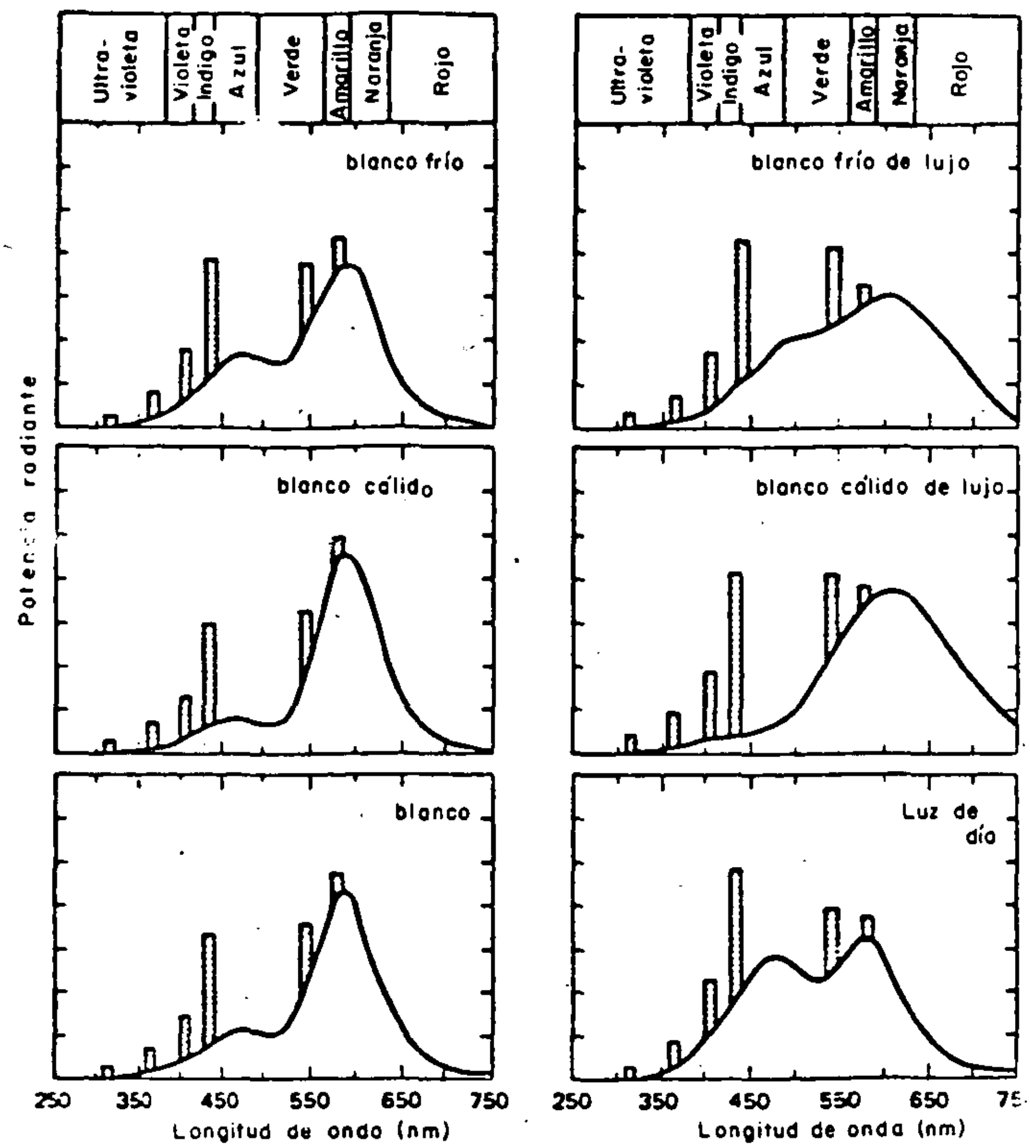


Figura 3-30 Distribución de Potencia Espectral de las Lámparas Fluorescentes Estandar.

Esta variedad de lámparas fluorescentes blancas ha sido desarrollada para satisfacer casi todas las necesidades de luz blanca. Estas lámparas se conocen como lámparas-blancas estandar, ya que las seis se pueden obtener con todos los grandes fabricantes de lámparas. Además de -- estas seis blancas estandar, cada fabricante vende blancos especiales y tubos fluorescentes de color.

La selección entre alguna de las lámparas fluorescentes siempre significa un compromiso entre eficacia y color. La selección del mejor rendimiento de color usualmente-significa una reducción en la eficacia. Las lámparas -- CW, WW, W y D tienen eficacias altas, pero son pobres - en rojos, dando como resultado una característica de pobre rendimiento de color. Las lámparas CWX y WWX son -- las que proporcionan el mejor rendimiento de color a -- los objetos y personas, con una razonable eficacia. Esto se obtiene con la adición de fósforos rojos en la -- mezcla. Sin embargo, ya que el ojo tiene menor respuesta a la energía roja, la eficiencia luminosa se reduce-alrededor de 30% de la salida de luz de las lámparas -- CW y WW.

Circuitos de cátodo caliente.- Hay tres tipos de lámparas fluorescentes de cátodo caliente y se definen por los circuitos para los cuales han sido diseñadas:

1.- Precalentamiento
2.- Encendido Instantáneo
3.- Encendido rápido

Circuitos de precalentamiento.- El circuito de precalentamiento fué el primer tipo en ser desarrollado. Requiere un arrancador separado que precalienta los electrodos, provocando una emisión de electrónes. Esto causa que la resistencia interna disminuya, lo cual permite establecer el arco. El proceso de precalentamiento requiere de algunos segundos, de aquí lo lento del encendido que es característica del circuito de precalentamiento. El precalentamiento puede ser efectuado por medio de un botón manual de arranque o por un arrancador automático. El arrancador hace circular corriente por los electrodos de la lámpara por un tiempo suficiente para calentarlos y entonces automáticamente (ó manualmente) interrumpe la corriente en los electrodos, causando que el voltaje aplicado entre los electrodos establezca el arco.

Circuitos de encendido instantaneo.- En 1944, el circuito de encendido instantáneo fué introducido para mejorar el lento encendido del circuito de precalentamiento. El circuito de encendido instantáneo elimina la necesidad de un arrancador y por lo tanto simplifica el sistema y su mantenimiento. Se aplica un alto voltaje entre los electrodos suficiente para vencer la resistencia de la lámpara y establecer el arco. El arco calienta rápidamente el filamento de los electrodos, lo cual hace que se emitan electrónes para sostener el arco. Ya que no se requiere de precalentamiento en las lámparas de encendido instantáneo, con un solo alfiler de contacto es suficiente. A este tipo de lámpara se le llama también lámpara Slimline.

Circuito de encendido rápido.- En 1952, se desarrollaron el circuito y la lámpara de encendido rápido. Esta enciende rápidamente sin la necesidad de un arrancador separado. Un balastro para encendido rápido es de menor tamaño y más eficiente que un balastro de encendido instantáneo para la misma potencia. El circuito de encendido rápido utiliza electrodos de baja resistencia los cuales son calentados contínuamente con muy bajas pérdidas.

La lámpara de encendido rápido es la lámpara más común y es adecuada para la mayoría de aplicaciones. Los circuitos de arranque rápido pueden ser intermitentes o atenuarse eficientemente.

Las lámparas circulares están disponibles para operación en circuítos de encendido rápido. También estan diseña-- das por usarse en circuitos de encendido rápido las lámparas en forma de "U". Las lámparas de encendido rápido- pueden usarse tanto en circuítos de precalentamiento como en circuítos de encendido rápido. Sin embargo, una -- lámpara con designación de "precalentamiento" no puede - usarse en un circuíto de encendido rápido. Los circuítos de encendido rápido son clasificados de acuerdo a la corriente de la lámpara:

RS - - - - - - - - - - - - -	430 MA
Circular - - - - - - - - - - - - -	390, 420 430 MA
HO - - - - - - - - - - - - -	800 MA
XHO, PG, VHO, SHO, T10 - - - - - - - -	1500 MA

Nomenclatura de lámparas.- La nomenclatura de una lámpara es de acuerdo a su Potencia o Longitud, Forma, Diámetro - en octavos de pulgada, y color. Las lámparas de precalentamiento y encendido rápido utilizan la potencia nominal- de la lámpara en su nomenclatura, mientras que las lámparas HO, VHO, encendido instantáneo y PG utilizan la longitud nominal en su nomenclatura. Algunos ejemplos se muestran a continuación:

Precalentamiento

F20T12/CW, fluorescente/Watts/Tubular/Diámetro/Color

Encendido rápido, 30 y 40 Watts

F30CW y F40CW, Fluorescente/Watts/Color

Encendido rápido (HO)

F96T12/CW/HO, Fluorescente/Longitud/Tubular/Diámetro/
Color/Encendido rapído

Características de funcionamiento.-

Vida.- La vida de la lámpara depende del tiempo de operación/encendido. Los valores de las lámparas estan dados - en la base de un ciclo de 3 horas por encendido. En 1973- se introdujo en las lámparas un nuevo gas colector. Este- gas previene la combustión del material emisor de los - - electrodos, cada vez que la lámpara es encendida; por lo- que, la vida de la lámpara no es grandemente afectada por los ciclos más frecuentes de apagado-encendido de la lámpara. Sin embargo, la importancia del tiempo de encendido puede verse en la operación por más tiempo de las lámparas en términos de los factores de vida:

6-h Operación/Encendido:	1.25 x Vida
12-h Operación/Encendido:	1.60 x Vida
Operación Continua	2.5 ó más x Vida

Efecto estroboscópico . Estroboscópico es una palabra griega que significa "ver movimiento". El arco se extingue durante cada paso por cero (120 veces/segundo) de la onda -- senoidal de Corriente Alterna; sin embargo, el recubrimiento de fósforo continúa radiando luz durante este pequeño - periodo. Generalmente, esto no es notorio, pero puede en - algunos casos hacer parecer a la maquinaria de alta velocidad estar estática. El uso de balastros de secuencia serie en circuítos de encendido rápido elimina este problema. -- Otra solución es el usar balastros adelantado-atrazado, el cual pone una lámpara fuera de fase con respecto a la otra en una unidad de dos lámparas. Esto da como resultado que- una lámpara esta al máximo de salida de luz mientras la -- otra está en cero. El efecto resultante es la eliminación- del parpadeo.

Efecto de la temperatura.- La operación más eficiente de - la lámpara se obtiene cuando la temperatura ambiente está- entre 70 a 90°F. (21 a 32°C). Temperaturas menores causan- una reducción en la presión del mercurio, lo cual significa que se produce menor energía ultravioleta; por lo que - al haber menos energía ultravioleta que actúe en el fósforo se produce menos luz. Altas temperaturas causan un cambio en la longitud de onda producida, haciendola más cercana al espectro visible. Las longitudes de onda más largastienen menos efecto en el fósforo, y por lo tanto hay -- menor salida de luz (ver figura 3-31)

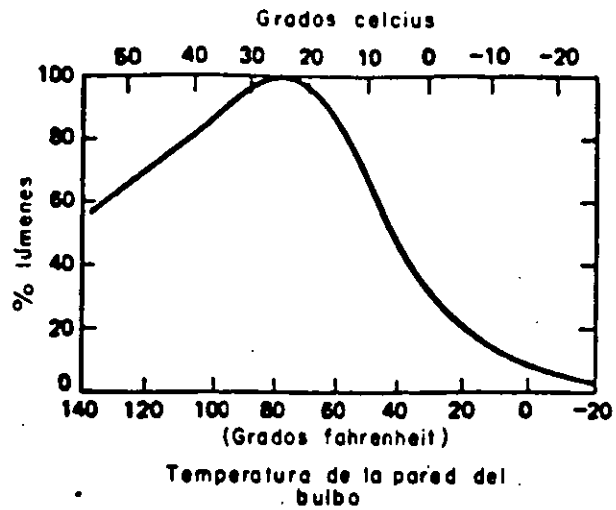


Figura 3-31 Efecto de la Temperatura en las Lámparas Fluorescentes.

Las lámparas fluorescentes estandar pueden operarse a una temperatura menor de hasta 50°F (10°C) sin un balastro -- especial. Sin embargo, como indica la figura 3-31, la salida de luz (lúmenes) será menor si la temperatura ambiente esta fuera de los 70 a 90°F (21 a 32°C). Existen balastros especiales de baja temperatura para encender y operar lámparas a 0 y 20°F. Estos balastros proporcionan un voltaje mayor de encendido y usualmente contienen un interruptor térmico de encendido.

Efecto de la humedad.- Los requerimientos de voltaje de - encendido son afectados por la carga electrostática en la superficie exterior de una lámpara fluorescente. El polvo y el aire humedo tienen efectos desfavorables en la carga de la superficie. Este factor debe ser tomado en consideración cuando la humedad relativa excede del 65%. Un re-- cubrimiento de silicón en la superficie exterior de la -- lámpara y la adecuada distancia entre la lámpara y el luminario, normalmente resuelven los problemas de encendido bajo cualquier condición de humedad. Sin embargo, la acumulación de polvo en la lámpara nulifica los efectos del- recubrimiento de silicón y provoca dificultades de encendido. No se debe limpiar la lámpara con un abrasivo, ya - que este también eliminará el recubrimiento de silicón.

Distribución de energía.- Del total de energía de entrada a una lámpara fluorescentes solo el 22% se convierte en - luz visible (ver figura 3-32)

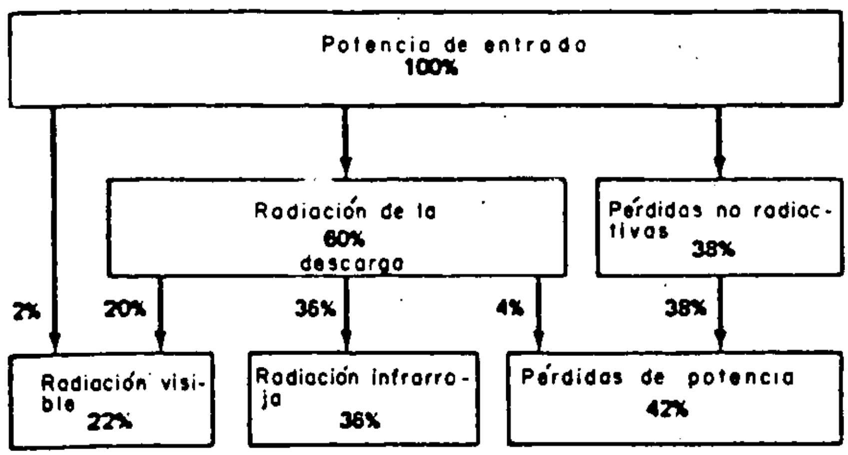


Figura 3-32 Distribución de Energía en una Lámpara Fluorescente con 78.8 lm/watt (40 watts) y con 22% de Radiación Visible.

Eficacia.- La eficacia de las lámparas fluorescentes para - la mayoría de los tamaños comunes de lámparas es de 75 a -- 80 lúmenes/Watt sin incluir las pérdidas en el balastro.- Para circuitos de dos lámparas F40 CW, la eficacia total - (lámpara más balastro será de 68.5 lm/w.

2F40CW: 2 x 3150 = 6300 lm

balastro con 2 lámparas encendido rápido, alto factor de - potencia = 92 W.

$$\text{Eficacia} = \frac{6300}{92} = 68.5 \text{ lm/w}$$

La lámpara F40 CW sola, tiene una eficacia de 78.8 lm/w.

Dispositivos ahorradores de energía.- Las lámparas ahorradoras de energía estan diseñadas para operar a una menor potencia con el mismo balastro para lámparas convencionales. La eficacia de algunas es menor, otras tienen una eficacia mayor. Recientemente se ha descubierto que las lámparas ahorradoras de energía, pueden ser la causa de la falla prematura del balastro debido a sobrecarga del capacitor. Un balastro de alto factor de potencia para dos lámparas contiene un capacitor de encendido y un capacitor para corregir el factor de potencia. Un incremento de 6 porciento en la corriente del capacitor de encendido es la causa de falla del balastro. Nuevos diseños de balastros han eliminado el problema; sin embargo los balastros antiguos o balastros defectuosos pueden aún mostrar un alto indice de falla. Las lámparas ahorradoras de energía deben solo ser consideradas para remodelar una instalación existente, la cual fué mal diseñada y esta proporcionando luz en exceso; no se deben utilizar para instalaciones nuevas.

Por razones económicas, el luminario con dos lámparas fluorescentes se prefirió al luminario con una lámpara antes de la crisis energética. El luminario de dos lámparas podía producir niveles mayores a los requeridos, pero en -- ese tiempo el costo de la energía era muy bajo. Debido al - bajo costo de la energía, era más económico comprar un luminario que operara dos lámparas con un solo balastro, que -- comprar un luminario con un balastro para una lámpara. El - balastro para una sola lámpara cuesta casi lo mismo que uno para dos lámparas, pero se podía producir más luz con menos energía con el luminario de dos lámparas.

F 40 CW: 3130 lm/lámpara

balastro alto factor de potencia para una lámpara = 52 W

Eficacia del sistema = $\frac{3150}{52}$ = 60.6 lm/w

Balastro alto factor de potencia para 2 lámparas = 92 W

Eficacia del sistema = $\frac{6300}{92}$ = 68.4 lm/w

Con el desarrollo de nuevos circuitos de balastros y el calentamiento contínuo de los cátodos, el efecto estroboscópico asociado con las unidades de una sola lámpara debe ser minimizado. Con el aumento a las tarifas de energía eléctrica (costo de operación) y el énfasis en la reducción del -- consumo de energía, el uso de luminarios con una sola lámpara se hace más importante . El eliminar una lámpara de un - luminario de dos lámparas, puede parecer una solución sim-- ple para reducir el consumo de energía en un edificio existente, donde existe un nivel alto de iluminación para tareas no críticas. Pero debido a que las dos lámparas - - - - - -

Características de funcionamiento.- Depreciación del flujo luminoso. El flujo luminoso aumenta ligeramente durante la vida de la lámpara. Se dice que el flujo luminoso es constante con un rango de temperatura de operación de - 10°C a + 40°C. El efecto en el flujo luminoso cuando la lámpara se opera fuera de este rango de temperatura no ha sido publicado.

Vida.- El tiempo de vida para todas las potencias es de 18,000 horas, basadas en un ciclo de encendido de 5 horas. La posición de encendido de la lámpara es crítica para la vida de esta, ya que ésta falla debido a la migración de sodio hacia los electrodos. Esta migración causa un aumento en los watts consumidos por la lámpara durante su vida, lo cual da como resultado que falle el electrodo.

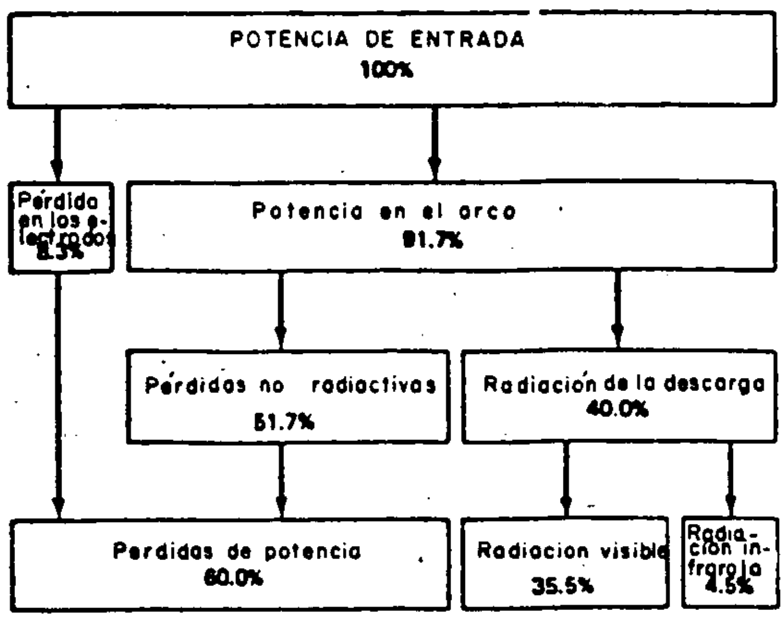


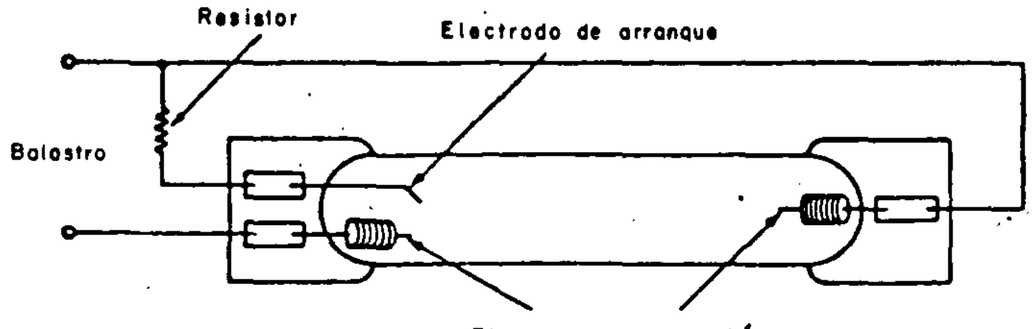
Figura 3-34 Distribución de Energía de una Lámpara de Sodio Baja Presión con 180 lm/watt y 35.5% de radiación Visible.

WATTS NOMINALES	LUMENES	WATTS DE LAMPARA (100 h)	EFICACIA LAMPARA (100 h)	WATTS DE LAMPARA (18000 h)	EFICACIA LAMPARA (18000 h)
35	4,640	36	129.2	44	105.7
55	7,700	53	145.3	62	124.2
90	12,500	90	138.9	122	102.5
135	21,500	130	165.4	178	120.8
180	33,000	176	187.5	241	136.9

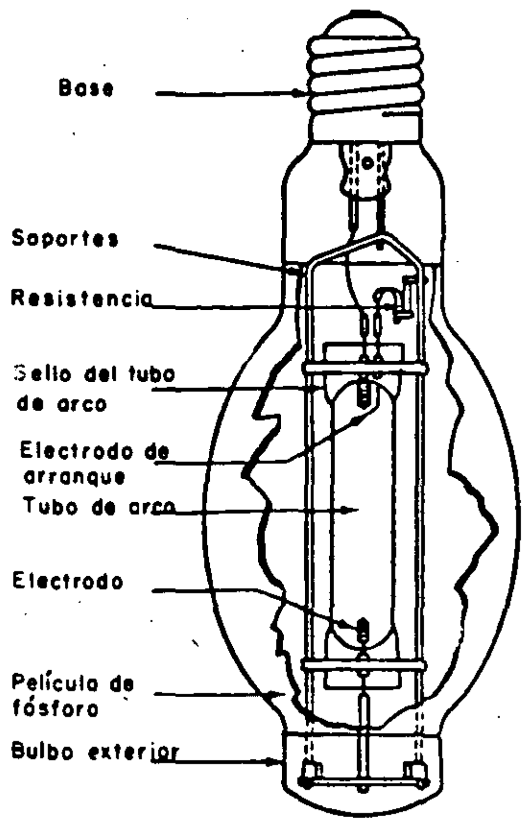
3.3.2.2. FUENTES DE DESCARGA GASEOSA DE ALTA PRESION (FUENTES DE DESCARGA DE ALTA INTENSIDAD).

Lámpara de Vapor de Mercurio.

Elemento productor de luz.- El elemento productor de luz -- es un tubo de arco. El tubo de arco es construido de cuarzo, el cual permite transmitir la radiación ultravioleta (ver figura 3-35). El tubo de arco contiene merçurio y una --- pequeña cantidad de argón, neón y kryptón. Cuando la lámpara es energizada, se genera un arco entre el electrodo principal y el de encendido, en cuanto se ioniza el mercurio,-- la resistencia dentro del tubo de arco disminuye. Cuando la resistencia interna del tubo de arco es menor que la resistencia externa, el arco se establece entre los electrodos - principales. El mercurio continua ionizandose, incrementandose la emisión luminosa, la luz producida es típica de --



(a)



(b)

Figura 3-35 Lámpara de Vapor de Mercurio y Tubo de Arco.

las líneas de mercurio (404.7, 435.8, 546.1, 577.9), -- además genera energía ultra violeta.

El tubo de arco es operado desde 1 a 10 atmósferas de -- presión.

TIEMPO DE ARRANQUE = 5 min. (80%) 7-10 min. (100%)
TIEMPO DE REENCENDIDO = 7 min. (80%)

Bulbo exterior.- Las funciones principales del bulbo exterior son tres:

1.- El vidrio primario actua como un filtro de rayos ultravioleta, el cual previene contra quemaduras en la piel y ojos.

2.- Proporciona también un ambiente constante para el -- tubo de arco. La presión del tubo de arco es afectada por el rápido cambio de temperatura y el movimiento del aire.

3.- Este proporciona una superficie para el recubrimiento de fósforo, el cual es colocado en el interior -- del bulbo exterior para corregir el rendimiento de - color de la lámpara de vapor de mercurio. Una lámpara con recubrimiento de fósforo requerirá de un lumi

La posición de encendido es función de la posición del --- electrodo de arranque. El electrodo de arranque debe es-- tar siempre colocado en la parte superior de la lámpara - para evitar que el mercurio se deposite en el electrodo - de arranque.

Características de Funcionamiento.-

Depreciación lumínica. La gráfica de depreciación lumínica para una lámpara de vapor de mercurio es algo drastica y es función del balastro y de la potencia. (ver figura -- 3-38). La lámpara de vapor de mercurio es la única lámpara que se publica su vida nominal y su vida útil.

La emisión lumínica también es función del suministro y regulación del voltaje a la lámpara (ver fig. 3-39).

Vida.- La vida de la lámpara de vapor de mercurio puede - ser descrita en términos de su vida útil o de su vida nominal, típicamente, la vida nominal de las lámparas se establece en base al 50% de la curva, de mortandad. Debido a su rápida depreciación de lumenes, la vida de la lámpara de vapor de mercurio se establece cuando aún hay más - del 50% de lámparas encendidas, para mantener una salida de lumenes más razonable (ver fig. 3-40) .

Distribución de energía.- La distribución de energía para las lámparas de vapor mercurio se muestra en la fig. 3-41

Eficacia de las lámparas.- La eficacia de la lámpara - -- varía con la potencia de esta. A mayor potencia de lámpara, mayor eficacia.

40/50 W : 25 a 30 Lm / W

75,100,175,250 W : 34 A 48.4 Lm / W

400 W : 55 A 60 Lm / W

1000 W : 57 A 63 Lm / W

H 33 GL - 400 / DX CON 22,500 Lm

$$\text{EFICACIA} = \frac{22,500}{400} = 56.3 \text{ Lm / W}$$

Lámparas de vapor de mercurio autobalastradas.- Las lámparas de vapor de mercurio autobalastradas contienen ya sea- un componente de estado sólido para arranque, o un filamento incandescente que actua como balastro. La lámpara con - componente de estado sólido no debe utilizarse en un lúminario totalmente cerrado, debido al calor generado por este tipo de lámpara. En general, la lámpara de vapor de mercurio autobalastradas, son 50% menos eficaces en comparación con las lámparas normales de mercurio, pero 50% más eficaces que las lámparas incandescentes.

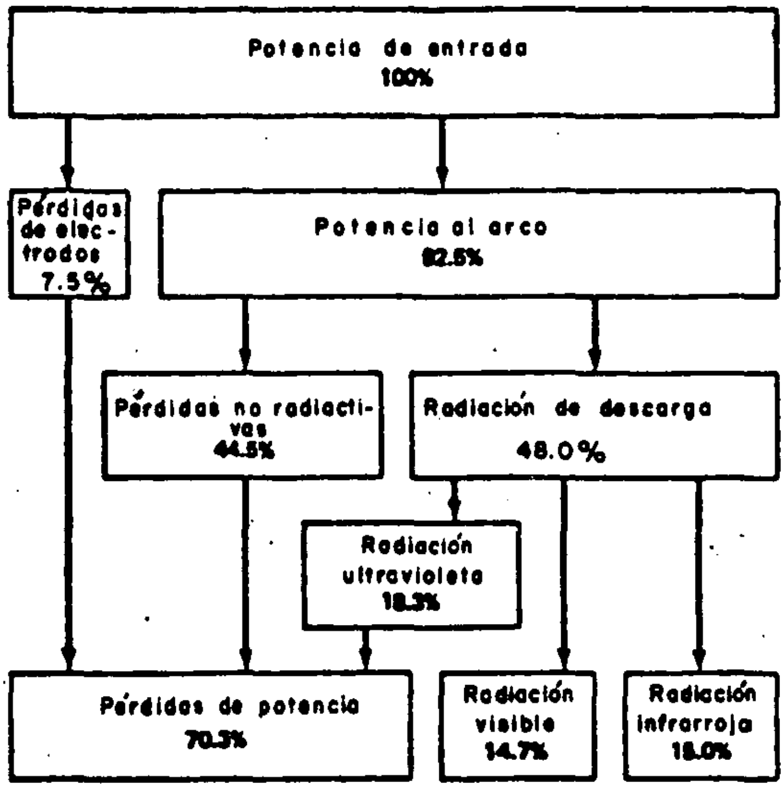


Figura 3-41 Distribución de Energía para Lámpara de Vapor de Mercurio con 56.3 lm/watt (400 w).

Estas lámparas debén limitarse a sustituir lámparas incan descentes, dónde el cambio de lámparas es difícil y el -- adicionar un balastro es impráctico.

Dispositivos ahorradores de energía.- Recientes desarro-- llos en los balastros electrónicos para lámparas de vapor de mercurio permiten atenuarlas actualmente. Los balas--- tros electrónicos han sido estudiados desde que apareció- la lámpara de vapor de mercurio. Existen todavía varios - problemas, entre ellos el alto costo; pero se sabe que -- con un balastro electrónico la eficacia de la lámpara y - la eficacia total del sistema aumentan considerablemente. Otras ventajas que se esperan del balastro electrónico -- son: el menor tamaño y peso, menor ruido, aumento de la - vida de la lámpara y mayor facilidad para atenuar.

Lámparas de Aditivos Metálicos.-

Elemento productor de luz.- El elemento productor de luz- es un tubo de arco. El tubo de arco tiene los mismos prin cipios de operación y tipo de construcción del de la lámpara de vapor de mercurio (ver fig. 3-42). El tubo de ar- co contiene además del mercurio, argón, neón y kryptón; - yoduros de metales. (Los aditivos primarios son el mercu- rio, sodio y escandio; otros son el talio, indio y cesio). Estos aditivos proporcionan colores adicionales a las - - líneas típicas del mercurio, esto es, rojo, naranja y ama rillo. El color de la lámpara de aditivos metálicos esta-balanceado a través del espectro. Debido a que la lámpara de aditivos metálicos mejora el color sin necesidad - de un recubrimiento de fósforo, la lámpara se aproxima - a una fuente puntual, lo cual da como resultado que se - facilite su control óptico. Para la posición horizontal- de encendido, el tubo de arco es curveado ligeramente, - para tener una temperatura más uniforme dentro del tubo- de arco (ver fig. 3-42).

Tiempo de encendido = 9 minutos (80%)

Tiempo de reencendido =10 a 15 minutos (80%)

Cubierta.- La cubierta exterior (bulbo) sirve solo para dos funciones.

1.- Filtro de luz ultravioleta
2.- Ambiente constante para el tubo de arco (mantiene la temperatura constante y evita las corrientes - de aire).

No se necesita un recubrimiento de fósforo para el buen -- rendimiento de color y además debe evitarse ya que afecta- en forma negativa el control óptico; esto es la lámpara ya no se aproxima a una fuente puntual.

Conexión eléctrica.- La lámpara de aditivos metálicos usa una base mogul para todas las potencias. Las lámparas para posición de operación horizontal que contienen el tubo de arco curvo (ver fig. 3-42), tienen un pasador en la -- base para posicionarlas. Existe un portalámpara especial- que asegura el posicionamiento adecuado del tubo de arco- cuando la lámpara es asegurada en el portalámpara adecuadamente. El tubo de arco curvo siempre debe ser colocado- con la curva hacia arriba en un plano vertical.

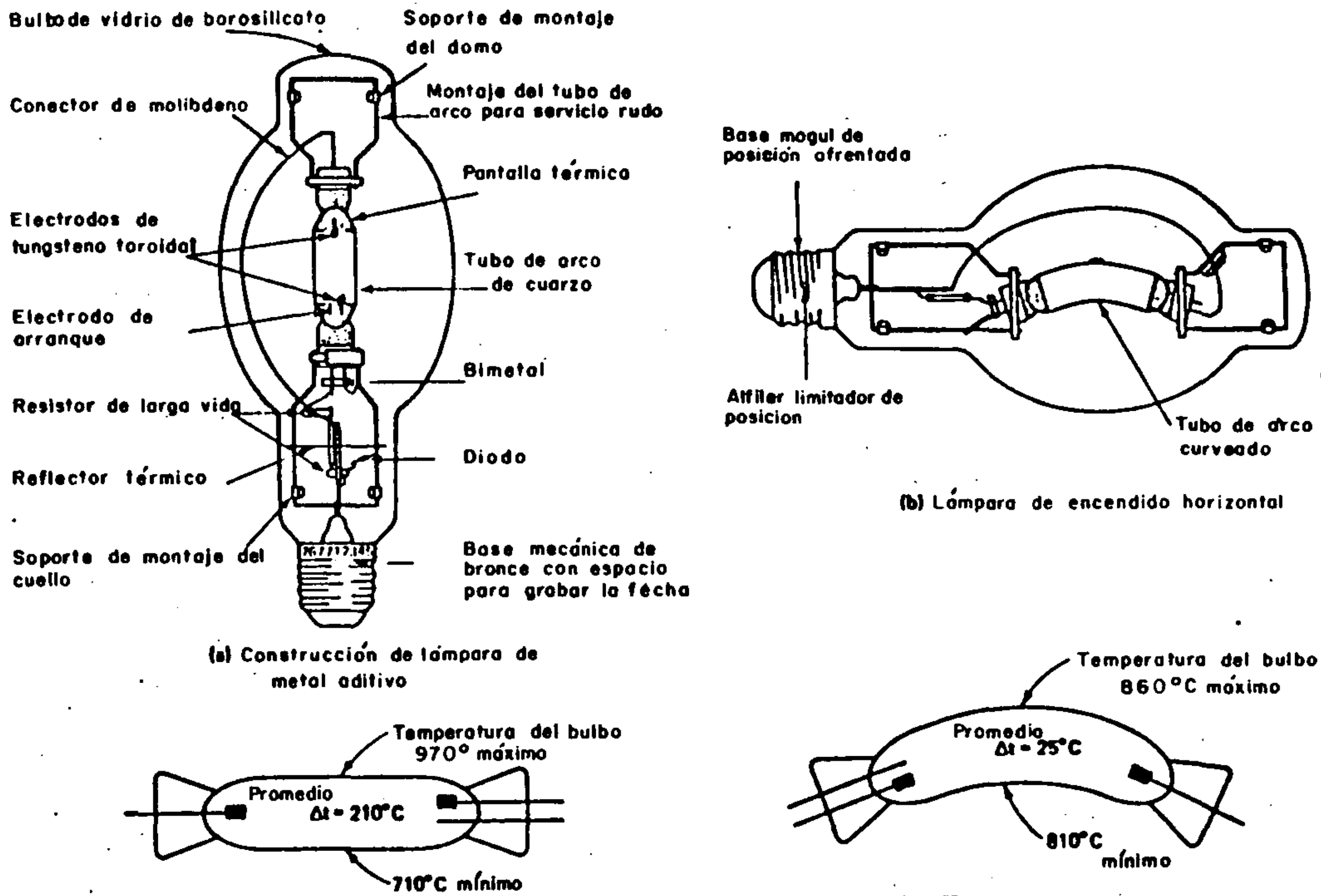


Figura 3-42 Variación de Temperatura Interna y Temperatura de la Pared, de una Lámpara de Aditivos Metálicos.

Características del color.- La lámpara de métales aditivos produce energía en todas las longitudes de onda a través -del espectro visible. Esto es, su distribución de energía-espectral esta bien balanceada, lo que significa que la --lámpara produce un buen rendimiento del color sin la necesidad de una pantalla de fósforo (ver fig. 3-43). La apa--riencia del color es una función del control de cálidad --de los aditivos dentro del tubo de arco. La consistencia -del color de una lámpara a otra es función del balastro, --del voltaje aplicado y edad de la lámpara. Donde es una --consideración importante de diseño el tener igualdad de --color entre las lámparas, estas deben cambiarse en grupo,-debido al cambio de color con el tiempo.

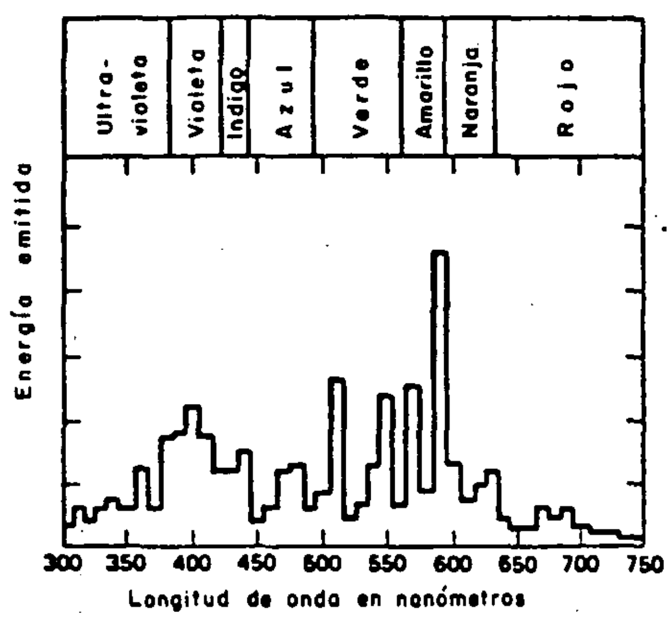


Figura 3-43 Distribución de Potencia Espectral de una Lámpara de Aditivos Metálicos.

Designación de la lámpara.- Las designaciones para lámparas de métales aditivos no han sido normalizadas. El ingeniero debe tener cuidado al especificar las lámparas con- designaciones no standar para evitar que algún fabricante sea descartado.

La designación de la letra M ó MH debe ser usada para - - identificar una lámpara de métales aditivos.

MH 400 / BU

Métal aditivo Watts Posición de operación - de la lámpara

Las lámparas de métales aditivos son especialmente sensibles a la posición de encendido. Los datos de los fabri-- cantes debén ser consultados para conocer los requerimientos de la posición de encendido.

El bulbo es designado por una letra y una combinación de- números. Las lámparas de métales aditivos se fabrican con bulbos BT y E (ver fig. 3-37). El número representa el -- diámetro exterior máximo del tubo, en octavos de pulgada.

$$BT - 37 \text{ Diámetro} = \frac{37"}{8} = 4\ 5/8"$$

Características de operación.-

Depreciación de lúmenes. La curva de depreciación de lúmenes para una lámpara de métales aditivos es sustancialmente mejor que la curva para una lámpara de vapor de mercurio. La salida de lúmenes al final de la vida de una lámpara de alta potencia es 75% (ver figura 3-44).

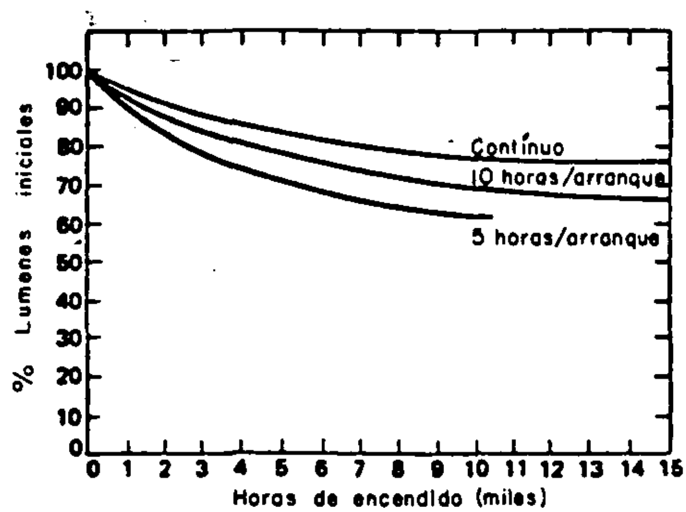


Figura 3-44 Depreciación de Lúmenes en la Lámpara de Aditivos Metálicos.

Vida.- La vida varía como una función de los watts de la lámpara y el lapso del tiempo que la lámpara ha estado en el mercado. Por ejemplo, la lámpara MH 175/Hor estaba comercialmente disponible en 1972.

La práctica normal en la industria de las lámparas es introducir todas las lámparas nuevas al mercado con un promedio de 7,500 hrs. Cuando los informes sobre mortandad y vida -- sean desarrollados, lo cual requiere pruebas a largo plazo, la vida de la lámpara se espera se incremente a un mínimo - de 15,000 hrs. Los catálogos de lámparas usuales de todos - los fabricantes, deben ser consultados para obtener el promedio de vida de las lámparas.

Distribución de energía.- La distribución de energía para - una lámpara de aditivos metálicos se muestra en la figura - 3-45.

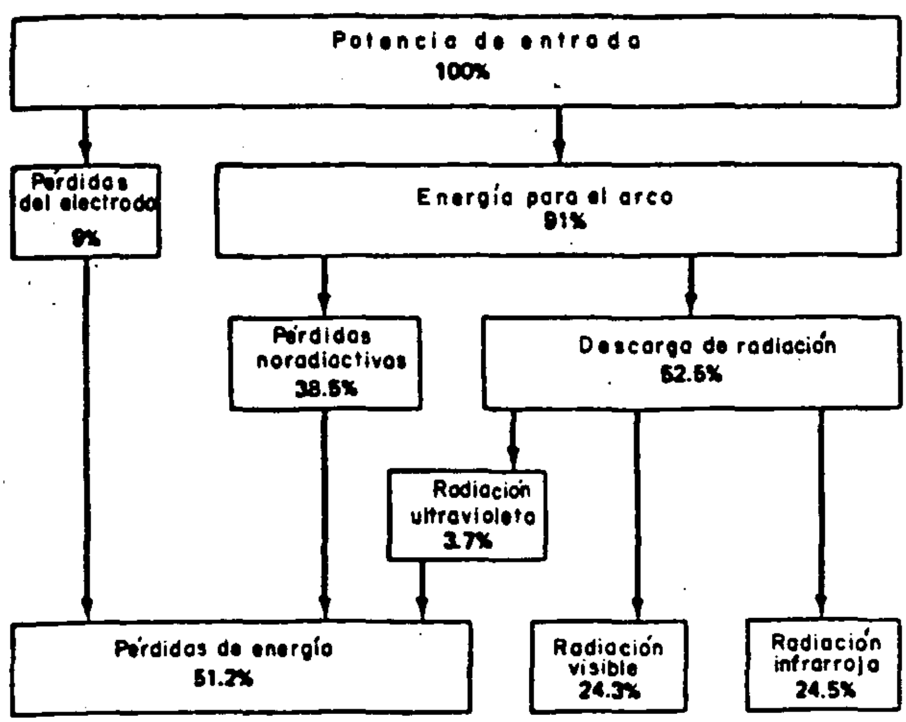


Figura 3-45 Distribución de Energía en una Lámpara de Adit Metálicos con 100 lm/watt y 24.3% de Radiación Visible

Eficacia de las lámparas.- Las eficacias de las lámparas varian con la posición de operación y los Watts de la -- lámpara. Mientras mayor es la potencia, mayor es la eficacia.

175 W : 80 a 85.7 Lm/W

250 W : 82 Lm/W

400 W : 85 a 100 Lm/W

1000 W : 100 a 115 Lm/W

1500 W : 96.7 a 10.33 Lm/W

NOTA: Los rangos de valores son debido a variaciones entre fabricantes.

Dispositivos de ahorro de energía.- El atenuado de lámparas de métales aditivos es un desarrollo reciente. La lámpara de 400 W puede ser atenuada (5 min.) en un 47% del - total de energía consumida, lo cual resulta en un 22% de- reducción en lúmenes. La lámpara de métales aditivos de - 1000 W puede ser atenuada (15 min.) en un 35% de su energía total consumida, o 14.6 de su rendimiento de lúmenes. Cuando ocurra un desarrollo tecnológico adicional, el --- costo de atenuación deberá disminuir y el rango incrementarse.

Lámparas de Sodio Alta Presión.

Elemento productor de luz.- El elemento productor de luz es un tubo de arco. El tubo de arco es pequeño en diámetro para mantener una temperatura de operación alta. Debido a que el diámetro es pequeño, no hay electrodo de arranque dentro del tubo de arco. El sodio operando a una presión alta y a alta temperatura tiene un efecto corrosivo sobre el vidrio ordinario o cuarzo. Por eso, el tubo de arco está hecho de cerámica de aluminio. El tubo de arco contiene Xenón, una amalgama de mercurio, y sodio operando a una presión de 200 mm., de mercurio.

Tiempo de encendido = 3 min. (80%)
reencendido = 1 min. (80%)

Envolvente (bulbo).- La envolvente ayuda a mantener el tubo de arco dentro de una temperatura ambiente constante y protege al tubo de arco de corrientes de aire.

Conexión eléctrica.- La conexión eléctrica es una base mogul. La lámpara requiere un pulso de energía de 2500 a 5000 V para el encendido de la lámpara. Esto se realiza por medio de un pequeño dispositivo de arranque electrónico, que suministra el pulso de alto voltaje para abatir la resistencia y encender la lámpara.

Características de color.- La lámpara de sodio de alta -- presión produce energía en todas las longitudes de onda - (fig. 3-46). Sin embargo la mayor porción de energía está concentrada en la parte amarillo-naranja del espectro. -- Las características de color de la lámpara cambian los -- objetos rojos a naranja y obscurece el color aparente de los objetos azul y verde, incrementando la presión en el tubo de arco parece mejorar la apariencia de color de --- rojos, azules y verdes. La consistencia del color de una - lámpara a otra es mejor que con las lámparas de métales - aditivos. Sin embargo, los cambios de color pueden ocu--- rrir debido a las variaciones de voltaje y diferencias -- en balastros.

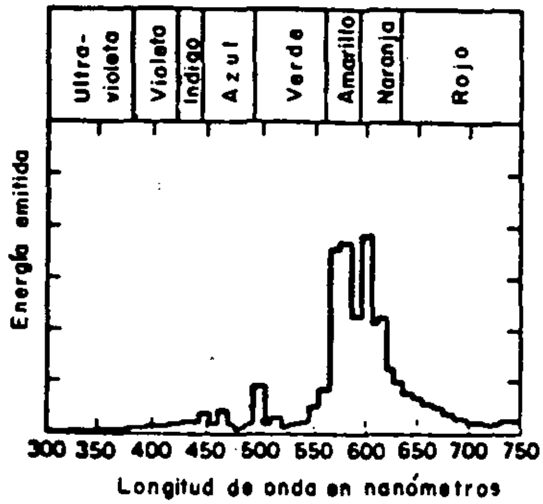


Figura 3-46 Distribución de Potencia Espectral para una Lámpara de Vapor de Sodío alta - Presión.

Designación de las lámparas.- Las designaciones de las -- lámparas de sodio de alta presión no han sido normaliza-- das por la Industria de lámparas. El ingeniero debe tener precaución en no especificar o usar nombres comerciales - que provoquen que lámparas aceptables queden descartadas. Las lámparas de sodio de alta presión estan disponibles - en bulbos, E, BT, y T (ver fig. 3-37). Se utiliza una - - combinación de letras y números para designar la configu- ración del bulbo.

Características de operación.-

Depreciación de lumenes.- La curva de depreciación de --- lúmenes de la lámpara de sodio alta presión es una de las mejores de las lámparas del tipo de descarga de alta inten sidad. El rendimiento lumínico al final de la vida de la- misma, para altas potencias es 80% (ver fig. 3-47).

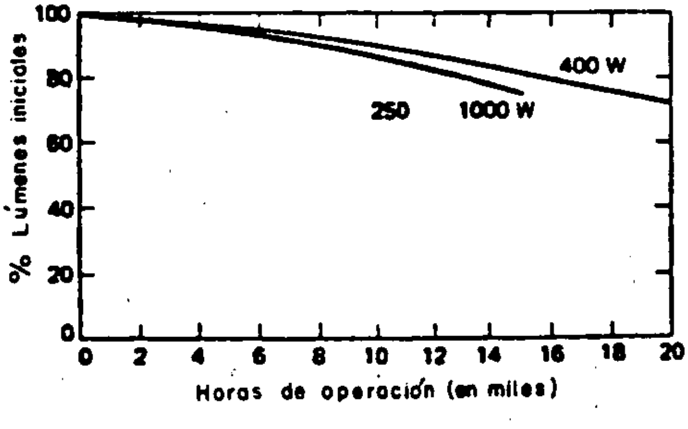


Figura 3-47 Depreciación de Lúmenes en una Lámpara de Sodio alta Presión.

Vida.- La vida varía en función de la potencia, el circuito del balastro y del fabricante. El rango es desde - --- 15,000 a 24000 hrs. para las lámparas de alta potencia -- más comunes.

Distribución de energía.- La distribución de energía para las lámparas de sodio alta presión es mostrada en la fig. 3-48

Eficacia de las lámparas.- La eficacia de las lámparas -- de sodio alta presión varía como función de la posición - de operación y de la potencia de la misma.

70 W : 77 a 82.9 Lm/W

100 W : 88 a 95 Lm/W

150 W : 100 a 106.7 Lm/W

250 W : 102 a 120 Lm/W

400 W : 118.8 a 125 Lm/W

1000 W : 140 Lm/W

Las lámparas de sodio alta presión también estan disponibles en potencias que pueden ser operadas con balastros- de mercurio. Las potencias disponibles son 150, 215, 310 y 360 W. Los informes de los fabricantes debén ser con-- sultados para una adecuada selección del balastro para - la lámpara.

Dispositivos de ahorro de energía.- Es posible atenuar -- algunas potencias de lámparas de sodio alta presión. La - lámpara de 1000 W puede ser reducida en un 38% de su po-- tencia total en aproximadamente 15 min., con una reducción en la salida de luz en un 20% de los lúmenes nominales.

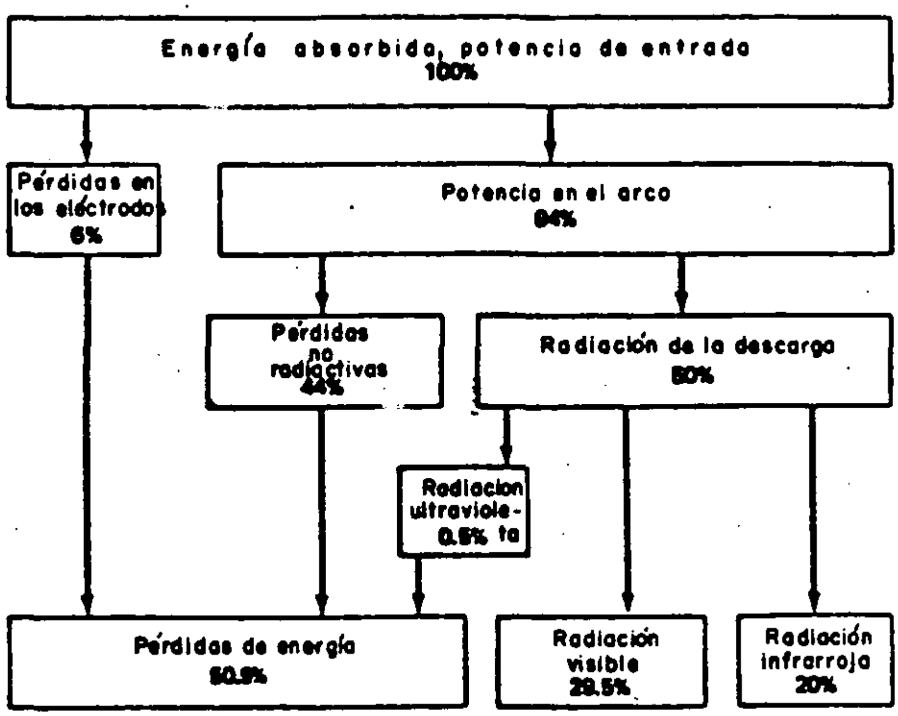


Figura 3-48 Distribución de Energía para la Lámpara de Sodio Alta Presión con 125 lm/watt y 29.5% de ra-- diación Visible.

Full-Size Fluorescent Lamps

Advanced Lighting Technologies Application Guidelines March 1990

Technology Description

Fluorescent lamp technology has made significant advances over the past few years. The trend has been from lamps with high energy use and/or poor color rendering ability to energy saving products with excellent color rendition. New lamp phosphors have created the color qualities and smaller diameter lamps have created new opportunities for efficient luminaire designs that focus the light where it is needed.

The fluorescent lamp is a glass tube with a fluorescing phosphor material coating the inside walls. The tube is filled with a gas and a small amount of mercury and is sealed. When a suitably high voltage is applied between the electrodes, at each end of the tube, the gas ionizes resulting in an electric current flowing through the tube. The current excites the vaporized mercury which returns to its initial state by the emission of ultra-violet (UV) radiation. When the UV radiation reaches the tube walls it is absorbed by the phosphor coating and re-emitted as visible light.

There are three basic types of fluorescent lamps:

- *Preheat lamps* employ an external starter to energize the cathodes (electrodes) prior to exciting the lamp.
- *Rapid start lamp* ballasts energize the cathodes prior to exciting the lamps and during normal operation.
- *Instant start lamp* ballasts do not energize the lamp's cathodes prior to starting or during normal operation.

Fluorescent lamps require a ballast to apply a high starting voltage and then to limit the current through the lamp. For optimum operation each lamp type is matched with a particular ballast.

Manufacturers can vary the lamp current, voltage, phosphor content and tube length to achieve different lamp characteristics. This has resulted in a wide range of lamps being designed and sold. The smallest standard lamp is the six-inch, four-watt preheat lamp; the largest and most powerful lamps are the eight-foot, 1500 ma very high output rapid start lamps.

The standard four-foot rapid start fluorescent lamp is the most common light source in commercial facilities. It employs a T-12 glass tube (T for tube, 12 for 12/8's of an inch diameter). There are about ten times as many F40T12-type lamps in use than all other types combined. Therefore, any improvement in energy efficiency in this lamp type will have profound implications.

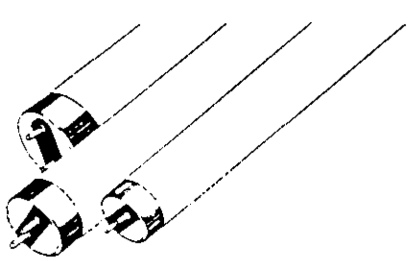
Contents

Standard Lamps

The standard 40 watt F40-type lamp is argon gas-filled. The most common phosphor is the halophosphate "cool white". The standard cool white lamp is rated at 3050 lumens when operated on a laboratory reference ballast in free air at 77°Fahrenheit. (These ratings have recently been reduced by about 3% due to removal of some minor constituents that have been declared toxic.)

The large demand for the 40 watt F40 lamp resulted in mass production and low cost. The most popular configuration in the 1970's was two F40T12 lamps on a ballast that draws approximately 96 watts, including ballast losses, and generates at least 92.5% of the rated light in open air at a temperature of 77° Fahrenheit.

The ballast manufacturers' design parameters establish a minimum percentag of the reference light output that is called the "ballast factor". The ballast factor is defined as the ratio of the actual light produced by the lamp-ballast system to the reference light output of the same lamp on an ANSI reference ballast.



Common Fluorescent Lamps

In 1982 California required that more "energy-efficient" (EE) ballasts be used reducing the power of the 2 lamp 40 watt F40 lamp-ballast system would draw to about 86 watts with the same light output. Federal law will require these ballasts to be used throughout the U.S. in April 1991.

"Energy Saving" Lamps

response to the energy crises of e 1970's, lamp companies introduced halophosphor F40T12 lamps filled with an argon-krypton gas mixture, rather than only argon. These lamps may be operated suitably with a 40 watt F40 T12 ballast, but because of the different gas mixture, draw about 34 watts per lamp. These lamps are coated with a transparent conductive coating to lower the high starting voltage and have a lower light output rating. With the 40 watt F40 ballast, light output is further reduced since this system has a lower ballast factor (about 87%) compared to the standard lamp-ballast system (92.5%). By using this lamp as a retrofit in over illuminated spaces the savings of 5 or 6 watts per lamp reduces energy use by 7%.

The "energy saving" halophosphor lamp (34 watt F40T12/ES) is intended as a retrofit solution to the energy problem. Although its unit wattage is reduced, it also has a lower light output. When operated on a standard or energy efficient magnetic ballast it only generates about 87% of its reference light at 77° Fahrenheit. This lamp-ballast system is less energy efficient than the standard argon-gas lamp-ballast system, since it generates fewer lumens per watt. This is due to increased ballast losses. In addition, these lamps cannot be dimmed as easily as standard 40 watt F40T12 lamps, and they are more sensitive to temperature.

Fluorescent Lamp Designations

F(B)n(Td)(/)color(/mod)

where

F	*means fluorescent*
(B)	*means "bent" or U-shaped*
n	*wattage family or length; by convention*
(Td)	*means tubular, d/8's of an inch diameter*
color	*color temperature in Kelvins*
mod	*is some variation like "energy saving" or "extended output"*
( )	*means optional (doesn't always appear)*

All manufacturers use variations of this nomenclature, mostly for advertising or "trade name" identification

Efficient T-12 Tri-Phosphor Lamps

More efficient versions of the standard size F40T12 lamps are available that use "rare earth" tri-phosphors to achieve higher lumen output. Two types are offered:

- thin coat that raises output about 3%
- thick coat that results in a 5% light output gain.

See the table "Lamp/Ballast System Comparison - Two Lamp" for performance benefits of the tri-phosphor lamp types compared to the halophosphor "cool white". In addition to the increase in efficiency, these lamps offer superior color rendering capabilities; above 70 CRI for thin coat and above 80 CRI for thick coat. The standard cool white lamp has a CRI of 56.

"Energy Saving Plus" Lamps

In a rapid start lamp, it is possible to disconnect the lamp heater filament after the lamp is operating. This saves the cathode heater wattage, about 2.5 watts per lamp, with only a slight loss in light output.

If the disconnection of the heater occurs in the ballast, any lamp can operate this way. (See Heater Cutout Ballast in the Energy Efficient and Electronic Ballast Guideline) For retrofit applications a special lamp with a cut-out device in the lamp is used. These lamps are commonly known as "energy-saving plus"(32 watt F40T12/ES/plus) lamps.

All energy saving plus lamps are argon-krypton gas-filled (34 watt F40T12/ES) lamps with the added cutout device. The lamp cost increase is amortized quickly. Reduced wattage may result in a slightly improved fixture efficiency due to improved thermal performance.

An operational drawback of this product is that a restrike time of about 1-2 minutes exists if the lamp is extinguished and then immediately restarted. Some manufacturers, but not all, have derated the lamp life by 25% when operated without energized cathodes. In general, the energy savings make this a cost-effective trade off even with the reduced life.

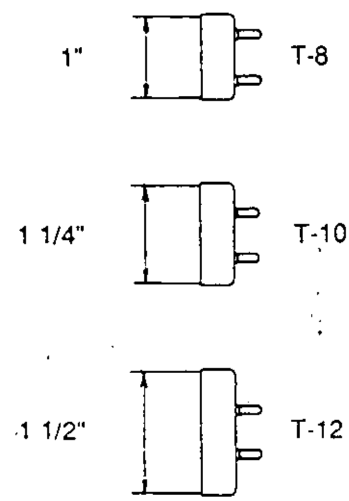
"Extended Output" Lamps

Another product worth considering is the "extended output" version of the standard F40T12 lamp, designated here as an F40T12/EO. (The "EO" nomenclature is not used by any manufacturer; current products use some sort of manufacturer's trade name or designation.) These are premium versions of the standard lamp which, due to gas fill and more efficient phosphors, generate more light with a slight increase in lamp watts. These lamps typically deliver about 7% to 9% more light.

Current Products

There are two new types of lamps that have improved efficacy (lumens per watt) compared to the standard fluorescent lamp/ballast system. These are the T8 and T10 lamp families.

By using a smaller diameter lamp and a ballast specifically designed for it, the potential for greater energy efficiency exists.



Medium Bipin Based Lamps

T-8 Lamps

The latest efficient product is the T-8 lamp system. Introduced in the American market in 1982, these lamps are now made by the major U.S. lamp manufacturers, and have the medium Bipin bases of the T-12 lamp allowing them to fit the same sockets.

The T-8 lamp operates at 265 milliamperes current, so it will not be properly matched if operated on a standard F40 T-12 type lamp ballast designed for 430 milliampere operation. However, there is only a minor cost difference between a T-8 lamp-ballast system and a 40W F40 T-12 lamp-ballast system.

A manufacturer of an electronic ballast for T-8 lamps makes a version with 2 level (Off-50%-100%) lighting control of all lamps. This alternative to alternate ballast switching will also meet Title 24's mandatory multiple lighting level control requirement.

T-8 lamps can also be dimmed. These require specialized dimmers and ballasts in order to work properly. Dimming range is typically down to 5% of lamp output.

The advantages of a T-8 lamp over T-12 are:

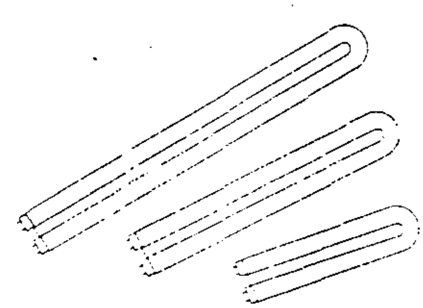
- The two lamp F32 T-8 system with an EE ballast has an efficacy of 77 lumens per watt. The two lamp F40T12 lamp system efficacy is 69 lumens per watt and the F40T12/ES lamp system efficacy is 68 lumens per watt.
- The two lamp F32 T-8 system with an electronic ballast has an efficacy of 90 lumens per watt. Given optimum electronic ballast designs, the maximum efficacy for a two lamp F40T12 system is 84 lumens per watt and for a two lamp F40T12/ES lamp system is also 84 lumens per watt.
- The T-8 lamp may even increase luminaire efficiency. For example, the use of T-8 lamps increases the efficiency of a common 3-lamp, high efficiency parabolic troffer from about 75% to 78%.

Advanced Fluorescent Lamp Technologies - Data

Lamp Style	*Watts*	*Lumens*	*Nominal Length*
Straight T-8 Bipin Lamps			
Requires specific T-8 265 mA ballast			
F17T8/color	*17*	*1350*	*2'*
F25T8/color	*25*	*2150*	*3'*
F32T8/color	*32*	*2900*	*4'*
F40T8/color	*40*	*3650*	*5'*
U-Shaped T-8 Bipin Lamps			
Requires specific T-8 265 mA ballast			
FB16T8/color	*16*	*1250*	*1'*
FB24T8/color	*24*	*2050*	*1.5'*
FB31T8/color	*31*	*2800*	*2'*
Straight T-10 Bipin Lamps			
Operate on Standard F40T12 ballast			
F40T10/color	*42*	*3600*	*4'*

- The heavier power loading of the small diameter lamps (more light per lamp surface area) requires that T-8 lamps use the rare earth (tri-stimulus) phosphors to maintain lamp lumen depreciation within accepted limits.
- Recent quotations involving orders of T-8 lamps show no cost premium being paid for T-8 in large quantities, as compared to a high color rendering T-12. T-8 lamps can actually cost less than 34 watt 4 foot F40T12/ES high color rendering lamps. On a life-cycle cost basis, a T-8 system is usually a better investment than any T-12 system.

T-8 lamps are currently offered in standard 2, 3, 4 and 5-foot-straight lamps, as well as 1, 1-1/2 and 2-foot-long U-shaped lamps.



2', 1.5' and 1' U-Shaped Lamps

T-10 Lamps

These lamps are primarily designed as a retrofit for the 40 watt F40T12 in the situation where a retrofit or delamping reduced light levels too much, but they should also be considered for new construction. They operate directly on a 40 watt F40 T-12 ballast, making them interchangeable with any 40 watt T-12 lamps.

T-10 lamps offer higher efficacies, increased light output and longer life, compared to standard lamps.

Four-Foot Fluorescent Lamp-Ballast System Efficacies*

[Based on two lamp ballast systems, for lamps coated with the 4100 Kelvin (70-75 CRI) tri-stimulus phosphor].

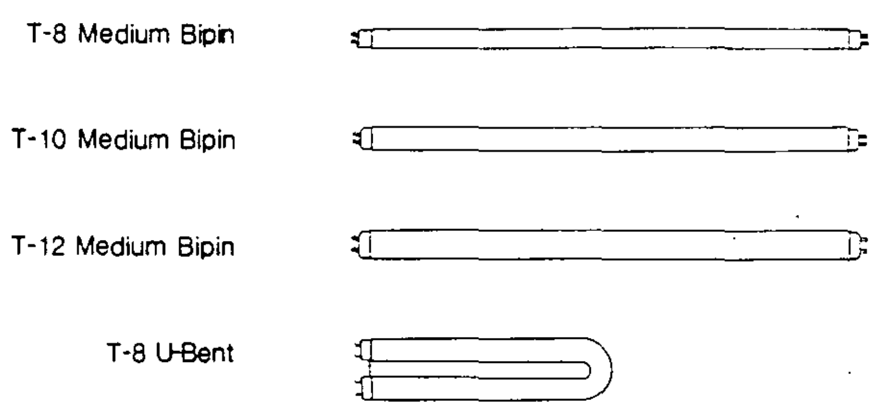
Lamp Type	*System Efficacy (lumens/watt) Magnetic EE Ballast*	*Electronic Ballast*
40W F40 T-12	*69*	*83*
34W F40 T-12 (ES)	*69*	*83*
34W F40 T-12 (ES/plus)	*79*	**
40W F40 T-12/EO	*73*	*85*
Advanced Technologies		
32W F32 T-8	*76*	*91*
40W F40 T-10	*76*	*83*

* *Measured under standard ANSI conditions, open air at 77°F ambient temperature.*
** *Cathode voltage removed during operation, not recommended for high frequency operation.*

The only T-10 lamp size being offered is the four-foot-long lamp replacement for the F40T12. It actually consumes about 43 watts, but due to its higher voltage it actually draws slightly less current (about 400 milliamps), and the ballast losses are lower. An energy-efficient magnetic ballast for (2) F40T10 lamps will draw about 88-92 watts, while each lamp provides 3420 lumens for a ballast factor of at least 92.5%.

T-10 lamps' greatest advantage is as a retrofit for T-12 lamps when no ballast change is needed and where increased light output is required. Some T-10 lamps may not start properly with the 40 watt T-12 ballast over the entire voltage input range. One manufacturer makes a ballast to match the T-10 lamp. At present, T-10 lamps are premium priced products.

Most manufacturers now make T-8 lamps, but only a few make T-10 lamps. The U-shaped T-8 lamps are considered competitors to higher-wattage compact fluorescent lamps, so U-shaped T-8 lamps are not presently manufactured by companies making the 18-40 watt rapid start compact twin tube lamps.



Straight and Bent Lamps

Lamp-Ballast System Comparison Two Lamp

			System			Comparative		
Lamps	Ballasts	Test Ballast Factor	Rated Lumens	Watts Input	Efficacy LPW	Watts Input	Lumen Output	System Efficacy
F40 T-12 4100K 40W Halophosphor Cool White 3050 Lumens	Magnetic EE	.94	5734	88	65	Base 100%	Base 100%	Base 100%
F40 T-12 4100K 40W Thin Coat Tri-Phosphor 3250 Lumens	Magnetic EE Heater Cutout Electronic	.94 .83 .85/.88	6110 5395 5525/5720	88 72 69/74	69 75 77/83	100% 82% 78%/84%	107% 94% 96%/100%	107% 115% 118%/128%
F40 T-12 4100K 40W Thick Coat Tri-Phosphor 3300 Lumens	Magnetic EE Heater Cutout Electronic	.94 .83 .85/.88	6204 5478 5610/5808	88 72 69/74	71 76 78/84	100% 82% 78%/84%	108% 96% 98%/101%	109% 117% 120%/129%
F40 T-12 ES 4100K 34W Thin Coat Tri-Phosphor 2850 Lumens	Magnetic EE Heater Cutout Electronic	.87 .80 .82/.87	4959 4560 4674/4959	72 58 57/63	69 79 74/83	82% 66% 65%/72%	86% 80% 82%/86%	106% 121% 114%/128%
F40 T-12 ES Plus 4100K 32W Thin Coat Tri-Phosphor 2800 Lumens	Magnetic EE	.88	4928	67	74	76%	86%	114%
F40 T-10 4100K 42W Thick Coat Tri-Phosphor 3600 Lumens	Magnetic EE Heater Cutout Electronic	.95 .84 .84/.88	6840 6048 6049/6336	90 76 72/76	76 80 84/83	102% 86% 82%/86%	119% 105% 105%/110%	117% 123% 128%/129%
F32 T-8 4100K 32W Thin Coat Tri-Phosphor 2900 Lumens	Magnetic EE Electronic	.94 .86/.97	5452 4988/5626	72 62/66	76 77/91	82% 70%/75%	95% 87%/98%	116% 118%/140%

Note: Open air bare lamp tests as per ANSI C82.2

Color Rendering

Both T-8 and T-10 technologies use the rare earth tri-stimulus phosphors which give better color rendering qualities than the standard T-12 lamp. The standard T-12 cool white lamp uses halophosphate phosphors with a CRI of 50+ and color temperature of 4100K. The variety of color temperatures now available with rare earth phosphors requires the designer to specify a lamp color temperature as part of the lamp nomenclature.

Manufacturers presently offer either high color rendering (CRI above 80) or moderately high color rendering (CRI between 70 and 75). In general, the higher color rendering lamps cost more than the moderately high color rendering lamps.

Not all manufacturers offer all lamp colors, nor do all manufacturers offer both high color rendering (CRI 80+) and moderate color rendering (CRI 70+) in a similar product. In fact, at present all T-10 lamps are high color rendering (CRI 80+) and each manufacturer of T-8 lamps offers either moderate color rendering or high color rendering, but not both.

Specifying Lamp Colors

Color Temp. Kelvins	*CRI*	*Various Tradename Designations**	*Matches*
3000	70+	SP30 D30 Spec30	Incandescent Halogen
	80+	SPX30 D830 30U AX30 30K	
[illegible]	70+	31K	Incandescent Halogen
3500	70+	SP35 D35 Spec35 35K	Halogen
	80+	SPX35 D835 35U AX35 35K	
4100	70+	SP41 D41 Spec41 41K	Metal Halide
	80+	SPX41 D841 41U AX41 41K	
5000	80+	50U AX50	Daylight

* *These are some designations of selected major manufacturers. To be assured of the proper color temperature and CRI, check each manufacturer's data to determine the exact color designation.*

Application Guidelines

Advanced technologies in full-size fluorescent lamps are used in making rapid-start straight and U-shaped lamps with unit lumen output comparable to the standard 40 watt F40T12 lamp. Applications generally include all situations where an F40T12 lamp would have been suitable.

T-12 Lamps

Retrofits Consider use of "Energy Saving Plus" lamps in applications where a 1 to 2 minute restrike time can be accepted.

New Construction Consider use of efficient tri-phosphors and "extended output" lamps when their extra output allows design with fewer luminaires or fewer lamps per luminaire.

T-10 Lamps

Retrofits Good applications for T-10 lamps are existing situations where delamping (alone, or combined with other retrofits like imaging reflectors) may produce unacceptably low lighting levels. T-10 lamps are designed specifically for these situations.

New Construction Although T-10 lamps were initially introduced as a retrofit they can be considered for new construction applications where a higher lighting level is required. For example, common lighting design problems can be solved using standard luminaires and T-12 EO lamps. Without changing the lighting design, a 13% increase in lighting level, with only a 5% increase in power, can be obtained by using T-10 lamps and appropriate luminaires.

T-8 Lamps

Retrofits In retrofit situations involving F40T12 lamps, where the existing ballast must be changed the T-8 lamp/ballast retrofits are often very cost effective. However, if the existing ballast is an F40T12 energy efficient, in good condition, then a T12 system retrofit is cost beneficial.

New Construction T-8 lamps are excellent for all new installations including:

- offices
- retail Stores
- commercial and Industrial Lighting
- special applications like task lights, undercabinet lights, cove lights, and surface and decorative lights

T-8 lamps are generally superior to any T-12 technology based upon efficacy and color rendering. Considering that T-8 lamps could make many popular luminaires more efficient, a T-8 system with magnetic ballasts will typically provide 8% to 9% more light at 4% to 9% fewer watts than a system using F40T12/ES lamps with equal color rendering. The lamp cost for larger commercial projects in major metropolitan areas is about the same.

Examples

New General Lighting Systems

A typical general lighting system using standard 3" deep cell, semi-specular, competitive parabolics utilizes three-lamp troffers on 8' by 10' centers. The following results can be obtained using non-air handling, high-efficiency parabolic troffers in a room with white tile ceiling, light-colored walls and normal carpet color.

Lamp Type	Ballast Type	Small Room (RCR=5) Footcandles*	Large Room (RCR=1) Footcandles*	W/sf	Relative Efficiency
F40T12	Magnetic	41	59	1.65	1.00
F40T12	Electronic	40	58	1.22	1.32
F40T12/ES	Magnetic	36	52	1.35	1.08
F40T12/ES	Electronic	35	51	1.13	1.25
F40T12/ES+	Magnetic	33	49	1.25	1.06
F40T12/EO	Magnetic	46	66	1.68	1.10
F40T10	Magnetic	48	69	1.68	1.15
F32T8	Magnetic	39	59	1.31	1.20
F32T8	Electronic	44	67	1.12	1.58

* Consult IES recommended lighting levels.

** This table will be updated as the blank tables in the Luminaires and Lighting Systems Guideline are completed.

Calculated using Lumen Method. See Computer Aided Lighting Design guideline for discussion of benefits of Point-by-Point Calculations.

A Retrofit Situation

A traditional lens troffer design from the early 1970's utilizes 4-lamp troffers on 8' by 8' centers. The resulting system generates about 88 footcandles maintained, (RCR=1) at 2.7 w/sf using F40T12 lamps, and about 84 footcandles at 2.4 w/sf using F40T12/ES lamps.

A survey of office spaces would reveal that the lighting levels are excessive for some office lighting situations. Average illuminance levels between 50 and 70 footcandles are presently considered appropriate for most office tasks. Therefore, an excellent energy-saving opportunity exists. The designer examines several options:

Action	Lamp/Ballast (All mag.=ES type)	Small Room (RCR=5) Footcandles*	Large Room (RCR=1) Footcandles*
Delamp	F40T12/Magnetic	30	44
Delamp	F40T12/Electronic	29	43
Delamp/Reflect.	F40T12/ES - Mag.	39	57
Delamp/Reflect.	F40T12/ES - Elec.	40	60
Delamp	F40T10/Magnetic	35	53
Delamp/Reflect.	F40T10/Magnetic	54	81
Delamp/Reflect.	F40T12/EO - Mag.	50	75
Delamp	F32T8/Magnetic	28	42
Delamp	F32T8/Electronic	32	48
Delamp/Reflect.	F32T8/Magnetic	37	55

* Consult IES recommended lighting levels.

- Check the ballast. If it is not an "energy-efficient" type, it almost always pays to replace with a new ballast. Options include T12 energy efficient, T12 electronic, T-8 energy efficient, or T-8 electronic.
- Luminaire efficiency can be increased by 10% to 15% through the use of a specular imaging reflector retrofit.
- Delamp, leaving 2 lamps in each luminaire. (Caution: disconnect unused ballast from line.)

Guideline Specifications

Specifying any of the more energy—saving fluorescent lamps is not difficult. Most of the products are now generally offered through major electrical distributors across the U.S. In the case of T-8 lamps, many manufacturers of commercial lighting equipment consider T-8 to be a standard option.

Lighting Fixture Schedules

Most lighting designs list fixtures by type or "tag" in a schedule. This schedule often contains all information needed for lamps and ballasts. To properly specify fluorescent lamps, however, it is recommended that a few special notes be included to clarify the designer's intent. Please refer to the suggested "Lighting Fixture Schedule".

Using lighting fixture schedules is an excellent method to properly specify lamps. There are several reasons:

- Lighting fixture schedules are used to quickly identify luminaires.
- Lighting fixture schedules contain most of the necessary information for complete specification of lighting on most projects.
- Most contractors and distributors actually read the fixture schedule, whereas written specifications are seldom read or referred to, except by the contractor's office personnel.

Standard Specifications

Most commercial projects use variations of standardized specifications from the Construction Specifications Institute (CSI) recommended format. This shorter specification format is better for smaller, less complex projects. It contains all the basic information to assure proper provision of the required lamps.

Specifiers should be diligent as minor cost advantages and "value engineering" may be used to substitute the less efficient T-12.

A Recommended Basic Specification

The following specification may be used for T-8 lamps with a magnetic ballast. See the application guideline "Energy Efficient and Electronic Ballasts" contained in this handbook for a specification guideline for electronic ballasts.

2.n FLUORESCENT LAMPS

1. Meet applicable sections of ANSI C82 and C78.
2. In general, lamps shall be 265 mA "T-8" rapid start type as follows:
   a. 2' lamps shall be 17 watt F17T8
   b. 3' lamps shall be 25 watt F25T8
   c. 4' lamps shall be 32 watt F32T8
   d. 5' lamps shall be 40 watt F40T8
   e. 1' MOL U-lamps shall be 16 watt FB16T8
   f. 1.5' MOL U-lamps shall be 24 watt FB24T8
   g. 2' MOL U-lamps shall be 31 watt FB31T8
3. Color: lamps shall be (3000)(3500)(4100) Kelvin correlated color temperature.
4. Color rendering index: lamps shall have a minimum CRI of (70)(80) through the use of rare earth tri-stimulus phosphors or in combination with halophosphate phosphors.
5. Lumen output, lamp life, and lumen depreciation, as a function of mean lumens, shall be determined in accordance with IESNA testing procedures and according to the ratings published in XYZ Manufacturer Catalog dated 1990.
6. Replace defective lamps occurring within 90 days of beneficial occupancy.
7. Approved manufacturers (list).
9. Any other project-specific data.

Extensive Specifications

CSI recommends that more extensive technical specifications be written for complex projects or projects being built overseas.

Lighting Fixture Schedule for Project XYZ

Tag	Description	Lamp	Ballast	Volt	Power(5)	Product
F1	2'X 4' Parabolic Troffer, 18 cell floating door semi-specular 3" deep louver heat extract air handling NEMA G tandem ballasted pairs per Title 24	(3)F32T8 /3500K	Magnetic Energy Efficient (1) 2-lamp in "slave" and (2) 2-lamp in "master"	277	100	LLL 123/ES PAIR
F1A	Same as F1	Same as F1	Magnetic energy saving (1) 2-lamp and (1) 1-lamp	277	103	LLL 123
F2	2'X 2' Parabolic troffer 16 cell floating door specular 4" deep louver static NEMA F	(2)FB31T8 /3500K	Electronic instant start type ABC 123 (2) lamp ballast	277	90	LLL 234

General Requirements

1. *Lamps and ballasts shall meet applicable standards of the American National Standards Institute (ANSI), National Electrical Manufacturers Association (NEMA), and Underwriters Laboratories (UL). Luminaires shall be UL listed, or listed by other recognized testing agency. Ballasts and other materials shall be UL listed or recognized, as appropriate, ballasts shall meet California Energy Standards.*
2. *Electronic ballasts shall be made by XXX manufacturer and shall be warranted for 3 years including material cost and a labor allowance.*
3. *Lamps shall be made by EEE, FFF, or GGG. Do not mix manufacturers of same type lamp.*
4. *(Insert any special project requirements here.)*
5. *Power (watts) includes ballast losses.*

Although significantly longer and more work for the specification writer, these specifications protect against substitution with inferior copy-cat products made by manufacturers over whom the designer has no influence. At present, world-wide specifications are reasonably standard. However, the cost or unusual nature of an advanced technology lamp may be a cause for substitution with the less efficient T-12 lamps

Manufacturer/Product References

Manufacturer	Product(s)
General Electric	Lamps, most types
Mitsubishi	Lamps, some types
Osram	Lamps, most types
Panasonic (Matsushita)	Lamps, some types
Philips	Lamps, most types
Sylvania	Lamps, most types

(Inclusion in this list does not infer applicability or endorsement. Additional companies may also manufacturer these products.)

Compact Metal Halide and White HPS Lamps

Advanced Lighting Technologies Application Guidelines March 1990

Technology Description

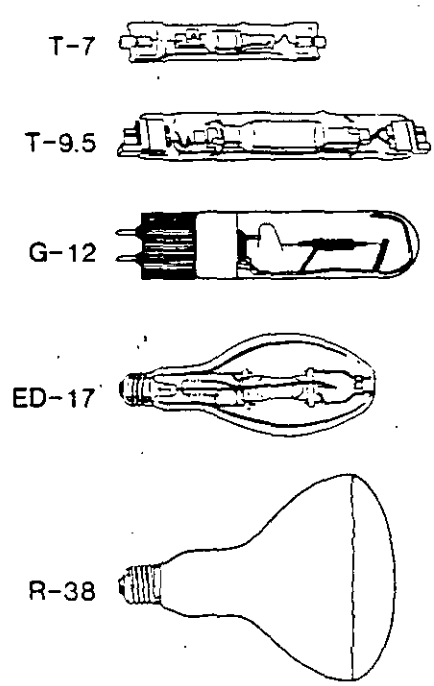
Metal halide and high pressure sodium are types of High Intensity Discharge (HID) lamps. Until recently, metal halide lamps were generally only manufactured in high wattages (175-1500) and large envelopes with mogul bases. Most high pressure sodium lamps suffer from poor color rendition. Compact versions of both types of lamps offer the possibility of high efficacy (from 50 to 60 lumens per watt) in lower wattage packages.

Compact metal halide lamps are the result of new developments in manufacturing methods allowing smaller wattage lamps to be made with smaller envelopes and bases. They produce brilliant white light in a comparatively small arc tube. Current products include:

- Single-ended lamps with medium bases (32-175 watts)
- Single ended bi-pin bases (35-150 watts)
- Double-ended recessed single contact (RSC and Fc2) lamps (70-250 watts)

Each of these lamps uses one of several possible chemistries. The rare earth chemistries typically found in most double-ended lamps generally provide excellent color rendition, but at the expense of efficacy. The sodium scandium chemistries of medium based lamps provide good color rendition and lower cost. All metal halide lamps are susceptible to lamp-to-lamp color differences, color shift over life, and moderate rated lives of 5000-10,000 hours for most compact lamps.

White high pressure sodium (HPS) lamps are moderately long-life lamps, (10,000 hours). While a major drawback of conventional HPS lamps is poor color rendition, white HPS lamps have very good incandescent like color rendition, (2600-2800K, 70-80 CRI).



Common High Intensity Discharge Lamps

Contents

Current products are all compact lamps. The compact lamp wattages of significant interest are 35, 50, 95, and 100 watts, using medium based envelopes. These products generally have a color rendering index (CRI) of 80 or more and a correlated color temperature of 2600-2800 K, making them appear very similar to incandescent light.

Efficacy and Efficiency

Both metal halide and white high pressure sodium lamps have reasonably high efficacy, generating 50 to 90 lumens/watt. In addition, the compact arc tubes allow optically efficient reflector design in luminaires of acceptable small size.

Color

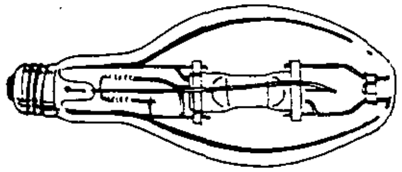
Metal halide lamps generate a white light. Most compact lamps have clear envelopes, although some lamps are available with phosphor coatings. Metal halide lamps tend to be either warm tone (about 3000 K) or cool tone (about 4100 K). Color rendering indices (CRI's) vary from 65 to 93. Compared to incandescent or halogen lamps, low color temperature metal halides will often appear slightly pinkish, and high temperature metal halides will appear slightly greenish.

White high pressure sodium lamps generate a warmish white light. Color temperatures of 2600-2800 K appear similar to slightly dimmed incandescent lamps. *Note: White HPS lamps can have color-life, after which the color quality and the color decay are similar to standard color HPS lamps.*

Ballasts

All HID lamps require ballasts to operate. In addition, some lamps require an external starting igniter to generate high-voltage pulses needed to begin the lamp arc. The distance between lamp and ballast depends on the starting method. Some manufacturers of smaller lamps, ballasts and igniters do not recommend remote ballast locations.

The American National Standards Institute (ANSI) publishes standards for metal halide and high pressure sodium ballasts.



ED-17 Bulb

Electronic Ballasts There are three electronic ballasts types available:

- **DC electronic ballast** designed to drive a specific, proprietary compact metal halide lamp (not ANSI standard)
- **high-frequency electronic ballast** to drive a specific compact metal halide lamp (ANSI standard lamp)
- **electronic regulating ballast** for white high pressure sodium lamps

Electronic ballasts, which are expected to evolve slowly into the HID marketplace, provide superior color consistency over the lamps life by maintaining constant arc power.

Electromagnetic Ballasts Most ballasts are electromagnetic types such as reactor, autotransformer, regulator or constant wattage autotransformer.

Burning Position

Most metal halide lamps have a limited number of acceptable burning positions. Lamps are designated BU for base up, BD for base down, HOR for horizontal (±45 degrees), or U for universal. This is a function of the lamp chemistry and how metal vapors enter and stay in the arc stream. Disregard for operating position ratings will result in short lamp life and poor color rendering.

Fixtures

All metal halide lamps require an enclosed fixture or other protective measures. This will protect against possible end-of-life lamp rupture and can also provide UV filtering when required.

Other Applicable Technologies

Compact white HPS and metal halide lamps are the highest efficacy point-sources in moderate lumen packages. However, in certain situations, other sources might be more applicable, such as:

- halogen capsule and infrared-reflecting halogen lamps, especially in wallwashing, and display lighting situations
- compact and full size fluorescent lamps, especially in area lighting and wall-washing situations
- high-wattage metal halide, standard HPS and white HPS generally offer much higher efficacies than compact HID lamps and would be used for large area lighting

Current Products

Current products are limited but growing in number and manufacturers. Each manufacturer has determined the best products for its market. Ultimately whole series of universal replacements in all wattages are expected to be available.

Application Guidelines

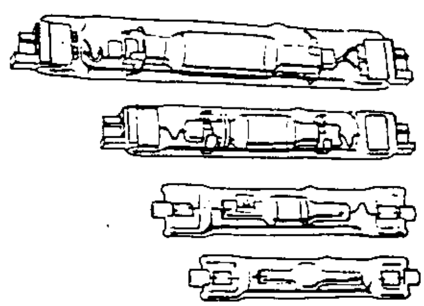
Typical Applications

Compact HID lamps are point sources which lend themselves to projection and floodlighting situations as well as general illumination. The best interior applications are those where lights are left on for long periods, or switched on a time clock, such as corridor or display lighting. Small HID's are especially good choices for all kinds of outdoor lighting, including architectural, landscape, parking, and security lighting.

All HID lamps require warm-up and restrike periods, so frequent switching installations should not utilize these HID lamps. The warm-up period is from 2 to 4 minutes and the restrike period is from 10 to 15 minutes. In addition, lamps of these types can only be dimmed with highly-specialized dimmers and ballasts. The effect of dimming is not nearly as appealing or as extensive as incandescent or fluorescent. Lamp efficacy and color stability suffer when HID's aren't operated at full light.

In general, compact HID lamps are best applied in one of the following ways:

- ***Energy-efficient Flood and Display Lighting*** In suitable modern luminaires, HID lamps can be used for a wide variety of retail display and floodlighting situations, including track, recessed, and surface installations.
- ***Energy-Efficient Lamps in Conventional General Lighting Luminaires*** As long as switching is not a concern, a wide variety of opportunities exist to use compact HID lamps for area lighting in both interior and exterior situations.



Double Ended Lamps with Fc2 and RSC ends

Residential Applications

Because frequent switching is common to residential operation, HID's aren't often used in homes. But the low wattage HID lamps are useful in outdoor security lighting situations.

Commercial Applications

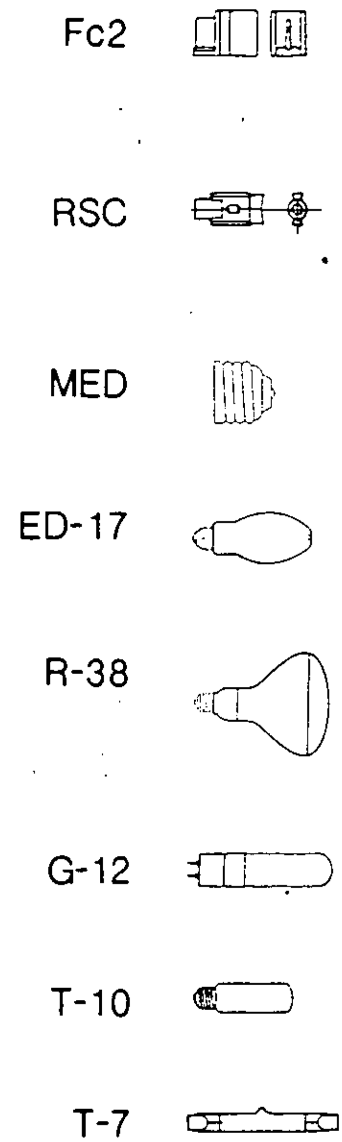
The compact HID lamp finally offers the designer an alternative to incandescent downlights, uplights, and accent lights. Unlike fluorescent alternatives, HID lamps are point sources, giving sparkle to polished surfaces and dramatic shadowing when used to accent a display. The compact lamp size allows for the use of many traditional luminaire types and shapes while employing a reasonable lumen package.

Interior Applications

The best applications are corridor and lobby downlighting, commercial wallwashing, lobby and office uplighting. Also, a number of commercial and industrial luminaires can be equipped with these lower wattage lamps, making them more suitable for smaller spaces than the larger lamps previously used. Even some types of highly decorative fixtures, like wall sconces or pendant chandeliers, can be designed for compact HID lamps.

Exterior Applications

There is a wide range of exterior applications such as bollards, tree uplights, wall lights, step lights, and architectural floodlights. New luminaire innovations based on these lamps include exterior asymmetric wallwashers and precision outdoor spot lights.



Lamp Shapes and Bases

Lamp Style	Watts	Lumens (Clear)	Lumens (Coated)	Life (Hrs)	ANSI Designation	Lamp + Ballast Watts
Compact Metal Halide Lamps						
Medium Based Universal	35	2300	2300	5000	Pending	45
Burning Position	50	3400	3400	5000	Pending	62
Lamps in ED-17	70	5000	5000	5000	M98	88
(Compact) Envelopes	100	7800	7800	10,000	M90	115
All lamps 60-65 CRI	100[1]	8500	8000	10,000	M90	115
and 4100-4300K	150	11,500	11,500	5000	M57	175
except as noted	175	14,000	14,000	7500	M57	195
Medium Based Base-Up	32	n.a.	2500	10,000	M100	38
Warm-toned lamps	35	n.a.	2300	5000	Pending	45
in ED-17 or similar	50	n.a.	3400	5000	Pending	62
(Compact) Envelopes	75	5600	5200	5000	M101	88
All lamps 3200K and	100	8500	8000	10,000	M90	115
65-70 CRI	150	13,500	12,700	10,000	M102	175
	175	n.a.	14,000	7500	M57	195
Double ended clear lamps;	70[2]	5000	n.a.	10,000	M85	94
require glass UV filter	70[4]	5000	n.a.	10,000	M85	94
Lamps 4300K 80-90 CRI	100[4]	6800	n.a.	10,000	M90	121
except as noted	100[3]	8500	n.a.	10,000	M91	121
	150[2]	11,000	n.a.	10,000	M81	175
	150[4]	12,000	n.a.	10,000	M81	175
	175[4]	14,000	n.a.	10,000	M96	195
	250	20,000	n.a.	10,000	M80	295
	250[4]	20,000	n.a.	10,000	M97	290
Medium Based Universal	70	n.a.	3000	5000	M98	88
Burning Position	100	n.a.	5000	7500	M90	115
Lamps in R-38	175	n.a.	9000	10,000	M57	195
Envelopes						
All Lamps 4300K						
Single Ended, G12, Bi-Pin	70	5200	n.a.	6000	M85	94
T8 Lamps; require glass UV	150	12,000	n.a.	6000	M81	175
filter; 3200K 80-90 CRI						
White High Pressure Sodium Lamps						
Medium Based Universal	50	2500	n.a.	12,000	S68	62
Burning Position Lamp						
50 watt in T-9.5 shape						
Medium Based Universal	95	5200	n.a.	10,000	Special	n.a.[5]
Burning Position Lamp						
90 watt in T-10						
Bi-pin PG-12 Based	35	1250	n.a.	10,000	S99	n.a.[5]
T-10 Lamps	50	2300	2190	10,000	Special	n.a.[5]
	100	4700	4470	10,000	Special	n.a.[5]

1 3200K
2 3200K or 4300K
3 3200K 60-70 CRI
4 4300K 60-70 CRI
5 Lamps requiring a proprietary electronic ballast
n.a. Not available

Guideline Specifications

In order to specify compact metal halide and high pressure sodium lamps, it is important to determine whether a proprietary specification designating the acceptable vendors of lamp and ballast is required. Although ANSI designations apply to most products in this category, there are important exceptions.

The lamp designation can be specified as follows:

Metal Halide or Sodium/Wattage Group/Lamp Shape-Size/MED or RSC base/(phosphor or diffuse Coated)/(Warm or Neutral)/(standard or DX color)

> *Example:* A 70 watt double ended metal halide (3000K) in deluxe 81 CRI color would be
>
> M85/T-7/RSC/WDX

A common designation is not possible for white HPS lamps because most products in this category are proprietary.

Example

Lobby Downlighting

An office building lobby and corridors typically use downlights on about 6' centers using about 75-watt incandescent lamps. Using metal halide lamps, the design could be spaced further (about 8' centers) while using 50-watt HID lamps. Including ballast losses, the HID design uses less than half of the wattage of the incandescent design while providing an essentially similar aesthetic. The increased luminaire cost is mostly offset by the reduced quantity of luminaires.

Savings potential: The per unit reductions are about 25 watts per socket, or 30% plus 20% for the increased spacing.

Manufacturer/Product References

Manufacturer	***Product***
General Electric	*Compact metal halide lamps*
	White HPS lamps
Iwasaki	*White HPS lamps*
Osram	*Compact metal halide lamps*
Philips	*Compact metal halide lamps*
	White HPS lamps
Sylvania	*Compact metal halide lamps*
Venture Lighting International	*Compact metal halide lamps*

(Inclusion in this list does not infer applicability or endorsement. Additional companies may also manufacturer these products.)

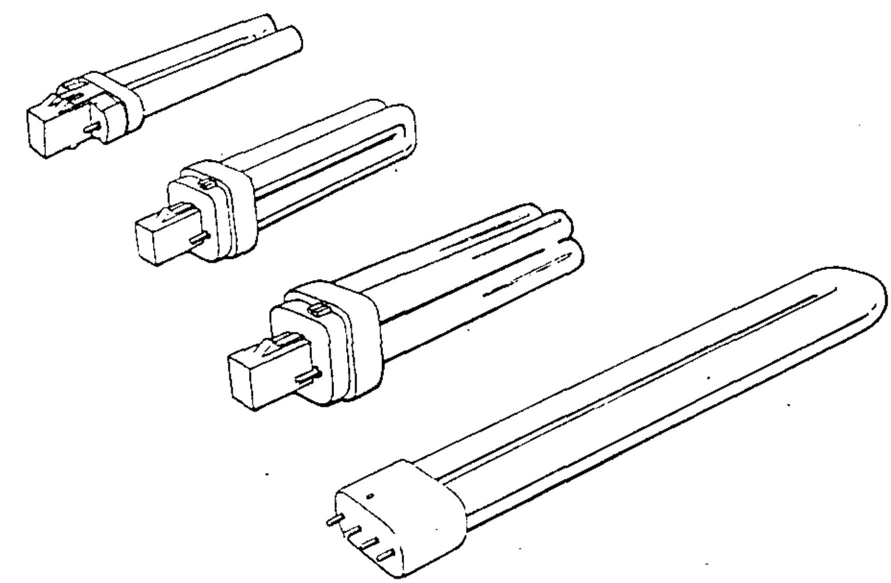
Compact Fluorescent Lamps

Advanced Lighting Technologies' Application Guidelines — March 1990

Technology Description

Compact fluorescent lamps are an energy-efficient, long-lasting substitute for the incandescent lamp. For example a 13-watt compact fluorescent lamp (about 17 watts with the ballast) provides about the same illumination as a 60-watt incandescent lamp and lasts up to 10 times longer.

Compact fluorescent lamps have excellent color rendering and are available in a variety of sizes, shapes and wattages to meet most any design application.



Shapes of Common Compact Fluorescents

The new compact lamps are easy to install and use. Many have a starter in the plug base so that maintenance is generally limited to periodical lamp replacement. Previous small fluorescent lamps were like smaller standard fluorescent tubes with double-ended bipin bases which made them hard to install. Furthermore, they required external starters, as well as a ballast, to operate them.

Compact fluorescent lamps were developed in the late 1970's and introduced to the U.S. market in the early 1980's.

Compact fluorescent lamps have significantly higher lumen output per unit length than conventional small fluorescent lamps. This is due to the high phosphor loading which is necessary because of their small diameter and sharp corner, twin-tube bulb shape.

Contents

These compact lamps produce high lumen output because they utilize high efficacy, high color rendering rare earth phosphors. Color temperature is varied according to the relative balance among the phosphors.

All compact fluorescent lamps have good color rendering, with many choices of color temperature (warmth or coolness) available to the designer. The 2,700 Kelvin (K) color temperature is generally employed since it simulates the color of the standard incandescent lamp.

They all have a single ended base rather than the more awkward, double ended bi-pin bases of the conventional small fluorescent lamps.

There are four major families of compact fluorescent lamps:

- *T-4 diameter twin-tube preheat lamps* with starter devices in the base of the lamp. These lamps can use inexpensive reactor ballasts resulting in an economical alternative to incandescent lighting.
- *T-4 or T-5 diameter quad-tube preheat lamps* (double twin-tube and four-finger), also having plug bases and integral starters. Some of these lamps use reactor ballasts; others require autotransformer/reactor types. These are designed to be a more compact, higher lumen output variation of the twin-tube.
- *T-5 diameter twin-tube rapid start/preheat lamps* designed for use with external rapid start and electronic ballasts. These lamps are generally higher-output lamps, designed to provide the lumen output of conventional fluorescent lamps in smaller packages. These lamps can be dimmed with the appropriate electronic ballast.
- *Special T-4 diameter rapid start lamps* without an integral starter in the base of the lamp. These can be used with special dimming or low temperature ballasts.

Other Applicable Technologies

The rapid start compact fluorescent lamps are capable of generating about 50-70 lumens per watt, not including ballast losses, when operated with a magnetic, electronic or dimming ballast. Their advantages notwithstanding, compact fluorescent lamps have similar overall energy efficiency as several other technologies of equal lumen output including:

- compact low wattage metal halide and white high pressure sodium lamps
- conventional, straight or bent, T-5, T-8, and T-12 fluorescent lamps

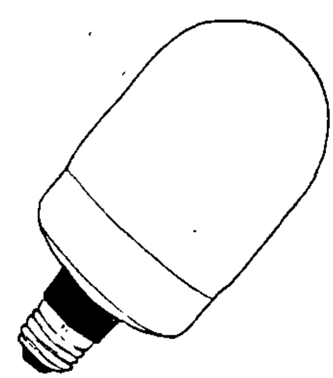
Typical Applications

The low-wattage compact fluorescent lamps are designed to be used in place of incandescent lamps in a wide variety of luminaire shapes and types. The twin-tube style is especially good for task lights and some wall sconces. The quad tube is generally better in downlights and wallwashers, as its shape better approximates the envelope of an incandescent lamp.

The larger, T-5 twin tube lamps are well suited for most fluorescent applications, ranging from recessed troffers and indirect lighting to exterior garden and sign lights. The lamps are designed for fixtures having a 12" to 24" maximum illuminated lengths.

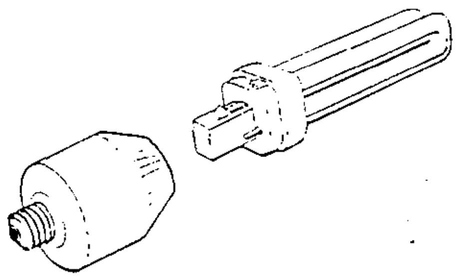
Retrofitting

The compact fluorescents with a medium edison screwbase socket are generally not as efficient, but do offer a means to upgrade existing incandescent lighting. This lamp type is available with either an electronic ballast or a magnetic ballast. The electronic ballast operates at a higher efficiency and without noise or flicker.



Integral Ballast Screw-Based Compact Fluorescent

They are available either as a single unit consisting of the starter, the ballast and the lamp or as an edison screwbase socket adapter that includes the ballast and a separate lamp. The adapter unit permits replacing the lamp when it burns out whereas the single unit must be replaced entirely.



Screw-Based Compact Fluorescent

> ***Ballast Options***
>
> ***Normal Power Factor (NPF) Reactor Ballasts:*** *Available for the smaller internal starter lamps sizes. The 120 volt version is generally the least expensive and smallest ballast option. They exhibit very low power factors (.45 for 120 volt, .25 for 277 volt) so extra caution must be taken to correctly calculate circuit loading when designing the electrical circuits.*
>
> ***High Power Factor (HPF) Reactor Ballasts:*** *Also for the smaller internal starter lamps, these ballasts contain capacitance to raise the power factor to .90 . More expensive and larger than the NPF type, but they allow for conventional branch circuit design and lower installation costs.*
>
> ***Conventional Magnetic Energy Saving Ballasts:*** *The higher wattage lamps designed for rapid start operation generally operate on single or multiple lamp ballasts similarly to standard fluorescent lamps types. Most ballasts are "energy efficient" type consistent with California and national ballast standards.*
>
> ***Electronic Ballasts:*** *Some of the higher wattage T-5 twin tube lamps can be operated by electronic ballasts designed specifically for these lamps or that are rated for these lamps and 265 mA T-8 lamps.*
>
> ***Dimming Ballasts:*** *The starterless quad-tube lamp can be used with either a magnetic dimming ballast with appropriate wallbox dimmer, or a special electronic dimmer and electronic dimming ballast. Some larger lamps will also operate well on electronic dimming and adjustable output ballasts. Check with the manufacturer.*

Fixture Design

The exciting energy saving possibilities of compact lamp fixtures have caused many manufacturers to rush products to market that are incandescent fixtures with fluorescent sockets. Specifiers should be cautious of the following potential problems:

- overheating which causes short lamp and ballast life and low output (fixture design problem)
- ballasts and lamps making acoustic noise (fixture and application problem)
- unusually low or high bulb wall temperature causing significant departure from rated lamp lumens (fixture design and application problem)
- ballast factor and power factor of particular lamp/ballast combinations

Ballasting

All fluorescent lamps require a ballast in order to start and operate properly. Medium-based screw-in compact fluorescent lamps and compact fluorescent lamp adapters have a ballast in the base. All other compact fluorescent lamps are designed to have an external ballast which needs to be specified for each individual lamp type and wattage.

Special attention is called to the power factor of the ballast. Normal Power Factor (NPF) ballasts have a low power factor. Power factor is the ratio of the actual power of the lamp and ballast to the total volt-amperes (VA) of the lamp and ballast. So a 13-watt lamp having a total lamp plus ballast load of 17 watts at a power factor of .45 actually draws.38 VA. Branch circuit current and overcurrent protection are based on VA. Whether using high power factor or low power factor ballasts, the input current instructions of each ballast should be followed, and added, to design the circuit loading.

Current Products

Lamp products are classified by the American National Standards Institute (ANSI). Fluorescent lamps fall into two classifications which establish dimensional and electrical characteristics:

- standard C78.1 for rapid start lamps
- standard C78.2 for preheat lamps

Each manufacturer tends to create "marketable" product names and identifications. These names make for better marketing but are more difficult to specify. Ongoing ANSI committee work has developed the proposed standard nomenclature used here. In most cases the specifier will easily relate the popular product to the ANSI code. For greater ease in making this correlation, remember a lamp tube diameter of 10 mm is about a T-4, and a lamp tube diameter of 15 mm is about a T-5.

Switching

All compact fluorescent lamps, like any other fluorescent lamp, are typically controlled by switching the ballast and lamp circuit on and off. The rated life given in the tables is a function of the average time per start. In frequently switched situations, lamps will last fewer operating hours.

Some of the larger rapid start lamps operate on 265 mA ballasts originally designed to operate 4' F32 T-8 lamps. A manufacturer of an electronic ballast for T-8 lamps makes a version with 2 level (Off-50%-100%) lighting control of all lamps. This alternative to alternate ballast switching will also meet the California Code of Regulations' Title 24 mandatory multiple lighting level control requirement.

Dimming

Certain versions of the smaller quad-tube lamps can be dimmed. These require specialized dimmers and ballasts in order to work properly. At least two major dimmer manufacturers have offered products to dim these lamps. Dimming range is typically down to 5% of lamp output.

The T-5 diameter 270mA lamps can be dimmed with electronic dimming ballasts already on the market. Conventional fluorescent dimming equipment having a ballast and solid-state dimmer are not used. Instead, the ballast varies the lamp's high frequency operation while maintaining filament power. It is important that filament power be maintained in the dimmed mode to preserve lamp life.

Residential Applications for Compact Fluorescent Lamps

Living Rooms

- *Task lights*
- *Swing-arm lights*
- *Undercabinet lights*
- *General downlighting*

Bedrooms

- *Task lights*
- *Closet lights*

Bathrooms

- *Mirror (makeup) lights*
- *General downlighting*
- *Shower/tub light*

Utility

- *Stairs*
- *Laundry areas*
- *Attics/crawl spaces*

Exterior

- *Lanterns*
- *Garage lights*
- *Landscape lights*
- *Security lights*

Application Guidelines

In general, compact fluorescent lamps are best applied in one of these ways:

•As an energy-saving alternative to incandescent lighting The smaller lamps are generally applied where incandescent lamps would typically have been used before, such as in desk lights, wall-mounted area illumination fixtures, undershelf fixtures, landscape floodlights, and a variety of other applications. In most instances, approximately 1 compact fluorescent lamp watt replaces 3 to 4 incandescent lamp watts. Therefore, a 13 watt compact fluorescent provides approximately the light of a 40-60 watt incandescent lamp.

•As an alternative to other fluorescent lamps In the lower wattages, other types of fluorescent lamps lack the convenient single-ended plug base and the consistent good color rendering of compact fluorescent lamps. Many typical fluorescent applications for smaller lamps, like task lights and corridor lights, will be better served using compact lamps.

In the higher wattages, T-5 twin tube compact lamps can be used instead of conventional straight and U-shaped tubes to provide greater amounts of light in a smaller area, and to gain optical efficiency. These higher wattage compact fluorescent lamps are designed to operate better in normal lighting fixture interior ambient temperatures. Also, the high color rendering quality of the compact lamp is maintained with every lamp replacement.

In new concepts and applications The long life and high quality light of the compact lamps allows lighting effects which were formerly difficult to achieve due to heat problems.

Residential Applications

Compact fluorescent lamps should be used carefully in residential lighting design. The benefits of energy efficiency and long life are sometimes outweighed by concerns for the acoustic noise of some ballasts, or by a negative reaction to the starting flicker of the preheat lamps.

In general, use compact fluorescent lamps for all utility lighting applications, and as extensively as possible in the kitchen and bathrooms. Use them in enclosed fixtures outside (except in cold climates) in lanterns and security lighting. Use them in hard-to-reach places. And use them in task lights, especially those types designed for the shape and light of the compact fluorescent lamps.

Color Options of Standard Compact Fluorescent Lamps

Color Temp.	*Typ. CRI*	*Matches*
2700K	*80-83*	*Warm White Incandescent*
3000K	*80-83*	*Warm White Incandescent Halogen Other 3000 Kelvin fluorescent and HID lamps*
3500K	*80-83*	*Halogen Other 3500 Kelvin fluorescent lamps*
4100K	*80-83*	*Cool white Metal halide Other 4100 Kelvin fluorescent and HID lamps*
*5000K**	*85*	*C/D50 and all other high color temperature fluorescent and HID lamp*

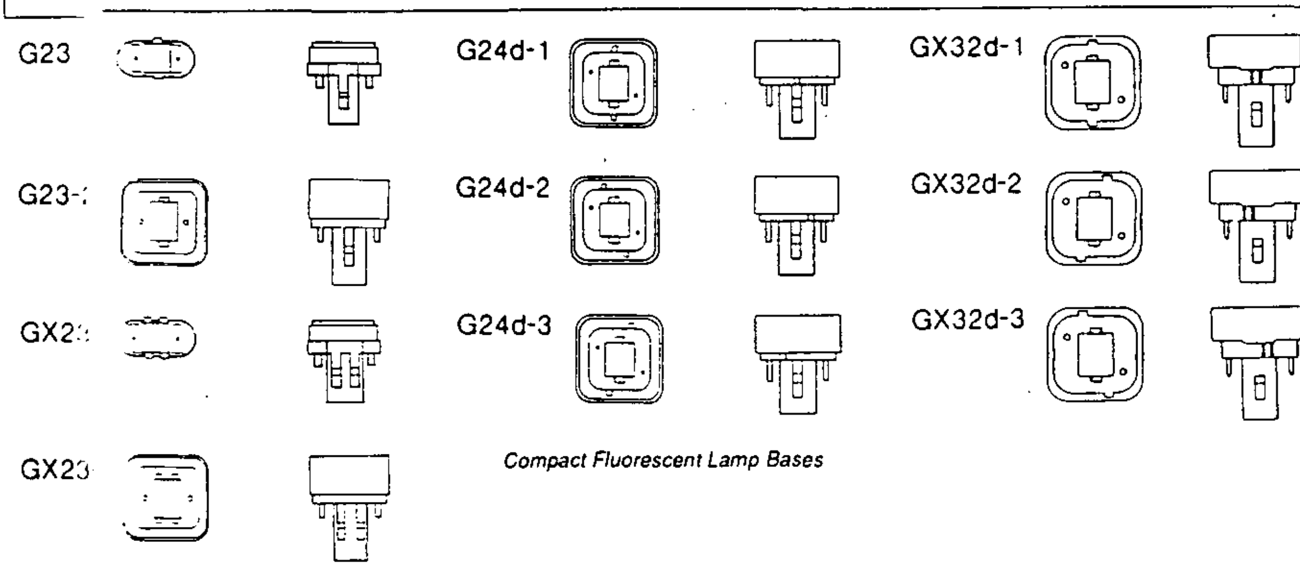
** not as many products available as other colors.*

The net result of a commitment to using compact fluorescent lamps could be important: 5-10% of the lighting electrical energy used by every home could be saved if advantage was taken of all acceptable fluorescent applications.

Comp[illegible]t Fluorescent Lamps with Integral Base Starters

ANSI [illegible]mp Code (watt/l[illegible]gth and tubin[illegible]ize/Twin or Qu[illegible] base/Pre-Heat [illegible] Rapid Start)	Typical Lamp+ Ballast Watts	Rated Lumen	Typical Ballast Factor 120 v.	Rated Lamp Life Hours @ 3 hrs/start	Ballast	Rated System Efficacy Lumens/watt, @ 25°C
5W/4[illegible]/G23/PH	9	250	.95-1.0	10000	5W Reactor[5]	26-28
7W/5[illegible]/G23/PH[1]	11	400	.89-.90	10000	7W Reactor[5]	32-33
9W/6[illegible]/G23/PH[1]	13	600	.79-.83	10000	9W Reactor[5]	36-38
13W/7[illegible]T/GX23/PH[1]	17	900	.95-1.0	10000	13W Reactor	50-53
9W/4[illegible]/G23-2/PH	13	600	.79-.83	10000	9W Reactor[5]	36-38
13W/5[illegible]Q/GX23-2/PH[2]	17	860	.95-1.0	10000	13W Reactor	50-53
10W/5[illegible]Q/G24d-1/PH	16 13	600	.90-1.0	10000	10/13W Autotrans.[3] 10/13W Reactor[4]	34-38 42-46
13W/6[illegible]Q/G24d-1/PH	18 16	900	.90-1.0	10000	10/13W Autotrans.[3] 10/13W Reactor[4]	45-50 51-56
18W/7[illegible]Q/G24d-2/PH[2]	25 22	1250	.90-1.0	10000	18W Autotrans.[3] 18W Reactor[4]	45-50 51-57
26W/6[illegible]Q/G24d-3/PH[2]	37 31	1800	.90-1.0	10000	26W Autotrans.[3] 26W Reactor[4]	44-49 52-58
15W/5[illegible]Q/GX32d-1/PH	20	900	.90-1.0	10000	16W Reactor	41-45
20W/6[illegible]Q/GX32d-2/PH	27	1200	.90-1.0	10000	22W Reactor	40-44
27W/7[illegible]Q/GX32d-3/PH	34	1800	.90-1.0	10000	28W Reactor	48-53

Notes
1. Mo[illegible]ommon lamps when standard twin-tube lamps are specified
2. Mo[illegible]ommon lamps when standard quad tube lamps are specified
3. 12[illegible]peration
4. 277 [illegible]eration
5. Mul[illegible]attage ballasts are available but may result in low lumen output and short lamp life.



Compact Fluorescent Lamp Bases

Compact Fluorescent Rapid-Start/Preheat Lamps

ANSI Lamp Code	Typical Lamp+ Ballast Watts	Rated Lumens	Ballast Factor 120 v.	Average Lamp Life Hours @ 3 hrs/start	Ballast	Rated System[2] Efficacy, lumens/ watt @25°C
18-20W/9T5/T/2G11/PH-RS	22	1250	.90-1.0	10000	18W 370mA Preheat	51-57
18W/10T5/T/2G11/RS	23	1250	.90-1.0	20000	18W 270mA Rapid Start	49-54
	17	1250	.95-1.0	15000	265mA 2 lamp elect.[1]	70-74
24-27W3/12T5/T/2G11/PH-RS[3]	32	1800	.925	10000	27W 340mA Rapid Start	52
	21	1800	.810	15000	265mA 2 lamp elect.[1]	69
36-39W4/16.5T5/T/2G11/PH-RS[4]	51	2900	.925	10000	39W 430mA Rapid Start	53
	26	2900	.690	15000	265mA 2 lamp elect.[1]	77
40W/22.5T5/T/2G11	50	3150	.925	20000	40W 265mA Rapid Start	58
	36	3150	.960	15000	265mA 2 lamp elect.[1]	84

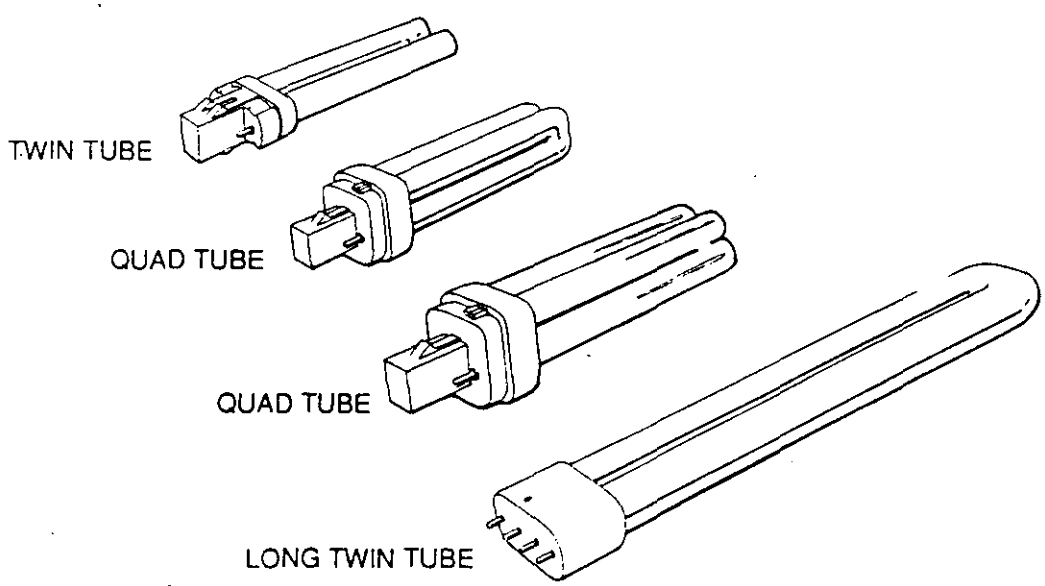
Notes:

1 Specific data from one manufacturer using an instant-start ballast. Ratings per lamp.

2 Rated lamp lumens times ballast factor gives actual lamp lumens at 25 degrees Centigrade (77° F). This value is actual lamp lumens divided by (lamp+ballast) watts.

3 24 watts with preheat ballast

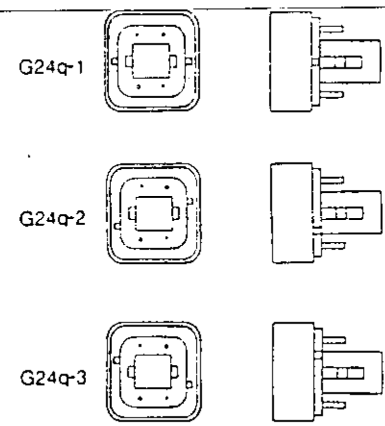
4 36 watts with preheat ballast



Four Pin Base Compact Fluorescent Lamps for Electronic Ballast and Dimming Applications

ANSI Lamp Code	*Lamp Watts*	*Rated Lumens*
10W/5T4/Q/G24q-1	*10*	*600*
13W/6T4/Q/G24q-1	*13*	*900*
18W/7T4/Q/G24q-2	*18*	*1250*
26W/8T4/Q/G24q-3	*26*	*1800*

These lamps can only be dimmed with specially designed ballasts and specially designed control or dimmer devices. Do not dim compact fluorescent lamps any other way.



Four Pin Lamp Bases

Commercial Applications

Commercial lighting represents the best application for compact fluorescent technology. With the advent of the dimmable compact lamp, most incandescent applications can be replaced with a fluorescent equivalent. It is now possible to design a first-class project using compact fluorescent in place of most incandescent lamps.

It is difficult to tell that compact fluorescent downlights and wall washers have been used in a building lobby unless one looks up inside the fixture from directly below.

Compact fluorescent lamps can be used in most design situations. For example, when a more concentrated light source is desired, the 3-lamp 2'x 2' troffer provides almost the same amount of light as the 3-lamp 2'x 4' troffer, but with a smaller ceiling opening.

In office lighting design, not every incandescent luminaire has a fluorescent counterpart, but many do. By using fluorescent troffers, downlights and wallwashers, offices and other types of commercial and institutional spaces can be designed to look good and operate efficiently. In doing so, most designs will more easily comply with the applicable Title 24 standard contained in the California Code of Regulations. Incandescent lighting is saved for the few key situations, such as the board room, where the wider dimming range of incandescent lamps is really needed.

In retail lighting design, fluorescent is appropriate for general illumination, wall washing, and some types of case lighting. The prudent designer only uses incandescent or halogen sources where point-source sparkle or candlepower are really needed, such as display lighting, jewelry case lighting, etc.

In restaurants and hotels, most of the circulation area lighting and other public spaces can be illuminated with compact fluorescent (or HID in certain instances), and some chandeliers can be equipped with fluorescent tubes. Incandescent lighting can then be used where it's really needed, where dimming and special effects are important. Many fast food/fast action spaces can take advantage of the smaller general illumination fixtures made possible by compact fluorescent.

In hospitals, laboratories, schools, and other institutions, compact fluorescent lamps can generally replace most incandescent applications. One advantage of compact fluorescents is size; a standard 40W compact lamp is 22.5" long, and occupies less than 1/2 the volume of a normal F40T12 4-foot lamp. The result is significantly smaller lamp stock storage rooms, and much greater ease of maneuvering lamps around facilities for spot relamping maintenance.

In industrial lighting, compact fluorescent lamps have limited applications. But the low heat of compact fluorescent lamps make it worth using in hazardous environment luminaires, task lights, and a host of other applications where a relatively small amount of light is needed for a localized lighting problem.

Examples

General Downlighting

Many corridors and lobbies are downlighted with round, recessed fixtures. Typical designs call for incandescent "cans" or "tophat" luminaires. The more energy-efficient solution uses downlights designed specifically for compact fluorescent twin-tube or quad-tube lamps. By careful selection, the specifier can choose a fluorescent luminaire which appears similar to standard incandescent downlights. A general rule-of-thumb is to use about 25% of the required incandescent lamp wattage. In other words, use a downlight with two 13-watt lamps to replace a 100-watt incandescent lamp; two 18-watt lamps to replace a 150-watt incandescent lamp; and two 26-watt lamps to replace a 200-watt incandescent lamp. Avoid using compact fluorescent edison socket screw-in adaptors in new construction, as they are not as efficient and can be easily compromised by having incandescent lamps screwed in later.

Whereas small differences in illumination may occur, savings potential with the fluorescent system is significant. For example, to provide 15-20 footcandles in a corridor, fixtures are provided about every 30 square feet. The fluorescent scheme operates at about 1.0 w/sf, whereas the incandescent scheme operates at over 3 w/sf. The savings of over 6 kWhr/sf/yr saves $0.60/sf/yr, or about $18/yr/fixture (1990 costs).

Added benefits result from a much longer lamp life. The incandescent burns out approximately 10 times during the life of one compact fluorescent thus reducing maintenance costs.

Outdoor Floodlights

Many floodlighting schemes for shorter walls, signs, etc. use a PAR-38 flood lamp. In many situations, a short fluorescent flood lamp luminaire would be better when ambient temperatures are high enough for proper operation. Four-foot fixtures would be too long; a short, powerful fluorescent providing about 25% of the incandescent wattage would be appropriate. In this case, the 39-watt twin-tube fluorescent, which is 6-1/2" long, is possibly a good choice. The specifier also gains the advantage of color options to match the floodlight with other sources in the area.

Savings potential is significant. The fluorescent provides a better light for floodlighting and uses 45 watts less than a halogen PAR and 105 watts less than a standard PAR at every fixture.

Commercial Applications for Compact Fluorescent Lamps

General Lighting

- *Recessed 2'x 2' troffers*
- *Recessed 1'x 1' troffers*
- *Recessed 6" to 9" dia. downlights*
- *Suspended designer luminaires*
- *Indirect lighting*

Accent and Specialty lighting

- *Recessed and track wallwashers*
- *Undercabinet/under-shelf lights*
- *Cove lights*
- *Modular strip outlining*
- *Sign and display internal/backlighting*
- *Case display lighting*

Decorative and Portable lighting

- *Wall sconces*
- *Chandeliers*
- *Table and floor lamps*
- *Makeup and dressing lights*

Utility Lighting

- *Security lighting*
- *Step lights*
- *Exit signs*
- *Task lights*

Exterior Illumination

- *Landscape floodlights*
- *Pedestrian post-top and bollard lights*
- *Step and under-rail lights*
- *Vandal resistant security lights*

General Illumination

Designers should consider compact fluorescent lamps in traditional luminaire shapes and styles. For example, the use of 1'x 1' troffers in lieu of other types of downlights allows the use of efficient sources and electronic ballasts with good performance in recessed luminaires (peak light output is achieved in a normal non-ventilated troffer luminaire). Similarly, 2'x 2' and other types of general lighting luminaires may be able to be used in a variety of applications with no major drawbacks, keeping in mind that a 22.5" compact lamp generates as much light as a two-foot U-lamp.

Decorative Lighting

Many chandeliers, sconces, and other types of decorative lamps can be fitted with fluorescent sources. For example, replacing 4 watts of incandescent or 3 watts of halogen with 1 watt of fluorescent in appropriate fixtures works out fairly well. Dimming is probably the only situation where this type of replacement isn't recommended with 1990 technology (expected to be worthwhile by late-1990's).

Guideline Specifications

Specifying compact fluorescent lamps is not difficult. There are several ways to make the preferred lamp and ballast selection clear.

Lighting Fixture Schedules

Most lighting designs list fixtures by type or "tag" in a schedule. This schedule often contains all information needed for lamps and ballasts. To properly specify compact fluorescent lamps, however, it is recommended that slightly more information be contained in the schedule than often encountered.

It is recommended that the specifier identify one manufacturer who makes all lamp products and use this nomenclature throughout. This way, the competitive bidder can easily list his/her corresponding lamp numbers in a general letter of proposed substitution.

Occasionally, there may be a specific lamp type which is unique to the specifier. For example, only one manufacturer makes a "dimmable" quad lamp in 1990. It may help to separately identify and list this lamp by naming the manufacturer in the lamp specification column.

Standard Specifications

Most commercial projects use variations of standardized specifications based on the Construction Specifications Institute (CSI) recommended format. This shorter specification format is better for smaller or less complex projects:

2. COMPACT FLUORESCENT LAMPS

a. Rapid Start lamps per ANSI C78.1.

b. Preheat lamps per ANSI C78.2.

c. Tri-color phosphor having a minimum CRI of 80 with a correlated color temperature of (2700) (3000) (3500) (4100) (5000) K unless scheduled or noted otherwise.

d. Lumen output, rated lamp life, and lumen depreciation determined in accordance with IES testing procedures and equal to published values in (XYZ Manufacturer) (year/edition) catalog.

e. Replace defective lamps occurring within 90 days of beneficial occupancy.

f.. Approved Manufacturers: (List)

Lighting Fixture Schedule for Project XYZ

Tag	Description	Lamp	Ballast	Volt	Watt	Product
F1	Downlight 7" dia. clear alzak	(2) 3000K 13W/7T4/T/GX23/PH	HPF	277	35	LLL #333
F2	Downlight 1'X 1' parabolic clear alzak semi-specular louver	(3)3000K 18W/10T5/T/2G11	Electronic	277	51	AAA #222
F3	Downlight 2'X 2' slotted-T lay-in parabolic clear alzak semi-specular louver	(2) 3500K 40W/22.5T5/T/2G11	Standard Energy Efficient	277	87	QQQ #222

General Requirements

1. Lamps and ballasts shall meet applicable standards of the California Energy Commission (CEC), American National Standards Institute (ANSI), National Electrical Manufacturers Association (NEMA), and Underwriter's Laboratories (UL). Luminaires shall be UL listed. Ballasts and other materials shall be UL recognized or listed as appropriate.
2. Electronic ballasts shall be Brand X, model a.
3. Lamps shall be made by EEE, FFF, or GGG. Do not mix manufacturers of the same type lamp.
4. (Insert any other project requirements here.)

Extensive Specifications

Construction Specifications Institute (CSI) recommends that more extensive technical specifications be written for complex projects or projects which are being built overseas. Although significantly longer and more work for the specification writer, these specifications protect the design against substitution by inferior copy-cat products made by manufacturers over whom the designer has no control.

Manufacturer/Product References

Manufacturer	Product(s)
General Electric	Lamps, most types
Mitsubishi	Lamps, some types
Osram	Lamps, most types
Panasonic (Matsushita)	Lamps, some types
Philips	Lamps, most types
Sylvania	Lamps, most types
Advance	Ballasts, magnetic and electronic
Electronic Ballast Technology	Ballasts, electronic
Magnetek	Ballasts, magnetic and electronic
Quality Service Electronics	Ballasts, magnetic
Radionic	Ballasts, magnetic
Robertson	Ballasts, magnetic
Schumacher	Ballasts, magnetic
Valmont Electric	Ballasts, magnetic and electronic

(Inclusion in this list does not infer applicability or endorsement. Additional companies may also manufacturer these products.)

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ILUMINACION INTERIOR: PRINCIPIOS, DISEÑOS Y APLICACIONES.

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Lighting System Design Considerations

SECTION 2

As an introduction to the subject of lighting design, Section 1 discusses lighting design and lighting systems in general terms. On the other hand, Sections 5 through 18 provide specific design and evaluation information for the most common interior and exterior facilities, and Sections 3 and 4 cover economics and energy management, in depth, as they relate to lighting. This section is presented as a bridge between the general design and the specific application discussions by providing material on design considerations that apply to each of the application sections that follow. The 1981 Reference Volume provides the basic data and procedures as reference for design purposes.

PSYCHOLOGICAL CONSIDERATIONS

In the planning of lighting systems, lighting designers should be sensitive to more than simple task requirements for reading, typing, sewing, shaving, cooking, etc. They should, of course, be sensitive to the adverse effects of glare. They should also become sensitive to the uses of silhouette, sparkle, focal emphasis, color, and other patterns of spatial light, and become sensitive to the fact that the correct use of these patterns is fundamental in satisfying some space-activity requirements—as when they need to reinforce attraction or attention, reinforce impressions of spaciousness, stimulate sensations of spatial intimacy or warmth, and reinforce impressions of cheerfulness or playfulness.

Categories of Environmental Lighting. In considering the space-activity requirements mentioned above, there are basically two kinds of environmental lighting systems as discussed below:

1. *Lighting systems that flood a space somewhat indiscriminately with permissive illumination from general overhead luminaires.* These systems tend to be behaviorally neutral, in the sense that they tend *not* to exert an intentional reinforcing or guiding influence on user impressions or behavior. Instead, these systems are usually intended to permit:
a. Easy perception of reading or manual tasks.
b. Random circulation and unguided attention.
c. Flexible relocation of furniture and work centers without changes in the room lighting.

This type of system may, therefore, offer many advantages in regard to utility, flexibility and general clarity. But for some types of activities, the resulting diffusion and uniformity are rather significant shortcomings due to the often bland psychological effect of the room when it is lighted in this manner. (It should be recognized that this blandness can often be relieved by a sensitive use of surface color.)

2. *Systems that develop specific patterns of light and shade to reinforce selected information or room cues.* This kind of lighting is much more active behaviorally, in the sense that such systems are generally intended to reinforce a specific pattern of user impression or behavior. As such, this approach requires more specific design intentions.

These designs are often based on the idea that light can be a vehicle that influences users' selective attention or alters the information content in the visual field. As such, these lighting designs should be carefully evaluated for their role in establishing *cues* that reinforce users' understanding of their environment and the activities around them.

NOTE. References are [illegible]

In this regard consideration should be given to the following categories of visual experience:

a. The effect of light on user orientation and room comprehension. Some lighting patterns seem to affect personal orientation and user understanding of the room and its artifacts. For example, spotlighting or shelf-lighting affects user attention and consciousness; wall-lighting or corner-lighting affects user understanding of room size and shape. Together, these lighting elements can establish or modify the users' sense of visual limits or enclosure.

b. The effect of light on impressions of activity setting or mood. Other lighting patterns seem to involve the communication of ideas or impressions—with the suggestion that light is, in part, a medium that assists communication of spatial ideas and moods.

In this sense, spatial lighting patterns are becoming recognized as part of a visual language that can assist the designer in implementing impressions such as "somberness," "playfulness," "pleasantness," "tension," etc. Similarly, the designer can use light patterns to affect psychosocial impressions such as "intimacy," "privacy" and "warmth." In other words, lighting can be used in one way to produce a carnival-like atmosphere and in another way to produce a somber place for quiet meditation. Lighting can be used to produce a cold, impersonal public place or conversely, a warm, intimate place where one feels a greater sense of privacy. More than esthetic amenities are to be considered here, because these impressions or moods are often fundamental in satisfying some experience and activity requirements in a designed space.

"Light Structure" Models. There is considerable evidence that light can (and does) make an identifiable contribution to the quality of a room—and this contribution clearly goes beyond simplistic concepts of task visibility.

Qualitative influences can be identified through the use of "light structure" models that are developed with contemporary research methods in the behavioral sciences.[1-4] This concept is based on the theory that the experience of room lighting is, in part, an experience of recognizing and assimilating communicative patterns. There is the suggestion that patterns of light can convey information; and that the brain constructs an impression of the phenomenal world from this information. This concept of information content and "meaning" further suggests that lighting should be considered not merely as a stimulus but also as a "structure."

An example of a "light structure" model is shown in Fig. 2-1. Models have been developed to serve as a partial guide for the use of lighting effects appropriate for various task and non-task applications.

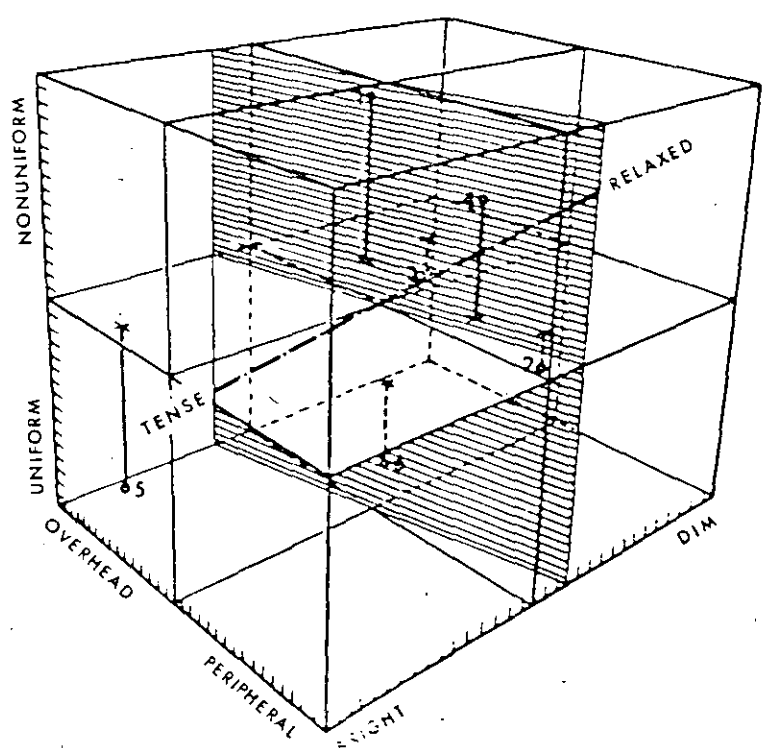

Fig. 2-1. Light structure model indicating lighting design decision for affecting impressions of relaxation (and tension).

Impressions of Relaxation. Impression of relaxation is an important subjective factor to be considered in the design of more casual areas, such as waiting rooms, lounges, some restaurants, etc. It is a subjective visual impression that appears to be reinforced by the following lighting influences (see Fig. 2-1):

1. Uniformity (*i.e.*, reinforced by nonuniform lighting).
2. Distribution (*i.e.*, reinforced more specifically by nonuniform wall lighting).
3. Color (*i.e.*, some studies indicate reinforcement by warm colors of white light).

Ongoing research in the behavioral sciences will provide valuable knowledge about the influences of lighting quality and quantity on the human organism. Lighting designers should seek the results of these studies for guidance in their design.

Impressions of Perceptual Clarity. Impressions of perceptual clarity are an important subjective factor to be considered in the design of work spaces. It is a subjective visual impression that appears to be reinforced by four lighting influences:

1. Luminance (*i.e.*, reinforced by higher luminance on the horizontal plane).
2. Locational (*i.e.*, reinforced by luminance in the central part of the room).
3. Color (*i.e.*, reinforced by cool tone, continuous spectrum light sources).
4. Distribution (*i.e.*, reinforced by peripheral wall brightness).

Impressions of Spaciousness. Impression of spaciousness is an important subjective factor to be considered in the design of circulation and assembly spaces, such as corridors, lobbies, assembly halls, etc. It is a subjective visual impression that appears to be reinforced by uniform, peripheral lighting. Color of white light (warm or cool) appears to be a negligible subjective factor.

ILLUMINATION CONSIDERATIONS

In this section, illumination considerations include: illuminance, luminance ratios, visual comfort, reflected glare, disability glare, veiling reflections, color and shadows. Each is an important consideration and no emphasis is intended by order of presentation or length of the discussions that follow (some have additional coverage in other sections of this volume and in the 1981 Reference Volume).

Illuminance Selection and Application

A New Illuminance Selection Procedure. Since 1958 the Society has been publishing single-value illuminance recommendations based on a method established at that time.[5] In recent years it became apparent, through on-going research and design experience, that it was time to move away from the single-value recommendations to a range approach—illuminance ranges accompanied by a weighting-factor guidance system reflecting lighting-performance trends found in research. In 1979 the Society established such a new procedure.[6]

Since early 1979 the Society's committees have applied the new procedure in preparing new interior illuminance recommendations* for this Handbook and for the Society's recommended practices and committee reports.

It is intended that this new procedure will accommodate a need for flexibility in determining illuminance levels so that lighting designers can tailor lighting systems to specific needs, especially in an energy conscious era. Such flexibility requires that additional information be available to effectively use the new range approach—a *lighting task* must be considered to be composed of the following:

1. The visual display (details to be seen).
2. The age of the observers.
3. The importance of speed and/or accuracy for visual performance.
4. The reflectance of the task (background on which the details are seen).

The visual display is the object being viewed—it will present some inherent visual difficulty. The age of the observer is a predictor of the condition of the observer's visual system. The importance of speed and/or accuracy distinguishes between casual, important and critical seeing requirements. The reflectance will determine the adaptation luminance produced by the illuminance. These characteristics, considered in concert, determine the appropriate amount of light for the *lighting task*. All four must be considered as comprising the lighting task.

In applying the new procedure the first step is to determine a range of illuminances appropriate for the visual difficulty presented by the visual display, the first of the above characteristics; and then to determine a target value from that range on the basis of the remaining three characteristics. The Society's application committees, on a consensus basis, have established appropriate

* At this time illuminances for exteriors and for certain applications continue to be provided as single-value recommendations established on [illegible] Fig. 2-2. See [illegible]

ranges of illuminances for various types of visual displays. Experience and judgment played an obvious, important role in the pairing of visual displays and these ranges. Nine ranges, called *Illuminance Categories*, have been established, patterned after those in the CIE Report No. 29.[7] These are designated "A" through "I," covering illuminance levels from 20 to 20,000 lux [2 to 2000 footcandles]. See Part I of Fig. 2-2. Further work of the application committees resulted in recommended ranges of illuminance for specific visual displays (tasks) and areas (see Fig. 2-2, Parts II and III).

Alternatively, if the inherent visual difficulty of a visual display has been measured in terms of its equivalent contrast, $\tilde{C}$, the Illuminance Category can be determined from Fig. 2-3.[6] This table of equivalent contrasts and Illuminance Categories was established on a consensus basis by the Society's Committee on Recommendations for Quality and Quantity of Illumination.

For a given visual display, a specific value of illuminance can be chosen from the recommended range only if the second, third, and fourth characteristics of the lighting task are known; *i.e.*, observers age, importance of speed and/or accuracy, and task reflectance. These should be determined at design time, by the designer in conjunction with the user. Specific target values of maintained illuminance *cannot* be determined before hand by the Society. Thus, the recommendations for most interior lighting tasks consist of an Illuminance Category determined by the visual display.

A guide for using the second, third and fourth characteristics of the lighting task, to determine a specific target value of illuminance, takes the form of a table of Weighting Factors (see Fig. 2-4). The designer or user determines the weight of each characteristic. A combined weighting factor then indicates whether the lower, middle or upper value of illuminance in the range is appropriate (see the procedure outlined below).

It can be seen that over-all design of this procedure makes it an illuminance *selection* procedure, where consensus-determined recommended ranges combine with user supplied information and judgment. The result is the determination of a specific target value of illuminance appropriate for the lighting task under consideration.

Limitations of the New Selection Procedure. This illuminance selection procedure is intended for use in interior environments where visual performance is an important consideration. It has been developed from a consideration of experience and research results from visual performance experiments. Its use is then limited to applications where this information can be applied directly. Thus, the illuminance selection procedure[6] is *not* used to determine the appropriate illuminances when:

1. Merchandising is the principal activity in the space and the advantageous display of goods is the purpose of lighting.
2. Advertising, sales promotion or attraction is the purpose of lighting.
3. Lighting is for sensors other than the eye, as in film and television applications.
4. The principle purpose of lighting is to achieve artistic effects.
5. Luminance ratios have a greater importance than adaptation luminance, as when it is desired to achieve a particular psychological or emotional setting rather than provide for visual performance.
6. Minimum illuminances are required for safety.
7. Maximum illuminances are established to prevent nonvisual effects, such as bleaching or deterioration due to ultraviolet and infrared radiation in a museum.
8. Illuminances are part of a test procedure for evaluating equipment, such as for surgical lighting systems.

Procedure for Selecting Illuminances. The procedure provides a method for determining a target maintained illuminance value for a single visual task, and as such will not assure an adequate illuminance level for a given space. This is especially true for those spaces in which a variety of visual tasks occurs. To help assure appropriate task illuminance as well as provide potential for increased energy savings, the designer should consider an illuminance target as the quantity of light required on the plane of the task.

The designer should be aware of, or assume, the potential visual tasks to be performed within the space. The illuminance level determined using this procedure is a function of the visual characteristics of that task. Therefore, the importance, duration and difficulty of each task in the space must be considered as each may dictate a different illuminance level. The importance of providing various illuminance levels can then be rated accordingly. Multiple level lighting systems, segregation of certain visual tasks, nonuniform lighting systems, or single level systems to meet the commonly occurring most critical visual task requirements, are options the designer must consider for system optimization.

The four step procedure described below requires the designer to select an Illuminance Cat-

Continued on page 2-20

Fig. 2-2. Currently Recommended Illuminance Categories and Illuminance Values for Lighting Design—Target Maintained Levels

The tabulation that follows is a consolidated listing of the Society's current illuminance recommendations. This listing is intended to guide the lighting designer in selecting an appropriate illuminance for design and evaluation of lighting systems.

Guidance is provided in two forms: (1). in Parts I, II and III as an *Illuminance Category*, representing a range of illuminances (see page 2-4 for a method of selecting a value within each illuminance range); and (2). in parts IV, V and VI as an *Illuminance Value*. Illuminance Categories are represented by letter designations A through I. Illuminance Values are given in *lux* with an approximate equivalence in *footcandles* and as such are intended as *target* (nominal) values with deviations expected. These target values also represent *maintained* values (see page 2-24).

This table has been divided into the six parts for ease of use. Part I provides a listing of both Illuminance Categories and Illuminance Values for generic types of interior activities and normally is to be used when Illuminance Categories for a specific Area/Activity cannot be found in parts II and III. Parts IV, V and VI provide target maintained Illuminance Values for outdoor facilities, sports and recreational areas, and transportation vehicles where special considerations apply as discussed on page 2-4.

In all cases the recommendations in this table are based on the assumption that the lighting will be properly designed to take into account the visual characteristics of the task. See the design information in the particular application sections in this Application Handbook for further recommendations.

I. Illuminance Categories and Illuminance Values for Generic Types of Activities in Interiors

Type of Activity	Illuminance Category	Ranges of Illuminances		Reference Work-Plane
		Lux	Footcandles	
Public spaces with dark surroundings	A	20-30-50	2-3-5	General lighting throughout spaces
Simple orientation for short temporary visits	B	50-75-100	5-7.5-10	
Working spaces where visual tasks are only occasionally performed	C	100-150-200	10-15-20	
Performance of visual tasks of high contrast or large size	D	200-300-500	20-30-50	Illuminance on task
Performance of visual tasks of medium contrast or small size	E	500-750-1000	50-75-100	
Performance of visual tasks of low contrast or very small size	F	1000-1500-2000	100-150-200	
Performance of visual tasks of low contrast and very small size over a prolonged period	G	2000-3000-5000	200-300-500	Illuminance on task, obtained by a combination of general and local (supplementary lighting)
Performance of very prolonged and exacting visual tasks	H	5000-7500-10000	500-750-1000	
Performance of very special visual tasks of extremely low contrast and small size	I	10000-15000-20000	1000-1500-2000	

II. Commercial, Institutional, Residential and Public Assembly Interiors

Area/Activity	Illuminance Category
Air terminals (see Transportation terminals)	
Armories	C[1]
Art galleries (see Museums)	
Auditoriums	
Assembly	C[1]
Social activity	B
Banks (also see Reading)	
Lobby	
General	C
Writing area	D
Tellers' stations	E[2]

Area/Activity	Illuminance Category
Barber shops and beauty parlors	E
Churches and synagogues	(see page 7-2)[4]
Club and lodge rooms	
Lounge and reading	D
Conference rooms	
Conferring	D
Critical seeing (refer to individual task)	
Court rooms	
Seating area	C
Court activity area	E[3]
Dance halls and discotheques	B

For footnotes, see page 2-[illegible]

Fig. 2-2. *Continued*

II. *Continued*

Area/Activity	Illuminance Category
Depots, terminals and stations	
(see **Transportation terminals**)	
Drafting	
Mylar	
High contrast media; India ink, plastic leads, soft graphite leads	E[3]
Low contrast media; hard graphite leads	F[3]
Vellum	
High contrast	E[3]
Low contrast	F[3]
Tracing paper	
High contrast	E[3]
Low contrast	F[3]
Overlays[5]	
Light table	C
Prints	
Blue line	E
Blueprints	E
Sepia prints	F
Educational facilities	
Classrooms	
General (see **Reading**)	
Drafting (see **Drafting**)	
Home economics (see **Residences**)	
Science laboratories	E
Lecture rooms	
Audience (see **Reading**)	
Demonstration	F
Music rooms (see **Reading**)	
Shops (see Part III, Industrial Group)	
Sight saving rooms	F
Study halls (see **Reading**)	
Typing (see **Reading**)	
Sports facilities (see Part V, Sports and Recreational Areas)	
Cafeterias (see **Food service facilities**)	
Dormitories (see **Residences**)	
Elevators, freight and passenger	C
Exhibition halls	C[1]
Fire halls (see Municipal buildings)	
Food service facilities	
Dining areas	
Cashier	D
Cleaning	C
Dining	B[6]
Food displays (see **Merchandising spaces**)	
Kitchen	E
Garages—parking	(see page 14-24)
Gasoline stations (see Service stations)	
Graphic design and material	
Color selection	F[11]
Charting and mapping	F
Graphs	E
Keylining	F
Layout and artwork	F
Photographs, moderate detail	E[13]

Area/Activity	Illuminance Category
Health care facilities	
Ambulance (local)	E
Anesthetizing	E
Autopsy and morgue[17,18]	
Autopsy, general	E
Autopsy table	G
Morgue, general	D
Museum	E
Cardiac function lab	E
Central sterile supply	
Inspection, general	E
Inspection	F
At sinks	E
Work areas, general	D
Processed storage	D
Corridors[17]	
Nursing areas—day	C
Nursing areas—night	B
Operating areas, delivery, recovery, and laboratory suites and service	E
Critical care areas[17]	
General	C
Examination	E
Surgical task lighting	H
Handwashing	F
Cystoscopy room[17,18]	E
Dental suite[17]	
General	D
Instrument tray	E
Oral cavity	H
Prosthetic laboratory, general	D
Prosthetic laboratory, work bench	E
Prosthetic laboratory, local	F
Recovery room, general	C
Recovery room, emergency examination	E
Dialysis unit, medical[17]	F
Elevators	C
EKG and specimen room[17]	
General	B
On equipment	C
Emergency outpatient[17]	
General	E
Local	F
Endoscopy rooms[17,18]	
General	E
Peritoneoscopy	D
Culdoscopy	D
Examination and treatment rooms[17]	
General	D
Local	E
Eye surgery[17,18]	F
Fracture room[17]	
General	E
Local	F
Inhalation therapy	D
Laboratories[17]	
Specimen collecting	E
Tissue laboratories	F
Microscopic reading room	D
Gross specimen review	F

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

Fig. 2-2. *Continued*

II. *Continued*

Area/Activity	Illuminance Category
Chemistry rooms	E
Bacteriology rooms	
General	E
Reading culture plates	F
Hematology	E
Linens	
Sorting soiled linen	D
Central (clean) linen room	D
Sewing room, general	D
Sewing room, work area	E
Linen closet	B
Lobby	C
Locker rooms	C
Medical illustration studio[17,18]	F
Medical records	E
Nurseries[17]	
General[18]	C
Observation and treatment	E
Nursing stations[17]	
General	D
Desk	E
Corridors, day	C
Corridors, night	A
Medication station	E
Obstetric delivery suite[17]	
Labor rooms	
General	C
Local	E
Birthing room	F[7]
Delivery area	
Scrub, general	G
General	G
Delivery table	(see page 7-15)
Resuscitation	G
Postdelivery recovery area	E
Substerilizing room	B
Occupational therapy[17]	
Work area, general	D
Work tables or benches	E
Patients' rooms[17]	
General[18]	B
Observation	A
Critical examination	E
Reading	D
Toilets	D
Pharmacy[17]	
General	E
Alcohol vault	D
Laminar flow bench	F
Night light	A
Parenteral solution room	D
Physical therapy departments	
Gymnasiums	D
Tank rooms	D
Treatment cubicles	D
Postanesthetic recovery room[17]	
General[18]	E
Local	H
Pulmonary function laboratories[17]	E

Area/Activity	Illuminance Category
Radiological suite[17]	
Diagnostic section	
General[18]	A
Waiting area	A
Radiographic/fluoroscopic room	A
Film sorting	F
Barium kitchen	E
Radiation therapy section	
General[18]	B
Waiting area	B
Isotope kitchen, general	E
Isotope kitchen, benches	E
Computerized radiotomography section	
Scanning room	B
Equipment maintenance room	E
Solarium	
General	C
Local for reading	D
Stairways	C
Surgical suite[17]	
Operating room, general[18]	F
Operating table	(see page 7-12)
Scrub room[18]	E
Instruments and sterile supply room	D
Clean up room, instruments	E
Anesthesia storage	C
Substerilizing room	C
Surgical induction room[17,18]	E
Surgical holding area[17,18]	E
Toilets	C
Utility room	D
Waiting areas[17]	
General	C
Local for reading	D
Homes (see Residences)	
Hospitals (see Health care facilities)	
Hotels	
Bathrooms, for grooming	D
Bedrooms, for reading	D
Corridors, elevators and stairs	C
Front desk	E[3]
Linen room	
Sewing	F
General	C
Lobby	
General lighting	C
Reading and working areas	D
Canopy (see Part IV, Outdoor Facilities)	
Kitchens (see Food service facilities or Residences)	
Libraries	
Reading areas (see Reading)	
Book stacks (vertical 760 millimeters (30 inches) above floor)	
Active stacks	D
Inactive stacks	B
Book repair and binding	D

For footnotes, see page 2-19. For illuminance values for each Illuminance Category, see page 2-5.

Fig. 2-2. *Continued*

II. *Continued*

Area/Activity	Illuminance Category
Cataloging	D[3]
Card files	E
Carrels, individual study areas (see **Reading**)	
Circulation desks	D
Map, picture and print rooms (see **Graphic design and material**)	
Audiovisual areas	D
Audio listening areas	D
Microform areas (see **Reading**)	
Locker rooms	C
Merchandising spaces	
Alteration room	F
Fitting room	
Dressing areas	D
Fitting areas	F
Locker rooms	C
Stock rooms	D
Wrapping and packaging	D
Sales transaction area	E
Circulation	(see page 8-6)[8]
Merchandise	(see page 8-6)[8]
Feature display	(see page 8-6)[8]
Show windows	(see page 8-6)[8]
Motels (see Hotels)	
Municipal buildings—fire and police	
Police	
Identification records	F
Jail cells and interrogation rooms	D
Fire hall	D
Museums	
Displays of non-sensitive materials	D
Displays of sensitive materials	(see page 7-29)[2]
Lobbies, general gallery areas, corridors	C
Restoration or conservation shops and laboratories	E
Nursing homes (see Health care facilities)	
Offices	
Accounting (see **Reading**)	
Conference areas (see **Conference rooms**)	
Drafting (see **Drafting**)	
General and private offices (see **Reading**)	
Libraries (see **Libraries**)	
Lobbies, lounges and reception areas	C
Mail sorting	E
Off-set printing and duplicating area	D
Post offices (see Offices)	
Reading	
Copied tasks	
Ditto copy	E[3]
Micro-fiche reader	B[12,13]
Mimeograph	D
Photographs, moderate detail	E[13]
Thermal copy, poor copy	F[3]
Xerograph	D
Xerography, 3rd generation and greater	E

Area/Activity	Illuminance Category
Electronic data processing tasks	
CRT screens	B[12,13]
Impact printer	
good ribbon	D
poor ribbon	E
2nd carbon and greater	E
Ink jet printer	D
Keyboard reading	D
Machine rooms	
Active operations	D
Tape storage	D
Machine area	C
Equipment service	E[10]
Thermal print	E
Handwritten tasks	
#3 pencil and softer leads	E[3]
#4 pencil and harder leads	F[3]
Ball-point pen	D[3]
Felt-tip pen	D
Handwritten carbon copies	E
Non photographically reproducible colors	F
Chalkboards	E[3]
Printed tasks	
6 point type	E[3]
8 and 10 point type	D[3]
Glossy magazines	D[13]
Maps	E
Newsprint	D
Typed originals	D
Typed 2nd carbon and later	E
Telephone books	E
Residences	
General lighting	
Conversation, relaxation and entertainment	B
Passage areas	B
Specific visual tasks[20]	
Dining	C
Grooming	
Makeup and shaving	D
Full-length mirror	D
Handcrafts and hobbies	
Workbench hobbies	
Ordinary tasks	D
Difficult tasks	E
Critical tasks	F
Easel hobbies	E
Ironing	D
Kitchen duties	
Kitchen counter	
Critical seeing	E
Noncritical	D
Kitchen range	
Difficult seeing	E
Noncritical	D
Kitchen sink	
Difficult seeing	E
Noncritical	D
Laundry	
Preparation and tubs	D
Washer and dryer	D

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

Fig. 2-2. Continued

II. Continued

Area/Activity	Illuminance Category
Music study (piano or organ)	
Simple scores	D
Advanced scores	E
Substand size scores	F
Reading	
In a chair	
Books, magazines and newspapers	D
Handwriting, reproductions and poor copies	E
In bed	
Normal	D
Prolonged serious or critical	E
Desk	
Primary task plane, casual	D
Primary task plane, study	E
Sewing	
Hand sewing	
Dark fabrics, low contrast	F
Light to medium fabrics	E
Occasional, high contrast	D
Machine sewing	
Dark fabrics, low contrast	F
Light to medium fabrics	E
Occasional, high contrast	D
Table games	D
Restaurants (see Food service facilities)	
Safety	(see page 2-45)
Schools (see Educational facilities)	
Service spaces (see also Storage rooms)	
Stairways, corridors	C
Elevators, freight and passenger	C
Toilets and wash rooms	C
Service stations	
Service bays (see Part III, Industrial Group)	
Sales room (see Merchandising spaces)	
Show windows	(see page 8-6)
Stairways (see Service spaces)	
Storage rooms (see Part III, Industrial Group)	
Stores (see Merchandising spaces and Show windows)	
Television	(see Section 11)
Theatre and motion picture houses (see Section 11)	
Toilets and washrooms	C
Transportation terminals	
Waiting room and lounge	C
Ticket counters	E
Baggage checking	D
Rest rooms	C
Concourse	B
Boarding area	C

III. Industrial Group

Area/Activity	Illuminance Category
Aircraft maintenance	(see page 9-12)[21]
Aircraft manufacturing	(see page 9-12)[21]
Assembly	
Simple	D
Moderately difficult	E
Difficult	F
Very difficult	G
Exacting	H
Automobile manufacturing	(see page 9-17)[21]
Bakeries	
Mixing room	D
Face of shelves	D
Inside of mixing bowl	D
Fermentation room	D
Make-up room	
Bread	D
Sweet yeast-raised products	D
Proofing room	D
Oven room	D
Fillings and other ingredients	D
Decorating and icing	
Mechanical	D
Hand	E
Scales and thermometers	D
Wrapping	D
Book binding	
Folding, assembling, pasting	D
Cutting, punching, stitching	E
Embossing and inspection	F
Breweries	
Brew house	D
Boiling and keg washing	D
Filling (bottles, cans, kegs)	D
Building construction (see Part IV, Outdoor Facilities)	
Building exteriors (see Part IV, Outdoor Facilities)	
Candy making	
Box department	D
Chocolate department	
Husking, winnowing, fat extraction, crushing and refining, feeding	D
Bean cleaning, sorting, dipping, packing, wrapping	D
Milling	E
Cream making	
Mixing, cooking, molding	D
Gum drops and jellied forms	D
Hand decorating	D
Hard candy	
Mixing, cooking, molding	D

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

Fig. 2-2. *Continued*

III. *Continued*

Area/Activity	Illuminance Category
Die cutting and sorting	E
Kiss making and wrapping	E
Canning and preserving	
Initial grading raw material samples	D
Tomatoes	E
Color grading and cutting rooms	F
Preparation	
Preliminary sorting	
Apricots and peaches	D
Tomatoes	E
Olives	F
Cutting and pitting	E
Final sorting	E
Canning	
Continuous-belt canning	E
Sink canning	E
Hand packing	D
Olives	E
Examination of canned samples	F
Container handling	
Inspection	F
Can unscramblers	E
Labeling and cartoning	D
Casting (see Foundries)	
Central stations (see Electric generating stations)	
Chemical plants (see Petroleum and chemical plants)	
Clay and concrete products	
Grinding, filter presses, kiln rooms	C
Molding, pressing, cleaning, trimming	D
Enameling	E
Color and glazing—rough work	E
Color and glazing—fine work	F
Cleaning and pressing industry	
Checking and sorting	E
Dry and wet cleaning and steaming	E
Inspection and spotting	G
Pressing	F
Repair and alteration	F
Cloth products	
Cloth inspection	I
Cutting	G
Sewing	G
Pressing	F
Clothing manufacture (men's)	
Receiving, opening, storing, shipping	D
Examining (perching)	I
Sponging, decating, winding, measuring	D
Piling up and marking	E
Cutting	G
Pattern making, preparation of trimming, piping, canvas and shoulder pads	E
Fitting, bundling, shading, stitching	D
Shops	F
Inspection	G
Pressing	F
Sewing	G
Control rooms (see Electric generating stations—interior)	
Corridors (see Service spaces)	
Cotton gin industry	
Overhead equipment—separators, driers, grid cleaners, stick machines, conveyers, feeders and catwalks	D
Gin stand	D
Control console	D
Lint cleaner	D
Bale press	D
Dairy farms (see Farms)	
Dairy products	
Fluid milk industry	
Boiler room	D
Bottle storage	D
Bottle sorting	E
Bottle washers	[22]
Can washers	D
Cooling equipment	D
Filling: inspection	E
Gauges (on face)	E
Laboratories	E
Meter panels (on face)	E
Pasteurizers	D
Separators	D
Storage refrigerator	D
Tanks, vats	
Light interiors	C
Dark interiors	E
Thermometer (on face)	E
Weighing room	D
Scales	E
Dispatch boards (see Electric generating stations—interior)	
Dredging (see Part IV, Outdoor Facilities)	
Electrical equipment manufacturing	
Impregnating	D
Insulating: coil winding	E
Electric generating stations—interior (see also Nuclear power plants)	
Air-conditioning equipment, air preheater and fan floor, ash sluicing	B
Auxiliaries, pumps, tanks, compressors, gauge area	C
Battery rooms	D
Boiler platforms	B
Burner platforms	C
Cable room	B
Coal handling systems	B
Coal pulverizer	C
Condensers, deaerator floor, evaporator floor, heater floors	B
Control rooms	
Main control boards	D[23]
Auxiliary control panels	D[23]
Operator's station	E[23]

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

Fig. 2-2. *Continued*

III. *Continued*

Area/Activity	Illuminance Category
Maintenance and wiring areas	D
Emergency operating lighting	C
Gauge reading	D
Hydrogen and carbon dioxide manifold area	C
Laboratory	E
Precipitators	B
Screen house	C
Soot or slag blower platform	C
Steam headers and throttles	B
Switchgear and motor control centers	D
Telephone and communication equipment rooms	D
Tunnels or galleries, piping and electrical	B
Turbine building	
Operating floor	D
Below operating floor	C
Visitor's gallery	C
Water treating area	D
Electric generating stations—exterior (see Part IV, Outdoor Facilities)	
Elevators (see Service spaces)	
Explosives manufacturing	
Hand furnaces, boiling tanks, stationary driers, stationary and gravity crystallizers	D
Mechanical furnace, generators and stills, mechanical driers, evaporators, filtration, mechanical crystallizers	D
Tanks for cooking, extractors, percolators, nitrators	D
Farms—dairy	
Milking operation area (milking parlor and stall barn)	
General	C
Cow's udder	D
Milk handling equipment and storage area (milk house or milk room)	
General	C
Washing area	E
Bulk tank interior	E
Loading platform	C
Feeding area (stall barn feed alley, pens, loose housing feed area)	C
Feed storage area—forage	
Haymow	A
Hay inspection area	C
Ladders and stairs	C
Silo	A
Silo room	C
Feed storage area—grain and concentrate	
Grain bin	A
Concentrate storage area	B
Feed processing area	B
Livestock housing area (community, maternity, individual calf pens, and loose housing holding and resting areas)	B
Machine storage area (garage and machine shed)	B
Farm shop area	
Active storage area	B
General shop area (machinery repair, rough sawing)	D
Rough bench and machine work (painting, fine storage, ordinary sheet metal work, welding, medium benchwork)	D
Medium bench and machine work (fine woodworking, drill press, metal lathe, grinder)	E
Miscellaneous areas	
Farm office (see Reading)	
Restrooms (see Service spaces)	
Pumphouse	C
Farms—poultry (see Poultry industry)	
Flour mills	
Rolling, sifting, purifying	E
Packing	D
Product control	F
Cleaning, screens, man lifts, aisleways and walkways, bin checking	D
Forge shops	E
Foundries	
Annealing (furnaces)	D
Cleaning	D
Core making	
Fine	F
Medium	E
Grinding and chipping	F
Inspection	
Fine	G
Medium	F
Molding	
Medium	F
Large	E
Pouring	E
Sorting	E
Cupola	C
Shakeout	D
Garages—service	
Repairs	E
Active traffic areas	C
Write-up	D
Glass works	
Mix and furnace rooms, pressing and lehr, glass-blowing machines	C
Grinding, cutting, silvering	D
Fine grinding, beveling, polishing	E
Inspection, etching and decorating	F
Glove manufacturing	
Pressing	G
Knitting	F
Sorting	F
Cutting	G
Sewing and inspection	G
Hangars (see Aircraft manufacturing)	
Hat manufacturing	
Dyeing, stiffening, braiding, cleaning, refining	E

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

Fig. 2-2. *Continued*

III. *Continued*

Area/Activity	Illuminance Category
Forming, sizing, pouncing, flanging, finishing, ironing	F
Sewing	G
Inspection	
Simple	D
Moderately difficult	E
Difficult	F
Very difficult	G
Exacting	H
Iron and steel manufacturing	(see page 9-63)[21]
Jewelry and watch manufacturing	G
Laundries	
Washing	D
Flat work ironing, weighing, listing, marking	D
Machine and press finishing, sorting	E
Fine hand ironing	E
Leather manufacturing	
Cleaning, tanning and stretching, vats	D
Cutting, fleshing and stuffing	D
Finishing and scarfing	E
Leather working	
Pressing, winding, glazing	F
Grading, matching, cutting, scarfing, sewing	G
Loading and unloading platforms (see Part IV, Outdoor Facilities)	
Locker rooms	C
Logging (see Part IV, Outdoor Facilities)	
Lumber yards (see Part IV, Outdoor Facilities)	
Machine shops	
Rough bench or machine work	D
Medium bench or machine work, ordinary automatic machines, rough grinding, medium buffing and polishing	E
Fine bench or machine work, fine automatic machines, medium grinding, fine buffing and polishing	G
Extra-fine bench or machine work, grinding, fine work	H
Materials handling	
Wrapping, packing, labeling	D
Picking stock, classifying	D
Loading, inside truck bodies and freight cars	C
Meat packing	
Slaughtering	D
Cleaning, cutting, cooking, grinding, canning, packing	D
Nuclear power plants (see also Electric generating stations)	
Auxiliary building, uncontrolled access areas	C
Controlled access areas	
Count room	E[23]
Laboratory	E
Health physics office	F
Medical aid room	F
Hot laundry	D
Storage room	C
Engineered safety features equipment	D
Diesel generator building	D
Fuel handling building	
Operating floor	D
Below operating floor	C
Off gas building	C
Radwaste building	D
Reactor building	
Operating floor	D
Below operating floor	C
Packing and boxing (see Materials handling)	
Paint manufacturing	
Processing	D
Mix comparison	F
Paint shops	
Dipping, simple spraying, firing	D
Rubbing, ordinary hand painting and finishing art, stencil and special spraying	D
Fine hand painting and finishing	E
Extra-fine hand painting and finishing	G
Paper-box manufacturing	E
Paper manufacturing	
Beaters, grinding, calendering	D
Finishing, cutting, trimming, papermaking machines	E
Hand counting, wet end of paper machine	E
Paper machine reel, paper inspection, and laboratories	F
Rewinder	F
Parking areas	(see page 14-24)
Petroleum and chemical plants	(see page 9-51)[21]
Plating	D
Polishing and burnishing (see Machine shops)	
Power plants (see Electric generating stations)	
Poultry industry (see also Farm—dairy)	
Brooding, production, and laying houses	
Feeding, inspection, cleaning	C
Charts and records	D
Thermometers, thermostats, time clocks	D
Hatcheries	
General area and loading platform	C
Inside incubators	D
Dubbing station	F
Sexing	H
Egg handling, packing, and shipping	
General cleanliness	E
Egg quality inspection	E
Loading platform, egg storage area, etc.	C
Egg processing	
General lighting	E
Fowl processing plant	
General (excluding killing and unloading area)	E
Government inspection station and grading stations	E
Unloading and killing area	C

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

Fig. 2-2. *Continued*

III. *Continued*

Area/Activity	Illuminance Category
Feed storage	
Grain, feed rations	C
Processing	C
Charts and records	D
Machine storage area (garage and machine shed)	B
Printing industries	
Type foundries	
Matrix making, dressing type	E
Font assembly—sorting	D
Casting	E
Printing plants	
Color inspection and appraisal	F
Machine composition	E
Composing room	E
Presses	E
Imposing stones	F
Proofreading	F
Electrotyping	
Molding, routing, finishing, leveling molds, trimming	E
Blocking, tinning	D
Electroplating, washing, backing	D
Photoengraving	
Etching, staging, blocking	D
Routing, finishing, proofing	E
Tint laying, masking	E
Receiving and shipping (see **Materials handling**)	
Railroad yards (see Part IV, Outdoor Facilities)	
Rubber goods—mechanical	(see page 9-56)[21]
Rubber tire manufacturing	(see page 9-56)[21]
Safety	(see page 2-45)
Sawmills	
Secondary log deck	B
Head saw (cutting area viewed by sawyer)	E
Head saw outfeed	B
Machine in-feeds (bull edger, resaws, edgers, trim, hula saws, planers)	B
Main mill floor (base lighting)	A
Sorting tables	D
Rough lumber grading	D
Finished lumber grading	F
Dry lumber warehouse (planer)	C
Dry kiln colling shed	B
Chipper infeed	B
Basement areas	
Active	A
Inactive	A
Filing room (work areas)	E
Service spaces (see also **Storage rooms**)	
Stairways, corridors	B
Elevators, freight and passenger	B
Toilets and wash rooms	C
Sheet metal works	
Miscellaneous machines, ordinary bench work	E
Presses, shears, stamps, spinning, medium bench work	E
Punches	E
Tin plate inspection, galvanized	F
Scribing	F
Shoe manufacturing—leather	
Cutting and stitching	
Cutting tables	G
Marking, buttonholing, skiving, sorting, vamping, counting	G
Stitching, dark materials	G
Making and finishing, nailers, sole layers, welt beaters and scarfers, trimmers, welters, lasters, edge setters, sluggers, randers, wheelers, treers, cleaning, spraying, buffing, polishing, embossing	F
Shoe manufacturing—rubber	
Washing, coating, mill run compounding	D
Varnishing, vulcanizing, calendering, upper and sole cutting	D
Sole rolling, lining; making and finishing processes	E
Soap manufacturing	
Kettle houses, cutting, soap chip and powder	D
Stamping, wrapping and packing, filling and packing soap powder	D
Stairways (see **Service spaces**)	
Steel (see **Iron and steel**)	
Storage battery manufacturing	D
Storage rooms or warehouses	
Inactive	B
Active	
Rough, bulky items	C
Small items	D
Storage yards (see Part IV, Outdoor Facilities)	
Structural steel fabrication	E
Sugar refining	
Grading	E
Color inspection	F
Testing	
General	D
Exacting tests, extra-fine instruments, scales, etc.	F
Textile mills	
Staple fiber preparation	
Stock dyeing, tinting	D
Sorting and grading (wool and cotton)	E[16]
Yarn manufacturing	
Opening and picking (chute feed)	D
Carding (nonwoven web formation)	D[24]
Drawing (gilling, pin drafting)	D
Combing	D[24]
Roving (slubbing, fly frame)	E
Spinning (cap spinning, twisting, texturing)	E
Yarn preparation	
Winding, quilling, twisting	E
Warping (beaming, sizing)	F[16]
Warp tie-in or drawing-in (automatic)	E

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see [illegible]

Fig. 2-2. *Continued*

III. *Continued*

Area/Activity	Illuminance Category
Fabric production	
Weaving, knitting, tufting	F
Inspection	G[16]
Finishing	
Fabric preparation (desizing, scouring, bleaching, singeing, and mercerization)	D
Fabric dyeing (printing)	D
Fabric finishing (calendaring, sanforizing, sueding, chemical treatment)	E[16]
Inspection	G[16,25]
Tobacco products	
Drying, stripping	D
Grading and sorting	F
Toilets and wash rooms (see Service spaces)	
Upholstering	F
Warehouse (see Storage rooms)	
Welding	
Orientation	D
Precision manual arc-welding	H
Woodworking	
Rough sawing and bench work	D
Sizing, planing, rough sanding, medium quality machine and bench work, gluing, veneering, cooperage	D
Fine bench and machine work, fine sanding and finishing	E

IV. Outdoor Facilities

Area/Activity	Lux	Footcandles
Building (construction)		
General construction	100	10
Excavation work	20	2
Building exteriors		
Entrances		
Active (pedestrian and/or conveyance)	50	5
Inactive (normally locked, infrequently used)	10	1
Vital locations or structures	50	5
Building surrounds	10	1
Buildings and monuments, floodlighted		
Bright surroundings		
Light surfaces	150	15
Medium light surfaces	200	20
Medium dark surfaces	300	30
Dark surfaces	500	50
Dark surroundings		
Light surfaces	50	5
Medium light surfaces	100	10
Medium dark surfaces	150	15
Dark surfaces	200	20
Bulletin and poster boards		
Bright surroundings		
Light surfaces	500	50
Dark surfaces	1000	100
Dark surroundings		
Light surfaces	200	20
Dark surfaces	500	50
Central station (see Electric generating stations—exterior)		
Coal yards (protective)	2	0.2
Dredging	20	2
Electric generating stations—exterior		
Boiler areas		
Catwalks, general areas	20	2
Stairs and platforms	50	5
Ground level areas including precipitators, FD and ID fans, bottom ash hoppers	50	5
Cooling towers		
Fan deck, platforms, stairs, valve areas	50	5
Pump areas	20	2
Fuel handling		
Barge unloading, car dumper, unloading hoppers, truck unloading, pumps, gas metering	50	5
Conveyors	20	2
Storage tanks	10	1
Coal storage piles, ash dumps	2	0.2
Hydroelectric		
Powerhouse roof, stairs, platform and intake decks	50	5
Inlet and discharge water area	2	0.2
Intake structures		
Deck and laydown area	50	5
Valve pits	20	2
Inlet water area	2	0.2
Parking areas		
Main plant parking	20	2
Secondary parking	10	1
Substation		
Horizontal general area	20	2
Vertical tasks	50	5
Transformer yards		
Horizontal general area	20	2
Vertical tasks	50	5
Turbine areas		
Building surrounds	20	2
Turbine and heater decks, unloading bays	50	5

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

Fig. 2-2. *Continued*

IV. *Continued*

Area/Activity	Lux	Footcandles
Entrances, stairs and platforms	50[3]	5[3]
Flags, floodlighted (see Bulletin and poster boards)		
Gardens[19]		
General lighting	5	0.5
Path, steps, away from house	10	1
Backgrounds—fences, walls, trees, shrubbery	20	2
Flower beds, rock gardens	50	5
Trees, shrubbery, when emphasized	50	5
Focal points, large	100	10
Focal points, small	200	20
Gasoline station (see Service stations in Part II)		
Highways (see page 14-8)		
Loading and unloading platforms	200	20
Freight car interiors	100	10
Logging (see also Sawmills)		
Yarding	30	3
Log loading and unloading	50	5
Log stowing (water)	5	0.5
Active log storage area (land)	5	0.5
Log booming area (water)—foot traffic	10	1
Active log handling area (water)	20	2
Log grading—water or land	50	5
Log bins (land)	20	2
Lumber yards	10	1
Parking areas (see page 14-24)		
Piers		
Freight	200	20
Passenger	200	20
Active shipping area surrounds	50	5
Prison yards	50	5
Quarries	50	5
Railroad yards		
Retarder classification yards		
Receiving yard		
Switch points	20	2
Body of yard	10	1
Hump area (vertical)	200	20
Control tower and retarder area (vertical)	100	10
Head end	50	5
Body	10	1
Pull-out end	20	2
Dispatch or forwarding yard	10	1
Hump and car rider classification yard		
Receiving yard		
Switch points	20	2
Body of yard	10	1
Hump area	50	5
Flat switching yards		
Side of cars (vertical)	50	5
Switch points	20	2
Trailer-on-flatcars		
Horizontal surface of flatcar	50	5
Hold-down points (vertical)	50	5
Container-on-flatcars	30	3
Roadways (see page 14-8)		
Sawmills (see also Logging)		
Cut-off saw	100	10
Log haul	20	2
Log hoist (side lift)	20	2
Primary log deck	100	10
Barker in-feed	300	30
Green chain	200 to 300[26]	20 to 30[26]
Lumber strapping	150 to 200[26]	15 to 20[26]
Lumber handling areas	20	2
Lumber loading areas	50	5
Wood chip storage piles	5	0.5
Service station (at grade)		
Dark surrounding		
Approach	15	1.5
Driveway	15	1.5
Pump island area	200	20
Building faces (exclusive of glass)	100[14]	10[14]
Service areas	30	3
Landscape highlights	20	2
Light surrounding		
Approach	30	3
Driveway	50	5
Pump island area	300	30
Building faces (exclusive of glass)	300[14]	30[14]
Service areas	70	7
Landscape highlights	50	5
Ship yards		
General	50	5
Ways	100	10
Fabrication areas	300	30
Smokestacks with advertising messages (see Bulletin and poster boards)		
Storage yards		
Active	200	20
Inactive	10	1
Streets (see page 14-8)		
Water tanks with advertising messages (see Bulletin and poster boards)		

For footnotes, see [illegible]

Fig. 2-2. *Continued*

V. Sports and Recreational Areas

Area/Activity	Lux	Footcandles
Archery (indoor)		
Target, tournament	500[14]	50[14]
Target, recreational	300[14]	30[14]
Shooting line, tournament	200	20
Shooting line, recreational	100	10
Archery (outdoor)		
Target, tournament	100[14]	10[14]
Target, recreational	50[14]	5[14]
Shooting line, tournament	100	10
Shooting line, recreational	50	5
Badminton		
Tournament	300	30
Club	200	20
Recreational	100	10
Baseball		
Major league		
Infield	1500	150
Outfield	1000	100
AA and AAA league		
Infield	700	70
Outfield	500	50
A and B league		
Infield	500	50
Outfield	300	30
C and D league		
Infield	300	30
Outfield	200	20
Semi-pro and municipal league		
Infield	200	20
Outfield	150	15
Recreational		
Infield	150	15
Outfield	100	10
Junior league (Class I and Class II)		
Infield	300	30
Outfield	200	20
On seats during game	20	2
On seats before and after game	50	5
Basketball		
College and professional	500	50
College intramural and high school	300	30
Recreational (outdoor)	100	10
Bathing beaches		
On land	10	1
150 feet from shore	30[14]	3[14]
Billiards (on table)		
Tournament	500	50
Recreational	300	30
Bowling		
Tournament		
Approaches	100	10
Lanes	200	20
Pins	500[14]	50[14]
Recreational		
Approaches	100	10
Lanes	100	10
Pins	300[14]	30[14]

Area/Activity	Lux	Footcandles
Bowling on the green		
Tournament	100	10
Recreational	50	5
Boxing or wrestling (ring)		
Championship	5000	500
Professional	2000	200
Amateur	1000	100
Seats during bout	20	2
Seats before and after bout	50	5
Casting—bait, dry-fly, wet-fly		
Pier or dock	100	10
Target (at 24 meters [80 feet] for bait casting and 15 meters [50 feet] for wet or dry-fly casting)	50[14]	5[14]
Combination (outdoor)		
Baseball/football		
Infield	200	20
Outfield and football	150	15
Industrial softball/football		
Infield	200	20
Outfield and football	150	15
Industrial softball/6-man football		
Infield	200	20
Outfield and football	150	15
Croquet or Roque		
Tournament	100	10
Recreational	50	5
Curling		
Tournament		
Tees	500	50
Rink	300	30
Recreational		
Tees	200	20
Rink	100	10
Fencing		
Exhibitions	500	50
Recreational	300	30
Football		
Distance from nearest sideline to the farthest row of spectators		
Class I Over 30 meters [100 feet]	1000	100
Class II 15 to 30 meters [50 to 100 feet]	500	50
Class III 9 to 15 meters [30 to 50 feet]	300	30
Class IV Under 9 meters [30 feet]	200	20
Class V. No fixed seating facilities	100	10

It is generally conceded that the distance between the spectators and the play is the first consideration in determining the class and lighting requirements. However, the potential seating capacity of the stands should also be considered and the following ratio is suggested: Class I for

F [illegible], see p. 2-19.

Fig. 2-2. *Continued*

V. *Continued*

Area/Activity	Lux	Footcandles
over 30,000 spectators: Class II for 10,000 to 30,000; Class III for 5000 to 10,000; and Class IV for under 5000 spectators.		
Football, Canadian—rugby (see Football)		
Football, six-man		
High school or college	200	20
Jr. high and recreational	100	10
Golf		
Tee	50	5
Fairway	10, 30[14]	1, 3[14]
Green	50	5
Driving range		
At 180 meters [200 yards]	50[14]	5[14]
Over tee area	100	10
Miniature	100	10
Practice putting green	100	10
Gymnasiums (refer to individual sports listed)		
General exercising and recreation	300	30
Handball		
Tournament	500	50
Club		
Indoor—four-wall or squash	300	30
Outdoor—two-court	200	20
Recreational		
Indoor—four-wall or squash	200	20
Outdoor—two-court	100	10
Hockey, field	200	20
Hockey, ice (indoor)		
College or professional	1000	100
Amateur	500	50
Recreational	200	20
Hockey, ice (outdoor)		
College or professional	500	50
Amateur	200	20
Recreational	100	10
Horse shoes		
Tournament	100	10
Recreational	50	5
Horse shows	200	20
Jai-alai		
Professional	1000	100
Amateur	700	70
Lacrosse	200	20
Playgrounds	50	5
Quoits	50	5
Racing (outdoor)		
Auto	200	20
Bicycle		
Tournament	300	30
Competitive	200	20
Recreational	100	10
Dog	300	30

Area/Activity	Lux	Footcandles
Dragstrip		
Staging area	100	10
Acceleration, 400 meters [1320 feet]	200	20
Deceleration, first 200 meters [660 feet]	150	15
Deceleration, second 200 meters [660 feet]	100	10
Shutdown, 250 meters [820 feet]	50	5
Horse	200	20
Motor (midget or motorcycle)	200	20
Racquetball (see Handball)		
Rifle 45 meters [50 yards]—outdoor)		
On targets	500[14]	50[14]
Firing point	100	10
Range	50	5
Rifle and pistol range (indoor)		
On targets	1000[14]	100[14]
Firing point	200	20
Range	100	10
Rodeo		
Arena		
Professional	500	50
Amateur	300	30
Recreational	100	10
Pens and chutes	50	5
Roque (see Croquet)		
Shuffleboard (indoor)		
Tournament	300	30
Recreational	200	20
Shuffleboard (outdoor)		
Tournament	100	10
Recreational	50	5
Skating		
Roller rink	100	10
Ice rink, indoor	100	10
Ice rink, outdoor	50	5
Lagoon, pond, or flooded area	10	1
Skeet		
Targets at 18 meters [60 feet]	300[14]	30[14]
Firing points	50	5
Skeet and trap (combination)		
Targets at 30 meters [100 feet] for trap, 18 meters [60 feet] for skeet	300[14]	30[14]
Firing points	50	5
Ski slope	10	1
Soccer (see Football)		
Softball		
Professional and championship		
Infield	500	50
Outfield	300	30
Semi-professional		
Infield	300	30
Outfield	200	20

For [illegible] 2-19

Fig. 2-2. *Continued*

V. *Continued*

Area/Activity	Lux	Footcandles
Industrial league		
Infield	200	20
Outfield	150	15
Recreational (6-pole)		
Infield	100	10
Outfield	70	7
Slow pitch, tournament—see industrial league		
Slow pitch, recreational (6-pole)—see recreational (6-pole)		
Squash (see Handball)		
Swimming (indoor)		
Exhibitions	500	50
Recreational	300	30
Underwater—1000 [100] lamp lumens per square meter [foot] of surface area		
Swimming (outdoor)		
Exhibitions	200	20
Recreational	100	10
Underwater—600 [60] lamp lumens per square meter [foot] of surface area		

Area/Activity	Lux	Footcandles
Tennis (indoor)		
Tournament	1000	100
Club	750	75
Recreational	500	50
Tennis (outdoor)		
Tournament	300	30
Club	200	20
Recreational	100	10
Tennis, platform	500	50
Tennis, table		
Tournament	500	50
Club	300	30
Recreational	200	20
Trap		
Targets at 30 meters [100 feet]	300[14]	30[14]
Firing points	50	5
Volley ball		
Tournament	200	20
Recreational	100	10

VI. Transportation Vehicles

Area/Activity	Lux	Footcandles
Aircraft		
Passenger compartment		
General	50	5
Reading (at seat)	200	20
Airports		
Hangar apron	10	1
Terminal building apron		
Parking area	5	0.5
Loading area	20[14]	2[14]
Rail conveyances		
Boarding or exiting	100	10
Fare box (rapid transit train)	150	15
Vestibule (commuter and inter-city trains)	100	10
Aisles	100	10
Advertising cards (rapid transit and commuter trains)	300	30
Back-lighted advertising cards (rapid transit and commuter trains)—860 cd/m² (250 fL) average maximum.		
Reading	300[3]	30[3]
Rest room (inter-city train)	200	20
Dining area (inter-city train)	500	50
Food preparation (inter-city train)	700	70
Lounge (inter-city train)		
General lighting	200	20
Table games	300	30
Sleeping car		
General lighting	100	10
Normal reading	300[3]	30[3]
Pr[illegible]	700[3]	70[3]

Area/Activity	Lux	Footcandles
Road Conveyances		
Step well and adjacent ground area	100	10
Fare box	150	15
General lighting (for seat selection and movement)		
City and inter-city buses at city stop	100	10
Inter-city bus at country stop	20	2
School bus while moving	150	15
School bus at stops	300	30
Advertising cards	300	30
Back-lighted advertising cards (see Rail conveyances)		
Reading	300[3]	30[3]
Emergency exit (school bus)	50	5
Ships		
Living Areas		
Staterooms and Cabins		
General lighting	100	10
Reading and writing	300[15.3]	30[15.3]
Prolonged seeing	700[16.3]	70[16.3]
Baths (general lighting)	100	10
Mirrors (personal grooming)	500	50
Barber shop and beauty parlor	500	50
On subject	1000	100
Day rooms		
General lighting	200[15]	20[15]
Desks	500[16.3]	50[16.3]
Dining rooms and messrooms	200	20

For [illegible]

Fig. 2-2. *Continued*

VI. *Continued*

Area/Activity	Lux	Footcandles
Enclosed promenades		
General lighting	100	10
Entrances and passageways		
General	100	10
Daytime embarkation	300	30
Gymnasiums		
General lighting	300	30
Hospital		
Dispensary (general lighting)	300[16]	30[16]
Operating room		
General lighting	500[16]	50[16]
Doctor's office	300[16]	30[16]
Operating table	20000	2000
Wards		
General lighting	100	10
Reading	300	30
Toilets	200	20
Libraries and lounges		
General lighting	200	20
Reading	300[16.3]	30[16.3]
Prolonged seeing	700[16.3]	70[16.3]
Purser's office	200[16]	20[16]
Shopping areas	200	20
Smoking rooms	150	15
Stairs and foyers	200	20
Recreation areas		
Ball rooms	150[15]	15[15]
Cocktail lounges	150[15]	15[15]
Swimming pools		
General	150[15]	15[15]
Underwater		
Outdoors—600 [60] lamp lumens/square meter [foot] of surface area		
Indoors—1000 [100] lamp lumens/square meter [foot] of surface area		
Theatre		
Auditorium		
General	100[15]	10[15]
During picture	1	0.1
Navigating Areas		
Chart room		
General	100	10
On chart table	500[16.3]	50[16.3]
Gyro room	200	20
Radar room	200	20
Radio room	100[15]	10[16]
Radio room, passenger foyer	100	10
Ship's offices		
General	200[16]	20[16]
On desks and work tables	500[16.3]	50[16.3]
Wheelhouse	100	10

Area/Activity	Lux	Footcandles
Service Areas		
Food preparation		
General	200[16]	20[16]
Butcher shop	200[16]	20[16]
Galley	300[16]	30[16]
Pantry	200[16]	20[16]
Thaw room	200[16]	20[16]
Sculleries	200[16]	20[16]
Food storage (non-refrigerated)	100	10
Refrigerated spaces (ship's stores)	50	5
Laundries		
General	200[16]	20[16]
Machine and press finishing, sorting	500	50
Lockers	50	5
Offices		
General	200	20
Reading	500[16.3]	50[16.3]
Passenger counter	500[16.3]	50[16.3]
Storerooms	50	5
Telephone exchange	200	20
Operating Areas		
Access and casing	100	10
Battery room	100	10
Boiler rooms	200[16]	20[16]
Cargo handling (weather deck)	50[16]	5[16]
Control stations (except navigating areas)		
General	200	20
Control consoles	300	30
Gauge and control boards	300	30
Switchboards	300	30
Engine rooms	200[16]	20[16]
Generator and switchboard rooms	200[16]	20[16]
Fan rooms (ventilation & air conditioning)	100	10
Motor rooms	200	20
Motor generator rooms (cargo handling)	100	10
Pump room	100	10
Shaft alley	100	10
Shaft alley escape	30	3
Steering gear room	200	20
Windlass rooms	100	10
Workshops		
General	300[16]	30[16]
On top of work bench	500[16]	50[16]
Tailor shop	500[16]	50[16]
Cargo holds		
Permanent luminaires	30[16]	3[16]
Passageways and trunks	100	10

[1] Include provisions for higher levels for exhibitions.

[2] Specific limits are provided to minimize deterioration effects.

[3] Task subject to veiling reflections. Illuminance listed is not an ESI value. Currently, insufficient experience in the use of ESI target values precludes the direct use of Equivalent Sphere Illumination in the present consensus approach to recommend illuminance values. Equivalent Sphere Illumination may be used as a tool in determining the effectiveness of controlling veiling reflections and as a part of the evaluation of lighting systems.

[4] Illuminance values are listed based on experience and [illegible]. Values relate to needs during various religious ceremonies.

[5] Degradation factors [illegible] factor for [illegible] (overlay) Used material—[illegible]

Fig. 2-2. *Continued*

[6] Provide higher level over food service or selection areas.

[7] Supplying illumination as in delivery room must be available.

[8] Illuminance values developed for various degrees of store area activity.

[9] Or not less than ⅕ the level in the adjacent areas.

[10] Only when actual equipment service is in process. May be achieved by a general lighting system or by localized or portable equipment.

[11] For color matching, the spectral quality of the color of the light source is important.

[12] Veiling reflections may be produced on glass surfaces. It may be necessary to treat plus weighting factors as minus in order to obtain proper illuminance.

[13] Especially subject to veiling reflections. It may be necessary to shield the task or to reorient it.

[14] Vertical.

[15] Illuminance values may vary widely, depending upon the effect desired, the decorative scheme, and the use made of the room.

[16] Supplementary lighting should be provided in this space to produce the higher levels required for specific seeing tasks involved.

[17] Good to high color rendering capability should be considered in these areas. As lamps of higher luminous efficacy and higher color rendering capability become available and economically feasible, they should be applied in all areas of health care facilities.

[18] Variable (dimming or switching).

[19] Values based on a 25 per cent reflectance, which is average for vegetation and typical outdoor surfaces. These figures must be adjusted to specific reflectances of materials lighted for equivalent brightnesses. Levels give satisfactory brightness patterns when viewed from dimly lighted terraces or interiors. When viewed from dark areas they may be reduced by at least ½; or they may be doubled when a high key is desired.

[20] General lighting should not be less than ⅓ of visual task illuminance nor less than 200 lux [20 footcandles].

[21] Industry representatives have established a table of single illuminance values which, in their opinion, can be used in preference to employing reference 6. Illuminance values for specific operations can also be determined using illuminance categories of similar tasks and activities found in this table and the application of the appropriate weighting factors in Fig. 2-4.

[22] Special lighting such that (1) the luminous area is large enough to cover the surface which is being inspected and (2) the luminance is within the limits necessary to obtain comfortable contrast conditions. This involves the use of sources of large area and relatively low luminance in which the source luminance is the principal factor rather than the illuminance produced at a given point.

[23] Maximum levels—controlled system.

[24] Additional lighting needs to be provided for maintenance only.

[25] Color temperature of the light source is important for color matching.

[26] Select upper level for high speed conveyor systems. For grading redwood lumber 3000 lux [300 footcandles] is required.

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egory based on types of visual tasks to be performed in the design space. Each category prescribes a range of illuminances permitting the designer to establish a target illuminance responsive to several task and observer characteristics, including the importance of speed and/or accuracy in performing the task, and the age of the observer.

Step 1. Define Visual Task. Determine the type of activity for which the level of lighting is to be selected (*e.g.*, reading typed originals). Also establish the plane of the visual task to which the illuminance level is to be applied.

Step 2. Select Illuminance Category. Select the appropriate Illuminance Category from one of the following:

a. Fig. 2-2, Parts II and III—when a review of typical tasks reveals specific task types.

b. Fig. 2-2, Part I—if specific tasks cannot be established, generic task descriptions must be used.

c. Fig. 2-3—if an equivalent contrast ($\tilde{C}$) has been determ[illegible]

Step 3. Determine Illuminance Range. Referring to Fig. 2-2, Part I, and using the Illuminance Category selected in Step 2, determine the recommended range of illuminances.

Because of the characteristics of the functions in Categories A through C, illuminances are required over the entire area of the interior space considered. For instance, in a lobby area, one visual task is walking to an elevator lobby. This visual task remains constant throughout time and space; therefore, a general level of illumination should be provided throughout the lobby.

Categories D through F, however, are for tasks which remain relatively fixed at one location for meaningful visual performance, although tasks may change considerably from one location to another within a given space. For example, an accounting office may have a secretarial pool where reading felt-tip-pen hand-written notes and proofreading typed originals are prominent tasks, while at the same time accountants may be reading computer printouts. Each task calls [illegible] illuminance [illegible] factory visual performance, and so each task should be lighted accordingly. Therefore, Categories D through F should be applied to the appropriate task areas only.

Categories G through I are for extremely difficult visual tasks, and may be difficult to illuminate. For practical and economical reasons, lighting systems for these tasks may require a combination of general over-all illumination and task area illumination. Because of the unusual conditions associated with tasks in Categories G through I, very careful analysis is recommended.

Step 4. Establish Illuminance Target Value. From the range of illuminances determined in Step 3, a design illuminance is to be established based upon several factors. These factors vary depending upon the visual task. For Illuminance Categories A through C use step *a*, below, for establishing a design illuminance. Use step *b* for Categories D through I.

a. For Categories A Through C. To establish an appropriate illuminance target value, the designer should be familiar with the design space and intended occupants, to the extent that the following information can be determined:

(1) Occupants ages (*e.g.*, if the design space is an elevator lobby in a senior citizens' housing complex, then establish ages of the housing occupants).

(2) Surface reflectances (*e.g.*, if the design space is a building lobby, and the floor is to be slate, with walls of teak, their reflectances must be established).

After the above information has been established, the designer may determine an appropriate target value from the Illuminance Category by using Fig. 2-4a as follows:

(a) Review each of the two characteristics and determine the appropriate weighting factors (−1, 0, +1).

(b) Add the two factors algebraically taking into account the signs.

(c) If the total factor is −2, use the lowest of the three illuminances in the established range; if the total factor is +2, use the highest of the three illuminances; otherwise use the middle illuminance.

b. For Categories D Through I. At this point the designer should become thoroughly familiar with the anticipated task and anticipated space occupants to the extent that the following information can be established:

(1) The precise task considered (*e.g.*, if the [illegible] computer printouts, obtain a

Fig. 2-4. Weighting Factors to be Considered in Selecting Specific Illuminance Within Ranges of Values for Each Category.

a. For Illuminance Categories A through C

Room and Occupant Characteristics	Weighting Factor		
	−1	0	+1
Occupants ages	Under 40	40–55	Over 55
Room surface reflectances*	Greater than 70 per cent	30 to 70 per cent	Less than 30 per cent

b. For Illuminance Categories D through I

Task and Worker Characteristics	Weighting Factor		
	−1	0	+1
Workers ages	Under 40	40–55	Over 55
Speed and/or accuracy**	Not important	Important	Critical
Reflectance of task background***	Greater than 70 per cent	30 to 70	Less than 30 per cent

* Average weighted surface reflectances, including wall, floor and ceiling reflectances, if they encompass a large portion of the task area or visual surround. For instance, in an elevator lobby, where the ceiling height is 7.6 meters (25 feet), neither the task nor the visual surround encompass the ceiling, so only the floor and wall reflectances would be considered.

** In determining whether speed and/or accuracy is not important, important or critical, the following questions need to be answered: What are the time limitations? How important is it to perform the task rapidly? Will errors produce an unsafe condition or product? Will errors reduce productivity and be costly? For example, in reading for leisure there are no time limitations and it is not important to read rapidly. Errors will not be costly and will not be related to safety. Thus, speed and/or accuracy is not important. If however, prescription notes are to be read by a pharmacist, accuracy is critical because errors could produce an unsafe condition and time is important for customer relations.

*** The task background is that portion of the task upon which the meaningful visual display is exhibited. For example, on this page the meaningful visual display includes each letter which combines with other letters to form words and phrases. The display medium, or task background, is the paper, which has a reflectance of approximately 85 per cent.

Fig. 2-3. Illuminance Categories of Fig. 2-2, Part I, for Measured Equivalent Contrast Values of Task Visual Displays.

Equivalent Contrast $\tilde{C}$†	Illuminance Category**
over 1.0	*
.75–1.0	D
.62– .75	E
.50– .62	F
.40– .50	G
.30– .40	H
under .30	I

* Use 200 lux [20 footcandles] and omit use of Fig. 2-4 and footnote (**) below.

** If task reflectance is between 5 and 20 per cent use next higher illuminance category; *i.e.*, D to E, E to F, etc. If less than 5 per cent use two categories higher.

† As determined using a visibility meter and the procedure outlined in Reference 8.

Note: Although specific equivalent contrasts are established scientifically, a consensus [illegible] has been [illegible] establishing corresponding Illuminance [illegible] sample to determine the reflectance of the computer paper alone—this is the task background reflectance).

(2) Occupant ages (*e.g.*, if the task is writing payroll checks, and only the senior accountants perform this task, then establish the approximate ages of the senior accountants).

(3) Importance of speed (*e.g.*, if the occupants are under abnormal time constraints, as in a newscopy proofreading room, then speed might be considered critical).

(4) Importance of accuracy (*e.g.*, if accuracy could be a life-death matter as in prescription reading/filling, then accuracy is considered critical).

After the above information has been established, the designer may determine an appropriate target value from the Illuminance Category by using Fig. 2-4b as follows:

(a) Review each of the three characteristics and determine the appropriate weighting factors (−1, 0, +1).

(b) Add the three factors algebraically, taking into account the signs.

(c) If the total weighting factor is −2 or −3, use the lowest of the three illuminances in the established range; if the total factor is +2 or +3, use the highest of the three illuminances; otherwise use the middle illuminance.

(d) When designing spaces with tasks in Categories D through I, it is recommended that 200 lux [20 footcandles] be regarded as the minimum acceptable horizontal illuminance for the general, non-task area.

Proper determination of the weighting factors requires information and judgment on the part of the user. Guessed values are poor substitutes for information and can result in over or under design. Whenever possible, design information should be used in determining values of the weighting factors for each characteristic of the lighting task.

Simplification of Steps 3 and 4. Fig. 2-5 is provided as a means of combining the tables referred to in Steps 3 and 4 as a short cut method once Steps 3 and 4 are understood. In Fig. 2-5, the Illuminance Category from Step 2 and Weighting Factor information (age, speed and accuracy, and reflectance) are used to directly select the illuminances in lux (if footcandles are desired, divide by 10). For a rough estimate of reflectances a gray scale marked with per cent reflectances may prove helpful. Where surfaces are in color, the Munsell value scales for judging reflectance will [illegible] und to be helpful. See Section [illegible] [illegible]erence Volume

Example of Illuminance Selection. A classroom in a high school is to be relighted. The designer in consultation with the teacher and school administrators has determined the following:

1. The task is reading mimeograph material with a reflectance of about 80 per cent.
2. The students are teenagers.
3. The students practice typing to improve speed and accuracy, thus speed and accuracy are considered to be important, but not critical.

Using the above step-by-step procedure:

Step 1. The visual task is defined above.

Step 2. Referring to Fig. 2-2 an Illuminance Category of D is found under Reading, Mimeograph, on page 2-8.

Step 3. Referring to Part I of Fig. 2-2, the illuminance range is found to be 200-300-500 lux [20-30-50 footcandles].

Step 4. Referring to Fig. 2-4b and the above information, the weighting factors selected are: −1 for workers' ages; 0 for speed and/or accuracy; and −1 for reflectance of task background. The algebraic sum is −1 +0 −1 = −2. Therefore, the illuminance to be selected is the lowest valu *i.e.*, 200 lux [20 footcandles].

If the task were reading #3 pencil handwriting on 80 per cent reflectance paper and the students were older (an adult education course), the Illuminance Category would change to E, the illuminance range would become 500-750-1000 lux [50-75-100 footcandles], and the weighting factor for age would be 0. The new algebraic sum of the weighting factors is 0 + 0 −1 = −1. Therefore, the illuminance to be selected is the mid value in the new range, *i.e.*, 750 lux [75 footcandles].

By referring to Fig. 2-5 after step 2, the illuminance can be selected without referring to Part I of Fig. 2-2 or to Fig. 2-4.

Application of Illuminance Values Selected. The use of selected illuminance values may be influenced by work areas involving many visual tasks. The designer, usually through client/occupant/designer interaction, must establish the task of prime importance, with the subsequent heirarchy of remaining tasks. Similarly, the time duration of each task, worker ages, expected task performance, and task characteristics must be determined. If all or many of the tasks require similar lighting qualities, then the designer might design the lighting system to meet one task, and will therefore meet the m[illegible]jority of the other tasks' requirements. If ho[illegible]ever, the tasks vary considerably in lighting requirements, then the designer should consid[illegible]

Fig. 2-5. Illuminance Values, Maintained, in Lux, for a Combination of Illuminance Categories and User, Room and Task Characteristics (For Illuminance in Footcandles, Divide by 10).

a. General Lighting Throughout Room

Weighting Factors		Illuminance Categories		
Average of Occupants Ages	Average Room Surface Reflectance (per cent)	A	B	C
Under 40	Over 70	20	50	100
	30-70	20	50	100
	Under 30	20	50	100
40-55	Over 70	20	50	100
	30-70	30	75	150
	Under 30	50	100	200
Over 55	Over 70	30	75	150
	30-70	50	100	200
	Under 30	50	100	200

b. Illuminance on Task

Weighting Factors			Illuminance Categories					
Average of Workers Ages	Demand for Speed and/or Accuracy*	Task Background Reflectance (per cent)	D	E	F	G**	H**	I**
Under 40	NI	Over 70	200	500	1000	2000	5000	10000
		30-70	200	500	1000	2000	5000	10000
		Under 30	300	750	1500	3000	7500	15000
	I	Over 70	200	500	1000	2000	5000	10000
		30-70	300	750	1500	3000	7500	15000
		Under 30	300	750	1500	3000	7500	15000
	C	Over 70	300	750	1500	3000	7500	15000
		30-70	300	750	1500	3000	7500	15000
		Under 30	300	750	1500	3000	7500	15000
40-55	NI	Over 70	200	500	1000	2000	5000	10000
		30-70	300	750	1500	3000	7500	15000
		Under 30	300	750	1500	3000	7500	15000
	I	Over 70	300	750	1500	3000	7500	15000
		30-70	300	750	1500	3000	7500	15000
		Under 30	300	750	1500	3000	7500	15000
	C	Over 70	300	750	1500	3000	7500	15000
		30-70	300	750	1500	3000	7500	15000
		Under 30	500	1000	2000	5000	10000	20000
Over 55	NI	Over 70	300	750	1500	3000	7500	15000
		30-70	300	750	1500	3000	7500	15000
		Under 30	300	750	1500	3000	7500	15000
	I	Over 70	300	750	1500	3000	7500	15000
		30-70	300	750	1500	3000	7500	15000
		Under 30	500	1000	2000	5000	10000	20000
	C	Over 70	300	750	1500	3000	7500	15000
		30-70	500	1000	2000	5000	10000	20000
		Under 30	500	1000	2000	5000	10000	20000

* NI = not important, I = important, and C = critical

** Obtained by a combination of general and supplementary lighting multiple level systems, variable control systems or a combination of systems in order to accommodate a number of tasks of varying visual requirements in an energy-economic manner.

The target values obtained from this procedure are conventional illuminance values in lux or footcandles and are values to be maintained in service. For many visual displays this is a reasonable indicator of display visibility. Some displays, however, can exhibit veiling reflections and serious contrast loss as indicated by a superscript 3 in Fig. 2-2. In these cases, the illuminance alone is not a reliable indicator of visibility; the contrast of the display must also be taken into account. Equivalent sphere illumination (ESI) is a measure of visibility that takes both illuminance and contrast into account.

Currently, insufficient experience with the use of ESI target values precludes the direct use of ESI values as part of the consensus approach recommendation process. Thus, the recommendations are in conventional units of illuminance. However, ESI may be used as a tool in determining the effectiveness of controlling veiling reflection and as part of the evaluation of lighting systems.

The target values of illuminance for Illuminance Categories A to C are *average maintained illuminances*, and the lumen method, using zonal-cavity calculated coefficients of utilization for luminaires, or for daylighting, predicts such average illuminance values. The target values of illuminance obtained for visual displays in the last six categories (D through I) are localized values, that is, *maintained illuminance on the task* and point calculation methods are appropriate. In either case the procedure for determining light loss factors should be used in calculating maintained average or point illuminances. See page 9-1 of the 1981 Reference Volume.

Luminance Ratios

Luminances in the visual field which surrounds an object or a task can have different effects on visual ability depending upon the areas involved, their location with respect to the line of sight, and their actual luminances as compared with that of the task. These luminances may produce a decrement in visual ability, visual comfort, or both. For this reason, the luminances of the various surfaces in the visual field should be controlled and limited.

When there is a large difference in luminances [illegible]een areas (a high lumi[illegible]nce ratio), for example a large difference between the luminance of a task and that of a bright window during the day or a dark window at night, there may be losses in the ability to see the task display if one looks away from the task to the window and then back at the task. This is due to transient adaptation and the changes in sensitivity of the eye (see Section 3 of the 1981 Reference Volume). If the ratio is high, there also may be a reaction of discomfort.

As a guide for design purposes, luminance ratio limits have been recommended for various applications, such as offices, educational facilities, institutions, industrial areas and residences (see Sections 5 through 10). For additional guidance, recommended limits of reflectances (both upper and lower), of large area surfaces, are given for the same applications. The use of these reflectance limits, along with a selection of appropriate colors, should help to control luminances and keep within the ratio limits without creating a bland and uninteresting environment.

Visual Comfort

Visual discomfort may occur when excessively high luminances are within the visual field. High luminances also can distract and even reduce visibility (see above).

When luminances and their relationships in the field of view cause visual discomfort but do not necessarily interfere with seeing, the sensation experienced by an observer is termed *discomfort glare*. It usually is produced by direct glare from light sources or luminaires which are too bright, inadequately shielded, or of too great an area. Discomfort glare also can be caused by annoying reflection of bright areas in specular surfaces (known as reflected glare). The latter should not be confused with veiling reflections which impair visual performance rather than cause discomfort.

Both maximum and average luminances of a potential glare source are significant factors in evoking a glare sensation, but average luminances are recognized as being the more pertinent. A rating system based on the degree of freedom from discomfort glare in a lighting installation called Visual Comfort Probability (VCP), uses average luminances. This system evaluates lighting systems in terms of direct glare. It is an estimator of the fraction of the observer population which will accept the lighting system and its environment as being comfortable, using the perception of glare due to direct light from luminaires to the observer as a criterion.

This evaluation of comfort is based on the following factors which influence subjective judgments of visual comfort: room size and shape; room surface reflectances; illuminance levels; luminaire type, size, luminance, maximum luminance and light distribution; number and location of luminaires; luminance of the entire field of view; observer location and line of sight; and differences in individual glare sensitivity.

Extensive investigations and analyses (See page 3-12 in the 1981 Reference Volume) have resulted in a comprehensive standard discomfort glare evaluation procedure which takes these factors into account. The final product of the evaluation procedure is a Visual Comfort Probability (VCP) rating of the lighting system expressed as a per cent of people viewing along a specified line of sight who will be expected to find it acceptable.

VCP can be calculated for specific lighting systems and given observer lines of sight (see page 9-71 in the 1981 Reference Volume). However, in order to systematize the calculations, to aid in the development of VCP tables, and to permit comparison of luminaires, standard conditions have been adopted:[9]

1. An initial level of 1000 lux [100 footcandles].
2. Room surfaces of 80 per cent for the effective ceiling cavity reflectance, 50 per cent for the wall reflectance and 20 per cent for the effective floor cavity reflectance.
3. Mounting heights above the floor of 2.6, 3, 4 and 4.9 meters (8.5, 10, 13 and 16 feet).
4. A range of room dimensions to include square, long-narrow, and short-wide rooms.
5. A standard layout involving luminaires uniformly distributed throughout the space.
6. An observation point 1.2 meters (four feet) in front of the center of the rear wall and 1.2 meters (four feet) above the floor.
7. A horizontal line of sight directly forward.
8. A limit to the field of view corresponding to an angle of 53 degrees above and directly forward from the observer.

By consensus, direct glare will not be a problem in lighting installations if all three of the following conditions are satisfied.[9]

1. The VCP is 70 or more;
2. The ratio of maximum*-to-average luminaire luminance does not exceed five to one at 45, 55, 65, 75 and 85 degrees from nadir crosswise and lengthwise; and
3. Maximum luminaire luminances crosswise and lengthwise do not exceed the following values:

Angle Above Nadir (degrees)	Maximum Luminance (candelas per square meter)	(footlamberts)
45	7710	2250
55	5500	1605
65	3860	1125
75	2570	750
85	1695	495

The principal research used to establish the VCP system involved luminances of a magnitude compatible with fluorescent lamps. Further, the most extensive field validification utilized lighting systems typical of fluorescent luminaires. Although the mathematics can be applied to virtually any situation, extrapolation to significantly different visual fields has not been validified.

The VCP system is based on empirical relations derived from a variety of experiments. It has been concluded that differences of 5 percentage points or less are meaningless, *i.e.*, if two lighting systems do not differ by more than 5 in VCP, the VCP system provides no basis for judging a difference in visual comfort. Here, it is assumed that this entire difference is due to the lighting systems. Artifacts introduced by using different computational procedures for two lighting systems can further spread the VCP values for two systems that are not demonstrably different.[10]

An alternate simplified method of providing an acceptable degree of comfort has been derived from the formulas for discomfort glare. This simplified method is based on the premise that luminaire designers do not design different units for rooms of different sizes, but consider the probable range of room sizes and design for the "commonly found more difficult" potential glare situation. (In rooms less than 6 meters (20 feet) in length and width, the luminaires are largely out of the field of view.) This simplified method is only applicable to flat bottom luminaires. See page 9-73 in the 1981 Reference Volume.[11]

Reducing Discomfort Glare. Discomfort glare can be reduced by:

1. Decreasing the luminance of lighting equipment or other sources of objectionable glare, such as windows and overhead skylights, relative to the over-all luminance.
2. Diminishing the area of uncomfortable luminances (with level of constant luminance).
3. Increasing the angle between the source and line of sight.
4. Increasing the general luminance in the room (se[illegible] recommended luminance ratios).

* Brightest 6.54 square centimeters [illegible] area.

Reflected Glare

Glare resulting from specular reflections of high luminance in polished or glossy surfaces is known as reflected glare and, as mentioned above, it may cause discomfort. If the reflections are of high luminance and of significant area, they also may produce disability glare if near the line of sight and may prove distracting to workers.[12] Bright reflections of small size often do not cause reflected glare but provide *enhancing reflections*, desired sparkle, such as in jewelry, glassware or tableware on display. When specular reflections of high or low luminance veil the visual task, this effect is known as veiling reflections. (See below.)

There is little in the way of research to quantify the visual impact of reflections in specular surfaces. Generally, the conditions which cause reflected glare are sufficiently obvious as to indicate the lighting solution. In general, large area low luminance sources are preferred where the task has even a small degree of specularity. Additional considerations in this regard are discussed in the various application sections. For example, finishes on office furniture and equipment should be matte.

Disability Glare

Disability glare is caused by stray light within the eyes, producing a veiling luminance upon the retinal image of an object to be seen, resulting in reduced object visibility (see page 3-12 in the 1981 Reference Volume). In most interior lighting situations, disability glare does not present a severe problem if discomfort glare and reflected glare are minimized and luminance ratios are controlled as discussed above. However, in the case of roadway lighting, vehicle headlights, and certain types of industrial lighting, the effects of stray light may have to be taken into consideration.

Veiling Reflections

For years lighting designers and those engaged in vision research have recognized that substantial losses in contrast, hence, in visibility and visual performance, can result when light sources are reflected in specular or semi-specular visual tasks.[13, 14] This has been known as the general subject of reflected glare. The effects vary from the reflection of an incandescent filament in a polished metal surface at one extreme, in which case the result is annoying, distracting and disabling, from the visual standpoint, to the other extreme where there is a reflection of a large luminous area in the surface of a magazine printed on dull or matte paper. With the latter, the effect may be undetectable by the naked eye and may be almost unmeasurable by instruments. The term "reflected glare" is reserved today for effects toward the first extreme and the term "veiling reflection" for effects near the second. Perhaps the greatest and certainly the most insidious problem is the reflection of luminaires or skylights in semi-specular and semi-matte surfaces such as a printed page and pencil writing on paper.

There are a great many factors that contribute to veiling reflections and each of them individually has long been known. The problem is to integrate the effects of these interrelated factors. Much has been learned, particularly the contributions made by Illuminating Engineering Research Institute (IERI) research.

Factors Causing Contrast Loss. In the study of contrast losses due to veiling reflections, the visual task (printing or handwriting on paper are usually considered as the visual task in the following discussions), the workers' orientation and viewing angle, and the lighting system all must be analyzed.

The Visual Task. The specularity of paper covers a wide range of degrees and modes of appearance. Most papers consist of rough fibers that have been matted together. Generally the fibers are somewhat shiny in themselves, but because of their random orientation they reflect light more or less equally in all directions. The harder the paper is pressed the more specular it becomes. Some papers are filled with clay or other coating so that the surface is very smooth. Some papers are actually glazed. The luminance of the paper depends both on the amount of light being diffusely reflected from it and whatever bright surface may be reflected in it. This reflection may be discernible as in the case of coated papers or glossy photographs, but frequently it is so indistinct as to go undetected even though serious losses in visibility occur.

The specularity of the graphic medium—pencil, pen, ink, carbon, etc.—again covers a very wide range. The degree of specularity depends on how the medium is deposited. For example, a very soft pencil brushed lightly across rough paper would leave a very diffuse mark. On the other hand, a hard pencil applied with pressure on a smooth surface can be very shiny. The

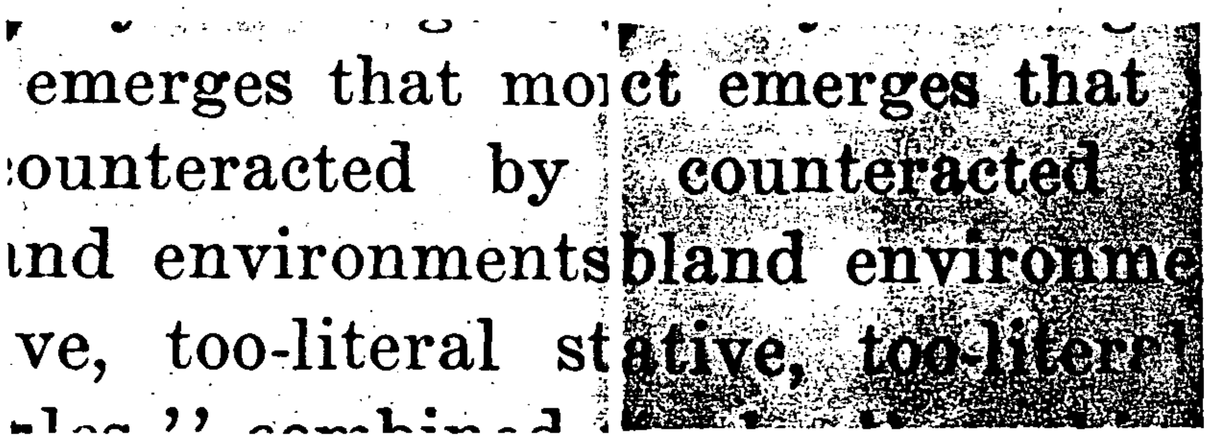


Fig. 2-6. An example of black printing on glossy paper. In the photograph above, a spotlight is located behind the camera in a position to cause minimum veiling reflections. The upper right photograph shows the same task lighted by a troffer that is positioned above and in front of the task in the offending zone. Note the subtle character of the specular reflections so that the loss of contrast is not immediately obvious. Note also that the specular reflections occur in different positions on different letters. The photograph at the right shows the same paper with a spotlight in the offending zone which creates the maximum veiling reflection effect. This condition might be called reflected glare. The image on the page is apparent as are the highlights in the letter stroke. Note how highlights tend to occur along the edges of the letter indicating that the type has embossed the paper.

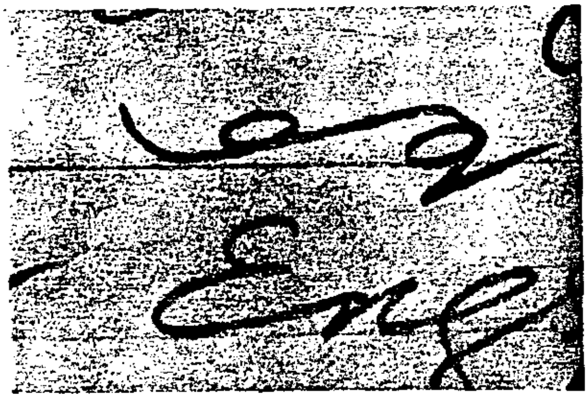
luminance of the mark again depends on the amount of light being diffusely reflected from it and the reflection in it of luminous areas. Therefore, when considering task contrast, both diffuse and specular reflectance of both paper and graphic medium should be considered as well as the reflection of light sources in relation to the illuminance level. Figs. 2-6 and 2-7 illustrate a range of conditions of veiling reflections.

If the paper and the graphic medium could be considered as being perfect planes, the problem would be simpler than is the actual case. The pressure applied by the pencil, pen, typewriter key or printing type actually embosses the paper. The groove thus created causes the reflection of the light source to occur from positions on the ceiling other than the normal angle of reflection from the plane of the paper. Thus the part of the ceiling that is causing the problem may not be immediately obvious.

Consideration should be given to whether the task is lying in a horizontal plane or is slanted as is the case of a letter being hand-held, a book on a slanted school desk top, or a pencil drawing on a vertical drafting board. Chalkboards in classrooms, merchandise in stores, and signs are tasks of prime importance that lie in a vertical plane. The relative importance of various tasks and the planes in which they occur also should be considered. For example, office lighting should really be designed not just in terms of a task lying flat on a desk but also for one hand-held at about 45 degrees.

The Worker. The orientation of the worker with respect to the task greatly influences the magnitude of the effect of veiling reflections. First, for one eye position and one point of regard, a simplified relationship between the eye, the task, the perpendicular to the task, and an "offending zone" can be established. See Fig. 2-8. If the task were perfectly specular and flat, the offending zone would merely be a point. However, since the types of tasks involved here are more or less diffusing, the theoretical offending point becomes enlarged to an offending zone. Now if the eye is in such a position that the rays of light from the offending zone are reflected toward it, veiling reflections will occur. The angle of reflection is considered as the viewing angle. As the viewing angle increases, effects of the specular characteristics of the paper and the ink or pencil increase.

It has been found that people work throughout



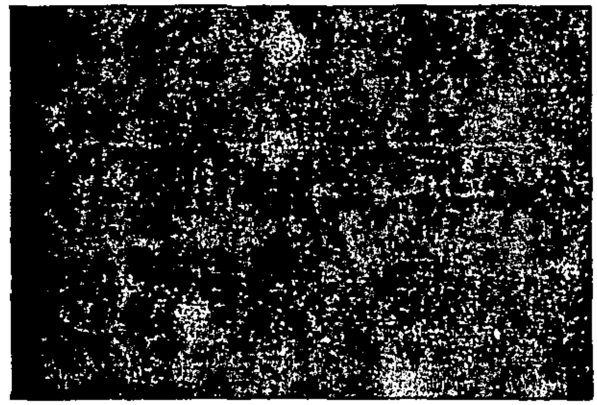


Fig. 2-7. The upper left photograph shows pencil stenographic notes lighted by a spotlight located behind the camera. It can be seen that in this case the pencil stroke is relatively light because even in the darker parts of the stroke, areas of white paper show through. The photograph directly above shows the same task with the spotlight in the offending zone (above and in front of the task). As is frequently the case with this type of task, negative contrast or contrast reversal occurs where the pencil stroke can actually become brighter than the paper. In the photograph at the left the same task is lighted with an indirect lighting system.

a range of viewing angles[15, 16] with a peak at about 25 degrees as indicated by the approximate frequency distribution curves for office workers and for school children shown in Fig. 2-9a. Fig. 2-9b shows that 85 per cent of seeing occurs within 0 to 40-degree viewing angles, with higher angles used for only occasional glances. This is due to foreshortening of the task and to the increased viewing distance (see Fig. 2-9c) and to the resulting increase of task difficulty as shown in Fig. 2-9d. On this basis it seems reasonable to use 0 to 40 degrees as the practical range of viewing angles for design purposes.

Next the location and orientation of the worker and the task in the room must be evaluated. A worker with his back to a wall and facing out toward the center of the room has the maximum ceiling area as a potential offending zone. Furthermore, he has relatively little light coming from behind him which would cause little or no veiling reflections. A worker facing the wall would have minimum veiling reflections (not an appealing position psychologically). A person in the center of the room has light falling on the task from all directions. The ceiling may or may not constitute the offending zone, depending on the viewing angle.

A person sitting beside a window would have greatly reduced veiling reflections because the major source of illumination is outside the offending zone. It is also true that if a person were seated facing a window he would have potentially serious veiling reflection conditions.

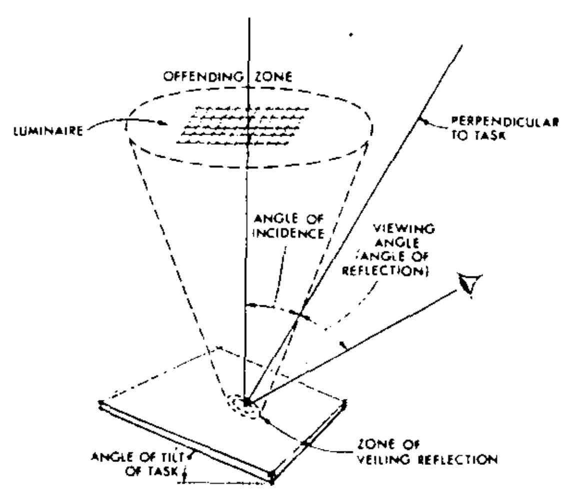


Fig. 2-8. Generalized description of angular relationships in analyzing veiling reflections.

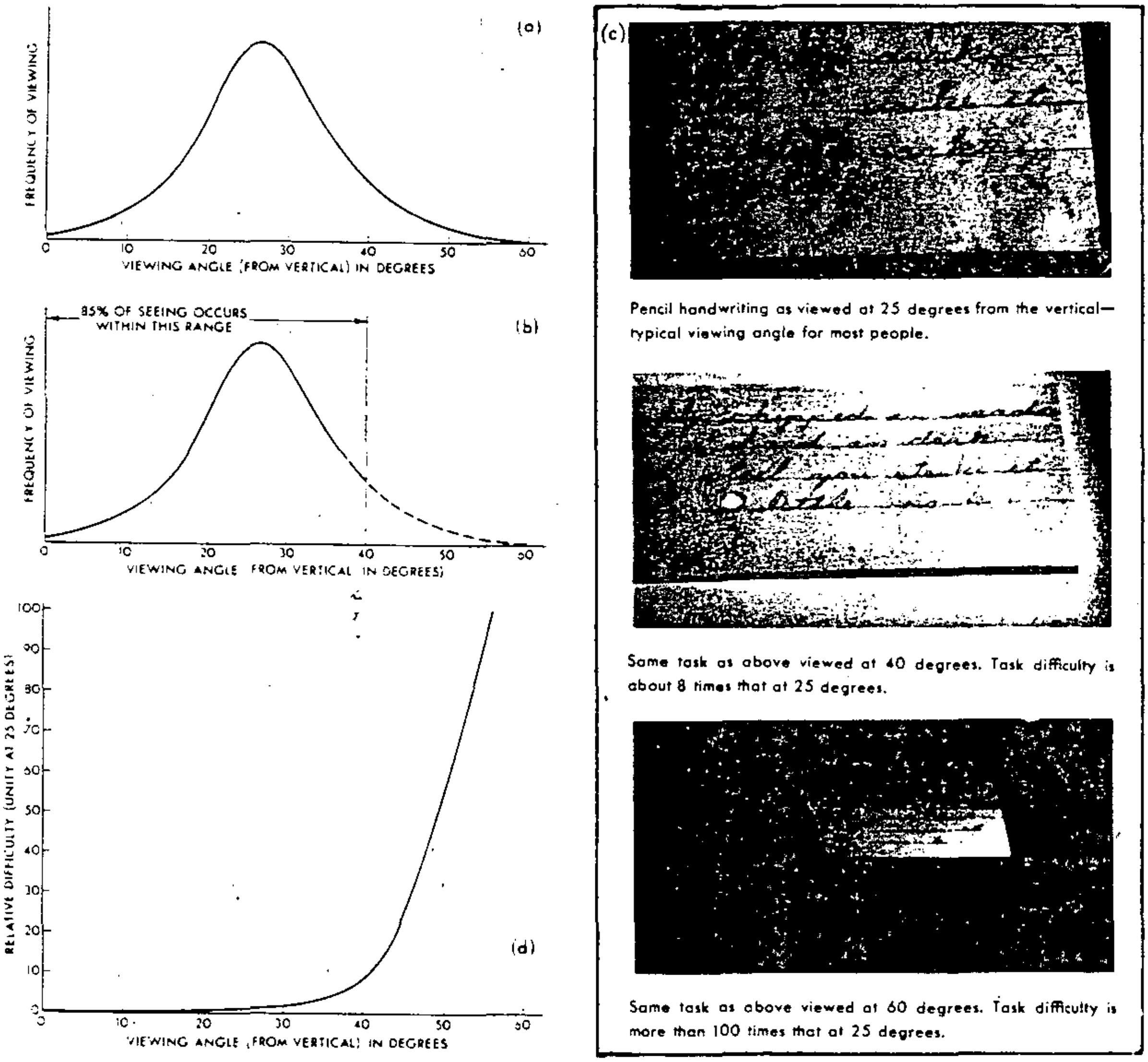


Fig. 2-9. Task viewing angles. *a*. People use a range of viewing angles in their work but the peak is about 25 degrees. *b*. Eighty-five per cent of seeing occurs within a range of 0 to 40 degrees, with seeing at large angles limited to occasional glances due to foreshortening and increased viewing distance. *c*. Photographs of an actual pencil handwriting sample as seen at viewing angles of 25, 40, and 60 degrees. *d*. Curve showing the relative difficulty of the pencil handwriting shown in *c* as measured with the Visual Task Evaluator.

The Lighting System. The worst condition is represented by a highly concentrated, very bright source with maximum candlepower directed toward the task. It is also likely to be uncomfortable as one looks around the room, and it may create shadows that interfere with writing, etc. Paradoxically, it is also the condition under which the worker can most easily escape veiling reflections by tilting the task so that the reflected rays do not reach his eye. When the task is truly a flat surface this is an effective solution. Because of embossing and curvature of many tasks such as books and magazines, reflections are not so easily eliminated.

Another condition would be a luminous dome placed over the worker and the task. Here the effect of veiling reflections would be reduced, but could not be escaped since there would always be a luminous area in the offending zone. Furthermore, through a rather wide range of illuminances the lighting system would generally be considered comfortable.

Between these two conditions lies the full range of luminaires of various sizes spaced so as to occupy various proportions of the ceiling and employing materials that produce varying candlepower distribution.

Lighting materials with reference to horizontal tasks may be compared as follows:

Diffusing. At small viewing angles (looking nearly straight down at the task) this material has the minimum luminance exposed to be reflected in the task. At large viewing angles it tends to have the highest luminance. This helps reduce veiling reflections but tends to reduce visual comfort per unit area.

Prismatic. A wide range of materials comes under this category, but generally they tend to expose greater flux toward the work for small viewing angles. Many of them have good light control at large viewing angles. Prismatic materials have been designed to produce special flux distributions referred to below.

Louvers. These materials expose the maximum luminance to the work at small viewing angles. They generally have lower luminance at large viewing angles. Translucent louvers have the least control; opaque louvers next; and specular parabolic wedge louvers have the maximum.

Polarizing. Available materials of the flake or layer type have a degree of diffusion that exposes less luminance to the work than prismatic or louver materials. They have less luminance at large angles than diffusing, about the same as prismatic, and more than opaque louvers.

Polarization can reduce veiling reflections. The effect is greatest at large viewing angles and least at small viewing angles. For any single ray of light, polarization in a plane perpendicular to the task always tends to reduce veiling reflections.

These have been termed "radial" polarizers because in azimuth they produce the same degree of polarization in all directions. "Linear" and "dichroic" polarizers can also be useful—particularly for specialized application.

Special. New optical designs of luminaires and materials have been produced with candlepower distributions that reduce the flux coming from the offending zone and minimize the luminance directed to the eye of the worker. While there are distinct variations in effective illumination and visual comfort for various orientations and positions of the worker, very significant improvements are provided in controlling veiling reflections.

Guides for Reducing Veiling Reflections.

The Task. Where possible the written or printed task should be on matte paper using nonglossy inks. The use of glossy paper stock and hard pencils should be minimized.

The Worker. The orientation and the position of the worker is very important. The desirable position only can be determined by actually determining CRF values (see page 9-63 in the 1981 Reference Volume). It is also true that various orientations will produce varying degrees of visual comfort.

The Lighting System. In smaller spaces such as offices where desk positions can be determined, substantial gains can be made by not positioning lighting equipment in the general area above and forward of the desk. Positions on either side and behind the worker are preferred. Where desk positions are random, as in large general offices, it is desirable to have as much light as possible reach the task from sources outside the offending zone. Taken to the extreme this will suggest the utilization of over-all ceiling treatments.

Any decision on a lighting installation should be made on an over-all basis rather than on any one factor. Thus in addition to considering the illuminance and the effect of veiling reflections produced by a lighting system and the material, the efficiency of the system and the visual comfort in the space should be considered as prime factors.

Methods of Evaluation. Those tasks which are subject to veiling reflections are subject to the visibility criteria known as equivalent sphere illumination (ESI). ESI is best used as a tool in determining the effectiveness of controlling veiling reflections and as part of the evaluation of lighting systems. The concept of ESI can best be understood by reviewing some basic principles behind ESI.

The concept begins by the establishment of a reference lighting condition. Sphere lighting (perfectly diffuse lighting) is used as the reference, since spheres are relatively easy to construct and have repeatable illumination characteristics. Sphere illumination is not said to be the best lighting condition and does not necessarily dictate the use of diffuse light in the real environment. It is an arbitrary benchmark type of lighting used to measure relative visibility potential. This reference lighting condition is such that the same amount of (sphere) illumination will always produce the same amount of visibility.

Equivalent sphere illumination is the same concept, except taken one step further—to the real lighting environment. The ESI of a visual task in a real environment is the equivalent illuminance produced by a sphere which makes the task as visible in the sphere as it is in the real environment. That is, the visibility of the task in the real environment is *equivalent* to that produced by a certain amount of sphere illumination. Thus, the term Equivalent Sphere Illumination. ESI is analogous to a measure of visibility in the real environment and as such can be used as a tool in evaluating lighting equipment or alternate lighting schemes.

Erroneous evaluations can result if ESI is not completely understood. The visual task, the observers orientation in the space, the lighting system, and the detrimental effects of veiling reflections all play a part in the determination of ESI values. See Sections 3 and 9 of the 1981 Reference Volume for discussions of visibility, veiling reflections and ESI.

Color

The importance of color in illuminating engineering and particularly lighting design should not be underestimated. An entire section (Section 5) in the 1981 Reference Volume is devoted

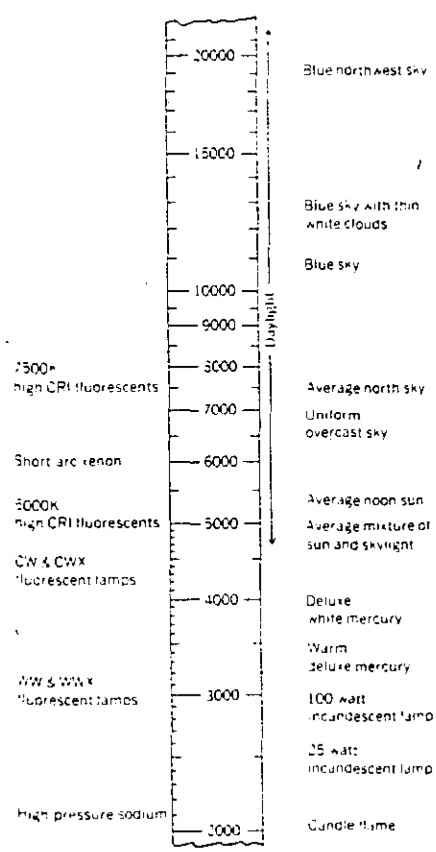


Fig. 2-10. Correlated color temperature in kelvins, of several electric light and daylight sources.

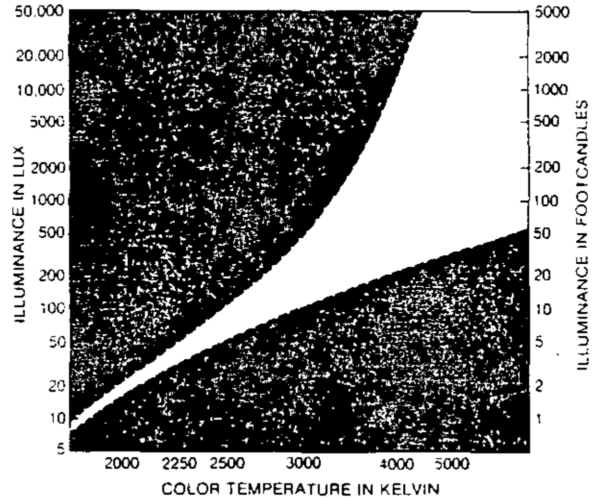


Fig. 2-11. Experiments[18] have shown the preferred color temperature of light sources at various illuminance levels (the unshaded area). Color temperatures—illuminance combinations in the lower shaded area produce cold, drab environments, while those in the upper shaded area can produce overly colorful and unnatural appearances.

to the basic concepts of color, chromaticity, color rendering and the use of color. The lighting designer is referred to that material, especially the portion on the use of color on page 5-18.

There often is confusion between two color characteristics of light sources—chromaticity and color rendering—and especially their use. In simple terms, chromaticity refers to color appearance of a light source, or its color temperature. (Fig. 2-10 diagrammatically shows the approximate color temperatures in kelvins of several electric light sources and daylight.) Color rendering refers to the ability of a light source, with its particular chromaticity, to render colors of objects as one would expect them to appear at the same color temperature. A useful tool in selecting an appropriate color temperature is shown in Fig. 2-11, which has been developed from experiments by Kruithof.[18] If in the design process the designer has selected an illuminance level, Fig. 2-11 can be referred to in selecting a light source color temperature that should be acceptable, in that it produces neither a cold, drab nor too warm, overly colorful environment.

Shadows

The direction of illumination is especially important when viewing three dimensional objects. As is illustrated in Figs. 2-12 and 2-13, shadows can aid or hinder the seeing of details. In the

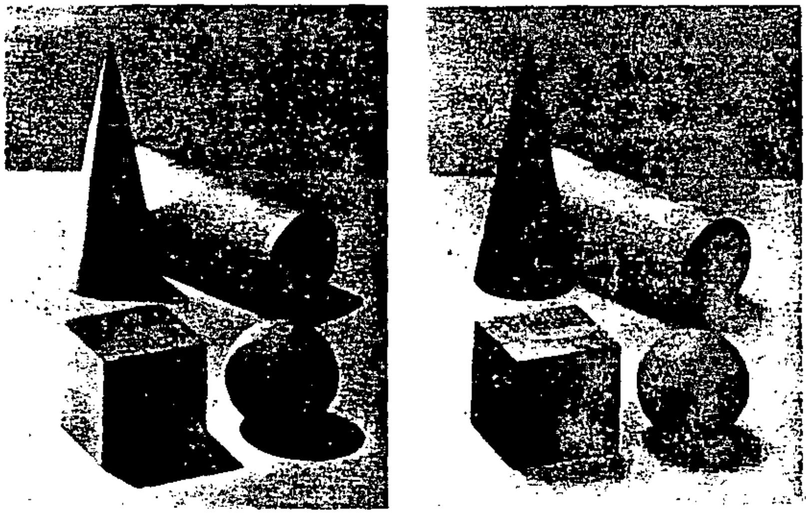


Fig. 2-12. Harsh shadows produced by unidirectional illumination (left) and soft shadows produced by diffuse illumination (right).

case of curved and faceted surfaces which are polished or semi-polished, the direction of the lighting is important in controlling highlights. Some shadow contributes to the identification of form.

Fig. 2–13. Multiple shadows (upper left) are confusing; single shadows (center) may confuse but can help; diffused light (lower right) erases the shadows.

PHYSICAL CONSIDERATIONS

Luminaire Spacing

At one time in the past, "good lighting" was specified in terms of horizontal illuminance with the criterion that the point-to-point variations did not exceed plus or minus one-sixth of the average value. Even if this were an acceptable basis, an installation which provides uniform horizontal illuminance may still represent a poor lighting installation. For example, if there is insufficient overlapping of luminaire distributions as may occur with sharp cut-off luminaires near the maximum calculated spacings, the illuminance at many points can be unidirectional with the consequential strong shadows, dark areas with single lamp failures, etc.

Today, with our broader understanding of the requirements for good lighting, it is quite possible that the old concept of an average horizontal illuminance level plus or minus one-sixth will be violated in the process of designing good lighting. However, usually there still will be a requirement that the illuminance meet some degree of uniformity.

Many factors contribute to the total quality of a lighting system. Horizontal work-plane illuminance represents only one aspect. Horizontal illuminance at other levels throughout the space cannot be ignored. The directional qualities of the illuminance at specific points within the room can be considered in terms of cast shadows,[19] vector and scalar illuminance,[20] vertical components of illuminance,[21] and the like. Often, varying visual tasks occur at different locations within the space. These and similar factors must be considered for lighting system evaluation. In specific cases, some factors may be extremely important while others can be safely omitted from consideration. Nevertheless, the lighting designer must deliberately make the choice.

In those situations for which a relatively uniform illuminance is an accepted performance criterion, certain guidelines can be an important aid to the lighting designer in determining the luminaire layout. To achieve acceptable uniformity, luminaires should not be spaced too far apart or too far from the walls. Spacing limitations between luminaires are related to the intensity distribution of the luminaires, placement of the luminaires within the room, and the reflectances of the room surfaces. The principal factor for direct, semi-direct and general diffuse luminaires is the mounting height above the work-plane; for semi-indirect and indirect luminaires, it is the ceiling height above the work-plane.

The lighting designer often is faced with the problem of selecting luminaires that are potential candidates for a particular design, and the Luminaire Spacing Criterion (SC) is a parameter to assist in this decision. This standard method of classifying luminaire spread (SC) is given numerically. (See the 1981 Reference Volume, Section 9.) It is a spacing of luminaires expressed as a fraction or multiple of the luminaire mounting height above the work-plane.

The SC is a measure of the beam spread or coverage of the direct component of illuminance from direct and semi-direct illuminaires. It is a guide to permit the designer to evaluate the potential suitability of a luminaire before executing a complete design analysis. The SC permits a designer to separate luminaires into two categories for a particular lighting layout: those which are likely to produce reasonably uniform horizontal illuminance and those which will not produce uniform horizontal illuminance in a specific layout pattern. It does this by evaluating one aspect of uniformity at a few select points. This limited evaluation can be based on a luminaire characteristic alone (luminaire intensity distribution) and consequently is a property attributable to the luminaire.

The immediate use of such SC values is to estimate the relative direct coverage of luminaires. Further, there is a general trend that the uniformity of horizontal illuminance decreases as the spacing between luminaires is increased. Fig. 2-14 illustrates the spacing between luminaires. The product of SC times the mounting height (MH) gives a spacing which generally is in the vicinity of the dividing point between a reasonably acceptable uniformity of horizontal illuminance and a noticeably poorer uniformity of horizontal illuminance.

As a general trend, horizontal illuminance will tend to be relatively uniform for luminaire spacing less than that given by the SC, and uniformity will tend to decrease as the spacing exceeds that

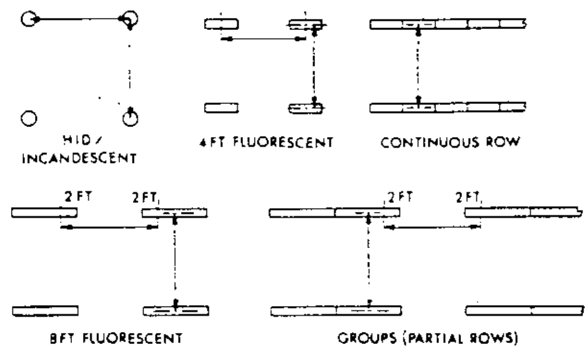


Fig. 2-14. Spacing dimensions (in feet) to be used in relation to Spacing Criterion (SC). Mounting height is from luminaire to work-plane for direct, semi-direct and general-diffuse luminaires and from ceiling to work-plane for semi-indirect and indirect luminaires.

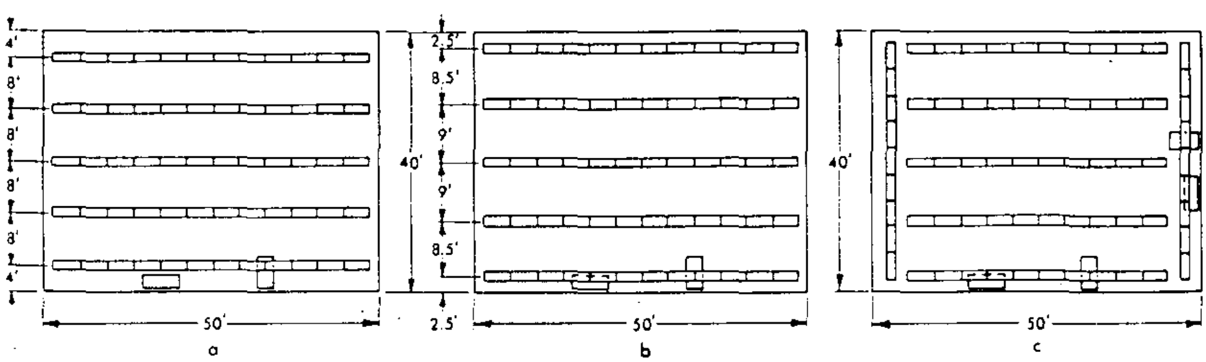


Fig. 2-15. (a) Lighting layout using equal spacing between continuous rows of luminaires. (b) Layout is changed to provide higher illuminance near side walls. (c) By adding four more units on each end, layout (b) can be modified to provide 80 per cent more light near the end walls and prevent possible scallop effects. Dimensions are in feet.

given by the SC. Certain luminaires* may produce a horizontal illuminance where the uniformity is acceptable over a specific limited range of spacings. In such cases the SC is not an applicable measure for the luminaire. Here, the manufacturer states specific spacing instructions rather than giving an SC value.

The commonly used practice of letting the distance from the luminaires to the wall equal one-half the distance between rows (see Fig. 2–15a) results in inadequate illuminance near the walls. Since desks and benches are frequently located along the walls, a distance of 760 millimeters (2½ feet) from the wall to the center of the luminaire should be employed to avoid excessive drop-off in illuminance. This will locate the luminaires over the edge of desks facing the wall or over the center of desks that are perpendicular to the wall (see Fig. 2–15b). To further improve illuminance uniformity across the room, it is often desirable to use somewhat closer spacings between outer rows of luminaires than between central rows, taking care to be sure that no spacing exceeds the maximum permissible spacing.

To prevent excessive reduction in illuminance at the ends of the room, the ends of fluorescent luminaire rows should preferably be 150 to 300 millimeters (6 to 12 inches) from the walls, or in no case more than 610 millimeters (2 feet) from the walls. Even the 150- to 300-millimeter (6- to 12-inch) spacing leaves much to be desired from the standpoint of uniformity and, where practicable, the arrangement shown in Fig. 2–15c is much more satisfactory. With this arrangement, the units at each end of the row are replaced by a continuous row parallel to, and 760 millimeters (2½ feet) from, the end wall. In the example shown, 5 units were replaced by 9 units providing a potential increase in the illuminance at the end of the room of 80 per cent over what it would be with the layout shown by Fig. 2–15b. This technique not only improves uniformity but also eliminates scallops of light on the end walls and provides a uniform wash of light on all four walls.

Another excellent method of compensating for the normal reduction in illuminance that may be expected at the ends of rows is to use a greater number of lamps in the end units. Still another technique is to provide additional units between the rows at each end. The units could be either parallel or at right angles to the rows.

Spacings closer than the maximum permissible are often highly desirable to reduce harsh shadows and veiling reflections in the task as well as further improve uniformity. This is particularly true for direct and semi-direct equipment, and spacings that are substantially less than the maximum permissible spacing should be seriously considered.

The following formulas can be used to calculate the values:

1. For individually mounted luminaires, the wall-to-luminaire spacing should be:

$$\text{Wall-to-Luminaire Spacing} = \frac{\text{Luminaire-to-Luminaire Spacing}}{3}$$

2. For individual units or crosswise spacing of continuous rows:

$$\text{Minimum Number of Rows} = \frac{\text{Room Width}}{\text{Maximum Spacing Allowed}}$$

3. For lengthwise spacing in continuous rows:

$$\text{Maximum Number of Units Per Row} = \frac{\text{Room Length} - 0.3}{\text{Luminaire Length}}$$

(allows 0.15 meters end spacing when lengths are in meters)

or

$$\frac{\text{Room Length} - 1}{\text{Luminaire Length}}$$

(allows one-half-foot end spacing when lengths are in feet)

$$\text{Minimum Number of Units Per Row} = \frac{\text{Room Length} - 1.22}{\text{Luminaire Length}}$$

(allows 0.61-meter end spacing when lengths are in meters)

or

$$\frac{\text{Room Length} - 4}{\text{Luminaire Length}}$$

(allows two-foot end spacing when lengths are in feet)

Dimming Devices

The most practical method of controlling light output for nearly every purpose is to control the electrical input to the light source. There are several methods by which this may be accomplished, based on one of two principles: the input current can be varied by changing the amplitude

* For example, some sharp cut-off batwing distribution luminaires.

of the current, or it can be varied by changing the amount of time during a cycle that it is permitted to flow.

Change in amplitude can be accomplished by resistance dimmers. The metallic rheostatic dimmer, one of the earliest controls developed, is still made and offers features which prescribe its use under certain circumstances. A resistance dimmer is connected in series in the circuit and the voltage which appears across the lamp is equal to the line voltage less the voltage drop (IR) across the resistance dimmer. To vary the amount of light, adjustment to the rheostat is made by moving a contact which adds or subtracts resistance to the circuit. The dimmer capacity must be selected to match the lamp load fairly closely if dimming control to blackout is to be achieved. The resistance loss in the dimmer is an appreciable percentage of the lamp load at low luminance levels, liberating large amounts of heat which must be disposed of and consuming considerable power.

Change in amplitude can also be accomplished by continuously adjustable autotransformers. A single layer of copper magnet wire is wound over an iron core to form a toroid. Each wire turn is "bared" to form a commutator for the carbon brush. When a 120-volt ac line is applied to this winding, sliding the brush from turn to turn allows tapping off the desired ac output voltage. Wire size, number of turns, and brush dimensions have been carefully designed so brush contact is made with the next turn before leaving the previous conductor, assuring perfectly smooth, flickerless type of light control of almost infinite fineness from zero to full luminance. A dimmer of such design has excellent regulation—there is no visual change in light intensity as lamps are added or removed from the circuit, and it will also dim equally well all sizes of lamps at the same time. Autotransformer dimmers provide fairly good efficiency up to a maximum of 95 per cent. Although solid-state dimmers have tended to replace autotransformer dimmers, 1000- to 2000-watt units are still available. Larger capacity autotransformers (above 2000 watts) are available with motor drives.

The saturable reactor was the first of the electronic type or phase angle control dimmers. It consists of a magnetic core associated with dc and ac windings. By adjusting the current of the dc winding, the inductive reactance of the ac winding may be varied smoothly from approximately zero to its maximum value. Saturable reactors are not in much use today in lighting applications because of their weight, size and slowness of response; however, because they are good in the control of very heavy loads, they do fill some requirements.

Thyratron tube control is another of the earlier electronic methods. A gating type of control is obtained from a thyratron tube when ac voltage is applied to its plate and an ac voltage of adjustable phase is applied to its grid. As the phase angle between the voltage on the plates and grids is adjusted, the tube can be made to conduct various length portions of the cycle. Two thyratrons are connected back to back so that each one may conduct during each half cycle. While response is very rapid, all filaments in this tube system must be preheated approximately ½ minute or more. Should a power failure occur during use, the need to preheat becomes a great inconvenience.

Magnetic amplifiers or self saturating reactors became popular as high power dimmers for a short period. Although the performance of this type of system was generally good, it was replaced by thyristor controlled dimmers because of their size and weight advantages.

Solid-state electronics has virtually taken over the field of present day dimming equipment, from the 600-watt wallbox dimmer to the 100-kilowatt or higher theatrical or architectural system. The thyristor has become the main component in most incandescent and fluorescent dimmer manufacturing. The original solid-state equipment designs utilized dual back-to-back silicon controlled rectifiers (SCR). This arrangement has given way to the equally reliable but more cost-efficient triac devices in most dimmers rated at less than 6 kilowatts. However, many of the larger theatrical units rated at 6 and 12 kilowatts still employ dual SCRs because of the lack of high current triacs.

Because thyristors are fast switching devices, some radio frequency interference will be generated unless suitable filtering is designed into the dimmer. Extensive filtering is generally provided in larger architectural or theatrical systems to completely eliminate any possible interaction with sensitive equipment. While solid-state dimmers are typically 98 to 99 per cent efficient, they still have to dissipate heat, and cool operation is the key to long dimmer lifetime.

Thyristor controlled fluorescent dimmers are being applied in many commercial applications, such as conference rooms, offices, restaurants, schools and churches.

Recent advances in device technology and circuit design have made it possible to dim high intensity discharge lamps (see Section 8 of the 1981 Reference Volume). It has also become practical to convert low frequency ac to high frequency ac in order to improve the efficacy of standard fluorescent lamps. Further advances have been made in energy management of lighting through integrated circuit technology. Automatic dimming system control by means of photoelectric feedback, time programming, and other computer controlled demand limiting are all available. Photoelectric devices can adjust the lighting to allow for minimum power consumption when daylight is available. Time programming can automatically adjust light levels to suit task changes, such as from work to leisure to cleaning or security modes. Computer operated controls can be used to reduce light levels to reduce the load in peak demand periods.

Solid-state dimming offers the following:

For incandescent sources

1. Full range adjustability of light for various tasks or moods, down to zero light output.
2. Energy savings—only 1 to 2 per cent of the connected load is dissipated in the dimmer.
3. Increase in lamp life—lamps will last up to 20 times the rated life at 50 per cent light output (70 per cent power).

For fluorescent sources

1. Continuously variable light output down to a fraction of a per cent of full output, with no discernible color shift.
2. Power control—per cent energy savings equal to the per cent light reduction down to about 50 per cent light output (see Fig. 8–46 in the 1981 Reference Volume).

For high intensity discharge sources

1. Range of light output control from 2 per cent minimum for mercury to 40 per cent minimum for metal halide and high pressure sodium lamps.
2. Power control—energy savings nearly the same as shown in the fluorescent power curve, down to 50 to 60 per cent light output.

Energy management devices as previously mentioned can be effectively applied to all sources listed above.

Wiring for Lighting

Every electric lighting system, regardless of its size, scope, simplicity or complexity should have a well designed, trouble free electrical wiring system. Its size and capacity, its electrical characteristics (voltages, frequencies, phases, etc.), feeders, branch circuit layouts, and switch and dimmer controls, must all be specifically selected and designed to conform to the layout and design of the lighting systems which it is to operate and control.

Lighting designers should know the basic fundamentals of electrical wiring system design to insure that they can obtain the maximum flexibility and efficiency from the lighting system. Quite often lighting designers are the consulting electrical engineers on the project. In this case, they usually are qualified to design and specify the electrical wiring system for the lighting. However, if the lighting designers are not qualified to design the electrical wiring system, they should seek the services of a qualified electrical consultant or electrical contractor when designing the lighting system, to insure that the wiring system and controls will provide all the lighting variations and flexibility that is desired and intended. All electrical systems must be designed and installed in accordance with the provisions and requirements of the *National Electrical Code* and other local or state code requirements, and the electrical consultant is qualified to include these provisions and requirements in the design and specifications.

The first step in the design of the electrical wiring system is to determine the total electrical load for the lighting system. On large projects, it may be desirable to break down the lighting load into logical sub-loads, for serving individually from separate load centers. These sub-loads can then be further broken down for individual panelboard control. On smaller projects, this usually resolves itself into selection and location of one or more lighting panels, each conveniently located near the center of the lighting load it serves, compatible with the character, use, and structural configuration of the building.

When lighting loads have been determined, the characteristics of the electric power supply, such as voltage, phase and frequency, must be considered and evaluated in order to select optimum locations for load centers and panelboards.

For relatively small projects of 100 kilovolt-amperes or less, most utilities supply 120/208-volt three-phase four-wire, 120/240-volt three-phase four-wire, or 120/240-volt single-phase three-wire service. For larger projects, 277/480-volt three-phase four-wire service is usually available. Lighting loads are usually served with 120 volts or 277 volts from these systems. Low-voltage light sources which may be incorporated in the lighting system may be operated at their rated voltages by using small dry-type step-down transformers operating from any of the higher standard voltages.

Care should be exercised in the selection of voltage due to certain provisions of various codes which prohibit the use or restrict the use of higher voltage lighting devices in various occupancies.

Various techniques for switching, such as half switching four-lamp fluorescent luminaires, or row switching to provide various lighting levels should be employed for energy conservation.

The requirements of energy conservation suggest the use of short three-phase home run circuits in order to minimize energy losses. For wiring economics as well as energy conservation, high power-factor ballasts should be specified for discharge type lighting.

Outdoor lighting systems generally employ the same techniques for wiring system design. Longer distances involved require voltage drop calculations to be performed to assure adequate voltage at the luminaire. Systems will usually perform adequately when the voltage drop does not exceed 5 per cent at the farthest outlet. Higher voltage luminaires, such as those operated on 480 volts may generally be used outdoors when permitted by codes to reduce the size and quantities of circuit conductors.

In the United States 60-hertz power is almost universal for lighting systems. However, lighting designers and electrical consultants sometimes consider the use of high-frequency electric power for the operation of fluorescent lighting systems, especially when the advantages of high-frequency operation are important (see Section 8 of the 1981 Reference Volume). One such advantage might be the reduction of the excessive weight of normal ballasts used for 60-hertz power. Another might be to obtain the maximum light output of the fluorescent lamps being considered for the project. In earlier installations, frequencies of 360, 420, and 840 hertz were used. More recently, a 3000-hertz system has been used, which reportedly converts power from 60 to 3000 hertz at about 93 per cent efficiency, compared with over-all conversion efficiencies of only 80 to 85 per cent for the earlier model converters operating at the lower frequencies.

Total system efficiency, from system electrical watts input to system useful lumen output, must be considered to properly evaluate a lighting system's efficiency. The evaluation of partial systems often leads to erroneous conclusions. Lowest watts per luminaire does not guarantee lowest lighting energy use for the system.

The total electrical load required for the lighting system is first calculated in total watts or kilowatts. For purposes of selection of transformers, main switchboards, circuit breakers, and other similar electrical distribution considerations, kilowatts (kw) or kilovolt amperes (kva) are used. However, when converted to "watts per square meter (foot)," the term becomes more meaningful and useful not only to the lighting designer, from the standpoint of an economical lighting system, but also to the air-conditioning and heating engineers. The chart shown in Fig. 2-16 shows maintained average illuminance for each of a variety of luminaires based on their wiring capacity expressed in watts per square meter (foot). The data in this chart are only approximate, and are based on a room of average shape with a Room Cavity Ratio of 2.5 and for high reflectances of 80 per cent for the ceiling cavity, 50 per cent for the walls, and 20 per cent for the floor cavity. For more accurate results, data for specific luminaires, and for specific sized rooms and reflectances should be used. However, the chart is useful for quick appraisals when one type of luminaire is being considered versus other types, especially in early stages of the lighting design procedure.

Rooms with numerically higher Room Cavity Ratios will require higher loadings (watts per square meter (foot)); with lower Room Cavity Ratios, the loadings will be correspondingly reduced. With other parameters constant, the required loading for any luminaire in an area with another Room Cavity Ratio is inversely proportional to the Coefficients of Utilization associated with the Room Cavity Ratios of the two areas. Similarly, changes in reflectances will also affect the required loading in inverse proportion to the Coefficients of Utilization associated with the reflectance conditions.

The wiring system should be designed to provide maximum flexibility with adequate capacity for present and anticipated future needs. Overloading or excessive extensions of circuits, in addition to the hazards involved, results in a lowering of the light output of both incandescent filament and fluorescent lamps. As an example, the light output of an incandescent filament lamp is about three per cent less for each volt the lamp is operated under its rated voltage. Fluorescent lamp light output is also affected by undervoltage operation but not to so great an extent; starting difficulties and reduced lamp life may also result. For further information, see Section 8 of the 1981 Reference Volume.

With gaseous discharge sources, the wattage consumed and the current carrying capacity required will, in general, be greater than the rated wattage of the light sources. Provision for auxiliary wattage losses and for power factors lower than unity must be made in the wiring system. Mercury, metal halide, and high pressure sodium lamps require a warm-up period of several minutes. During this time, or with certain types of

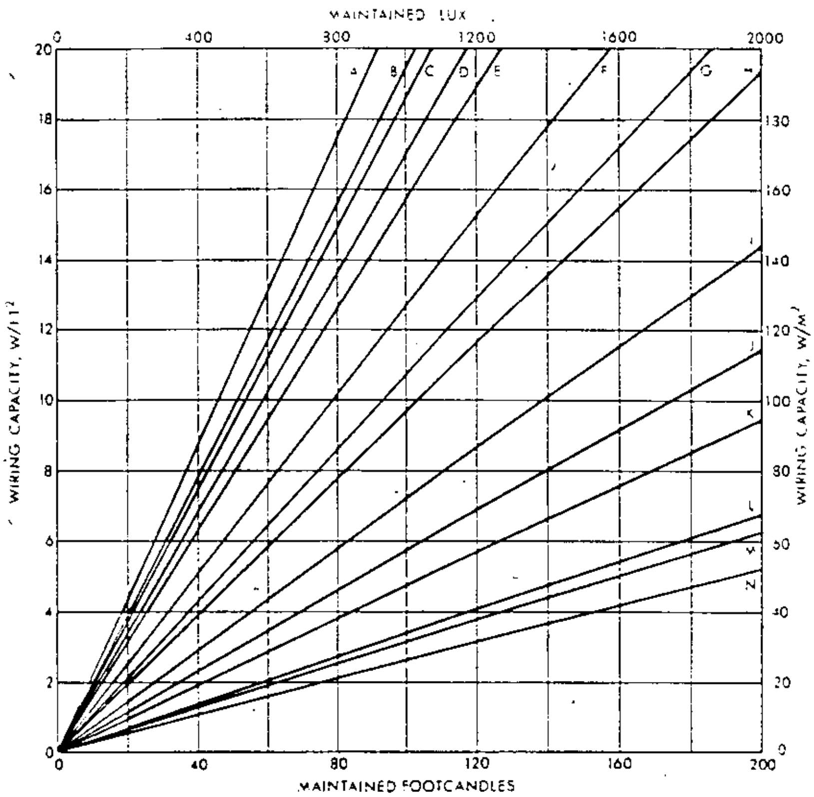


Fig. 2-16. Approximate wiring capacity to provide a given maintained illuminance level in a room of 2.5 Room Cavity Ratio by means of the following:

A - Indirect, incandescent filament (silvered bowl)
B - Direct, incandescent filament (with diffuser)
C - Direct, incandescent filament (downlight)
D - General diffuse, incandescent filament
E - Direct, incandescent filament (lens)
F - Direct, incandescent filament (industrial)
Indirect, fluorescent (cove)
G - Indirect, fluorescent (extra high output)
H - Direct, fluorescent (extra high output) (louvered)
I - Direct, fluorescent (louvered)
J - Luminous ceiling, fluorescent
K - Direct, fluorescent (lens)
Direct, HID (mercury)
L - Direct/Semi-direct, fluorescent (industrial)
M - Direct, metal halide
N - Direct, high pressure sodium

auxiliaries, the current may be as much as twice the operating current. Wiring capacity must be provided for the starting current where it exceeds the operating current.

Minimum wiring capacity requirements are given in the *National Electrical Code*. The purpose of the Code is the practical safeguarding of persons and buildings and their contents from hazards arising from the use of electricity for light, heat, power, radio, signaling, and other purposes, and compliance with its requirements does not insure adequacy either for present use or future growth.

Although the *National Electrical Code* does not purport to be a design manual, the lighting designer and engineer should be familiar with minimum lighting circuit capacities; *i.e.*, Section 220-2 of the 1978 *National Electrical Code*. The circuit capacities required are frequently far in excess of that required by modern efficient lighting systems.

Wiring design information based on current good practice for specific applications may be found in the following publications:

IEEE Recommended Practice for Electric Power Systems in Commercial Buildings—1974, IEEE No. 241, Institute of Electrical and Electronic Engineers, New York.

Agricultural Wiring Handbook—1971, Edison Electric Institute, Washington, DC.

IEEE Recommended Practice for Electric Power Distribution for Industrial Plants—1976, IEEE No. 141, New York.

Electrical Systems for Power and Light—1964, McGraw-Hill Book Company, New York.

Standard Handbook for Electrical Engineers—McGraw-Hill Book Company, New York.

Electrical Engineers' Handbook—John Wiley & Sons, Inc., New York.

American Electricians' Handbook—McGraw-Hill Book Company, New York.

THERMAL CONSIDERATIONS

The Total Environment

Today, more than ever, architectural and engineering design philosophy reflects conscientious efforts to provide man with a "total physical environment". To accomplish this objective all facets of the building's interior systems must be successfully coordinated since they all are dependent upon one another.

The physical and psychological elements which influence this design flow include such diverse factors as sight, sound, thermal comfort, spatial organization and esthetics. The integration of these factors cannot be realized without the combined efforts of all those who deal with them in their design process.

As recently as the late 1960's lighting engineers and designers utilized quantity of illumination as the primary factor in their designs while paying little or no attention to energy control and consumption. However, as modern technology in the fields of light and vision advanced, the direction of design theory shifted toward qualitative aspects and de-emphasized the quantitative. Concepts of Equivalent Sphere Illumination and Visual Comfort Probability proved that better control of the visible part of the spectrum could reduce lighting watts and increase visual quality. Even with these reductions in lighting watts the part of the spectrum which is emitted as heat still contributes significantly to a space's thermal environment. Since it is impossible to eliminate this heat from the light source, it is important that it be manipulated so that it can work advantageously within the environment.

Heat from light sources is useful in replacing building heat losses during the heating season. Since the building's thermal needs vary not only seasonally but from area to area within the structure, control of lighting heat and integration with the heating and cooling system are essential. This is particularly evident when the thermal factors dictate that the interior zones be on a virtually continuous cooling cycle. Good design today requires provision for efficient utilization or dissipation of the lighting heat.

Comfort Parameters

Temperature. Any light source adds heat to the interior in which it operates. This creates a relationship between lighting and room temperature and, in turn, human thermal comfort. However, comfort depends not only on the room temperature, but other factors, as well.

Heat gains and losses in a room result from heat transfer through walls and ceilings, heat transfer with air changes, solar gain from radiation through transparent surfaces such as windows, electric lighting, heat emitted by people, and heat from occupational processes in the space, such as from production equipment, computers and office machines. The proportion of heat gain from each factor varies widely, depending on building design, use of the space, climate, etc. Procedures for determining the magnitude of various loads are outlined in handbooks published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

Any source of energy which changes the temperature is termed *sensible* heat. Convection energy from lamps is sensible heat which raises the air temperature. Lamps also produce radiant energy which does not heat air directly, but is converted to sensible heat when intercepted and absorbed by a person or surface.

Use of lamps of higher efficacy, such as fluorescent or high intensity discharge, will provide a given illuminance level with less heat than with incandescent lamps. However, incandescent lamps frequently have characteristics which make them a superior choice for an application, regardless of efficacy.

Humidity. Luminaires usually do not impact the humidity in the space because they neither add nor remove moisture from the air. Since the human body regulates its temperature by evaporation of moisture from the skin as well as by radiation and convection, humidity is important. Air has the property of sharing space with water vapor up to a specific amount. The variation of water vapor below this maximum, expressed in per cent, is called *relative humidity*.

Relative humidity is measured by comparing wet bulb and dry bulb thermometer readings. The wet bulb type has its bulb area covered with a wet cloth. Evaporation will lower the wet bulb reading below the dry bulb, to a degree depending on the amount of water vapor in the air. With the two readings and a psychrometric chart the relative humidity may be determined. Since a luminaire may raise the dry bulb temperature in a space, the relative humidity may change while the amount of water vapor in the air remains constant.

Relative humidity values over 90 per cent are called extreme, between 60 and 90 per cent humid, between 40 and 60 per cent normal, and under 40 per cent dry. These are generalizations since ambient temperature, air motion, and activity make appreciable differences in the apparent sensation experienced.

Comfort Limits. Human satisfaction is a response to several interacting variables. These stimuli cannot be considered separately; they must be considered together as each affects the action of the others. The dry bulb temperature, water vapor pressure, mean radiant temperature and air velocity all affect the thermal environment. Both steady-state and non-steady state criteria for these stimuli must be satisfied.

Research performed by ASHRAE prior to 1974 resulted in the specification[22] of the comfort envelope as shown in Fig. 2-17. This specification covers a wide range of environmental applications such as offices, homes, schools, shops, theatres, etc. It applies for average clothing and activity.

ASHRAE recommends that the dry bulb temperature be adjusted for any change in mean radiant temperature by:

$$\text{ADBT} = \frac{\text{DBT} + \text{MRT}}{2}$$

where:

ADBT = adjusted dry bulb temperature
DBT = dry bulb temperature
MRT = mean radiant temperature*

The relative humidity should be maintained between approximately 20 per cent and 65 per cent while the air velocity, without regard to direction, in the occupied zone is controlled to less than 0.35 meters per second (70 feet per minute) at any point.

Additional research has been performed at The Institute of Environmental Research at Kansas State University under ASHRAE contract.[23,24] These studies provide methods for varying the comfort envelope for lightly clothed persons and sendentary activity.[25]

Further research has been carried out by Fanger[26] beginning in 1966 at Kansas State University and continued at the Technical University of Denmark. From a comfort equation developed by Fanger it is possible to predict a combination of environmental factors that produce a "comfortable" environment for a clothed person performing any selected activity.

The details of all these methods of defining comfort levels are beyond the scope of this section. The reader should consult the references for more detailed information.

Lighting Load on Air Conditioning

Fig. 2-18 gives one example of interior load distribution in a particular office building. The amount of heat gain through the exterior masonry is small enough to be neglected. Fluorescent lighting is provided consuming 27 watts per square meter (2.5 watts per square foot). It is assumed that Venetian blinds will be lowered during corresponding sunny hours.

* The uniform surface temperature of an imaginary black enclosure with which man exchanges the same heat by radiation as in the actual environment.

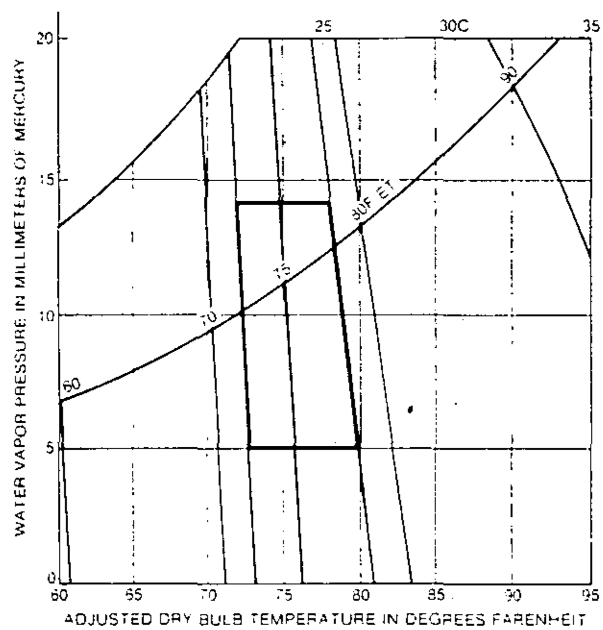


Fig. 2-17. Comfort envelope.[22]

In typical buildings, factors such as solar radiation through windows, heat transmitted through wall and roofs, and cooling of ventilation air, people, and machines comprise 50 to 80 per cent of the total cooling load. The refrigeration and/or air handling capacity required for lighting may be reduced if some of the principles described later in this section can be applied.

For the building of Fig. 2-18 the relative magnitude of all heat sources at the time of the total building peak cooling load is shown in Column A of Fig. 2-19. For comparison, analyses of the total cooling load for two other installations are shown in Columns B and C. The buildings are based on 27 and 32 watts per square meter (2.5 and 3 watts per square foot) respectively.

Electric Lamps as Heat Sources. Electric lamps are efficient converters of electric power to heat energy. Each watt of electric power consumed by a lamp generates 1 watt (3.4 British thermal units per hour) of heat, just as any electric heating device. The energy takes two principal forms: (1) conduction-convection energy, and (2) radiant energy (including infrared, light and ultraviolet). From this it is obvious that only a part of the energy generated by electric lamps is light. However, light itself produces heat. It does not heat air as convection sources do, but it raises the temperature of any surface which absorbs it.

A knowledge of the relative amount of each type of energy emanating from an electric lamp can be helpful in analyzing its performance and the effect it may have on thermal considerations, Figs. 2-20, 2-21, and 2-22 show approximate data for some representative fluorescent, incandescent and high intensity discharge lamps, respectively. These values are for lamps suspended in space under specific operating conditions.[27] Low energy ballasts will exhibit lower ballast losses; and although total lamp energy and bulb wall temperatures will differ, the lamp energy proportion may be considered typical for low energy lamps as well. Energy output for an individual luminaire in space, or for a system of luminaires installed in a room is likely to vary considerably from that for lamps alone.

Fig. 2-18. Example of Cooling Load Distribution in One Modern Office Building

Heat Source	Exterior Offices*				Interior Offices
	North	East	South	West	
Glass	46%	70%	65%	69%	—%
Lighting	30	18	20	17	39
Occupants	20	8	11	10	55
Miscellaneous	4	4	4	4	6
Totals	100%	100%	100%	100%	100%

* Per cent at time of maximum load in each office.

Fig. 2-19. Example of Cooling Load for Several Types of Installations

	Office Building A	Chain Store B	Clinic C
Glass	16%	6%	15%
Lighting	22	20	17
Roof and walls	1	12	33
Occupants	21	34	16
Ventilation	35	22	19
System power	5	4	—
	100%	100%	100%
Glass and lighting	38%	26%	32%

Fig. 2-20. Energy Output for Some Fluorescent Lamps of Cool White Color (Lamps Operated at Rated Watts on High Power Factor, 120-Volt, 2-Lamp Ballasts; Ambient Temperature 25 °C (77 °F) Still Air)

Type of Energy	40WT12	96 Inch T12 (800 mA)	PG17† (1500 mA)	T12 (1500 mA)
Light	19.0%	19.4%	17.5%	17.5%
Infrared (est.)*	30.7	30.2	41.9	29.5
Ultraviolet	0.4	0.5	0.5	0.5
Conduction-convection (est.)	36.1	36.1	27.9	40.3
Ballast	13.8	13.8	12.2	12.2
Approximate average bulb wall temperature	41 °C (106 °F)	45 °C (113 °F)	60 °C (140 °F)	

* Principally far infrared (wavelengths beyond 5000 nanometers).
† Grooves sideways.

Fig. 2-21. Energy Output for Some Incandescent Lamps

Type of Energy	100-Watt* (750-hour life)	300-Watt (1000-hour life)	500-Watt (1000-hour life)	400-Watt‡ (2000-hour life)
Light	10.0%	11.1%	12.0%	13.7%
Infrared†	72.0	68.7	70.3	67.2
Conduction-convection	18.0	20.2	17.7	19.1

* Coiled-coil filament.
† Principally near infrared (wavelengths from 700 to 5000 nanometers).
‡ Tungsten-halogen lamp.

Fig. 2-22. Energy Output for Some High Intensity Discharge Lamps

Type of Energy	400-Watt Mercury	400-Watt Metal Halide	400-Watt High Pressure Sodium	180-Watt Low Pressure Sodium
Light	14.6%	20.6%	25.5%	29.0%
Infrared	46.4	31.9	37.2	3.7
Ultraviolet	1.9	2.7	0.2	0
Conduction-convection	27.0	31.1	22.2	49.1
Ballast	10.1	13.7	14.9	18.2

Luminaires as Heat Sources. Performance characteristics of luminaires are well documented in terms of luminous efficiency, light control and candlepower distribution because equipment designers have been concerned primarily with the purposeful distribution of visible light. Now it is necessary to consider the total energy distribution of any luminaire destined to become a component of a building.

From Figs. 2-20, 2-21 and 2-22 it can be seen that the high percentage of energy converted by electric lamps is radiation lying predominantly in the near infrared or far infrared regions—the proportions depend on the light source. Because the properties of lighting materials are different in the range from visible to invisible radiation, it is important to consider the underlying physics.

Fig. 2-23 shows that some materials used in luminaires can be good reflectors of light and good absorbers of far infrared. Several materials used to transmit light show significant differences in the far infrared reflected.

Any quantitative analysis of luminaires as heat sources should assume conditions of temperature

Fig. 2-23. Properties of Lighting Materials
(Per Cent Reflectance (R) and Transmittance (T) at Selected Wavelengths)

Material	Visible Wavelengths						Near Infrared Wavelengths						Far Infrared Wavelengths							
	400 nm		500 nm		600 nm		1000 nm		2000 nm		4000 nm		7000 nm		10,000 nm		12,000 nm		15,000 nm	
	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T
Specular aluminum	87	0	82	0	86	0	97	0	94	0	88	0	84	0	27	0	16	0	14	0
Diffuse aluminum	79	0	75	0	84	0	86	0	95	0	88	0	81	0	68	0	49	0	44	0
White synthetic enamel	48	0	85	0	84	0	90	0	45	0	8	0	4	0	4	0	2	0	9	0
White porcelain enamel	56	0	84	0	83	0	76	0	38	0	4	0	2	0	22	0	8	0	9	0
Clear glass-3.2 millimeters (.125 inch)	8	91	8	92	7	92	5	92	23	90	2	0	0	0	24	0	6	0	5	0
Opal glass-3.9 millimeters (.155 inch)	28	36	26	39	24	42	12	59	16	71	2	0	0	0	24	0	6	0	5	0
Clear acrylic-3.1 millimeters (.120 inch)	7	92	7	92	7	92	4	90	8	53	3	0	2	0	2	0	3	0	3	0
Clear polystyrene-3.1 millimeters (.120 inch)	9	87	9	89	8	90	6	90	11	61	4	0	4	0	4	0	4	0	5	0
White acrylic-3.2 millimeters (.125 inch)	18	15	34	32	30	34	13	59	6	40	2	0	3	0	3	0	3	0	3	0
White polystyrene-3.1 millimeters (.120 inch)	26	18	32	29	30	30	22	48	9	35	3	0	3	0	3	0	3	0	4	0
White vinyl-0.76 millimeters (.030 inch)	8	72	8	78	8	76	6	85	17	75	3	0	2	0	3	0	3	0	3	0

Note: (a) Measurements in visible range made with General Electric Recording Spectrophotometer. Reflectance with black velvet backing for samples (b) Measurements at 1000 nm and 2000 nm made with Beckman DK2-R Spectrophotometer. (c) Measurements at wavelengths greater than 2000 nm made with Perkin-Elmer Spectrophotometer. (d) Reflectances in infrared relative to evaporative aluminum on glass.

stabilization, constant voltage, and service position. In this state, total energy may not follow the distribution of light energy. However, it will be helpful to compare total energy distribution with the general classifications assigned to candlepower distribution curves.

Thermal distribution characteristics would narrow the CIE classifications to (1) semi-direct, (2) direct-indirect, and (3) semi-indirect, as illustrated in Fig. 2-24. Totally direct or indirect lighting classifications are unlikely in total energy distribution curves. Of the two general diffuse lighting classifications, direct-indirect would be more appropriate.

Several test methods have been employed to assess the *total energy* distribution from a particular luminaire. One involves an adaptation of photometric techniques. Two others involve calorimetry, including a continuous water flow calorimeter[28] and continuous air flow calorimeters.[29, 30] Though procedures and equipment varied widely, test results were of the same order of magnitude.[31]

Testing guides for determining the thermal performance of luminaires have been published by ADC,* IES and NEMA. IES approved a new test method in 1978 which considers the effect of plenum temperature and air return in the light output. The test also provides data on heat distribution and power input dependent upon return air flow through the luminaire.[32]

Lighting Systems as Heat Sources. Visual and thermal conditions are two of the most important considerations in a planned interior environment. Visual comfort is partly due to quantity and quality of illumination. Thermal comfort is the result of a proper balance in temperature,

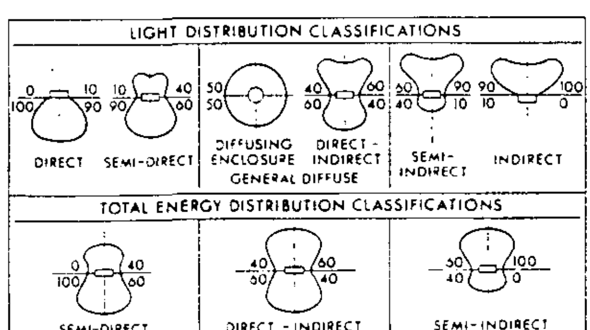


Fig. 2-24. Light distribution curves by CIE classifications of luminaires, compared with typical total energy distribution types. Upward and downward components are in percentage ranges.

* Air Diffusion Council.

relative humidity and air motion. If these factors are to be fully evaluated, consideration should be given to the total energy distribution of luminaires, their relationship to room surfaces, and to the type of conditioning system contemplated.

While total energy should ultimately be considered within the building envelope, comfort conditions will be primarily affected by that portion of the energy distributed into the occupied space. Thus, actual lighting and heating characteristics will be influenced by luminaire performance, ambient temperatures, surrounding materials and surface reflectances.

The *ASHRAE Fundamentals Handbook* covers the calculation of space load due to lighting for various luminaires and ventilation arrangements.[33] Generally, the instantaneous heat load from the lighting system is expressed using the relationship:

$$P_i = P_l \times \text{BLF} \times \text{CLF} \times \text{UF}$$

where

P_i = instantaneous heat load from the lighting system in watts (multiply by 3.41 to get Btu/h)

P_l = total lamp power in watts

BLF = ballast load factor—
incandescent, BLF = 1.00
rapid-start fluorescent, BLF = 1.08 to 1.30
high intensity discharge, BLF = 1.04 to 1.37

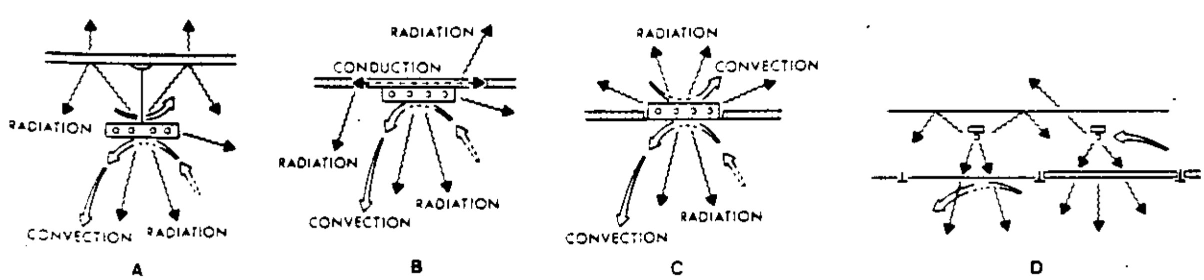
CLF = cooling load factor, a factor that allows for the type luminaire, furnishings, room envelope, length of time lights are on, etc. See reference 33.

UF = utilization factor, percentage of installed power in use expressed as a decimal. For commercial applications such as stores, UF is generally unity.

Luminaire mounting has an important role in the distribution of thermal energy. Fig. 2-25 illustrates typical heat flows for various types of ceiling-to-luminaire relationships. Total energy distribution involves all three mechanisms of heat transfer—radiation, conduction and convection. Although the illustration shows a fluorescent luminaire, HID luminaires exhibit similar patterns. The input of the suspended luminaire in Fig. 2-25 (A) would be convected and radiated in all directions to be reflected or absorbed and reradiated. Essentially, all of the input energy would remain within the occupied space.

Heat transfers from the surface mounted semi-direct luminaire in Fig. 2-25 (B) involve radiation, conduction and convection. Assuming good contact with the ceiling, upper surfaces of the luminaire will transfer energy to or from the ceiling by conduction. Since many acoustical ceiling materials are also good thermal insulators, it may be assumed that temperatures within the luminaire will be elevated. Thus, lower luminaire surfaces will tend to radiate and convect to the space below at a somewhat higher rate. Unless the ceiling material is a good heat conductor and can reradiate above, essentially all of the input energy will remain in the space.

A different situation exists when components of the system are separated from the space. The recessed luminaire in Fig. 2-25(C) distributes some portion of input wattage above the suspended ceiling. The actual ratio is a function of luminaire design and plenum and ambient conditions. For most recessed static luminaires, the



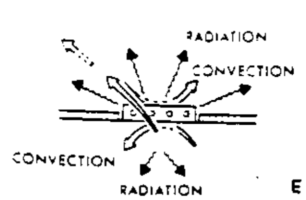


Fig. 2-25. Effect of ceiling-to-luminaire relationship upon lighting system heat transfer. Fluorescent luminaire has direct-indirect total energy distribution classification. (A) Suspension mounting. (B) Surface mounting. (C) Recessed. (D) Luminous and louvered ceiling. (E) Heat transfer luminaire.

ratio is very nearly 50 per cent above the ceiling and 50 per cent below.

Lighting systems of luminous and louvered ceiling types are illustrated in Fig. 2-25 (D). A similarity with the heat transfers of Fig. 2-25 (A) is noted. Although luminaires are separated from the occupied space, plastics and glass used in luminous ceilings are good absorbers of infrared. White synthetic enameled louvers are also good absorbers, whereas aluminum louvers reflect a high percentage of infrared. Unless some means of controlling the energy is employed, all of the electrical input energy also remains in the occupied space.

Heat transfer recessed luminaires are illustrated in Fig. 2-25 (E). Here, the convected and radiated component to the space have been reduced considerably while the upward energy has increased a proportional amount. Under certain conditions it is possible for the space load to consist almost entirely of light energy. The majority of the power input to the luminaire is directed upward where it can be captured by the system and be subject to some form of control. Laboratory tests conducted in accordance with IES procedures[32] will provide energy distribution data for evaluative purposes. However, the total system must be evaluated because heat removal to the plenum may raise plenum temperatures which cause conductive heat transfer back through the ceiling and floor to the space below and above adding thermal load back to the space.

Task/ambient systems have a different lighting energy distribution. Care must be exercised in the selection of the cooling load factor (CLF). Depending on the installation, it may be necessary to calculate task and ambient heat loads separately.

It is possible to have both systems completely within the space. This would be the case if suspended or surface-mounted luminaires were used for ambient lighting with task lighting being incorporated into the furniture or with suspended or surface-mounted luminaires being used for both. In this case, the entire input power is instantaneous space load.

With recessed luminaires utilized for ambient lighting and either suspended or furniture mounted for task lighting, the heat loads must be figured separately as only the task lighting load is entirely instantaneous space load. The recessed luminaire heat contribution may be considered less depending upon the CLF.

Systems can also utilize recessed luminaires for both task and ambient lighting. Here, both would impose a heat load which would be reduced by the CLF.

Benefits of Integrated Designs

The benefits of integrating building heat in lighting design are: (1) improved performance of the air conditioning system, (2) more efficient handling of lighting heat, and (3) more efficient lamp performance.

The control and removal of lighting heat can reduce heat in the occupied space, reduce air changes and fan horsepower, lower temperature differentials required in the space, enable a more economical cooling coil selection because of the higher temperature differential across the coil, and reduce luminaire and ceiling temperature thereby minimizing radiant effects.

The degree to which any of these benefits may be obtained depends on many variables such as the quantity of energy involved, the type of heat transfer mechanism, the temperature difference between source and sink, and the velocity and quantity of fluids and/or air available for heat transfer. However, in most applications luminaire temperature will be higher than room temperature so fluids at room temperature can be effective in heat transfer. Any unwanted heat that can be removed at room temperature or above can be removed much more economically than at lower temperatures.

The full benefits of integrated design can be achieved only through the combined efforts of a design team which should include architects, space planners, interior designers, electrical engineers, mechanical engineers, illuminating engineers and cost analysts.

LIGHTING FOR SAFETY

Importance. Safe conditions are essential to any inhabited space and the effect of light on safety must be considered. The environment should be designed to help compensate for the limitations of human capability. Any factor that aids visual effectiveness increases the probability that a person will detect the potential cause of an accident and act to correct it.

In many instances where illumination is associated with accidents, the cause is attributed to inadequate illuminance levels or poor quality of illumination. However, there are many less tangible factors associated with poor illumination which can contribute to many accidents. Some of these are: direct glare, reflected glare, and harsh shadows—all of which hamper seeing. Excessive visual fatigue itself may be an element leading toward accidents. Accidents may also be prompted by the delayed eye adaptation a person experiences when moving from bright surroundings into dark ones and vice versa. Some accidents which have been attributed to an individual's carelessness could have been partially due to difficulty in seeing from one or more of the above mentioned factors. The accidents might have been avoided through the use of good lighting principles.

Illuminance Levels. The lighting recommendations in Fig. 2-2 provide a guide for efficient visual performance rather than for safety alone; therefore, they are not to be interpreted as requirements for regulatory minimum illuminance levels.

Fig. 2-26 has been developed to list illuminance levels regarded as *absolute minimums for safety alone.* To assure these values are maintained, higher initial levels must be provided as required by the maintenance conditions. In those areas which do not have fixed lighting, localized illumination should be provided during occupancy by portable or material handling and vehicle mounted lighting equipment.

Other Factors. A visually safe installation must be free of excessive glare and of uncontrolled, large differences in luminances. Appropriate guides to limiting glare and adaptation effects are given earlier in this Section in discussions of luminance ratios and visual comfort. Maximum luminance ratios are important to avoid temporarily noticeable reductions in visibility because of changes in eye adaptation when alternately looking at areas of widely different luminances.

Fig. 2-26. Illuminance Levels for Safety*

Hazards Requiring Visual Detection	Slight		High	
Normal† Activity Level	Low	High	Low	High
Illuminance Levels				
Lux	5.4	11	22	54
Footcandles	0.5	1	2	5

* Minimum illuminance for safety of people, absolute minimum at any time and at any location on any plane where safety is related to seeing conditions.

† Special conditions may require different illuminance levels. In some cases higher levels may be required as for example where security is a factor. In some other cases greatly reduced levels, including total darkness, may be necessary, specifically in situations involving manufacturing, handling, use, or processing of light-sensitive materials (notably in connection with photographic products). In these situations alternate methods of insuring safe operations must be relied upon.

Note: See specific application reports of the IES for guidelines to minimum illuminances for safety by area.

Illumination Evaluation. Although the proper quality and quantity of illumination may be designed for safety in an area, it is necessary to know whether the design meets requirements. A standard procedure, titled "How to Make a Lighting Survey,"[34] has been developed in cooperation with the U.S. Public Health Service. This standard procedure is recommended for use in surveys of lighting for safety.

EMERGENCY LIGHTING

Consideration should be given to emergency lighting needs early in the planning stages of a building. Consultation between the owner and/or occupier of the premises, the architect, the lighting designer, the utility, and others concerned, should be arranged when, or perhaps before, the normal lighting planning is discussed. The installation contractor should be made aware of emergency lighting requirements at the earliest possible time.

Definitions. The following definitions are given for the terms used in this section:

Emergency lighting: Lighting provided for use when the power supply for the normal lighting fails, to insure that escape routes can be effectively identified and used.

Exit: A way out of the premises that is intended to be used at any time while the premises are occupied.

Emergency exit: A way out of the premises that is intended to be used only during an emergency.

Escape route: A route from a point inside the premises to an exit or emergency exit.

Normal lighting: All permanently installed electric lighting normally used when the premises are occupied.

Guides for the following are not provided here but are defined so that they are clearly excluded from this section.

Safety lighting: That part of emergency lighting that is provided to insure the safety of workers having to remain at work when the normal lighting fails.

Standby lighting: That part of emergency lighting that is sometimes provided to enable normal activities to continue.

Basic requirements for escape lighting are specified by federal codes and frequently are strengthened by local codes. The material that follows refers only to emergency lighting without regard for the type or location of the emergency power, which may be emergency motor driven generators, central battery systems, central inverter systems, unit inverters or unit equipment.

Emergency lighting is specified by the Life Safety Code (NFPA 101)[35] to be necessary in certain interiors where people work or meet, in order to enable them to leave the interior safely in the event that an emergency situation arises due to the failure of the normal power. References to that code, as well as any existing local codes, should be made at all times.

Design Requirements for Emergency Lighting.

When the normal lighting of an occupied building fails, irrespective of the cause, the emergency lighting is required to fulfill the following functions:

1. Indicate clearly and unambiguously the escape routes.
2. Provide illumination and a comforting visual environment along the escape routes sufficient to facilitate safe movement along them toward and through the exits and emergency exits provided.
3. Permit ready identification of all fire alarm call points and firefighting equipment provided along the escape routes under emergency lighting conditions.

Escape Route Indication. Signs are required to be illuminated in time of emergency to insure that from any point within the premises an escape route can be easily identified and followed in an emergency.

All normal exits should be illuminated at all times when the premises are occupied. This lighting should, practically speaking, be external to the exit signs themselves.

Where direct sight of an exit or emergency exit is not possible, a directional sign or series of signs should be provided. They should be so placed that a person following them will be progressed toward the nearest exit or emergency exit.

Exit signs cannot be counted on to be visible to many people at distances of more than 30 meters (100 feet), and should not be expected to be visible at longer intervals on long escape routes.

Illumination of Exit Signs. Either of the following methods of illumination may be used: (a) lamps external to the sign and (b) lamps contained within the sign. It is recommended that the method of illumination of exit signs described under (b) be used within any area where the normal lighting may be deliberately dimmed or extinguished, *e.g.*, places of entertainment.

In the event of failure of the supply to the normal lighting, escape route signs should receive the power needed for illumination from the emergency lighting supply. Power for exit signs should be unswitched or have the switch accessible only to authorized personnel.

Visual Impact and Legibility of Internally Illuminated Signs. Impact and legibility of exit signs are dependent upon luminance, size, viewing distance, contrast, positioning and uniformity.

Luminance: Where codes exist, an illuminance of 54 lux (5 footcandles) on the face of the sign is usually specified. Illuminance is an inappropriate parameter for internally illuminated signs. Currently research is being done along this line, but a luminance of 7 to 10 candelas per square meter (2 to 3 footlamberts) on the lighted area of the sign seems to be a reasonable level and parameter, because it appears to be adequate under emergency lighting conditions, is measurable, and provides better contrast under normal light.

Size: Letters must have at least a 19-millimeter (¾-inch) wide stroke and must be at least 150 millimeters (6 inches) high.

Viewing distance: In an emergency, an exit sign should not be expected to be useful at a distance greater than 30 meters (100 feet).

Contrast: Once other parameters have been met, this is a remaining important parameter. See luminance above. Transilluminated letters usually provide the best visibility. Color of letters is not an important point, so long as adequate light and contrast are provided. There seems to be little differentiation between dark letters on light background or illuminated (light) letters on dark or opaque background. Contrast is the important consideration.

Positioning: The location of the emergency exit sign will usually be determined by the desirable location under normal power conditions since, except for emergency exits, emergency exit signs mark the location of normal exit doors.

Uniformity: The exit sign face should be uniformly lighted, with a variation of not more than a factor of 2 above or below the average level over the lettered area.

All exit signs in a collective area should be of a similar color and design, as an aid to ready identification.

Externally Illuminated Exit Signs. Externally illuminated exit signs vary so greatly in design, material, color and printing that standards are difficult to establish. NFPA 101 requires 54 lux (5 footcandles) on the face of the sign. However, consideration must be given to contrast, glare, veiling reflectance, as well as reliability of the emergency power source for the external light, but the minimum letter size must adhere to that given above.

Egress Route Emergency Illumination

Illuminance. The horizontal illuminance of any escape route should be not less than 1 per cent of the average provided by the normal lighting, with a minimum average of 5 lux [0.5 footcandle] at floor level.

Illuminance Uniformity. Illuminance uniformity is more easily achieved by using a greater number of lamps with lower light output than by employing a lesser number of more widely spaced units with higher light output.

A uniformity ratio (E_{max}/E_{min}) of up to 20:1 along the center line of an escape route is desirable for safe movement. A value of 40:1 should not be exceeded.

Visibility of Hazards. By itself, illuminance is not a sufficient criterion of visibility, since it refers only to the light falling on a surface and not the amount reflected back to the eye. Luminance is really the only relevant measure.

It is recommended that all potential obstructions or hazards on an escape route be light in color with contrasting surroundings. Such hazards include the nosings of stair treads, barriers and walls at right angles to the direction of movement.

In restricted areas such as corridors, light-colored decoration throughout is an advantage and, under emergency conditions, prominent vertical surfaces can assist considerably in defining the escape route.

Location of Egress Luminaires. A luminaire should be provided for each exit door and emergency exit door and at points where it is necessary to emphasize the position of potential hazards, sufficient to light that area to a level of 30 lux [3 footcandles].

The floor area to be so lighted should be a square at the threshold of the point of egress that is double the width of the egress opening, or equal to the width of the corridor, whichever is less. Illuminance measurement should be on the horizontal.

Examples of such areas are:

1. Intersection of corridors.
2. Abrupt changes of direction of the egress path.
3. Staircases. Each flight of stairs should receive direct light.
4. Other changes of floor level that may constitute a hazard.
5. Outside each exit and emergency exit, and close to it.

Additional lamps, as required, should be located so as to ensure that the lighting throughout the escape routes complies with the recommendations for minimum illuminance and illuminance uniformity given above.

Windowless offices occupied by less than five people normally should not require emergency lighting, provided proper escape route light exists in the corridor.

Handicapped people and other special situations could be an exception.

A room nominally occupied by five or more people and not otherwise requiring emergency light, should have an illuminance at the door equal to the egress route, or a glass paneled door. Under these circumstances, solid doors should be avoided.

Illumination of Fire Alarm Call Points and Fire Fighting Equipment. Fire alarm call points and fire fighting equipment provided along escape routes should be illuminated either by emergency lighting or by normal electric lighting or daylight at all times while the premises are occupied.

Length of Time an Emergency Lighting System Should Operate Without Recharging

The time required to evacuate a premise will depend upon its size and complexity but it should normally be possible to complete an orderly evacuation, even of the largest premises, in less than one and one half hours. An owner, architect, or engineer, may agree that a lesser time is acceptable.

With battery operated emergency lighting, adequate light must be provided without the battery voltage dropping below 87½ per cent of rated voltage within the required time.

In an emergency, evacuation times may be considerably increased; for example, some of the escape routes may have been cut off, injured people may have to be found and possibly given on-the-spot medical treatment, etc. The time for which escape lighting is required to operate will, therefore, always be longer than the absolute minimum time required to evacuate the premises under ideal conditions.

Facilities designed especially for older and partially or wholly incapacitated people present special problems and special attention should be given to this parameter under these circumstances.

Power Supply Systems for Emergency Lighting

Emergency lighting is provided for use when the supply for the normal lighting fails and must, therefore, be powered by a source independent from that of the normal lighting. The recommendations here are confined to illumination by means of electric lamps. Furthermore, because this section is concerned primarily with permanently installed emergency lighting systems, the only power sources considered are motor driven electric generators and combinations of rechargeable secondary batteries together with suitable chargers.

The National Electrical Code section 700[36] specifically forbids the use of nonrechargeable (primary) batteries for emergency lighting.

Generator-Powered Systems. Emergency lighting systems should provide the required illuminance within a 10 second (NFPA101) period of the interruption of the normal lighting. If, therefore, such a system is to be powered by a generator, it is essential that the generator can be run up to its required output within the specified period, and that start-up be automatic on failure of the normal lighting. Care should be taken that batteries for generator starting are of a type specially designed for standby operation and are provided with suitable chargers.

Battery-Powered Systems. A battery-powered emergency lighting system utilizing suitable rechargeable secondary batteries may be designed for operation from a centrally located battery and charger combination (central system) or from batteries located at the lamps themselves (unit equipment). The battery/charger combination should, in each case, be so designed that, after the battery has been discharged for the specified duration of the category of the system, it should be capable of again supporting the emergency lighting system for one hour following a 24-hour recharge period.

All central battery powered units should be adequately ventilated.

Categories. Any emergency lighting system may be designed to supply the required load for any desired time. However, it must be designed to supply the minimum illuminances as established above.

Special areas: Almost every commercial building or apartment house normally occupied by 100 persons or more will have areas requiring special attention in the layout of the emergency lighting system. Examples are heavy machinery work areas, windowless stockrooms, restrooms and, particularly, stairwells. Emergency lighting for such areas only can be designed using good judgment and common sense.

The need for exterior emergency lighting to light escape routes away from the building, should not be overlooked.

Service and Maintenance

All emergency lighting systems should be tested and inspected at least every 30 days, no matter what type of emergency power is used.

For large installations where responsible semi-skilled personnel are not available, a service contract with a responsible service organization should be provided. In some cases, this contract can be included in the specifications for the system, or it may be negotiated later between the owner and the service organization. Competent emergency lighting service organizations operate in most cities.

Criteria for Measurement of Emergency Lighting

Because of the very low illuminances provided by emergency lighting and because only escape routes need to be lighted, lux (footcandle) and watts per square meter (foot) are not suitable measuring criteria. Adequate visibility is really the only suitable criteria. However, at the present time there appears to be no better way to specify that than in illuminance or luminance.

Caution

Section 700 of the National Electrical Code[36] contains specifications for the installation of emergency lighting and these should be adhered to.

All emergency lighting equipment should carry the label of a nationally recognized testing laboratory.

ECONOMICS

Economic analysis is an important tool to be used in making lighting design decisions. It is based on the economic impact of various alternatives, and assumes that the relevant variables are expressible in monetary units. In comparing a number of different lighting systems, for example, a life cycle cost study is not relevant unless all systems are functionally acceptable. There is no monetary expression that says one alternative doesn't provide enough light, or that another alternative is a system with a great deal of discomfort glare. Therefore, the analysis assumes that all alternatives are functionally equivalent.

Since money has a time value, a monetary unit (*e.g.*, dollar, peso, etc.) at one date is not directly comparable with the same monetary unit at another date. It is not sufficient, therefore, to determine the amounts of expenditures and receipts. It is necesary to determine the times of these cash flows. This is the essence of *life cycle costing*. All expenditures and receipts for the anticipated life of the system or length of the study period are expressed in terms of present worth.

For life cycle costing of a lighting system an evaluation is made of a series of payments which include initial cost, power costs, replacement lamp and ballast costs, cleaning and maintenance labor costs, etc. Life cycle costing is particularly useful in determining the most economical system when a series of costs are likely over a long period of time. With power costs, labor costs, and replacement parts increasing at a rapid rate, the system with the least initial cost may be the most expensive alternative over the life of the system.

For more specific information, see Section 3, Lighting Economics.

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FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

CURSOS ABIERTOS.

ILUMINACION INTERIOR: PRINCIPIOS, DISEÑOS Y APLICACIONES.

CALCULO DE ILUMINACION

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CALCULO DE ILUMINACION DE INTERIORES

METODO DE CAVIDAD ZONAL

TABLAS DE DATOS

EJEMPLOS

HOJA DE TRABAJO

CONTENIDO

EL PROCEDIMIENTO DE CALCULO DE ILUMINACION, AUNQUE MAS BIEN FACIL PARA EL DISEÑADOR EXPERIMENTADO, EN OCASIONES PARECE SER COMPLICADO PARA EL PRINCIPIANTE. EN ESCENCIA EL METODO INVOLUCRA EVALUACIONES PRELIMINARES, DETERMINACION DE PARAMETROS Y CALCULOS.

UNA DIFICULTAD DURANTE EL ESTUDIO DE ESTAS NOTAS, PUEDE SER LA CARENCIA DE FAMILIARIDAD CON LA TERMINOLOGIA. AUNQUE LOS TERMINOS DE ESTAS NOTAS SON EXPLICADOS CONFORME SON INTRODUCIDOS, OTRAS DEFINICIONES PUEDEN REQUERIR LA REFERENCIA A OTRAS PUBLICACIONES.

ANTES DE ABORDAR LAS SIGUIENTES PAGINAS, LA DESCRIPCION DEL CONTENIDO DE ESTAS NOTAS PUEDE SER UTIL.

1.- INTRODUCCION: UNA BREVE DEFINICION DEL SISTEMA; POR QUE ES LLAMADO "METODO DE CAVIDAD ZONAL", ETC.

2.- CALCULO DE ILUMINACION; UNA EXPOSICION DE LAS RELACIONES BASICAS (LA "ECUACION" O "FORMULA") DE LA CANTIDAD DE ILUMINACION A LA CANTIDAD DE LUZ QUE ES GENERADA POR UN SISTEMA DE ILUMINACION.

    LA ECUACION BASICA DE EXPANDE PARA INCLUIR UN NUMERO DE FACTORES LOS CUALES MODIFICAN EL COMPORTAMIENTO DE LA LUZ ENTRE EL LUMINARIO Y EL PLANO DE TRABAJO QUE VA A SER ILUMINADO.

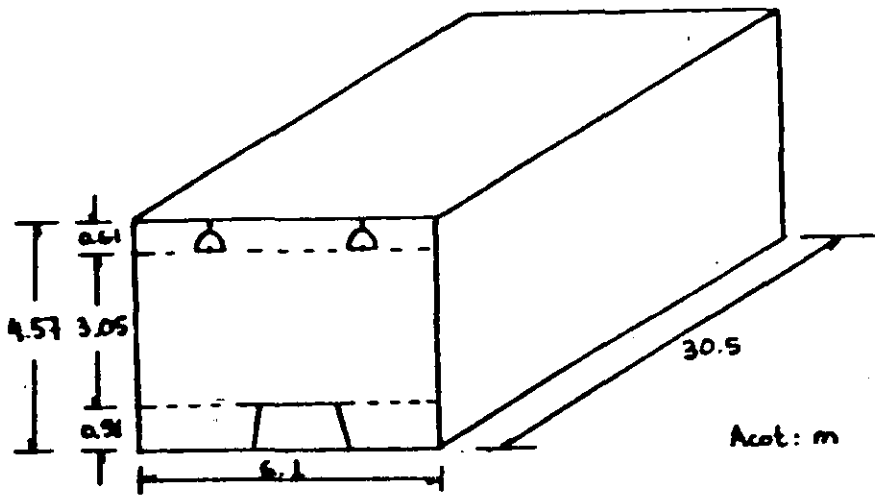
    NOTA: ESTOS FACTORES SE DEFINEN CONFORME SE PRESENTAN PERO LA FORMA DE DETERMINARLOS ES EXPLICADA HASTA QUE LA ECUACION ESTA COMPLETAMENTE DESARROLLADA.

3.- ECUACIONES DE TRABAJO: SON LAS EXPRESIONES MATEMATICAS PREVIAMENTE DETERMINADAS. ESTAS SON LAS FORMULAS "DESARROLLADAS" LAS CUALES SE UTILIZAN PARA LOS CALCULOS.

4.- DETERMINACION DE FACTORES: EL PROCEDIMIENTO PASO POR PASO PARA LA EXACTA DETERMINACION DE LOS FACTORES "DESCONOCIDOS" LOS CUALES VAN A SER SUSTITUIDOS EN LAS "ECUACIONES DE TRABAJO".

5.- ARREGLO DE LUMINARIOS: UNA EXPLICACION DE COMO DISTRIBUIR LOS LUMINARIOS QUE SE HA CALCULADO SON NECESARIOS PARA PROPORCIONAR LA ILUMINACION REQUERIDA.

EL DESARROLLO DE CADA UNO DE LOS FACTORES SE ILUSTRA MEDIANTE "EJEMPLOS" BASADOS EN EL SIGUIENTE PROBLEMA:



(1) LOCAL INDUSTRIAL
(2) NIVEL DE ILUMINACION MINIMO: 1180 LUXES
(3) LAMPARA A UTILIZAR: LUCALOX DE 250 WATTS (LU250/U)
(4) LUMINARIO A UTILIZAR: N° 16, PAG. A-4
(5) CONDICION DE SUCIEDAD: "MEDIA"
(6) MANTENIMIENTO DEL SISTEMA DE ILUMINACION: CADA 24 MESES

CALCULO DE ILUMINACION POR EL METODO DE CAVIDAD ZONAL.

1.- INTRODUCCION

EL METODO DE CAVIDAD ZONAL PARA EL CALCULO DE ILUMINACION, DESARROLLADO POR LA SOCIEDAD DE INGENIERIA DE ILUMINACION (IES), DETERMINA LOS NIVELES DE ILUMINACION PROMEDIO DE LA LUZ EMITIDA POR LOS LUMINARIOS DENTRO DE UN ESPACIO CE-RRADO. ESTE METODO ES PREFERIDO SOBRE OTROS NO PORQUE SEA NECESARIAMENTE MAS EXACTO, SINO PORQUE ES RELATIVAMENTE - SIMPLE Y FLEXIBLE. SUS RESULTADOS SON GENERALMENTE MAS - REPRESENTATIVOS DE UNA SITUACION DE ILUMINACION REAL Y -- PUEDE SER APLICADO A CUALQUIER TIPO DE SISTEMA DE ILUMINACION EN LOCALES RECTANGULARES O DE FORMAS ESPECIALES.

EL TERMINO "CAVIDAD ZONAL" SE DERIVA DE SUPONER QUE EL ES-PACIO EN CONSIDERACION ESTA DIVIDIDO EN CAVIDADES SOBREPUESTAS (MAXIMO 3) E INVESTIGA EL COMPORTAMIENTO DE LA LUZ EN CADA UNO ANTES DE QUE LA LUZ ALCANCE EL NIVEL (EL "PLANO - DE TRABAJO") EN EL CUAL SE LOCALIZA LA TAREA VISUAL.

ESTAS NOTAS EXPLICAN ESTE FENOMENO, TAMBIEN PROPORCIONA UNA EXPLICACION DEL PROCEDIMIENTO DE CALCULO DE ILUMINACION PA-SO POR PASO (CON EJEMPLOS APROPIADOS).

2.- CALCULO DE ILUMINACION

EL CALCULO DE ILUMINACION ESTA BASADO EN LA DEFINICION DE LA CANTIDAD DE ILUMINACION: EL "LUX".

$$(1) \qquad LUX = \frac{LUMENES}{AREA\ (\ EN\ METROS\ CUADRADOS\ )}$$

LA ECUACION ES BASICA: EN ESTA SE ASUME QUE TODA LA LUZ GENERADA (LUMENES) SE VUELVE ILUMINACION EN EL PLANO DE TRABAJO. EN REALIDAD, EXISTE UN GRAN NUMERO DE PARAMETROS QUE DEBILITAN EL SISTEMA DE ILUMINACION. ESTE METODO DE ILUMINACION INVOLUCRA CUATRO DE ELLOS - Y EL INGENIERO DE ILUMINA-CION LOS COMPENSARA MEDIANTE LA APLICACION DE FACTORES ADI-CIONALES EN LA ECUACION (1):

COEFICIENTE DE UTILIZACION (CU)
DEPRECIACION DE LOS LUMENES DE LA LAMPARA (DLL):
DEPRECIACION POR POLVO EN EL LUMINARIO (DPL)
DEPRECIACION POR SUCIEDAD DEL LOCAL (DPSL)

EL PROPOSITO ESCENCIAL (Y PROCEDIMIENTO MAS LARGO) DEL METODO DE CAVIDAD ZONAL ES LA DETERMINACION DEL COEFICIENTE DE UTILIZACION.

COEFICIENTE DE UTILIZACION (CU)

LAS LAMPARAS DE UN LUMINARIO GENERAN UNA CANTIDAD CONOCIDA DE LUMENES, PERO UNICAMENTE UNA PORCION DE ESOS LUMENES SALE DEL LUMINARIO. EL RESTO ES ABSORBIDO POR EL LUMINARIO MISMO (AL PORCENTAJE QUE ES EMITIDO SE LE DENOMINA LA "EFICIENCIA" DEL LUMINARIO). LA LUZ QUE ESCAPA SUFRE PERDIDAS POSTERIORES - DEBIDAS A LA GEOMETRIA DEL LOCAL Y A LA REFLECTANCIA INICIAL DE SUS SUPERFICIES. ENTONCES, EL CU ES EL PORCENTAJE DE LUZ GENERADA POR LA LAMPARA QUE FINALMENTE INCIDE EN EL PLANO DE TRABAJO. ASI LA ECUACION (1) SE MODIFICA:

$$(2) \qquad \text{LUXES} = \frac{\text{LUMENES} \times \text{CU}}{\text{AREA}}$$

FACTOR DE PERDIDA DE LUZ (FPL)

EL TIEMPO IMPONE UNA REDUCCION GRADUAL DE ILUMINACION. LOS LUMENES DE SALIDA DE LA LAMPARA DISMINUYEN. LA SUCIEDAD DE LAMPARAS Y LUMINARIOS REDUCE LA EFICIENCIA. LA SUCIEDAD DEL LOCAL ATENUA LA REFLECTIVIDAD. DEBIDO A QUE EL NIVEL DE ILUMINACION USUALMENTE ES CALCULADO COMO UN VALOR MANTENIDO -- (UN NIVEL MINIMO RECOMENDADO), EL DISEÑO DE ILUMINACION REQUIERE UN NIVEL INICIAL MAYOR; POR TANTO, LA ECUACION (2) - DEBE SER MODIFICADA MEDIANTE LA INCLUSION DE "FACTORES DE - DEPRECIACION" COMPENSADORES.

DEPRECIACION DE LOS LUMENES DE LA LAMPARA (DLL)

COMPENSA LAS PERDIDAS DE LOS LUMENES DE SALIDA. EL FACTOR DLL ES PROPORCIONADO POR EL FABRICANTE DE LA LAMPARA.

DEPRECIACION POR POLVO EN EL LUMINARIO (DPL)

COMPENSA LAS PERDIDAS OCASIONADAS POR LA ACUMULACION DE POLVO EN LAMPARAS Y LUMINARIOS. EL VALOR DEPENDE DEL DISEÑO DEL LUMINARIO Y DE LAS CONDICIONES AMBIENTALES; POR EJEMPLO, LA PERDIDA ES MAYOR EN UNA FUNDICION QUE EN UNA OFICINA CON AIRE ACONDICIONADO Y FILTRADO. EL FACTOR DPL SE DETERMINA CON UNA EXACTITUD APROXIMADA MEDIANTE EL EMPLEO DE TABLAS APROPIADAS O GRAFICAS.

DEPRECIACION POR SUCIEDAD DEL LOCAL (DPSL)

COMPENSA LAS PERDIDAS QUE OCASIONA LA SUCIEDAD EN LA REFLECTIVIDAD DE LAS SUPERFICIES DEL LOCAL. DPSL SE DETERMINA MEDIANTE TABLAS.

INCLUYENDO TODOS ESTOS FACTORES EN LA ECUACION (2)

$$(3) \qquad \text{LUXES} = \frac{\text{LUMENES} \times \text{CU} \times \text{DLL} \times \text{DPL} \times \text{DPSL}}{\text{AREA}}$$

FPL ES EL PRODUCTO DE TODOS LOS FACTORES DE DEPRECIACION:

$$(4) \qquad \text{FPL} = \text{DLL} \times \text{DPL} \times \text{DPSL}$$

ENTONCES, LA ECUACION (3) PUEDE SER EXPRESADA COMO

$$(5) \qquad \text{LUXES} = \frac{\text{LUMENES} \times \text{CU} \times \text{FPL}}{\text{AREA}}$$

3.- LAS ECUACIONES DE TRABAJO

EL DISEÑO DE ILUMINACION IMPLICA LA DETERMINACION DEL NUMERO TOTAL DE LUMENES (POR TANTO, LA CANTIDAD DE LUMINARIOS) REQUERIDOS PARA PRODUCIR UN NIVEL ESPECIFICO DE LUXES EL CUAL ES UN VALOR CONOCIDO. OTROS FACTORES DE LA ECUACION (5) SON DETERMINABLES. ENTONCES, ES CONVENIENTE TRANSFORMAR LA ECUACION PARA DETERMINAR EL TOTAL DE LUMENES DESCONOCIDOS.

$$(6) \qquad \boxed{\text{LUMENES TOTALES} = \frac{\text{LUXES} \times \text{AREA}}{\text{CU} \times \text{FPL}}}$$

CADA LUMINARIO TIENE UN NUMERO CONOCIDO DE LAMPARAS; CADA LAMPARA GENERA UNA CANTIDAD CONOCIDA DE LUMENES. POR TANTO, LA CANTIDAD DE LUMENES PRODUCIDOS DENTRO DE CADA LUMINARIO ES:

(7) LUMENES POR LUMINARIO = N° DE LAMPS. x LUMENES POR LAMP.

EL PASO FINAL CONSISTE EN DETERMINAR EL NUMERO REQUERIDO (N) DE LUMINARIOS:

$$(8) \quad N = \frac{\text{LUMENES TOTALES}}{\text{LUMENES POR LUMINARIO}}$$

ES SIN DUDA MEJOR PARA EL PRINCIPIANTE USAR LAS ECUACIONES (6), (7), Y (8) EN SECUENCIA. SIN EMBARGO ESTOS PASOS PUEDEN SER COMBINADOS EN UNA SOLA ECUACION:

$$(9) \quad N = \frac{\text{LUXES} \times \text{AREA}}{\text{CU} \times \text{FPL} \times (\text{LUMENES/LAM}) \times (\text{LAMPS/LUMINARIO})}$$

UNA VEZ DETERMINADO "N", EL DISEÑADOR DE ILUMINACION TRANSLADA ESTA INFORMACION AL "ARREGLO DE LUMINARIOS". LA GEOMETRIA DEL LOCAL Y/O LAS CONDICIONES MECANICAS PUEDEN REQUERIR LIGERAS MODIFICACIONES A LA CANTIDAD DE LUMINARIOS.

4.- DETERMINACION DEL COEFICIENTE DE UTILIZACION

COMO PREVIAMENTE SE ANALIZO, EL CU ES EL PORCENTAJE DE LUZ, GENERADA POR UN SISTEMA DE ILUMINACION, QUE ALCANZA FINALMENTE EL PLANO DE TRABAJO. ESTE VALOR DEPENDE DE LAS SIGUIENTES CONSIDERACIONES:

- LA EFICIENCIA DEL LUMINARIO Y SU CARACTERISTICA DE DISTRIBUCION DE LUZ.
- LAS PROPORCIONES GEOMETRICAS DEL LOCAL: LA RELACION DE SUPERFICIES VERTICALES Y SUPERFICIES HORIZONTALES.
- LAS REFLECTANCIAS DE LAS SUPERFICIES DEL LOCAL Y LAS INTERREFLEXIONES DENTRO DE "CAVIDADES ZONALES" DEFINIDAS.

EL CU APROPIADO SE EXTRAE DE TABLAS CALCULADAS Y PROPORCIONADAS POR EL FABRICANTE DEL LUMINARIO. (CADA LUMINARIO TIENE SU PROPIA TABLA DE CU.) LA ILUSTRACION SIGUIENTE, ES UN EJEMPLO DE UNA TABLA TIPICA. ANTES DE QUE EL CU SE PUEDA EXTRAER, ES NECESARIO DETERMINAR VARIOS FACTORES DE ENTRADA. ESTOS INVOLUCRAN CALCULOS PRELIMINARES Y/O REFERENCIA A OTRAS TABLAS.

LOS FACTORES DE ENTRADA SON:

1.- PORCIENTO DE REFLECTANCIA EFECTIVA DE LA CAVIDAD DEL TECHO (PCT). →

2.- PORCIENTO DE REFLECTANCIA DE LA PARED (Pw). →

3.- RELACION DE CAVIDAD DEL LOCAL (RCL) O (RCR). →

(Para cualquier altura especifica, RCR's más grandes indican locales más pequeños)

Coeficientes de Utilización

ρ_{cc} →	80			70			50			30			10	
ρ_w →	50	30	10	50	30	10	50	30	10	50	30	10	50	30
RCR ↓	Coeficiente de utilización para 20% de reflectancia efectiva de piso (ρ_{fc} = 20)													
0	.63	.63	.63	.62	.62	.62	.59	.59	.59	.58	.56	.56	.54	
1	.58	.56	.54	.57	.55	.54	.54	.53	.52	.52	.51	.50		
2	.53	.50	.48	.52	.49	.47	.50	.48	.46	.48	.47			
3	.48	.45	.42	.47	.44	.42	.46	.43	.41	.44				
4	.44	.40	.37	.43	.40	.37	.42	.39	.37					
5	.40	.36	.33	.39	.36	.33	.38	.35						
6	.36	.32	.30	.36	.32	.29	.35							
7	.33	.29	.26	.33	.29	.26								
8	.30	.26	.23	.30	.26									
9	.27	.23	.21	.27										
10	.25	.21												

Estos son los CU's
Note como decrecen cuando las reflectancias disminuyen y las RCR's aumentan.

LAS "REFLECTANCIAS EFECTIVAS" SE EXTRAEN DE OTRAS TABLAS Y SON UNA MODIFICACION DE LAS REFLECTANCIAS REALES DE LAS SUPERFICIES DEL LOCAL. ESTAS ULTIMAS SON ESPECIFICADAS, MEDIDAS O - EN OCACIONES - ESTIMADAS. SIN EMBARGO, ES NECESARIO PRIMERO DETERMINAR LAS RELACIONES DE CAVIDAD.

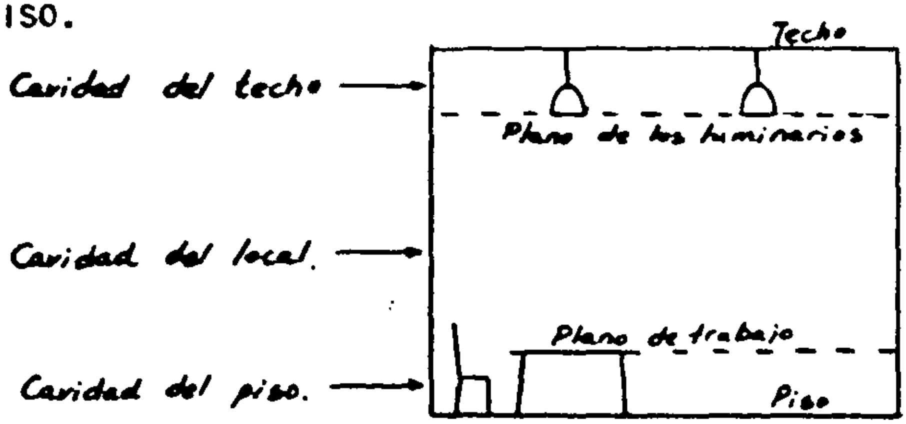
DETERMINACION DE RELACIONES DE CAVIDAD

SUPONGA UN LOCAL RECTANGULAR DIVIDIDO EN TRES CAVIDADES HORIZONTALES, CADA UNA LIMITADA VERTICALMENTE POR LAS PAREDES:

(1) LA "CAVIDAD DEL TECHO"- ENTRE EL TECHO Y UN PLANO IMAGINARIO EN LA PARTE INFERIOR DE LOS LUMINARIOS.

(2) LA "CAVIDAD DEL LOCAL"- ENTRE EL PLANO DE LOS LUMINARIOS Y UN PLANO IMAGINARIO SOBRE LAS SUPERFICIES DE TRABAJO (ESCRITORIOS, HERRAMIENTAS, ETC.).

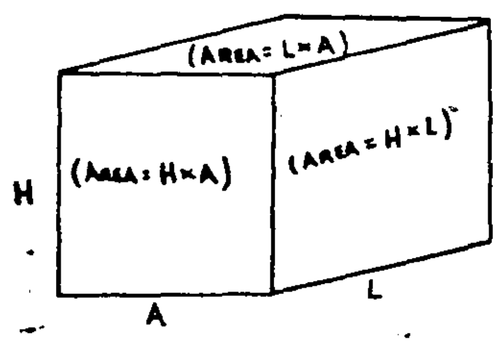
(3) LA "CAVIDAD DEL PISO" - ENTRE EL PLANO DE TRABAJO Y EL PISO.



NOTA: SI LOS LUMINARIOS ESTAN EMPOTRADOS EN EL TECHO, O SI LA SUPERFICIE DE MONTAJE ES POCO PROFUNDA, NO EXISTE CAVIDAD DEL TECHO. SI EL PLANO DE TRABAJO COINCIDE CON EL PISO, NO EXISTE CAVIDAD DEL PISO. SIEMPRE EXISTE UNA CAVIDAD DEL LOCAL.

DENTRO DE ESTAS CAVIDADES, LA LUZ DE INTERREFLEXION SE COMPORTA DIFERENTE CUANDO LA RELACION DE AREA VERTICAL SOBRE HORIZONTAL DIFIERE; POR LO TANTO, EL PRIMER PASO PARA DETERMINAR ESE COMPORTAMIENTO IMPLICA LA DETERMINACION: LAS RELACIONES DE AREA VERTICAL SOBRE AREA HORIZONTAL EN CADA UNA DE LAS CAVIDADES. ESAS SON LLAMADAS "RELACIONES DE CAVIDAD" (RC).

PARA ENTENDER ESTAS RELACIONES RC, SUPONGA UNA CAVIDAD CUYAS DIMENSIONES SE MUESTRAN EN LA FIGURA ADJUNTA.



(1) EL AREA DE CADA PARED FRONTAL O POSTERIOR ES (H × A); O, EL AREA COMBINADA ES 2 (H × A).

(2) EL AREA DE CADA PARED LATERAL ES (H × L); COMBINADA, 2(H × L).

(3) EL AREA TOTAL DE PAREDES ES : $[2(H \times A) + 2(H \times L)]$; O, SIMPLIFICADO, 2H (L + A).

(4) EL AREA DEL TECHO Y DEL PISO ES (L x A); COMBINADO, --- 2(L x A).

(5) POR TANTO, LA <u>RELACION</u> DE AREAS VERTICALES SOBRE HORIZONTALES (LA RELACION DE CAVIDAD) ES:

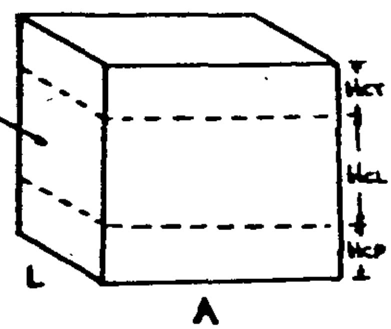
$$RC = \frac{2H\ (L + A)}{2\ (L \times A)} = \frac{H(L + A)}{L \times A}$$

REFIRIENDO AL CU TABLA (PAG. 5), SE NOTARA QUE LA COLUMNA IZQUIERDA TIENE VALORES DE RELACION DE CAVIDAD DEL LOCAL - (RCL) O (RCR) DE 1 A 10. SI SE SUSTITUYEN DIMENSIONES REALES EN LA ECUACION, LAS RELACIONES DE CAVIDAD PARA LA MAYORIA DE LOCALES CAERA ENTRE 0.2 Y 2.0. LAS RELACIONES DE CAVIDAD PARA TECHOS Y PISOS SERIAN AUN MAS PEQUEÑAS. PARA ESTABLECER NUMEROS DE RC MAS CONVENIENTES PARA ENTRAR A - LAS TABLAS DE CU, LAS RC'S ESTAN ARBITRARIAMENTE MULTIPLICADAS POR 5 - UN ARTIFICIO QUE NO MODIFICA LA RELACION:

$$RC = \frac{5H\ (L + A)}{L \times A}$$

SE PUEDE AHORA DETERMINAR LAS TRES RELACIONES DE CAVIDAD; NORMALMENTE, PRIMERO <u>RCL (RCR EN INGLES)</u>

$$RCL = \frac{5HCL\ (L + A)}{L \times A}$$



$$RCT = \frac{5HCT(L + A)}{L \times A}$$

$$RCP = \frac{5HCP(L + A)}{L \times A}$$

LA LONGITUD Y EL ANCHO SON CONSTANTES: ENTONCES, SE PUEDE CALCULAR RCL Y EN FUNCION DE ESTE, RCT Y RCP (CADA UNO ES PROPORCIONAL AL OTRO DE ACUERDO A SU VALOR DE H):

$$RCT = RCL\ \frac{HCT}{HCL} \qquad\qquad RCP = RCL\ \frac{HCP}{HCL}$$

<u>Ejemplo:</u> $H_{CT} = 0.61$ m , $H_{CL} = 3.05$ m y $H_{CP} = 0.91$ m L = 30.5 m, A = 6.1 m

$$R_{CL} = \frac{5 \times 3.05\,(30.5 + 6.1)}{30.5 \times 6.1} = 3.0\ ; \quad R_{CT} = 3.0\left(\frac{0.61}{3.05}\right) = 0.6\ ; \quad R_{CP} = 3.0\left(\frac{0.91}{3.05}\right) = 0.9$$

DETERMINACION DE LAS REFLECTANCIAS EFECTIVAS DE LAS CAVIDADES.

UN PASO MAS SE NECESITA PARA OBTENER LOS DATOS SUFICIENTES PARA LA DETERMINACION DEL CU: LA DETERMINACION DE LAS "REFLECTANCIAS EFECTIVAS DE TECHO Y PISO".

ES IMPORTANTE QUE EL ESTUDIANTE DISTINGA ENTRE LAS REFLECTANCIAS REALES DE UNA SUPERFICIE Y LAS REFLECTANCIAS EFECTIVAS DE LA CAVIDAD. CUANDO LA LUZ SALE DEL LUMINARIO LO HACE EN VARIAS DIRECCIONES. CUALQUIER RAYO DE LUZ "REBOTA" CONSIDERABLEMENTE DE UNA SUPERFICIE A OTRA. CADA REBOTE CAUSA ALGUNAS PERDIDAS (POR ABSORCION) Y LA POSTERIOR DISPERSION DE LA PORCION NO ABSORBIDA EN MAS RAYOS EN MUCHAS OTRAS DIRECCIONES. ESTE ES EL PROCESO DE INTERREFLEXION QUE PRODUCE REFLECTANCIAS EN LAS CAVIDADES LAS CUALES PUEDEN DIFERIR DE LAS OBSERVADAS EN LAS SUPERFICIES BASICAS (TECHO O PISO) DE LAS CAVIDADES RESPECTIVAS.

LAS REFLECTANCIAS EFECTIVAS DE LAS CAVIDADES SE EXTRAEN DE LA TABLA 1 (UNA PARTE DE ESTA SE MUESTRA ABAJO)

PARA OBTENER LA REFLECTANCIA EFECTIVA DE LA CAVIDAD DEL TECHO (PCT):

(1) ENTRE A LA COLUMNA IZQUIERDA DE LA TABLA CON RCT.
(2) ENTRE A LA LINEA SUPERIOR CON LA REFLECTANCIA REAL DEL TECHO.
(3) ENTRE A LA SEGUNDA LINEA CON LA REFLECTANCIA REAL DE LA PARED.
(4) OBTENGA LA REFLECTANCIA EFECTIVA DE LA CAVIDAD DEL TECHO EN LA INTERSECCION DE (1) CON (2) Y (3).

PARA OBTENER LA REFLECTANCIA EFECTIVA DE LA CAVIDAD DEL PISO (PCP):

(1) ENTRE A LA COLUMNA IZQUIERDA DE LA TABLA CON RCP.
(2) ENTRE A LA LINEA SUPERIOR CON LA REFLECTANCIA REAL DEL PISO.
(3) ENTRE A LA SEGUNDA LINEA CON LA REFLECTANCIA REAL DE LA PARED.
(4) OBTENGA LA REFLECTANCIA EFECTIVA DE LA CAVIDAD DEL PISO EN LA INTERSECCION DE (1) CON (2) Y (3).

(De Tabla 1, pag. A-1 y A-2)

Porcentaje de las reflectancias efectivas de techo o piso

% de reflectancia base*	90	80 (ρ_T)	10 (ρ_P)
% de reflectancia de pared	90 80 70 60 50 40 30 20 10 0	90 80 70 60 50 40 30 20 10	70 60 50 40 30 20 10
Relación de cavidad			
0.2	89 88 88 87 86 85 85 84 84 82	79 78 78 77 77 76 76 75	11 11 11 10 10 10 10 09 09
0.4	88 87 86 85 84 83 81 80 79 76	79 77 76 75 74 73 72 7	12 11 11 11 11 10 10 09 09
0.6 (R_{CT})	87 86 84 82 80 79 77 76 74 73	78 76 75 73 71 70 68	13 13 12 11 11 10 10 09 08
0.8	87 85 82 80 77 75 73 71 69 67	78 75 73 71 69 67 64	15 14 13 12 11 10 10 09 08
1.0	86 83 80 77 75 72 69 66 64 62	77 74 72 69 67 65 13	16 14 13 12 12 11 10 09 08
1.2	85 82 78 75 72 69 66 63 60 57	76 73 70 67 64 14 12	17 15 14 13 12 11 10 09 07
1.4	85 80 77 73 69 65 62 59 57 52	76 72 68 65 65 13 12	18 16 14 13 12 11 10 09 07
1.6	84 79 75 71 67 63 59 56 53 50	75 71 67 63 15 13 11	19 17 15 14 12 11 09 08 07
1.8	83 78 73 69 64 60 56 53 50 48	75 70 66 65 14 12 10	19 17 15 14 13 11 09 08 06
2.0	83 77 72 67 62 56 53 50 47 43	74 69 64 15 13 11 09	20 18 16 14 13 11 09 08 06

R_{CT} → 0.6; R_{CP} → 0.9; R_W

Ejemplo:
Del ejem. 7
$R_{CT} = 0.6$
$R_{CP} = 0.9$
$\rho_T = 80\%$
$\rho_W = 50\%$
$\rho_P = 10\%$
$\rho_{CT} = 71\%$ (70%
$\rho_{CP} = 11.5\%$

SELECCION DE LAMPARAS Y LUMINARIOS

EL PLANTEAMIENTO DE UN SISTEMA DE ILUMINACION PRESUPONE QUE L DISEÑADOR HA ESTUDIADO EL PROBLEMA Y HA DETERMINADO AL MEOS UNA SELECCION TENTATIVA DE LA COMBINACION LAMPARA-LUMINARIO, LOS PARAMETROS QUE DEBERA HABER CONSIDERADO PREVIAMENTE INCLUYEN:

FUNCIONES Y/O ACTIVIDADES EN EL LOCAL
ILUMINACION MANTENIDA RECOMENDADA
GEOMETRIA DEL LOCAL Y REFLECTANCIAS DE LAS SUPERFICIES
ECONOMIA DE ENERGIA Y DE PESOS
CONSIDERACIONES ESTRUCTURALES, ETC.

LA SELECCION DEL LUMINARIO DEBE SER PREVIA A LA INVESTIGACION DEL CU EN TABLAS (LAS CUALES, RECUERDE, ESTAN CALCULADAS PARA LUMINARIOS ESPECIFICOS). AL MISMO TIEMPO, ES VENTAJOSO DETERMINAR LOS LUMENES DE SALIDA DE LA LAMPARA PROPUESTA - LO CUAL SE OBTIENE DE DATOS PROPORCIONADOS POR EL FABRICANTE DE LA LAMPARA.

SUPONGA QUE SE CONTINUA LA INVESTIGACION DE DATOS, ALGUNOS DE ELLOS HAN SIDO DETERMINADOS EN LOS EJEMPLOS PREVIOS, Y AHORA SE HA DECIDIDO USAR:

~~(1) LAMPARAS G.E. DE 250 WATTS LUCALOX (LU250/BU)~~
(2) LUMINARIO DE HID, CURVA DE DISTRIBUCION AMPLIA, TIPO DIRECTO. (N° 16 EN TABLA 2).

PARA ESTE CALCULO, INTERESA LOS LUMENES INICIALES DE SALIDA DEL LU250/BU. DIRIGIENDOSE A LA PAGINA APROPIADA DEL CATALOGO DE LAMPARAS, LA DETERMINACION DE LOS LUMENES ES UNA SIMPLE EXTRACCION:

LAMPARAS GENERAL ELECTRIC DE DESCARGA DE ALTA INTENSIDAD

PARA USARSE EN CUALQUIER POSICION DE ENCENDIDO EXCEPTO EN LAS ANOTADAS

Linea No.	Bulbo (Bombilla)	Base (Casquillo)	Favor ordenar por este numero de catalogo	Precio de Lista	Descripcion (Ver notas de Aplicación pág. 21)	C	Largo Total en cm	Largo al Centro de Luz en cm	Vida Aprox. en Horas	Lumenes Aprox. Iniciales	Lumenes Aprox. Medios
LAMPARAS LUCALOX ® (de Vapor de Sodio en Alta Presión)											
250 WATTS											
18	E-18 •	401 MOGUL MECANICA (C38-41)	LU250	~~1,750.00~~	CLARO		24.76	14.6	24,000	27,500	24,750
19			LU250/S	—	CLARO		24.76	14.6	24,000	30,000	27,000
20	E-28"		LU250/D	—	DIFUSO		22.86	12.7	24,000	26,000	23,400
400 WATTS											
21	E-18 •	401 MOGUL MECANICA (C38-41)	LU400	1,820.00	CLARO		24.76	14.6	24,000	50,000	45,000
22	E-37 •		LU400/D	—	DIFUSO		28.73	17.8	24,000	47,500	42,750

(De Catalogo G.E.)

NOTESE, OTRA VEZ, QUE TODO EL TRABAJO DE LAS PAGINAS PREVIAS HA SIDO PARA ESTABLECER LOS DATOS QUE SON PRELIMINARES PARA LA OBTENCION DEL COEFICIENTE DE UTILIZACION Y NO SON, POR SI MISMOS, UNA PARTE DEL CALCULO DE ILUMINACION. SIN EMBARGO, SE ESTA PREPARADO - AL FIN - PARA REFERIRSE A LA TABLA DE LA CUAL SE PUEDE EXTRAER EL CU.

EXTRACCION DEL CU

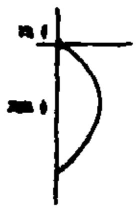
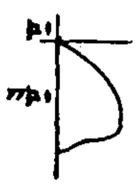
UN INGENIERO NO CALCULA LOS CU'S; ELLOS SON CALCULADOS DE MEDICIONES DE POTENCIA LUMINICA EN LOS LABORATORIOS FOTOMETRICOS DEL FABRICANTE. UNA SECCION DE LA TABLA 3 DE CU SE MUESTRA, A CONTINUACION.

PARA EXTRAER EL CU;

(1) ENTRE A LA COLUMNA DE RCR CON EL VALOR APROPIADO.
(2) ENTRE A LA LINEA SUPERIOR CON PCT

(3) ENTRE A LA SEGUNDA LINEA CON PW.
(4) OBTENGA EL CU EN LA INTERSECCION DE (1), (2) Y (3).

(De Tabla 2, pag. A-4)

Tipo de luminario	Distribución típica y % de lúmenes de la lámpara: Cat. de Mant.	Máximo espaciamiento S/MH	ρcc → / ρw → / RCR ↓	80			70 (ρ_{CT})			50			30		
			ρw →	50	30	10	50	30	10	50	30	10	50	30	10
				Coeficiente de utilización para 20% de reflectancia efectiva de piso											
15  Reflector con ventilación para distribución intermedia con lámpara clara de descarga de alta intensidad.	III 	1.0	0	.91	.91	.91	[illegible]	.89	.89	.84	.84	.84			
			1	.84	.81	.79	[illegible]	.80	.78	.79	.77	.76			
			2	.77	.73	.70	[illegible]	.72	.70	.73	.70	.68			
			3	.71	.66	.63	[illegible]	.65	.62	.67	.64	.61			
			4	.65	.60	.56	[illegible]	.58	.56	.62	.58	.56			
			5	.59	.54	.50	[illegible]	.54	.50	.57	.53				
			6	.54	.49	.46	[illegible]	.49	.45	.52	.48				
			7	.50	.44	.40	[illegible]	.44	.40	.48	.43				
			8	.45	.40	.36	[illegible]	.40	.36	.44	.39				
			9	.41	.36	.32	[illegible]	.36	.32	.40	.35				
			10	.38	.33	.29	[illegible]	.32	.29	.37	.32				
16  Reflector con ventilación para distribución difusa con lámpara clara de descarga de alta intensidad.	III 	1.5	0	.92	.92	.92	[illegible]	.90	.90	.86					
			1	.86	.82	.80	[illegible]	.81	.79	.79					
			2	.77	.73	.70	[illegible]	.72	.69	.73					
			3	[illegible]	[illegible]	[illegible]	68	.64	.60	.66					
			4	.63	.58	.53	[illegible]	.57	.53	.60					
			5	.57	.51	.47	.56	.51	.47	.55					
			6	.51	.45	.41	.51	.45	.41	.49					
			7	.46	.40	.36	.45	.39	.35	[illegible]					
			8	.41	.35	.31	.41	.35	.31						
			9	.37	.31	.27	.37	.31							
			10	.33	.27	.24	.33	.27							

NOTE!

Ejemplo:
De pags. anteriores
$\rho_{CT} = 71\% \rightarrow (70\%)$
$\rho_W = 50\%$
$\rho_{CP} = 11.5\%$
$R_{CL} = RCR = 3.0$
si se emplea el luminario Nº 16
∴ CU = 0.68

Este valor es correcto cuando $\rho_{CP} = 20\%$. Para este ejemplo $\rho_{CP} = 11.5\%$ ∴ es necesario aplicar una correccion (f_c)

EN OCASIONES ES NECESARIO INTERPOLAR VALORES DE CU PARA OBTENER EL BUSCADO. LOS VALORES DE CU VARIAN CASI LINEALMENTE, POR LO QUE LA INTERPOLACION A UTILIZAR ES LINEAL.

LAS TABLES DE CU ESTAN CALCULADAS PARA LOCALES QUE TENGAN UNA REFLECTANCIA DE LA CAVIDAD DEL PISO DE 20%. SI EL PCP QUE SE TENGA VARIA NOTABLEMENTE DE 20%, ES NECESARIO CORREGIR EL CU CON UN "FACTOR DE MULTIPLICACION".

AJUSTE DEL CU

LA TABLA 3 SE USA PARA ESTE PROPOSITO. EL PROCEDIMIENTO DE ENTRADA ES EXACTAMENTE EL MISMO QUE EL DESCRITO PARA EL USO DE LA TABLA DE CU: RCR EN LA COLUMNA IZQUIERDA; LAS REFLECTANCIAS EFECTIVAS DE LAS CAVIDADES DE TECHO Y PISO A LO LARGO DE LAS LINEAS SUPERIORES. EL "FACTOR DE MULTIPLICACION" SE EXTRAE DE LA INTERSECCION.

EL CU "AJUSTADO" ES SIMPLEMENTE EL PRODUCTO DE ESE FACTOR Y EL CU ORIGINAL.

$$CU_{AJUSTADO} = CU_{ORIGINAL} \times \text{FACTOR DE MULTIPLICACION}$$

Y ES EL VALOR QUE ENTONCES VA A SER USADO EN LA ECUACION (6) PARA CALCULAR LOS LUMENES TOTALES.

(De Tabla 3 pag. A-5)

Factores utilizados para reflectancias efectivas de piso diferentes al 20%

% de reflectancia Efectiva de cavidad de techo, ρ_{cc}	80				70 (P_{CT})				50			30		
% de reflectancia de paredes, ρ_w	70	50	30	10	70	50 (R_W)	30	10	50	30	10	50	30	10
Para 30% de reflectancia efectiva de cavidad de piso (20% = 1.00)														
Relación de cavidad de local														
1	1.092	1.082	1.075	1.068	1.077	1.070	1.064	1.059	1.049	1.044	1.040			
2	1.079	1.066	1.055	1.047	1.068	1.057	1.048	1.039	1.041	1.033	1.027			
3	1.070	1.054	1.042	1.033	1.061	1.048	1.037	1.028	1.034	1.027	1.020			
4	1.062	1.045	1.033	1.024	1.055	1.040	1.029	1.021	1.030	1.022	1.015			
5	1.056	1.038	1.026	1.018	1.050	1.034	1.024	1.015	1.027	1.018	1.012			
6	1.052	1.033	1.021	1.014	1.047	1.030	1.020	1.012	1.024	1.015	1.009			
7	1.047	1.029	1.018	1.011	1.043	1.026	1.017	1.009	1.022	1.013	1.007			
8	1.044	1.026	1.015	1.009	1.040	1.024	1.015	1.007	1.020	1.012	1.006			
9	1.040	1.024	1.014	1.007	1.037	1.022	1.014	1.006	1.019	1.011	1.005			
10	1.037	1.022	1.012	1.006	1.034	1.020	1.012	1.006	1.017	1.010	1.004			
P_{CP} → **Para 10% de reflectancia efectiva de cavidad de piso** (Muy aproximado a P_{CP} = 11.5)														
Relación de cavidad de local														
1	.923	.929	.935	.940	.933	.939	.943	.948	.956	.960				
2	.931	.942	.950	.958	.940	.949	.957	.963	.962	.968				
3 (R_{CL})	.939	.951	.961	.969	.945	.957	.966	.973	.967	.975				
4	.944	.958	.969	.978	.950	.963	.973	.960	.972	.980				
5	.949	.964	.976	.983	.954	.968	.978	.985	.975					
6	.953	.969	.980	.966	.958	.972	.982	.989	.977					
7	.957	.973	.983	.991	.961	.975	.985							
8	.960	.976	.986	.993	.963									
9	.963	.978	.987											
10	.965													

Ejemplo:

El CU extraido en la pag. 11 es 0.68. El factor de multiplicación de esta tabla es = 0.957

$\therefore CU_{AJUSTADO} = 0.68 \times 0.957 = 0.651$

o con dos decimales

CU = 0.65

LOS FACTORES DE PERDIDA DE LUZ

EN LA PAGINA 2 SE DEFINIERON TRES FACTORES QUE CONTRIBUYEN EN LA REDUCCION DE ILUMINACION: DLL, DPL Y DPSL. CADA UNO ES UNA PREDICCION, EN PORCIENTO, DE LA CANTIDAD DE LUZ QUE "SOBREVIVIRA" ESTOS EFECTOS REDUCTORES SOBRE UN TIEMPO DETERMINADO. EL PRODUCTO DE TODOS ESTOS ES LLAMADO EL FACTOR DE PERDIDA DE LUZ (FPL).

DETERMINACION DE LA DEPRECIACION DE LOS LUMENES DE LA LAMPARA -- (DLL).

LA TASA DE DEPRECIACION DE LOS LUMENES PARA CUALQUIER LAMPARA -- PUEDE PREDECIRSE EXACTAMENTE Y GRAFICADA Y TABULADA. EN ESTAS NOTAS, SE CONSIDERARA DLL COMO LA DEPRECIACION QUE SE ESPERA CUANDO LA LAMPARA HAYA SIDO OPERADA POR UN TIEMPO IGUAL A APROXIMADAMENTE EL 70 % DE SU VIDA NOMINAL PROMEDIO.

LA DETERMINACION DE DLL ES UNA SIMPLE EXTRACCION DE LA TABLA 4.

(De Tabla 4, pag. A-6)

TIPO DE LAMP.	WATTS	MEAN LUMEN FACTOR*	(%) DLL**
HID			
MERCURY+			
H175DX39-22	175	84	78
H250DX37-5	250	81	[illegible]
H400DX33-1	400	[illegible]	67
H1000DX36-15	[illegible]	72	63
	1000	80	75
[illegible]	1000	79	70
LUCALOX®			
TODAS LAS POTENCIAS ESTANDAR (LU50-LU1000)		90	82
LUH150	150	90	83
LUH215	215	90	83

Ejemplo: Suponga el uso de una lampara Lucalox de 250 watts (LU250)

DLL = 0.82

DETERMINACION DE LA DEPRECIACION POR POLVO EN EL LUMINARIO (DPL)

ESTE ES UNA "SUPOSICION" BASADA EN LA "CONDICION DE SUCIEDAD", - EN EL TIPO DE LUMINARIO Y EN LA PRACTICA DE MANTENIMIENTO DEL -- CONSUMIDOR (O CLIENTE). ES POSIBLE UNA EXACTITUD RAZONABLE MEDIANTE EL USO DE GRAFICAS (COMO LA MOSTRADA ABAJO) LAS CUALES EL IES HA DESARROLLADO PARA SEIS CATEGORIAS DE LUMINARIOS (VER TABLA 5).

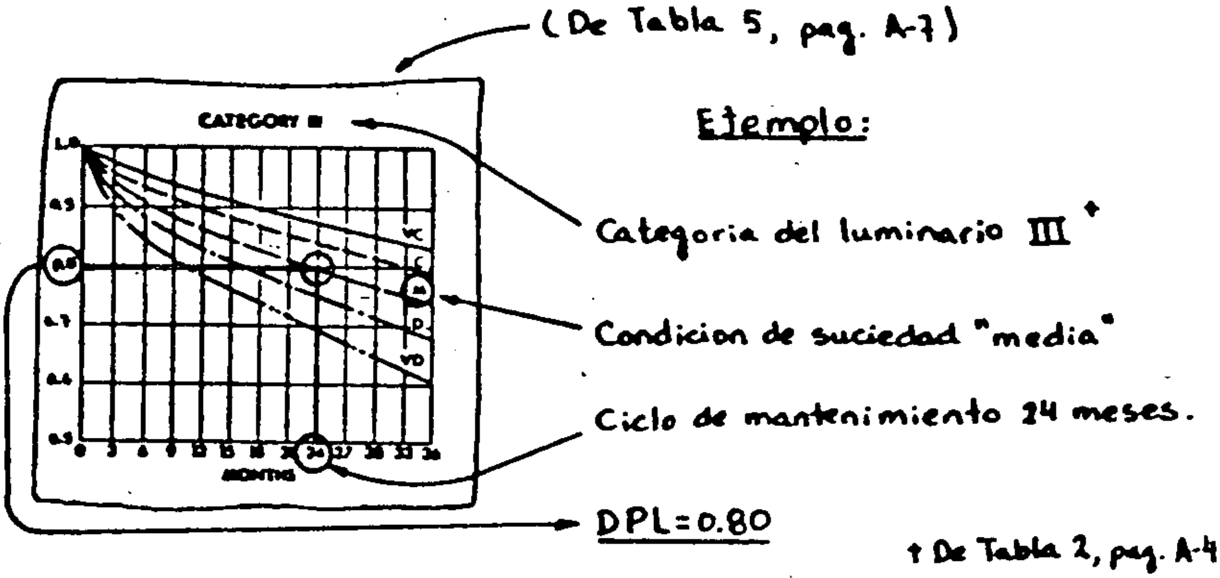
PARA DETERMINAR DPL

(1) ENTRE A LA LINEA INFERIOR CON EL "CICLO DE MANTENIMIENTO ASUMIDO" (EN MESES).

(2) SIGA HACIA ARRIBA HASTA LA INTERSECCION CON LA "CONDICION DE SUCIEDAD" ESPERADA.

(3) SIGA HACIA LA IZQUIERDA HASTA LA ESCALA VERTICAL.

(4) EXTRAIGA EL DPL.



DETERMINACION DE LA DEPRECIACION POR SUCIEDAD DEL LOCAL (DPSL)

LA DETERMINACION DE DPSL ES SIMILAR AL DE DPL - MAS EL USO DE — DE UNA TABLA DISTINTA A LA TABLA DE CU. ESTA INVOLUCRA LA IDENTIFICACION PREVIA DEL TIPO DE CURVA DE DISTRIBUCION DEL LUMINARIO (DIRECTO, SEMI-DIRECTO, ETC.) *(Definidos en la pag. A-8)*

PARA DETERMINAR DPSL, USE LA TABLA 6.

A. REFIERASE A LA PEQUEÑA GRAFICA EN LA PARTE SUPERIOR IZQUIERDA.

(1) ENTRE A LA LINEA INFERIOR DE LA GRAFICA CON EL CICLO DE MANTENIMIENTO PROPUESTO EN MESES.

(2) SIGA HACIA ARRIBA HASTA LA INTERSECCION CON LA CURVA QUE PERTENECE A LA "CONDICION DE SUCIEDAD" AMBIENTAL ESPERADA.

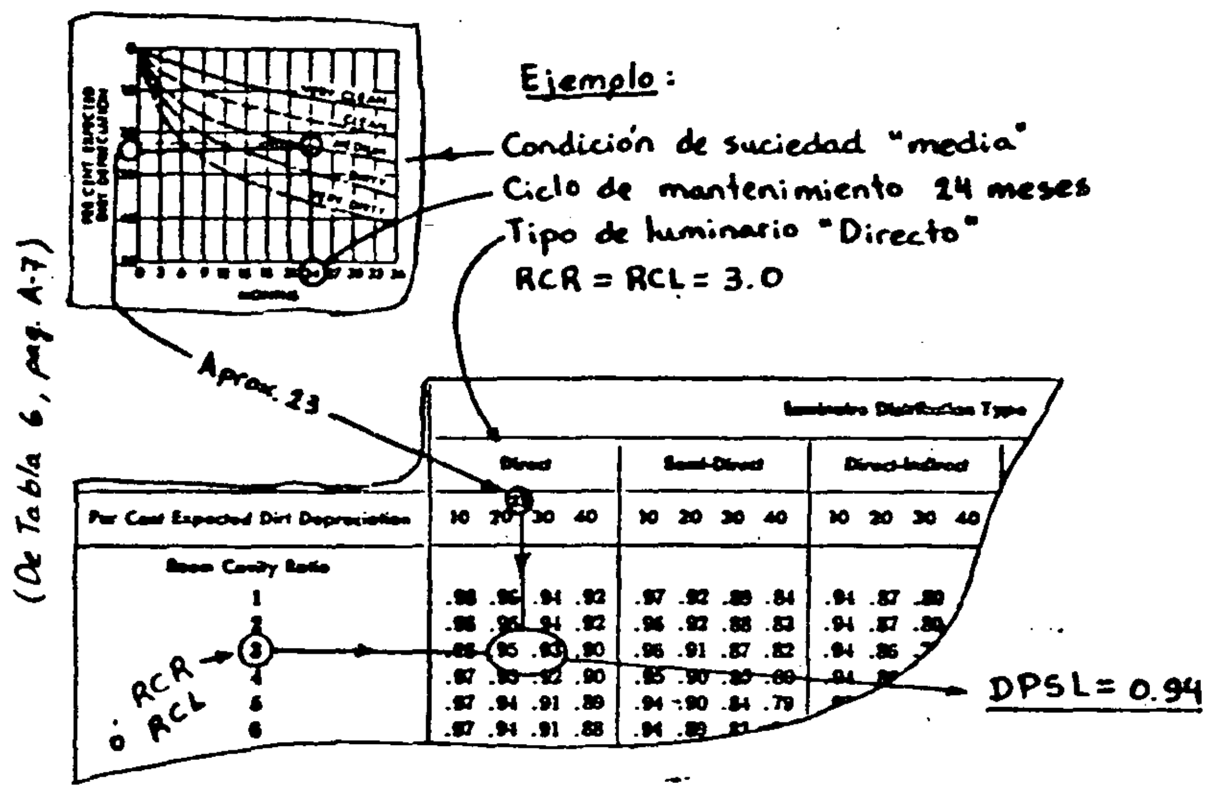
(3) SIGA HACIA LA IZQUIERDA HASTA LA ESCALA VERTICAL: EXTRAIGA EL "PORCIENTO DE DEPRECIACION POR SUCIEDAD ESPERADO".

B. REFIERASE A LA TABLA.

(1) USE EL VALOR ANTERIOR (3) PARA ENTRAR A LA SEGUNDA LINEA DE LA TABLA DEL DPSL - BAJO EL TIPO APROPIADO DE CURVA DE DISTRIBUCION DEL LUMINARIO.

(2) ENTRE A LA COLUMNA IZQUIERDA CON RCR.

(3) EN LA INTERSECCION DE (1) Y (2), EXTRAIGA DPSL INTERPOLANDO SI ES NECESARIO.



∴ De paginas 12, 13, 14 y 15:

$$FPL = DLL \times DPL \times DPSL = 0.82 \times 0.80 \times 0.94 = 0.62 \qquad \boxed{FPL = 0.62}$$

Ahora, ya se pueden emplear las ecuaciones (6) y (8) pags. 3 y 4

$L \times A = 30.5 \times 6.1$

Luxes = 1180

CU = 0.65

FPL = 0.62

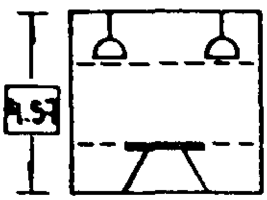
(6) $\text{LUMENES TOTALES} = \frac{1180 \times 30.5 \times 6.1}{0.65 \times 0.62} = 544762$ Lumenes.

(8) $N = \frac{544762}{27500} = 19.81 \longrightarrow \boxed{20 \text{ Luminarios}}$

Entonces 20 luminarios prod[illegible] [illegible]l mínimo mantenido [illegible]0 Luxes.

EL SUMARIO DE LA HOJA ANTERIOR (PAG. 15) SE HA TRANSCRITO A ESTA "HOJA DE TRABAJO". AL FINAL DE LAS NOTAS SE PROPORCIONA UNA EN BLANCO.

HOJA DE CALCULO POR EL METODO DE CAVIDAD ZONAL
(LA LETRA (X) INDICA NOTA)



H_{CT} = 0.61
H_{CL} = 3.05
H_{CP} = 0.91

INFORMACION DEL LOCAL

1. DIMENSIONES DEL LOCAL: L 30.5 A 6.1 ; ALTURA → 4.57
2. REFLECTANCIAS: (por ciento) TECHO (P_T) 80 PAREDES (P_P) 50 PISO (P_P) 10
3. RELACIONES DE CAVIDAD A. $RCL = \frac{5 H_{CL}(L+A)}{L \times A} = \frac{5 \times 3.05(30.5+6.1)}{30.5 \times 6.1}$ = 3.0 — P_{CL} = 50 (De línea 2)

(B) $RCT = RCL\left(\frac{H_{CT}}{H_{CL}}\right) = 3.0\left(\frac{0.61}{3.05}\right)$ = 0.6 — P_{CT} = 71

$RCP = RCL\left(\frac{H_{CP}}{H_{CL}}\right) = 3.0\left(\frac{0.91}{3.05}\right)$ = 0.9 — P_{CP} = 11.5

DATOS LAMPARA/LUMINARIO

4. LUMINARIO No. 16 TIPO ______ CAT. DE MANTO III COND. DE SUCIEDAD MEDIA CICLO DE LIMPIEZA 24 MESES ______ S/MH 1.5
5. A. LAMPARA: LU250W (B.) LUMENES: 27500 C. LAMPARAS / LUMINARIO : 1 D. LUMENES/LUMINARIO: 27.500
6. (A.) DLL 0.82 x (B.) DPL 0.80 x (C) DPSL 0.94 = FPL: 0.62
7. (A.) COEFICIENTE DE UTILIZACION (CU): 0.68 → x (B) 0.957 = CU CORREGIDO: 0.651

LX

(B.) NIVEL DE ILUMINACION REQUERIDO (LX) = 1180

CALCULOS

9. LUMENES TOTALES = $\frac{\text{LUXES} \times \text{AREA}}{\text{CU} \times \text{FPL}} = \frac{1180 \times 186.05}{0.651 \times 0.62}$ = 543,925
10. No. DE LUMINARIOS = $\frac{\text{LUMENES TOTALES}}{\text{LUMENES POR LUMINARIO}} = \frac{543,925}{27.500}$ = 19.78 → 20

LA PARTE INFERIOR FALTANTE CORRESPONDE A DATOS PARA EL "ESPACIAMIENTO DE LUMINARIOS" QUE SE ESTUDIA EN LA SIGUIENTE SECCION "ARREGLO DE LUMINARIOS".

5.- ARREGLO DE LUMINARIOS

UN ELEMENTO ESCENCIAL DEL DISEÑO DE ILUMINACION ES EL "ARREGLO" - UNA DISTRIBUCION DE LOS LUMINARIOS DETERMINADA POR EL DISEÑADOR. (EN OCASIONES, ES NECESARIO PROPORCIONAR "DETALLES" ADICIONALES Y "SECCIONES" VERTICALES DEL ARREGLO.)

EL LOCAL SE DIBUJA A UNA ESCALA ADECUADA (USUALMENTE 1:50 ó 1:100). EL EQUIPO DE ILUMINACION SE INDICA FRECUENTEMENTE POR SIMBOLOS:

○ (NO A ESCALA) DESIGNA UN LUMINARIO INCANDESCENTE O HID DE MONTAJE INDIVIDUAL .

├──┤ (LONGITUD A ESCALA) DESIGNA UNA LAMPARA FLUORESCENTE

▭ (A ESCALA) DESIGNA UN LUMINARIO FLUORESCENTE

SE EMPLEAN SIMBOLOS ADICIONALES PARA DIFERENCIAR TIPOS DE LUMINARIOS . TODOS DEBERAN SER DIBUJADOS EN EL PLANO DE TAL FORMA QUE INDIQUE SU UBICACION EN EL LOCAL .

ALGUNAS VECES EL DIBUJO SERVIRA PARA MOSTRAR LO IMPRACTICO DEL ARREGLO; POR EJEMPLO, PUEDE MOSTRAR QUE EL ESPACIAMIENTO SEA EXCESIVO O MUY CONCENTRADO EN TALES CASOS PUEDE SER NECESARIO RECALCULAR Y REUBICAR LUMINARIOS USANDO OTROS TIPOS Y/O LAMPARAS.

EL PASO INICIAL PARA EL ARREGLO ES DETERMINAR EL ESPACIAMIENTO DE LUMINARIOS .

DETERMINACION DEL ESPACIAMIENTO

A. LUMINARIOS DE MONTAJE INDIVIDUAL

1.- DETERMINE EL "AREA POR LUMINARIO"

$$\text{AREA POR LUMINARIO} = \frac{\text{AREA DEL LOCAL}}{\text{NUMERO DE LUMINARIOS}} \longrightarrow a = \frac{A}{N}$$

2.- DETERMINE EL "ESPACIAMIENTO APROXIMADO"

$$\text{ESPACIAMIENTO APROXIMADO} = \sqrt{\text{AREA POR LUMINARIO}} \rightarrow \boxed{S = \sqrt{a}}$$

POR EJEMPLO :

AREA DEL LOCAL = 2,500 m^2

NUMERO DE LUMINARIOS = 100

$$a = \frac{2,500}{100} = 25$$

$$S = \sqrt{25} = 5 \text{ m} \quad \text{(CENTRO A CENTRO)}$$

EN OTRAS PALABRAS, SI LOS LUMINARIOS SE INSTALAN EN UN PATRON DE 5m X 5m, EL ARREGLO SERA UNIFORME GEOMETRICAMENTE.

TAL ARREGLO UNIFORME PUEDE SER DESEABLE PERO NO NECESARIAMENTE APLICABLE: LA LOCALIZACION DE TRABES, VIGAS, VARILLAS U OTROS IMPEDIMENTOS PUEDEN FORZAR LA MODIFICACION, ENTONCES, LA DISTANCIA ENTRE LUMINARIOS PUEDE TENER QUE INCREMENTARSE EN UNA DIRECCION Y DECREMENTARSE EN LA OTRA; SIN EMBARGO, EL AREA POR LUMINARIO DEBE MANTENERSE TAN EXACTAMENTE COMO SEA PRACTICO.

B. HILERAS CONTINUAS DE LUMINARIOS FLUORESCENTES.

1.- DETERMINE EL "AREA POR LUMINARIO" (COMO EN A)

2.- DETERMINE EL ESPACIAMIENTO DE LA HILERAS.

$$\text{ESPACIAMIENTO} = \frac{\text{AREA POR LUMINARIO}}{\text{LONGITUD DEL LUMINARIO}} \longrightarrow \boxed{S = \frac{a}{L}}$$

POR EJEMPLO:

AREA DEL LOCAL 150 m^2
NUMERO DE LUMINARIOS = 56
LONGITUD DEL LUMINARIO = 1.22 m

APLICANDO ESTE RAZONAMIENTO AL "PROBLEMA EJEMPLO" EN EL QUE SE TIENE:

MH - 3.05 m
S/MH = 1.5

INSERTANDO ESTA INFORMACION EN LA SECCION INTERIOR DE LA "HOJA DE TRABAJO".

DATOS DE ESPACIAMIENTO

11. AREA POR LUMINARIO (AL) = $\frac{\text{AREA TOTAL}}{\text{No./LUMINARIOS}} = \frac{186.05}{20}$ = 9.3025 [9.3025]

12. ESPACIAMIENTO APROXIMADO
A. PARA UNIDADES INDIVIDUALES $\sqrt{AL} = \sqrt{9.3025}$ = [3.05]
B. PARA TIRAS CONTINUAS: $\frac{\text{AL}}{\text{LONGITUD DEL LUMINARIO}}$ = = [N/A]

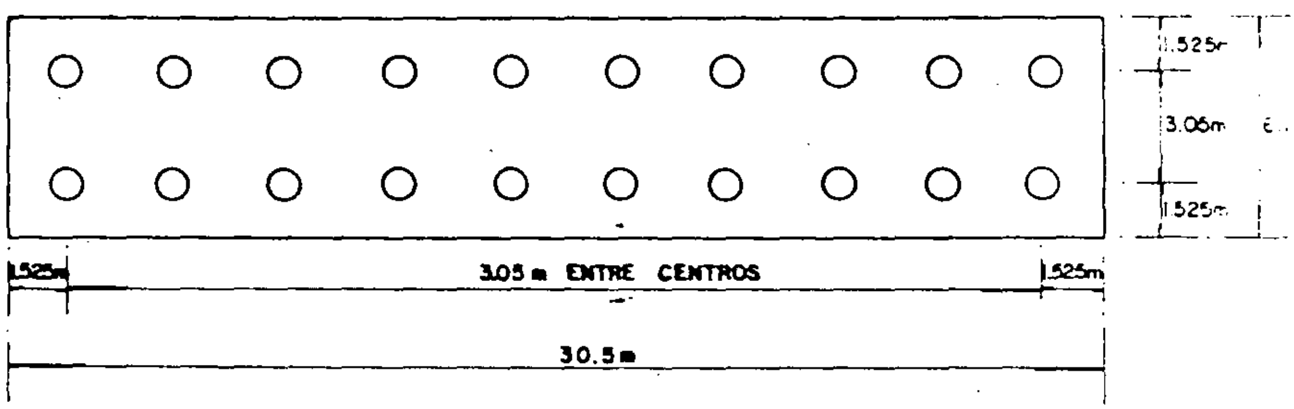
COMPROBACION

DATOS FINALES: No. DE LUMINARIOS [20] ESPACIAMIENTO: [3.05×3.05] LUXES: [1180]

COMPROBACION DE ESPACIAMIENTO: H_{CL} X S/MH = 3.05 x 1.5 = [4.575] ESPACIAMIENTO MAXIMO O.K.
(De línea 1 línea 4)

LX = $\frac{LT \times FPL \times C...}{AREA}$

LA CANTIDAD DE LUMINARIOS Y EL ESPACIAMIENTO PUEDE SER TRANSLADADO A UN ARREGLO COMO SE MUESTRA:



DE ACUERDO A RECOMENDACIONES EN ARREGLOS, EL ESPACIAMIENTO DE 1.525 m DE PARED A LUMINARIOS ESTA EN EL LIMITE (VER SIGUIENTE SECCION).

$$a = \frac{150}{56} = 2.68 \ m^2$$

$$s = \frac{2.68}{1.22} = \underline{2.19 \ m}$$

AQUI, EL ESPACIAMIENTO PRACTICO DE LAS HILERAS PUEDE SER AUN DE 2 m. (ESTA DETERMINACION DE ESPACIAMIENTO, TAMBIEN SE APLICA A LA DISTANCIA ENTRE CENTROS).

<u>COMPROBACION DEL MAXIMO ESPACIAMIENTO: UTILIZANDO LA RELACION "S/MH"</u>

NORMALMENTE, CUALQUIER PUNTO DEL PLANO DE TRABAJO DEBERA SER ILUMINADO POR VARIOS LUMINARIOS -ASEGURANDO EL TRASLAPE DE SUS RAYOS DE LUZ. DEBIDO A QUE EL DISEÑO DEL LUMINARIO TIENE SUS PROPIAS CARACTERISTICAS DE "DISTRIBUCION DE LUZ" (LOS ANGULOS DE SUS RAYOS DE LUZ), ES NECESARIO CONOCER SU RELACION MAXIMA DE "ESPACIAMIENTO A ALTURA DE MONTAJE (S/MH). ESTOS VALORES USUALMENTE FLUCTUAN ENTRE 0.5 Y 2.0 . ESTA INFORMACION LA PROPORCIONA EL FABRICANTE DEL LUMINARIO .

EL MAXIMO ESPACIAMIENTO ES EL <u>PRODUCTO</u> DEL S/MH Y LA ALTURA DE LOS LUMINARIOS <u>ARRIBA DEL PLANO DE TRABAJO</u> :

SMAX = S/MH x MH   MH = ALTURA DE MONTAJE

SI EL ESPACIAMIENTO DEL ARREGLO EL ESPACIAMIENTO MAXIMO PERMISIBLE, LA UNIFORMIDAD DE LA ILUMINACION SE AFECTARA (CON EQUIPO HID, PUEDE HABER SOMBRAS) E INEVITABLEMENTE SERA NECESARIO REDISEÑAR.

EJEMPLO: CONSIDERE DOS LUMINARIO (A y B) CON VALORES S/MH DE 0.6 Y 1.5

ESPACIAMIENTO DE LUMINARIOS 3.6 m
ALTURA DE MONTAJE = 3m

A. S/MH = 0.6 : SMAX. = 0.6 x 3 = 1.8 (3.6 m DE ESPACIAMIENTO ES EXCESIVO)

B. S/MH = 1.5 : SMAX. = 1.5 x 3 = 4.5 (3.6 m DE ESPACIAMIENTO ES CORRECTO)

ESPACIAMIENTO PARED - A - LUMINARIO

EL ESPACIAMIENTO EXCESIVO ENTRE UNA PARED Y LOS LUMINARIOS ADYACENTES PRODUCEN DOS EFECTOS ADVERSOS:

(1) SE REDUCE LA ILUMINACION HORIZONTAL CERCA DE LA PARED.

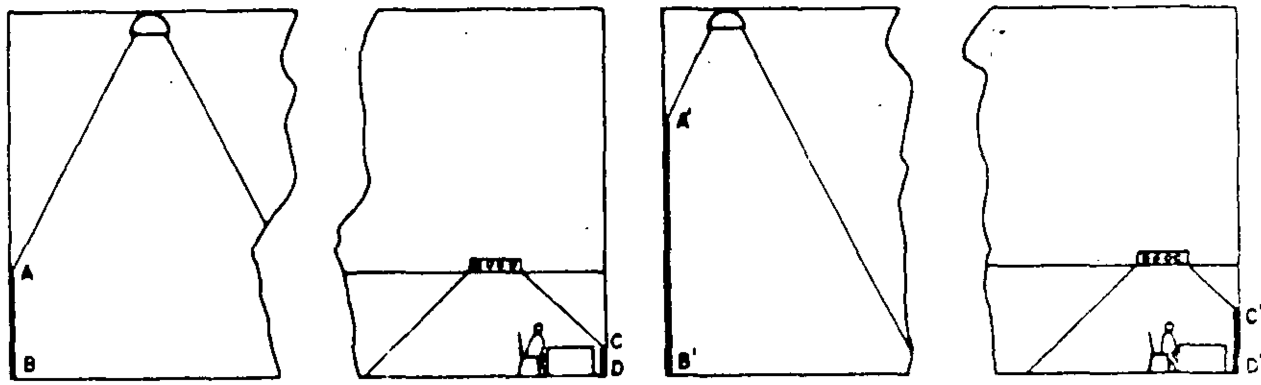
(2) SE REDUCE LA ILUMINACION VERTICAL SOBRE LA PARED.

A MENUDO SE LOCALIZAN EN ESAS AREAS ESCRITORIOS IMPORTANTES, MESAS O MAQUINAS DE TRABAJO. ESAS FUNCIONES REQUIEREN ILUMINACION EQUIVALENTE A LAS QUE SE LOCALIZAN EN EL INTERIOR DEL LOCAL.

LA REDUCCION DE ILUMINACION EN LA PARED PERJUDICA EL ASPECTO EN UN AMBIENTE VISUAL BUENO.

ES BUENA PRACTICA OBSERVAR LAS SIGUIENTES REGLAS.

FUNCION	TIPO DE ILUMINACION	MAXIMO ESPACIAMIENTO DE HILERAS	ESPACIAMIENTO PARED-LUMINARIO	
			DESEABLE	MAXIMO
OFICINAS	FLUORESCENTE	1x M H	30-50 cm.	60 cm.
INDUSTRIAL	FLUORESCENTE	1x M H	1/3 MH	1/2 MH
	HID	S/MHx MH	1/3 M H	1/2 MH



UN ESPACIAMIENTO PARED-LUMINARIO EXCESIVO RESULTA EN UN BRILLO EN LA PARED INSUFICIENTE (AB ; CD) . INSTALANDO LOS LUMINARIOS DE LA PERIFERIA CERCA DE LA PARED SE INCREMENTA LA ALTURA Y EL AREA DE BRILLO CON UNA MEJORA RESULTANTE EN EL AMBIENTE VISUAL (A'B' ; C'D'). ESTA TECNICA BIEN MEJORA LA CALIDAD Y EL NIVEL DE ILUMINACION A TAREAS LOCALIZADAS ADYACENTES A LA PARED.

FINALMENTE, EL PROCEDIMIENTO COMPLETO SE RECAPITULA EN UNA HOJA DE TRABAJO (PAGINA A-O).

* * *

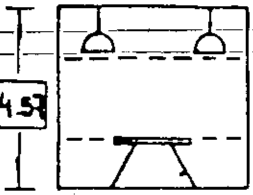
SUBSECUENTES PAGINAS FORMAN UN APENDICE DE DIVERSAS TABLAS DE REFERENCIA E INFORMACION UTIL.

TODAS LAS TABLAS (EXCEPTO LA No. 4) SON EXTRACTO DEL IES LIGHTING HANDBOOK, 1981

TABLA No.	DESCRIPCION	PAGINAS
1	REFLECTANCIAS EFECTIVAS	A-1 Y A-2
2	COEFICIENTES DE UTILIZACION	A-3 Y A-4
3	FACTORES DE CORRECCION CU	A-5
4	DEPRECIACION DE LOS LUMENES DE LA LAMPARA	A-6

HOJA DE CALCULO POR EL METODO DE CAVIDAD ZONAL

(LA LETRA (X) INDICA NOTA)



H_{CT} = 0.61 | H_{CL} = 3.05 | H_{CP} = 0.91

INFORMACION DEL LOCAL

1. DIMENSIONES DEL LOCAL: L 30.5 A 6.1 ALTURA → 4.57

2. REFLECTANCIAS: (por ciento) TECHO (P_T) 80 PAREDES (P_W) 50 PISO (P_P) 10

3. RELACIONES DE CAVIDAD
   A. $RCL = \frac{5 H_{CL} (L+A)}{L \times A} = \frac{5 \times 3.05 (30.5 + 6.1)}{30.5 \times 6.1} = 3.0$ — P_{CL} = 50 (De línea 2)

   (B) $RCT = RCL \left(\frac{H_{CT}}{H_{CL}}\right) = 3.0 \left(\frac{0.61}{3.05}\right) = 0.6$ — P_{CT} = 71

   $RCP = RCL \left(\frac{H_{CP}}{H_{CL}}\right) = 3.0 \left(\frac{0.91}{3.05}\right) = 0.9$ — P_{CP} = 11.5

DATOS LAMPARA/LUMINARIO

4. LUMINARIO No. 16 TIPO ____ CAT. DE MANTO III COND. DE SUCIEDAD MEDIA CICLO DE LIMPIEZA 24 MESES ____ S/MH 1.5

5. A. LAMPARA: LU250/V (B.) LUMENES: 27 500 C. $\frac{\text{LAMPARAS}}{\text{LUMINARIO}}$: 1 D. LUMENES/LUMINARIO: 27,500

6. (A.) DLL 0.82 x (B.) DPL 0.80 x (C) DPSL 0.94 = → FPL: 0.62

7. (A.) COEFICIENTE DE UTILIZACION (CU): 0.68 → x (B) 0.957 = CU CORREGIDO: 0.651

LX

(8.) → NIVEL DE ILUMINACION REQUERIDO (LX) = → 1180

CALCULOS

9. LUMENES TOTALES $= \frac{\text{LUXES} \times \text{AREA}}{\text{CU} \times \text{FPL}} = \frac{1180 \times 186.05}{0.651 \times 0.62} = 543,925$

10. No. DE LUMINARIOS $= \frac{\text{LUMENES TOTALES}}{\text{LUMENES POR LUMINARIO}} = \frac{543\ 925}{27.500} = 19.78$ → 20

DATOS DE ESPACIAMIENTO

11. AREA POR LUMINARIO (AL) $= \frac{\text{AREA TOTAL}}{\text{No./LUMINARIOS}} = \frac{186.05}{20} =$ 9.3025

12. ESPACIAMIENTO APROXIMADO
   A. PARA UNIDADES INDIVIDUALES $\sqrt{AL} = \sqrt{9.3025} =$ 3.05
   B. PARA TIRAS CONTINUAS: $\frac{AL}{\text{LONGITUD DEL LUMINARIO}} = \quad =$ N/A

COMPROBACION

DATOS FINALES: No. DE LUMINARIOS 20 ESPACIAMIENTO: 3.05 - 3.05 LUXES: 1180

$LX = \frac{LT \times FPL \times CU}{AREA}$

COMPROBACION DE ESPACIAMIENTO: $H_{CL} \times S/MH = 3.05 \times 1.5 = 4.575$ (De línea 1, línea 4)

ESPACIAMIENTO MAXIMO O.K.

(3B) P_{CT} a P_{CP} DE NOTAS. TABLA 1

(5B) DE CATALOGO DE LAMPARAS GE

(6A) DE NOTAS TABLA 4

(6B) DE NOTAS. TABLA 5

(6C) DE NOTAS. TABLA 6

(7A) DE NOTAS TABLA 2

(7B) DE NOTAS. TABLA 3

(8) COMO SE ESPECIFIQUE Ó RECOMIENDE

Tabla No. 1

Porcentaje de las reflectancias efectivas de techo o piso para varias combinaciones de reflectancias

% de reflectancia base*	90									
% de reflectancia de pared	90	80	70	60	50	40	30	20	10	0
Relación de cavidad 0.2	89	88	88	87	80	86	85	84	84	82
0.4	88	87	80	85	84	83	81	80	79	76
0.6	87	80	84	82	80	70	77	70	74	73
0.8	87	85	82	80	77	75	73	71	00	07
1.0	80	83	80	77	75	72	00	00	04	02
1.2	85	82	78	75	72	00	00	03	00	57
1.4	86	80	77	73	00	08	02	59	57	52
1.6	84	70	75	71	07	03	50	50	53	50
1.8	83	78	73	00	04	00	50	53	50	48
2.0	83	77	72	07	02	50	53	50	47	43
2.2	82	70	70	05	59	54	50	47	44	40
2.4	82	75	09	04	58	53	48	45	41	37
2.6	81	74	07	02	50	51	40	42	38	35
2.8	81	73	00	60	54	49	44	40	30	34
3.0	80	72	04	58	52	47	42	38	34	30
3.2	70	71	03	50	50	45	40	30	32	28
3.4	70	70	02	54	48	43	38	34	30	27
3.6	78	60	01	53	47	42	38	32	28	25
3.8	78	00	60	51	45	40	35	31	27	23
4.0	77	00	58	51	44	39	33	20	25	22
4.2	77	02	57	50	43	37	32	28	24	21
4.4	76	01	50	40	42	30	31	27	23	20
4.6	70	00	55	47	40	35	30	20	22	10
4.8	75	50	54	40	30	34	29	25	21	18
5.0	75	50	53	45	38	33	28	24	20	10
6.0	73	01	40	41	34	20	24	20	10	11
7.0	70	58	48	38	30	27	21	18	11	08
8.0	08	55	42	35	27	23	18	15	12	06
9.0	00	52	38	31	25	21	10	14	11	05
10.0	05	51	30	29	22	19	15	11	09	04

% de reflectancia base*	80									
% de reflectancia de pared	90	80	70	60	50	40	30	20	10	0
Relación de cavidad 0.2	79	78	78	77	77	76	76	75	74	72
0.4	79	77	76	75	74	73	72	71	70	68
0.6	78	76	75	73	71	70	08	06	05	03
0.8	78	75	73	71	09	07	65	03	01	57
1.0	77	74	72	00	07	05	02	00	57	55
1.2	76	73	70	67	04	01	58	55	53	51
1.4	70	72	08	05	02	59	55	53	50	48
1.6	75	71	07	03	60	57	53	50	47	44
1.8	75	70	00	02	58	54	50	47	44	41
2.0	74	09	04	00	50	52	48	45	41	38
2.2	74	08	03	58	54	49	45	42	38	35
2.4	73	07	61	50	52	47	43	40	30	33
2.6	73	60	60	55	50	45	41	38	34	31
2.8	73	05	59	53	48	43	39	30	32	29
3.0	72	05	58	52	47	42	37	34	30	27
3.2	72	06	57	51	45	40	35	33	28	25
3.4	71	04	50	49	44	39	34	32	27	24
3.6	71	03	54	48	43	38	32	30	25	23
3.8	70	02	53	47	41	30	31	28	24	22
4.0	70	01	53	40	40	35	30	20	22	20
4.2	00	00	52	45	39	34	20	25	21	18
4.4	09	60	51	44	38	33	28	24	20	17
4.6	60	59	50	43	37	32	27	23	10	15
4.8	05	58	49	42	30	31	20	22	18	14
5.0	05	58	48	41	35	30	25	21	18	14
6.0	06	55	44	38	31	27	22	19	16	10
7.0	04	53	41	36	28	24	10	10	12	07
8.0	02	50	38	32	25	21	17	14	11	05
9.0	61	49	30	30	23	19	15	13	10	04
10.0	59	46	33	27	21	18	14	11	08	03

% de reflectancia base*	70									
% de reflectancia de pared	90	80	70	60	50	40	30	20	10	0
Relación de cavidad 0.2	70	69	68	68	67	67	66	66	65	64
0.4	09	08	67	00	65	04	03	62	61	58
0.6	00	67	65	04	63	61	59	58	57	54
0.8	08	06	04	02	00	58	56	55	53	50
1.0	08	05	02	00	58	55	53	52	50	47
1.2	07	04	01	50	57	54	50	48	40	44
1.4	07	03	00	58	55	51	47	45	44	41
1.6	67	02	59	56	53	47	45	43	41	38
1.8	00	01	58	54	51	40	42	40	38	35
2.0	00	00	56	52	49	45	40	38	30	33
2.2	60	00	55	51	48	43	38	30	34	32
2.4	05	00	54	50	46	41	37	35	32	30
2.6	05	59	54	49	45	40	35	33	30	28
2.8	65	59	53	48	43	38	33	30	28	26
3.0	04	58	52	47	42	37	32	29	27	24
3.2	04	58	51	40	40	36	31	28	25	23
3.4	04	57	50	45	39	35	29	27	24	22
3.6	63	56	40	44	38	33	28	25	22	20
3.8	03	56	49	43	37	32	27	24	21	19
4.0	63	55	48	42	30	31	20	23	20	17
4.2	02	55	47	41	35	30	25	22	10	16
4.4	62	54	40	40	34	20	24	21	18	16
4.6	62	53	45	39	33	28	24	21	17	14
4.8	62	53	45	38	32	27	23	20	10	13
5.0	01	52	44	30	31	20	22	19	10	12
6.0	00	51	41	35	28	24	19	10	13	09
7.0	58	48	38	32	20	22	17	14	11	00
8.0	57	40	36	29	23	19	15	13	10	05
9.0	50	45	33	27	21	18	14	12	09	04
10.0	55	43	31	25	19	16	12	10	08	03

% de reflectancia base*	60									
% de reflectancia de pared	90	80	70	60	50	40	30	20	10	0
Relación de cavidad 0.2	60	59	59	59	58	57	56	56	55	53
0.4	60	50	59	58	57	55	54	53	52	50
0.6	60	58	57	56	55	53	51	51	50	40
0.8	59	57	50	55	54	51	48	47	40	43
1.0	50	57	55	53	51	48	45	44	43	41
1.2	60	56	54	51	49	40	44	42	40	38
1.4	59	56	53	49	47	44	41	30	38	30
1.6	60	55	52	48	45	42	39	37	35	33
1.8	58	55	51	47	44	40	37	35	33	31
2.0	58	54	50	40	43	39	35	33	31	29
2.2	58	53	40	45	42	37	34	31	29	28
2.4	58	53	48	44	41	30	32	30	27	26
2.6	58	53	48	43	39	35	31	28	20	24
2.8	58	53	47	43	38	34	29	27	24	22
3.0	57	52	40	42	37	32	28	25	23	20
3.2	57	51	45	41	36	31	27	23	22	18
3.4	57	51	45	40	35	30	20	23	20	17
3.6	57	50	44	39	34	29	25	22	19	16
3.8	57	50	43	38	33	29	24	21	19	15
4.0	57	49	42	37	32	28	23	20	18	14
4.2	50	40	42	37	32	27	22	10	17	14
4.4	50	40	42	30	31	27	22	10	16	13
4.6	50	40	41	35	30	20	21	18	10	13
4.8	50	48	41	34	29	25	21	18	15	12
5.0	50	48	40	34	28	24	20	17	14	11
6.0	55	45	37	31	25	21	17	14	11	07
7.0	54	43	35	30	24	20	15	12	09	05
8.0	53	42	33	28	22	18	14	11	08	04
9.0	52	40	31	26	20	16	12	10	07	03
10.0	51	30	29	24	18	15	11	09	07	02

% de reflectancia base*	50									
% de reflectancia de pared	90	80	70	60	50	40	30	20	10	0
Relación de cavidad 0.2	50	50	49	49	48	48	47	40	40	44
0.4	50	49	48	48	47	40	45	45	44	42
0.6	50	48	47	40	45	44	43	42	41	38
0.8	50	48	47	45	44	42	40	30	38	30
1.0	50	48	40	44	43	41	38	37	30	34
1.2	50	47	45	43	41	30	30	35	34	29
1.4	50	47	45	42	40	38	35	34	32	27
1.6	50	47	44	41	39	30	33	32	30	20
1.8	50	40	43	40	38	35	31	30	28	25
2.0	50	40	43	40	37	34	30	28	20	24
2.2	50	40	42	38	30	33	29	27	24	22
2.4	50	40	42	37	35	31	27	25	23	21
2.6	50	40	41	37	34	30	20	23	21	20
2.8	50	40	41	30	33	20	25	22	20	19
3.0	50	45	40	30	32	28	24	21	19	17
3.2	50	44	30	35	31	27	23	20	18	10
3.4	50	44	39	35	30	20	22	10	17	15
3.6	50	44	39	34	20	25	21	18	10	14
3.8	50	44	38	34	20	25	21	17	15	13
4.0	50	44	38	33	28	24	20	17	15	12
4.2	50	43	37	32	28	24	20	17	14	12
4.4	50	43	37	32	27	23	19	16	13	11
4.6	50	43	30	31	20	22	18	16	13	10
4.8	50	43	30	31	20	22	18	15	12	09
5.0	50	42	35	30	25	21	17	14	12	09
6.0	50	42	34	20	23	10	15	13	10	00
7.0	40	41	32	27	21	18	14	11	08	05
8.0	40	40	30	25	10	10	12	10	07	03
9.0	48	39	20	24	18	15	11	09	07	03
10.0	47	37	27	22	17	14	10	08	00	02

* Techo, piso, o piso de la cavidad.
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Tabla No. 1

Porcentaje de las reflectancias efectivas de techo o piso para varias combinaciones de reflectancias

% de reflectancia base*	40									
% de reflectancia de pared	90	80	70	60	50	40	30	20	10	0
Relación de cavidad 0.2	40	40	39	39	39	38	38	37	36	36
0.4	41	40	39	39	38	37	36	35	34	34
0.6	41	40	39	38	37	36	34	33	32	31
0.8	41	40	38	37	36	35	33	32	31	29
1.0	42	40	38	37	35	33	32	31	29	27
1.2	42	40	38	36	34	32	30	29	27	25
1.4	42	39	37	35	33	31	29	27	25	23
1.6	42	39	37	35	32	30	27	25	23	22
1.8	42	39	36	34	31	29	26	24	22	21
2.0	42	39	36	34	31	28	25	23	21	19
2.2	42	39	36	33	30	27	24	22	19	18
2.4	43	39	35	33	29	27	24	21	18	17
2.6	43	39	35	32	29	26	23	20	17	15
2.8	43	39	35	32	28	25	22	19	16	14
3.0	43	39	35	31	27	24	21	18	16	13
3.2	43	39	35	31	27	23	20	17	15	13
3.4	43	39	34	30	26	23	20	17	14	12
3.6	44	39	34	30	26	22	19	16	14	11
3.8	44	38	33	29	25	22	18	16	13	10
4.0	44	38	33	29	25	21	18	15	12	10
4.2	44	38	33	29	24	21	17	15	12	10
4.4	44	38	33	28	24	20	17	14	11	09
4.6	44	38	32	28	23	19	16	14	11	08
4.8	44	38	32	27	22	19	16	13	10	08
5.0	45	38	31	27	22	19	15	13	10	07
6.0	44	37	30	25	20	17	13	11	08	05
7.0	44	36	29	24	19	16	12	10	07	04
8.0	44	35	28	23	18	15	11	09	06	03
9.0	44	35	26	21	16	13	10	08	05	02
10.0	43	34	25	20	15	12	08	07	05	02

% de reflectancia base*	30									
% de reflectancia de pared	90	80	70	60	50	40	30	20	10	0
Relación de cavidad 0.2	31	31	30	30	29	29	29	28	28	27
0.4	31	31	30	30	29	28	28	27	26	25
0.6	32	31	30	29	28	27	26	26	25	23
0.8	32	31	30	29	28	26	25	25	23	22
1.0	33	32	30	29	27	25	24	23	22	20
1.2	33	32	30	28	27	25	23	22	21	19
1.4	34	32	30	28	26	24	22	21	19	18
1.6	34	33	29	27	25	23	22	20	18	17
1.8	35	33	29	27	25	23	21	19	17	16
2.0	35	33	29	26	24	22	20	18	16	14
2.2	36	32	29	26	24	22	19	17	15	13
2.4	36	32	29	26	24	22	19	16	14	12
2.6	36	32	29	25	23	21	18	16	14	12
2.8	37	33	29	25	23	21	17	15	13	11
3.0	37	33	29	25	22	20	17	15	12	10
3.2	37	33	29	25	22	19	16	14	12	10
3.4	37	33	29	25	22	19	16	14	11	09
3.6	38	33	29	24	21	18	16	13	10	09
3.8	38	33	28	24	21	18	15	13	10	08
4.0	38	33	28	24	21	18	14	12	09	07
4.2	38	33	28	24	20	17	14	12	09	07
4.4	39	33	28	24	20	17	14	11	09	06
4.6	39	33	28	24	20	17	13	10	08	06
4.8	39	33	28	24	20	17	13	10	08	05
5.0	39	33	28	24	19	16	13	10	08	05
6.0	39	33	27	23	18	15	11	09	06	04
7.0	40	33	26	22	17	14	10	08	05	03
8.0	40	33	26	21	16	13	09	07	04	02
9.0	40	33	25	20	15	12	09	07	04	02
10.0	40	32	24	19	14	11	08	06	03	01

% de reflectancia base*	20									
% de reflectancia de pared	90	80	70	60	50	40	30	20	10	0
Relación de cavidad 0.2	21	20	20	20	20	20	19	19	19	17
0.4	22	21	20	20	20	19	19	18	18	16
0.6	23	21	21	20	19	19	18	18	17	15
0.8	24	22	21	20	19	19	18	17	16	14
1.0	25	23	22	20	19	18	17	16	15	13
1.2	25	23	22	20	19	17	17	16	14	12
1.4	26	24	22	20	18	17	16	15	13	12
1.6	26	24	22	20	18	17	16	15	13	11
1.8	27	25	23	20	18	17	15	14	12	10
2.0	28	25	23	20	18	16	15	13	11	09
2.2	28	25	23	20	18	16	14	12	10	09
2.4	29	26	23	20	18	16	14	12	10	08
2.6	29	26	23	20	18	16	14	11	09	08
2.8	30	27	23	20	18	15	13	11	09	07
3.0	30	27	23	20	17	15	13	11	09	07
3.2	31	27	23	20	17	15	12	11	09	06
3.4	31	27	23	20	17	15	12	10	08	06
3.6	32	27	23	20	17	15	12	10	08	05
3.8	32	28	23	20	17	15	12	10	07	05
4.0	33	28	23	20	17	14	11	09	07	05
4.2	33	28	23	20	17	14	11	09	07	04
4.4	34	28	24	20	17	14	11	09	07	04
4.6	34	29	24	20	17	14	11	09	07	04
4.8	35	29	24	20	17	13	10	08	06	04
5.0	35	29	24	20	16	13	10	08	06	04
6.0	36	30	24	20	16	13	10	08	05	02
7.0	36	30	24	20	15	12	09	07	04	02
8.0	37	30	23	19	15	12	08	06	03	01
9.0	37	29	23	19	14	11	08	06	03	01
10.0	37	29	22	18	13	10	07	05	03	01

% de reflectancia base*	10									
% de reflectancia de pared	90	80	70	60	50	40	30	20	10	0
Relación de cavidad 0.2	11	11	11	10	10	10	10	09	09	09
0.4	12	11	11	11	11	10	10	09	09	08
0.6	13	13	12	11	11	10	10	09	08	08
0.8	15	14	13	12	11	10	10	09	08	07
1.0	16	14	13	12	12	11	10	09	08	07
1.2	17	15	14	13	12	11	10	09	07	06
1.4	18	16	14	13	12	11	10	09	07	06
1.6	19	17	15	14	12	11	09	08	07	06
1.8	19	17	15	14	13	11	09	08	06	05
2.0	20	18	16	14	13	11	09	08	06	05
2.2	21	19	16	14	13	11	09	07	06	05
2.4	22	19	17	15	13	11	09	07	06	05
2.6	23	20	17	15	13	11	09	07	06	04
2.8	23	20	18	16	13	11	09	07	05	03
3.0	24	21	18	16	13	11	09	07	06	03
3.2	25	21	18	16	13	11	09	07	05	03
3.4	26	22	18	16	13	11	09	07	06	03
3.6	26	22	19	16	13	11	09	06	04	03
3.8	27	23	19	17	14	11	09	06	04	02
4.0	27	23	20	17	14	11	09	06	04	02
4.2	28	24	20	17	14	11	09	06	04	02
4.4	28	24	20	17	14	11	08	06	04	02
4.6	29	25	20	17	14	11	08	06	04	02
4.8	29	25	20	17	14	11	08	06	04	02
5.0	30	25	20	17	14	11	08	06	04	02
6.0	31	26	21	18	14	11	08	06	03	01
7.0	32	27	21	17	13	11	08	06	03	01
8.0	33	27	21	17	13	10	07	05	03	01
9.0	34	28	21	17	13	10	07	05	02	01
10.0	34	28	21	17	12	10	07	05	02	01

% de reflectancia base*	0									
% de reflectancia de pared	90	80	70	60	50	40	30	20	10	0
Relación de cavidad 0.2	02	02	02	01	01	01	01	00	00	0
0.4	04	03	03	02	02	02	01	01	00	0
0.6	05	05	04	03	03	02	02	01	01	0
0.8	07	06	05	04	04	03	02	02	01	0
1.0	08	07	06	05	04	03	02	02	01	0
1.2	10	08	07	06	05	04	03	02	01	0
1.4	11	09	08	07	06	04	03	02	01	0
1.6	12	10	09	07	06	05	03	02	01	0
1.8	13	11	09	08	07	05	04	03	01	0
2.0	14	12	10	09	07	05	04	03	01	0
2.2	15	13	11	09	07	06	04	03	01	0
2.4	16	13	11	09	08	06	04	03	01	0
2.6	17	14	12	10	08	06	05	03	02	0
2.8	17	15	13	10	08	07	05	03	02	0
3.0	18	16	13	11	09	07	05	03	02	0
3.2	19	16	14	11	09	07	05	03	02	0
3.4	20	17	14	12	09	07	05	03	02	0
3.6	20	17	15	12	10	08	05	04	02	0
3.8	21	18	15	12	10	08	05	04	02	0
4.0	22	18	15	13	10	08	05	04	02	0
4.2	22	19	16	13	10	08	06	04	02	0
4.4	23	19	16	13	10	08	06	04	02	0
4.6	23	20	17	13	11	08	06	04	02	0
4.8	24	20	17	14	11	08	06	04	02	0
5.0	25	21	17	14	11	08	06	04	02	0
6.0	27	23	18	15	12	09	06	04	02	0
7.0	28	24	19	15	12	09	06	04	02	0
8.0	30	25	20	15	12	09	06	04	02	0
9.0	31	25	20	15	12	09	06	04	02	0
10.0	31	26	20	15	12	09	06	04	02	0

* Techo, piso, o piso de la cavidad.
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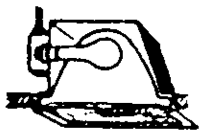
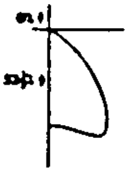
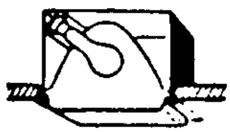
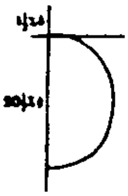
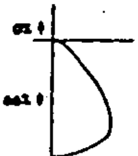
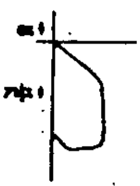
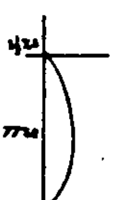
Tabla No. 2

Coeficientes de Utilización

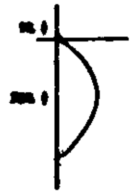
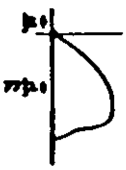
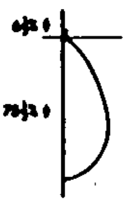
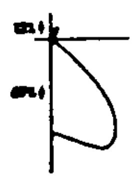
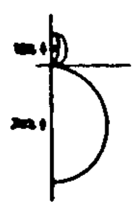
Tipo de luminario	Cat. de Mant.	Máximo espaciamiento[d] S/MH	ρ_{cc}[a] → RCR[c] ↓	80 / ρ_w[b] 50	80 / 30	80 / 10	70 / 50	70 / 30	70 / 10	50 / 50	50 / 30	50 / 10	30 / 50	30 / 30	30 / 10	10 / 50	10 / 30	10 / 10	0 / 0	WDRC
				Coeficiente de utilización para 20% de reflectancia efectiva de piso (ρ_{fc} = 20)																
10 	V	1.4 	0	.63	.63	.63	.62	.62	.62	.59	.59	.59	.56	.56	.56	.54	.54	.54	.53	
			1	.58	.56	.54	.57	.55	.54	.54	.53	.52	.52	.51	.50	.50	.50	.49	.48	.14
			2	.53	.50	.48	.52	.49	.47	.50	.48	.46	.48	.47	.45	.47	.45	.44	.43	.13
			3	.48	.45	.42	.47	.44	.42	.46	.43	.41	.44	.42	.40	.43	.41	.40	.39	.12
			4	.44	.40	.37	.43	.40	.37	.42	.39	.37	.41	.38	.36	.40	.38	.36	.35	.12
			5	.40	.36	.33	.39	.36	.33	.38	.35	.33	.37	.35	.32	.36	.34	.32	.31	.11
			6	.36	.32	.30	.36	.32	.29	.35	.32	.29	.34	.31	.29	.33	.31	.29	.28	.11
			7	.33	.29	.26	.33	.29	.26	.32	.28	.26	.31	.28	.26	.30	.28	.26	.25	.10
			8	.30	.26	.23	.30	.26	.23	.29	.26	.23	.28	.25	.23	.28	.25	.23	.22	.10
			9	.27	.23	.21	.27	.23	.21	.26	.23	.21	.26	.23	.20	.25	.23	.20	.19	.09
Unidad de distribución amplia con lente plano y lámpara acabado perla.			10	.25	.21	.18	.25	.21	.18	.24	.21	.18	.24	.20	.18	.23	.20	.18	.17	.09
11 	V	1.3 	0	.61	.61	.61	.60	.60	.60	.57	.57	.57	.54	.54	.54	.51	.51	.51	.50	
			1	.53	.51	.48	.52	.50	.47	.49	.47	.46	.47	.46	.44	.45	.44	.42	.41	.23
			2	.46	.42	.39	.45	.42	.39	.43	.40	.38	.41	.39	.37	.39	.37	.35	.34	.20
			3	.40	.36	.33	.40	.35	.32	.38	.34	.31	.36	.33	.31	.35	.32	.30	.29	.18
			4	.36	.31	.28	.35	.31	.28	.34	.30	.27	.32	.29	.26	.31	.28	.26	.25	.16
			5	.32	.27	.24	.31	.27	.24	.30	.26	.23	.29	.25	.23	.28	.25	.22	.21	.15
			6	.29	.24	.20	.28	.24	.20	.27	.23	.20	.26	.22	.20	.25	.22	.19	.18	.13
			7	.26	.21	.18	.25	.21	.18	.24	.20	.17	.23	.20	.17	.22	.19	.17	.16	.12
			8	.23	.19	.16	.23	.18	.15	.22	.18	.15	.21	.18	.15	.20	.17	.15	.14	.11
			9	.21	.17	.14	.21	.16	.14	.20	.16	.13	.19	.16	.13	.19	.15	.13	.12	.11
Unidad de empotrar con difusor de vidrio.			10	.19	.15	.12	.19	.15	.12	.18	.14	.12	.18	.14	.12	.17	.14	.12	.11	.10
12 	V	1.3 	0	.78	.78	.78	.76	.76	.76	.73	.73	.73	.70	.70	.70	.67	.67	.67	.65	
			1	.71	.69	.68	.70	.68	.66	.67	.66	.64	.65	.64	.62	.62	.62	.61	.59	.17
			2	.65	.62	.59	.64	.61	.58	.62	.59	.57	.60	.58	.56	.58	.56	.55	.54	.16
			3	.59	.55	.52	.58	.55	.52	.57	.53	.51	.55	.53	.50	.53	.51	.49	.48	.15
			4	.54	.50	.47	.54	.50	.46	.52	.49	.46	.51	.48	.45	.49	.47	.45	.43	.14
			5	.50	.45	.42	.49	.45	.41	.48	.44	.41	.47	.43	.41	.46	.43	.40	.39	.13
			6	.46	.41	.37	.45	.40	.37	.44	.40	.37	.43	.39	.37	.42	.39	.36	.35	.13
			7	.41	.37	.33	.41	.36	.33	.40	.36	.33	.39	.35	.33	.38	.35	.32	.31	.12
			8	.38	.33	.30	.38	.33	.30	.37	.33	.30	.36	.32	.29	.35	.32	.29	.28	.12
			9	.35	.30	.27	.34	.30	.27	.34	.29	.26	.33	.29	.26	.32	.29	.26	.25	.11
Lámpara de descarga de alta intensidad clara refractor de plástico entre el controlente y la lámpara.			10	.32	.27	.24	.31	.27	.24	.31	.27	.24	.30	.26	.24	.30	.26	.23	.22	.11
13 	V	1.4 	0	.85	.85	.85	.83	.83	.83	.79	.79	.79	.76	.76	.76	.73	.73	.73	.71	
			1	.78	.76	.74	.76	.74	.73	.73	.72	.70	.71	.69	.68	.68	.67	.66	.65	.17
			2	.71	.68	.65	.70	.67	.64	.68	.65	.63	.65	.63	.61	.63	.62	.60	.59	.16
			3	.65	.61	.57	.64	.60	.57	.62	.59	.56	.60	.57	.55	.59	.56	.54	.53	.16
			4	.60	.55	.51	.59	.54	.51	.57	.53	.50	.55	.52	.50	.54	.51	.49	.48	.15
			5	.54	.49	.45	.54	.49	.45	.52	.48	.45	.51	.47	.44	.50	.46	.44	.43	.14
			6	.49	.44	.40	.49	.44	.40	.47	.43	.40	.46	.42	.40	.45	.42	.39	.38	.14
			7	.44	.39	.35	.44	.39	.35	.43	.38	.35	.42	.38	.35	.41	.37	.35	.33	.14
			8	.40	.35	.31	.40	.35	.31	.39	.35	.31	.38	.34	.31	.38	.34	.31	.30	.13
			9	.37	.31	.28	.36	.31	.28	.36	.31	.28	.35	.31	.28	.34	.30	.27	.26	.13
Luminaio tipo cerrado con lámpara incandescente.			10	.33	.28	.25	.33	.28	.25	.32	.28	.25	.32	.28	.25	.31	.27	.24	.23	.12
14 	III	0.7 	0	.92	.92	.92	.90	.90	.90	.86	.86	.86	.82	.82	.82	.78	.78	.78	.76	
			1	.87	.85	.83	.85	.83	.82	.81	.80	.79	.78	.77	.76	.75	.75	.74	.72	.11
			2	.81	.79	.76	.80	.77	.75	.77	.75	.73	.75	.73	.72	.72	.71	.70	.69	.10
			3	.77	.73	.71	.76	.72	.70	.73	.71	.69	.71	.69	.67	.70	.68	.66	.65	.10
			4	.73	.69	.66	.72	.68	.65	.70	.67	.64	.68	.66	.64	.67	.65	.63	.62	.09
			5	.69	.65	.62	.68	.64	.61	.66	.63	.61	.65	.62	.60	.64	.61	.59	.58	.09
			6	.65	.61	.58	.64	.61	.58	.63	.60	.57	.62	.59	.57	.61	.58	.56	.55	.09
			7	.62	.57	.54	.61	.57	.54	.60	.56	.54	.59	.56	.53	.58	.55	.53	.52	.09
			8	.58	.54	.51	.58	.54	.51	.57	.53	.51	.56	.53	.51	.55	.52	.50	.49	.09
			9	.55	.51	.48	.55	.51	.48	.54	.50	.48	.53	.50	.48	.53	.50	.48	.47	.08
Reflector con ventilación. Distribución concentrada con lámpara clara de descarga de alta intensidad.			10	.53	.49	.46	.52	.48	.46	.52	.48	.46	.51	.48	.45	.50	.47	.45	.44	.08

[a] ρ_{cc} = % de reflectancia efectiva de cavidad de techo.
[b] ρ_w = % de reflectancia de paredes.
[c] RCR = Relación de cavidad de local.
[d] Máximo espaciamiento S/MH = Relación de espaciamiento máximo del luminario a altura de montaje.
Cortesía IES Handbook.

27-

Tabla No. 2

Coeficientes de Utilización

Tipo de luminario	Distribución típica y % de lúmenes de la lámpara: Cat. de Mant.	Máximo espaciamiento[d] S/MH	ρ_{cc}[a] →	80			70			50			30			10			0	WDRC
			ρ_w[b] →	50	30	10	50	30	10	50	30	10	50	30	10	50	30	10	0	↓
			RCR[c] ↓	Coeficiente de utilización para 20% de reflectancia efectiva de piso (ρ_{fc} = 20)																
15  Reflector con ventilación para distribución intermedia con lámpara clara de descarga de alta intensidad.	III 	1.0	0	.91	.91	.91	.89	.89	.89	.84	.84	.84	.81	.81	.81	.77	.77	.77	.75	
			1	.84	.81	.79	.82	.80	.78	.79	.77	.76	.76	.74	.73	.73	.72	.71	.69	.16
			2	.77	.73	.70	.76	.72	.70	.73	.70	.68	.70	.68	.66	.68	.66	.65	.63	.16
			3	.71	.66	.62	.69	.65	.62	.67	.64	.61	.65	.62	.60	.63	.61	.59	.57	.15
			4	.65	.60	.56	.64	.59	.56	.62	.58	.55	.60	.57	.54	.59	.56	.54	.52	.15
			5	.59	.54	.50	.59	.54	.50	.57	.53	.50	.56	.52	.49	.54	.51	.49	.47	.14
			6	.54	.49	.45	.54	.49	.45	.52	.48	.45	.51	.47	.44	.50	.47	.44	.42	.14
			7	.50	.44	.40	.49	.44	.40	.48	.43	.40	.47	.43	.39	.46	.42	.39	.38	.14
			8	.45	.40	.36	.45	.40	.36	.44	.39	.36	.43	.39	.35	.42	.38	.35	.34	.13
			9	.41	.36	.32	.41	.36	.32	.40	.35	.32	.39	.35	.32	.38	.35	.32	.30	.13
			10	.38	.33	.29	.37	.32	.29	.37	.32	.29	.36	.32	.29	.35	.31	.28	.27	.12
16  Reflector con ventilación para distribución difusa con lámpara clara de descarga de alta intensidad.	III 	1.5	0	.92	.92	.92	.90	.90	.90	.86	.86	.86	.82	.82	.82	.79	.79	.79	.77	
			1	.86	.83	.80	.83	.81	.79	.79	.78	.76	.76	.75	.74	.74	.72	.71	.70	.19
			2	.77	.73	.70	.75	.72	.69	.73	.70	.67	.70	.68	.66	.68	.66	.64	.63	.19
			3	.70	.65	.61	.68	.64	.60	.66	.62	.59	.64	.61	.58	.62	.59	.57	.56	.18
			4	.63	.58	.53	.62	.57	.53	.60	.56	.52	.58	.55	.52	.57	.54	.51	.49	.18
			5	.57	.51	.47	.56	.51	.47	.55	.50	.46	.53	.49	.46	.52	.48	.45	.44	.17
			6	.51	.45	.41	.51	.45	.41	.49	.44	.40	.48	.43	.40	.47	.43	.40	.38	.16
			7	.46	.40	.36	.45	.39	.35	.44	.39	.35	.43	.38	.35	.42	.38	.34	.33	.16
			8	.41	.35	.31	.41	.35	.31	.40	.34	.31	.39	.34	.30	.38	.33	.30	.29	.15
			9	.37	.31	.27	.37	.31	.27	.36	.30	.27	.35	.30	.27	.34	.30	.26	.25	.15
			10	.33	.27	.24	.33	.27	.23	.32	.27	.23	.31	.27	.23	.31	.26	.23	.22	.14
17  Reflector con ventilación para distribución intermedia con lámpara fosforada de descarga de alta intensidad.	III 	1.0	0	.96	.96	.96	.93	.93	.93	.87	.87	.87	.82	.82	.82	.77	.77	.77	.75	
			1	.89	.87	.84	.86	.84	.83	.82	.80	.79	.78	.76	.75	.74	.73	.72	.70	.14
			2	.82	.79	.76	.80	.77	.74	.76	.74	.72	.73	.71	.69	.70	.68	.67	.65	.13
			3	.76	.72	.68	.74	.70	.67	.71	.68	.65	.68	.66	.63	.66	.63	.61	.60	.13
			4	.70	.66	.62	69	.65	.61	.66	.63	.60	.64	.61	.58	.62	.59	.57	.55	.13
			5	.65	.60	.56	64	.59	.56	.62	.58	.54	.60	.56	.53	.58	.55	.52	.51	.12
			6	.60	.55	.51	59	.55	.51	.57	.53	.50	.56	.52	.49	.54	.51	.48	.47	.12
			7	.56	.51	.47	55	.50	.46	.53	.49	.46	.52	.48	.45	.50	.47	.44	.43	.12
			8	.52	.47	.43	51	.46	.43	.50	.45	.42	.48	.44	.41	.47	.43	.41	.40	.11
			9	.48	.43	.39	47	.42	.39	.46	.42	.39	.45	.41	.38	.44	.40	.38	.36	.11
			10	.45	.40	.36	44	.39	.36	.43	.39	.36	.42	.38	.35	.41	.37	.35	.34	.10
18  Reflector con ventilación para distribución difusa con lámpara fosforada de alta intensidad.	III 	1.5	0	.93	.93	.93	.89	.89	.89	.83	.83	.83	.77	.77	.77	.71	.71	.71	.68	
			1	.85	.83	.81	82	.80	.78	.77	.75	.74	.72	.71	.69	.67	.66	.65	.63	.15
			2	.78	.74	.71	76	.72	.69	.71	.68	.66	.67	.65	.63	.63	.61	.60	.58	.14
			3	71	.67	.63	69	.65	.62	.65	.62	.59	.62	.59	.57	.58	.56	.54	.53	.14
			4	.66	.60	.56	64	.59	.55	.60	.56	.53	.57	.54	.51	.54	.52	.50	.48	.13
			5	.60	.54	.50	.58	.53	.49	.55	.51	.48	.53	.49	.46	.50	.47	.45	.43	.13
			6	.54	.49	.45	.53	.48	.44	.51	.46	.43	.48	.45	.42	.46	.43	.40	.39	.13
			7	.49	.44	.40	48	.43	.39	.46	.41	.38	.44	.40	.37	.42	.39	.36	.34	.13
			8	.45	.39	.35	44	.38	.35	.42	.37	.34	.40	.36	.33	.38	.35	.32	.31	.13
			9	.41	.35	.31	.40	.34	.31	.38	.33	.30	.36	.32	.29	.35	.31	.28	.27	.12
			10	.37	.31	.27	.36	.31	.27	.34	.30	.26	.33	.29	.26	.32	.28	.25	.24	.11
19  Reflector acabado, pintura porcelanizada con lámpara fluorescente, reflector 14° C.W.	III 	1.3	0	1.00	1.00	1.00	.96	.96	.96	.89	.89	.89	.82	.82	.82	.76	.76	.76	.73	
			1	.88	.85	.82	.85	.82	.79	.79	.77	.74	.73	.72	.70	.68	.67	.66	.63	.27
			2	.78	.72	.67	.75	.70	.66	.70	.66	.62	.65	.62	.59	.61	.58	.56	.53	.26
			3	.69	.62	.57	.66	.60	.56	.62	.57	.53	.58	.54	.51	.54	.51	.48	.46	.23
			4	.61	.54	.48	.59	.52	.47	.55	.50	.45	.52	.47	.43	.49	.45	.42	.39	.22
			5	.54	.46	.41	.52	.45	.40	.49	.43	.39	.46	.41	.37	.43	.39	.36	.33	.20
			6	.48	.41	.35	.47	.40	.35	.44	.38	.34	.41	.36	.32	.39	.34	.31	.29	.19
			7	.43	.36	.31	.42	.35	.30	.40	.34	.29	.37	.32	.28	.35	.31	.27	.25	.17
			8	.39	.32	.27	.38	.31	.26	.36	.30	.25	.34	.28	.24	.32	.27	.24	.22	.16
			9	.35	.28	.23	.34	.27	.23	.32	.26	.22	.30	.25	.21	.28	.24	.20	.19	.15
			10	.32	.25	.20	.31	.24	.20	.29	.23	.19	.28	.22	.19	.26	.21	.18	.17	.14

[a] ρ_{cc} = % de reflectancia efectiva de cavidad de techo.
[b] ρ_w = % de reflectancia de paredes.
[c] RCR = Relación de cavidad de local.
[d] Máximo espaciamiento S/MH = Relación de espaciamiento máximo del luminario a altura de montaje.
Cortesía IES Handbook.

28

Tabla No. 3

Factores utilizados para reflectancias efectivas de piso diferentes al 20%

% de reflectancia efectiva de cavidad de techo, ρc	80				70				50			30			10		
% de reflectancia de paredes, ρw	70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10

Para 30% de reflectancia efectiva de cavidad de piso (20% = 1.00)

Relación de cavidad de local																	
1	1.092	1.082	1.075	1.068	1.077	1.070	1.064	1.059	1.049	1.044	1.040	1.028	1.026	1.023	1.012	1.010	1.008
2	1.079	1.066	1.055	1.047	1.068	1.057	1.048	1.039	1.041	1.033	1.027	1.026	1.021	1.017	1.013	1.010	1.006
3	1.070	1.054	1.042	1.033	1.061	1.048	1.037	1.028	1.034	1.027	1.020	1.024	1.017	1.012	1.014	1.009	1.005
4	1.062	1.045	1.033	1.024	1.055	1.040	1.029	1.021	1.030	1.022	1.015	1.022	1.015	1.010	1.014	1.009	1.004
5	1.056	1.038	1.026	1.018	1.050	1.034	1.024	1.015	1.027	1.018	1.012	1.020	1.013	1.008	1.014	1.009	1.004
6	1.052	1.033	1.021	1.014	1.047	1.030	1.020	1.012	1.024	1.015	1.009	1.019	1.012	1.006	1.014	1.008	1.003
7	1.047	1.029	1.018	1.011	1.043	1.026	1.017	1.009	1.022	1.013	1.007	1.018	1.010	1.005	1.014	1.008	1.003
8	1.044	1.026	1.015	1.009	1.040	1.024	1.015	1.007	1.020	1.012	1.006	1.017	1.009	1.004	1.013	1.007	1.003
9	1.040	1.024	1.014	1.007	1.037	1.022	1.014	1.006	1.019	1.011	1.005	1.016	1.009	1.004	1.013	1.007	1.002
10	1.037	1.022	1.012	1.006	1.034	1.020	1.012	1.005	1.017	1.010	1.004	1.015	1.009	1.003	1.013	1.007	1.002

Para 10% de reflectancia efectiva de cavidad de piso (20% = 1.00)

Relación de cavidad de local																	
1	.923	.929	.935	.940	.933	.939	.943	.948	.956	.960	.963	.973	.976	.979	.989	.991	.993
2	.931	.942	.950	.958	.940	.949	.957	.963	.962	.968	.974	.976	.980	.985	.988	.991	.995
3	.939	.951	.961	.969	.945	.957	.966	.973	.967	.975	.981	.978	.983	.988	.988	.992	.996
4	.944	.958	.969	.978	.950	.963	.973	.980	.972	.980	.986	.980	.986	.991	.987	.992	.996
5	.949	.964	.976	.983	.954	.968	.978	.985	.975	.983	.989	.981	.988	.993	.987	.992	.997
6	.953	.969	.980	.986	.958	.972	.982	.989	.977	.985	.992	.982	.989	.995	.987	.993	.997
7	.957	.973	.983	.991	.961	.975	.985	.991	.979	.987	.994	.983	.990	.996	.987	.993	.998
8	.960	.976	.986	.993	.963	.977	.987	.993	.981	.988	.995	.984	.991	.997	.987	.994	.998
9	.963	.978	.987	.994	.965	.979	.989	.994	.983	.990	.996	.985	.992	.998	.988	.994	.999
10	.965	.980	.989	.995	.967	.981	.990	.995	.984	.991	.997	.986	.993	.998	.988	.994	.999

Para 0% de reflectancia efectiva de cavidad de piso (20% = 1.00)

Relación de cavidad de local																	
1	.859	.870	.879	.886	.873	.884	.893	.901	.916	.923	.929	.948	.954	.960	.979	.983	.987
2	.871	.887	.903	.919	.886	.902	.916	.928	.926	.938	.949	.954	.963	.971	.978	.983	.991
3	.882	.904	.915	.942	.898	.918	.934	.947	.936	.950	.964	.958	.969	.979	.976	.984	.993
4	.893	.919	.941	.958	.908	.930	.948	.961	.945	.961	.974	.961	.974	.984	.975	.985	.994
5	.903	.931	.953	.969	.914	.939	.958	.970	.951	.967	.980	.964	.977	.988	.975	.985	.995
6	.911	.940	.961	.976	.920	.945	.965	.977	.955	.972	.985	.966	.979	.991	.975	.986	.996
7	.917	.947	.967	.981	.924	.950	.970	.982	.959	.975	.988	.968	.981	.993	.975	.987	.997
8	.922	.953	.971	.985	.929	.955	.975	.986	.963	.978	.991	.970	.983	.995	.976	.988	.998
9	.928	.958	.975	.988	.933	.959	.980	.989	.966	.980	.993	.971	.985	.996	.976	.988	[illegible]
10	.933	.962	.979	.991	.937	.963	.983	.992	.969	.982	.995	.973	.987	.997	.977	.989	[illegible]

Cortesía IES Handbook.

TABLA 4: FACTORES DE DEPRECIACION DE LOS LUMENES DE LA LAMPARA (DLL). EN (%).

TIPO DE LAMP.	WATTS	MEAN LUMEN FACTOR*	DLL**
INCANDESCENTE			
75ER30	75	90	86
100A	100	93	90
150A	150	93	93
150PAR/SP & FL	150	84	78
150R/SP & FL	150	89	85
300M/IF	300	91	87
300R/SP & FL	300	94	92
500/IF	500	91	88
1000/IF	1000	92	89
1500/IF	1500	84	78
QUARTZLINE R			
Q250CL	250	97	96
Q250PAR38/SP	250	93	93
Q250PAR38/FL	250	93	93
Q500T3/CL	500	97	96
FLUORESCENTE			
F40/CW/WM	35	87	83
F40LW/WM	35	87	83
F40CW/S	40	90	87
F40CW	40	87	83
F40WW	40	87	83
F40CWX	40	83	73
F40WWX(SW)	40	83	73
F96T12/CW/WM	60	93	89
F96T12/LW/WM	60	93	89
F96T12/CW	75	93	89
F96T12/WW	75	93	89
F96T12/CWX	75	89	85
F48T12/CW/HO	110	87	82
F96T12/CW/HW	110	87	82
F96T12/CW/HO/WM	95	87	82
F48PG17/CW	110	72	64
F96PG17/CW	215	76	67
F96PG17/CW/WM	185	76	67
F48T12/CW/1500	110	72	64
F96T12/CW/1500	215	76	67

GE LAMP TYPE	WATTS	MEAN LUMEN FACTOR*	DLL**
HID			
MERCURY +			
H175DX39-22	175	84	78
H250DX37-5	250	81	75
H400DX33-1	400	78	71
H1000DX36-15	1000	63	52
MULTI-VAPOR ®			
MV175	175	77	—
MV175/C	175	73	—
MV250	250	83	76
MV250/C	250	78	71
MV400	400	75	67
MV400/C	400	72	63
MV1000	1000	80	75
MV1000/C	1000	79	70
LUCALOX ®			
TODAS LAS POTENCIAS ESTANDAR (LU50-LU1000)	—	90	82
LUH150	150	90	83
LUH215	215	90	83

* USE EL FACTOR DE LUMENES MEDIOS CUANDO LOS CALCULOS INVOLUCREN ILUMINACION PROMEDIO. (BASADA EN LA LUZ DE SALIDA DE LA LAMPARA EN EL 40 AL 50% DE SU VIDA)

** USE DLL CUANDO LOS CALCULOS INVOLUCREN ILUMINACION MINIMA (BASADA EN LA LUZ DE SALIDA DE LA LAMPARA EN EL 70% DE SU VIDA.

\+ LOS FACTORES PARA LAMPARAS DE MERCURIO ESTAN BASADAS EN UNA VIDA DE 24,000 HORAS.

TABLA 5. FACTORES DE DEPRECIACION POR POLVO EN EL LUMINARIO (DPL). (PARA SEIS CATEGORIAS Y CINCO CONDICIONES DE SUCIEDAD).

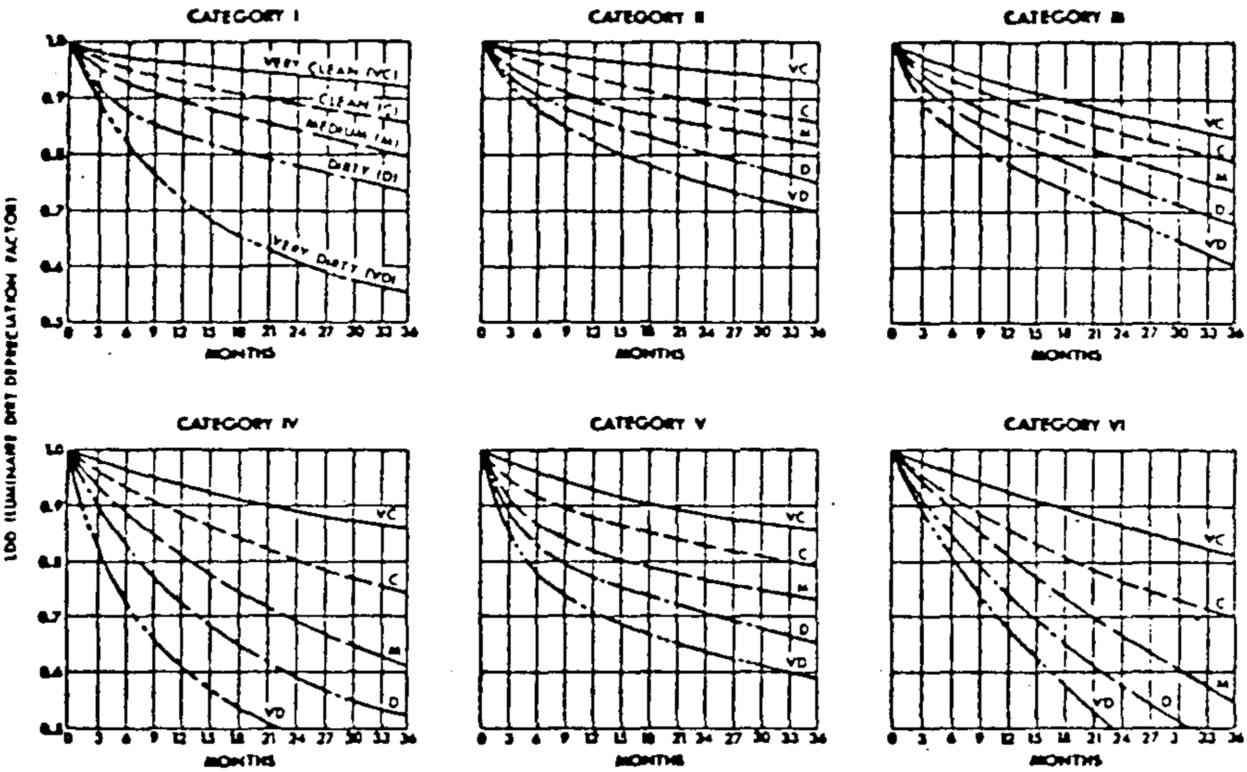
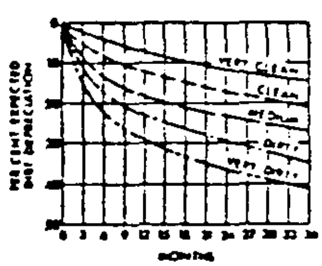


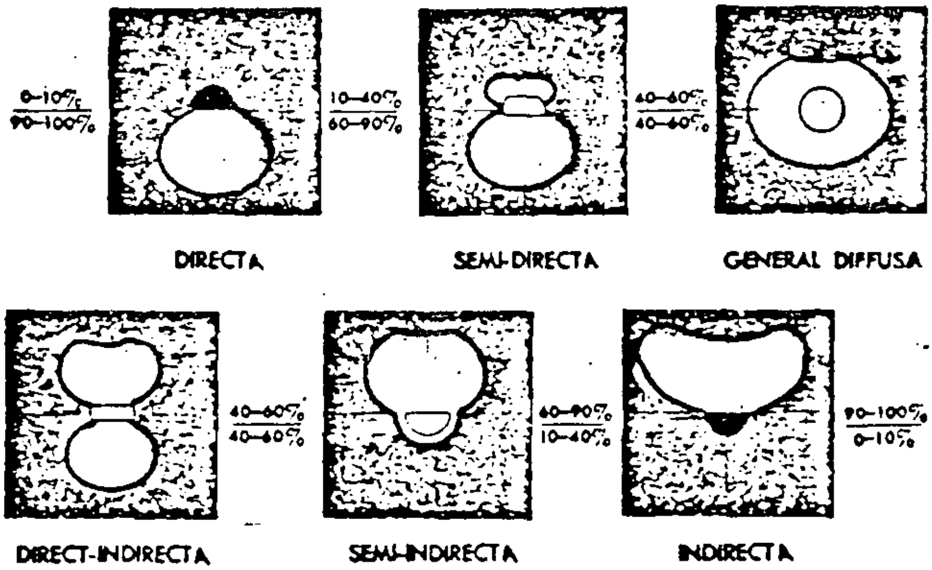
TABLA 6. FACTORES DE DEPRECIACION POR SUCIEDAD DEL LOCAL (DPSL).



	Luminaire Distribution Type																			
	Direct				Semi-Direct				Direct-Indirect				Semi-Indirect				Indirect			
Per Cent Expected Dirt Depreciation	10	20	30	40	10	20	30	40	10	20	30	40	10	20	30	40	10	20	30	40
Room Cavity Ratio																				
1	.98	.96	.94	.92	.97	.92	.89	.84	.94	.87	.80	.76	.94	.87	.80	.73	.90	.80	.70	.60
2	.98	.96	.94	.92	.96	.92	.88	.83	.94	.87	.80	.75	.94	.87	.79	.72	.90	.80	.69	.59
3	.98	.95	.93	.90	.96	.91	.87	.82	.94	.86	.79	.74	.94	.86	.78	.71	.90	.79	.68	.58
4	.97	.96	.93	.90	.95	.90	.85	.80	.94	.86	.79	.73	.94	.86	.78	.70	.89	.78	.67	.56
5	.97	.94	.91	.89	.94	.90	.84	.79	.93	.86	.78	.72	.93	.86	.77	.69	.89	.78	.66	.55
6	.97	.94	.91	.88	.94	.89	.83	.78	.93	.85	.78	.71	.93	.85	.76	.68	.89	.77	.56	.54
7	.97	.94	.90	.87	.93	.88	.82	.77	.93	.84	.77	.70	.93	.84	.76	.66	.89	.76	.65	.53
8	.96	.93	.89	.86	.93	.87	.81	.75	.93	.84	.76	.69	.93	.84	.76	.65	.88	.76	.64	.52
9	.96	.92	.88	.85	.93	.87	.80	.74	.93	.84	.76	.68	.93	.84	.75	.67	.88	.75	.63	.51
10	.96	.92	.87	.83	.93	.86	.79	.72	.93	.84	.75	.67	.92	.83	.75	.67	.88	.75	.62	.50

DISTRIBUCION DEL LUMINARIO

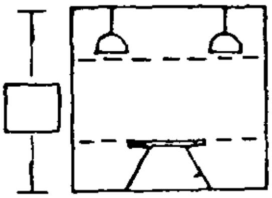
CLASIFICACION DEL TIPO DE LUMINARIO POR LA COMISION INTERNACIONAL DE ILUMINACION (CIE).



LOS LUMINARIOS ESTAN CLASIFICADOS POR LA CIE DE ACUERDO A LOS PORCENTAJES DE LUZ EMITIDOS HACIA ARRIBA Y HACIA ABAJO DE LA HORIZONTAL. LA FUENTE DE LUZ Y/O EL LUMINARIO AFECTARAN LA DISTRIBUCION.

HOJA DE CALCULO POR EL METODO DE CAVIDAD ZONAL

(LA LETRA (X) INDICA NOTA)



INFORMACION DEL LOCAL

1. DIMENSIONES DEL LOCAL: L [ ] A [ ] ALTURA → [ ]
2. REFLECTANCIAS: (por ciento) TECHO (P_T) [ ] PAREDES (P_W) [ ] PISO (P_P) [ ]
3. RELACIONES DE CAVIDAD A. $RCL = \frac{5 H_{CL}(L+A)}{L \times A} = \frac{5 \times (\quad + \quad)}{\times}$ = [ ] → P_{CL} = [ ] (De línea 2)

   (B) $RCT = RCL\left(\frac{H_{CT}}{H_{CL}}\right) = \left(\frac{}{}\right)$ ——— = [ ] — P_{CT} = [ ]

   $RCP = RCL\left(\frac{H_{CP}}{H_{CL}}\right) = \left(\frac{}{}\right)$ ——— = [ ] — P_{CP} = [ ]

DATOS LAMPARA/LUMINARIO

4. LUMINARIO No. ____ TIPO ____ CAT.DE MANTO ____ COND. DE SUCIEDAD ____ CICLO DE LIMPIEZA ____ MESES ____ S/MH ____
5. A. LAMPARA: ____ (B) LUMENES: ____ C. $\frac{\text{LAMPARAS}}{\text{LUMINARIO}}$: ____ D. LUMENES/LUMINARIO: [ ]
6. (A) DLL [ ] x (B) DPL [ ] x (C) DPSL [ ] = ——— FPL: [ ]
7. (A) COEFICIENTE DE UTILIZACION (CU): [ ] → x (B) [ ] = CU CORREGIDO: [ ]

LX

(8.) ——— NIVEL DE ILUMINACION REQUERIDO (LX) = ——— [ ]

CALCULOS

9. LUMENES TOTALES = $\frac{\text{LUXES} \times \text{AREA}}{\text{CU} \times \text{FPL}}$ = ——— = [ ]
10. No. DE LUMINARIOS = $\frac{\text{LUMENES TOTALES}}{\text{LUMENES POR LUMINARIO}}$ = ——— = [ ]

DATOS DE ESPACIAMIENTO

11. AREA POR LUMINARIO (AL) = $\frac{\text{AREA TOTAL}}{\text{No./LUMINARIOS}}$ = ——— = [ ]
12. ESPACIAMIENTO APROXIMADO A. PARA UNIDADES INDIVIDUALES $\sqrt{AL} = \sqrt{\quad}$ = [ ]

    B. PARA TIRAS CONTINUAS: $\frac{AL}{\text{LONGITUD DEL LUMINARIO}}$ = = [ ]

COMPROBACION

DATOS FINALES: No. DE LUMINARIOS [ ] ESPACIAMIENTO: [ ] LUXES: [ ]

COMPROBACION DE ESPACIAMIENTO: H_{CL} X S/MH = ——— x ——— = [ ] ESPACIAMIENTO MAXIMO

(De línea 1) (línea 4)

$LX = \frac{LT \times FPL \times CU}{AREA}$

(3B) P_{CT} & P_{CP} DE NOTAS. TABLA 1

(5B) DE CATALOGO DE LAMPARAS GE

(6A) DE NOTAS TABLA 4

(6B) DE NOTAS. TABLA 5

(6C) DE NOTAS. TABLA 6

(7A) DE NOTAS TABLA 2

(7B) DE NOTAS. TABLA 3

(8) COMO SE ESPECIFIQUE ó RECOMIENDE

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

ILUMINACION INTERIOR: PRINCIPIOS DISEÑOS Y APLICACIONES

E J E R C I C I O

EXPOSITOR: ING. CARLOS GARCIA R.

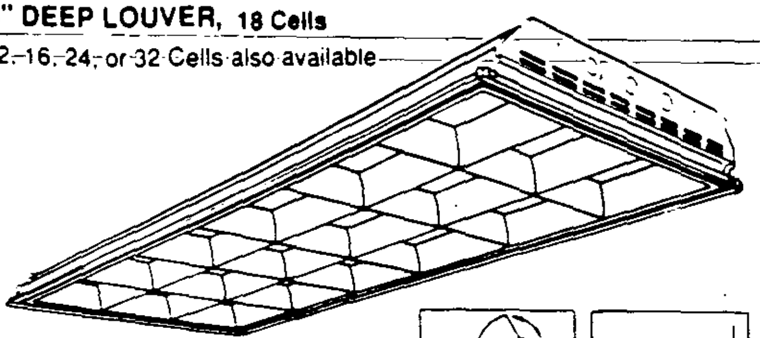
Palacio de Minería Calle de Tacuba 5 Primer piso Deleg. Cuauhtémoc 06000 México, D.F. Tel.: 521-40-20 Apdo. Postal M-2285

PARAMAX®

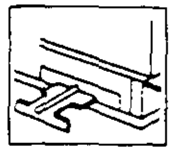
PARABOLIC TROFFER
2' x 4' • 3 LAMPS • RAPID START

3" DEEP LOUVER, 18 Cells

12, 16, 24, or 32 Cells also available



SPRING-LOADED CAM LATCHES



STEEL T-HINGES

Metric sizes available. Consult factory.

- Precisely-formed parabolic louver, shipped in a protective polyethylene wrapper.
- Automated assembly, mitered corners, and interlocking construction assure precise parabolic shape.
- Pre-anodized aluminum louver, available in specular or semi-specular gold, specular or semi-specular silver, and low-iridescent specular or semi-specular silver.
- Louver secured by rugged T-hinges and spring-loaded cam latches. Hinges/latches from either side.
- Floating door appearance with full black reveal.
- Air supply/return models feature optional air pattern control blades. Fully adjustable without tools.
- Wireway covers (reflectors) fit against louver. Controls light leaks into adjacent lamp cavities.

SPECIFICATIONS

Ballast Data

Thermally-protected, resetting, Class P, HPF, non-PCB, UL listed, CSA certified ballast standard. Sound rating A. Standard combinations are CBM approved.

Wiring & Electrical

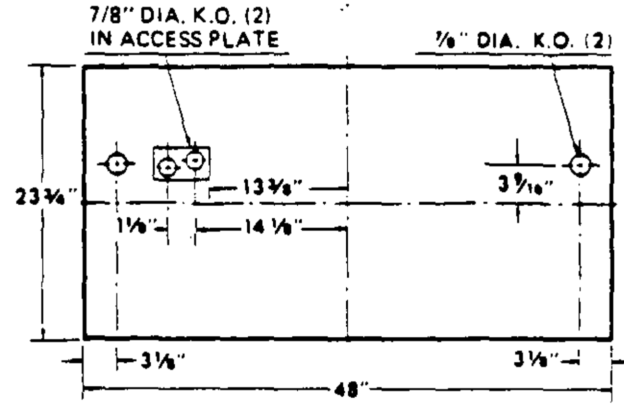
Fixture bears UL label and is suitable for damp locations. AWM, TFN, or THHN wire used throughout, rated for required temperatures. All ballast leads extend a minimum of 6" through access plate.

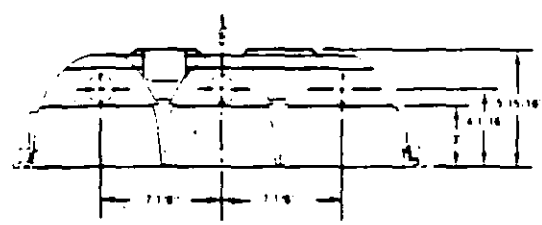
Materials

Louver parts constructed of pre-anodized aluminum. Steel parts die-formed from code-gauge cold-rolled steel. Housing embossed for rigidity. No asbestos is used in this product.

Finish

Five-stage iron-phosphate pre-treatment ensures superior paint adhesion and rust resistance. Painted parts finished with high-gloss, baked white enamel.

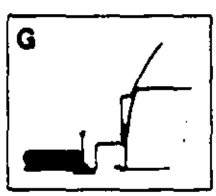




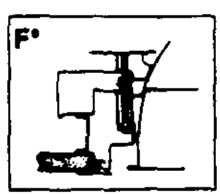
UL listed. CSA certified. Labeled I.B.E.W. - A.F. of L. Guaranteed for 1 year against mechanical defects in manufacture. Dimensions & specifications subject to change without notice.

MOUNTING DATA

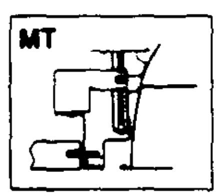
Ceiling Type	Appropriate Trim Type
Exposed grid tee	G
Concealed grid tee	G, ST
Concealed Z-spline	F, MT
Metal pan (consult factory)	MT
Screw slot (consult factory)	ST
Acoustical tile, plaster, or plasterboard on rigid supports parallel to lamps	F



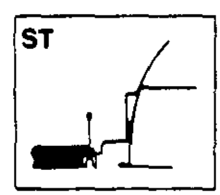
LAY-IN TRIM, exposed grid tee



OVERLAPPING FLANGED TRIM with swing-gate hangers



MODULAR FIT-IN TRIM with swing-gate hangers



SCREW SLOT TRIM, louver flush to ceiling

* Recommended rough-in dimensions for F trim fixtures: 24" x 48" (Tolerance is +1/4" - 0").
Swing-gate range: 1" - 3-3/8" from ceiling plane, span 23-1/2" - 26-5/16".

Approval

Job Information

Type ________

(Specify 120, 277 or 347V)

LITHONIA FLUORESCENT
COMMERCIAL & INDUSTRIAL LIGHTING

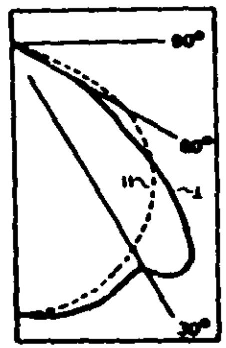
PARABOLIC TROFFER
2' x 4' • 3 LAMPS • RAPID START

PARAMAX®

PHOTOMETRICS

COEFFICIENTS OF UTILIZATION — ZONAL CAVITY

Pfc	20%													
Pcc	80%				70%				50%			30%		
Pw	70%	50%	30%	10%	70%	50%	30%	10%	50%	30%	10%	50%	30%	10%
1	79	76	74	70	77	75	73	71	72	70	69	69	68	67
2	74	69	65	62	72	68	64	62	66	61	60	63	61	59
3	68	63	58	54	67	61	57	54	59	56	53	58	54	52
4	63	56	51	47	62	55	51	47	54	50	46	52	49	46
5	58	50	45	41	57	50	45	41	48	44	40	47	43	40
6	54	45	40	36	53	45	40	36	44	39	35	42	39	35
7	50	41	36	32	49	40	36	31	39	34	31	38	34	31
8	46	37	31	27	45	36	31	27	35	31	27	35	30	27
9	42	33	28	24	41	33	27	24	32	27	23	31	26	23
10	39	30	24	21	38	30	24	21	29	24	21	28	24	21



*Standard ballasts, F40T12/CW lamps (3150 lumens)

Spacing criteria: II = 1.2 x mounting height
⊥ = 1.5 x mounting height

Full report available. Request ERL 6730.

For photometrics on other configurations, see Technical Data section or Lithonia representative

CANDLEPOWER

ANGLE	ALONG	45°	ACROSS
0	2845	2845	2845
5	2799	2814	2829
10	2772	2825	2876
15	2657	2748	2833
20	2572	2698	2783
25	2389	2528	2626
30	2306	2446	2829
35	2157	2342	2840
40	1961	2317	2453
45	1770	2136	1891
50	1557	1710	1197
55	1299	1132	761
60	1014	647	506
65	602	315	172
70	121	105	68
75	37	45	36
80	15	21	17
85	4	6	5
90	0	0	0

ZONAL LUMEN SUMMARY

ZONE	LUMENS	% LAMP	% FIXTURE
0-30	2234	23.6	33.5
30-60	3999	42.3	59.9
60-90	443	4.7	6.6
Total	6676	70.6	100.0

TYPICAL VCP PERCENTAGES

ROOM SIZE (FEET)	HEIGHT ALONG		HEIGHT ACROSS	
	8.5'	10.0'	8.5'	10.0'
20 x 20	75	70	83	80
30 x 30	82	78	87	84
30 x 60	85	81	89	86
60 x 30	84	81	88	86
60 x 60	87	84	90	88

HPM 140

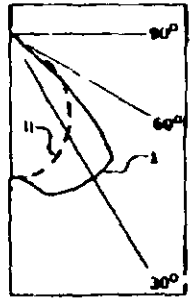
PARABOLIC TROFFER
1'x 4' • 1 LAMP • RAPID START

PHOTOMETRICS

HPM3GB 140-8*

COEFFICIENTS OF UTILIZATION — ZONAL CAVITY

pfc	20%													
pcc	80%				70%				50%			30%		
pw	70%	50%	30%	10%	70%	50%	30%	10%	50%	30%	10%	50%	30%	10%
1	78	76	74	69	77	75	73	71	72	70	69	69	68	67
2	73	69	66	63	72	68	65	62	66	61	61	63	61	59
3	68	63	59	55	67	62	58	54	60	58	54	58	56	53
4	64	57	52	48	62	56	52	48	55	51	47	53	50	47
5	58	51	46	42	57	51	46	42	48	45	42	48	44	41
6	55	48	41	38	53	46	41	37	45	40	37	44	40	37
7	50	42	37	33	48	42	38	33	41	35	32	39	35	32
8	47	38	32	28	45	37	32	28	38	32	28	36	31	28
9	43	34	29	25	42	33	28	25	33	29	25	32	28	24
10	38	31	25	22	38	30	25	22	38	25	22	28	25	22



CANDLEPOWER

ANGLE	ALONG	22.5°	45.0°	67.5°	ACROSS
0	896	896	896	896	896
5	908	910	918	921	920
10	900	918	954	984	991
15	871	909	993	1043	1052
20	821	890	985	1039	1058
25	753	850	948	1032	1056
30	703	823	941	1019	1052
35	828	754	884	968	1031
40	574	718	834	956	1016
45	504	646	757	777	727
50	412	553	592	414	296
55	325	437	330	182	149
60	209	251	127	88	57
65	85	69	54	39	32
70	30	28	25	24	20
75	17	15	12	10	8
80	8	7	6	5	3
85	2	2	2	2	1
90	0	0	0	0	0

ZONAL LUMEN SUMMARY

ZONE	LUMENS	% LAMP	% FIXTURE
0-30	788	25 0	35 7
0-40	1331	42 3	60 3
0-60	2121	67 4	96 1
0-90	2208	70 1	100 0

TYPICAL VCP PERCENTAGES

ROOM SIZE (FEET)	HEIGHT ALONG 8.5'	10.0'	HEIGHT ACROSS 8.5'	10.0'
20 x 20	82	77	88	84
30 x 30	86	82	91	88
30 x 60	87	84	92	89
60 x 30	87	85	92	89
60 x 60	88	86	92	90

*Standard ballast, F40T12/CW lamps (3150 lumens)
Spacing Criteria: II = 1.2 x mounting height
⊥ = 1.7 x mounting height
Full report available. Request ERL 7238
For photometrics on other configurations, see Technical Data section or Lithonia Representative

ORDERING INFORMATION

Example: HPM3GC 140-8

Explanation of Catalog Number: HPM3 [ ] [ ] [ ] 140 [ ] [ ] [ ] [ ]

Family
HPM3 – 3" Louver

TRIM TYPE

- **G** - Grid
- **F** - Flanged
- **M** - Modular
- **S** - Screw Slot
- **X** - Surface Mounting

AIR FUNCTION

- **B** - Static
- · Air Supply Return
- · Heat-Removal

VOLTAGE 120 or 277
Others available – consult factory

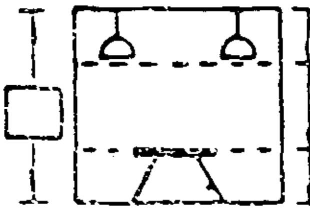
LOUVER FINISH

- **(Blank)** – Semi-Specular Silver
- **S** – Specular Silver
- **G** - Specular Gold
- **C** - Champagne Gold

NUMBER OF LOUVER CELLS
6, 8 or 9

HOJA DE CALCULO POR EL METODO DE CAVIDAD ZONAL

(LA LETRA (X) INDICA NOTA)



INFORMACION DEL LOCAL

1. DIMENSIONES DEL LOCAL L ____ A ____ ALTURA ____

2. REFLECTANCIAS: (por ciento) TECHO (Pт) ____ PAREDES (Ps) ____ PISO (Pp) ____

3. RELACIONES DE CAVIDAD
   - A. $RCL = \frac{5\,Hcl\,(L+A)}{L \times A} = \frac{5 \times (\quad + \quad)}{\quad \times \quad} =$ ____ → Pcl = ____ (De linea 2)
   - (B) $RCT = RCL\left(\frac{Hct}{Hcl}\right) =$ ____ = ____ → Pct = ____
   - $RCP = RCL\left(\frac{Hcp}{Hcl}\right) =$ ____ = ____ → Pcp = ____

DATOS LAMPARA / LUMINARIO

4. LUMINARIO No. ____ TIPO ____ CAT. DE MANTO ____ COND DE SUCIEDAD ____ CICLO DE LIMPIEZA ____ MESES ____ S/MH ____

5. A. LAMPARA ____ (B) LUMENES: ____ C. $\frac{LAMPARAS}{LUMINARIO}$: ____ D. LUMENES/LUMINARIO ____

6. (A) DLL ____ x (B) DPL ____ x (C) DPSL ____ = ____ FPL: ____

7. (A) COEFICIENTE DE UTILIZACION (CU): ____ x (B) ____ = CU CORREGIDO ____

8. (8) ____ NIVEL DE ILUMINACION REQUERIDO (LX) = ____

CALCULOS

9. LUMENES TOTALES = $\frac{LUXES \times AREA}{CU \times FPL}$ = ____ = ____

10. No. DE LUMINARIOS = $\frac{LUMENES\ TOTALES}{LUMENES\ POR\ LUMINARIO}$ = ____ = ____

DATOS DE ESPACIAMIENTO

11. AREA POR LUMINARIO (AL) = $\frac{AREA\ TOTAL}{No./LUMINARIOS}$ = ____ = ____

12. ESPACIAMIENTO APROXIMADO
   - A. PARA UNIDADES INDIVIDUALES $\sqrt{AL} = \sqrt{\quad}$ = ____
   - B. PARA TIRAS CONTINUAS: $\frac{AL}{LONGITUD\ DEL\ LUMINARIO}$ = ____ = ____

COMPROBACION

DATOS FINALES: No. DE LUMINARIOS ____ ESPACIAMIENTO: ____ LUXES: ____

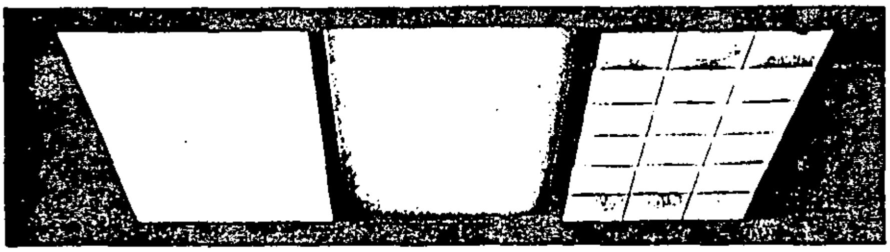
COMPROBACION DE ESPACIAMIENTO: Hcl X S/MH = ____ x ____ = ____ ESPACIAMIENTO MAXIMO
(De linea 1) (linea 4)

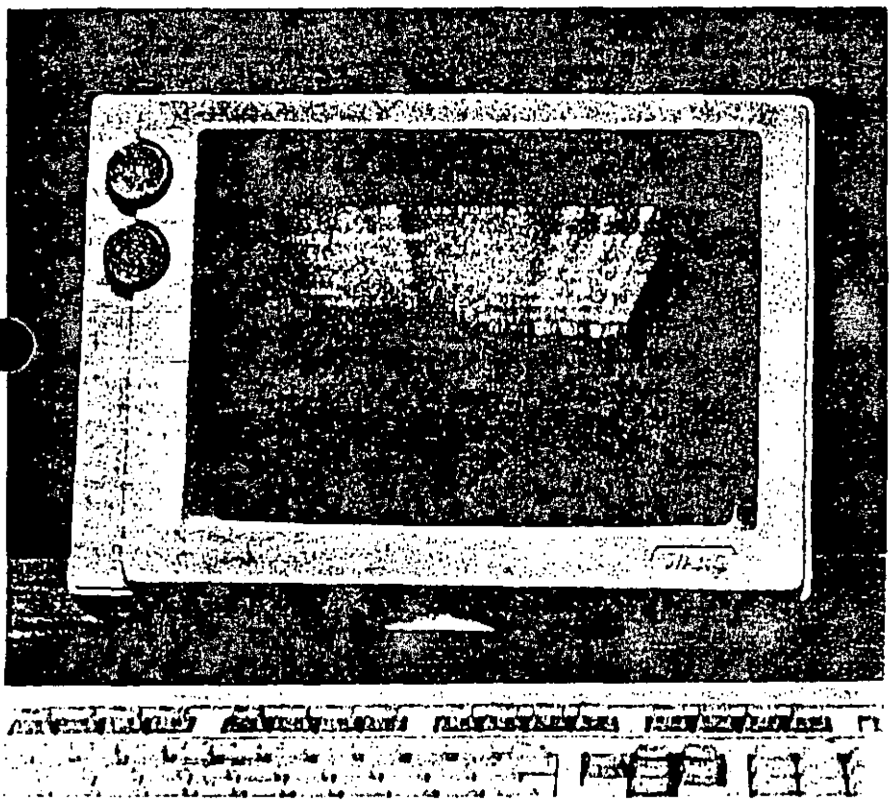
$LX = \frac{LT \times FPL \times CU}{AREA}$

(3B) Pct y Pcp DE NOTAS. TABLA 1	(6C) DE NOTAS. TABLA 6
(5B) DE CATALOGO DE LAMPARAS GE	(7A) DE NOTAS TABLA 2
(6A) DE NOTAS TABLA 4	(7B) DE NOTAS. TABLA 3
(6B) DE NOTAS TABLA 5	(8) COMO SE ESPECIFIQUE O RECOMIENDE

DESCRIPCION DEL CONTROLENTE

Comparación de pantallas comerciales típicas





Con la introducción de este nuevo controlente, basado en hemisferios refractivos, desaparece la necesidad de sacrificar la eficiencia de los luminarios para ganar en comodidad visual; creando un ambiente más confortable que con cualquier otro medio de control de luz.

REFRACTOGRID reduce el brillo del luminario hasta en un 70 %, lo cual incrementa la luz útil.

REFRACTOGRID es fruto del avance de la ciencia de la luminotécnia y la tecnología del diseño de lentes ópticos.

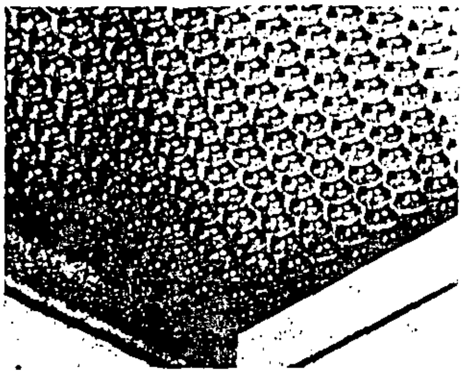
REFRACTOGRID ofrece nuevas perspectivas para la expresión arquitectónica al proporcionar un elemento de bajo contraste para techos y plafones, que se mezcla sutilmente con el entorno sin distraer la atención.

REFRACTOGRID es el patrón contra el cual todos los futuros diseños de lentes para control de luz serán medidos.

COMPARACION FOTOMETRICA

	Controlente Convencional	Refractogrid	Rejilla
Eficiencia del Gabinete	68.2%	69.8%	69.5%
Coeficiente de Utilización	0.59	0.61	0.61
Probabilidad de confort visual	70	81	77
Lúmenes en la zona 60° a 90°	8.3%	4.4%	4.6%

VENTAJAS DEL CONTROLENTE



REFRACTOGRID le ofrece los siguientes beneficios:

* 70% de reducción en luminancia (brillantez) en la visión directa comparado con los sistemas convencionales.

* Bajo contraste que no predomina en la apariencia de los techos.

* Configuración refractiva hemisférica que combina con cualquier diseño de plafón.

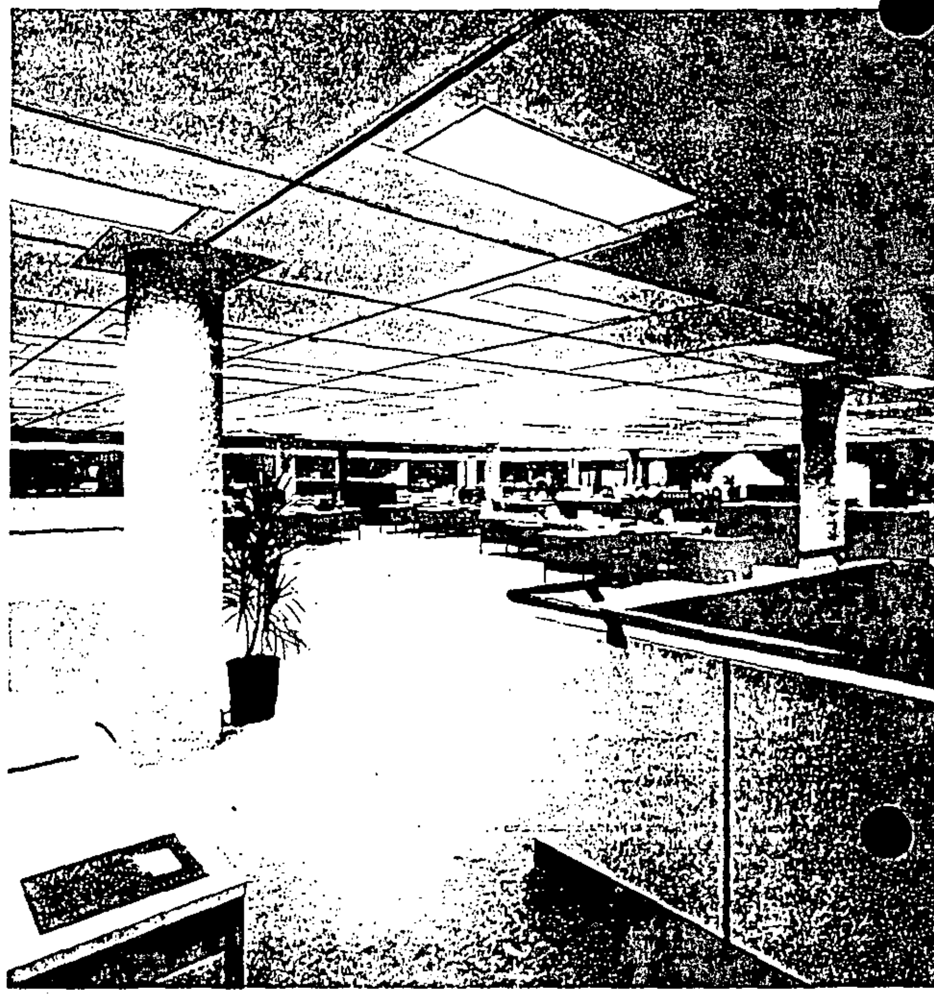
* Ocultamiento total de las lámparas en el ángulo normal de visión, que es único en el mercado.

* Alto confort visual.

* Uniformidad de iluminación superior debido a su gran relación de espaciamiento de 1.4 veces la altura de montaje.

* Más luz útil debido a sus elevados coeficientes de utilización.

* Todos los gabinetes vienen equipados con bases telescópicas para asegurar una efectiva conexión eléctrica a pesar de las vibraciones.



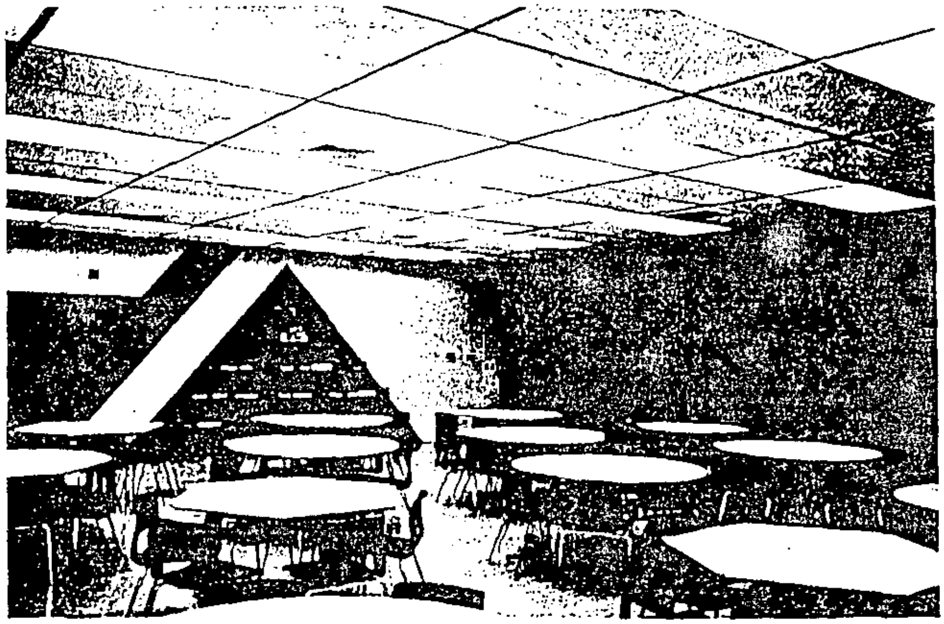
Para mayor información consulte a nuestros Asesores Técnicos o directamente a nuestro Departamento de Ventas.

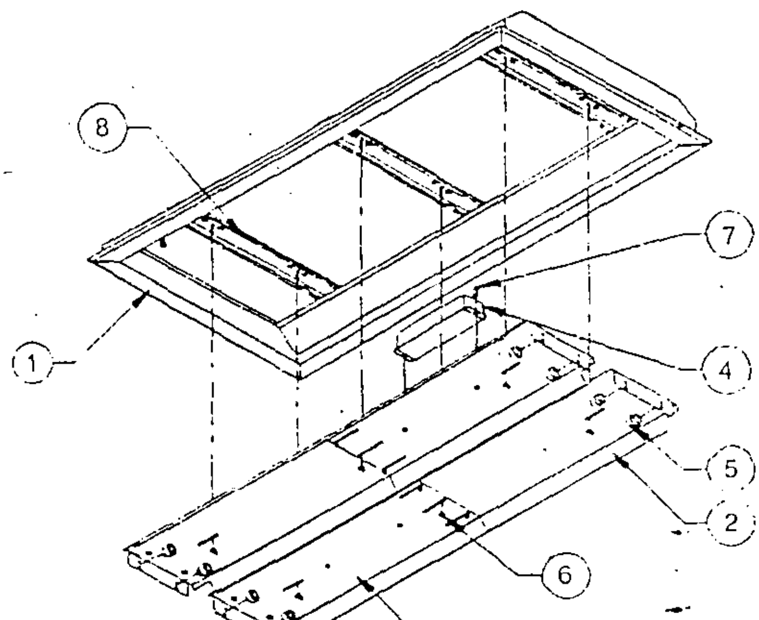
AHORRO DE ENERGIA

Holophane siempre preocupada por los cada vez más altos costos de enrgía eléctrica, le presenta la opción económica para su programa de mantenimiento, en sus instalaciones con luminarios fluorescentes de 2X40 w. que le van a proporcionar hasta un 25% de ahorro de energía.

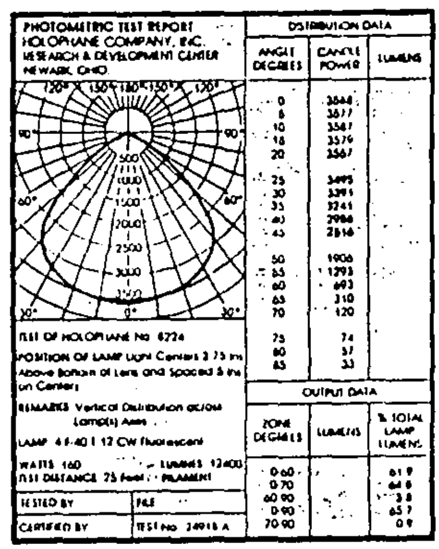
Esto únicamente se consigue con el uso de nuestro paquete de arnés de alta reflectancia (92%), balastro de bajas pérdidas, lámparas de 34 w. con bases telescópicas y el controlente **Refractogrid**.

Pregunte a nuestros distribuidores autorizados o directamente con nosotros por los luminarios tipo "IF".





DATOS FOTOMETRICOS



PART. DESCRIPCION

1. Gabinete Nuevo
2. Módulo eléctrico Derecho
3. Módulo Eléctrico Izquierdo
4. [illegible]alastro
5. Bases telescópicas
6. Tuerca Mariposa 3/16" Ø
7. Tuerca Exa 3/16" Ø
8. Refuerzo con Tornillo 3/16" Ø

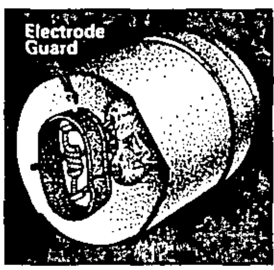
COEFICIENTES DE UTILIZACION

	plc 20%					
pcc	80%			50%		
pw	50%	30%	10%	50%	30%	10%
RCR 1	.71	.69	.67	.67	.65	.64
2	.65	.61	.58	.61	.59	.56
3	.58	.54	.51	.56	.52	.50
4	.53	.48	.45	.50	.47	.44
5	.48	.43	.39	.46	.41	.38
6	.43	38	.34	.41	.37	.34
7	.39	.34	.30	.37	.33	.30
8	.35	.30	.26	.34	.29	.26
9	.32	.26	.23	.30	.26	.23
10	.29	.24	20	.28	.23	.20

TL 80 Series Fluorescent Lamps
Electrical, Technical and Ordering Data (Subject to change without notice)

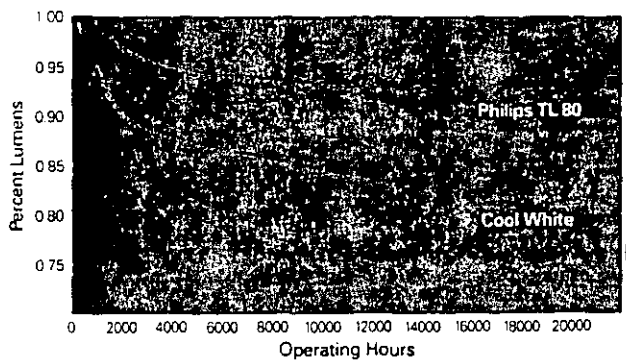
Product Number 046677-	Description	Nominal Watts	Bulb	Base	Std Pkg Qty	Lamp Current (Amps)	Color Temp (Kelvin)	Color Rendering (CRI)	Nominal Length (Feet)	Rated Average Life (Hrs)[1]	Approx. Initial Lumens	Design Lumens[2]
31980-6	F17T8/TL830	17	T-8	Md. Bipin	25	0.265	3000	85	2	20,000	1400	1300
32304-8	F17T8/TL835	17	T-8	Md. Bipin	25	0.265	3500	85	2	20,000	1400	1300
31983-0	F17T8/TL841	17	T-8	Md. Bipin	25	0.265	4100	85	2	20,000	1400	1300
31984-8	F25T8/TL830	25	T-8	Md. Bipin	25	0.265	3000	85	3	20,000	2250	2100
25798-0	F25T8/TL835	25	T-8	Md. Bipin	25	0.265	3500	85	3	20,000	2250	2100
31989-7	F25T8/TL841	25	T-8	Md. Bipin	25	0.265	4100	85	3	20,000	2250	2100
31991-3	F32T8/TL830	32	T-8	Md. Bipin	25	0.265	3000	85	4	20,000	3050	2850
31993-9	F32T8/TL835	32	T-8	Md. Bipin	25	0.265	3500	85	4	20,000	3050	2850
31994-7	F32T8/TL841	32	T-8	Md. Bipin	25	0.265	4100	85	4	20,000	3050	2850
31996-2	F40T8/TL830	40	T-8	Md. Bipin	25	0.265	3000	85	5	20,000	3800	3550
25799-8	F40T8/TL835	40	T-8	Md. Bipin	25	0.265	3500	85	5	20,000	3800	3550
31998-8	F40T8/TL841	40	T-8	Md. Bipin	25	0.265	4100	85	5	20,000	3800	3550

(1) Average life under specified test conditions with lamps turned off and restarted no more than once every 3 operating hours.
(2) Approximate lumens at 40% of rated average life (8000 Hours).



For maximum lumen maintenance, TL 80 Series lamps feature an "electrode guard" around each electrode to effectively reduce lamp darkening and retain a clean appearance for thousands of hours.

Lumen Maintenance: TL 80 vs. Cool White



Philips Lighting specialists are ready to help.

Philips Lighting has a team of specialists dedicated to commercial/office and retail lighting applications. They can provide a free lighting analysis which demonstrates how Philips TL 80 Series lamps can reduce energy costs in your building and improve the quality of light at the same time.

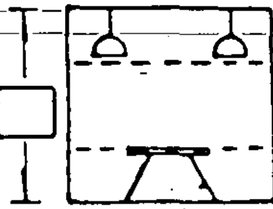
Call your Philips Lighting representative for a free fluorescent lighting analysis today: **1-800-631-1259.**

TL 80 System – lamp specification

"Lamps shall be Philips TL 80 Series lamps having:
- Color rendering index of 85
- T-8 diameter bulb
- Medium bi-pin bases
- Color temperature of ________ K (3000, 3500 or 4100)
- Initial lumens of ________ (1400, 2250, 3050 or 3800)
- Nominal wattage of ________ (17, 25, 32, 40)
- Powered by electronic ballasts designed for 265ma T-8 lamps
- An electrode guard."

HOJA DE CALCULO POR EL METODO DE CAVIDAD ZONAL

(LA LETRA (X) INDICA NOTA.)



Hcт = ☐
Hcʟ = ☐
Hcᴘ = ☐

INFORMACION DEL LOCAL

1. DIMENSIONES DEL LOCAL: L ☐ A ☐ ALTURA → ☐

2. REFLECTANCIAS: (por ciento) TECHO (Pт) ☐ PAREDES (Pᴘ) ☐ PISO (Pᴘ) ☐

3. RELACIONES DE CAVIDAD A. $RCL = \frac{5\,H_{CL}\,(L+A)}{L \times A} = \frac{5 \times (\quad + \quad)}{\times}$ = ☐ → Pcʟ = ☐ (De linea 2)

(B) $RCT = RCL\left(\frac{H_{CT}}{H_{CL}}\right) = \left(\frac{\quad}{\quad}\right)$ ——— = ☐ → Pcт = ☐

$RCP = RCL\left(\frac{H_{CP}}{H_{CL}}\right) = \left(\frac{\quad}{\quad}\right)$ ——— = ☐ → Pcᴘ = ☐

DATOS LAMPARA/LUMINARIO

4. LUMINARIO No. ____ TIPO ____ CAT. DE MANTO ____ COND DE SUCIEDAD ____ CICLO DE LIMPIEZA ____ MESES ____ S/Mh ____

5. A. LAMPARA: ____ (B) LUMENES: ____ C. $\frac{\text{LAMPARAS}}{\text{LUMINARIO}}$: ____ D. LUMENES/LUMINARIO: ☐

6. (A) DLL ☐ x (B) DPL ☐ x (C) DPSL ☐ = ——— FPL: ☐

7. (A) COEFICIENTE DE UTILIZACION (CU): ☐ → x (B) ☐ = CU CORREGIDO: ☐

(8) ——— NIVEL DE ILUMINACION REQUERIDO (LX) = ——— ☐

CALCULOS

9. LUMENES TOTALES = $\frac{\text{LUXES} \times \text{AREA}}{\text{CU} \times \text{FPL}}$ = ——— = ☐

10. No. DE LUMINARIOS = $\frac{\text{LUMENES TOTALES}}{\text{LUMENES POR LUMINARIO}}$ = ——— = ☐

DATOS DE ESPACIAMIENTO

11. AREA POR LUMINARIO (AL) = $\frac{\text{AREA TOTAL}}{\text{No./LUMINARIOS}}$ = ——— = ☐

12. ESPACIAMIENTO APROXIMADO A. PARA UNIDADES INDIVIDUALES $\sqrt{AL} = \sqrt{\quad}$ = ☐

B. PARA TIRAS CONTINUAS: $\frac{\text{AL}}{\text{LONGITUD DEL LUMINARIO}}$ = = ☐

COMPROBACION

DATOS FINALES: No. DE LUMINARIOS ☐ ESPACIAMIENTO: ☐ LUXES: ☐

COMPROBACION DE ESPACIAMIENTO: Hcʟ X S/MH = ——— X ——— = ☐ ESPACIAMIENTO MAXIMO

(De linea 1) (linea 4)

$LX = \frac{LT \times FPL \times CU}{AREA}$

(3B) Pcт & Pcᴘ DE NOTAS. TABLA 1	(6C) DE NOTAS. TABLA 6
(5B) DE CATALOGO DE LAMPARAS GE	(7A) DE NOTAS TABLA 2
(6A) DE NOTAS TABLA 4	(7B) DE NOTAS. TABLA 3
(6B) DE NOTAS TABLA 5	(8) COMO SE ESPECIFIQUE O RECOMIENDE

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

CURSOS ABIERTOS.

. ILUMINACION INTERIOR: PRINCIPIOS, DISEÑOS Y APLICACIONES.

ILUMINACION DE OFICINAS.

ING. JAVIER VILLASEÑOR.

Palacio de Minería Calle de Tacuba 5 Primer piso Deleg. Cuauhtémoc 06000 México, D.F. APDO. Postal M-2285
Teléfonos: 512-8955 512-5121 521-7335 521-1987 Fax 510-0573 521-4020 AL 26

CRITERIOS PARA LA ILUMINACION DE OFICINAS

FACTORES AMBIENTALES LUMINOSOS

Debido a que se utilizan grandes periodos de tiempo en ambientes de oficina, es importante que el total de todos los campos visuales esten balanceados. Este balance puede incluir extremos (limitados en cantidad o intensidad) pero deben centrarse predominantemente en relaciones de luminancia, reflectancias y colores que no sean excesivas. El ambiente luminoso debe permitir a los musculos del ojo trabajar en todo su rango.

La luz natural es deseable en el ambiente de una oficina y puede ser práctico tambien una variedad en el nivel de iluminancia y de cromaticidad.

Tambien es conveniente, cuando sea posible proporcionar vistas lejanas con el objeto de ofrecer una longitud focal infinita, la cual relaja los musculos de los ojos.

Para obtener un ambiente luminoso balanceado es necesario tomar en cuenta lo siguiente:

* Acabados del local
* El mobiliario y el equipo
* El color

Las superficies del local, las cuales incluyen techos, paredes y pisos, son factores importantes para determinar _ las relaciones de luminancia entre el equipo de iluminación y sus más lejanos alrededores.

Las reflectancias de las superficies del local __ tienen un efecto considerable en la utilización de la luz. El _ techo las paredes y el piso actúan como fuentes de luz secundaria, y si sus acabados tienen las reflectancias recomendadas incrementarán la utilización de la luz y reducirán ó atenuarán las sombras. Similarmente, superficies del local con menores reflectancias absorberán luz, reducirán el coeficiente de utilización y _ afectarán las relaciones de luminancia aceptables.

El uso de acabados mate que tienen las reflectancias recomendadas, previene contra las reflecciones especulares _ de luz, las cuales pueden distraer o pueden provocar relaciones _ excesivas de luminancia.

MOBILIARIO Y EQUIPO

- Reflectancias de planos de trabajo en oficinas. En un estudio efectuado recientemente en los Estados Unidos se encontro que las reflectancias de los diferentes planos de trabajo fueron desde 20.1% para una heliográfica azul a 91% para un escrito a máquina en papel blanco.

  La reflectancia del plano de trabajo más conveniente encontrada fué de 85%.

- Escritorios. Las cubiertas de escritorios pueden ser las áreas visuales más importantes en una oficina.

  Es esencial que estas superficies tengan acabados mate para minimizar el deslumbramiento reflejado.

  Es importante que las superficies verticales de escritorios y archiveros tengan acabados con el rango recomendado de reflectancias ya que generalmente, estos muebles ocupan una porción significativa del campo visual.

- Sistemas de muebles modulares. En oficinas grandes, los sistemas de muebles modulares ocupan una gran parte del campo visual, y debido a que los componentes estan sujetos a cambios, su variación de configuración debería ser anticipada.

  Con la iluminación integrada al mobiliario se debe tener cuidado de evitar que la brillantez del luminario quede en el campo de visión de otras personas.

- Máquinas de Oficina. Las máquinas de oficina se comparan con la superficie de los escritorios en importancia visual, ya que ocupan la parte central del campo de visión. Para lograr comodidad es necesario que los acabados tengan las reflectancias recomendadas y que las superficies brillantes sean eliminadas ya que aún una pequeña cantidad de estas pueden distraer.

- Zonas de transición. Las zonas de transición y los espacios de circulación son apropiadas para considerar el uso de colores, texturas y reflectancias que estan fuera del rango descrito anteriormente. En estas áreas, donde la permanencia es por poco tiempo y la concentración en trabajos individuales es menor, se pueden usar mayores relaciones de luminancia, reflejos y brillos de colores para proveer interes y variedad en el ambiente de la oficina.

EL SISTEMA DE ILUMINACION

El sistema de iluminación produce el medio ambiente visual. Es una combinación de fuentes de luz (artificial y/o natural) que crea las luminancias en las cuales se trabaja. La luz de estas fuentes incide en las superficies del local interreflejandose y produciendo finalmente luminancias. Son estas luminancias y las luminancias propias de las fuentes, las que se perciben cuando cualquier objeto es visto en el espacio.

El sistema de iluminación puede seccionarse en varios componentes que pueden ser controlados independientemente: Estos componentes incluyen el tipo de luminario, el arreglo de los luminarios, los controles eléctricos, las ventanas y tragaluces, y el medio ambiente, es decir forma del cuarto, Superficies y reflectancias, muebles etc.

EL LUMINARIO

Un sistema de iluminación puede tener cualquier número y tipo de luminarios.

Un luminario esta constituido por varios componentes que, debido a su construcción física, determinan su función.

- Lámparas. Las lámparas son la fuente de luz del sistema. Se cuenta con una amplia variedad de lámparas las cuales estan divididas en tres tipos básicos: Incandescentes, Fluorescentes y de descarga de alta Intensidad.

- Conjunto físico. Debido a que los luminarios son casi siempre visibles, su apariencia es importante. Se dispone de una amplia gama de estilos de luminarios los cuales satisfacen la mayor parte de las necesidades de los diseñadores.

- Caracteristicas fotométricas. Las caracteristicas fotométricas son descritas por medio de la distribución de candelas del luminario, esto nos indica como distribuye la luz el luminario.

- Mantenimiento. Para asegurar que el sistema de iluminación funcione como fué diseñado, se le debe dar mantenimiento al equipo de iluminación. Las lámparas deben ser cambiadas periodicamente, el alambrado deberá reponerse cuando sea necesario y las partes opticas deben mantenerse en un estado de limpieza óptimo.

- Integración con otros sistemas. Los luminarios deben integrarse con el sistema eléctrico, con el sistema de aire acondicionado y con el medio ambiente.

LA DISPOSICION FISICA

- El número de luminarios depende de la cantidad de luz requerida para alcanzar el nivel de iluminación adecuado.

- La localización de los luminarios es importante en donde este implícita una tarea visual. La adecuada posición de estos aumentará la iluminación en el plano de trabajo y al mismo tiempo deberá evitar los reflejos veladores.

- La orientación es el grado de rotación o inclinación a la que esta sujeto el luminario. Los luminarios pueden estar dirigidos hacia superficies u objetos. La orientación es la que determina el que un luminario sea utilizado en forma indirecta o en forma directa.

CONTROLES

Los controles eléctricos pueden ser considerados para economizar energía y proporcionar flexibilidad. El elevado costo de la energía puede justificar sistemas de control muy sofisticados y su consideración es muy recomendable.

Existen numerosos aspectos de la luz natural que hacen que su uso como fuente de luz en oficinas no solo sea deseable, sino tambien recomendable desde el punto de vista de economía y estética.

El uso apropiado de la luz natural requiere una planeación cuidadosa por parte del diseñador.

Para el mejor aprovechamiento de la luz natural, deben considerarse diversos factores los cuales incluyen:

Las características de la luz natural, su control, y aplicación.

EL MEDIO AMBIENTE

El medio ambiente luminoso esta constituido por todas las superficies expuestas en el espacio, su posición, orientación y reflectancias caracteristicas. Es la componente final de luminario- medio ambiente y la combinación produce el medio ambiente luminoso.

El diseñador puede tener gran influencia sobre estas superficies, aunque rara vez puede tener control directo sobrc ellas.

Lo anterior representa los componentes del sistema de iluminación. Ahora vamos a ver que tipos de sistemas de iluminación existen.

TIPOS DE SISTEMAS DE ILUMINACION

El sistema de iluminación es una combinación de factores que intervienen al mismo tiempo para proporcionar un ambiente luminoso. Criterios físicos y psicofísicos deben satisfacerse antes de que la mayoría de diseños sean considerados como aceptables.

Existen dos tipos de sistemas de iluminación: El directo y el indirecto.

SISTEMA DE ILUMINACION DIRECTO

Las curvas de distribución luminosa de luminarios directos varía de concentrada o amplia.

Donde la localización del plano de trabajo es conocida, la curva de distribución concentrada puede emplearse para aumentar la iluminación en la zona de trabajo. La curva de distribución concentrada puede utilizarse tambien para crear un ambiente no uniforme, pero se debe tener cuidado de evitar sombras desagradables que el sistema puede crear. Las superficies especulares tales como escritorios pueden causar deslumbramiento reflejado debido a luces bajas concentradas.

Los luminarios con distribución amplia emiten más luz a mayores ángulos que los luminarios con distribución concentrada. Estos proporcionan más uniformidad y típicamente produzcan más iluminancia vertical. Estos luminarios estan sujetos a brillo directo y a problemas de comodidad.

El sistema de iluminación directo se caracteriza por el hecho de que las superficies de los luminarios (controlentes, reflector, rejilla, etc.) son generalmente visibles y porque las superficies de trabajo estan directamente iluminadas por los luminarios.

SISTEMA DE ILUMINACION INDIRECTO

Los sistemas de iluminación indirecta se clasifican en dos grandes categorias: de techo y perimetral. El sistema indirecto de techo hace incidir la luz sobre el techo mientras que el sistema perimetral sobre las paredes. Amos tipos de sistemas pueden proporcionar la suficiente luz para iluminar superficies verticales (paredes, muebles, gente etc.) las cuales son generalmente importantes para percibir el volumen.

El sistema de iluminación indirecto se caracteriza porque la luz es reflejada en la mayoría de las superficies antes de llegar al plano de trabajo, y porque la superficie del luminario que emite luz no es vista bajo condiciones normales.

RESPUESTA SUBJETIVA

Las impresiones subjetivas estan influenciadas por diversos factores, pero para un espacio dado, se encontraron las siguientes tendencias:

- Amplitud de espacio.- La impresión de amplitud de espacio parece estar relacionada con la uniformidad de la luminancia de las superficies, a mayor uniformidad, es más fuerte la impresión de amplitud. Esta impresión se refuerza cuando el sistema de iluminación tiene un arreglo en forma periférica.

- Relajamiento. La sensación de relajamiento se refuerza cuando la iluminación se mueve de la parte superior hacia la periferia. La no uniformidad tambien incrementa la sensación de relajamiento.

- Claridad visual. La sensación de claridad visual se refuerza mediante sistemas de iluminación que sean claros, uniformes y periféricos.

- Privacia o intimidad. La sensación de privacia o intimidad es ayudada por sistemas de iluminación no uniforme cuando los ocupantes estan ubicados en áreas más obscuras.

- Satisfacción y Preferencia. La sensación de satisfacción y preferencia por ciertos espacios es aumentada por iluminación no uniforme y periférica.

Estas caracteristicas pueden ser usadas por el diseñador para el desarrollo de alternativas. El conocimiento de los ocupantes y el uso específico del espacio ayudará al diseñador a formular un sistema de iluminación que sea más apropiado para sus funciones.

ILUMINACION DE AREAS ESPECIFICAS

La iluminación en una oficina deberá proporcionar a la gente los medios visuales para ejecutar diversas labores con exactitud, eficiencia y comodidad. Las Areas a iluminar incluyen:

Areas Públicas
Areas de Recepción
Areas de Oficinas
Iluminación Exterior.

AREAS PUBLICAS

Las áreas públicas incluyen vestíbulos de acceso, corredores, elevadores y escaleras. Generalmente, no se ejecutan tareas visuales de gran dificultad en esta áreas. La iluminación es para proveer seguridad en los movimientos de los ocupantes y para establecer contactos sociales. Estas áreas dan al diseñador una oportunidad para desarrollar un sistema de iluminación inovador. El tratamiento adecuado de las áreas públicas puede crear una sensación de placer y una atmosfera de bienestar en los espacios.

- Vestibulos de acceso.- Una buena iluminación en los vestibulos de acceso es esencial ya que esta produce una primera impresión de facilidad en el acceso para el usuario. Un sistema bien diseñado puede complementar la arquitectura y el decorado de estas áreas. En ocasiones es deseable una iluminación no uniforme para añadir interes, para permitir la adecuada circulación y para resaltar la atención.

- Corredores. Los corredores proporcionan los medios para la circulación y el movimiento de un espacio a otro. La buena iluminación y el arreglo de los luminarios puede provocar dirección y perspectiva al espacio. Existen diversas formas de iluminar corredores y el diseñador puede emplear ideas innovadoras. La iluminación puede ser directa o indirecta. Los luminarios pueden estar colocados en hileras continuas o espaciados.

- Elevadores.- Los vestíbulos de entrada a los elevadores deberán estar iluminados para proporcionar seguridad en el acceso hacia los elevadores, esta iluminación no necesariamente deberá ser uniforme. El nivel de iluminación de la cabina del elevador deberá ser similar al del vestíbulo.

- Escaleras Eléctricas.- La iluminación de las escaleras eléctricas deberá proporcionar un nivel suficiente en los escalones para que una persona pueda subir o bajar sin dificultad. Los luminarios deberán estar colocados de tal forma que las personas que suben o bajan no produzcan sombras sobre los escalones.

- Escaleras.- Las escaleras generalmente son decorativas o de utilización, Las decorativas estan usualmente localizadas en rutas importantes y la iluminación deberá complementar la arquitectura. Las escaleras de utilización son usadas con el fín de desalojar el edificio en caso de emergencia. En este tipo de escaleras de deberá tener cuidado en la ubicación de los luminarios para proporcionar facilidad en el mantenimiento.

AREAS DE RECEPCION

El recepcionista frecuentemente efectúa trabajos de oficina además del trabajo de recepción. La iluminación deberá estar diseñada para proporcionar una visibilidad adecuada y que se complemente además con la arquitectura.

AREAS DE OFICINAS

Las oficinas son usadas para diversos trabajos, tales como lectura, mecanografía, archivo, procesamiento de datos, operación de computadoras, entrevistas, dibujo, juntas, etc. Los espacios de oficina varian desde grandes oficinas abiertas hasta pequeñas oficinas privadas.

- Oficinas Generales.- En oficinas generales se ejecutan una amplia variedad de labores, por lo que la iluminación deberá tener calidad y comodidad, Cuando se tienen muebles modulares los luminarios pueden integrarse al mueble para iluminar el plano de trabajo. Deberá tomarse en consideración la localización de escritorios y la futura división en pequeñas oficinas. Las paredes deberán iluminarse cuidadosamente ya que los escritorios generalmente estan colocados a lo largo de estas. Cuando el cliente no indica la localización de muebles, el diseñador deberá sugerir.

la localización y orientación de muebles cuyo arreglo aproveche mejor la iluminación.

- Oficinas privadas. La uniformidad de iluminación en una oficina privada no es generalmente lo más importante. Una adecuada iluminación general deberá ser diseñada para cubrir las superficies de trabajo. La iluminación suplementaria puede proveer luminancias complementarias en la oficina.

- Salas de juntas. Las tareas visuales en salas de juntas varian desde casuales hasta de dificil visión. La sala deberá contar con un sistema general de iluminación con apagadores o atenuadores para controlar los niveles de iluminación.

- Máquinas de Oficina.- Una gran variedad de máquinas son usadas en oficinas, entre ellas se tienen:

  Calculadoras, máquinas sumadoras, pantallas de terminales, etc. Se deberá tener cuidado para evitar reflejos veladores. Las pantallas de las terminales presentan grandes problemas. Las pantallas se aprecian mejor en niveles bajos de iluminación. El brillo y las imagenes reflejadas sobre las pantallas provienen de altos niveles y de ventanas que estan a espaldas o a un lado de la pantalla

- Salas de Computo.- En la sala de máquinas es suficiente un nivel bajo de iluminación, sin embargo, deberá proveerse un nivel adecuado para el mantenimiento y el servicio del equipo. Los luminarios deberán estar cuidadosamente ubicados de tal forma que no se produzcan reflejos veladores.

- Salas de Dibujo.- La tarea visual en las áreas de dibujo requiere una alta calidad de iluminación ya que se requiere una discriminación de detalles finos durante largos periodos de tiempo. Se puede usar una iluminación local suplementaria para proporcionar las iluminancias recomendadas y para reducir el consumo de energía.

- Areas de Archivo.- En áreas de archivo muy activas, el trabajo es probablemente prolongado y la tarea visual de mayor severidad. Cuando un local esta dedicado exclusivamente a archivo, se deberá considerar el diseño y localización de los luminarios para proveer las luminancias recomendadas sobre las superficies verticales.

- Sanitarios.- En los sanitarios no es necesario tener uniformidad en la iluminación. Los luminarios deberán estar localizados para proveer la adecuada iluminación en la vecindad de los espejos, lavabos, etc.

- Areas de servicio de alimentos.- Los servicios que normalmente hay en un edificio de oficinas son una cafetería o un restaurant. Las cocinas deberán estar provistas de una iluminación bien diseñada para proporcionar una atmosfera de limpieza e higiene. Las áreas de comedor deberán estar iluminadas de tal forma que la estancia sea placentera. Deberán proveerse atenuadores de luz en las áreas del comedor par permitir cambios en la atmosfera.

- Bibliotecas. La lectura es generalmente la actividad que más se efectua en una biblioteca. La iluminación seleccionada deberá proporcionar una visión confortable y puede ser similar al equipo de iluminación utilizado en oficinas generales. Los estantes para libros deberán estar iluminados adecuadamente.

- Salas de primeros auxilios.- La sala de primeros auxilios deberá estar provista de iluminación general. Para una inspección minuciosa del paciente se requiere iluminación suplementaria.

- Cuartos de utileria.- Se deberá proporcionar unicamente una iluminación general que sea adecuada.

ILUMINACION EXTERIOR

La iluminación exterior para un edificio de oficinas incluye iluminación de protección, iluminación de accesos, iluminación de pasillos, iluminación de estacionamientos.

- Iluminación de Protección.- Se deberá proveer una adecuada iluminación de protección con el objeto de proporcionar seguridad al edificio.

- Iluminación de accesos. La iluminación de las entradas, generalmente esta diseñada para complementar la estructura arquitectónica del edificio y permitir el acceso a este con buena visibilidad.

- Iluminación de Pasillos.- Se deberá proporcionar iluminación de los caminos de comunicación exteriores cuando el edificio se utiliza en las tardes.

- Iluminación de Estacionamiento.- Se deberá proveer iluminación a los estacionamientos con el objeto de desalentar el robo y el vandalismo.

MANEJO DE LA ENERGIA

Un diseño de iluminación no esta completo hasta que éste ha sido sujeto a una cuidadosa evaluación de su empleo de energía.

Habra un derroche de energía cuando existan cualquiera de las siguientes condiciones:

1) La fuente de iluminación esta energizada cuando no es necesario (esto se debe a un control pobre)

2) El sistema de iluminación es ineficiente o de poca calidad

3) La cantidad de luz es inadecuada para la ejecudión de la labor.

4) La cantidad de luz excede la necesaria

Las pérdidas directas en costo de energía eléctrica son aquellas que resultan de un control pobre, un sistema inefi-- ciente o un exceso de iluminación. Cada una de ellas puede eva-- luarse en forma cuantitativa en costo de kilowatts-hora, cuando _ se comparan las eficiencias de diseños semejantes.

CONTROLES

La habilidad para gobernar la operación de un siste ma de alumbrado adecuadamente es el factor más importante en el _ consumo de energía, por lo que es necesario utilizar mayor tiempo de ingeniería para desarrollar un cuidadoso análisis de los siste mas de control.

- Controles manuales.- La mayor parte de la iluminación en las oficinas se controla manualmente, por lo que _ se deberán considerar las siguientes condiciones:

1.- Cada oficina o área deberá tener su propio control.
2.- En grandes espacios abiertos, las áreas de trabajo deberán agruparse y controlarse independientemente
3.- Cuando se usan una o dos lámparas por luminario, los luminarios adyacentes se deben conectar en circuitos alternos.

4.- Cuando se usan luminarios de tres lámparas fluorescentes, la lámpara central debe conectarse a un circuito separado del de las lámparas exteriores.

5.- Cuando se usan luminarios de cuatro lámparas fluorescentes el par interior debe conectarse a un circuito separado del de las lámparas exteriores.

6.- Las áreas de trabajo que requieren altos niveles de iluminación deben conectarse en circuitos independientes.

- Controles automáticos.- Los controles automáticos pueden eliminar muchos de los problemas en el empleo de la energía, debidos a fallas de los ocupantes en el uso apropiado de los controles.

  Algunas de las técnicas de control automático son:

- Interruptores de tiempo
- Relojes
- Detectores de presencia
- Controles fotosensitivos
- relevadores
- Computadoras o microprocesadores

Esta última técnica se utiliza para resolver una gran variedad de problemas de alumbrado. Pueden instalarse para manejar grandes sistemas de alumbrado, respondiendo a una amplia variedad de localización de labores, además pueden manejar otras labores como pueden ser: calefacción, aire acondicionado, elevadores, etc.

- Atenuación de luz.- La utilidad de un sistema de iluminación puede ser aumentada, instalando atenuadores de luz en los locales donde se requiere una gran variedad de niveles de iluminación.

- Reducción de voltaje de operación. El alumbrado fluorescente puede ser operado a voltaje reducido con el uso del equipo y circuitos adecuados, logrando un considerable ahorro de energía.

- Apagado y encendido del alumbrado fluorescente. No existe situación alguna donde el apagado y encendido de lámparas fluorescentes tenga efectos económicos negativos. Una lámpara fluorescente pierde pocos minutos de vida por cada ciclo de apagado y encendido. Por lo regular el apagar las lámparas fluorescentes sirve para aumentar la vida util de la lámpara debido a que el tiempo en que ésta permanece apagada excede en tiempo a la reducción de su vida útil por el efecto de apagarlas y encenderlas.

- Apagado y encendido de lámparas de descarga de alta intensidad. El alumbrado de descarga de alta intensidad requiere de varios minutos para su reencendido despues de su desconexión. Debido a que el tiempo de reencendido de estas lámparas es entre 10 y 15 minutos se limitan los ciclos de apagado y encendido a las situaciones donde tales tiempos puedan ser tolerados. Por esta razón hay pocos beneficios en el pagar y encender los sistemas con lámparas de descarga de alta intensidad.

EFICIENCIA DEL SISTEMA DE ILUMINACION

La eficiencia de un sistema de iluminación es el resultado de la combinación de las eficiencias de los componentes de los luminarios y del medio ambiente.

- La mayor parte de los diseños de iluminación de oficinas continúan utilizando lámparas fluorescentes. Sin embargo a últimas fechas se ha empezado a incorporar lámparas de descarga de alta intensidad en el alumbrado interior. Los diseñadores deberán seleccionar las fuentes más eficaces que satisfagan las necesidades del área.

- La selección de las lámparas depende de; las necesidades de color, el tiempo de encendido y de la distribución deseada. La eficacia (lúmenes/watt de entrada) es diferente para cada grupo de lámparas (fluorescente, mercurial, aditivos metálicos, sodio alta presión, etc.) La eficacia también varía con la potencia, las lámparas de gran potencia son por lo general más eficaces.

- Existe una amplia gama de diseños de balastros, el perfeccionamiento en sus diseños da como resultado pocas pérdidas en nucleo y bobinas lo cual redunda en una vida mayor debido a su operación a menor temperatura. Tipicamente una reducción de 10°C en la temperatura del balastro ocaciona un aumento al doble de la vida esperada.

  Los avances en la tecnología de estado solido han dado como resultado el desarrollo de balastros electrónicos para lámparas fluorescentes y de descarga de alta intensidad, estos dispositivos reducen las pérdidas al eliminar el núcleo y las bobinas, ofreciendo una gran flexibilidad para el control .

- La luz que sale de las lámparas es dirigida a la tarea por los diferentes elementos del sistema óptico. Estos elementos son; el reflector y si se usan, los lentes o el refractor.

- Cada watt utilizado en el alumbrado introduce 3.41 BTU'S por hora de calor en la construcción. Existen sistemas para el control del calor producido por los luminarios. Estos sistemas pueden usar la parte superior del luminario para colectar el calor o incluir el uso de una manejadora de aire que asociada a ductos de aire remuevan el calor producido por el alumbrado.

- Medio Ambiente. Tan importante es establecer las especificaciones de un sistema de iluminación como lo es el establecer un lugar de trabajo eficiente.

- Localización de la tarea y calidad. La localización de las labores deberá planearse para proporcionar el mejor arreglo de luminarios. Esto es posible mediante el agrupamiento de labores que tengan requerimientos visuales similares.

- Reflectancias y Depreciación por polvo. Se debe de tratar de convencer a los clientes de utilizar colores con reflectancia alta para todas las paredes del área de trabajo. Además para lograr ahorros los calculos deben hacerse con los valores reales y no con valores estimados.

- Iluminación con luz natural.- La iluminación con luz natural puede ser un factor importante en el ahorro de energía. Que tanto se ahorra depende de varias variables tales como: la disponibilidad de luz natural, la orientación del edificio, horario en que se labore, tamaño y localización de las ventanas, niveles de iluminación requeridos y de la utilización de controles de iluminación.

CANTIDAD DE ILUMINACION

El seleccionar el nivel de iluminación adecuado es un aspecto muy importante en el ahorro de energía.

- Iluminación de áreas con labores definidas. La recomendación básica es proporcionar la cantidad de luz adecuada donde esta es necesaria, y evitar excederse en cantidad de luz en áreas donde la luz no tenga un propósito muy util.

- Iluminación de áreas con labores indefinidas. El mejor método para diseñar la iluminación de áreas con labores indefinidas es el proporciona flexibilidad a la istalación. Una técnica para lograr esto es utilizar un sistema de luminarios desconectables, el cual consiste de una red en el techo con contactos que acepte luminarios con cable y clavija.

- Mantenimiento de la iluminación. Se pueden mantener los niveles de iluminación iniciales compensando las diferentes pérdidas de luz que ocurran con el paso de los años en el sistema. Para esto, el diseñador y el encargado de mantenimiento deberán establecer un programa de mantenimiento y reemplazo de lámparas. Un buen programa de mantenimiento previene contra la utilización de niveles iniciales de iluminación altos.

AIRE ACONDICIONADO

Es deseable que el diseño de alumbrado este completo antes de determinar el tamaño del equipo de aire acondicionado, ya que al utilizar los valores reales de diseño se puede eliminar un aumento significativo en el tamaño del equipo.

ALUMBRADO DE EMERGENCIA

El alumbrado de emergencia proporciona seguridad a los ocupantes de un edificio cuando el sistema normal de iluminación falla. La iluminación proporcionada por el sistema de alumbrado de emergencia debe permitir salir en forma segura del edificio en caso de emergencia. Si el salir no es necesario , el sistema debe operar para proporcionar seguridad y comodidad a los ocupantes hasta que el sistema normal sea restablecido.

- Tipos de alumbrado.- Existen diferentes tipos de alumbrado de emergencia y su uso depende de las necesidades de cada edificio.

- Sistemas en uso. Existen tres tipos.

1) Un sistema de luminarios cableados independientemente y alimentados por un generador.
2) Un sistema de luminarios alimentados por dos fuentes independientes.
3) Equipo unitario con baterias individuales.

- Alumbrado de salidas.- Este alumbrado, debe proporcionar la iluminación requerida sobre el piso, en las trayectorias hacia salidas incluyendo la intersección de corredores, pasillos escaleras y puertas.

Cada salida debe ser claramente indentificada con señales luminosas. La fuente de luz puede ser propia o provenir del exterior, pero deberá operar durante las fallas o interrupciones de la fuente normal de energía.

SEGURIDAD

- Importancia.- En cualquier parte de una oficina, las condiciones para trabajar con seguridad son esenciales y por lo tanto, deben ser considerados los efectos de la luz. El medio ambiente de una oficina es importante diseñarlo con el objeto de compensar las limitaciones propias de la capacidad humana.

Cualquier factor que ayude a ver mejor, aumenta la probabilidad de que un empleado pueda detectar la causa potencial de un accidente de inmediato o impedirlo.

- Otros factores. Además de los niveles adecuados de iluminación, un área visualmente segura no debe tener brillo excesivo ni debería haber grandes contrastes dentro de ella. Debido a cambios en la adaptación del ojo cuando mira superficies de diferente luminancia, la relación de luminancia entre superficies adyacentes no debe exceder de 20 a 1.

- Evaluación de iluminación. Aunque el área de una oficina puede ser diseñada con la calidad y cantidad necesaria para seguridad, es necesario conocer si dichos requisitos han sido tomados en cuenta.

MANTENIMIENTO

Se debe proporcionar suficiente información al usuario para implementar un programa de mantenimiento. Esto es de suma importancia dado que el sistema de alumbrado es diseñado considerando factores de pérdidas de luz que requieren de un mantenimiento periodico para cumplir con los criterios básicos de diseño establecidos.

PLAN DE MANTENIMIENTO

Como una guía para elaborar un plan de mantenimiento se pueden utilizar los siguientes puntos:

- Limpiar luminarios y reemplazar lámparas periodicamente.
- Revisar todos los componentes de los luminarios
- Reemplazar luminarios viejos o dañados por unidades nuevas que se limpien facilmente
- Instalar lámparas de alta eficiencia
- Podar los árboles o arbustos que obstruyen la luz
- Repintar las superficies del local
- Minimizar el uso de la iluminación durante periodos de limpieza.

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CURSOS ABIERTOS

ILUMINACION INTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES

ILUMINACION DE EDIFICIOS PUBLICOS BANCOS, HOSPITALES HOTELES, IGLESIAS, BIBLIOTECAS, MUSEOS Y GALERIAS

EXPOSITOR: ARQ. ENRIQUE QUINTERO LOPEZ

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Institution and Public Building Lighting

SECTION 7

Banks, churches and synagogues, hotels and motels, food service facilities, libraries, and museum and art galleries are usually considered to be institutions or public buildings. The lighting of the spaces peculiar to these buildings is included in this section.

Appropriate design illuminances for areas and tasks in institutions and public buildings are given in Fig. 2-2, page 2-5, in terms of illuminance categories, and within this section in illuminance where specific values have been found to be effective based on criteria other than visual task performance.

For the lighting of office areas, merchandising areas, and exteriors of institutions and public buildings, see Sections 5, 8, and 12, respectively. For general information on interior lighting design and energy management, see Sections 1, 2 and 4.

BANKS

The various functions and tasks that occur in a bank are mainly the same as those that occur in offices, *i.e.*, conference areas, accounting, general and private offices, bookkeeping, etc. (see Section 5, Office Lighting). There are, however, several specific areas with special banking functions where the lighting needs may be different.

Specific Areas

The following are several specific banking areas to be considered (illuminance recommendations for areas and associated seeing tasks are given in Fig. 2-2):

Lobbies. Historically, bank lobbies have had very high ceilings, but today, because of high building costs, they are no more than 3.5 to 4.5 meters (12 to 15 feet) high. Where very high ceilings exist, the use of high intensity discharge lamps should be considered, not only for energy utilization but also for the economy of relamping and other maintenance procedures.

Special attention should be given to writing areas so that there is adequate illumination for the activities performed there. When promotional incentives, such as merchandise, are located in the lobby, there should be provisions for highlighting to create a point of interest (see Section 8, Lighting Merchandising Areas).

Tellers' Stations. The most active areas in a bank are the tellers' stations. Here the lighting should provide for fast, accurate transactions. Because of highly polished material for the deal plate, there is a tendency for reflections from lobby lights. One way to reduce reflections is to utilize a low brightness luminous ceiling. Recessed downlight luminaires directly over the deal plates should be avoided as they tend to cause shadows and discomfort glare for the teller.

The interior lighting at a *drive-up window* should be similar but due to sloping of the window glass, luminaires behind the drive-up teller should be of low brightness to minimize any reflections on the glass itself.

Probably the most neglected area of bank lighting is the *outdoor drive-up area.* The outside lighting there should be about the same magnitude as the interior to avoid a mirror effect on the glass, looking out from the drive-up teller's position. The lighting should be designed to light the person in the vehicle and the drive-up unit, not the top of the car. In addition to the "visual" drive-up teller facilities, where the teller visually sees the client, there are television or remote units requiring lighting for camera needs.

Note: References are listed at the end of each section.

Security Lighting. Security lighting should be incorporated in accordance with the Bank Protection Act of 1968, whereby adequate night lighting and exit lighting and lighting on the vault are on at all times. Also, there must be adequate interior lighting for an alarm camera system. Lighting requirements for cameras and films used should be evaluated.

CHURCHES AND SYNAGOGUES[1]

Skillfully used lighting can make worship services more meaningful and enhance the architectural design of the space. The lighting can mold and give depth, and can subdue or accentuate, or perhaps change its accent, as the service proceeds. In certain interiors it can add a fourth dimension: a suggestion of the infinite.

For good energy management, consideration should be given to the use of the least wattage to create a desired mood or to perform visual tasks, and the use of adequate controls and maintenance procedures. See Section 4.

Entrances

In the entrance vestibule or narthex, the lighting should enable the quick recognition of faces, facilitate the taking of notes of names and requests, and provide a transition between the exterior and main worship area brightness. Diffuse illumination should be used so that faces appear pleasantly lighted and are not made to appear lined or strained by highly directional harsh sources.

Fig. 7-1. Illuminances Currently Recommended for Churches and Synagogues[a]

Area	Illuminance: Lux	Illuminance: Footcandles
Altar, ark, reredos	1000[b]	100[b]
Choir[c] and chancel	300[b]	30[b]
Classrooms	300	30
Pulpit, rostrum (supplementary illumination)	500[b]	50[b]
Main worship area[c]		
Light and medium interior finishes	150[b]	15[b]
For churches with special zeal	300[c]	30[c]
Art glass windows (test recommended)		
Light color	500	50
Medium color	1000	100
Dark color	5000	500
Especially dense windows	10000	1000

[a] Maintained target values on tasks.

[b] Reduced or dimmed during sermon; prelude or meditation.

[c] Two-thirds this value if interior finishes are dark (less than 10 per cent reflectance) to avoid high luminance ratios, such as between hymnbook pages and the surround. Careful planning is essential for good design.

Main Worship Areas

There are vast differences in the service and liturgy of the many faiths and denominations and the lighting designer should be familiar with their customs in order to assure proper lighting emphasis at the proper time. Fig. 7-1 lists suggested illuminance values for design based on needs during various types of religious services.

General Lighting. There should be appropriate general lighting for reading, moving about, visual social contact, and to help the worshipper relate to the structure and its features. In many churches there is a trend away from the traditional service of listening, watching and meditating, to a service that includes more participation. Higher general lighting in the space can encourage the feeling of being part of a body of people. Such participation also means more reading—requiring particular attention to light at the pew.

Often there are two components to the general lighting: (1) direct lighting for the pews, and (2) indirect lighting to relieve shadows and to create desired brightnesses on the structure. Sometimes, indirect lighting provides all the general illumination—particularly if lighting equipment cannot be mounted on or in the ceiling.

Lighting from one direct point source creates dark shadows and specular reflections. This may be desirable to highlight an object, but it is undesirable where people are attempting to read or follow printed material. Also it can make the leader of a service appear unpleasant through deep eye and other facial shadows. An overlap of light from direct sources or the use of indirect lighting with direct light will soften shadows and reduce specular reflections.

Accent Lighting. Certain parts of the worship area become central at different times in the service, and when so, they should be highlighted. Those areas may be where the worship leader, the choir, the Torah, the communion table, the stations of the cross, the Bible and the Ark are located. Controlled beams of light should be used that will properly render the features in these areas and not create glare for those participating. This will mean careful choice of beam spread, intensity and location of spotlighting.

The location and orientation of the congregation should be kept in mind so that any directional lighting will not create glare. Particular attention to the shielding of directional lighting is needed for the church-in-the-round.

Controls. Lighting can help shift attention and emphasis during a service. By switching or dimming, the appropriate changes can be made in the brightness of different parts of the worship area. When dimming is used it produces these changes much more subtly than switching. This is particularly true of general lighting or lighting of large features.

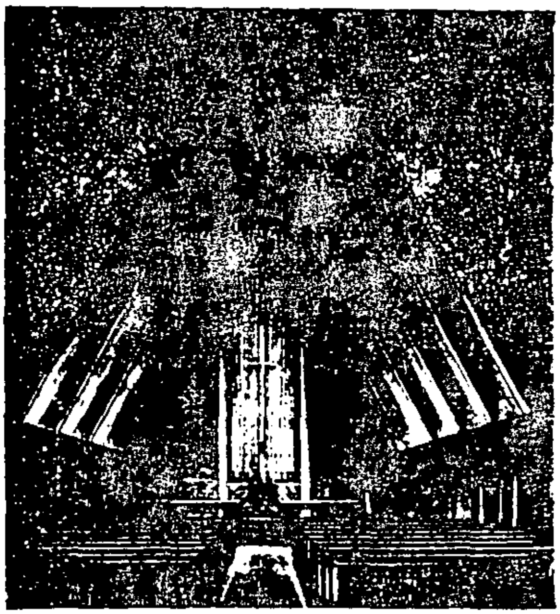


Fig. 7-2. Tent-type church. Exposed rafters conceal equipment which is aimed down and forward for lighting pews and chancel. Light from coves diffuses, balances and supplements the downlighting to create reverent mood desired during a service.

Church Architecture and Lighting

In the nave or main auditorium the quantity of light, and use of patterns of light and shade, vary widely with different architectural styles. See Figs. 7-2 through 7-5. The lighting designer should consult closely with the architect to understand the purpose behind the architectural style being used and to develop the lighting approach for it. They should cooperate through the following stages of translation: (1) the architect's concept of the space, (2) the brightness patterns desired and (3) the lighting equipment needed. For a further discussion of the relationship of light to architecture, see Section 1.

If lighting equipment is to be concealed in or behind a structural element, space is often limited. If care is not taken, the results may be uneven illumination and excessive brightness from spill light on exposed surfaces adjacent to the equipment. For example, incandescent lighting in a small cove or cornice should use a large number of small devices rather than a few high output units unless very compact, sophisticated optics are used; otherwise the adjacent ceiling or wall could be unevenly and excessively bright. When their color, dimming and starting capabilities are acceptable high intensity discharge and fluorescent sources should be considered. See Fig. 7-3 for one fluorescent application.

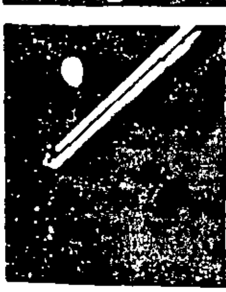


Fig. 7-3. As in Fig. 7-2, the ceiling design hides luminaires from the seated congregation. Incandescent and fluorescent sources (inset) provide varied lighting effects during a service. As the wiring is semi-exposec, lighting changes can be easily made in future years.

Fig. 7-4. Unsymmetrical design. Floodlights across court at [illegible] illuminate the ceiling of nave and part of chancel. [illegible]ner exterior floodlights, small in size, aim light down at a pool in the court so that reflected rays play faintly over the nave ceiling. Chancel and pew lighting come from behind the ceiling beams.

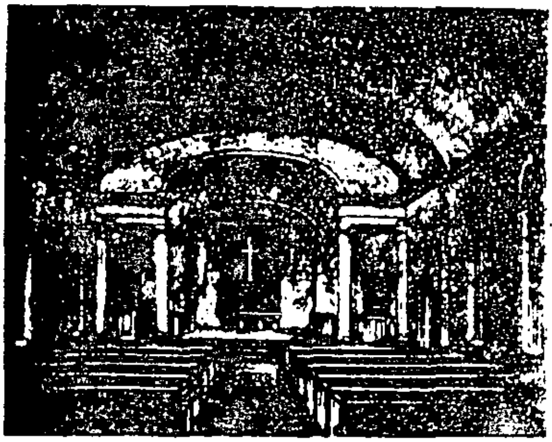


Fig. 7-5. Colonial church. The lighting designer worked with the interior designer to arrive at the feeling and the image required. Tradition and a worshipful atmosphere are preserved. After dark three systems of nave lighting provide effectively for evening worship. On rainy days, most or all of the evening lighting is used. On sunny mornings, interior lighting may be used to retain attention indoors.

Lanterns or other suspended decorative luminaires may be effectively used with many architectural styles. If they are to produce direct general illumination, however, care should be taked that there is sufficiently wide distribution of light for good coverage but without discomfort glare. This may be impossible if appearance dictates a very low suspension; in this case, other sources should be used to provide the illumination and the suspended equipment used as a luminous decorative element.

The reflectance of some large surfaces in the worship area—usually wood—may be very low. Such surfaces should be lighted to make them visible and to relieve an otherwise "too-dark" atmosphere, but not so much as to make them brighter than they would be expected to appear normally.

Art Windows

As in the architectural considerations for lighting, the lighting designer should work closely with the art window designer to determine the desired appearance of the lighted window. In all stained and art windows, the density, diffusion and refractive qualities of the glass or plastic will determine the light source luminance and size to be used.

It is not necessary to achieve a perfectly flat or uniform lighting effect. In fact, it is often not desirable. It is almost always necessary to set up a trial lighting system to see how the glass responds to different lighting. In such trials, a great deal of equipment may be necessary both to get sufficient light on the glass and to have enough different lighting approaches to examine.

Generally the lighting of art windows serves two main purposes: (1) for viewing from inside during nighttime services, and (2) for viewing from outside for passing traffic.

Viewing From Inside. The window can be lighted with outside floodlighting units if the glass has sufficient diffusion and refracting qualities (from irregularities on the surface of the glass and within the glass). If the glass is not extremely diffuse, the units should be located so that they are not seen through the glass and do not produce visual "hot spots." Clear stained glass needs a luminous background such as a closed light box around the outside of the window.

Viewing From Outside. The floodlighting approach above also can be used, but with equipment located inside. Spots of brightness may be more difficult to avoid, however, since lighting equipment is usually most conveniently located on the ceiling and the viewer is usually below the window. A larger number of lower intensity floodlights can make the spots of brightness less apparent. For clear stained glass a movable screen or drape can be used on the inside, lighted (either transilluminated or lighted from the window side) to form a luminous background for clear glass; it can be moved away for times of viewing from the inside.

HEALTH CARE FACILITIES[2]

The lighting of health care facilities presents many problems involving a wide range of seeing conditions. Optimum seeing conditions should be provided for doctors, nurses, technicians, maintenance workers and patients. For a better appreciation of the principles involved, a review should be made of Section 3, Light and Vision and Section 5, Color, of the 1981 Reference Volume; and Section 11, Interior Lighting Design, and Section 2, Lighting System Design Considerations, in this volume.

Many activities in health care facilities are not related directly to patient care but are necessary as supportive institutional functions. Areas such as business offices and laundries are not discussed in this section (See Sections 5 and 9). Some of the activities are identical or similar to ones in other institutions. These include libraries and kitchens. There will be some locations in which there is overlap in recommendations. For example, the patient room may be similar in its lighting requirements to the hotel room, *when it is used for minimal care patients*, yet the lighting must be considered differently in the patient room for the sick, the aged or the infirm.

Illuminance recommendations for health care facilities are given in Fig. 2-2, page 2-6. Where higher illuminances from localized lighting are required as in surgery, obstetrics, dentistry, emergency treatment and autopsies, it is desirable to insure comfortable lighting conditions by limiting luminance ratios between the task and other areas in the normal field of view; *i.e.*, the luminances between the task and adjacent surrounding should be limited to 1 to ⅓, between task and remote darker surfaces to 1 to ⅕ and to remote lighter sufaces to 1 to 5. To help achieve these reflectances, room surfaces should be within the following percentage ranges: ceilings, 80 to 90; walls, 40 to 60, furniture and equipment, 25 to 45, and floors, 20 to 40.

Types of Facilities

Health care facilities usually include acute general hospitals, chronic general and chronic specilized institutions for the care of the physically and mentally ill, and the extension of these services into facilities which offer more than the patient's own residence in professional care.

In describing good practice in lighting such institutions, the designer should take into account not only the immediate objectives, but also the services which might be required in the future. For example, a facility designed as an extended care unit in conjunction with an acute care hospital may find its beds recertified as acute care beds.

The Acute Care Hospital. While an acute care hospital might be faced with all of the diverse lighting design considerations in a complete multidisciplinary one, there may be some which will not. Obstetric and pediatric hospital sections are being allocated to certain hospitals and abandoned in others. This trend is increasing and results in greater specialization in each hospital. This will result in greater demand upon the support facilities.

Another trend is the expansion of outpatient services, particularly for those functions previously considered in-hospital ones. This does not mean complete abandonment of such functions for in-hospital patients, but it means a major reduction of these functions with a reduction of space allocation. Conversely, the planning of facilities for these and other activities such as laboratories will be partially moved to freestanding clinic buildings or office buildings designed for physicians and dentists. All of these require special illumination.

There are also constant transitions in the instrumentation of medical, surgical and dental practice. The computer and its application to radiology may entirely alter that specialty's requirements.

Where once there were large multibedded open wards now there are either single or double occupancy rooms. Where, in intensive care areas, there were multiple bed spaces individualized by curtains, there are now either semi-enclosures with glass observation windows or cubicles acting as open bed bays from a central hall or work space. By federal guideline these must have access to windows to afford the patient access to daylighted surroundings for orientation. The night and task illumination, however, presents the same problems for the designer.

The Chronic Hospital. The chronic long care facility is fortunately largely disappearing. The psychiatric institution is being replaced by mental health units often situated in general acute hospitals. The contagious disease hospitals, including the sanitaria for tuberculosis are also on the wane. This means provision for psychiatry and contagion in the acute care hospital.

The Extended Care Facility. The institutions which are proliferating are the extended care facilities: the nursing homes. Most of these are largely inhabited by an aging population. Many of these persons have vision difficulties: cataracts, yellowed lenses, aphakia or presbyopia. They, therefore, pose special problems for the lighting specialist.

Other Facilities. Free-standing office buildings, clinic buildings and medical teaching facilities also deserve consideration as they form an appreciable and growing part of health care. Every physician's office suite should contain lighting equipment that will provide that physician with the quantity, quality and directionality to permit performance of all functions with ease.

Lighting Objectives

In recent years there have been many changes in lighting concepts and in solutions to lighting problems. Basic research has increased our knowledge of visual requirements, industry has provided new equipment for producing light and modifying its quality, and there is a greater concern for energy conservation and management (see Section 4).

These years have also seen great growth in the medical techniques which have created new challenges for the lighting designer to provide the best lighting for the new visual tasks. For example, there is the problem of constant patient observation in intensive care units containing monitoring equipment, which must be constantly under meticulous visual and auditory surveillance, yet the illumination must be unobtrusive while being fully adequate so that the observer will not be visually fatigued.

A new appreciation of the sensibilities of the patient is another dimension to be considered by the designer. Although the lighting should serve the demands of the medical and nursing attendants, it also should be suited to the comfort needs of the patient. The patient must feel at ease in this environment. The illumination in multi-bed rooms should be designed to be unobtrusive to one roommate while remaining adequate for the other.

Lighting Design Considerations

A hospital is a very complex institution and has almost an infinite number of functions being carried out by persons who are normal or sick.

In designing the lighting system for a new or renovated space, consideration should be given to the needs of the occupant of that space—the visual tasks to be performed, the desired appearance of that space and energy and economic restraints. The recommendations that follow are for visual effectiveness and have been established based upon the state-of-the-art. It is recognized that there is still a need for further research in many areas.

The personnel working in the diagnostic and therapeutic facilities encompass a wide variety of ages, as do the patients, and, consequently the lighting should be planned to be adequate for all. The exact need for good color rendering appears to be obvious in most task-related areas of the hospital.

Task Lighting. In areas where visual tasks are performed, from surgical procedures to patient reading, the tasks are the focal point with less in the surround. Lighting for task performance depends upon (1) the importance and delicacy of the particular task from both the standpoint of time allowed and accuracy required without undue fatigue, (2) upon the person performing the task and (3) upon the task itself. See page 2-3.

Seeing is a dynamic activity and eyes do not remain fixed upon a single point, but move to all parts of the task and beyond it. For this reason, it has been suggested that where task levels are high, as in surgery, consideration be given to three zones of lighting—the highest in the operative field, a second of lower level surrounding the table, and a third peripheral one grazing the wall.

Hospital areas are designated for specific activities and, for these, some definitions of lighting requirements both quantitative and qualitative can be suggested.

Patients' Rooms—Adult. The patients' room lighting problems are to reconcile the need for lighting at various times by various people and usually to provide such lighting as simply and economically as possible. The patient, nurse, doctor and housekeeping personnel require different illuminance levels, in the same room, to accommodate their individual needs. This range of lighting is needed for a variety of nursing services; it should be provided in a way that is not objectionable to other patients in the same room and that caters to the lighting needs and whims of patients whose only field of view may be the ceiling.

Nursing Services. Since the primary purpose of the hospital is to restore the patient to health, lighting for nursing services and critical examinations is common to nearly all hospitals. The variation is in the provision for patient comfort during convalescence. This may vary greatly, depending upon the health and mobility of the patients, the quality of services supplied by the hospital, whether the hospital is public or private, and perhaps most important, on whether a room is for single or multiple occupancy.

Routine Nursing. For control of the general lighting level in patients' rooms to create a soft light for the patients' comfort, the use of variable-control dimmers located at the door of the patients' room is suggested. The nurse should never have to search for light to read charts and thermometers. Should more lighting be needed, the patient's reading light may be used. The luminance of luminaires and nearby surroundings should be less than 310 candelas per square meter (90 footlamberts) as usually seen from any normal reading or the patient's bed position.

Luminaires to meet these conditions should have low luminance. One or more such luminaires in a single or multiple occupancy room may be needed to provide general lighting 760 millimeters (30 inches) above the floor for normal use. To prevent excessive spottiness of general lighting, the installation should provide a lighting level ratio of not more than 1 to 5 on a horizontal plane 760 millimeters (30 inches) above the floor within a radial distance of 2.4 meters (8 feet) from the maximum level on that plane.

Observation of Patients. There should be provision for local low-level illumination of a color quality that will provide for proper diagnosis of the patients appearance. There should be lighting at each bed and its floor area so that the nurse may frequently observe the patient and equipment, such as drainage tubes and containers, during the night with minimum disturbance to patients. This light should be switched at the door, and may also be controlled by a dimmer. When the observation lighting must be left on all night, or when higher levels are needed, temporary screening from other patients may be necessary.

Night Lighting. Wall-bracket combination lighting units for patients' use frequently incorporate a night light with switch at the bed. A night light of this arrangement is desirable for the occasional use by patient or nurse. However, when it is left on continuously, the luminance produced in the surrounding field of darkness is sometimes a source of annoyance to patients wishing to sleep.

For continuous use, the night light recommended incorporates a low-brightness luminaire with louvered or refractive cover, flush wall type, installed so that its center is approximately 360 millimeters (14 inches) above the floor to direct a low illuminance along the floor where it is needed for walking or moving about in the room.

The important criterion for night lighting is limiting the source luminance. This luminance should not exceed 70 candelas per square meter (20 footlamberts) for continuous use, or 205 candelas per square meter (60 footlamberts) for a short time.

Critical Examination. The lighting for critical examination of the patient should be of a color quality that will not distort the color of skin or tissue and of a directional quality to permit careful inspection of surfaces and cavities. The examination lighting should, however, be confined to the bed area and should provide the recommended lighting in the center of a circular area 0.6 meter (2 feet) in diameter and at least half as much at the outer edge, when measured at a distance of not less than 0.6 meter (2 feet) from the lamp enclosure.

Patient Use. Patient use implies control by the patient for reading, visiting, self-care or viewing television. This control must be limited so as to prevent annoyance to other patients (see Fig. 7-6).

The reading light should provide light at the normal reading position, assumed to be 1.14 meters (3 feet 9 inches) above the floor. To allow the patient freedom to turn in bed without moving out of the reading light zone, the area of the

Fig. 7-6. Patient room lighting in a multiple occupancy accommodation. Note one patient reading while another sleeps under reduced illumination.

Fig. 7-7. Both under counter task lighting and ceiling general lighting are used to illuminate this nurses' station. The low luminance general lighting system was used so that patients in surrounding rooms would not see areas of high luminance at night.

reading plane lighted by an adjustable type of unit should be approximately 0.3 square meter (3 square feet), and for a nonadjustable unit the area should be approximately 0.7 square meter (6 square feet). To provide a reasonable degree of uniformity of light over these recommended areas, the lighting level at the outer edge of each area should not be less than two thirds of the lighting level at the center of the area. To provide comfortable lighting conditions for reading, the luminance in candela per square meter (footlamberts) on the ceiling, provided by some means of general lighting, should be at least equal to the illuminance in $1/\pi$ lux (footcandles) on the reading matter.

The luminance of the reading lamp and of any surface illuminated by it, as normally seen from any usual reading or the patient's bed position, should be less than 310 candelas per square meter (90 footlamberts). This condition is admittedly hard to secure and entails careful choice of luminaires and built-in limitations to its movements.

Housekeeping. A very important consideration is the lighting for housekeeping functions. Housekeepers need to see dust and dirt and to remove it. The housekeeper must be able to see beneath the furniture and to have oblique lighting over horizontal surfaces to observe dust.

Nursing Stations. In most hospitals each nursing unit is coordinated around a nursing station (see Fig. 7-7). At this point, charts are stored, read and written. Thus a desk or shelf is invariably provided, usually against some type of counter or below a hung cabinet. Lighting mounted beneath this counter should provide for the task lighting. It should be so arranged that it supplements the over-all illumination of the station.

Some of this lighting will be in continuous use, night and day. It is well to consider this in the lighting plan for the station. Usually, although by no means universally, when the nursing station is not visible from any of the patient accommodations, general ceiling sources remain lighted during the night hours.

The luminaires beneath counters, which are placed so that a person sitting at the desk is shielded from glare, should not be within the patient's direct view.

As the nurse must make frequent trips from the station to the patient facilities as well as to service locations, the corridors between should have transition lighting; a higher level during the day and switched or dimmed to a lower level at night. For safety, the illumination at the nursing stations is usually on an emergency auxiliary lighting system.

Critical Care Areas. The term critical care is replacing many of the former names such as intensive care. Critical care areas are especially designed for the very ill, and may be highly specialized or be quite flexible in their acceptance of patients. These accommodations have been designed for postsurgical patients, coronary disease, respiratory disease, burns, acute childhood and neonatal problems, isolation units, neurosurgical units, etc. Basically all of these require physical and instrument monitoring, and the capability for mounting emergency methods for resuscitation, hemorrhage and other situations which can be anticipated.

The illumination should enable the observer to note the prominence of veins on the neck and, if possible, the presence of yellow tints in the patients' eyes. Lighting should be avoided with a predominance of any color which may give the patients' complexion a false appearance. Thus, only improved color fluorescent lamps should be used. See Fig. 7-8.

While the demands for visual tasks in these units may be great, the psyche of the patient must also be carefully considered in planning. For example, the minimum requirements of construction of the Health Resources Administration (79-1450) require the provision of windows to enable *each* patient to be cognizant of the outdoor environment. Yet the provision of illumination by this means is not important.

The general lighting should be capable of dimming. It should be located so that neither the prone patient nor the one sitting with an elevated backrest will be subjected to glare. In addition to general lighting there should be lighting for examinations by the physician. Also, some type of surgical task light should be readily available for emergency procedures.

Most of these facilities contain a handwashing area.

Monitoring devices (see Fig 7-9) should be studied so that there will be adequate illumination for reading them. This also includes a review of their placement and whether or not they are internally illuminated.

Children's (Pediatric) Section. The child admitted to the hospital for the first time may feel dwarfed by its huge size and depressed by the concentration of suffering. Strange equipment may be frightening and alarm ill patients or intensify anxiety. For this reason the childrens' department should be provided with ample space for things for the children to do which will be diverting and educational. The lighting should be planned with this in mind, but should be similar to adult areas.

The use of daylight is essential. There should be a light and sunny atmosphere. Corridors should be pleasant with warm colors and surfaces, and diffused lighting used. However, spots of lighting patterns with interesting views shorten times of waiting and distances for travel down hospital corridors. Arrangements for vary-

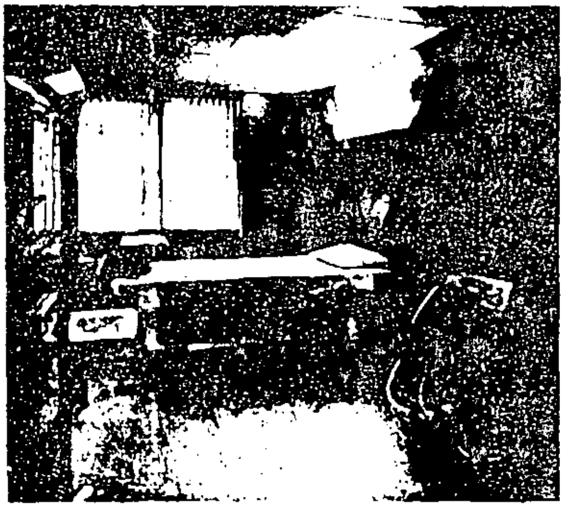


Fig. 7-8. Critical care room. Wall brackets contain two fluorescent lamps for indirect general lighting, one fluorescent lamp as a downlight for reading, and an incandescent night-light for surveillance from the nurses' station. Two 325-watt tungsten-halogen lamps in ellipsoidal reflectors are also provided for indirect examination light.

Fig. 7-9. Nursing station in critical care unit. Note the lighting beneath the counter and out of the patient's view. Also, monitoring devices are easily visible.

ing the lighting by multiple switching or dimming is often worthwhile.

Children play and sit on the floor, and often use it as a table. For this reason the lighting should be planned for reading, looking at pictures, drawing and other visual activity on the floor.

Nurseries. Nursery lighting should be designed so that infants in cribs and in incubators can be observed easily (see Fig. 7-10). General room illumination should be reducible for casual observation of the infants. Luminaires for general lighting should be of such a type or so installed that the luminance of any luminaires, ceiling or wall surface, as seen from working or normal bassinet position, would be less than 310 candelas per square meter (90 footlamberts).

There is often a need for higher level than that for the general lighting for careful observation, but it is not kept at this level too long in order to avoid retinal overexposure, for the infant does not have the ability to roll over or employ adult protective mechanisms. This must be taken into account when planning the illumination.

In order to recognize minor changes in the color of the skin and sclera, light sources should be specially chosen. It is preferable that these sources be in the higher kelvin ranges and have a relatively flat spectral power distribution.

There are special publications which should be referred to for information of the treatment of infantile jaundice with fluorescent light, and particularly to the precautions which are recommended for therapy,[3] and to the use of ultraviolet bactericidal barriers in pediatric sections.[4]

Mental Health Facilities. The facilities for mentally or emotionally disturbed patients are generally either of the open type in which the patients are unrestricted or of the closed variety where access is controlled. Either facility may house patients who are considered to be under maximum security. For this type of patient the lighting should be designed to be inaccessible to the patients to protect them from injuring themselves or others, and yet designed to avoid a prison-like environment. Lighting should be provided by non-adjustable recessed, ceiling luminaires, not only out of reach of the patient, but protected from access to thrown or other objects. These should be controlled by key switches preferably mounted in hallways outside of the detention area.

Most mental health facilities today handle other than just the severely disturbed patient. Regardless of the type of patient proper lighting depends on knowledgeable selection of patterns and areas of illumination most helpful and least disturbing. A generalized, basic guideline is that the lighting of these facilities should provide interest, warmth, definition of spaces, and illumination for tasks and safety.

Surgical Holding Areas. These areas (see Fig 7-11) are designed primarily for the retention of patients, nearly always supine on a wheeled stretcher (gurney) after they have had a sedative premedication. They are retained in this area out of the traffic stream for periods of from a few minutes to as much as 30 or more minutes.

The patient's eyes should not be exposed to a luminance of more than 100 candela per square meter (30 footlamberts). Most of the time a subdued slumber type of illumination is advisable, and designed to be out of the line of sight of the recumbent patient, but a higher level is needed for supervision and observation.

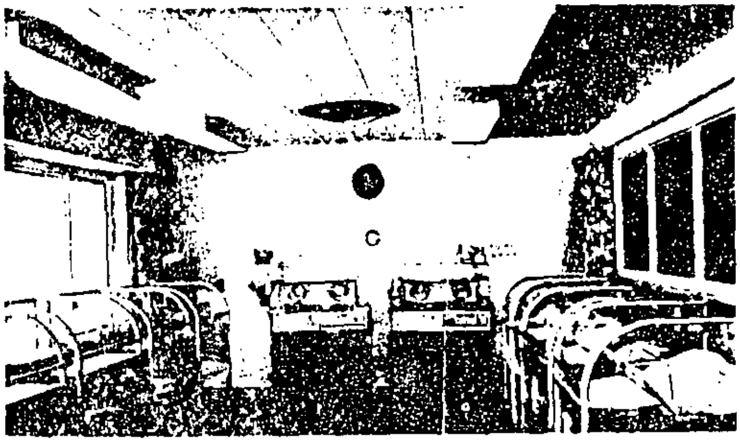


Fig. 7-10. Infant nursery. Windows at right permit relatives to view the babies.

Fig. 7-11. Surgical holding area where patients are kept before being taken into the operating room. Note each unit here is separately dimmable (surgical recovery similar).

The holding area is not usually designed for surgical induction; however, some hospitals will use it as such, and the planner must give such an arrangement additional consideration. Some type of lighting is useful which will facilitate the starting of intravenous lines, and other pre-anesthetic activities such as shaving, etc. This purpose might well be served by flexible wall hung bracket luminaires. One patient's preparation will not then disturb another waiting patient.

Surgical Induction Room. The patient is transferred here from a stretcher to an operating table, the anesthesia started, needles placed into the patient's veins, and the patient maneuvered into a variety of positions by manipulations of the operating table. Connections to a variety of monitoring devices are attached to the patient. The positioning of the patient might take a considerable time, but for this the patient is usually already partially anesthetized.

Ideally the patient is brought into this room under subdued light. The anesthesia can be induced after placement of a needle in the vein. For this, a task light of some type must be available. Once the patient is unconscious, the illumination can be increased to serve the needed staff tasks. The capability of again reducing the light in the room should be available while the anesthesiologist inserts a tube into the trachea (windpipe). This is accomplished utilizing a lighted laryngoscope. This device provides only a little light and thus a low ambient level is preferred.

Surgical Suite.

Operating Room. The lighting of the operating room is perhaps the most important in the hospital, not in the number of people to be satisfied but in the importance of the work done there. There should be no dense shadows to prevent the surgeon from seeing past his own hands and instruments, nor to prevent him from adequately seeing the patient's tissue, organs and blood exactly as they are. Sometimes he must see into deep body cavities, natural or artificial. To enhance physical comfort for the surgical team, heat reaching the back of the surgeon's head and neck from the overhead surgical light must be minimized. The surgeons must be able to work for hours, if necessary, without any discomfort and must be able to glance to and from their work without having to take time for their eyes to adjust to large differences in luminance. Even more important than the comfort of the surgeon and the surgical team is the safety of the patient. Body tissues exposed during an operation must not be excessively heated or dried.

Colors and reflectances of operating and delivery room interior surfaces, draping and gown fabrics should be somewhat as follows: ceilings, a nearwhite color with 90 per cent or more reflectance; walls, non-glossy surfaces of *any* light color with 60 per cent reflectance; floor reflectance preferably in the range of 20 to 30 per cent but may be as low as eight per cent depending on the limited selection of flooring materials available; and fabrics for gowns and surgical drapes should be colored, usually a dull shade of blue-green, turquoise or pearl gray with 30 per cent or less reflectance. Surgical instruments should be of a nonreflecting matte finish to minimize reflected glare in the area of the operative cavity. Any plastic materials used in draping should also be of matte finish.

Equipment such as that for x-ray, anesthesia and ventilation competes with the lighting system for the limited ceiling space available. Therefore, to achieve desired general levels, it is necessary to carefully plan the location and arrangement of the lighting system. Due to the variety of surgical procedures, it is highly desirable to allow for control of the general lighting system to suit visual requirements of the surgeon and staff. The general illumination in the operating room should provide a uniformly distributed level with provisions for reducing the level. Luminaires should be equipped with elements giving diffusion to the light and to prevent glare.

As levels of general lighting have become higher, luminance balance has assumed greater importance. To achieve this, luminance ratios (not illuminance ratios) between areas of appreciable size within view of the surgeon and his team, should be no greater than 1 to 3 between the wound and the surgical field and 5 to 1 between the surgical field and the instrument table. The surgical field to the room's lighter surfaces also should be no greater than 1 to 5. Visual comfort is probably greatest when there are no excessively bright reflections in the field.

When fluorescent luminaires are utilized in the surgical suite they should be designed to reduce electromagnetic interference to a level that will not interfere with operation of delicate electronic equipment in a life support system. This generally requires welded construction to minimize radio frequency leakage through openings, lenses with an electrically grounded conductive coating, and radio frequency filters to reduce the radio energy getting into the electric wiring.

The appearance of the patient should not change significantly when viewed under either the surgical light or the general room illumination. This is best achieved by matching the spectral power distributions to the two types of lights; however, usually it is only practical to match the color temperatures. For example, if the main surgical light has a color temperature of 4000 K, general room illumination should be provided by fluorescent lamps with similar color temperature—in this case, deluxe cool white fluorescent lamps. In all cases fluorescent lamps should be of the improved color type.

The surgical task lighting system (see Fig. 7-12) should be capable of providing a minimum of 27 kilolux (2500 footcandles) directed to the center of a 500 square centimeters (78 square inches) (or larger) pattern on a surgical table with the top 990 millimeters (39 inches) from the floor. This pattern is defined as an area within which the illuminance tapers from center to edge so that at the edge it is no less than 20 per cent of that at the center. For ceiling-suspended surgical lighting systems, the illuminance and patterns are measured 1070 millimeters (42 inches) from the face of the lamp cover glass, if a cover glass is used, or the lower edge of the outer reflectors in a multiple reflector unit with individual covers over each lighting source.

The above is intended as minimum for general surgical procedures. In many specialized instances higher illuminances, various pattern sizes and shapes, and control of level are desirable. Variable pattern sizes are provided by moving the light closer to or further from the patient. Some lights provide, in addition, a focusing con-

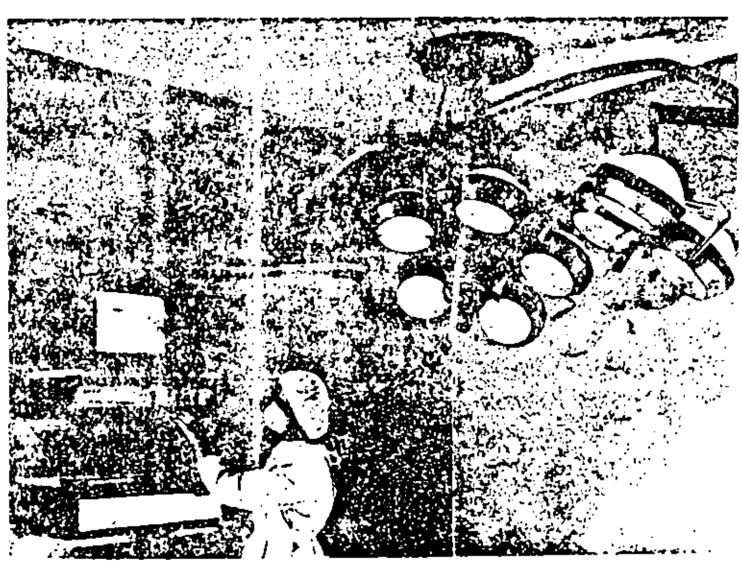


Fig. 7-12. Surgical light with a television camera fixed in the center of one of the directable units.

trol which varies pattern size. Users should determine the depth of field required for their work and evaluate the luminaires available that will give a useable pattern over the depth of field required. All illuminance measurements should be made with a color and cosine-corrected light sensing element that will indicate the average level over a 38-millimeter (1½-inch) diameter. To prevent obscuring shadows from the surgeon's hands, head, and instruments, the light should reach the operating area from wide angles. For test purposes, the light should provide a level of 10 per cent of the unshadowed level inside and at the bottom of a tube 50 millimeters (2 inches) in diameter and 76 millimeters (3 inches) long, finished flat black inside, from a distance of 1070 millimeters (42 inches) when the beam is obstructed by a disk 254 millimeters (10 inches) in diameter, 580 millimeters (23 inches) above the operating table, and normal to the axis of the tube. This means that, in the testing meter, a 38-millimeter (1½-inch) sensor is used. It is a very sensitive test which means that the black finish must have no specularity, and the disk and tube must be correctly positioned. See Fig. 7-13.

Protection should be given against a total lamp failure, for example, by multiple lamps in a single lighthead, or by multiple lightheads, etc.

The radiant heat produced by surgical lights must be minimized for protection of surgically exposed tissues and the comfort and efficiency of the surgeon and assistants. For most operations the radiant energy in the spectral region of 800 to 1000 nanometers should be kept at a minimum. This is the energy of infrared absorption by flesh and water and hence results in a noticeable heat to the surgeon, or more important may cause drying of exposed tissues. Current research suggests that in certain neurosurgical or intestinal procedures on delicate, thin, dry or abnormal tissue, the user of surgical lights should take care not to exceed approximately 25,000 microwatts per square centimeter at maximum intensity in the light pattern. The manufacturer of surgical lighting shou... provide information on conditions under which his equipment can exceed these energy levels. An irradiance factor ($\mu W\ cm^{-2}$) per lux or footcandle would be helpful to determine the total irradiance of the lighting system.

For general surgery, the light from the lumi-[illegible]re should have a color within an area de-[illegible]ned by a five-sided polygon on the CIE chromaticity diagram (see Section 5 of the 1981 Reference Volume). The range of CIE coefficients is appropriately defined by the following x and y values:

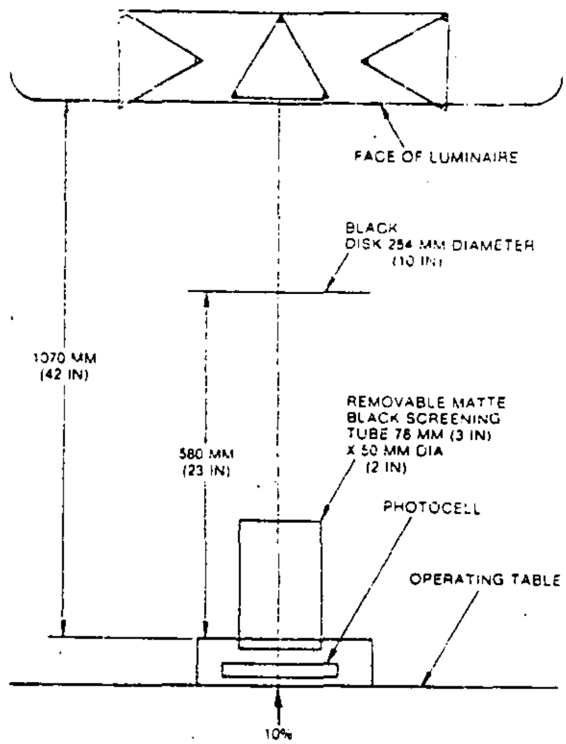


Fig. 7-13. The test for shadow reduction. Distance and sizes of objects are as shown above. Ten per cent of the incident light should be seen at the bottom of the tube.

x	y
.310	.310
.400	.375
.400	.415
.375	.415
.310	.365

When plotted, the above points will result in correlated color temperatures between 3500 K and 6700 K. Spectral power distribution should be so designed as to provide color rendering satisfaction to the surgeon.[5]

Secondary only to its unusual optical quality is the flexibility designed into the surgical lighting unit. This may be mechanical on units suspended from the ceiling or by electrical switching arrangements in stationary units in the ceiling. Directionality is sometimes achieved by permitting the scrubbed surgeon to adjust a sterile handle, but the asepsis of this technique has been questioned. If handles are used, they should be demountable for sterilization, smooth to avoid glove puncture, and have a guard to prevent contact with a nonsterile area.

The requirements for directional flexibility in the main task lighting system will vary with the surgeons and the type of surgical procedures to be performed and limited by the "five-foot" rule" imposed for the use of flammable anesthetic agents. (NFPA-56A-1973 permits breaching the "five-foot" rule when operating rooms are clearly defined to avoid all use and presence of flammable agents.) The requirements for orthopedic operations differ greatly from those for cardiovascular and neurosurgical which, in turn, differ from those of the gynecologist. Thus the selection of the lighting system cannot be simply defined and the prospective purchaser must be aware of the limitations of all of the equipment.

Two-team surgery is now frequently practiced for many procedures. For example, one team may remove a vein from the thigh while another implants it into the heart. Additional lightheads or satellite units may extend from the primary luminaire mounting. On the other hand the use of two or more luminaires on one surgical field is to be employed only with care. See above.

Supplemental surgical task illumination is of two main types: those with a beam encompassing the entire field and those which operate by directing light through a glass or plastic fiberoptic bundle. The former, if they are to be used in an operating room where flammable anesthetic gases are employed, must be explosion proof or limited in movement to 1.5 meters (5 feet) above the floor. The fiberoptic light source and all of its electrical system must be in accordance with NFPA 56A.[6] In addition supplemental headlamps, self-lamped, often project an image of a tungsten filament, without filtering, and should be tested for illumination safety in a manner similar to fiberoptic headlamps (see below). These units could produce six times the irradiance of surgical lighting for equal illuminance.

Freestanding lights must conform with safety from tipping, as prescribed in NFPA 56A, and must have a reasonable 'memory' for retaining their position. No part of the portable wide-beam lamp housing should project below 1.5 meters (5 feet) from the floor. The entire unit must be grounded through a third wire in the flexible cable.

A fiberoptic unit, for use in a sterile field must be capable of sterilization or be encased in a waterproof and sterile static-free barrier. At the exit face of the fiberoptic device the irradiance should be no more than 25,000 microwatts per square centimeter.

Low voltage lighting equipment (less than 8 volts) may be used in accordance with NFPA 56A, if supplied by an individual isolating transformer "connected by an anesthetizing location cord and plug" or from dry cell batteries or transformer above the "five-foot" level. Isolating transformers should have a grounded case and core.

The anesthesiologist usually sits behind a tent of surgical drapes which prevent an accurate view of the patient's face color. Most of the monitoring instruments and dials which must constantly be observed are hard to see. Their cover glasses usually are very reflective and may well produce veiling reflections or reflected glare. Furthermore, the anesthesiologist should be shielded from the operating task light and shielding of the general illumination system and other special lighting considerations also may be needed.

Scrub Room. Scrub areas and corridors adjacent to the operating room are areas where personnel can accommodate their eyes to the illuminances of the operating room. While scrubbing before an operation, the surgical team should be exposed to light of the same level that they will encounter in the operating room. This will not only insure a good job of scrubbing, but will allow them to enter the operating room fully light adapted. These illuminance levels will also promote a cleaner scrub area and consequently more aseptic conditions. This same reasoning holds for corridors leading to the operating room. These are the areas where the surgical team adapts to the operating room environment.

Not all operations are performed under higher illuminance levels, and in fact, many are carried out at very low ambient levels. For those the light should be reduced, by switching or dimming, to a low level, just sufficient to observe the clock and the technique of scrubbing. Adaptation from low to higher illuminances is very rapid, but dark adaptation is very slow so that the level should be kept low for endoscopic surgery.

Special Lighting. The lighting requirements for photography and television in the operating room have been given relatively little consideration.

Microsurgery may be televised and special cameras are built to be adapted to operating microscopes. When these are used, special attention should be directed toward heat production on the tissues being observed as associated beam splitting devices require increased light.

Surgical lights are available with color television cameras built into the lights (see Fig. 7-12). This automatically insures that the camera is aimed at the surgical site. These cameras are usually equipped with motorized zoom, focus and iris adjustments for the lens. Thus, all camera control can be done remotely. The color balance of the camera must be adjusted optically or electronically to match the spectral distribution of the light.

Specialized Operating Rooms.

Eye Surgery. Rooms for eye surgery contain some type of fixed pedestal or columns connected with an operating microscope. This equipment may contain its own luminaires and frequently beam splitting devices to permit viewing by more than one person. There may be camera or television equipment also attached. A separate ruby laser may also be present as well as an electromagnet for removing ferrous foreign material from the eye.

The general room illumination is planned to give the same level as in the general operating room. The surgeon will, at times however, require less general illumination and may prefer almost complete darkness. Therefore, a method for reducing the illumination becomes mandatory in the eye room. Separate lighting may be necessary for the anesthesiologist so that he may observe equipment.

Ear, Nose and Throat Surgery. The requirements for this specialty are identical with that of the eye surgery. Microscopic surgery is used for operations on the inner ear.

Neurosurgery. In general this operating room is no different in its visual requirements than the general surgery operating room. Some neurosurgeons prefer to use headlamps, frequently fiberoptic ones. Recently surgical microscopes have been employed in a darkened room. These operating microscopes contain their own illumination and may be ceiling or wall mounted. Neurosurgeons often require a horizontal rather than a vertical beam of light. Thus, luminaires that can be brought as low as the codes allow are needed.

Orthopedic Surgery. In general the orthopedic operating room visual needs are no different than those of the general surgery but better facilities for x-ray equipment may be necessary. The type of x-ray equipment and mounting needs to be coordinated with the lighting systems. Particular attention should be paid to flexibility of the luminaires, for orthopedic surgery frequently requires unique positioning on the side of the operating table for low level lighting of the patient's hip. Fluoroscopy with image intensification and television screening will permit the use of a room which is not darkened. Extra negatoscopes are required.

The orthopedic surgeon also uses the surgical microscope.

For implantable joint replacement, the orthopedist sometimes employs laminar airflow chambers, and surgical luminaires pose a problem both from their disturbance of the laminarity of the airflow and from the convection currents they cause. These situations are very difficult to avoid as the necessity for illumination of the surgical task is paramount.

Postanesthetic Recovery Room. This is an area of meticulous monitoring and equipment observation, plus the capability for carrying out certain emergency procedures. Color recognition for changes in the patient's skin must be facilitated. The lighting should be variable so that presentations on the face of oscilloscopes (electroencephelographic and electrocardiographic) can be recognized.

Cystoscopy Room. Cystoscopy is normally carried out in a dark room. The cystoscope is however introduced in a lighted room. For female procedures a gynecologic examining light should be provided. If flammable anesthetics are *not* used in the area (which is usual) the light should be available at the level just above the sitting urologist's shoulder.

The darkening of the room should be possible by switching or dimming. The low level should be adequate for the anesthesiologist to see his equipment and to recognize the patient's color. A surgical lighting capability should be available for the performance of some operative procedures. It should be centered in such a way as to illuminate the lower end of the cystoscopic table.

Obstetric Delivery Suite.

Labor Rooms. Monitoring apparatus is often applied to the patient to observe uterine contractions and the heart tones and responses of the unborn child. This is usually recorded on paper and must be observed by attendants. Examinations performed in this room are usually manual and will not require visual control. However, observation of the patient includes blood pressure measurement and observation of the patient's general status; therefore, good color rendering lighting is preferred so that any cyanosis (blueness) will be obvious.

Delivery Area. The area for delivery scrub should be identical in its illumination with the surgical scrub area. The general illumination of the delivery room should be achieved by recessed luminaires providing light through... the same as in the operating room.

The task light should be capable of focusing and produce a level of 27 kilolux (2500 footcandles) at its center. Ideally it should be capable of being centered over the shoulder of a sitting obstetrician. Mounting should be in accordance with NFPA 56A. Explosion-proof portable units are also available. In some institutions the anesthesiologist will ban the use of flammable anesthetic agents in the delivery suite and remove the explosion hazard.

A special lighting plan should exist for the area in which the newborn infant is resuscitated. The lighting should have good color rendering capability, particularly for cyanosis and jaundice.

General Radiographic/Fluoroscopic Room. In the modern unit, most fluoroscopy is now performed with image intensification with visualization on a television screen; therefore, complete darkness is no longer imperative. Overall illumination is necessary for cleanup. The general lighting should have a dimming capability as different radiologists prefer working under different levels of ambient lighting. Often the overhead lighting is extinguished by the foot switch on the radiographic unit so that the ambient light will go out when the fluoroscopy is in progress. Light localizing devices are sometimes used and are assisted by low general lighting.

The competition for ceiling space is great in these rooms and the placement of ceiling luminaires is very important.

Laboratories.

Specimen Collecting (Venipuncture) and Donor Areas for the Blood Bank. Lighting should be provided for the site of the venipuncture, at the height of the arm of an armchair. Veins are often best seen in other than flat light; therefore, ceiling luminaires or task lights should be placed to provide oblique illumination. The walls in this area should be of pastel shades of low reflectance for donor comfort and reassurance.

Tissue Laboratory. Lighting in a tissue laboratory should have an excellent color rendering quality. Of particular interest is that there are usually two counter heights [760 and 910 millimeters (30 and 36 inches)] involved, one to be used sitting, and another at standing bench level. The same lighting arrangements are valuable in the room devoted to the preparation of cytology specimens. Backgrounds for microscope viewing are best dark in color and of very low reflectance to avoid glare.

Microscopic Reading Room. The pathologists spend a considerable portion of their day in reading microscopic material. For this purpose the tables upon which the microscopes are placed are usually at a 810-millimeter (32-inch) level from the floor and the tabletop is of low reflectance often in a mahogany or walnut finish. Room lighting should be adjustable for long-time viewing.

Central Sterile Supply. The inspection area of the central processing department should have general lighting and in special areas where delicate instruments and other equipment are inspected, illumination should be increased.

Dental Suites. In the dental operatory the luminance differences between the patient's

Fig. 7-14. Current Recommended Illuminances in Lux and Footcandles, on Tasks, for Emergency or Continuity Service (for Use When Normal Service is Interrupted)*

	Lux	Footcandles
Exit Ways		
Corridors leading to exits, at floor	30	3
Stairways leading to exits, at floor	30	3
Exit direction signs, on face of luminaire	50	5
Exit doorway, at floor	30	3
Operating Room, surgical table	27000	2500
Operating Room, emergency table	22000	2000
Delivery Room, obstetrical table	27000	2500
Recovery Rooms for operating rooms and obstetrical suites	100	10
Nurseries, infant, 760 millimeters (30 inches) above floor	100	10
Nurseries, premature, 760 millimeters (30 inches) above floor	100	10
Nurseries, pediatric, 760 millimeters (30 inches) above floor	20	2
Medication Preparation Area, local	300	30
Nurses' Station	50	5
Pharmacy	50	5
Blood Bank Area	50	5
Central Suction Pump Area	50	5
Telephone Switchboard, face of board	50	5
Central Sterile Supply, issuing area	50	5
Psychiatric Patient Bed Area	20	2
Main Electrical Control Center	50	5
Hospital Elevator—Exit Lighting	50	5
Stairwells	50	5
Life Safety Areas (Life Support Areas)	50	5
Cardiac Catheter Laboratories	100	10
Coronary Care Units	300	30
Dialysis Units	200	20
Emergency Room Treatment Areas	500	50
Intensive Care Units	300	30

* These are minimum lighting levels. It is particularly desirable that they be increased to as near the levels normally provided in these areas as the available capacity of the emergency electrical supply will permit.

mouth and face, patient's bib, the instrument tray and the surrounding areas should be no greater than 3 to 1.

Lighting should be provided at the level of the patient's face and the instrument tray. Lighting inside the mouth, or oral cavity, should be supplied from a luminaire easily adjustable to exclude high luminance in the patient's eyes and at the same time provide such lighting as is needed by the dentist to see fine details over long periods of time. This light should have color characteristics and level suitable for the dentist to judge the matching of colors of teeth and fillings, and occlusions of dentures in any place within the mouth. The dentist must be able to judge accurately the depth of drillings and the preparation for retention of fillings.

A luminaire for producing such a penetrating light, relatively free of shadows at the oral cavity, must produce a convergent beam, and at a distance of about 1 meter (3 or 4 feet) should be capable of lighting a semicircular area with a cut-off to exclude the bright light from the patient's eyes.

Prosthetic work in the laboratory requires speed, accuracy and close inspection. Therefore, a general level should be provided, with a supplementary lighting at the workbench, and at one or more points depending on the number of people using the laboratory at any one time.

Examination and Treatment Rooms. For examination and nonsurgical treatment there should be general lighting with supplementary lighting on the table. Also, there should be a special lamp for vaginal inspection.

Emergency Outpatient. The emergency outpatient suite should be generally self-sufficient to handle most cases without resorting to the rest of the hospital. Fixed ceiling-mounted directional luminaires or portable lights that provide lighting at the center of the operating area, with a lower level of general illumination are usually adequate for examination and emergency surgery.

Autopsy Room and Morgue. Good lighting is imperative in the dissecting room. A surgical type of dissection must be performed, yet it is done in the open rather than in the restricted cavity as in the surgical exposure. Therefore, the highest levels of surgical illumination are not needed to overcome the losses in deep cavity lighting. While some of the dissection may be meticulous and tissue planes must be visualized, the meticulous placement of sutures and the meticulous placement of instruments to control bleeding from fine blood vessels is not necessary. Therefore, some of the contouring so advantageous in living surgery can be sacrificed.

The task light of the autopsy room can therefore be a nonadjustable large unit with good color rendering lamps augmented by spotlights providing illumination at a level of the autopsy table 760 millimeters (30 inches) above the floor. Surgical lights are not necessary in this room. A single spot with filters to greatly reduce infrared radiation is valuable for the skull portion of the autopsy. Additional lighting for a scale placed over a counter is also valuable.

Pharmacy. The pharmacy should be well illuminated so that labels and fine print of precautionary literature supplied with the medications can be read. Illumination should be provided at the workbench level 910 millimeters (36 inches) from the floor.

Emergency Lighting. Emergency lighting is needed to perform two categories of essential tasks: the task of evacuation under adverse conditions and the task of providing life support services to the patient who cannot be evacuated. These two categories may be thought of as requiring two lighting systems. The first is emergency light of relatively low level to provide adequately for ambulatory mobility of patients and staff, and the second is of higher level and in most applications equal to that provided by the regular lighting system.

With the increased usage of electrical power in the operating room and critical care areas there is a need to increase the reliability of the electrical service to these areas. The regular room lighting becomes the emergency lighting whenever the power supply to the critical care areas switches from the normal source to the emergency source. See NFPA 76A for information relating to essential electrical systems for hospitals.

The remaining areas of the hospital should have low level emergency lighting to give the levels recommended in Fig. 7-14.

HOTEL/MOTEL AND FOOD SERVICE FACILITIES

In designing lighting for hotels, motels and food service facilities the first task is to identify those things which the staff and users want or need to see. Both groups must be able to see and comprehend their environment, to move about and work within it. In addition, they should find it *enjoyable* to do so. In such facilities as hotels and restaurants, the psychological effects of lighting are particularly important. The lighting design becomes a marketing tool by creating a successful, attractive, comfortable and functional environment, but only if it is integrated with the over-all architectural design concept. Lighting which is inappropriate in terms of quality or quantity can ruin an otherwise successful installation. Using an appropriate combination of daylight and electric lighting, the designer can develop and reinforce almost any visual mood and satisfy the visual needs in any space by day and by night. The lighting system must be compatible with acoustic, thermal, spatial and esthetic requirements and objectives for each area. A successful total environment requires a cooperative effort by the owner, facility manager, architect, engineers, interior designer and specialized consultants who work to integrate all concepts into a harmonious final solution. In hotels and restaurants, where architectural treatment is critical, the lighting designer must seek to strike an appropriate balance between efficiency and esthetics while considering energy management. See Section 4.

The following general objectives should be addressed:

1. Harmony with the architectural and decorative character of the facility.
2. Provision of high quality illumination for visual tasks.
3. Control of glare and luminance ratios.
4. Provision of adequate quantity of illumination.
5. Cost optimization to maximize net revenues, including first costs, operating costs and maintenance costs. See Section 3.

Consideration must be given to the desired appearance of each space and to the seeing tasks to be performed. The factors which affect task visibility and performance are discussed in Section 3 of the 1981 Reference Volume. All potential hazards such as changes in floor level should be well lighted for protection of guests and staff. If thought out in advance, such highlighting of potential hazards can be made part of any decorative scheme.

Hotel and restaurant spaces often have different visual tasks at different times. Function rooms, for example, are used for dining, meetings, lectures, conferences, classroom applications, exhibitions and entertainment. To accommodate all these different uses with a variety of illuminance levels and distribution patterns, several lighting systems may be required with multiple switching and dimming.

Design Considerations for Specific Locations

Specific visual tasks and design considerations for different areas are discussed below. Illuminance recommendations are given in Fig. 2-2 and Fig. 2-26. The levels selected from Fig. 2-2 should be based on an evaluation of the needs of the occupant and on management experience. The levels in Fig. 2-26 represent minimums for safety alone.

Exterior and Site. The total exterior lighting system should identify the facility and create a favorable visual impression for welcoming patrons (see Fig. 7-15). Building facade lighting and marquee, walkway and parking lighting should be coordinated with signage to produce an effective coherent over-all impression. Grounds of buildings should be lighted:

1. To merchandise the property (when warranted).

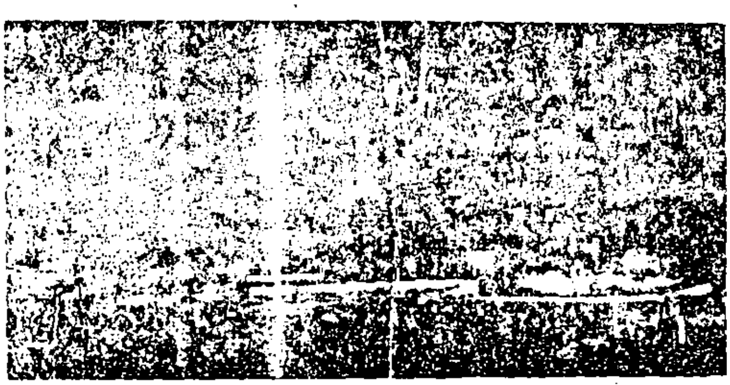


Fig. 7-15. Halos of clear decorative lamps operated at reduced voltage define the room towers of this hotel and, combined with the uplighted allee of trees framing the entrance drive and the line of glittering sources over the entry, creates a distinctive image for the facility.

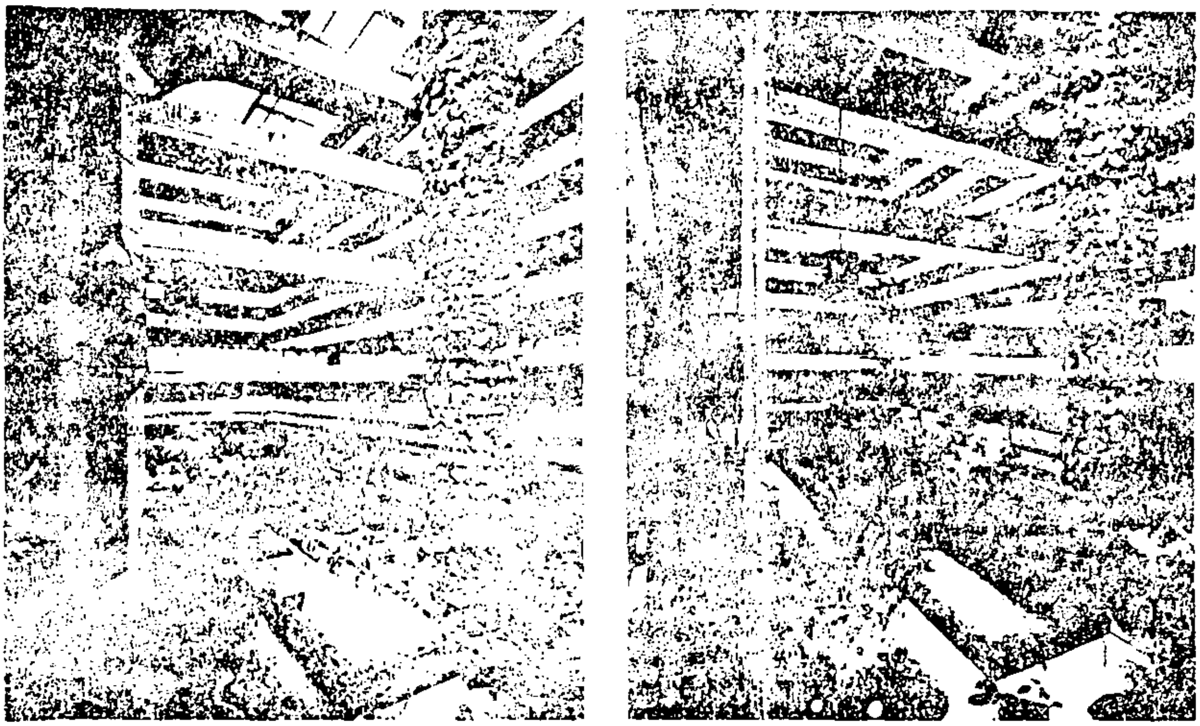


Fig. 7-16. By day, shafts of sunlight make this clear-glazed atrium dramatic. The high level daylighting is beneficial to the large trees. At night, the [illegible]ators become moving illuminated sculptures against a neutral sculptural background created by the gentle glow from flu[illegible]scent coves concealed in the handrails of the balconies and bridges. Uplighted trees and low mushroom lights reinforce the exterior imagery created by careful selection and detailing of materials. Pendant high intensity discharge downlights, required for tree maintenance, are only turned on late at night after the public has left the space.

2. To provide for the safety of guests and property, especially in parking areas and along pedestrian paths. It is also essential to make areas around steps, walkways and entries feel safe—which means the elimination of threatening shadows as much as it does the provision of an adequate level of light.
3. To eliminate areas which would otherwise be inviting to vandalism, or pose a problem in terms of security.
4. To make accessible to the handicapped all areas of barrier-free design.

All *entryways* shou[illegible] be well lighted to make them "landmarks" which may be used safely by guests. Lighting should be used to provide orientation and to reinforce intended traffic patterns. Marquees, portes-cochère, drive-ups, registration areas and unloading areas should be lighted in such a way as to distinguish them clearly from surrounding areas.

Lighting of *parking areas* should provide for visual security and physical safety. See Section 14, Roadway Lighting. Luminaire placement should be coordinated with buildings and plantings in such a way as to minimize shadows. Light sources should provide adequate color rendition for easy vehicle identification.

Public Spaces. The *lobby* typically establishes the main design themes for the facility, and houses a variety of functions which can be differentiated and enhanced with appropriate lighting techniques: elevator lobby, reception desk, lounge areas, bell captain's desk, etc. (see Fig. 7-16). The *entrance foyer* is a transition space between the outdoors and interior space, so foyer lighting should promote a sense of security and welcome while allowing adaptation between high and lower illuminances. In the *lounge area* both casual and prolonged reading tasks must be anticipated, though these can usually be accommodated with relatively low illuminances. A more residential treatment may be appropriate to create an inviting ambiance.

Many visual tasks are performe[illegible] at the registration desk. To make this area [illegible] to locate and to use (see Fig. 7-17), the desi[illegible] may choose a high general lighting level t[illegible] com-

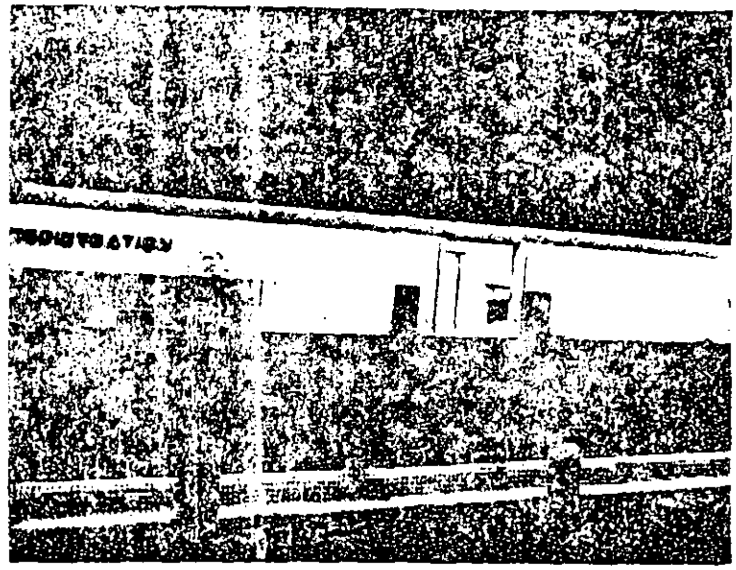


Fig. 7-17. At the registration desk concealed fluorescent sources are used to provide task light on the desk. The back wall is lighted indirectly to create a glowing band which draws the visitor to the desk. This is reinforced by the concealed fluorescent cove at the lower edge of the desk which washes the carpet. Low-brightness downlights put an even wash of low-level illumination on the richly colored carpet.

modate all tasks; however, a lower over-all level with a system of local task lighting should be considered. Care should be taken that the lighting be compatible with surrounding areas. (See Section 5 for the lighting of office areas).

Areas for storage of luggage, etc., should be lighted so that labels and other means of identification can be quickly and easily seen. In enclosed storage areas the color rendering qualities of the light should be adequate to permit correct identification of stored items. If not separated from the main lobby, storage areas should have somewhat higher illuminance levels than the general ambient.

The lighting for *elevator lobby areas* should be designed to orient people to the elevators and should enable them to read directional signage and instructions and select the proper signal controls for elevator call. Internally illuminated signage and controls should be considered.

Corridor lighting should illuminate room numbers, room name identification signs, and the locks in doors. Lighting should be designed to make the passage through hallways, on stairs and to elevators a pleasant and safe experience. Lighting should make guests feel secure. It should call attention to circulation modes such as elevators and vending areas. The tunnel effect associated with long corridors should be minimized.

Suitable lighting for *shops, newsstands and other specialized services* may require quite sophisticated equipment and controls. Such lighting should be considered as part of the over-all interior lighting scheme (see Fig. 7-18), and should not be so bright as to dominate adjacent public areas unless that is the intent of the design team. It may be possible to use display lighting which remains on 24 hours a day to light adjacent corridors, eliminating corridor luminaires.

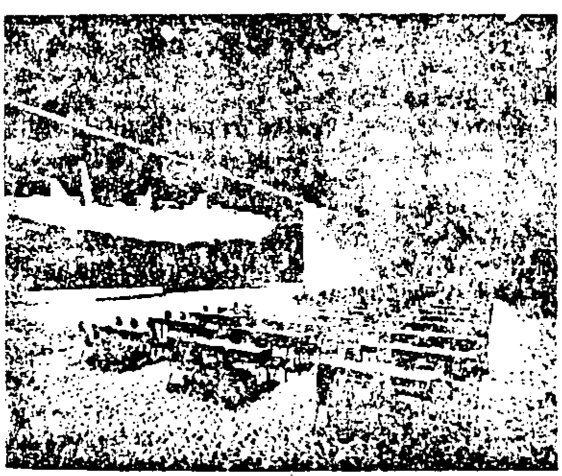
In *public lavatories*, visual tasks include grooming, which requires shadowless illumination on both sides of the face. Color rendition is important. Lounge areas in restrooms require only low levels of light.

In most cases lighting in *ballrooms, function and meeting rooms and conference areas* should be related to the over-all design themes for the hotel. See Fig. 7-19. These rooms are used for meetings, exhibits, dancing, dining and other functions, which makes it important to provide a variety of lighting levels and effects. If decorative luminaires such as chandeliers are used, at least one or two supplementary lighting systems will usually be required. Dimming and multiple switching should be provided, organized and clearly labeled for easy operation by banquet and function personnel. Lighting must be adequate for critical tasks such as reading and note-taking. Adjustable accent lighting should be provided at speaker's areas, head-table locations and likely locations for displays. Outlets for local lighting should be provided in exhibit areas. It should be remembered that highest lighting levels may be required for set-up and cleaning purposes.

Guest Rooms. The guest room is one of the major commodities of a motel or hotel. Since it is frequently used for small business conferences, flexibility needs to be a part of the lighting plan. General illumination from ceiling or wall-mounted luminaires provides a background for task lighting, aids in housekeeping and gives a feeling of cheer, as well as providing the needed flexibility for nonresidential uses. To establish an inviting, home-like atmosphere a variety of lighting equipment, some decorative in appearance, is usually needed. Visual tasks which need consideration in the guest room include: reading in chair or bed, desk work, television viewing, and grooming at the mirror in both the bathroom and at the dresser. See Section 10. The small entry foyer which is typically part of the guest room should have its own source of general illumination which reflects light from the ceiling or walls: Recessed incandescent luminaires are not usually suitable because the distribution of light is too narrow. Often the foyer lighting can be designed to illuminate closets, luggage storage and/or grooming areas as well (see Fig. 7-20). Switches with lighted handles are a convenience for guests in unfamiliar surroundings. Low wattage switch-controlled night lights should be installed in each guest room, usually in the bathroom so that guests do not leave other lights on all night long. Mirror lighting generally provides adequate illumination in bathrooms. If, however, there are separate compartments for toilet, tub or dressing, each space should have a separately switched source of general illumination adequate for safety when the door or curtain is closed.

Entertainment and Food Service Spaces. Entertainment and food service spaces within the hotel/motel and restaurant industry are complex and energy-intensive areas in which lighting plays a key role in establishing the mood or atmosphere. The success of lighting effects depends on the appropriateness of the illuminance level, color of light, luminaire candlepower distribution, type of luminaire and its locations in relation to the architecture, and source size. Well-shielded downlights, for example, can create a pleasing sparkle in reflective objects such as table settings, as well as an intimate feeling.

Fig. 7-18. In this commercial corridor, all "corridor lighting" is provided with spill light from displays.



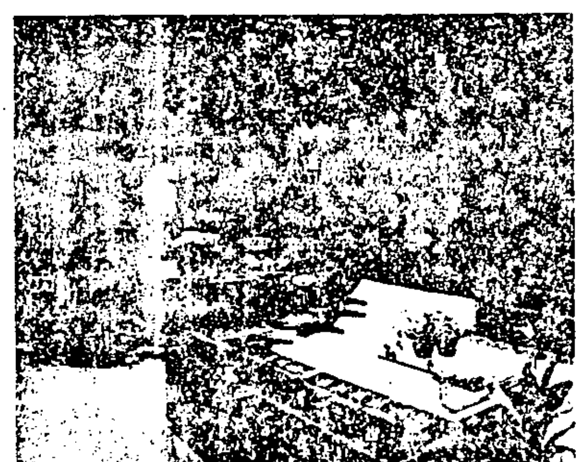


Fig. 7-19. (Left) Sections of tubing were flocked and hung from the structure over this ballroom to create a richly colored decorative ceiling in scale with the size of the room. Downlights, accent lights and air registers are concealed in and between the tubes. The large contemporary chandelier is made of planes of woven wire mesh, highlighted from lines of R-type lamps above. All circuits are dimmer controlled. (Right) Concealed in the decorative ceiling of this function room are several independently controlled lighting systems. Effects include wall washing, accent lighting for art and speakers, and neutral downlighting for projection and note-taking. The ceiling is fabricated of bronze acrylic cubes, the walls of which multiply the sparkle of incandescent sources.

On the other hand, indirect lighting or large-area diffuse sources such as fluorescent luminaires typically create a brighter looking space and call more attention to the whole room. The lighting of any feature in the dining area will need special attention. These can range from the highlighting of a picture or sculpture to a full luminous wall, with effects ranging from dramatic to open and friendly. The luminaires themselves may, if used decoratively, become distinctive features in their own right. Many suspended decorative luminaires, regardless of shape, size or style, have a general diffuse distribution that can produce dull, uniformly lighted spaces when used as the sole source of illumination. Unless low-wattage lamps are used, permitting these luminaires to act only as luminous ornaments, and supplementary lighting is provided, the luminance of such suspended luminaires can be uncomfortably high.

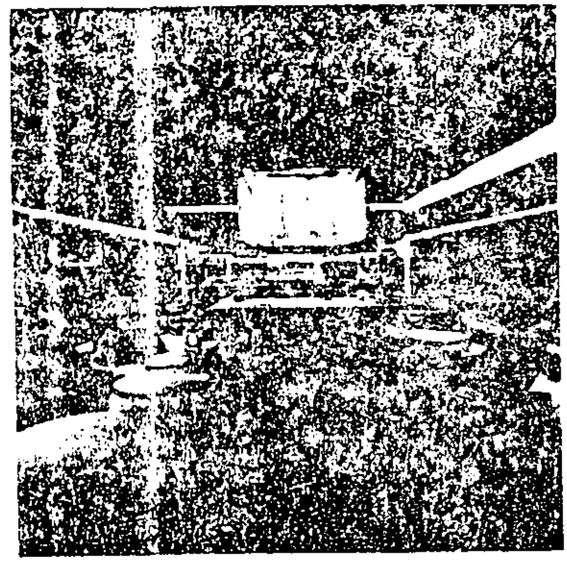


Fig. 7-21. In this bar, an indirect cove provides a gentle glow from the fabric ceiling. Clear decorative sources provide sparkle and light the walls. A central chandelier over the bar, consisting of downlighted plastic balls, makes the theme design statement for the room.

Fig. 7-20. A fluorescent luminaire concealed in the header of the closet door in this guest room foyer provides light for both closet and foyer (there is no wall above the luminaire). In the room beyond, a ceramic shade covers an inexpensive porcelain socket creating a decorative pattern of projected light and providing indirect ambient room illumination as well as reading light for the chair below.

In a multi-foodservice facility, switching, supplemental systems and/or the use of dimmers may be required to make the same space feel suitable for breakfast, lunch and dinner. Variation in illumination and level may be needed, both to change the mood for different times of the day, and to permit a higher level for clean-up than would be desirable for dining. Dimming control is preferable to switching since a smooth transition between levels is desirable.

The success of display lighting is best measured by how well it helps to sell merchandise. Food displays should be so lighted that attention is attracted to them and the details are clearly seen. Color rendition is even more important over fresh foods than it is over packaged foods. Heat from luminaires can be a major consideration over fresh, cooled or frozen foods. (See Section 8 for the lighting of merchandising areas.) A good rule is that the level used in food displays should be at least twice that in surrounding areas.

The mood established by lighting can vary from subdued and relaxing to bright and lively, depending on the type of facility and the intended clientele. Dining spaces are usually grouped into three categories: intimate, leisure and quick service.

The "intimate" type (see Fig. 7-21) consists of those areas where people congregate as much to visit, be entertained, and show off as to eat and drink. These include cocktail lounges, night clubs, and some dining rooms and restaurants. These spaces characteristically have a subdued atmosphere with low luminances throughout, accented with subtly lighted feature elements. Lighting must be well-controlled in terms of level and distribution.

The "leisure" type refers to most restaurants and many dining rooms—places where eating is the most important activity and time is often a factor. A restful, but interesting atmosphere is called for. Lighting should generally be unobtrusive except where decorative luminaires or highlighted features are used as part of the theme decor. Moderate illuminance levels are typical. Good control of glare is required.

The "quick-service" class includes lunchrooms, cafeterias, snack bars, coffee shops and franchise menu types, where the diner and management are both intent on fast service and quick customer turnover. Higher lighting levels and uniform distribution can be used to suggest a feeling of economy and efficiency.

Kitchen and Food Preparation Areas. Well-designed lighting helps to create a bright, hygienic atmosphere in a kitchen[7] and, by revealing dirt and the presence of debris, it can stimulate good housekeeping. Food preparation involves peeling, slicing, dicing and cutting operations, both by machine and by hand. These are obviously hazardous operations and lighting for safety must be a strong consideration. See Section 2. Good quality lighting can reduce accidents, reveal spills which make floors slippery, and emphasize hazardous areas. In kitchen and associated support areas there is a need to eliminate shadows and to provide illumination on both vertical and horizontal surfaces. While kitchens contain difficult and demanding tasks which may require relatively high light levels, it is important that luminaires be arranged and shielded so as not to create glare or "blasts of light" into adjacent intimate dining areas when kitchen doors are opened. Color rendering is important in food preparation and inspection areas.

Visibility is reduced by great variations in luminance in the task surround, and direct and reflected glare can be significant obstacles to employee comfort, productivity and safety. Therefore, exposed lamps in direct luminaires should not be used. Although glare can be controlled in direct luminaires by effective shielding of the lamp, indirect or semi-indirect lighting is preferable because it turns the entire ceiling into a large, low-brightness area source (see Fig. 7-22). Light colored walls will further diffuse the general lighting, reducing shadows. Because vertical surfaces of equipment and furnishings typically occupy a significant portion of the visual field, expecially in kitchens, light finishes are recommended for these surfaces. Horizontal surfaces such as table tops in restaurants and equipment tops in kitchens are very important because they serve as backgrounds for critical tasks. Whenever possible, matte finishes are preferable because they minimize reflected glare. Reflected glare can be exceedingly objectionable, and can produce discomfort and fatigue. Stainless steel kitchen equipment is a common offender in this respect. Matte or brushed finishes combined with careful placement of luminaires and good glare control can minimize these problems. The same principles apply elsewhere. Lighting near specular surfaces such as mirrored ceilings or glazed walls must be very carefully worked out if one is to avoid unintended reflections of sources.

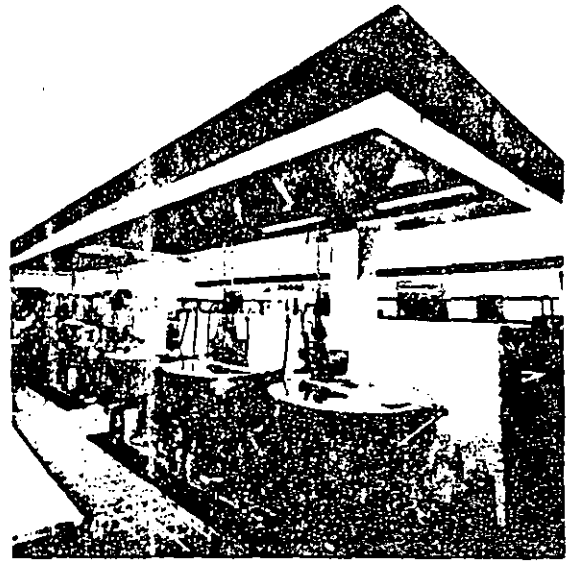


Fig. 7-22. Indirect fluorescent valances are arranged around the venting hoods to define the work islands in this commercial kitchen. High reflectance surfaces are used throughout. Sources are shielded from adjacent dining spaces.

All luminaires in kitchens should be so located and designed so that those entering or leaving the kitchen area will not see bare lamps or high brightness. This is particularly important when the adjacent dining area has lower light levels. Even the relatively low luminance of unshielded fluorescent lamps can produce a period of reduced visibility during adaptation. All luminaires should be designed for ease of cleaning and relamping, and should have high reflectance permanent surfaces. In areas such as bakeries and dishwashing areas which have inherent dust or moisture conditions, the use of enclosed dust-proof or vapor-tight luminaires is recommended. Where open type fluorescent luminaires are located directly over food storage, preparation, service or display areas, plastic sleeve protectors should be used to prevent glass and phosphor from falling into the food in case of breakage.

In *receiving and storage areas* lights should be installed in the aisles rather than near the walls, so that stacked shelves do not block the illumination.

Support Areas. Support areas include such spaces as key shops, plan rooms, paint shops, etc. The visual tasks in such areas are often demanding and sometimes dangerous. Where flammable materials are stored or used, explosion-proof luminaires should be used. Task lighting using localized luminaires should be considered as an alternative to general higher level lighting.

Refuse Areas. The maintenance of safe and sanitary conditions in refuse areas is extremely important. Illumination should permit all hazardous or unsanitary conditions such as slippery spots, dirty waste, and evidence of insects, rodents, or mold to be seen. Corners and other out-of-the-way places should be well lighted.

Merchandising Areas, Offices, Laundry and Valet Areas, Indoor and Outdoor Recreation Areas. For lighting recommendations for these spaces see Sections 8, 5, 9 and 13 respectively.

Selection of Architectural Finishes. The factors which influence how well people perceive a task or space are discussed in detail in Section 2. They include luminance and its distribution, contrast, size, color, form, texture, familiarity, and length of time for viewing. Some specific recommendations can be made here with regard to hotel, motel and food service facilities.

Because areas in these facilities typically include adjacent areas with very different lighting levels, adaptation can be a problem for both staff and patrons. The designer must, therefore, provide appropriately lighted transition spaces. For example, a patron who has been registering at the front desk usually adapts to a relatively high luminance. Turning back into the lobby, the person may be momentarily unable to distinguish the location of steps or to recognize faces if the difference in luminance is too great. As the potential hazard or task difficulty increases it becomes more and more important to keep luminance ratios within recommended limits.

Room surfaces exert an important influence on luminance ratios between luminaires and their surroundings, and between tasks and their backgrounds. On large surfaces the use of matte finishes with recommended reflectance, helps to prevent excessive luminance ratios and undesirable specular reflections. Light-colored matte surfaces serve as effective secondary light sources which can materially reduce shadows. Soft shadows generally accentuate the form and depth of objects, supporting rather than hindering the process of perception.

Selection of Light Sources. Both daylight and electric lighting systems are used in hotels, motels and restaurants. Each generic source has its own characteristics. The systems should be designed to complement each other.

Most hotel and food service spaces should have windows. The opportunity to look through windows can be psychologically satisfying and permits relaxation when the eyes can shift focus occasionally from nearby to distant objects. However, windows can bring large areas of high luminance into the field of view, causing discomfort, thus good control of glare is important. The designer should not locate very brightly lighted areas next to dimly lighted interior spaces without allowing adequate transition spaces between. Proper daylight control (see Section 7 of the 1981 Reference Volume) is preferable to increasing the level of electric lighting.

Enhancement of public spaces and provision of proper task lighting are the two principal considerations in the design of lighting systems. There are three basic electric light sources in use today: incandescent, fluorescent and high intensity discharge (HID). Source selection depends on the particular requirements of each space, the economics, and the personal preference of the system designer and the facility operator. Generally, for public spaces the use of incandescent filament or one of the improved-color white fluorescent lamps is recommended.

In these facilities, the chief advantages of incandescent lighting are low initial cost, good color-rendering properties, and the excellent optical control inherent in such a small source. Because they are so easily controlled by dimmers, it is recommended that all incandescent luminaires in public areas be dimmer-controlled. Drawbacks of incandescent lamps are their relatively short life and low efficacy.

In support areas, where optical control and good color rendition may be less critical, the designer should consider the more efficient and long-lived fluorescent and HID sources. When using mercury, metal halide, high or low pressure sodium, or fluorescent sources, the designer should avoid three common pitfalls: ballast hum, low ambient temperature effects and inadequacy of color rendition. Ballasts can generally be mounted remotely from critical areas if ballast noise will be objectionable. When using fluorescent sources outdoors and in unheated spaces such as garages, only lamps and ballasts rated for low ambient temperature should be used. The designer should personally verify the appropriateness of color temperature and color rendition of each source selected.

Color of Surfaces and Light. In any hotel or restaurant space, the color of the environment will affect both patrons and workers—positively or negatively, consciously or unconsciously, according to the harmony of the scheme and the expectations of the viewers. While no hard and fast rules exist, it is generally accepted that strong colors are relatively stimulating while less intense colors are more restful and tend to expand the perceived size of a space. Whatever the colors selected, it is imperative that they be evaluated under the light source or mix of sources which will be used in the finished space, since light sources vary significantly in their color-rendering qualities. See Section 5 of the 1981 Reference Volume. See also page 2-31. The use of colored light is often overlooked as a design tool. Strong colors of light can create interesting effects when surfaces are illuminated for decorative purposes, but should not be used to light food or people because of the inherent and undesirable color distortion which will result.

Emergency Lighting. In public facilities such as hotels, motels and food service establishments the designer must provide lighting for public safety during emergency conditions, without either disorienting or panicking the users. Emergency systems for public facilities should be designed to provide short-duration lighting for evacuation and safety of guests and staff. See Section 2. Longer duration emergency lighting may be required at hazardous locations, for security purposes, and to assure continuity of critical operations. A common mistake to avoid is the installation of permanently-on emergency luminaires in restaurants. Since these luminaires cannot be switched off or dimmed at night they are sure to disrupt an intimate dining atmosphere. While it may be possible in a small facility to meet emergency lighting needs with independent battery-powered units, a central emergency generator or battery installation may be required in a major hotel or motel. Options, of which the designer should be aware, include double-circuiting of luminaires and the use of transfer relays to provide power to emergency-only sources during power failures.

Safety. Safe working and living conditions in hotels, motels and food service facilities are dependent on good lighting. See Section 2.

LIBRARIES[8]

Libraries have a variety of seeing tasks. Among them are: (1) reading matter, (2) browsing or searching through book stacks or storage areas, (3) studying at a carrel or other work surface, (4) viewing microform or computer retrieval systems, (5) meeting or conferring, (6) general office and clerical work and (7) repair and inspection work. These tasks along with general illumination for circulation spaces or audio booths, special lighting for audio-visual areas and accent lights for exhibits and displays provide a variety of lighting problems.

Seeing Tasks in Libraries

Reading is by far the visual task performed most often in a library. Reading tasks vary from children's books printed in 10 to 14 point type on matte paper, to newspapers printed in 7 point type on low contrast off-white pulp paper, to law books with long paragraphs in condensed type, to rare books with unusual type faces printed on old paper. There are also handwriting tasks involving pencils and pens. Details about the general principles which must be considered to provide the quantity and quality of illumination needed for these tasks may be found in Sections 2 and 5. In addition, illuminance recommendations are found in Fig. 2-2, page 2-7.

A task that is fairly unique to the library is that of browsing and/or searching in a stack or other form of storage space. In public spaces material may be on low shelves, on tables, on racks, in bins, etc., which are very accessible and have limited quantities of items to view. However, the vast majority of books, magazines and reference materials are stored in shelving that is tightly spaced and up to 2.5 meters (8 feet) high or in compact shelving with limited aisles. The task involves reading a title or author's name assisted by perhaps a numbering system applied to the material. The books or other material are often well used or old causing the title or other means of identification to be of very poor contrast.

When a library is associated with an educational institution, areas used for studying involve both reading and writing tasks. Such areas may have several work stations or individual work stations such as a study carrel. Task lighting is often provided at these locations, and veiling reflections should be minimized at these study locations.

Lighting Systems

A variety of lighting systems are used in libraries. Many libraries make use of daylight through windows or skylights. In all cases the luminance comfort recommendations should be the same as for offices and educational facilities. See Sections 5 and 6.

In areas where architectural features are dominant, design concepts may require sacrifice of efficiency for esthetics when translating the architect's concepts into practical lighting designs. In areas that do not have dominant architectural features, the lighting systems should be selected to provide comfortable seeing conditions with more emphasis placed on economics and luminaire design features. See Figs. 7-23 and 7-24.

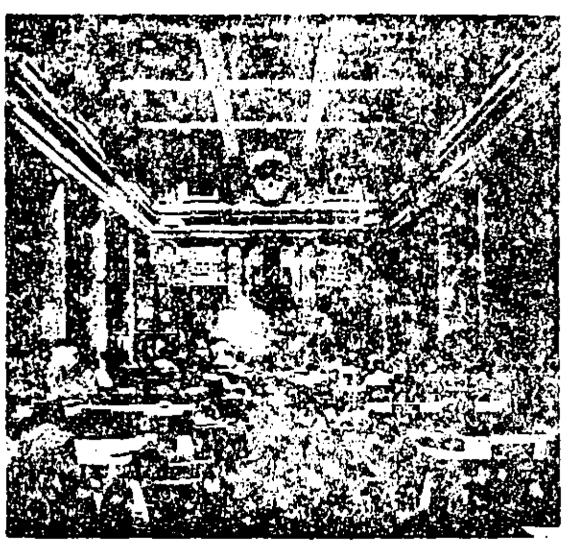


Fig. 7-23. Two lighting techniques are combined in this high-ceiling college library. General lighting is provided by a high intensity discharge lamp downlighting system. The chandeliers, with low-wattage lamps, are used as decorative elements in keeping with the original architect's design concept.

For library lighting applications, there are three basic types of light sources in use today: incandescent, fluorescent and high intensity discharge. (See Section 8 of the 1981 Reference Volume for light source data.) No one lighting system can be recommended exclusively. Each system has qualities that match the requirements for a given situation. The first consideration in choosing a lighting system should be to allow the library user to see efficiently and without distraction. The second should be the appearance of the installation within the architectural and decorative design concepts of the library. The third consideration is for the energy efficiency of the system.

In general it is desirable to provide sufficient illumination for the most common seeing task performed in an area. However, if a more difficult seeing task is being performed in a small portion of that area, additional illumination should be provided by providing additional overhead luminaires or by supplementary lighting equipment located in relation to the specific seeing task. Higher illuminances should also be provided in areas that will be used by persons with impaired vision. When relighting existing traditional-type library reading rooms, the use of supplementary lighting equipment consistent with the decorative treatment of the room is sometimes required. It is especially important to avoid direct and reflected glare and to avoid veiling reflections when using supplementary lighting equipment.

Specific Areas

Reading Areas. Reading areas in libraries, including main reading rooms and reference rooms, occur throughout almost the entire library. Reading is usually performed on either side of long tables, in lounge chairs, in study carrels or at the circulation desk. Care should be taken to locate the luminaires to avoid veiling reflections on the seeing tasks and to use luminaires that reduce the luminance in the direct glare zones.

Individual Study Areas (Carrels). Individual study areas or carrels may be found in almost any public area of the library building, such as main reading rooms, enclosed individual rooms

Fig. 7-24. Low ceiling library, where open access stacks are lighted with rows of fluorescent luminaires at right angles to the stacks.

and stack areas. One of the most serious lighting problems for carrels are the shadows produced by dividing walls. To avoid shadows it is desirable to provide lighting from as many directions as practicable. Special care should be taken to avoid veiling reflections especially from localized luminaires.

Shelving and Stack Areas. This area applies to shelving and storage units for all types of materials in addition to books. The visual tasks in book stacks are very difficult; for example, it is necessary to identify the book by number and author on the lowest shelf. As a result of studies made of typical books at actual viewing angles, it is recommended that, when practical, non-glossy plastic book jackets should be used rather than glossy; large and legible non-glossy lettering should be used for authors' names, book titles and index number. Dark book, shelf and floor surfaces reflect very little light; therefore, the use of light colored surfaces should be encouraged.

Open Access Stacks. Open access stacks are open to the public for finding their own books or for browsing. Book stacks are usually arranged in rows with continuous rows of fluorescent luminaires located along the center of each aisle. An alternative is to locate luminaires at right angles to the stacks (see Fig. 7-24). Obtaining maximum illumination on the lower shelves is the greatest concern.

Limited Access or Closed Stacks. These stacks are used primarily by library personnel. The aisles are usually narrower which increases the problem of obtaining illumination on the lower shelves. Compact shelves may also be used for limited access or closed stacks. Luminaires controlled by delayed time switches may be considered for these stack areas.

Card Catalogs. Individual files of card indexes are usually located in the main reading rooms. Location of overhead general lighting luminaires at right angles to the file cards rather than parallel to them will provide slightly better illumination on the vertical surfaces of the cards.

Circulation Desks. Circulation desks are usually located near the entrance to the main reading room. Often the general overhead lighting system will provide sufficient illumination for the desk; however, if not, sufficient supplementary illumination should be provided, which may be from an architectural element that will identify the circulation desk.

Conference and Seminar Rooms. Conferences are frequently scheduled in libraries, and groups hold seminars on occasion. In addition to general overhead lighting, provision should be made to illuminate the speakers and their materials at the lectern and at the seminar table. Several illuminance levels should be provided for the multiple type use of this space.

Display and Exhibition Areas. Many libraries have display and exhibition areas. These may be in glass covered horizontal cases or may be mounted on vertical walls or dividers. See Museums and Art Galleries, page 7-33 for lighting such displays.

Audio Visual Rooms. There is an increasing use of listening areas for lectures, music and other recorded material. These areas are either small rooms with individual reproducing equipment, or large rooms where head receivers may be plugged into circuits or carrels. Small rooms have poor utilization of light because more light is absorbed by the wall surfaces and, therefore, require a closer spacing between luminaires. Lighting similar to that required for carrels in a large room is also needed for the audio carrel system.

Lighting for CRT and Mircroform Viewing Areas. Computers and microform materials permit much larger holdings of newspaper files, rare books, special collections and technical publications. Microform materials include rolls and cartridges of microfilms on strips, aperture cards containing single frames of microfilm and microfiche cards or sheets containing a series of highly reduced micro-images. One of the most difficult seeing tasks is reading a screen filled with a printed page located under a general lighting system needed for other tasks in the area. (Reflections, diffuse and specular, tend to wash out the already poor image on the screen.) When notes must be taken over long periods of time, it is desirable to provide illumination on the note pad, but controlled to reduce reflections on the screen.

Higher illuminances are needed for files of microforms than are needed for viewing. Where viewers must be placed in reading areas or work areas with higher level general illumination and no controlled lighting or dimming is available, machines should be selected that are hooded and have screens which are treated to reduce reflections. A small luminaire should be provided between viewers to illuminate a fixed or sliding shelf in front of each machine for note taking. Such a luminaire should be moveable so that it may be individually located to accommodate right or left-handed operators.

Offices. Office areas in libraries should be illuminated in accordance with the recommendation for Office Lighting in Section 5.

Rare Book Rooms. Higher illuminances are recommended for rare book rooms because of the poor quality of printing often found in many rare books; however, lighting techniques such as those used in Museums and Art Galleries should be used for books displayed in glass cases. These would include means of reducing the amount of deleterious radiation.

Archives. Archives are for the storage and examination of public documents of all kinds. This would include legal documents, minutes of meeting, legislative actions and other historical papers. Pencil writing, small letters and condensed type are used in many of these documents.

Map Rooms. Map rooms have both storage and reading areas. Storage of maps involves the use of deep cabinets which, in turn, requires aisles sufficiently wide enough to open drawers for access to the maps. Maps mounted on vertical surfaces require vertical surface lighting.

Fine Arts, Picture and Print Rooms. See Museums and Art Galleries for the proper lighting of displays, paintings and art objects.

Group Study Rooms. Sometimes a group of 4 to 6 students is assigned to a project to be solved by consulting among themselves, and isolated rooms may be provided for this purpose. Techniques used for classroom lighting are recommended for these rooms. See Section 6, Educational Facilities Lighting.

Overnight Study Halls. Sometimes students prefer to work all night when preparing for examinations, and libraries may provide a portion of the building that can be isolated for this purpose. Lighting for these areas is similar to that required for Reading Areas or Individual Study Areas.

Entrance Vestibules and Lobbies. Lighting in entrance vestibules and lobbies should create an atmosphere suitable for the particular type of library. The lighting may emphasize the architectural features and provide a smooth transition to the functional areas.

MUSEUMS AND ART GALLERIES

A museum is defined by a leading organization (the American Association of Museums) as "an organized and permanent non-profit institution, essentially educational or esthetic in purpose, with professional staff, which owns and utilizes tangible objects, cares for them, and exhibits them to the public on a regular schedule." For illuminances recommendations, see Fig. 2-2, page 2-8.

A museum's highest responsibility is to the study and care of its collection and to the collection's effective public display. Thus, lighting has been considered to be the third, or perhaps the second, most important responsibility of the curator or designer, for lacking effective lighting, the most interesting collection and tasteful displays are ineffective. Lighting, however, can cause or accelerate degradation of certain kinds of museum and art gallery objects and this should be kept in mind

Damage to Museum and Gallery Objects

The principle risks associated with museum and art galley objects are due to:

1. Vandalism.
2. Excessive heat and humidity, especially rapid changes.
3. Chemical attack, such as from acidic matte boards.
4. Airborne pollutants, including vapors and dirt.
5. Improper handling or marking.
6. Radiant energy: infrared, light and ultraviolet.
7. Biological attack: insects, fungi, etc.

Each of these sources of damage must be dealt with by the curator and designer, often with the assistance of a consulting specialist; however, only the problems caused by radiant energy are covered here, along with guidance on minimizing the damages it can cause. All damage cannot be eliminated, but it can be restricted to an acceptable degree. For example, a suit of a famous 18th century American was displayed for 8 years under good controlled conditions with a maximum illuminance of 60 lux [6 footcandles] and no ultraviolet radiation—the dye was of poor quality and suffered noticeable fading.

Materials Subject to Light Damage. Essentially all materials of organic origin will change due to the absorption of light or its related energy. Among pigments, vegetable dyes should be treated with great care. Writing inks are also subject to extreme fading. The lower the reflectance of a colorant, the greater the energy absorbed and the greater the risk of deterioration. The material on which the pigment is placed and the thickness with which it is applied also affect its susceptibility. Prints and watercolor painting are more vulnerable than oil paintings.

The most fragile of the common fabric materials is silk. All other natural fibers have greater resistance, while the synthetic fibers, except nylon, are most resistant to destruction. Color, however, affects the degree of risk.

Other materials which can suffer degradation are paper, leather, fur, feathers, plastics and wood.

Minimizing Damage. To minimize damage:
1. The source of light should contribute as little heat as possible to the displayed object.
2. Humidity in the building and in display cases should be stabilized, whether lights are on or off.
3. All ultraviolet radiation should be removed by filters, such as UJ-3 acrylic sheet.
4. Total exposure, in terms of lux (footcandles) × hours, should be held to the absolute minimum as light damage is the product of illuminance and time (see Fig. 7-25). For highly susceptible materials, light should be fully excluded except during actual viewing.
5. For continuous exposure, the most precious and delicate objects should have no more than 50 lux [5 footcandles]. Surrounding areas of the museum will have to contribute to the viewer's accommodation to this low illuminance.
6. Daylight is potentially far more damaging than most electric light sources. Direct sunlight or sky light should not be allowed to reach susceptible materials. Daylight may be used if redirected by louvers, blinds or similar treatment onto upper wall or ceiling surfaces to indirectly illuminate a gallery. A paint containing zinc oxide or titanium dioxide will absorb ultraviolet radiation.
7. Period houses should have a ultraviolet absorbing plastic or film placed over the glass in all windows. Light can then be controlled with shutters, blinds or drapes, as may be appropriate. Louvered window screening is another possible control medium for daylight.
8. Display time for susceptible specimens can be shortened by rotating objects seasonally, putting copies on display part of the time, covering cases with opaque lids which the viewer can lift at will, or providing local switching for viewer operated lights (with or without timers, as appropriate). See page 19-31 for addition information on fading and bleaching.

Principles of Museum and Gallery Lighting

High contrast of light and co... produce tension and drama; over-all soft lighting and pastel colors create a mood of relaxation. Either treatment carried to extremes can produce fatigue or

Fig. 7-25. Recommended Total Exposure Limits in Terms of Illuminance-Hours Per Year to Limit Damage to Light-Susceptible Museum and Art Gallery Objects

Objects	Lux-Hours Per Annum	Footcandle-Hours Per Annum
Highly susceptible displayed materials—silk, art on paper, antique documents, lace, fugitive dyes	120,000*	12,000*
Moderately susceptible displayed materials—cotton, wool, other textiles where the dye is stable, certain wood finishes, leather	180,000**	18,000**

* Approximately 50 lux (5 footcandles) x 8 hours per day x 300 days per year.

** Approximately 75 lux (7.5 footcandles) x 8 hours per day x 300 days per year.

NOTE: These illuminances, if carefully applied, will not result in worse than just perceptible fading in the stated materials in ten years exposure. *All wavelengths shorter than 400 nanometers should be rigidly excluded.*

boredom. Museum curators and designers will usually be aware of these effects and will use their galleries appropriately. A museum may have a sculpture court or a hall devoted to light stable artifacts which could be daylighted or lighted with large general lighting luminaires providing excellent visibility. Drama may even be added with appropriate strong directional lights, but not always without a problem. One problem could be the need for an extreme change in illumination required in an adjacent space where light must be restricted because of perishable artifacts.

Superior gallery planning or visitor routing is the ordinary solution to this problem, but frequently these cannot be done. In this case, the brightly lighted space may need to be dimmed. The ratios of adjacent spaces in terms of luminance should not exceed 10 to 1 and preferably be less. This ratio of luminances is not merely the ratio of the two illuminance readings taken with an illuminance meter, but the apparent visual impact on normal viewers as they make the transition from one space to the next. This would allow the mathematical ratios to be violated by clever placement of a brightly lighted object or surface in an otherwise dark room. For example, if a daylighted court were devoted to showing frontier artifacts such as plows, wagons and locomotives, and adjacent space were devoted to native American objects such as fur, robes and feathers, an introductory display of replica costume pieces on a manikin could be very strongly illuminated to attract visitors to the dimly lighted room and to assist in the visual transition.

Museum display lighting tends to be principally oriented at objects or artwork. This would lead one to expect high drama in all exhibits, but this is rarely true. Background surfaces pick up spill and reflected light and modify the appearance and impact of the space. True focussed lighting only occurs when all surfaces are relatively dark. Such exhibits must be used sparingly since they tend to fatigue the visitor. As in all things, variety increases interest.

In some instances the light and the lighting equipment are part of the exhibit statement. These occasions are exceptions. Normally, the purpose of the lighting is to provide exhibit visibility and enhancement in the most unobtrusive manner possible.

Light Sources

Modern electric light sources for museum and art gallery lighting fall into three broad categories: incandescent, fluorescent, and high intensity discharge. The latter group is very efficient in generating light at low cost, but their spectra will usually make them unsuitable for most interior display lighting. Experienced lighting designers will use these sources in limited areas—for exterior floodlighting and protective lighting these lamps can be effective and economical.

Fluorescent Lighting. Fluorescent sources offer the following lighting advantages to museums:

1. High efficacy, resulting in lower energy use and costs and lower heat output.

The Metropolitan Museum of Art, Morris K. Jessup Fund, 1929. *The Metropolitan Museum of Art, Rogers Fund, 1912.* *The Metropolitan Museum of Art, Rogers Fund, 1917.*

Fig. 7-26. Lighting of sculpture. a. Concentrating sources, alone, from front left. b. Total overhead diffuse lighting conforms to expression of features. c. Low diffuse lighting and strong concentrated accent adds to stern expression. d. Light concentration from upper right. Strong overhead diffuse lighting aids in viewing the details of this complex sculpture.

2. Excellent range of colors (including over 20 different white lamps).
3. Excellent color appearance, when the correct lamps are chosen.
4. Long lamp life, reducing maintenance effort and cost.
5. Good size variety.

Fluorescent lamps are inherently large, soft light sources and are incapable of generating true beams of light. Creation of highlights and shadows for revealing three dimensional form and texture is not practical with fluorescent lamps. They *are* ideally suited to case lighting, dioramas, transparencies, luminous elements, creating false windows and virtually all practical working areas of a museum. They should also be used for stairway and other nightlights because of their economies. Wherever general illumination is required, fluorescent will usually be found to be effective.

Incandescent Lamps. Incandescent sources can be subdivided into four broad categories for museum and gallery use:
1. General service lamps in the familiar "A" and "PS" bulbs. They require directing of the light by reflectors and/or lenses. They are principally used for illumination of areas rather than specific objects. Most museums can fulfill all their needs with four of five sizes of these lamps.
2. Reflectorized lamps of the R, ER and PAR types, flood and spot distributions in a large range of sizes. See Section 8 of the 1981 Reference Volume. There are some varieties of low-voltage lamps available, but most are intended to operate directly at line voltage. Blown soft glass R and ER lamps are relatively inexpensive with reasonable life ratings, and are generally highly useful. The "field" of the light beam is usually quite smooth and the beam edge is not pronounced.

Molded hard glass PAR lamps, in flood and spot, have a beam narrower than the corresponding R lamp beam. The field of the beam may often contain irregularities and the beam edge is considerably more noticeable than with R lamps. Life rating is generally the same as R lamps and cost is slightly higher. For longer beam throws and higher drama, the PAR spot is superior to the R spot. One particular caution; these lamps are relatively heavy and should not be mounted above glass cases or fragile objects.
3. Low voltage lamps are available in general service and reflectorized types. Small low-voltage lamps are useful in simulating candle or oil lamp light in period rooms. The most useful low voltage lamps are the 25- and 50-watt spot and flood types. These produce excellent shaped beams with very little spill light. The beams can be projected considerable distances and the lamps are physically compact, allowing easy concealment. They have two disadvantages: their maintenance and that they require transformers. They are, however, energy efficient.
4. Tungsten-halogen lamps. They are: more efficient, whiter in color, more compact, longer lived than standard lamps of the same type. They are also hotter, more costly, produce *double* the ultraviolet radiation and are difficult to filter. These qualities suggest their use in intense light on metal or stone objects, but preclude their use in many other museum areas.

Specific Museum Lighting Problems

Museum exhibit design work can be divided into the categories shown below and further divided into "permanent" and "temporary." Many museums have spaces intended for changing exhibits and these require great flexibility. After discussing the most basic design problems, techniques of flexible lighting will be described for solving these problems in short-term exhibits.

Large Three-Dimensional Objects. Whether sculpture or machinery, or costume manikins or cannon, an important aspect of such objects is their mass. Lighting must reveal their plasticity and as much surface detail as is appropriate to the object. Total uniformity of lighting is rarely called for. There should be some distinction of strong and weak illumination, such as a spot light from one side and a flood light from the other. A degree of shadow is desirable (see Fig. 7-26). The shadow should not be so dark as to conceal significant details, or to produce distortions in appearance, but the shadow is a significant visual clue to the solidity of the object.

If not objectionable from the standpoint of honesty, subtle color differences may be used in the lighting from different directions. For example, a portrait bust might be placed near a window with a spot light directed at the other side. Even more subtle is the difference between a standard incandescent lamp and a tungsten-halogen lamp, but the difference is sufficient to improve surface texture in an object that must have almost equal illuminance from all directions.

When large objects are placed in open space, light will usually need to be directed sharply downward to avoid glare to the observer on the opposite side of the object. If some degree of upward lighting is required to avoid overly harsh shadows, this can frequently be achieved by providing a high reflectance base, such as white linoleum, to bounce the light upward. Small mirrors, strategically placed also may serve, if they are not distractions themselves. Direct lighting from the bottom is possible, but care must be observed that nearer surfaces are not overlighted, producing the unpleasant effect of shadows running upward.

Where the object is placed in a niche and the viewing will be only from one direction, the lighting can be as theatrical as desired. Lighting that strikes the objects directly from the front, at the same angle that the object is viewed, will tend to flatten surface features. This could be desirable for revealing the colors of a tapestry, while concealing the weave, but it would be undesirable for most sculpture.

Flat Displays on Vertical Surfaces. Paintings, prints and documents fit into this very important category. There are essentially three approaches to this display problem: light the entire space uniformly, light the vertical surfaces, or light only the objects. The first approach assumes that the object will be prominent in its environment without lighting assistance. This may well be the case where the objects are in high contrast to the wall surface. Many of our classical museums were designed in this manner, but the trend is to provide some additional focused light to enhance paintings or text materials. The National Gallery in Washington employs skylights, but has recently installed a system of spotlights to add warm color to the artworks and to provide more focus on them.

A gallery space may be the ideal setting for the objects exhibited and supplemental lighting might seem artificial. This is true of period rooms and houses, so that specific objects are rarely highlighted in these spaces.

Lighting only the vertical surface is often a very attractive method of displaying flat objects. Several commercial "wall-washer" luminaire systems are available in all lamp types. Fluorescent types offer very smooth continuous illumination and can provide good uniformity vertically, when used according to the manufacturer's directions. The appeal of the displayed object is again related to the contrast with the background. Incandescent wall-washers have optical devices to provide lighting higher on the wall than a common downlight. This minimizes scalloping and provides a more even wash on the wall for a predetermined area. Such wall washers are normally mounted quite close to the wall and the manufacturer's installation directions should be followed closely. Since such units are providing light at a steep angle, shadows of frames, shelves, etc., can be troublesome.

Lighting vertical objects individually, the third technique, permits more dramatic separation of objects, including lighting from varying angles and at varying illuminances. Where correctly used, this method is highly effective. Where incorrectly used, glare or shadows can seriously detract from the finished appearance (see Fig. 7-27). Fig. 7-28 shows preferred angles for lighting flat vertical displays. If the display has considerable relief or heavy frames, the angle can be

Fig. 7-27. Raking of weave of Renaissance tapestry by high angle directional light (left). Same tapestry with concentrated light at 60 degrees incident angle (right).

The Metropolitan Museum of Art, Bequest of George Blumenthal, 1941.

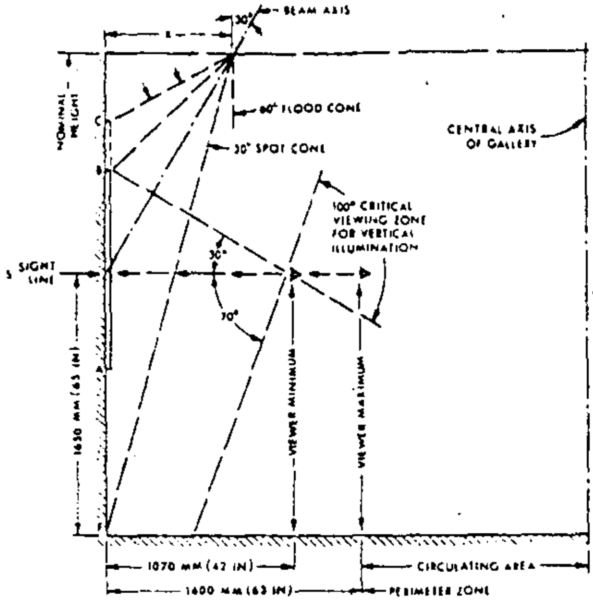


Fig. 7-28. Model perimeter (viewing) zones at nominal ceiling height. Model based on: (1) primary diffuse component (of vertical illuminance) at approximately 40 per cent of horizontal illuminance at S, (2) height of wall-hung display, (3) ideal utilization of beam cones, and (4) minimum effective viewing distance relative to a nominal height of object (A to B = 1320 millimeters (52 inches) for a 30-degree cone, A to C = 1650 millimeters (65 inches) for a 60-degree cone). To calculate viewing zones for higher objects, increase horizontal dimensions 38 millimeters (1.5 inches) for each 25-millimeter (1.0-inch) increase in height of object.

$$X = (\text{ceiling height} - \text{eye height})\,(.577)$$

for an aiming angle of 30 degrees from the vertical.

greater and distance X increased. If the display is mounted high and has substantial glossy areas, the reverse is appropriate. Unless there is a contrary reason, normal eye height is assumed to be 1650 millimeters (65 inches) above the floor.

Display Cases. Built-in display cases are generally provided with customized lighting which is integral to the case. While any surface could be the location for the lights, certain objects dictate specific lighting approaches. Glass, for example, looks very handsome when back or bottom lighted. Objects with little surface detail, but interesting shapes may be silhouetted. Most objects, however, will be top, or top-front, lighted, since this is most effective and natural. In these categories, the lighting units should be fully concealed. Fluorescent lighting is particularly appropriate to this purpose since the source delivers more light with less damaging heat and can be readily filtered against ultraviolet radiation. The entire case is then lighted with considerable uniformity and objects are made to assume importance by their position and the contrast with the case background. In most light finished cases there will not be substantial variation in the light vertically, due to the multitude of interior reflections, including the front glazing. Dark finished cases will have much more top-to-bottom variation. In these, it may be necessary to overcome this by arranging the smaller items high in the case and the larger, crude items toward the bottom. Occasionally this will require side lighting, particularly where the case is taller than wide.

Display case luminaires (light boxes) do not need to extend the entire length of the case and, in fact, will produce a very noticeable end scallop if they do. Normally, fluorescent lamps should end 100 to 200 millimeters (4 to 8 inches) from the end walls. In a recessed case, the light box can be completely out of sight in the top front of the case and no lens or louver is required for concealment (though a sheet of clear UF-3 plastic should be installed).

Most often, the light box will need to be in the viewer's line of sight and concealment of the light source is important. A low brightness lens or louver is then mandatory. The parabolic-wedge louver is highly favored for this, but it will produce a partial dark area at the top walls of the case because of the cut-off of the louver. In tall cases, or in those where the display begins somewhat below the top, this is a desirable feature, but in others, it may be preferred to use an angled louver to provide the lamp shielding while still providing light to the top of the rear panel.

Incandescent spotlights can be provided in cases to add warm color or to highlight specific items. Jewelry has more sparkle and can be placed on dark backgrounds when the items are individually spotlighted. The light box then requires greater depth, both for the bulkier lamps and to allow for greater heat dissipation. The use of plastics for glazing is limited because of the heat in the light beam.

In all instances of built-in cases, provision must be made for easy access to the lighting compartment. This access should not be through the case interior, thus risking damage to the displayed objects. Recent designs of fluorescent ballasts have greatly reduced their heat output and have made the risk of ballast leakage almost disappear; it is therefore no longer necessary to mount ballasts remote from the case. Remote ballasting requires more complex wiring and creates greater problems when replacements are needed.

Freestanding cases also can be lighted externally by the room illumination or by spotlights. If the general room illumination serves the cases, they will be undifferentiated from the remainder of the space and will have lesser impact. Spotlights on cases can give the color and emphasis that the display deserves; however, there will be a shadow of the top edge of the case somewhere within the case, unless the lights are directly above, and there will be a reflection of light from the top of the case onto the ceiling. By careful positioning of the case or the lights, these problems can be overcome.

The most severe problem with all cases is reflections in the viewing glass. This is most noticeable when a relatively dark case faces an area of high brightness. The only complete solutions are to use either specially curved glass (so-called invisible glass) at great cost in money and space, or to place all cases opposite dark walls. Other partial solutions are: to slope the front glass of the case outward to that only the floor is reflected to the viewer, and then the floor must have a relatively dark, matte surface; to place cases at right angles to each other so that there is at least one favorable viewing position; or to keep all case interiors very bright in appearance. In period rooms, natural settings, etc., it may be possible to omit the front glazing if other suitable protection of the displayed objects can be achieved; *e.g.*, railings and alarms, or a taut wire screen. A truly non-reflective glass is available, but at very high cost and only in limited dimensions. Areas of cases below eye level will normally reflect the floor to the viewer.

Table cases always reflect the ceiling area opposite, and this portion of the ceiling should be free of lights and relatively dark to avoid reflections. Table cases against a wall will reflect the wall directly above the case, thus restricting the use of this for vertical displays or text. Sloping cases will present troublesome reflection problems unless the designer makes a preliminary sketch in profile showing the normal viewing positions and the areas that will be reflected to the viewer. Such a sketch, done accurately, will anticipate problems and show the designer where the lights must be mounted to minimize both shadows and reflections.

The above three categories (large objects, wall displays and cases) cover virtually all museum displays; however, another category could be called "environments." This includes houses or period rooms which are not treated as cases—any exhibit where the public walks into the actual display. For such spaces, naturalism will enhance the ambience, but the problem of object degradation complicates this. Genuine antique or natural items must be protected against the very light that the original owner lived by. Windows will need to have ultraviolet filtering, and it may also be necessary to provide drapes or blinds to reduce total lighting levels. In this case, the guide or docent will be instructed to open the blinds for better lighting and close them as the visitors leave. Concealed lights can be controlled by switches or an automatic program device to point out objects in the space with short duration spots of light.

Halls or Galleries for Changing Exhibits. If a flexible exhibit space is consistently used for the same type of display, such as a changing exhibit of prints, then it can be lighted in a semipermanent manner, positioning lights on regular spacings, permitting the changes with variable lamp wattages, beam patterns and luminaire aiming. Alternatively, track can be installed parallel to the areas of interest at appropriate distances from the surface or area to be lighted and a selection of track units kept available to provide the necessary variety.

Many changeable spaces are not used in a predictable manner from one show to the next, and this would call for considerably higher degrees of variability than can be accomplished with simple straight runs of lighting track. One solution uses a "track-on-track" approach, allowing lighting units to be placed virtually at any point in a space. This calls for a heavy investment in built-in and auxiliary lighting hardware and will always result in a certain degree of ceiling clutter. The aesthetics of track lighting systems are important to the interior museum environment. Luminaire types should have compatible housings and be finished in neutral colors to blend with ceiling architecture. The other extreme is to merely provide sufficient electrical service above a dropped ceiling and reconstruct the ceiling for each exhibit, locating all lights in the new ceiling design. A variation in this last, is to provide a modular ceiling grid with lighting units mounted in standard panel sizes. These would be removed and replaced at will. Grid patterns of lighting track can be installed, with flexibility dependent on the closeness of the grid spacing.

When preparing service for such a changeable space, it is desirable to allow at least 50 watts per square meter (5 watts per square foot) in the panel and cable sizes, *though this high loading will probably never be fully utilized at any given time.*

Standard receptacles should be provided on relatively close spacings, about 2.5 meters (8 feet) on center in all permanent partitions, and additional provision should be made to provide electrical service in the middle of the area, either through the floor or the ceiling.

Conservation and Restoration Shop. Non-display portions of museums should be designed in accordance with the best modern techniques. One unique museum space which may require special attention, is the conservation and restoration shop. Such a space should have moderately high illuminances with special localized task lighting units available. All the fixed lighting should be color balanced according to the preference of the working conservator and should also be fully filtered against ultraviolet. Special ultraviolet portable examination lights will usually be required for specific tests.

Entrance Foyer or Lobby. An entrance foyer or lobby should be regarded as a vision conditioning space in which the visitor's eyes are permitted to adjust from daylight levels to the lower lighting in most galleries and museums. It is useful to have some control over the general illumination level in such foyers to adjust to the changing need.

Color

In general, the color of exhibit lighting is intended to achieve the highest degree of verisimilitude for the material displayed. This would suggest that daylight tonalities should be used for all items that were found in nature, or that were created under daylight. A major problem arises here. The high illuminance levels that nature provides are not permitted and the cool tones of daylight become gloomy and cold at low levels. See Fig. 2-11. The color of the noonday sky is about 5000 K. The correlated color temperature of a deluxe cool white fluorescent lamp is only about 4100 K, and yet the light could appear excessively cold in many exhibit circumstances. In fact, where illuminances are at or below 200 lux [20 footcandles], light source colors should rarely exceed 3400 K. Exhibits should be prepared, or checked under the light source that will be used for display.

Actual tinting of the illuminant color should be used with great discretion, and only with the concurrence of the curator concerned. Where this is done, it is preferred to use glass filters over incandescent lamps rather than colored lamps, first because this is more economical and second because the range of colors in glass filters permits more freedom than the limited number of lamp colors available.

Providing color with fluorescent lamps is relatively easy in the more popular sizes (such as the 40-watt lamp). See Fig. 8-115 in the 1981 Reference Volume. Where more than one lamp is used, a combination of types can provide almost unlimited color choice. Interposing colored acrylic filters can further extend color possibilities; and for short term exhibits, theatrical color gels are appropriate.

Maintenance

One of the larger problems of the museum administrator is providing good maintenance on restricted budget. Lighting, requiring constant attention and being highly visible, is a very significant part of this problem.

The designer of museum lighting can ease the burden by following the listed precepts:

1. Use as few types and styles of lamps as practical.
2. Use as much inherently long-lived types of lighting as practical.
3. Avoid lamps which require disassembly of the luminaire for changing.
4. Don't use special purpose lamps where general service lamps can serve.
5. Provide ready accessibility to all lighting equipment.
6. Where possible, use fewer large lamps instead of many small lamps (this will materially increase efficiency as well).
7. For incandescent lamps, use those with medium screw base, unless there is a demonstrable advantage to a lamp with a different base type.
8. Provide adequate storage space for lamps and maintenance supplies.
9. Provide ladders, towers, hand-tools and cleaning materials; any material device which will expedite lighting maintenance.
10. Treat the lighting maintenance person as the skilled, important person which the position justifies.

Energy Management

Museums will require more incandescent lighting than most other categories of public building. This will not justify careless or wasteful lighting practices. To achieve higher lighting energy efficiency, designers must think as follows: "Lamp and luminaire *X* is the most efficient available. Will this work effectively for the exhibit lighting problem? No. Then lamp and luminaire *Y* is the next most efficient system. Will that work?" and so forth until they arrive at the most satisfactory lighting solution.

In general, museum and gallery illuminances will not be high and lighting energy consumption should be quite moderate. Over and above conserving energy, maintaining a low lighting energy use contributes to better specimen conservation, since there will be less drastic temperature changes as lights are turned on and off. See Section 4.

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FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

CURSOS ABIERTOS.

ILUMINACION INTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES.

ILUMINACION INDUSTRIAL.

ING. CARLOS GARCIA.

CRITERIOS PARA ILUMINACION INDUSTRIAL

CRITERIOS PARA LA ILUMINACION INDUSTRIAL

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INTRODUCCION

El proposito de la iluminac ón en una industria es proporcionar luz suficiente en cantidad y calidad para tener seguridad y para aumentar la visibilidad y productividad con un ambiente placentero. Con el fin de conocer la actividad, el medio ambiente y por lo tanto la iluminación requerida, se deben considerar las siguientes recomendaciones:

1.- Diseñar la iluminación para la actividad planeada (más luz en el área en que se desarrolla la actividad que en sus alrededores).

2.- Diseñar con luminarios eficientes.

3.- Usar fuentes de luz de alta eficacia (mayor salida de lúmenes por watt).

4.- Utilizar eficientemente los luminarios.

5.- Utilizar luminarios controlados térmicamente.

6.- Utilizar acabados claros en techos, paredes, pisos y mobiliario.

7.- Utilizar eficientemente las lámparas.

8.- Apagar las luces cuando no se necesiten.

9.- Controlar el brillo de las ventanas.

10.- Utilizar la luz del día cuando sea práctico.

11.- Conservar el equipo de iluminación limpio y en buenas condiciones de trabajo

12.- Elaborar instrucciones para la operación y el mantenimiento.

2 CONDICIONES GENERALES

2.1.- FACTORES QUE AFECTAN LAS TAREAS VISUALES EN INDUSTRIAS.

2.1.1.- Generalidades. El ojo humano ve los objetos por reflexión transmisión o silueta.
Los planos de trabajo en industrias varian en dificultad visual desde visible hasta casi invisible. Los factores que afectan la visibilidad del plano de trabajo son: Contraste, luminancia, tamaño y tiempo. Estos factores son tan interdependientes que para mantener igual visibilidad, la deficiencia en uno de ellos puede ser compensada (dentro de ciertos limites) mediante el aumento de uno de los otros.

2.1.2.- Contraste. La visibilidad es máxima, cuando el contraste entre las luminancias (o colores) de la tarea visual y su fondo es mayor.

2.1.3.- Luminancia. Otro factor que afecta la visibilidad es la luminancia, ya que para que un objeto sea visible debe estar iluminado y diferir en luminancia de su fondo.

Para una misma tarea visual, los ojos de personas mayores necesitan mayores luminancias que los de personas jovenes.

2.1.4.- Tamaño. El tamaño de la tarea visual es un factor muy importante para la visibilidad. Mientras más grande es un objeto o tarea visual, más facilmente se puede ver. Por el contrario, mientras más pequeño, es más difícil verlo.

2.1.5.- Tiempo. Para asimilar los detalles de un objeto o tarea visual, el ojo necesita tiempo. Si la visibilidad es pobre debido a un bajo contraste, a baja luminancia o tamaño del detalle, entonces la relación de asimilación disminuya y el trabajo visual toma más tiempo.

Cuando el detalle que se quiera ver es pequeño, o las letras son muy tenues con respecto al fondo en que estan escritas, entonces tomamos más tiempo para poder apreciar completamente el detalle de que se trate. Esto implica que si queremos disminuir el tiempo para ver un detalle completamente, necesitamos ya sea aumentar el nivel de iluminación, aumentar el tamaño del detalle o mejorar el contraste entre el detalle y su fondo.

2.1.6.- Edad y visión Subnormal

2.1.6.1.- Tamaño de la pupila. Con la edad disminuye el tamaño de la pupila; por lo tanto para tener la misma visibilidad que la de ojos más jovenes es necesario aumentar la luminancia de los objetos.

2.1.6.2.- Acomodación. La acomodación es la habilidad de los lentes del ojo para ajustar el enfoque de una distancia a otra. La edad tiende a aplanar estos lentes pero la habilidad de los ojos para acomodarse, mejora con un incremento en la iluminación.

Hasta ahora hemos hablado sobre los factores que afectan las tareas visuales en Industrias, ahora vamos a hablar sobre los criterios para obtener una buena iluminación:

2.2.- Criterios de iluminación para el desempeño y comodidad visual.

2.2.1.- Debido a que una buena iluminación depende de muchos factores, las instalaciones de alumbrado deben ser diseñadas por un ingeniero de iluminación competente. Estos factores pueden ser agrupados en criterios de calidad y criterios de cantidad.

2.2.2.- Calidad de la Iluminación.

2.2.2.1.- El deslumbramiento, difusión y dirección de la luz, uniformidad, color, luminancia y relaciones de luminancia tienen un efecto significativo sobre la facilidad y presición de la visión. Un análisis cuidadoso sugiere que algunas tareas, tales como el discernimiento de detalles finos, requieren una calidad mucho mayor que aquellos que son casuales o de duración relativamente corta.

Aunque el alumbrado deficiente es facilmente reconocido como incomodo y posiblemente peligroso, las deficiencias moderadas no son detectadas facilmente.

2.2.2.2. Deslumbramiento. El deslumbramiento es causado por cualquier luminancia dentro del campo de visión que causa incomodidad, fatiga o interferencia con la visión.

Hay dos tipos de deslumbramiento al deslumbramiento directo y el deslumbramiento reflejado.

2.2.2.2.1.- Deslumbramiento directo. El deslumbramiento directo es causado principalmente por la iluminancia, de las fuentes de luz dentro del campo de visión. Tambien las ventanas son causa frecuente de deslumbramiento.

El deslumbramiento directo puede reducirse: (1) disminuyendo la luminancia de las fuentes de luz o del equipo de alumbrado, o ambas; (2) reduciendo el área de alta luminancia causante del deslumbramiento; (3) aumentando el ángulo entre la fuente que deslumbra y la línea de visión; (4) aumentando la luminancia del área que circunda la fuente que deslumbra y contra la cual se esta viendo.

2.2.2.2.2.- Deslumbramiento reflejado y "Reflejos veladores".

El deslumbramiento reflejado es causado por la luz reflejada en cualquier superficie brillante. Los reflejos veladores son causados por las imagenes reflejadas de las fuentes de luz en el plano de trabajo.

El deslumbramiento reflejado es frecuentemente más molesto que el reflejo directo debido a que esta más cerca de la línea de visión y el ojo no puede evitarlo. Además, los "reflejos veladores" pueden reducir el contraste en el plano de trabajo; y por lo tanto, la habilidad para distinguir los detalles.

Existen varias formas de disminuir estas molestias:

1) La luminancia de la fuente debe ser lo más baja posible y las ventanas deben tener cortinas.

2) Se deben posicionar los luminarios de tal forma que la imagen reflejada este dirigida fuera de los ojos del observador.

3) Instalar mayor número de luminarios de baja potencia. Con esto se logra disminuir el efecto de deslumbramiento reflejado y los "reflejos veladores", mediante el incremento de la iluminación proporcionada al plano de trabajo

por lámparas localizadas en posiciones diferentes de las que causan reflejos.

4) Cambiando el acabado de las superficies que producen reflejos.

2.2.2.3.- Uniformidad, Reflejos y Sombras.- a) La uniformidad de la iluminación, es apropiada para interiores industriales donde los planos de trabajo están muy próximos y donde las tareas visuales requieren la misma cantidad de luz.

b) Los reflejos de fuentes de luz en el plano de trabajo pueden ser útiles si no crean deslumbramientos reflejados o "reflejos veladores". En el maquinado e inspección de partes metálicas pequeñas, los reflejos pueden indicar fallas en el contorno, hacer las marcas más visibles, etc. Estos reflejos son creados por fuentes de luz posicionadas cuidadosamente.

c) Las sombras producidas por el sistema de alumbrado general pueden acentuar la profundidad y forma de los objetos; pero deben evitarse sombras pronunciadas.

Las sombras pueden ser suavizadas si el objeto es iluminado por muchas fuentes o por luminarios grandes difusos. Cuando se necesitan este tipo de sombras es mejor obtenerlas combinando el alum brado general con alumbrado direccional suplementario.

2.2.2.4.- Calidad del color de la fuente de luz. Las fuentes de luz deben ser seleccionadas cuidadosamente cuando la discriminación del color es importante.

2.2.3.- Cantidad de iluminación.

La cantidad de luz necesaria en cualquier instalación, depende principalmente de la naturaleza del trabajo. A medida que la iluminación del plano de trabajo se incrementa, la facilidad, velocidad y presición con la cual la tarea puede ser realizada, tambien se incrementa.

La recomendaciones de iluminación de esta tabla estan basadas en las caracteristicas de la tarea visual y en el funcionamiento visual requerido por jovenes con visión normal.

Estos valores fueron determinados usando los procedimientos establecidos por el IES en sus recomendaciones para calidad y cantidad de iluminación.

La cantidad de luz recomendada debe ser proporcionada en el punto y en el plano en el cual se efectúe la tarea visual, ya sea horizontal, vertical o algún ángulo intermedio.

Cuando no se encuentre en esta tabla la tarea visual que va a ser ejecutada, entonces se debe seleccionar la tarea que más se asemeje a la tarea en cuestión.

Si la tarea no es similar a ninguna de las listadas en esta tabla, la siguiente tabla puede utilizarse.

Type of Activity	Illuminance Category	Ranges of Illuminances		Reference Work-Plane
		Lux	Footcandles	
Public spaces with dark surroundings	A	20–30–50	2–3–5	General lighting throughout spaces
Simple orientation for short temporary visits	B	50–75–100	5–7.5–10	
Working spaces where visual tasks are only occasionally performed	C	100–150–200	10–15–20	
Performance of visual tasks of high contrast or large size	D	200–300–500	20–30–50	Illuminance on task
Performance of visual tasks of medium contrast or small size	E	500–750–1000	50–75–100	
Performance of visual tasks of low contrast or very small size	F	1000–1500–2000	100–150–200	
Performance of visual tasks of low contrast and very small size over a prolonged period	G	2000–3000–5000	200–300–500	Illuminance on task, obtained by a combination of general and local (supplementary lighting)
Performance of very prolonged and exacting visual tasks	H	5000–7500–10000	500–750–1000	
Performance of very special visual tasks of extremely low contrast and small size	I	10000–15000–20000	1000–1500–2000	

Esta tabla contiene descripciones generales de tareas visuales y actividades, a las cuales corresponden categorias de iluminancia. A cada categoría corresponde un rango de iluminancia.

Para seleccionar el valor del rango que debe utilizarse se puede referir a la siguiente tabla.

Características de la tarea y el trabajador	Factor		
Edad de los trabajadores	Menos de 40	40-55	Mas de 55
Velocidad y/o exactitud	No importante	Importante	Critica
Reflectancia del fondo del plano de trabajo	Mayor de 70%	30% a 70%	Menos de 30%

En esta tabla cada caracteristica debe ser evaluada para determinar el factor que le corresponde ya sea -1, - cero ó + 1. Estos factores se suman algebraicamente para determinar el factor de importancia. Si la suma es menor o igual a-2 se debe utilizar el vapor menor de -- iluminancia, si el resultado esta entre +1 y -1 se debe utilizar el valor medio de iluminancia y por último si la suma es mayor o igual a 2 se debe utilizar el valor mayor de iluminancia.

2.3.- Influencia de los factores del medio ambiente.

2.3.1.- Luminancia y relaciones de luminancia. La habilidad - para ver un detalle depende de la diferencia en lumi--

nancia entre el detalle y su fondo, es decir del contraste. Las luminancias dentro del campo visual afectan condiciones de visibilidad.

Las relaciones de luminancia recomendadas son las siguientes:

- Entre el área de trabajo y áreas adyacentes 1 a 1/3.
- Entre el área de trabajo y las superficies más remotas 1 a 1/10.
- Entre el área de trabajo y las superficies iluminadas más remotas 1 a 10.

Estas relaciones son las máximas recomendadas; reducciones en estas relaciones son beneficas generalmente.

Para obtener las relaciones de luminancia recomendadas es necesario seleccionar las reflectancias de los acabados de todas las superficies del local y del equipo, y controlar las caracteristicas de distribución y luminancia de los luminarios utilizados.

2.3.2.- Acabados del local.- Las reflectancias de las paredes, techo y piso (y aún las del equipo) determinan los patrones de luminancia. El acabado del local es muy importante en la utilización de la luz; y por lo tanto de la energía. Los valores recomendados de reflectancia son los que a continuación se presentan.

2.3.3.- Color de las máquinas y sus alrededores.- Las reflectancias altas, y las superficies mate son generalmente buenas porque proporcionan un mejor patrón de luminancia, una mayor utilización de la luz y mejoran la apariencia del local.

El color puede hacer al medio ambiente de trabajo más interesante y placentero. Los colores crema, marfil y amarillo claro son sicológicamente "calientes" y tienden a hacer que el local paresca más pequeño.

El color verde y el azul son sicologicamente "frios", y tienden a hacer que el local paresca más grande. Los acabados de gris claro son neutros y son excelentes ya sea como fondo o para equipo y maquinaria. Sin embargo, el uso del gris para ambos puede hacer al medio ambiente aburrido y monótono.

Los colores fuertes deben comunmente ser limitados a porciones pequeñas del campo visual.

2.4.- Construcción de edificios industriales.

2.4.1.- Las construcciones de edificios industriales son clasificadas como áreas de bahía baja y áreas de bahía alta. Se consideran áreas de bahía baja aquellas que tienen una altura de 7.5 m ó menos, del piso a la parte más baja de la estructura del mayor de 7.5 metros.

3.- LUZ NATURAL

3.1.- Hay varios factores que afectan el aprovechamiento de la luz natural. Algunos de estos factores son: Las variaciones en la cantidad y dirección de la luz del sol incidente; La distribución de luminancias de cielos claros, parcialmente nublados o completamente nublados; los efectos producidos por terrenos, patios y edificios cercanos.

La luz del día, disponible para usarse dentro de los edificios, depende del diseño arquitectónico de las ventanas y de la decoración y amueblado del interior.

Las ventanas tienen cuando menos tres fines útiles en edificios industriales, ya que admiten, controlan y distribuyen la luz del día, proporcionan una longitud focal infinita la cual relaja los musculos del ojo y eliminan la sensación de confinamiento que algunas personas experimentan en lugares completamente cerrados. Sin embargo, siempre es necesario un sistema de iluminación eléctrico debido a las variaciones de la luz del día (con la hora y el clima).

3.2.- Orientación del edificio y condiciones de ubicación.

3.2.1.- Las ventanas deben ser adecuadas a la orientación del edificio, a las variaciones en la topografía y a las vistas correspondientes a cada pared exterior.

Todas las ventanas deben ser equipadas con dispositivos apropiados de control, para evitar cualquier problema de luminancia.

Se le debe dar especial atención al control del deslumbramiento en lugares donde las ventanas frecuentemente reciben más de 100,000 luxes.

3.3.- Secciones arquitectónicas de edificios.

3.3.1.- Sección unilateral.- La iluminación unilateral es la más simple y común de las secciones arquitectónicas, este diseño permite tener ventanería contínua. La luz que entra por la parte superior de las ventanas, es usualmente la más efectiva para iluminar las áreas más alejadas de estas.

3.3.2.- Sección bilateral.- Para locales anchos la iluminación bilateral es preferible, dado que al menos una de las ventanas estará expuesta directamente al sol.

3.3.3.- Ventana en el techo de la nave.- Algunas veces se emplea una ventana en la parte más alta de la nave en la misma dirección que las ventanas laterales principales para superar las limitaciones del ancho del local, de una sección unilateral.

3.3.4.- Secciones diente de sierra.- Las secciones diente de sierra son aquellas en las cuales se tiene una sección alta con pendiente que se repite una o más veces. Debido a que las ventanas usualmente dan hacia el norte no se requieren controles de luz.

3.3.5.- Tragaluces.- La disposición de tragaluces es muy similar a la de iluminación eléctrica y algunas veces se emplean rejillas para controlar la iluminancia.

3.4.- Materiales transmisores y elementos que limitan el paso de la luz.

Los materiales y elementos que limitan el paso de la luz, que son utilizados para controlar la luz, que son utilizados para controlar la luz del día, son similares a los empleados para la iluminación eléctrica;

Estos materiales son seleccionados por su habilidad para transmitir, difundir, refractar, absorver o reflejar la luz.

3.5.- Acumulación de polvo.

La acumulación de polvo en las ventanas, reduce la luz transmitida. La cantidad que se redusca depende de la localización, el ángulo de montaje y la frecuencia de limpieza. Bajo condiciones industriales típicas, la depreciación de luz al cabo de sus meses puede equivaler a la mitad de la ventana en el sentido vertical y dos tercios en el sentido horizontal.

4.- ILUMINACION ELECTRICA

4.1.- La iluminación eléctrica se requiere para la mayoria de las áreas industriales, debido a que no se dispone frecuentemente de la cantidad suficiente de luz del día, aún bajo condiciones óptimas de luz.

4.2.- Tipos de luminarios. Existen muchos tipos de luminarios industriales. La selección del tipo específico para una instalación nueva, requiere el considerar: La distribución de candelas; la eficiencia, el control del brillo; las características de mantenimiento de lúmenes; la construcción mecánica; las características de la instalación y si es apropiado para utilizarse en áreas normales, clasificadas (es decir peligrosas) o especiales.

Existen cinco clasificaciones de luminarios para aplicación interior.

- Directo
- Semidirecto
- Difuso ó directo-indirecto
- Semi-indirecto
- Indirecto

4.2.1.- Luminarios Directos. Los luminarios clasificados como directos son aquellos que emiten prácticamente toda la luz (es decir del 90% al 100%) por abajo de la horizontal.

Aunque susualmente este tipo de luminarios proporcionan la iluminación más eficiente del área de trabajo, frecuentemente es a expensas de otros factores. Por ejemplo, las sombras pueden ser excesivas a menos que la unidad tenga un área luminosa relativamente grande, o esten montadas más cerca que la relación de espaciamiento a altura de montaje máxima sugerida.

El deslumbramiento directo producido por un luminario directo, puede ser mayor debido a la diferencia de luminancia entre la fuente de brillo y el área circundante más obscura; sin embargo con un luminario bien diseñado el reflejo directo puede ser bajo.

Los luminarios directos para aplicaciones industriales, comunmente son clasificados de acuerdo a su curva de distribución, desde muy concentrada hasta amplia.

Esta clasificación puede expresarse en términos de su máxima relación de espaciamiento a altura de montaje, como se muestra en la siguiente tabla:

CLASIFICACION DE LUMINARIOS DIRECTOS, EN TERMINOS DE RELACION DE ESPACIAMIENTO A ALTURA DE MONTAJE.

RELACION DE ESPACIAMIENTO A ALTURA DE MONTAJE	CLASIFICACION DE LUMINARIOS
Hasta 0.5	Muy Concentrado
0.5 a 0.7	Concentrado
0.7 a 1	Medio
1 a 1.5	Amplio
más de 1.5	Muy amplio

En general, para áreas de bahía alta es mejor utilizar distribuciones concentradas y medias, y en zonas donde se requiera una iluminación más elevada que el promedio, se pueden instalar luminarios con distribución muy concentra da. La curva de distribución mas adecuada para cada aplicación, puede determinarse comparando las curvas fotométricas de los luminarios y utilizandolas para calcular valores de iluminación en diferentes puntos.

4.2.2.- Luminarios semi-directos. Los luminarios semi directos son aquéllos que evitan del 60 al 90% de la luz por abajo de la horizontal. La utilización de la luz de estos luminarios en gran parte de la reflectancia del techo. Con techos de colores claros, la utilización no solo excede a la de los luminarios directos sino que además se mejora la comodidad visual.

El aumento de la iluminación en el techo debida a la distribución semidirecta, reduce la diferencia de luminancia entre el techo y el luminario, aumenta la difusión y atenúa las sombras. La combinación de luz hacia arriba y la baja brillantez proporciona una excelente comodiad visual, particularmente con fuentes de luz de alta luminancia.

4.2.3.- Luminarios difusos o directos-indirectos. Estos luminarios tienen sus componentes de luz hacia arriba y hacia abajo aproximadamente iguales es decir emiten del 40% al 60% de la luz por abajo de la horizontal. Los luminarios difusos emiten aproximadamente la misma cantidad de luz en todas direcciones; los luminarios directos-indirectos emiten muy poca luz en ángulos cercanos a la horizontal, por lo que se prefieren generalmente debido a su baja luminancia en la zona de reflejo directo.

La eficiencia de este tipo de luminarios depende de la reflectancia de todas las superficies del local, particularmente del techo. Los luminarios con este tipo de distribución son ampliamente utilizados en oficinas y laboratorios; sin embargo su uso está creciendo a áreas limpias de manufactura, donde las tareas visuales son críticas.

4.2.4.- Luminarios semi-indirectos. Este tipo de luminarios emiten la mayor parte de luz (60% a 90%) hacia arriba de la horizontal. La mayor parte de la luz que llega al plano de trabajo debe ser reflejada desde el techo y la parte superior de las paredes; por lo tanto es imperativo que estas superficies tengan alta reflectancia.

El uso del luminario semi-indirecto en industrias, se limita a áreas donde es necesario minimizar el deslumbramiento reflejado por superficies especulares.

4.2.5.- Luminario Indirecto. Los luminarios indirectos emiten del 90% al 100% de su luz hacia arriba de la horizontal, rara vez se utilizan en industrias (aunque generalmente son los más confortables) debido a su pobre coeficiente de utilización y su dificultad de mantenimiento.

4.2.6.- **Resumen.** Como conclusión de lo anterior podemos decir que ningún luminario puede ser recomendado, excluyendo a los otros; ya que cada uno tiene características que pueden o no pueden combinar con las necesidades de una aplicación específica. La evaluación de cada uno de ellos determinará cual puede proporcionar iluminación eficiente a una área dada, con calidad y cantidad suficientes. Parte de esta evaluación incluye; el investigar las caracteristicas de la tarea visual y el programa de mantenimiento.

Aunque todos los tipos de luminarios tienen una aplicación específica, los luminarios tipo directo y semidirecto son los más comunmente utilizados para aplicaciones industriales.

4.3.- Metodos de iluminación para áreas industriales.

El principal requerimiento de la iluminación Industrial es el facilitar la ejecución de la tarea visual mediante una iluminación de alta calidad. Con esta iluminación, el personal será capaz de observar y controlar eficientemente la operación y mantenimiento de los diferentes tipos de máquinas y procesos.

En la actualidad se ha enfatizado la necesidad de diseños de sistemas de iluminación, más eficientes en cuanto a utilización de la energía.

Estos diseños deben elaborarse en base a un cuidadoso estudio de las tareas visuales, que se desempeñan en cualquier industria.

Existen tres técnicas de iluminación que son utilizadas en industrias; estas son: iluminación general, iluminación general localizada y alumbrado suplementario. En áreas industriales grandes, las diferentes tareas requieren de diferentes niveles de iluminación; el sistema de alumbrado general debe proporcionar iluminación suficiente unicamente para las tareas visuales menos importantes. El alumbrado general localizado y/o el suplementario debe ser usado para cumplir con los requerimientos de iluminación de las tareas visuales más importantes.

4.3.1.- Alumbrado General. El alumbrado general se diseña para proporcionar una iluminación relativamente uniforme a un área específica, en la cual se desempeñan tareas visuales similares. Se entiende como iluminación uniforme la iluminación que no excede en 6 arriba o 1/6 abajo a la iluminación promedio.

Si se exceden las relaciones de separación a altura de montaje puede haber diferencias perceptibles en la iluminación. Las relaciones máximas de separación a altura de montaje generalmente las dan los fabricantes de los luminarios.

Las áreas cercanas a las paredes, deben tener una cantidad de alumbrado general comparable con la del área central.

4.3.2.- Alumbrado General Localizado. En muchas industrias existen maquinarias o tareas de ensamble o inspección que pueden necesitar un nivel de iluminación más alto que el nivel general. Para obtener un nivel más elevado se puede aumentar el número (6 lineas) de luminarios y/o la potencia por luminario para proporcionar los luxes adicionales necesarios.

4.3.3.- Alumbrado suplementario. Algunas tareas visuales requieren una cantidad y calidad especifica de iluminación la cual no puede obtenerse facilmente del alumbrado general. Este tipo de problemas se resuelven frecuentemente utilizando luminarios suplementarios. Antes de poder especificar el alumbrado suplementario es necesario conocer la naturaleza exacta de la tarea visual y entender sus características de reflectancia o transmitancia. El mejorar la visibilidad del plano de trabajo dependerá de uno o más de los cuatro factores que afectan la visibilidad; luminancia, contraste, tamaño y tiempo.

El equipo suplementario debe ser cuidadosamente aislado para prevenir deslumbramientos del usuario y de los trabajadores que se encuentren cerca.

Las relaciones de luminancia deben ser controladas cuidadosamente: Los trabajadores frecuentemente ven hacia lugares diferentes del plano de trabajo por lo que es recomendable usar cortinas en las ventanas para reducir la luminancia del exterior y/o instalar luminarios en una posición que incremente la luminancia de las paredes obscuras.

4.3.3.1.- Luminarios para alumbrado suplementario. Los luminarios para alumbrado suplementario pueden ser divididos en cinco tipos de acuerdo a su distribución de potencia luminosa en candelas.

Tipo S-I direccional: este tipo incluye todas las unidades concentradas. Algunos ejemplos son: reflectores spots; luminarios con reflectores concentrados o lentes incluyendo lámparas fluorescentes en un reflector concentrado.

Tipo S-II amplio: Este tipo incluye fuentes de área pequeña (incandescentes o HID). Un ejemplo de este tipo es un reflector abierto difuso con una lámpara de sodio en alta presión.

Tipo S-III amplio: Incluye todas las unidades fluorescentes que tienen una variación en luminancia mayor de dos a uno.

Tipo S-IV luminancia uniforme: Incluye todas las unidades que tengan una variación en luminancia menor que dos a uno.

Tipo S-V Luminancia uniforme: Es un luminario similar al tipo S-IV excepto que el patrón de rayas o líneas esta sobrepuesto en el panel.

4.3.3.2.- Luminarios portátiles. Donde sea posible, los luminarios suplementarios deben ser localiza-dos permanentemente para producir el efecto de iluminación más apropiado.

Frecuentemente se adaptan a luminarios que re-quieren flexibilidad, brazos ajustables y/o ró-tulas giratorias. El equipo portátil, sin em-bargo, puede ser usado ventajosamente alrede-dor de máquinas u objetos móviles o para ver el interior de estos. Este tipo de luminarios deben ser robustos eléctrica y mecánicamente y las lámparas deben protegerse y ser del tipo de servicio pesado.

4.3.3.3.- Efectos especiales y técnicas.

4.3.3.3.1.- Color. En lugares donde el color de un objeto es crítico, una vez que se determina la fuente de luz apropiada, es importante excluir cualquier luz extraña de una característica espectral diferente. Es importante también evitar brillos reflejados que pueden cambiar la apariencia del color del plano de trabajo.

a) **Enfasis del color.** El color de la luz pue-de ser usado para aumentar el contraste, ya sea intensificando o atenuando ciertos colores inherentes al plano de trabajo. Para intensificar (abrillantar) un color, la fuente de luz debe ser fuerte en ese color; para obscurecer, debe ser relativamente debil en ese color.

Por ejemplo, para ver el amarillo con un fondo negro, una fuente de luz rica en amarillo aumentará el contraste intensificando el amarillo; para ver el amarillo con un fondo blanco, una fuente de luz rica en azul aumentará el contraste haciendo grizaseo el amarillo.

b) Selección del color.- Los colores originales seleccionados para ser usados como referencia standard, estan gobernados por muchos factores estéticos y económicos. Solo el diseñador conoce la impresión que quiere se le de al observador o consumidor; por lo tanto, se debe tener cuidado de asegurar que esta impresión esté inherente bajo cualquier condición de alumbrado. Muchos problemas de color pueden evitarse evaluando la referencia bajo fuentes de luz comunmente usadas así como bajo fuentes de luz normalizadas.

c) Graduación del color. La graduación del color es el juicio de la igualdad (o de la cantidad y caracter de la diferencia) en el color de los objetos. Muchos productos como algodón, tabaco, fruta, vegetales, etc. pueden ser aceptados o rechazados en base al color especificado. La luz del día se usa frecuentemente para evaluar, sin embargo, la cantidad y temperatura del color varía con las condiciones del sol y del cielo, por lo que se prefiere el alumbrado eléctrico con propiedades de rendimiento de color aproximados a la luz del día.

d) Comparación de colores. La comparación del color es la determinación de que una o más muestras de un material o sustancia son idénticas a una referencia.

Muchos materiales parecen iguales bajo una fuente de luz pero no bajo otra. Este problema puede ser detectado cuando la comparación entre una muestra y una referencia se hace bajo dos fuentes de luz diferentes (por ejemplo roja y verde o amarilla y azul) Las lámparas incandescentes que son predominantemente rojizas y las lámparas fluorescentes de colores frios predominantemente azulosas son frecuentemente utilizadas como las dos fuentes de luz disimilares.

Matizado del color. El matizado de color - es el ajuste de proporción de ingredientes (colorantes) de una mezcla para acercar el color a una referencia. La mezcla de pigmentos o tintas es un ejemplo del matizado de colores. Como lo anterior es también una comparación de colores se requiere utilizar lo recomendado para la compración de colores.

Corrección de Color. La corrección del color es el ajuste del proceso de reproducción del color de una reproducción para -- que esta se parezca al original. Para la - corrección del color, es preferible una -- fuente de luz que aproxime su distribución espectral de energía a la luz del día.

4.3.3.3.2.- Objetos tridimensionales. Los objetos tridimensionales son vistos en sus formas aparentes debido a las sombras producidas por ciertas componentes direccionales de la -- luz. Este efecto direccional es particularmente útil para enfatizar la textura y defectos de superficies irregulares.

4.3.3.3.3.- Siluetas. La silueta es un medio efectivo de comprobar el contorno con un patrón. La iluminación atrás del patrón mostrará brillantez donde halla diferencia entre el --

contorno del patrón y la del objeto que está siendo comprobado.

4.3.3.3.4.- Fluorescencia bajo radiación ultravioleta. Las superficies fluorescentes bajo radiación ultravioleta se utilizan frecuentemente para crear contrastes. Los defectos en las superficies de metales fluorescente.

4.3.3.3.5.- Detalles pequeños y alta presición. El observar objetos muy pequeños a través de lentes simplifica la inspección. La imagen amplificada del objeto puede ser proyectada en una pantalla. Debido a que la silueta proyectada es una amplificación del objeto, cualquier forma irregular o espaciamiento inadecuado puede detectarse. Se utilizan dispositivos similares para inspeccionar partes de maquinaria para obtener dimensiones y contornos exactos.

4.3.3.3.6.- Partes en movimiento. Algunas veces es necesario inspeccionar partes en movimiento. La iluminación estroboscópica puede ajustarse para "detener" o "disminuir" el movimiento de maquinaria rotatoria y reciprocante de velocidad constante.

Las lámparasestrobscópicas emiten destellos de luz a intervalos (frecuencias) controlables. El destello puede ser tan sincronizado que cada vez que el destello ocurra, el objeto rotatorio o reciprocante parezca estar exactamente en la misma posición estacionaria.

4.3.3.3.7.- Tareas visuales en superficies verticales. Los objetos montados verticalmente tales - como relojes, mapas, pánales, etc. Frecuentemente requieren técnicas especiales. La iluminación uniforme es importante especialmente si el área iluminada es grande. Si - el objeto está atrás de una cubierta transparente, es importante localizar el alumbrado suplementario de tal manera que ninguna reflexión coincida con el ángulo de visión. Si el plano de trabajo está localizado, el alumbrado suplementario de tal manera que - ninguna reflexión coincida con el ángulo de visión. Si el plano de trabajo está localizado adyacente a una fuente de alta luminancia, tal luminancia debe ser reducida a los límites anteriormente indicados.

4.3.5.- Alumbrado de emergencia. Generalmente, el alumbrado de emergencia se diseña para proporcionar alumbrado en dos condiciones básicas: (1) para periodos de corta dura--- ción en los que se requiere seguridad para evacuar al - personal; y (2) para periodos largos donde el alumbrado se requiere para seguridad o continuidad de operación. Cada una de estas condiciones requiere el uso de una fuente de potencia de reserva. Las dos más importantes son: baterias y plantas de emergencia. Cada una de estas puede utilizarse para cumplir con los requerimientos necesarios. Un sistema de alumbrado de emergencia puede ser parte de, o separado de, el sistema de alumbrado. El mantenimiento periódico planeado de todas las componentes del sistema de emergencia es esencial para su funcionamiento adecuado.

Las unidades de alumbrado de emergencia con alacenamiento en baterias se utilizan para proporcionar alumbrado en corredores, escaleras, salidas, locales con equipo, maquinaria y otras áreas peligrosas. La capacidad de las baterias y el número de lámparas y su potencia deben estar correlacionadas para proporcionar alumbrado durante el tiempo requerido.

Las plantas de emergencia son fuentes de potencia para proporcionar alumbrado de emergencia durante periodos mayores de tiempo. Las plantas de emergencia constan de un generador impulsado por un motor que arranca automáticamente o manualmente en caso de falla de la alimentación de potencia normal. La transferencia de potencia normal a emergencia se efectúa por medio de un interruptor de transferencia que invierte la función cuando se restablece la potencia normal.

Fig. 2-2. Currently Recommended Illuminance Categories and Illuminance Values for Lighting Design—Target Maintained Levels

The tabulation that follows is a consolidated listing of the Society's current illuminance recommendations. This listing is intended to guide the lighting designer in selecting an appropriate illuminance for design and evaluation of lighting systems.

Guidance is provided in two forms: (1), in Parts I, II and III as an *Illuminance Category*, representing a range of illuminances (see page 2-4 for a method of selecting a value within each illuminance range); and (2), in parts IV, V and VI as an *Illuminance Value*. Illuminance Categories are represented by letter designations A through I. Illuminance Values are given in *lux* with an approximate equivalence in *footcandles* and as such are intended as *target* (nominal) values with deviations expected. These target values also represent *maintained* values (see page 2-24).

This table has been divided into the six parts for ease of use. Part I provides a listing of both Illuminance Categories and Illuminance Values for generic types of interior activities and normally is to be used when Illuminance Categories for a specific Area/Activity cannot be found in parts II and III. Parts IV, V and VI provide target maintained Illuminance Values for outdoor facilities, sports and recreational areas, and transportation vehicles where special considerations apply as discussed on page 2-4.

In all cases the recommendations in this table are based on the assumption that the lighting will be properly designed to take into account the visual characteristics of the task. See the design information in the particular application sections in this Application Handbook for further recommendations.

I. Illuminance Categories and Illuminance Values for Generic Types of Activities in Interiors

Type of Activity	Illuminance Category	Ranges of Illuminances: Lux	Ranges of Illuminances: Footcandles	Reference Work-Plane
Public spaces with dark surroundings	A	20-30-50	2-3-5	General lighting throughout spaces
Simple orientation for short temporary visits	B	50-75-100	5-7.5-10	
Working spaces where visual tasks are only occasionally performed	C	100-150-200	10-15-20	
Performance of visual tasks of high contrast or large size	D	200-300-500	20-30-50	Illuminance on task
Performance of visual tasks of medium contrast or small size	E	500-750-1000	50-75-100	
Performance of visual tasks of low contrast or very small size	F	1000-1500-2000	100-150-200	
Performance of visual tasks of low contrast and very small size over a prolonged period	G	2000-3000-5000	200-300-500	Illuminance on task, obtained by a combination of general and local (supplementary lighting)
Performance of very prolonged and exacting visual tasks	H	5000-7500-10000	500-750-1000	
Performance of very special visual tasks of extremely low contrast and small size	I	10000-15000-20000	1000-1500-2000	

II. Commercial, Institutional, Residential and Public Assembly Interiors

Area/Activity	Illuminance Category
Air terminals (see Transportation terminals)	
Armories	C[1]
Art galleries (see Museums)	
Auditoriums	
Assembly	C[1]
Social activity	B
Banks (also see Reading)	
Lobby	
General	C
Writing area	D
Tellers' stations	E[3]
Barber shops and beauty parlors	E
Churches and synagogues	(see page 7-2)*
Club and lodge rooms	
Lounge and reading	D
Conference rooms	
Conferring	D
Critical seeing (refer to individual task)	
Court rooms	
Seating area	C
Court activity area	E[3]
Dance halls and discotheques	B

For footnotes, see page 2-19.

Fig. 2-2. *Continued*

II. *Continued*

Area/Activity	Illuminance Category
Depots, terminals and stations (see **Transportation terminals**)	
Drafting	
Mylar	
High contrast media; India ink, plastic leads, soft graphite leads	E[3]
Low contrast media; hard graphite leads	F[3]
Vellum	
High contrast	E[3]
Low contrast	F[3]
Tracing paper	
High contrast	E[3]
Low contrast	F[3]
Overlays[5]	
Light table	C
Prints	
Blue line	E
Blueprints	E
Sepia prints	F
Educational facilities	
Classrooms	
General (see **Reading**)	
Drafting (see **Drafting**)	
Home economics (see **Residences**)	
Science laboratories	E
Lecture rooms	
Audience (see **Reading**)	
Demonstration	F
Music rooms (see **Reading**)	
Shops (see Part III, Industrial Group)	
Sight saving rooms	F
Study halls (see **Reading**)	
Typing (see **Reading**)	
Sports facilities (see Part V, Sports and Recreational Areas)	
Cafeterias (see **Food service facilities**)	
Dormitories (see **Residences**)	
Elevators, freight and passenger	C
Exhibition halls	C
Fire halls (see **Municipal buildings**)	
Food service facilities	
Dining areas	
Cashier	D
Cleaning	C
Dining	B[6]
Food displays (see Merchandising spaces)	
Kitchen	E
Garages—parking	(see page 14-24)
Gasoline stations (see **Service stations**)	
Graphic design and material	
Color selection	F[11]
Charting and mapping	F
Graphs	E
Keylining	F
Layout and artwork	F
Photographs, moderate detail	E[13]

Area/Activity	Illuminance Category
Health care facilities	
Ambulance (local)	E
Anesthetizing	E
Autopsy and morgue[17,18]	
Autopsy, general	E
Autopsy table	G
Morgue, general	D
Museum	E
Cardiac function lab	E
Central sterile supply	
Inspection, general	E
Inspection	F
At sinks	E
Work areas, general	D
Processed storage	D
Corridors[17]	
Nursing areas—day	C
Nursing areas—night	B
Operating areas, delivery, recovery, and laboratory suites and service	E
Critical care areas[17]	
General	C
Examination	E
Surgical task lighting	H
Handwashing	F
Cystoscopy room[17,18]	E
Dental suite[17]	
General	D
Instrument tray	E
Oral cavity	H
Prosthetic laboratory, general	D
Prosthetic laboratory, work bench	E
Prosthetic laboratory, local	F
Recovery room, general	C
Recovery room emergency examination	E
Dialysis unit, medical[17]	F
Elevators	C
EKG and specimen room[17]	
General	B
On equipment	C
Emergency outpatient[17]	
General	E
Local	F
Endoscopy rooms[17,18]	
General	E
Peritoneoscopy	D
Culdoscopy	D
Examination and treatment rooms[17]	
General	D
Local	E
Eye surgery[17,18]	F
Fracture room[17]	
General	E
Local	F
Inhalation therapy	D
Laboratories[17]	
Specimen collecting	E
Tissue laboratories	F
Microscopic reading room	D
Gross specimen review	F

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

33 -

Fig. 2-2. *Continued*

II. *Continued*

Area/Activity	Illuminance Category
Chemistry rooms	E
Bacteriology rooms	
General	E
Reading culture plates	F
Hematology	E
Linens	
Sorting soiled linen	D
Central (clean) linen room	D
Sewing room, general	D
Sewing room, work area	E
Linen closet	B
Lobby	C
Locker rooms	C
Medical illustration studio[17,18]	F
Medical records	E
Nurseries[17]	
General[18]	C
Observation and treatment	E
Nursing stations[17]	
General	D
Desk	E
Corridors, day	C
Corridors, night	A
Medication station	E
Obstetric delivery suite[17]	
Labor rooms	
General	C
Local	E
Birthing room	F[7]
Delivery area	
Scrub, general	G
General	G
Delivery table	(see page 7-15)
Resuscitation	G
Postdelivery recovery area	E
Substerilizing room	B
Occupational therapy[17]	
Work area, general	D
Work tables or benches	E
Patients' rooms[17]	
General[18]	B
Observation	A
Critical examination	E
Reading	D
Toilets	D
Pharmacy[17]	
General	E
Alcohol vault	D
Laminar flow bench	F
Night light	A
Parenteral solution room	D
Physical therapy departments	
Gymnasiums	D
Tank rooms	D
Treatment cubicles	D
Postanesthetic recovery room[17]	
General[18]	E
Local	H
Pulmonary function laboratories[17]	E
Radiological suite[17]	
Diagnostic section	
General[18]	A
Waiting area	A
Radiographic/fluoroscopic room	A
Film sorting	F
Barium kitchen	C
Radiation therapy section	
General[18]	B
Waiting area	B
Isotope kitchen, general	E
Isotope kitchen, benches	E
Computerized radiotomography section	
Scanning room	B
Equipment maintenance room	E
Solarium	
General	C
Local for reading	D
Stairways	C
Surgical suite[17]	
Operating room, general[18]	F
Operating table	(see page 7-12)
Scrub room[18]	E
Instruments and sterile supply room	D
Clean up room, instruments	E
Anesthesia storage	C
Substerilizing room	C
Surgical induction room[17,18]	E
Surgical holding area[17,18]	E
Toilets	C
Utility room	D
Waiting areas[17]	
General	C
Local for reading	D
Homes (see Residences)	
Hospitals (see Health care facilities)	
Hotels	
Bathrooms, for grooming	D
Bedrooms, for reading	D
Corridors, elevators and stairs	C
Front desk	E[3]
Linen room	
Sewing	F
General	C
Lobby	
General lighting	C
Reading and working areas	D
Canopy (see Part IV, Outdoor Facilities)	
Kitchens (see Food service facilities or Residences)	
Libraries	
Reading areas (see **Reading**)	
Book stacks (vertical 760 millimeters (30 inches) above floor)	
Active stacks	D
Inactive stacks	B
Book repair and binding	D

For footnotes, see page 2-13. For illuminance ranges for each Illuminance Category, see page 2-5.

Fig. 2-2. *Continued*

II. *Continued*

Area/Activity	Illuminance Category
Cataloging	D[1]
Card files	E
Carrels, individual study areas (see **Reading**)	
Circulation desks	D
Map, picture and print rooms (see **Graphic design and material**)	
Audiovisual areas	D
Audio listening areas	D
Microform areas (see **Reading**)	
Locker rooms	C
Merchandising spaces	
Alteration room	F
Fitting room	
Dressing areas	D
Fitting areas	F
Locker rooms	C
Stock rooms	D
Wrapping and packaging	D
Sales transaction area	E
Circulation	(see page 8-6)[8]
Merchandise	(see page 8-6)[8]
Feature display	(see page 8-6)[8]
Show windows	(see page 8-6)[8]
Motels (see Hotels)	
Municipal buildings—fire and police	
Police	
Identification records	F
Jail cells and interrogation rooms	D
Fire hall	D
Museums	
Displays of non-sensitive materials	D
Displays of sensitive materials	(see page 7-29)[2]
Lobbies, general gallery areas, corridors	C
Restoration or conservation shops and laboratories	E
Nursing homes (see Health care facilities)	
Offices	
Accounting (see **Reading**)	
Conference areas (see **Conference rooms**)	
Drafting (see **Drafting**)	
General and private offices (see **Reading**)	
Libraries (see **Libraries**)	
Lobbies, lounges and reception areas	C
Mail sorting	E
Off-set printing and duplicating area	D
Post offices (see Offices)	
Reading	
Copied tasks	
Ditto copy	E[3]
Micro-fiche reader	B[12,13]
Mimeograph	D
Photographs, moderate detail	E[13]
Thermal copy, poor copy	F[3]
Xerograph	D
Xerography, 3rd generation and greater	E

Area/Activity	Illuminance Category
Electronic data processing tasks	
CRT screens	B[12,13]
Impact printer	
good ribbon	D
poor ribbon	E
2nd carbon and greater	E
Ink jet printer	D
Keyboard reading	D
Machine rooms	
Active operations	D
Tape storage	D
Machine area	C
Equipment service	E[10]
Thermal print	E
Handwritten tasks	
#3 pencil and softer leads	E[3]
#4 pencil and harder leads	F[3]
Ball-point pen	D[3]
Felt-tip pen	D
Handwritten carbon copies	E
Non photographically reproducible colors	F
Chalkboards	E[3]
Printed tasks	
6 point type	E[3]
8 and 10 point type	D[3]
Glossy magazines	D[13]
Maps	E
Newsprint	D
Typed originals	D
Typed 2nd carbon and later	E
Telephone books	E
Residences	
General lighting	
Conversation, relaxation and entertainment	B
Passage areas	B
Specific visual tasks[20]	
Dining	C
Grooming	
Makeup and shaving	D
Full-length mirror	D
Handicrafts and hobbies	
Workbench hobbies	
Ordinary tasks	D
Difficult tasks	E
Critical tasks	F
Easel hobbies	E
Ironing	D
Kitchen duties	
Kitchen counter	
Critical seeing	E
Noncritical	D
Kitchen range	
Difficult seeing	E
Noncritical	D
Kitchen sink	
Difficult seeing	E
Noncritical	D
Laundry	
Preparation and tubs	D
Washer and dryer	D

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

Fig. 2-2. *Continued*

II. *Continued*

Area/Activity	Illuminance Category
Music study (piano or organ)	
Simple scores	D
Advanced scores	E
Substand size scores	F
Reading	
In a chair	
Books, magazines and newspapers	D
Handwriting, reproductions and poor copies	E
In bed	
Normal	D
Prolonged serious or critical	E
Desk	
Primary task plane, casual	D
Primary task plane, study	E
Sewing	
Hand sewing	
Dark fabrics, low contrast	F
Light to medium fabrics	E
Occasional, high contrast	D
Machine sewing	
Dark fabrics, low contrast	F
Light to medium fabrics	E
Occasional, high contrast	D
Table games	D
Restaurants (see **Food service facilities**)	
Safety	(see page 2-45)

Area/Activity	Illuminance Category
Schools (see **Educational facilities**)	
Service spaces (see also **Storage rooms**)	
Stairways, corridors	C
Elevators, freight and passenger	C
Toilets and wash rooms	C
Service stations	
Service bays (see Part III, Industrial Group)	
Sales room (see **Merchandising spaces**)	
Show windows	(see page 8-5)
Stairways (see **Service spaces**)	
Storage rooms (see Part III, Industrial Group)	
Stores (see **Merchandising spaces** and **Show windows**)	
Television	(see Section 11)
Theatre and motion picture houses (see Section 11)	
Toilets and washrooms	C
Transportation terminals	
Waiting room and lounge	C
Ticket counters	E
Baggage checking	D
Rest rooms	C
Concourse	B
Boarding area	C

III. Industrial Group

Area/Activity	Illuminance Category
Aircraft maintenance	(see page 9-12)[21]
Aircraft manufacturing	(see page 9-12)[21]
Assembly	
Simple	D
Moderately difficult	E
Difficult	F
Very difficult	G
Exacting	H
Automobile manufacturing	(see page 9-17)[21]
Bakeries	
Mixing room	D
Face of shelves	D
Inside of mixing bowl	D
Fermentation room	D
Make-up room	
Bread	D
Sweet yeast-raised products	D
Proofing room	D
Oven room	D
Fillings and other ingredients	D
Decorating and icing	
Mechanical	D
Hand	E
Scales and thermometers	D
Wrapping	D

Area/Activity	Illuminance Category
Book binding	
Folding, assembling, pasting	D
Cutting, punching, stitching	E
Embossing and inspection	F
Breweries	
Brew house	D
Boiling and keg washing	D
Filling (bottles, cans, kegs)	D
Building construction (see Part IV, Outdoor Facilities)	
Building exteriors (see Part IV, Outdoor Facilities)	
Candy making	
Box department	D
Chocolate department	
Husking, winnowing, fat extraction, crushing and refining, feeding	D
Bean cleaning, sorting, dipping, packing, wrapping	D
Milling	E
Cream making	
Mixing, cooking, molding	D
Gum drops and jellied forms	D
Hand decorating	D
Hard candy	
Mixing, cooking, molding	D

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

Fig. 2-2. *Continued*

III. *Continued*

Area/Activity	Illuminance Category
Die cutting and sorting	E
Kiss making and wrapping	E
Canning and preserving	
Initial grading raw material samples	D
Tomatoes	E
Color grading and cutting rooms	F
Preparation	
Preliminary sorting	
Apricots and peaches	D
Tomatoes	E
Olives	F
Cutting and pitting	E
Final sorting	E
Canning	
Continuous-belt canning	E
Sink canning	E
Hand packing	D
Olives	E
Examination of canned samples	F
Container handling	
Inspection	F
Can unscramblers	E
Labeling and cartoning	D
Casting (see Foundries)	
Central stations (see Electric generating stations)	
Chemical plants (see Petroleum and chemical plants)	
Clay and concrete products	
Grinding, filter presses, kiln rooms	C
Molding, pressing, cleaning, trimming	D
Enameling	E
Color and glazing—rough work	E
Color and glazing—fine work	F
Cleaning and pressing industry	
Checking and sorting	E
Dry and wet cleaning and steaming	E
Inspection and spotting	G
Pressing	F
Repair and alteration	F
Cloth products	
Cloth inspection	I
Cutting	G
Sewing	G
Pressing	F
Clothing manufacture (men's)	
Receiving, opening, storing, shipping	D
Examining (perching)	I
Sponging, decating, winding, measuring	D
Piling up and marking	E
Cutting	G
Pattern making, preparation of trimming, piping, canvas and shoulder pads	E
Fitting, bundling, shading, stitching	D
Shops	F
Inspection	G
Pressing	F
Sewing	G

Area/Activity	Illuminance Category
Control rooms (see Electric generating stations—interior)	
Corridors (see Service spaces)	
Cotton gin industry	
Overhead equipment—separators, driers, grid cleaners, stick machines, conveyers, feeders and catwalks	D
Gin stand	D
Control console	D
Lint cleaner	D
Bale press	D
Dairy farms (see Farms)	
Dairy products	
Fluid milk industry	
Boiler room	D
Bottle storage	D
Bottle sorting	E
Bottle washers	[22]
Can washers	D
Cooling equipment	D
Filling: inspection	E
Gauges (on face)	E
Laboratories	E
Meter panels (on face)	E
Pasteurizers	D
Separators	D
Storage refrigerator	D
Tanks, vats	
Light interiors	C
Dark interiors	E
Thermometer (on face)	E
Weighing room	D
Scales	E
Dispatch boards (see Electric generating stations—interior)	
Dredging (see Part IV, Outdoor Facilities)	
Electrical equipment manufacturing	
Impregnating	D
Insulating: coil winding	E
Electric generating stations—interior (see also Nuclear power plants)	
Air-conditioning equipment, air preheater and fan floor, ash sluicing	B
Auxiliaries, pumps, tanks, compressors, gauge area	C
Battery rooms	D
Boiler platforms	B
Burner platforms	C
Cable room	B
Coal handling systems	B
Coal pulverizer	C
Condensers, deaerator floor, evaporator floor, heater floors	B
Control rooms	
Main control boards	D[23]
Auxiliary control panels	D[23]
Operator's station	E[23]

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category see page 2-5.

37-

Fig. 2-2. *Continued*

III. *Continued*

Area/Activity	Illuminance Category
Maintenance and wiring areas	D
Emergency operating lighting	C
Gauge reading	D
Hydrogen and carbon dioxide manifold area	C
Laboratory	E
Precipitators	B
Screen house	C
Soot or slag blower platform	C
Steam headers and throttles	B
Switchgear and motor control centers	D
Telephone and communication equipment rooms	D
Tunnels or galleries, piping and electrical	B
Turbine building	
Operating floor	D
Below operating floor	C
Visitor's gallery	C
Water treating area	D
Electric generating stations—exterior (see Part IV, Outdoor Facilities)	
Elevators (see **Service spaces**)	
Explosives manufacturing	
Hand furnaces, boiling tanks, stationary driers, stationary and gravity crystallizers	D
Mechanical furnace, generators and stills, mechanical driers, evaporators, filtration, mechanical crystallizers	D
Tanks for cooking, extractors, percolators, nitrators	D
Farms—dairy	
Milking operation area (milking parlor and stall barn)	
General	C
Cow's udder	D
Milk handling equipment and storage area (milk house or milk room)	
General	C
Washing area	E
Bulk tank interior	E
Loading platform	C
Feeding area (stall barn feed alley, pens, loose housing feed area)	C
Feed storage area—forage	
Haymow	A
Hay inspection area	C
Ladders and stairs	C
Silo	A
Silo room	C
Feed storage area—grain and concentrate	
Grain bin	A
Concentrate storage area	B
Feed processing area	B
Livestock housing area (community, maternity, individual calf pens, and loose housing holding and resting areas)	B
Machine storage area (garage and machine shed)	B
Farm shop area	
Active storage area	B
General shop area (machinery repair, rough sawing)	D
Rough bench and machine work (painting, fine storage, ordinary sheet metal work, welding, medium benchwork)	D
Medium bench and machine work (fine woodworking, drill press, metal lathe, grinder)	E
Miscellaneous areas	
Farm office (see **Reading**)	
Restrooms (see **Service spaces**)	
Pumphouse	C
Farms—poultry (see **Poultry industry**)	
Flour mills	
Rolling, sifting, purifying	E
Packing	D
Product control	F
Cleaning, screens, man lifts, aisleways and walkways, bin checking	D
Forge shops	E
Foundries	
Annealing (furnaces)	D
Cleaning	D
Core making	
Fine	F
Medium	E
Grinding and chipping	F
Inspection	
Fine	G
Medium	F
Molding	
Medium	F
Large	E
Pouring	E
Sorting	E
Cupola	C
Shakeout	D
Garages—service	
Repairs	E
Active traffic areas	C
Write-up	D
Glass works	
Mix and furnace rooms, pressing and lehr, glass-blowing machines	C
Grinding, cutting, silvering	D
Fine grinding, beveling, polishing	E
Inspection, etching and decorating	F
Glove manufacturing	
Pressing	G
Knitting	F
Sorting	F
Cutting	G
Sewing and inspection	G
Hangars (see **Aircraft manufacturing**)	
Hat manufacturing	
Dyeing, stiffening, braiding, cleaning, refining	E

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

Fig. 2–2. *Continued*

III. *Continued*

Area/Activity	Illuminance Category
Forming, sizing, pouncing, flanging, finishing, ironing	F
Sewing	G
Inspection	
Simple	D
Moderately difficult	E
Difficult	F
Very difficult	G
Exacting	H
Iron and steel manufacturing	(see page 9–63)[21]
Jewelry and watch manufacturing	G
Laundries	
Washing	D
Flat work ironing, weighing, listing, marking	D
Machine and press finishing, sorting	E
Fine hand ironing	E
Leather manufacturing	
Cleaning, tanning and stretching, vats	D
Cutting, fleshing and stuffing	D
Finishing and scarfing	E
Leather working	
Pressing, winding, glazing	F
Grading, matching, cutting, scarfing, sewing	G
Loading and unloading platforms (see Part IV, Outdoor Facilities)	
Locker rooms	C
Logging (see Part IV, Outdoor Facilities)	
Lumber yards (see Part IV, Outdoor Facilities)	
Machine shops	
Rough bench or machine work	D
Medium bench or machine work, ordinary automatic machines, rough grinding, medium buffing and polishing	E
Fine bench or machine work, fine automatic machines, medium grinding, fine buffing and polishing	G
Extra-fine bench or machine work, grinding, fine work	H
Materials handling	
Wrapping, packing, labeling	D
Picking stock, classifying	D
Loading, inside truck bodies and freight cars	C
Meat packing	
Slaughtering	D
Cleaning, cutting, cooking, grinding, canning, packing	D
Nuclear power plants (see also **Electric generating stations**)	
Auxiliary building, uncontrolled access areas	C
Controlled access areas	
Count room	E[23]
Laboratory	E
Health physics office	F
Medical aid room	F
Hot laundry	D
Storage room	C
Engineered safety features equipment	D
Diesel generator building	D
Fuel handling building	
Operating floor	D
Below operating floor	C
Off gas building	C
Radwaste building	D
Reactor building	
Operating floor	D
Below operating floor	C
Packing and boxing (see Materials handling)	
Paint manufacturing	
Processing	D
Mix comparison	F
Paint shops	
Dipping, simple spraying, firing	D
Rubbing, ordinary hand painting and finishing art, stencil and special spraying	D
Fine hand painting and finishing	E
Extra-fine hand painting and finishing	G
Paper-box manufacturing	E
Paper manufacturing	
Beaters, grinding calendering	D
Finishing, cutting, trimming, papermaking machines	E
Hand counting, wet end of paper machine	E
Paper machine reel, paper inspection, and laboratories	F
Rewinder	F
Parking areas	(see page 14–24)
Petroleum and chemical plants	(see page 9–51)[21]
Plating	D
Polishing and burnishing (see Machine shops)	
Power plants (see Electric generating stations)	
Poultry industry (see also Farm—dairy)	
Brooding, production, and laying houses	
Feeding, inspection, cleaning	C
Charts and records	D
Thermometers, thermostats, time clocks	D
Hatcheries	
General area and loading platform	C
Inside incubators	D
Dubbing station	F
Sexing	H
Egg handling, packing, and shipping	
General cleanliness	E
Egg quality inspection	E
Loading platform, egg storage area, etc.	C
Egg processing	
General lighting	E
Fowl processing plant	
General (excluding killing and unloading area)	E
Government inspection station and grading stations	E
Unloading and killing area	C

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

39-

Fig. 2-2. *Continued*

III. *Continued*

Area/Activity	Illuminance Category
Feed storage	
Grain, feed rations	C
Processing	C
Charts and records	D
Machine storage area (garage and machine shed)	B
Printing industries	
Type foundries	
Matrix making, dressing type	E
Font assembly—sorting	D
Casting	E
Printing plants	
Color inspection and appraisal	F
Machine composition	E
Composing room	E
Presses	E
Imposing stones	F
Proofreading	F
Electrotyping	
Molding, routing, finishing, leveling molds, trimming	E
Blocking, tinning	D
Electroplating, washing, backing	D
Photoengraving	
Etching, staging, blocking	D
Routing, finishing, proofing	E
Tint laying, masking	E
Receiving and shipping (see Materials handling)	
Railroad yards (see Part IV, Outdoor Facilities)	
Rubber goods—mechanical	(see page 9-56)[21]
Rubber tire manufacturing	(see page 9-56)[21]
Safety	(see page 2-45)
Sawmills	
Secondary log deck	B
Head saw (cutting area viewed by sawyer)	E
Head saw outfeed	B
Machine in-feeds (bull edger, resaws, edgers, trim, hula saws, planers)	B
Main mill floor (base lighting)	A
Sorting tables	D
Rough lumber grading	D
Finished lumber grading	F
Dry lumber warehouse (planer)	C
Dry kiln colling shed	B
Chipper infeed	B
Basement areas	
Active	A
Inactive	A
Filing room (work areas)	E
Service spaces (see also Storage rooms)	
Stairways, corridors	B
Elevators, freight and passenger	B
Toilets and wash rooms	C
Sheet metal works	
Miscellaneous machines, ordinary bench work	E
Presses, shears, stamps, spinning, medium bench work	E
Punches	E
Tin plate inspection, galvanized	F
Scribing	F
Shoe manufacturing—leather	
Cutting and stitching	
Cutting tables	G
Marking, buttonholing, skiving, sorting, vamping, counting	G
Stitching, dark materials	G
Making and finishing, nailers, sole layers, welt beaters and scarfers, trimmers, welters, lasters, edge setters, sluggers, randers, wheelers, treers, cleaning, spraying, buffing, polishing, embossing	F
Shoe manufacturing—rubber	
Washing, coating, mill run compounding	D
Varnishing, vulcanizing, calendering, upper and sole cutting	D
Sole rolling, lining, making and finishing processes	E
Soap manufacturing	
Kettle houses, cutting, soap chip and powder	D
Stamping, wrapping and packing, filling and packing soap powder	D
Stairways (see Service spaces)	
Steel (see Iron and steel)	
Storage battery manufacturing	D
Storage rooms or warehouses	
Inactive	B
Active	
Rough, bulky items	C
Small items	D
Storage yards (see Part IV, Outdoor Facilities)	
Structural steel fabrication	E
Sugar refining	
Grading	E
Color inspection	F
Testing	
General	D
Exacting tests, extra-fine instruments, scales, etc.	F
Textile mills	
Staple fiber preparation	
Stock dyeing, tinting	D
Sorting and grading (wool and cotton)	E[16]
Yarn manufacturing	
Opening and picking (chute feed)	D
Carding (nonwoven web formation)	D[24]
Drawing (gilling, pin drafting)	D
Combing	D[24]
Roving (slubbing, fly frame)	E
Spinning (cap spinning, twisting, texturing)	E
Yarn preparation	
Winding, quilling, twisting	E
Warping (beaming, sizing)	F[16]
Warp tie-in or drawing-in (automatic)	E

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

Fig. 2-2. *Continued*

III. *Continued*

Area/Activity	Illuminance Category	Area/Activity	Illuminance Category
Fabric production		**Upholstering**	F
Weaving, knitting, tufting	F		
Inspection	G[16]	**Warehouse (see Storage rooms)**	
Finishing			
Fabric preparation (desizing, scouring, bleaching, singeing, and mercerization)	D	**Welding**	
		Orientation	D
Fabric dyeing (printing)	D	Precision manual arc-welding	H
Fabric finishing (calendaring, sanforizing, sueding, chemical treatment)	E[16]	**Woodworking**	
Inspection	G[16, 25]	Rough sawing and bench work	D
Tobacco products		Sizing, planing, rough sanding, medium quality machine and bench work, gluing, veneering, cooperage	D
Drying, stripping	D		
Grading and sorting	F		
Toilets and wash rooms (see Service spaces)		Fine bench and machine work, fine sanding and finishing	E

IV. Outdoor Facilities

Area/Activity	Lux	Footcandles	Area/Activity	Lux	Footcandles
Building (construction)			Stairs and platforms	50	5
General construction	100	10	Ground level areas including precipitators, FD and ID fans, bottom ash hoppers	50	5
Excavation work	20	2	Cooling towers		
Building exteriors			Fan deck, platforms, stairs, valve areas	50	5
Entrances			Pump areas	20	2
Active (pedestrian and/or conveyance)	50	5	Fuel handling		
Inactive (normally locked, infrequently used)	10	1	Barge unloading, car dumper, unloading hoppers, truck unloading, pumps, gas metering	50	5
Vital locations or structures	50	5	Conveyors	20	2
Building surrounds	10	1	Storage tanks	10	1
Buildings and monuments, floodlighted			Coal storage piles, ash dumps	2	0.2
Bright surroundings			Hydroelectric		
Light surfaces	150	15	Powerhouse roof, stairs, platform and intake decks	50	5
Medium light surfaces	200	20	Inlet and discharge water area	2	0.2
Medium dark surfaces	300	30	Intake structures		
Dark surfaces	500	50	Deck and laydown area	50	5
Dark surroundings			Value pits	20	2
Light surfaces	50	5	Inlet water area	2	0.2
Medium light surfaces	100	10	Parking areas		
Medium dark surfaces	150	15	Main plant parking	20	2
Dark surfaces	200	20	Secondary parking	10	1
Bulletin and poster boards			Substation		
Bright surroundings			Horizontal general area	20	2
Light surfaces	500	50	Vertical tasks	50	5
Dark surfaces	1000	100	Transformer yards		
Dark surroundings			Horizontal general area	20	2
Light surfaces	200	20	Vertical tasks	50	5
Dark surfaces	500	50	Turbine areas		
Central station (see Electric generating stations—exterior)			Building surrounds	20	2
Coal yards (protective)	2	0.2	Turbine and heater decks, unloading bays	50	5
Dredging	20	2			
Electric generating stations—exterior					
Boiler areas					
Catwalks, general areas	20	2			

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

41

Fig. 2-2. *Continued*

IV. *Continued*

Area/Activity	Lux	Footcandles
Entrances, stairs and platforms	50[9]	5[9]
Flags, floodlighted (see **Bulletin and poster boards**)		
Gardens[19]		
General lighting	5	0.5
Path, steps, away from house	10	1
Backgrounds—fences, walls, trees, shrubbery	20	2
Flower beds, rock gardens	50	5
Trees, shrubbery, when emphasized	50	5
Focal points, large	100	10
Focal points, small	200	20
Gasoline station (see **Service stations** in Part II)		
Highways (see page 14-8)		
Loading and unloading platforms	200	20
Freight car interiors	100	10
Logging (see also **Sawmills**)		
Yarding	30	3
Log loading and unloading	50	5
Log stowing (water)	5	0.5
Active log storage area (land)	5	0.5
Log booming area (water)—foot traffic	10	1
Active log handling area (water)	20	2
Log grading—water or land	50	5
Log bins (land)	20	2
Lumber yards	10	1
Parking areas (see page 14-24)		
Piers		
Freight	200	20
Passenger	200	20
Active shipping area surrounds	50	5
Prison yards	50	5
Quarries	50	5
Railroad yards		
Retarder classification yards		
Receiving yard		
Switch points	20	2
Body of yard	10	1
Hump area (vertical)	200	20
Control tower and retarder area (vertical)	100	10
Head end	50	5
Body	10	1
Pull-out end	20	2
Dispatch or forwarding yard	10	1
Hump and car rider classification yard		
Receiving yard		
Switch points	20	2
Body of yard	10	1
Hump area	50	5
Flat switching yards		
Side of cars (vertical)	50	5
Switch points	20	2
Trailer-on-flatcars		
Horizontal surface of flatcar	50	5
Hold-down points (vertical)	50	5
Container-on-flatcars	30	3
Roadways (see page 14-8)		
Sawmills (see also **Logging**)		
Cut-off saw	100	10
Log haul	20	2
Log hoist (side lift)	20	2
Primary log deck	100	10
Barker in-feed	300	30
Green chain	200 to 300[26]	20 to 30[26]
Lumber strapping	150 to 200[26]	15 to 20[26]
Lumber handling areas	20	2
Lumber loading areas	50	5
Wood chip storage piles	5	0.5
Service station (at grade)		
Dark surrounding		
Approach	15	1.5
Driveway	15	1.5
Pump island area	200	20
Building faces (exclusive of glass)	100[14]	10[14]
Service areas	30	3
Landscape highlights	20	2
Light surrounding		
Approach	30	3
Driveway	50	5
Pump island area	300	30
Building faces (exclusive of glass)	300[14]	30[14]
Service areas	70	7
Landscape highlights	50	5
Ship yards		
General	50	5
Ways	100	10
Fabrication areas	300	30
Smokestacks with advertising messages (see **Bulletin and poster boards**)		
Storage yards		
Active	200	20
Inactive	10	1
Streets (see page 14-8)		
Water tanks with advertising messages (see **Bulletin and poster boards**)		

For footnotes, see page 2-19.

Fig. 2-2. *Continued*

V. Sports and Recreational Areas

Area/Activity	Lux	Footcandles
Archery (indoor)		
Target, tournament	500[14]	50[14]
Target, recreational	300[14]	30[14]
Shooting line, tournament	200	20
Shooting line, recreational	100	10
Archery (outdoor)		
Target, tournament	100[14]	10[14]
Target, recreational	50[14]	5[14]
Shooting line, tournament	100	10
Shooting line, recreational	50	5
Badminton		
Tournament	300	30
Club	200	20
Recreational	100	10
Baseball		
Major league		
Infield	1500	150
Outfield	1000	100
AA and AAA league		
Infield	700	70
Outfield	500	50
A and B league		
Infield	500	50
Outfield	300	30
C and D league		
Infield	300	30
Outfield	200	20
Semi-pro and municipal league		
Infield	200	20
Outfield	150	15
Recreational		
Infield	150	15
Outfield	100	10
Junior league (Class I and Class II)		
Infield	300	30
Outfield	200	20
On seats during game	20	2
On seats before and after game	50	5
Basketball		
College and professional	500	50
College intramural and high school	300	30
Recreational (outdoor)	100	10
Bathing beaches		
On land	10	1
150 feet from shore	30[14]	3[14]
Billiards (on table)		
Tournament	500	50
Recreational	300	30
Bowling		
Tournament		
Approaches	100	10
Lanes	200	20
Pins	500[14]	50[14]
Recreational		
Approaches	100	10
Lanes	100	10
Pins	300[14]	30[14]

Area/Activity	Lux	Footcandles
Bowling on the green		
Tournament	100	10
Recreational	50	5
Boxing or wrestling (ring)		
Championship	5000	500
Professional	2000	200
Amateur	1000	100
Seats during bout	20	2
Seats before and after bout	50	5
Casting—bait, dry-fly, wet-fly		
Pier or dock	100	10
Target (at 24 meters [80 feet] for bait casting and 15 meters [50 feet] for wet or dry-fly casting)	50[14]	5[14]
Combination (outdoor)		
Baseball/football		
Infield	200	20
Outfield and football	150	15
Industrial softball/football		
Infield	200	20
Outfield and football	150	15
Industrial softball/6-man football		
Infield	200	20
Outfield and football	150	15
Croquet or Roque		
Tournament	100	10
Recreational	50	5
Curling		
Tournament		
Tees	500	50
Rink	300	30
Recreational		
Tees	200	20
Rink	100	10
Fencing		
Exhibitions	500	50
Recreational	300	30
Football		
Distance from nearest sideline to the farthest row of spectators		
Class I Over 30 meters [100 feet]	1000	100
Class II 15 to 30 meters [50 to 100 feet]	500	50
Class III 9 to 15 meters [30 to 50 feet]	300	30
Class IV Under 9 meters [30 feet]	200	20
Class V No fixed seating facilities	100	10

It is generally conceded that the distance between the spectators and the play is the first consideration in determining the class and lighting requirements. However, the potential seating capacity of the stands should also be considered and the following ratio is suggested: Class I for

For footnotes, see page 2-19.

Fig. 2-2. *Continued*

V. *Continued*

Area/Activity	Lux	Footcandles
over 30,000 spectators; Class II for 10,000 to 30,000; Class III for 5000 to 10,000; and Class IV for under 5000 spectators.		
Football, Canadian—rugby (see Football)		
Football, six-man		
High school or college	200	20
Jr. high and recreational	100	10
Golf		
Tee	50	5
Fairway	10, 30[14]	1, 3[14]
Green	50	5
Driving range		
At 180 meters [200 yards]	50[14]	5[14]
Over tee area	100	10
Miniature	100	10
Practice putting green	100	10
Gymnasiums (refer to individual sports listed)		
General exercising and recreation	300	30
Handball		
Tournament	500	50
Club		
Indoor—four-wall or squash	300	30
Outdoor—two-court	200	20
Recreational		
Indoor—four-wall or squash	200	20
Outdoor—two-court	100	10
Hockey, field	200	20
Hockey, ice (indoor)		
College or professional	1000	100
Amateur	500	50
Recreational	200	20
Hockey, ice (outdoor)		
College or professional	500	50
Amateur	200	20
Recreational	100	10
Horse shoes		
Tournament	100	10
Recreational	50	5
Horse shows	200	20
Jai-alai		
Professional	1000	100
Amateur	700	70
Lacrosse	200	20
Playgrounds	50	5
Quoits	50	5
Racing (outdoor)		
Auto	200	20
Bicycle		
Tournament	300	30
Competitive	200	20
Recreational	100	10
Dog	300	30

Area/Activity	Lux	Footcandles
Dragstrip		
Staging area	100	10
Acceleration, 400 meters [1320 feet]	200	20
Deceleration, first 200 meters [660 feet]	150	15
Deceleration, second 200 meters [660 feet]	100	10
Shutdown, 250 meters [820 feet]	50	5
Horse	200	20
Motor (midget or motorcycle)	200	20
Racquetball (see Handball)		
Rifle 45 meters [50 yards]—outdoor)		
On targets	500[14]	50[14]
Firing point	100	10
Range	50	5
Rifle and pistol range (indoor)		
On targets	1000[14]	100[14]
Firing point	200	20
Range	100	10
Rodeo		
Arena		
Professional	500	50
Amateur	300	30
Recreational	100	10
Pens and chutes	50	5
Roque (see Croquet)		
Shuffleboard (indoor)		
Tournament	300	30
Recreational	200	20
Shuffleboard (outdoor)		
Tournament	100	10
Recreational	50	5
Skating		
Roller rink	100	10
Ice rink, indoor	100	10
Ice rink, outdoor	50	5
Lagoon, pond, or flooded area	10	1
Skeet		
Targets at 18 meters [60 feet]	300[14]	30[14]
Firing points	50	5
Skeet and trap (combination)		
Targets at 30 meters [100 feet] for trap, 18 meters [60 feet] for skeet	300[14]	30[14]
Firing points	50	5
Ski slope	10	1
Soccer (see Football)		
Softball		
Professional and championship		
Infield	500	50
Outfield	300	30
Semi-professional		
Infield	300	30
Outfield	200	20

For footnotes, see page 2-19.

Fig. 2-2. *Continued*

V. *Continued*

Area/Activity	Lux	Footcandles
Industrial league		
Infield	200	20
Outfield	150	15
Recreational (6-pole)		
Infield	100	10
Outfield	70	7
Slow pitch, tournament—see industrial league		
Slow pitch, recreational (6-pole)—see recreational (6-pole)		
Squash (see Handball)		
Swimming (indoor)		
Exhibitions	500	50
Recreational	300	30
Underwater—1000 [100] lamp lumens per square meter [foot] of surface area		
Swimming (outdoor)		
Exhibitions	200	20
Recreational	100	10
Underwater—600 [60] lamp lumens per square meter [foot] of surface area		

Area/Activity	Lux	Footcandles
Tennis (indoor)		
Tournament	1000	100
Club	750	75
Recreational	500	50
Tennis (outdoor)		
Tournament	300	30
Club	200	20
Recreational	100	10
Tennis, platform	500	50
Tennis, table		
Tournament	500	50
Club	300	30
Recreational	200	20
Trap		
Targets at 30 meters [100 feet]	300[14]	30[14]
Firing points	50	5
Volley ball		
Tournament	200	20
Recreational	100	10

VI. Transportation Vehicles

Area/Activity	Lux	Footcandles
Aircraft		
Passenger compartment		
General	50	5
Reading (at seat)	200	20
Airports		
Hangar apron	10	1
Terminal building apron		
Parking area	5	0.5
Loading area	20[14]	2[14]
Rail conveyances		
Boarding or exiting	100	10
Fare box (rapid transit train)	150	15
Vestibule (commuter and inter-city trains)	100	10
Aisles	100	10
Advertising cards (rapid transit and commuter trains)	300	30
Back-lighted advertising cards (rapid transit and commuter trains)—860 cd/m^2 (250 fL) average maximum.		
Reading	300[3]	30[3]
Rest room (inter-city train)	200	20
Dining area (inter-city train)	500	50
Food preparation (inter-city train)	700	70
Lounge (inter-city train)		
General lighting	200	20
Table games	300	30
Sleeping car		
General lighting	100	10
Normal reading	300[3]	30[3]
Prolonged seeing	700[3]	70[3]

Area/Activity	Lux	Footcandles
Road Conveyances		
Step well and adjacent ground area	100	10
Fare box	150	15
General lighting (for seat selection and movement)		
City and inter-city buses at city stop	100	10
Inter-city bus at country stop	20	2
School bus while moving	150	15
School bus at stops	300	30
Advertising cards	300	30
Back-lighted advertising cards (see Rail conveyances)		
Reading	300[3]	30[3]
Emergency exit (school bus)	50	5
Ships		
Living Areas		
Staterooms and Cabins		
General lighting	100	10
Reading and writing	300[15.3]	30[15.3]
Prolonged seeing	700[16.3]	70[16.3]
Baths (general lighting)	100	10
Mirrors (personal grooming)	500	50
Barber shop and beauty parlor	500	50
On subject	1000	100
Day rooms		
General lighting	200[15]	20[15]
Desks	500[16.3]	50[16.3]
Dining rooms and messrooms	200	20

For footnotes, see page 2-19.

Fig. 2-2. *Continued*

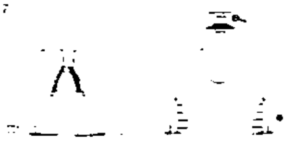
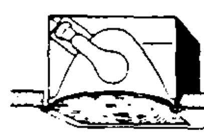
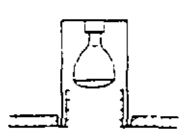
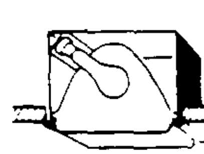
VI. *Continued*

Area/Activity	Lux	Footcandles
Enclosed promenades		
General lighting	100	10
Entrances and passageways		
General	100	10
Daytime embarkation	300	30
Gymnasiums		
General lighting	300	30
Hospital		
Dispensary (general lighting)	300[16]	30[16]
Operating room		
General lighting	500[16]	50[16]
Doctor's office	300[16]	30[16]
Operating table	20000	2000
Wards		
General lighting	100	10
Reading	300	30
Toilets	200	20
Libraries and lounges		
General lighting	200	20
Reading	300[16,3]	30[16,3]
Prolonged seeing	700[16,3]	70[16,3]
Purser's office	200[16]	20[16]
Shopping areas	200	20
Smoking rooms	150	15
Stairs and foyers	200	20
Recreation areas		
Ball rooms	150[15]	15[15]
Cocktail lounges	150[15]	15[16]
Swimming pools		
General	150[15]	15[15]
Underwater		
Outdoors—600 [60] lamp lumens/square meter [foot] of surface area		
Indoors—1000 [100] lamp lumens/square meter [foot] of surface area		
Theatre		
Auditorium		
General	100[15]	10[15]
During picture	1	0.1
Navigating Areas		
Chart room		
General	100	10
On chart table	500[16,3]	50[16,3]
Gyro room	200	20
Radar room	200	20
Radio room	100[16]	10[16]
Radio room, passenger foyer	100	10
Ship's offices		
General	200[16]	20[16]
On desks and work tables	500[16,3]	50[16,3]
Wheelhouse	100	10
Service Areas		
Food preparation		
General	200[16]	20[16]
Butcher shop	200[16]	20[16]
Galley	300[16]	30[16]
Pantry	200[16]	20[16]
Thaw room	200[16]	20[16]
Sculleries	200[16]	20[16]
Food storage (non-refrigerated)	100	10
Refrigerated spaces (ship's stores)	50	5
Laundries		
General	200[16]	20[16]
Machine and press finishing, sorting	500	50
Lockers	50	5
Offices		
General	200	20
Reading	500[16,3]	50[16,3]
Passenger counter	500[16,3]	50[16,3]
Storerooms	50	5
Telephone exchange	200	20
Operating Areas		
Access and casing	100	10
Battery room	100	10
Boiler rooms	200[16]	20[16]
Cargo handling (weather deck)	50[16]	5[16]
Control stations (except navigating areas)		
General		
Control consoles	200	20
Gauge and control boards	300	30
	300	30
Switchboards	300	30
Engine rooms	200[16]	20[16]
Generator and switchboard rooms	200[16]	20[16]
Fan rooms (ventilation & air conditioning)	100	10
Motor rooms	200	20
Motor generator rooms (cargo handling)	100	10
Pump room	100	10
Shaft alley	100	10
Shaft alley escape	30	3
Steering gear room	200	20
Windlass rooms	100	10
Workshops		
General	300[16]	30[16]
On top of work bench	500[16]	50[16]
Tailor shop	500[16]	50[16]
Cargo holds		
Permanent luminaires	30[16]	3[16]
Passageways and trunks	100	10

[1] Include provisions for higher levels for exhibitions.
[2] Specific limits are provided to minimize deterioration effects.
[3] Task subject to veiling reflections. Illuminance listed is not an ESI value. Currently, insufficient experience in the use of ESI target values precludes the direct use of Equivalent Sphere Illumination in the present consensus approach to recommend illuminance values. Equivalent Sphere Illumination may be used as a tool in determining the effectiveness of controlling veiling reflections and as a part of the evaluation of lighting systems.
[4] Illuminance values are listed based on experience and consensus. Values relate to needs during various religious ceremonies.
[5] Degradation factors: Overlays—add 1 weighting factor for each overlay; Used material— [illegible] timate additional factors.

46-

Fig. 9-12. *Continued (see page 9-13 for instructions and notes)*

Typical Luminaire	Maint Cat	SC	Typical Intensity Distribution and Per Cent Lamp Lumens	RCR	ρcc → 80			70			50			30			10			0	WDRC	ρcc → RCR
				ρw →	50	30	10	50	30	10	50	30	10	50	30	10	50	30	10	0		ρw →
				RCR ↓	Coefficients of Utilization for 20 Per Cent Effective Floor Cavity Reflectance (ρfc = 20)																	RCR ↓
7 	IV	0.7	0% ↑  43½% ↓	0	52	52	52	51	51	51	48	48	48	46	46	46	45	45	45	44	—	0
				1	49	48	48	48	48	47	47	46	46	45	45	44	44	43	43	42	036	1
				2	47	46	45	46	45	44	45	44	43	44	43	42	43	42	42	41	034	2
				3	45	44	43	45	43	42	44	42	42	43	42	41	42	41	40	40	033	3
				4	43	42	41	43	41	40	42	41	40	41	40	39	41	40	39	38	032	4
				5	42	40	39	41	40	38	41	[illegible]	38	40	39	38	39	38	35	37	033	5
				6	40	39	37	40	38	37	39	[illegible]	37	39	38	37	38	37	36	36	032	6
EAR-38 lamp above 51 mm (2") diameter aperture (increase efficiency to 54½% for 76 mm (3") diameter aperture)*				7	39	37	36	39	37	36	38	37	35	38	36	35	37	36	35	35	032	7
				8	37	36	34	37	35	34	37	35	34	36	35	34	36	35	34	33	032	8
				9	36	34	33	36	34	33	35	34	33	35	34	33	35	33	33	32	032	9
				10	35	33	32	35	33	32	34	33	32	34	33	32	34	32	31	31	032	10
8 	V	1.0	0% ↑  54½% ↓	0	65	65	65	63	63	63	60	60	60	58	58	58	55	55	55	54	—	0
				1	60	58	57	58	57	56	56	55	54	54	53	52	52	52	51	50	112	1
				2	55	53	51	54	52	50	52	50	49	51	49	48	49	48	47	46	106	2
				3	51	48	46	50	47	45	49	46	44	47	45	44	46	44	43	42	102	3
				4	47	44	41	47	44	41	45	43	41	44	42	40	43	41	40	39	097	4
				5	44	40	38	43	40	38	42	39	37	41	39	37	40	38	37	36	093	5
				6	41	37	35	40	37	35	39	36	34	39	36	34	38	36	34	33	089	6
				7	38	34	32	37	34	32	37	34	31	36	33	31	35	33	31	30	086	7
				8	35	32	29	35	31	29	34	31	29	34	31	29	33	30	29	28	083	8
Medium distribution unit with lens plate and inside frost lamp				9	33	29	27	32	29	27	32	29	26	31	28	25	31	28	26	25	080	9
				10	30	27	25	30	27	24	30	27	24	29	26	24	29	26	24	23	077	10
9 	IV	0.5	0% ↑  68½% ↓	0	82	82	82	80	80	80	76	76	76	73	73	73	70	70	70	69	—	0
				1	75	77	75	77	76	75	74	74	73	72	71	71	69	69	69	68	028	1
				2	76	74	73	75	73	72	73	71	70	71	70	69	69	68	67	67	027	2
				3	74	72	70	73	71	70	71	70	69	70	69	68	68	67	67	66	024	3
				4	72	70	68	71	69	68	70	68	67	69	67	66	67	66	66	65	024	4
				5	70	68	66	69	67	66	68	67	65	67	66	65	67	65	64	64	025	5
				6	69	66	65	68	66	65	67	66	64	67	65	64	66	65	64	63	024	6
				7	67	65	63	67	65	63	66	64	63	65	64	63	65	64	62	62	024	7
Recessed baffled downlight, 140 mm (5½") diameter aperture—150-PAR/FL lamp				8	66	64	62	65	63	62	65	63	62	64	63	62	64	62	61	61	024	8
				9	65	63	61	64	62	61	64	62	61	63	62	61	63	62	61	60	024	9
				10	63	61	60	63	61	60	63	61	60	62	61	60	62	61	60	59	024	10
10 	IV	0.5	0% ↑  85% ↓	0	101	101	101	99	99	99	95	95	95	91	91	91	87	87	87	85	—	0
				1	97	95	94	95	94	92	92	91	90	88	88	87	86	85	84	83	053	1
				2	93	91	89	91	89	88	89	87	86	86	85	84	84	83	82	81	051	2
				3	90	87	85	89	86	84	87	85	83	85	83	82	83	82	81	79	048	3
				4	87	84	82	86	83	81	84	82	80	83	81	79	81	80	79	78	048	4
				5	84	81	79	83	80	78	82	79	78	81	79	77	80	78	76	75	049	5
				6	82	79	76	81	78	75	80	78	76	79	77	75	78	76	75	74	047	6
				7	79	76	74	79	76	74	78	75	73	77	75	73	76	74	73	72	047	7
Recessed baffled downlight, 140 mm (5½") diameter aperture—75ER30 lamp				8	77	74	72	77	74	72	76	73	71	75	73	71	75	72	71	70	047	8
				9	75	72	70	75	72	70	74	71	69	73	71	69	73	71	69	68	047	9
				10	73	70	68	73	70	68	72	69	68	72	69	67	71	69	67	67	046	10
11 	V	1.4	0% ↑  53½% ↓	0	63	63	63	62	62	62	59	59	59	57	57	57	54	54	54	53	—	0
				1	58	56	54	57	55	54	54	53	52	52	51	50	50	50	49	48	135	1
				2	53	50	48	52	49	47	50	48	46	48	47	45	47	45	44	43	[illegible]	2
				3	48	45	42	47	44	42	46	43	41	44	42	40	43	41	40	39	122	3
				4	44	40	37	43	40	37	42	39	37	41	38	36	40	37	36	35	116	4
				5	40	36	33	39	36	33	38	35	33	37	35	32	36	34	32	31	111	5
				6	36	32	30	36	32	29	35	32	29	34	31	29	33	31	29	28	106	6
				7	33	29	26	33	29	26	32	28	26	31	28	26	30	28	26	25	102	7
				8	30	26	23	30	26	23	29	26	23	28	25	23	28	25	23	22	098	8
Wide distribution unit with lens plate and inside frost lamp				9	27	23	21	27	23	21	26	23	21	26	23	20	25	22	20	19	094	9
				10	25	21	18	25	21	18	24	21	18	24	20	18	23	20	18	17	090	10
12 	V	1.3	1½% ↑  50½% ↓	0	62	62	62	60	60	60	57	57	57	54	54	54	52	52	52	51	—	0
				1	53	51	48	52	49	47	49	47	46	47	45	44	45	43	42	41	234	1
				2	46	42	39	45	42	39	43	40	38	41	39	36	39	37	35	34	204	2
				3	40	36	33	40	35	32	38	34	31	36	33	31	35	32	30	29	182	3
				4	36	31	28	35	31	28	34	30	27	32	29	26	31	28	26	25	161	4
				5	32	27	24	31	27	24	30	26	23	29	25	23	28	25	22	21	147	5
				6	29	24	20	28	24	20	27	23	20	26	22	20	25	22	19	18	134	6
				7	26	21	18	25	21	18	24	20	17	23	20	17	22	19	17	16	124	7
				8	23	19	16	23	18	15	22	18	15	21	18	15	20	17	15	14	115	8
Recessed unit with dropped diffusing glass				9	21	17	14	21	16	14	20	16	13	19	16	13	19	15	13	12	107	9
				10	19	15	12	19	15	12	18	14	12	18	14	12	17	14	12	11	100	10

* Also, reflector downlight with baffles and inside frosted lamp.

47

Fig. 9-12. *Continued (see page 9-13 for instructions and notes)*

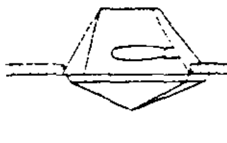
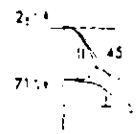
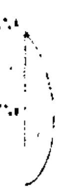
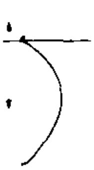
Typical Luminaire	Typical Intensity Distribution and Per Cent Lamp Lumens — Maint. Cat.	SC	ρcc →	80			70			50			30			10			0	WDRC ρcc →	
			ρw →	50	30	10	50	30	10	50	30	10	50	30	10	50	30	10	0		
			RCR ↓	Coefficients of Utilization for 20 Per Cent Effective Floor Cavity Reflectance (ρfc = 20)																	RCR
13	V	N.A.	0	87	87	87	85	85	85	80	80	80	76	76	76	73	73	[illegible]	71	—	0
	2½% ↑ 		1	76	73	72	74	71	69	71	68	66	67	65	64	64	63	61	60	237	1
	71½% ↓		2	67	62	58	66	61	57	63	59	56	60	57	54	57	55	53	51	252	2
	45		3	59	54	49	58	53	48	56	51	47	53	49	46	51	47	45	43	230	3
			4	53	47	42	52	46	42	50	45	41	48	44	40	46	42	39	38	209	4
			5	47	41	36	46	40	36	44	39	35	43	38	35	41	37	34	32	193	5
			6	42	36	31	41	35	31	40	34	30	38	33	30	37	33	29	27	180	6
			7	37	31	26	37	[illegible]	26	35	30	26	34	29	25	33	28	25	24	170	7
			8	34	27	23	33	27	23	32	26	22	31	26	22	30	25	22	[illegible]	158	8
Bilateral batwing distribution—clear HID with dropped prismatic lens			9	30	24	20	29	24	20	28	23	19	27	23	19	27	22	19	17	149	9
			10	27	21	17	27	21	17	26	20	17	25	20	17	24	19	16	15	140	10
14	V	1.3	0	78	78	78	77	77	77	73	73	73	70	70	70	67	67	67	66	—	0
	0% ↑ 		1	71	69	67	71	68	66	67	66	64	65	64	62	62	61	61	59	166	1
	66% ↓		2	65	61	58	64	61	58	62	59	57	60	58	56	58	56	55	54	155	2
			3	59	55	52	58	55	52	57	53	51	55	52	50	53	51	49	48	149	3
			4	54	50	47	54	49	46	52	49	46	51	48	45	49	47	45	43	141	4
			5	50	45	42	49	45	41	48	44	41	47	43	41	46	[illegible]	40	39	134	5
			6	46	41	37	45	40	37	44	40	37	43	39	37	42	[illegible]	36	35	128	6
			7	41	37	33	41	36	33	40	36	33	39	35	33	38	35	32	31	123	7
			8	38	33	30	38	33	30	37	33	30	36	32	29	35	32	29	28	118	8
Clear HID lamp and glass refractor above plastic lens panel			9	35	30	27	34	30	27	34	29	26	33	29	26	32	29	26	25	113	9
			10	33	27	24	31	27	24	31	27	24	30	26	24	30	26	23	22	109	10
15	V	1.4	0	85	85	85	83	83	83	80	80	80	76	76	76	73	73	73	72	—	0
	0% ↑ 		1	79	76	74	78	74	73	73	72	70	71	69	68	68	67	66	65	167	1
	71½% ↓		2	71	68	65	70	67	64	68	65	63	65	63	61	63	62	60	59	159	2
			3	65	61	57	64	60	57	62	59	56	60	57	55	59	55	54	53	156	3
			4	60	55	51	59	54	51	57	53	50	55	52	50	54	51	49	48	149	4
			5	54	49	45	54	49	45	52	48	45	51	47	44	50	46	44	43	144	5
			6	49	44	40	49	44	40	48	43	40	46	42	40	45	42	39	38	140	6
			7	44	39	35	44	39	35	43	38	35	42	38	35	41	37	35	33	137	7
			8	40	35	31	40	35	31	39	35	31	38	34	31	38	34	31	30	131	8
Enclosed reflector with an incandescent lamp			9	37	31	28	36	31	28	36	31	28	35	31	28	34	30	27	26	126	9
			10	33	28	25	33	29	25	32	26	25	32	26	25	31	27	24	23	121	10
16	III	0.7	0	93	93	93	90	90	90	86	86	86	82	82	82	78	78	78	77	—	0
	1½% ↑ 		1	87	85	83	85	83	82	81	80	79	78	77	76	75	75	74	72	107	1
	77% ↓		2	81	79	76	80	77	75	77	75	73	75	73	72	72	71	70	69	101	2
			3	77	73	71	76	72	70	73	71	69	71	69	67	70	69	66	65	098	3
			4	73	69	66	72	68	66	70	67	64	68	66	64	67	65	63	62	094	4
			5	69	65	62	68	64	61	66	63	61	65	63	61	64	61	59	58	093	5
			6	66	61	58	64	61	58	63	60	57	62	59	57	61	58	56	55	089	6
			7	62	57	54	61	57	54	60	56	54	59	56	53	58	55	53	52	086	7
			8	58	54	51	58	54	51	57	53	51	56	53	51	55	52	50	49	086	8
High bay, narrow distribution ventilated reflector with clear HID lamp			9	55	51	48	55	51	48	54	50	48	53	50	46	53	50	48	47	084	9
			10	53	49	46	52	48	46	52	48	46	51	48	45	50	47	45	44	081	10
17	III	1.0	0	91	91	91	89	89	89	85	85	85	81	81	81	78	78	78	76	—	0
	1% ↑ 		1	84	82	80	82	80	78	79	77	76	76	74	73	73	72	71	69	163	1
	76% ↓		2	77	73	70	76	72	70	73	70	68	70	68	66	68	66	65	63	158	2
			3	71	66	63	69	65	62	67	64	61	65	62	60	63	61	59	57	154	3
			4	65	60	56	64	59	56	62	58	55	60	57	54	59	56	54	52	148	4
			5	59	54	50	59	54	50	57	53	50	56	52	49	54	51	48	47	144	5
			6	54	49	45	54	49	45	52	48	45	51	47	44	50	47	44	42	139	6
			7	50	44	40	49	44	40	48	43	40	47	43	39	46	42	39	38	136	7
High bay, intermediate distribution ventilated reflector with clear HID lamp			8	45	40	36	45	40	36	44	39	36	43	39	35	42	38	35	34	131	8
			9	41	36	32	41	36	32	40	35	32	39	35	32	38	35	32	30	127	9
			10	36	33	29	37	32	29	37	32	29	36	32	29	35	31	28	27	122	10
18	III	1.5	0	93	93	93	91	91	91	87	87	87	83	83	83	79	79	79	78	—	0
	1½% ↑ 		1	85	82	80	83	81	79	79	78	76	76	75	74	74	72	71	70	194	1
	77½% ↓		2	77	73	70	76	72	69	73	70	67	72	69	66	68	66	64	63	187	2
			3	70	65	61	68	64	60	66	62	59	64	61	58	62	59	57	56	164	3
			4	63	58	53	62	57	53	60	56	52	58	55	52	57	54	51	49	[illegible]	4
			5	57	51	47	56	51	47	55	50	46	53	49	46	52	48	45	44	[illegible]	5
			6	51	45	41	51	45	41	49	44	40	48	43	40	47	43	40	38	164	6
			7	46	40	35	45	39	35	44	39	35	43	38	35	42	38	34	33	159	7
			8	41	35	31	41	35	31	40	34	31	39	34	30	36	33	30	29	152	8
High bay, wide distribution ventilated reflector with clear HID lamp			9	37	31	27	37	31	27	36	30	27	35	30	27	34	30	26	25	146	9
			10	33	28	24	33	27	23	32	27	23	31	27	23	31	26	23	22	140	10

Fig. 9-12. *Continued (see page 9-13 for instructions and notes)*

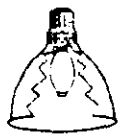
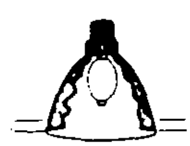
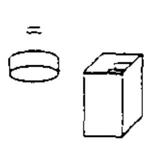
Typical Luminaire	Typical Intensity Distribution and Per Cent Lamp Lumens	Maint. Cat.	SC	RCR	ρCC → 80			70			50			30			10			0	WDRC	RCR
				ρW →	50	30	10	50	30	10	50	30	10	50	30	10	50	30	10	0		
					Coefficients of Utilization for 20 Per Cent Effective Floor Cavity Reflectance (ρFC = 20)																	
19  High bay—intermediate distribution ventilated reflector with phosphor coated HID lamp	6½% ↑ 75½% ↓	III	1.0	0	96	96	96	93	93	93	88	88	88	83	83	8[illegible]	78	7[illegible]	78	76	—	0
				1	89	87	84	86	84	83	83	80	79	78	76	75	74	72	70	70		1
				2	8[illegible]	79	76	80	77	74	76	74	72	7[illegible]	7[illegible]	69	70	68	67	64		2
				3	76	72	68	74	70	67	7[illegible]	68	65	64	66	[illegible]	66	62	62	60	[illegible]	3
				4	70	66	62	69	65	61	66	63	60	64	61	59	62	59	5[illegible]	[illegible]	1[illegible]	4
				5	65	60	56	64	59	56	62	58	54	[illegible]	58	5[illegible]	54	5[illegible]	52	[illegible]	1[illegible]	5
				6	61	55	[illegible]	59	55	51	57	53	51	[illegible]	52	44	54	5[illegible]	48	47	1[illegible]	6
				7	56	50	[illegible]	[illegible]	50	46	53	49	46	50	48	4[illegible]	51	47	44	41	1[illegible]	7
				8	52	47	[illegible]	[illegible]	46	41	50	45	42	46	44	41	47	43	41	4[illegible]	1[illegible]	8
				9	48	43	[illegible]	47	40	39	46	42	39	45	41	38	44	40	38	36	1[illegible]	9
				10	45	40	36	44	39	36	43	39	36	41	38	35	41	37	35	34	1[illegible]	10
20  High bay—wide distribution ventilated reflector with phosphor coated HID lamp	12% ↑ 69½% ↓	III	1.5	0	93	93	93	90	90	90	83	83	83	77	77	77	72	72	72	69	—	0
				1	85	83	81	82	80	78	77	75	74	72	71	69	[illegible]	66	66	62	146	1
				2	78	74	71	76	72	69	71	68	66	67	64	62	[illegible]	61	60	58	135	2
				3	71	67	63	69	65	62	66	62	59	62	59	57	56	56	54	5[illegible]	127	3
				4	65	60	56	64	59	55	60	56	53	57	54	51	54	50	50	45	132	4
				5	60	54	50	58	53	49	55	51	48	51	49	46	50	47	45	43	129	5
				6	54	49	45	53	49	44	51	46	[illegible]	46	45	42	46	43	40	38	125	6
				7	49	44	40	48	43	39	46	41	[illegible]	44	40	37	40	39	36	34	12[illegible]	7
				8	45	39	35	44	38	35	42	37	34	41	36	33	38	35	32	31	12[illegible]	8
				9	41	35	31	40	34	31	38	33	32	36	32	28	[illegible]	31	28	27	11[illegible]	9
				10	37	31	27	36	31	27	34	30	26	33	29	26	[illegible]	26	26	24	113	10
21  Low bay—rectangular pattern, lensed bottom reflector unit with clear HID lamp	0% ↑ 66½% ↓ 45	V	1.6	0	82	82	82	80	80	80	76	76	76	73	73	73	70	70	70	68	—	0
				1	73	71	69	72	69	67	69	67	65	66	65	63	64	61	61	60	209	1
				2	66	62	58	64	61	58	62	59	56	60	57	55	58	57	54	53	199	2
				3	58	54	50	57	53	49	55	52	48	54	50	48	52	49	47	46	192	3
				4	52	47	43	51	46	43	50	45	40	48	45	42	47	44	41	40	181	4
				5	47	41	37	46	41	37	45	40	36	43	39	36	42	36	36	34	1[illegible]	5
				6	42	36	32	41	36	32	40	35	31	39	34	31	35	34	31	29	1[illegible]	6
				7	37	31	27	36	31	27	35	30	27	34	30	26	33	29	26	26	1[illegible]	7
				8	33	27	23	32	27	23	31	26	23	31	26	23	30	26	23	21	14[illegible]	8
				9	29	24	20	29	23	20	28	23	20	27	23	19	27	22	19	16	14[illegible]	9
				10	26	20	17	26	20	17	25	20	17	24	20	17	24	20	17	14	1[illegible]	10
22  Low bay—lensed bottom reflector unit with clear HID lamp	3% ↑ 68% ↓	V	1.9	0	83	83	83	81	81	81	77	77	77	73	73	73	70	70	70	68	—	0
				1	73	70	67	71	68	66	67	65	63	64	62	61	61	[illegible]	58	57	2[illegible]	1
				2	64	59	55	63	58	54	59	56	52	57	54	51	54	52	49	48	2[illegible]	2
				3	56	50	45	54	49	45	52	47	44	51	46	43	47	44	42	41	2[illegible]	3
				4	49	43	38	48	42	38	46	41	37	44	40	36	40	39	36	34	2[illegible]	4
				5	43	37	32	42	36	32	41	35	31	39	34	31	37	33	32	29	19[illegible]	5
				6	38	32	27	37	31	27	36	30	26	34	30	26	33	29	28	24	183	6
				7	34	27	23	33	27	22	31	26	22	32	25	22	29	25	21	21	17[illegible]	7
				8	30	24	19	29	23	19	28	23	19	27	22	19	26	22	18	17	159	8
				9	27	21	16	26	20	16	25	20	16	24	19	16	23	19	18	14	149	9
				10	24	18	14	24	18	14	23	17	14	22	17	14	21	17	13	12	139	10
23  Wide spread, recessed, small open bottom reflector with low wattage diffuse HID lamp	0% ↑ 56½% ↓	IV	1.7	0	67	67	67	65	65	65	62	62	62	60	60	60	57	57	57	56	—	0
				1	60	58	57	59	57	56	57	55	54	54	53	52	52	52	51	50	159	1
				2	54	51	48	53	50	45	51	49	47	49	47	46	48	46	45	44	155	2
				3	48	44	41	47	44	41	46	43	40	44	42	40	43	41	39	38	152	3
				4	43	39	36	42	38	35	41	35	35	42	37	34	39	35	34	33	144	4
				5	38	34	30	38	34	30	37	33	30	38	32	30	35	32	29	28	138	5
				6	34	30	26	34	29	26	32	29	26	32	28	26	31	28	26	24	130	6
				7	30	26		30	25	22	29	25	22	28	25	22	27	24	22	21	126	7
				8	27	23		27	22	19	26	22	19	25	22	19	25	21	19	18	119	8
				9	24	20	17	24	20	17	23	19	17	23	19	16	22	19	16	15	113	9
				10	22	17	14	22	17	14	21	17	14	21	17	14	20	17	14	13	107	10
24  Open top, indirect, reflector type unit with HID lamp (mult. by 0.9 for lens top)	78½% ↑ 0% ↓	VI	N.A.	0	74	74	74	63	63	63	43	43	43	25	25	25	08	08	08	00	—	0
				1	64	62	59	55	53	51	36	36	35	22	21	20	07	07	07	00	000	1
				2	56	52	48	45	45	42	33	31	29	19	18	17	06	06	05	00	000	2
				3	49	44	40	42	38	35	29	26	24	17	15	14	05	05	05	00	000	3
				4	43	38	33	37	33	29	26	23	20	15	13	12	05	04	04	00	000	4
				5	38	33	28	33	28	25	23	20	17	13	12	10	04	04	03	00	000	5
				6	34	28	24	29	25	21	20	17	15	12	10	09	04	03	03	00	000	6
				7	31	25	21	26	22	18	18	15	13	11	09	08	03	03	03	00	000	7
				8	28	22	18	24	19	16	16	13	11	10	08	07	03	03	02	00	000	8
				9	25	20	16	21	17	14	15	12	10	09	07	06	03	02	02	00	000	9
				10	23	18	14	20	15	12	14	11	09	08	06	05	03	02	02	00	000	10

Fig. 9–12. *Continued (see page 9-13 for instructions and notes)*

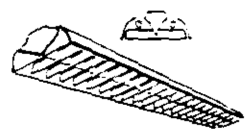
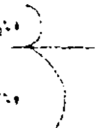
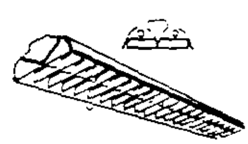
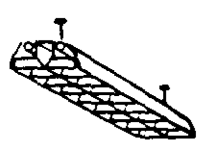
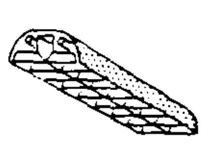
Typical Luminaire	Typical Intensity Distribution and Per Cent Lamp Lumens	Maint Cat	SC	RCR ↓ \ ρCC → 80: ρW → 50	80: 30	80: 10	70: 50	70: 30	70: 10	50: 50	50: 30	50: 10	30: 50	30: 30	30: 10	10: 50	10: 30	10: 10	0: 0	WDRC	RCR
				Coefficients of Utilization for 20 Per Cent Effective Floor Cavity Reflectance (ρ_{FC} = 20)																	
25		II	1.3	0	99	99	99	94	94	94	85	85	85	77	77	77	69	69	69	66	—	0
				1	88	85	80	84	81	79	76	74	72	69	67	66	62	61	60	57	214	1
	22½%↑ 			2	79	73	69	74	70	66	65	64	61	60	59	56	56	54	52	49	201	2
				3	[illegible]	63	58	67	61	57	61	56	53	56	52	49	51	48	46	43	186	3
				4	62	55	50	60	53	49	55	50	46	50	46	43	46	43	40	37	173	4
	65%↓			5	55	48	43	53	47	42	49	44	39	45	41	37	41	38	35	32	164	5
				6	50	43	38	48	41	37	44	39	35	41	36	33	37	34	31	29	153	6
				7	45	38	33	43	37	30	40	34	30	37	32	29	34	30	27	25	143	7
				8	[illegible]	34	29	39	32	28	36	30	27	33	28	26	31	27	24	22	136	8
Porcelain-enameled reflector with				9	[illegible]	30	25	35	29	24	32	27	23	30	25	22	28	24	21	19	129	9
35°CW shielding				10	33	[illegible]	22	32	25	22	29	24	20	27	23	19	25	21	18	17	121	10
26		II	1.5/1.3	0	95	95	95	91	91	91	83	83	83	76	76	76	69	69	69	66	—	0
				1	85	82	80	82	79	77	75	73	72	69	68	66	64	63	62	59	180	1
	17%↑ 			2	76	70	66	74	70	66	68	65	62	63	61	58	58	56	55	52	174	2
				3	69	63	59	66	61	57	62	58	54	57	54	51	53	51	48	46	166	3
				4	62	56	51	60	54	50	56	51	47	52	48	45	48	45	43	41	159	4
				5	55	49	44	53	48	43	50	45	41	47	43	39	44	40	38	36	153	5
	66%↓			6	50	43	39	48	42	38	45	40	36	42	38	35	40	36	33	31	145	6
				7	45	38	34	43	37	33	41	36	32	38	34	30	36	32	29	27	138	7
				8	40	34	29	39	33	29	37	31	28	34	30	26	32	28	25	24	133	8
Diffuse aluminum reflector with				9	36	30	25	35	29	25	33	28	24	31	26	23	29	25	22	20	127	9
35°CW shielding				10	33	26	22	32	26	22	30	25	21	28	23	20	26	22	19	18	121	10
27		II	1.0	0	91	91	91	86	86	86	77	77	77	68	68	68	61	61	61	57	—	0
				1	81	78	76	77	74	72	69	67	66	62	61	59	56	55	54	51	164	1
	23½%↑ 			2	72	68	64	69	65	61	62	59	57	56	54	52	51	49	47	45	158	2
				3	65	59	55	62	57	53	56	52	49	51	48	45	46	44	42	39	148	3
				4	58	52	45	56	50	46	51	46	43	46	43	40	42	39	37	35	140	4
	57%↓			5	52	46	41	50	44	40	46	41	37	42	38	35	38	35	33	30	134	5
				6	47	41	36	45	39	35	41	37	33	38	34	31	35	31	29	27	126	6
				7	43	36	32	41	35	31	38	33	29	34	30	27	32	29	26	24	[illegible]	7
				8	38	32	28	37	31	27	34	29	26	31	[illegible]	24	29	25	23	21	[illegible]	8
Porcelain-enameled reflector with				9	35	29	24	33	28	24	31	26	22	28	24	21	26	22	20	18	[illegible]	9
30°CW × 30°LW shielding				10	32	26	22	30	25	21	28	23	20	26	22	19	24	20	18	16	[illegible]	10
28		II	1.5/1.1	0	83	83	83	79	79	79	72	72	72	65	65	65	59	59	59	56	—	0
				1	75	72	70	72	69	67	65	64	62	60	59	58	55	54	53	50	146	1
	17½%↑ 			2	67	62	60	65	61	58	59	57	54	55	53	51	50	49	47	45	141	2
				3	61	56	52	58	54	51	54	50	48	50	47	45	46	44	42	40	135	3
				4	55	49	45	53	48	44	49	45	42	45	42	40	42	39	37	36	130	4
				5	49	44	40	47	42	39	44	40	37	41	38	35	38	35	33	31	125	5
	56½%↓			6	45	39	35	43	38	34	40	36	33	37	34	31	35	32	30	29	118	6
				7	40	35	31	39	34	30	36	32	29	34	30	27	32	29	26	25	113	7
				8	36	31	27	35	30	26	33	28	25	31	27	24	29	25	23	21	109	8
Diffuse aluminum reflector with 35°CW				9	33	27	23	32	26	23	29	25	22	28	24	21	26	20	20	19	104	9
× 35°LW shielding				10	30	24	21	29	24	20	27	22	19	25	21	19	23	20	18	16	099	10
29		II	1.1	0	75	75	75	69	69	69	57	57	57	46	46	46	37	37	37	32	—	0
				1	67	64	62	61	59	57	51	50	49	42	41	40	34	33	32	29	084	1
	39%↑ 			2	59	55	52	55	51	49	46	44	42	38	36	35	31	30	29	25	082	2
				3	53	46	45	49	45	42	41	39	36	35	32	31	28	27	26	23	077	3
				4	47	42	39	44	40	36	37	34	32	31	29	27	26	24	23	20	073	4
				5	43	37	33	40	35	31	34	30	28	28	26	24	23	22	20	18	070	5
				6	39	33	29	36	31	28	31	27	25	26	23	21	22	20	18	16	065	6
	32%↓			7	35	30	26	33	28	25	28	24	22	24	21	19	20	18	16	15	062	7
				8	32	26	23	30	25	22	25	22	19	22	19	17	18	16	15	13	059	8
Metal or dense diffusing sides with				9	29	24	20	27	22	19	23	20	17	20	17	15	16	15	13	12	057	9
45°CW × 45°LW shielding				10	26	21	18	25	20	17	21	18	15	18	15	14	15	13	12	10	054	10
30		IV	1.0	0	61	61	61	58	58	58	55	55	55	51	51	51	48	46	45	46	—	0
	6%↑ 			1	54	52	51	52	51	49	49	48	47	46	45	44	43	43	42	40	143	1
				2	48	46	43	47	44	42	44	42	40	42	40	38	39	38	37	35	133	2
				3	44	40	37	43	39	37	40	38	35	38	36	34	36	34	33	31	122	3
				4	41	36	33	39	35	32	37	34	31	35	32	30	33	31	29	28	113	4
				5	36	32	29	35	31	28	33	30	28	32	29	27	30	28	26	25	106	5
	46%↓			6	33	29	26	32	28	25	30	27	25	29	26	24	28	25	23	22	099	6
				7	30	26	23	29	25	23	28	25	22	27	24	22	25	23	21	20	093	7
				8	27	23	20	27	23	20	25	22	20	24	21	19	23	21	19	18	088	8
Same as unit #29 except with top re-				9	25	21	18	24	21	18	23	20	18	22	19	17	21	19	17	16	084	9
flectors				10	23	19	16	22	19	16	21	18	16	20	18	16	20	17	15	14	079	10

Fig. 9-12. Continued (see page 9-13 for instructions and notes)

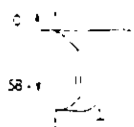
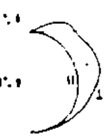
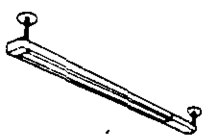
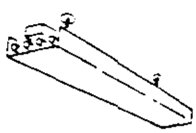
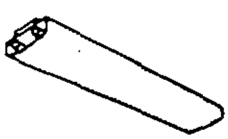
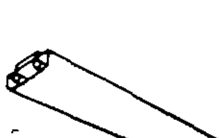
Typical Luminaire	Typical Intensity Distribution and Per Cent Lamp Lumens — Maint. Cat.	SC		RCR ↓ (ρcc →)	80			70			50			30			10			0	WDRC	RCR ↓
				ρw →	50	30	10	50	30	10	50	30	10	50	30	10	50	30	10	0		
					Coefficients of Utilization for 20 Per Cent Effective Floor Cavity Reflectance (ρfc = 20)																	
31  150 mm × 150 mm (6" × 6") cell parabolic wedge louver (multiply by 1.1 for 250 × 250 mm (10 × 10") cells)	IV	1.5/1.2	0 ↑ 58 ↓ 	0	69	69	69	67	67	67	64	64	64	62	62	62	59	59	59	58	—	0
				1	63	61	59	60	60	58	59	58	57	57	56	55	55	54	53	52	146	1
				2	57	54	52	56	53	51	54	52	50	52	50	49	51	49	48	47	140	2
				3	52	48	45	51	47	45	49	46	44	46	45	43	46	44	42	41	139	3
				4	47	42	39	46	42	39	44	41	38	43	40	38	42	40	38	36	135	4
				5	42	37	34	41	37	34	40	36	34	39	36	33	38	35	33	32	131	5
				6	38	33	30	37	33	30	36	32	29	35	32	29	34	31	29	28	126	6
				7	34	29	26	33	29	26	32	29	26	32	28	26	31	29	26	24	120	7
				8	30	26	22	30	25	22	29	25	22	28	25	22	25	24	22	21	115	8
				9	27	22	19	27	22	19	26	22	19	25	22	19	25	21	19	18	110	9
				10	24	20	17	24	20	17	23	19	17	23	19	17	22	19	17	16	106	10
32  2 lamp surface mounted bare lamp unit—Photometry with 460 mm (18") wide panel above luminaire (lamps on 150 mm (6") centers)	I	1.3	9½ ↑ 78 ↓ 	0	102	102	102	99	99	99	92	92	92	86	86	86	81	81	81	78	—	0
				1	86	82	78	83	79	75	76	74	71	73	70	67	68	66	64	61	426	1
				2	74	67	61	71	65	60	66	61	57	62	58	54	56	55	52	49	365	2
				3	64	56	50	62	55	49	58	52	47	54	49	45	51	47	43	41	313	3
				4	56	48	42	55	47	41	51	45	39	48	42	38	45	40	36	34	276	4
				5	49	41	35	48	40	34	45	38	33	42	36	32	39	34	30	28	250	5
				6	44	36	30	43	35	29	40	33	28	38	32	27	35	30	26	24	226	6
				7	39	31	25	38	30	25	36	29	24	34	28	23	32	27	23	21	206	7
				8	35	27	22	34	27	22	32	26	21	30	24	20	29	23	19	18	190	8
				9	32	24	19	31	23	19	29	22	18	27	21	17	26	20	17	15	176	9
				10	29	21	17	28	21	16	26	20	16	25	19	16	23	18	15	13	163	10
33  Luminous bottom suspended unit with extra-high output lamp	VI	N.A.	66 ↑ 12 ↓ 	0	77	77	77	66	66	66	50	50	50	34	34	34	19	19	19	12	—	0
				1	67	64	62	59	57	54	44	42	41	30	29	28	17	16	16	10	043	1
				2	59	54	50	52	48	45	38	36	34	26	25	23	15	14	13	09	041	2
				3	51	46	42	45	41	37	34	31	28	23	21	20	13	12	12	07	037	3
				4	45	40	35	40	35	31	30	27	24	20	18	17	12	11	10	06	035	4
				5	40	34	30	35	30	27	26	23	20	18	16	14	10	09	08	05	032	5
				6	36	30	26	32	27	23	24	20	18	16	14	12	09	08	07	05	030	6
				7	32	26	22	28	23	20	21	18	15	15	12	11	08	07	06	04	028	7
				8	29	23	19	25	21	17	19	16	13	13	11	09	08	06	06	03	026	8
				9	26	20	17	23	18	15	17	14	12	12	10	08	07	06	05	03	025	9
				10	24	18	15	21	16	13	16	12	10	11	09	07	06	05	04	03	023	10
34  Prismatic bottom and sides, open top, 4 lamp suspended unit—see note 7	VI	1.4/1.2	33 ↑ 50 ↓ 	0	91	91	91	85	85	85	74	74	74	64	64	64	54	54	54	50	—	0
				1	80	77	74	75	73	70	66	64	62	57	55	54	49	48	47	43	163	1
				2	71	66	62	67	63	59	59	56	53	51	49	47	44	43	41	39	151	2
				3	63	58	53	60	55	50	53	49	45	46	43	41	40	38	36	33	140	3
				4	57	50	45	53	48	43	47	43	39	41	38	35	36	34	32	29	131	4
				5	50	44	39	48	42	37	42	38	34	37	34	31	33	30	28	25	124	5
				6	45	39	34	43	37	33	38	33	30	34	30	27	30	27	24	22	116	6
				7	41	34	30	39	33	28	34	30	26	30	27	24	27	24	21	19	109	7
				8	37	30	26	35	29	25	31	26	23	27	24	21	24	21	19	17	103	8
				9	33	27	22	31	26	22	28	23	20	25	21	19	22	19	16	15	098	9
				10	30	24	20	28	23	19	25	21	18	23	19	16	20	17	14	13	093	10
35  2 lamp prismatic wraparound—see note 7	V	1.5/1.2	11½ ↑ 58½ ↓ 	0	81	81	81	78	78	78	72	72	72	66	66	66	61	61	61	59	—	0
				1	71	69	66	69	66	64	64	62	60	59	58	56	55	54	53	50	204	1
				2	64	59	56	61	58	54	57	54	51	53	51	49	49	48	46	44	184	2
				3	57	52	49	55	50	47	51	48	45	48	45	42	45	42	40	38	168	3
				4	51	46	41	49	44	41	46	42	39	43	40	37	41	38	35	34	156	4
				5	46	40	36	44	39	35	41	37	34	39	35	32	37	33	31	29	147	5
				6	41	35	31	40	35	31	38	33	30	35	31	28	33	30	27	26	137	6
				7	37	31	27	36	31	27	34	29	26	32	29	25	30	27	24	23	129	7
				8	33	28	24	32	27	23	30	26	22	29	25	22	27	24	21	19	122	8
				9	30	24	20	29	24	20	27	23	19	26	22	19	24	21	18	17	116	9
				10	27	22	18	26	21	18	25	20	17	23	19	16	22	18	16	15	110	10
36  2 lamp prismatic wraparound—see note 7	V	1.2	24 ↑ 50 ↓ 	0	82	82	82	77	77	77	[illegible]	69	69	61	61	61	53	53	53	50	—	0
				1	71	68	65	67	65	62	[illegible]	58	56	53	51	50	47	45	44	41	215	1
				2	63	58	54	59	55	52	53	50	47	47	45	42	42	40	38	35	182	2
				3	56	50	46	53	48	44	47	44	40	42	39	37	35	35	33	31	158	3
				4	50	44	40	48	42	38	43	39	35	38	35	32	34	32	29	27	142	4
				5	45	39	34	43	37	33	38	34	31	35	31	28	31	28	25	24	130	5
				6	41	35	30	39	33	29	35	30	27	32	28	25	28	25	23	21	119	6
				7	37	31	27	35	30	26	32	27	24	29	25	22	26	23	20	19	111	7
				8	33	27	23	32	26	23	29	24	21	26	22	20	23	20	18	16	104	8
				9	30	24	20	29	23	20	26	22	19	24	20	17	21	18	16	14	098	9
				10	27	22	18	26	21	18	[illegible]	19	16	22	18	15	19	16	14	13	092	10

Fig. 9-12. *Continued* (see page 9-13 for instructions and notes)

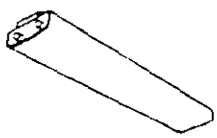
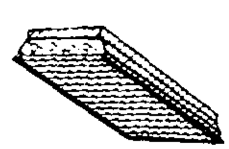
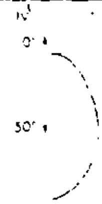
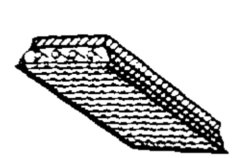
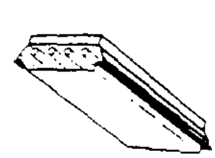
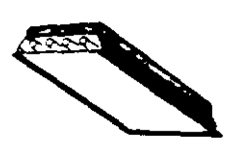
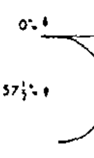
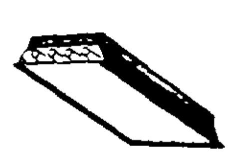
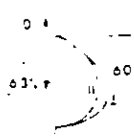
Typical Luminaire	Typical Intensity Distribution and Per Cent Lamp Lumens: Maint Cat	SC	ρcc → / ρw → / RCR ↓	80			70			50			30			10			0	WDRC	ρcc → / ρw → / RCR ↓
				50	30	10	50	30	10	50	30	10	50	30	10	50	30	10	0		
				Coefficients of Utilization for 20 Per Cent Effective Floor Cavity Reflectance (ρfc = 20)																	
37  2 lamp diffuse wraparound—see note 7	V 	1.3	0	52	52	52	50	50	50	46	46	46	43	43	43	39	39	39	36	—	0
			1	45	43	41	43	41	39	40	38	37	36	35	34	34	33	32	30	183	1
			2	39	35	33	37	34	32	34	32	30	32	30	28	29	26	25	25	160	2
			3	34	30	27	33	29	26	30	27	25	28	26	24	26	24	22	21	140	3
			4	30	26	23	29	25	22	27	24	21	25	22	20	23	21	19	18	128	4
			5	26	22	19	25	21	19	23	20	18	22	19	17	20	18	16	15	[illegible]	5
			6	23	19	16	23	19	16	21	18	15	19	17	14	18	16	14	13	[illegible]	6
			7	21	17	14	20	16	14	19	16	13	18	15	13	16	14	12	11	096	7
			8	19	16	12	18	14	12	17	14	11	16	13	11	15	12	10	09	088	8
			9	17	12	10	16	13	10	15	12	10	14	11	09	13	11	09	08	082	9
			10	15	12	09	15	11	09	14	11	09	13	10	08	10	10	08	07	077	10
38  4 lamp 610 mm (2') wide troffer with 45° plastic louver—see note 7	IV 	1.0	0	60	60	60	58	58	58	56	56	56	53	53	53	51	51	51	50	—	0
			1	54	52	50	52	51	49	50	49	46	48	47	46	47	46	45	44	151	1
			2	48	45	43	47	44	42	45	43	41	44	42	40	42	41	39	39	144	2
			3	43	40	37	42	39	37	41	38	36	40	37	36	39	37	35	34	134	3
			4	39	35	32	38	35	32	37	34	32	36	33	31	35	33	31	30	126	4
			5	35	31	28	35	31	28	34	30	28	33	30	28	32	29	27	26	119	5
			6	32	28	25	32	28	25	31	27	25	30	27	25	29	26	24	23	111	6
			7	29	25	22	29	25	22	28	25	22	27	24	22	[illegible]	[illegible]	22	21	104	7
			8	26	22	20	26	22	20	25	22	20	25	22	19	[illegible]	[illegible]	19	18	099	8
			9	24	20	17	24	20	17	23	20	17	23	19	17	22	19	17	16	094	9
			10	22	18	16	22	18	16	21	18	16	21	18	15	20	17	15	15	089	10
39  4 lamp 610 mm (2') wide troffer with 45° white metal louver—see note 7	IV 	0.9	0	55	55	55	54	54	54	51	51	51	49	49	49	47	47	47	46	—	0
			1	50	48	47	49	47	46	47	46	45	45	44	43	43	43	42	41	122	1
			2	45	43	41	44	42	40	43	41	39	41	40	38	40	39	37	37	118	2
			3	41	38	36	40	38	35	39	37	35	38	36	34	37	35	34	33	111	3
			4	37	34	32	37	34	31	36	33	31	35	32	31	34	32	30	29	105	4
			5	34	30	28	33	30	28	32	30	27	32	29	27	31	29	27	26	100	5
			6	31	28	25	31	27	25	30	27	25	29	27	25	29	26	24	24	094	6
			7	29	25	23	28	25	23	28	25	23	27	24	22	26	24	22	21	088	7
			8	26	23	20	26	23	20	25	22	20	25	22	20	24	22	20	19	084	8
			9	24	20	18	24	20	18	23	20	18	23	20	18	22	20	18	17	081	9
			10	22	19	16	22	19	16	21	18	16	21	18	16	20	18	16	[illegible]	077	10
40  Fluorescent unit dropped diffuser, 4 lamp 610 mm (2') wide—see note 7	V 	1.2	0	73	73	73	71	71	71	68	68	68	65	65	65	62	62	62	61	—	0
			1	64	61	59	62	60	58	60	58	56	57	56	54	55	54	52	51	234	1
			2	56	52	49	55	51	48	52	49	47	50	48	46	48	46	44	43	217	2
			3	50	45	41	49	44	41	47	43	40	45	42	39	43	41	38	37	196	3
			4	44	39	35	43	38	35	42	37	34	40	36	33	39	36	33	32	182	4
			5	39	34	30	38	33	29	37	32	29	36	32	29	34	31	28	27	168	5
			6	35	30	26	34	29	25	33	29	25	32	28	25	31	27	25	23	155	6
			7	31	26	22	31	26	22	30	25	22	29	25	22	28	24	22	20	143	7
			8	28	23	19	28	23	19	27	22	19	26	22	19	25	22	19	18	134	8
			9	25	20	17	25	20	17	24	20	17	23	19	16	23	19	16	15	126	9
			10	23	18	15	23	18	15	22	18	15	[illegible]	[illegible]	15	21	17	14	13	115	10
41  Fluorescent unit with flat bottom diffuser, 4 lamp 610 mm (2') wide—see note 7	V 	1.2	0	69	69	69	67	67	67	64	64	64	61	61	61	59	59	59	58	—	0
			1	61	58	56	59	57	56	57	55	54	55	53	52	53	52	51	49	204	1
			2	53	50	47	52	49	46	50	48	45	49	46	44	47	45	43	42	195	2
			3	47	43	40	47	42	39	45	41	38	43	40	38	42	39	37	36	180	3
			4	42	37	34	41	37	33	40	36	33	39	35	33	37	35	32	31	167	4
			5	37	32	29	37	32	29	35	31	28	34	31	28	33	30	27	26	157	5
			6	33	28	25	33	28	25	32	28	24	31	27	24	30	27	24	23	145	6
			7	30	25	22	30	25	21	29	24	21	28	24	21	27	24	21	20	135	7
			8	27	22	19	27	22	19	26	22	18	25	21	19	24	21	18	17	126	8
			9	24	19	16	24	19	16	23	19	16	23	19	16	22	18	16	15	119	9
			10	22	17	14	22	17	14	21	17	14	21	17	14	20	17	14	13	112	10
42  Fluorescent unit with flat prismatic lens, 4 lamp 610 mm (2') wide—see note 7	V 	1.4/1.2	0	75	75	75	73	73	73	70	70	70	67	67	67	64	64	64	63	—	0
			1	67	65	63	66	64	62	63	62	60	61	60	58	59	58	57	55	189	1
			2	60	57	54	59	56	53	57	54	52	55	53	51	53	51	50	49	180	2
			3	54	50	47	53	49	46	52	48	45	50	47	45	48	46	44	43	169	3
			4	49	44	40	48	44	40	47	43	40	45	42	39	44	41	39	37	160	4
			5	44	39	35	43	38	35	42	38	34	41	37	34	40	36	34	33	152	5
			6	40	34	31	39	34	31	38	34	30	37	33	30	36	32	30	29	143	6
			7	36	30	27	35	30	27	34	30	27	33	29	26	32	29	26	25	135	7
			8	32	27	23	32	27	23	31	26	23	30	26	23	29	26	23	22	129	8
			9	29	24	20	28	23	20	28	23	20	27	23	20	26	23	20	19	123	9
			10	26	21	18	26	21	18	25	21	18	24	20	18	24	20	18	16	116	10

Fig. 9-12. *Continued* (see page 9-13 for instructions and notes)

Coefficients of Utilization for 20 Per Cent Effective Floor Cavity Reflectance (ρ_{FC} = 20)

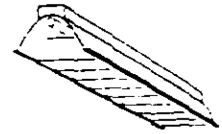
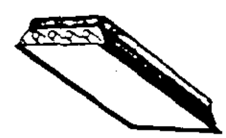
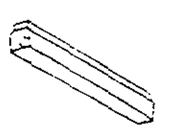
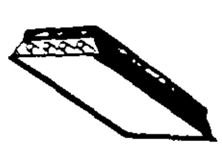
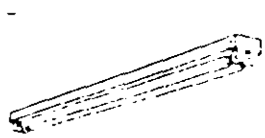
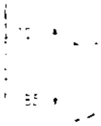
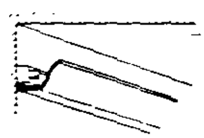
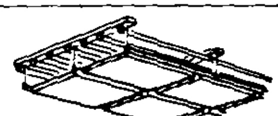
Typical Luminaire	Typical Intensity Distribution and Per Cent Lamp Lumens	Maint. Cat.	SC	RCR ↓	ρcc → 80 / ρw → 50	80 / 30	80 / 10	70 / 50	70 / 30	70 / 10	50 / 50	50 / 30	50 / 10	30 / 50	30 / 30	30 / 10	10 / 50	10 / 30	10 / 10	0 / 0	WDRC	RCR
43  4 lamp 610 mm (2') wide unit with sharp cutoff (high angle—low luminance) flat prismatic lens—see note	0 ↑ 65½ ↑ 50	V	1.4/1.3	0	78	78	78	76	76	76	73	73	73	70	70	70	67	67	67	66	—	0
				1	71	69	67	70	68	66	67	65	64	64	63	62	62	61	60	59	165	1
				2	64	61	58	63	60	58	61	59	56	59	57	55	57	55	54	53	161	2
				3	58	54	51	57	54	51	56	53	50	54	51	49	52	50	48	47	155	3
				4	53	48	45	52	48	44	51	47	44	49	46	43	48	45	43	42	150	4
				5	48	43	39	47	42	39	46	42	39	45	41	38	43	40	38	37	145	5
				6	43	38	35	43	38	34	42	37	34	40	37	34	40	36	34	32	138	6
				7	39	34	30	38	34	30	38	33	30	37	33	30	36	32	30	28	132	7
				8	35	30	26	35	30	26	34	29	26	33	29	26	32	29	26	25	126	8
				9	31	26	23	31	26	23	30	26	23	30	26	23	29	25	23	21	122	9
				10	28	24	20	28	23	20	28	23	20	27	23	20	26	23	20	19	117	10
44  Bilateral batwing distribution—louvered fluorescent unit	0 ↑ 50 ↑ 45	IV	N.A.	0	71	71	71	70	70	70	66	66	66	64	64	64	61	61	61	60	—	0
				1	65	63	61	63	62	60	61	59	58	59	57	56	57	56	55	54	154	1
				2	59	55	53	58	55	52	56	53	51	54	52	50	52	50	49	45	150	2
				3	53	49	46	52	48	45	50	47	45	49	46	44	47	45	43	42	147	3
				4	47	43	40	47	43	40	45	42	39	44	41	39	43	40	38	37	143	4
				5	42	38	34	42	37	34	41	37	34	40	36	34	39	36	33	32	139	5
				6	38	33	30	38	33	30	37	32	30	36	32	29	35	32	29	28	133	6
				7	34	29	26	33	29	26	33	29	26	32	29	26	31	28	25	24	128	7
				8	30	25	22	30	25	22	29	25	22	28	24	22	27	24	21	20	123	8
				9	27	22	19	26	22	18	26	21	18	25	21	18	24	21	18	17	119	9
				10	24	19	16	24	19	16	23	19	16	22	19	16	22	18	16	15	113	10
45  Bilateral batwing distribution—4 lamp 610 mm (2') wide fluorescent unit with flat prismatic lens and overlay—see note 7	0 ↑ 45 ↑ 45	V	N.A.	0	57	57	57	56	56	56	53	53	53	51	51	51	49	49	49	48	—	0
				1	50	48	47	49	47	46	47	46	44	45	44	43	44	43	42	41	185	1
				2	44	41	38	43	40	38	41	39	37	40	38	36	38	37	35	34	175	2
				3	39	35	32	38	34	31	37	33	31	35	33	30	34	32	30	29	161	3
				4	34	30	27	33	29	26	32	29	26	31	28	26	30	27	25	24	149	4
				5	30	26	22	29	25	22	28	24	22	27	24	21	26	23	21	20	140	5
				6	26	22	19	26	22	18	25	21	18	24	21	18	23	20	18	17	130	6
				7	23	19	16	23	19	16	22	18	16	21	18	15	21	18	15	14	121	7
				8	21	16	13	20	16	13	19	16	13	19	15	13	18	15	13	12	113	8
				9	18	14	11	18	14	11	17	14	11	17	13	11	16	13	11	10	106	9
				10	16	12	09	16	12	09	15	12	09	15	12	09	14	12	09	08	099	10
46  Bilateral batwing distribution—one lamp surface mounted fluorescent with prismatic wraparound lens	12 ↑ 63½ ↑ 45	V	N.A.	0	87	87	87	84	84	84	77	77	77	72	72	72	66	66	66	64	—	0
				1	76	73	70	73	70	67	67	65	63	63	61	59	58	57	55	53	270	1
				2	66	61	57	64	59	56	59	56	52	55	52	49	51	49	47	44	241	2
				3	59	53	48	56	51	47	53	48	44	49	45	42	46	43	40	38	216	3
				4	52	45	40	50	44	40	47	42	38	44	39	36	41	37	34	32	196	4
				5	46	39	34	44	38	33	41	36	32	39	34	31	36	32	29	27	182	5
				6	41	34	29	39	33	29	37	31	27	34	30	26	32	28	25	23	168	6
				7	36	30	26	35	29	24	33	27	23	31	26	23	29	25	22	21	157	7
				8	32	26	21	31	25	21	29	24	20	27	22	19	26	21	18	17	147	8
				9	29	22	16	28	22	16	26	21	17	24	20	16	23	19	15	14	138	9
				10	26	20	16	25	19	15	23	19	15	22	17	14	20	16	13	12	129	10
47  Radial batwing distribution—4 lamp 610 mm (2') wide fluorescent unit with flat prismatic lens—see note 7	0 ↑ 59½ ↑	V	1.7	0	71	71	71	69	69	69	66	66	66	63	63	63	61	61	61	60	—	0
				1	62	60	58	61	59	57	59	57	55	56	55	53	54	53	52	51	227	1
				2	55	51	47	53	50	47	51	48	46	49	47	45	48	45	44	42	216	2
				3	48	43	39	47	43	39	45	41	38	44	40	36	42	39	37	36	193	3
				4	42	37	33	41	37	33	40	36	32	39	35	32	37	34	31	30	184	4
				5	37	32	27	36	31	27	35	30	27	34	30	27	33	29	26	25	172	5
				6	33	27	23	32	27	23	31	26	23	30	26	23	29	25	23	21	159	6
				7	29	24	20	29	24	20	28	23	20	27	23	20	26	22	19	18	148	7
				8	26	21	17	25	20	17	25	20	17	24	20	17	23	19	16	15	138	8
				9	23	18	14	23	18	14	22	17	14	21	17	14	21	17	14	13	130	9
				10	21	16	12	20	16	12	20	15	12	19	15	12	19	15	12	11	121	10
48  2 lamp fluorescent strip unit	20½ ↑ 68 ↑	I	1.6/1.2	0	101	101	101	96	96	96	87	87	87	79	79	79	72	72	72	68	—	0
				1	85	81	77	81	77	73	73	70	67	66	64	62	60	58	56	53	378	1
				2	73	66	61	69	63	58	63	58	54	57	53	50	51	48	45	42	323	2
				3	63	56	50	60	53	48	55	49	44	50	45	41	45	41	38	35	277	3
				4	56	47	41	53	46	40	48	42	37	44	39	34	40	35	32	29	244	4
				5	49	40	34	46	39	33	42	36	31	38	33	29	35	30	26	24	221	5
				6	43	35	29	41	34	28	38	31	26	34	29	24	31	26	23	20	200	6
				7	39	31	25	37	29	24	34	27	23	31	25	21	28	23	19	17	182	7
				8	34	27	21	33	26	21	30	24	19	27	22	18	25	20	17	15	167	8
				9	31	23	18	30	23	18	27	21	17	25	19	15	22	18	14	12	155	9
				10	28	21	16	27	20	16	25	19	15	22	17	14	20	16	13	11	144	10

Fig. 9-12. *Continued (see page 9-13 for instructions and notes)*

	Typical Luminaire	Typical Intensity Distribution and Per Cent Lamp Lumens: Maint. Cat.	SC	RCR ↓	ρcc → 80, ρw → 50	30	10	ρcc 70, ρw 50	30	10	ρcc 50, ρw 50	30	10	ρcc 30, ρw 50	30	10	ρcc 10, ρw 50	30	10	ρcc 0, ρw 0	WDRC	RCR ↓
					Coefficients of Utilization for 20 Per Cent Effective Floor Cavity Reflectance (ρ_{FC} = 20)																	
49		I 	1.4/1.2	0	113	113	113	109	109	109	101	101	101	94	94	94	88	88	88	85	—	0
		12½% ↑		1	96	90	86	93	89	85	87	83	80	81	78	75	75	73	71	68	422	1
				2	83	76	70	80	74	68	75	69	65	70	[illegible]	61	65	61	58	55	369	2
				3	73	65	58	70	63	57	66	59	54	61	[illegible]	52	57	53	49	46	331	3
				4	64	56	49	62	54	49	58	51	46	54	48	44	51	46	42	39	286	4
		35½% ↓		5	56	47	41	55	46	40	51	44	39	48	42	37	45	39	35	33	251	5
				6	50	41	35	49	40	34	46	38	33	43	36	33	42	35	32	28	237	6
				7	45	36	30	44	35	30	41	34	28	38	32	27	36	31	26	24	211	7
				8	40	32	26	39	31	25	37	30	25	35	28	24	33	27	22	21	201	8
	2 lamp fluorescent strip unit with 235° reflector fluorescent lamps			9	36	28	22	35	27	22	33	26	21	31	25	20	29	24	20	19	187	9
				10	33	25	20	32	24	19	30	23	19	28	22	18	27	21	17	16	174	10

	Typical Luminaires	RCR ↓	ρcc → 80, ρw → 50	30	10	ρcc 70, ρw 50	30	10	ρcc 50, ρw 50	30	10	ρcc 30, ρw 50	30	10	ρcc 10, ρw 50	30	10	ρcc 0, ρw 0
			Coefficients of Utilization for 20 Per Cent Effective Floor Cavity Reflectance, ρ_{FC} = 20															
50		1	42	40	39	36	35	33	25	24	23	Coves are not recommended for lighting areas having low reflectances						
		2	37	34	32	32	29	27	22	20	19							
		3	32	29	26	28	25	23	19	17	16							
		4	28	25	22	25	22	19	17	15	13							
		5	25	21	18	22	19	16	15	13	11							
		6	23	19	16	20	16	14	14	12	10							
		7	20	17	14	17	14	12	12	10	09							
		8	18	15	12	16	13	10	11	09	08							
	Single row fluorescent lamp cove without reflector, mult. by 0.93 for 2 rows and by 0.85 for 3 rows	9	17	13	10	15	11	09	10	08	07							
		10	15	12	09	13	10	08	09	07	06							
51	ρcc from below ~65% 	1				60	58	56	58	56	54							
		2				53	49	45	51	47	43							
		3				47	42	37	45	41	36							
		4				41	36	32	39	35	31							
		5				37	31	27	35	32	28							
	Diffusing plastic or glass	6				33	27	23	31	26	23							
	1) Ceiling efficiency ~60%; diffuser transmittance ~50%; diffuser reflectance ~40%. Cavity with minimum obstructions and painted with 80% reflectance paint—use ρc = 70	7				29	24	20	28	23	20							
		8				26	21	18	25	22	17							
		9				23	19	14	23	19	16							
	2) For lower reflectance paint or obstructions—use ρc = 50	10				21	17	13	21	18	13							
52	ρcc from below ~60% 	1				71	68	66	67	66	65	66	64	62				
		2				63	60	57	61	58	55	59	56	54				
		3				57	53	49	55	52	48	54	50	47				
		4				52	47	42	50	46	42	48	44	40				
		5				46	41	37	44	40	37	43	40	36				
	Prismatic plastic or glass	6				42	37	33	41	36	32	40	35	32				
	1) Ceiling efficiency ~67%; prismatic transmittance ~72%; prismatic reflectance ~18%. Cavity with minimum obstructions and painted with 80% reflectance paint—use ρc = 70	7				38	32	29	37	31	28	36	31	28				
		8				34	28	25	33	28	25	32	28	25				
		9				30	25	22	30	25	21	29	25	21				
	2) For lower reflectance paint or obstructions—use ρc = 50	10				27	23	19	27	22	19	26	22	19				
53	ρcc from below ~45% 	1							51	49	46				47	46	45	
		2							46	44	42				43	42	40	
		3							42	39	37				39	38	36	
		4							38	35	33				36	34	32	
		5							35	32	29				33	31	29	
	Louvered ceiling	6							32	29	26				30	28	26	
	1) Ceiling efficiency ~50%; 45° shielding opaque louvers of 80% reflectance. Cavity with minimum obstructions and painted with 80% reflectance paint—use ρc = 50	7							29	26	23				29	25	23	
		8							27	23	21				26	23	21	
		9							24	21	19				24	21	19	
	2) For other conditions refer to Fig. 9-48	10							22	19	17				22	19	17	

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CURSOS ABIERTOS

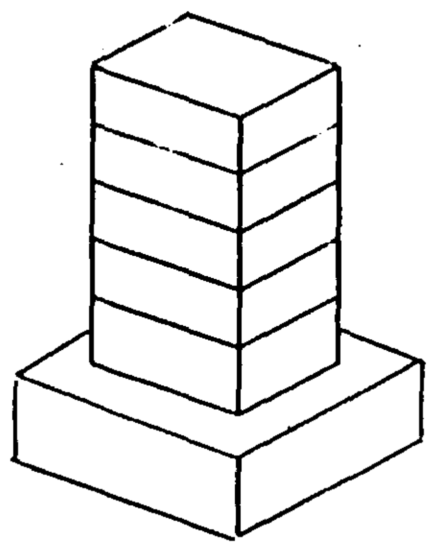
ILUMINACION INTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES

AHORRO DE ENERGIA EN INSTALACIONES DE ILUMINACION

ING. CARLOS GARCIA ROMERO

NOVIEMBRE, 1993.

ADMINISTRACION EFICIENTE DE LA ENERGIA ELECTRICA EN LA ILUMINACION DE EDIFICIOS DE OFICINAS



LA ADMINISTRACION DE LA ENERGIA ELECTRICA EN LA ILUMINACION DE EDIFICIOS DE OFICINAS, SE APLICA SOLAMENTE A INSTALACIONES EXISTENTES Y COMPRENDE CINCO PASOS:

1. REALIZAR UNA AUDITORIA AL SISTEMA DE ILUMINACION.

2. IDENTIFICAR LAS OPCIONES PARA EL BUEN USO DE LA ILUMINACION.

3. DESARROLLAR UN PLAN PARA EL BUEN USO DE LA ILUMINACION.

4. IMPLEMENTAR EL PLAN DE ACCION.

5. MONITOREAR LOS RESULTADOS OBTENIDOS Y MANTENERLOS ACTUALIZADOS.

I. AUDITORIA AL SISTEMA DE ILUMINACION.

CON LA AUDITORIA AL SISTEMA DE ILUMINACION SE OBTIENE EL CONOCIMIENTO DE LA INSTALACION EXISTENTE.

EQUIPO REQUERIDO PARA EFECTUARLA:

- LUXOMETRO.
- MULTIMETRO GRAFICO PARA MEDIR: POTENCIA, VOLTAJE Y CORRIENTE.
- CAMARA FOTOGRAFICA DE REVELADO INSTANTANEO.
- GRABADORA PORTATIL DE CINTA.
- ESCALERA DE MANO.
- TABLA PARA TOMAR NOTAS CON PAPEL MILIMETRICO.
- CINTA METRICA.
- FORMATOS PARA EL LEVANTAMIENTO.

REFERENCIAS: MANUAL DE ILUMINACION DE LA "IES", RECOMENDACIONES SOBRE DENSIDAD DE CARGA E INFORMACION TECNICA.

II. IDENTIFICAR LAS OPCIONES PARA EL BUEN USO DE LA ILUMINACION.

EXISTEN DIVERSAS OPCIONES PARA EL BUEN USO DE LA ILUMINACION COMO SON:

- NUEVOS TIPOS DE LAMPARAS.
- BALASTROS ELECTROMAGNETICOS DE ALTA EFICIENCIA Y ELECTRONICOS.
- REFLECTORES ESPECULARES.
- REEMPLAZO DE LUMINARIOS.
- ADICION DE CONTROLES (MANUALES O AUTOMATICOS).

SE REQUIERE CONOCER AMPLIAMENTE LAS OPCIONES PARA PODER IDENTIFICAR APROPIADAMENTE LAS ALTERNATIVAS DE AHORRO Y, EN ALGUNOS CASOS, REALIZAR PRUEBAS PARA ASEGURARSE DE LOS RESULTADOS.

III. DESARROLLAR UN PLAN PARA EL BUEN USO DE LA ILUMINACION.

EL PLAN PARA EL BUEN USO DE LA ILUMINACION IDENTIFICA LAS OPCIONES QUE SERAN IMPLEMENTADAS, CADA RECOMENDACION DEBERA IDENTIFICAR Y CUANTIFICAR:

- EL AREA AFECTADA.
- LA NATURALEZA DE LA ILUMINACION POR INSTALAR.
- LA CANTIDAD Y CALIDAD DE ILUMINACION POR INSTALAR.
- CONSUMO DE ENERGIA ACTUAL Y PROYECTADA, AHORROS ESTIMADOS.
- COSTOS DE ENERGIA Y MANTENIMIENTO ACTUALES Y AHORROS PROYECTADOS.
- NATURALEZA DE LAS MODIFICACIONES PROPUESTAS.
- BENEFICIOS GENERALES DE LA IMPLEMENTACION DE LAS MODIFICACIONES (SEGURIDAD, PRECISION EN EL DESARROLLO DE LAS TAREAS, PRODUCTIVIDAD, CONFORT).

III. DESARROLLAR UN PLAN PARA EL BUEN USO DE LA ILUMINACION.

- COSTOS QUE IMPLIQUEN EL CAMBIO.
- VALOR ESTIMADO DE LOS BENEFICIOS GENERALES DERIVADOS.
- DENSIDAD DE CARGA ACTUAL Y PROYECTADA.
- TASA DE RETORNO DE LA INVERSION U OTRO INDICE FINANCIERO.

ES IMPORTANTE TOMAR EN COSIDERACION LAS INTERRELACIONES QUE TIENE EL SISTEMA DE ILUMINACION CON EL AIRE ACONDICIONADO, LA DECORACION Y EL MOBILIARIO DEL EDIFICIO.

IV. IMPLEMENTAR EL PLAN DE ACCION.

LOS PLANES PARA LA ADMINISTRACION EFICIENTE DE LA ENERGIA ELECTRICA EN LA ILUMINACION DE LOS EDIFICIOS DE OFICINAS FRECUENTEMENTE SE DISEÑAN PARA IMPLEMENTARSE EN ETAPAS.

LA SELECCION DE LAS OPCIONES PARA INICIAR LA IMPLEMENTACION DE LAS ACCIONES, USUALMENTE SE SELECCIONAN LAS DE MAYOR RELACION BENEFICIO-COSTO GENERALMENTE CON UNA MODESTA INVERSION Y ALGUNAS VECES MINIMA, EN SEGUNDO TERMINO SE SELECCIONAN LAS DE MAYOR TASA DE RETORNO DEL CAPITAL SOBRE LA INVERSION Y EN TERCER LUGAR LAS OPCIONES QIE REQUIEREN UNA INVERSION SUBSTANCIAL DE CAPITAL.

IV. IMPLEMENTAR EL PLAN DE ACCION.

ES APROPIADO INFORMAR A TODOS LOS EMPLEADOS ACERCA DE LOS CAMBIOS HECHOS EN LA ILUMINACION, YA QUE ELLOS ESTARAN GUSTOSOS AL TENER UNA MEJORIA EN EL MEDIO AMBIENTE QUE IMPACTARA EN SU TRABAJO.

AL TERMINAR LA IMPLEMENTACION DE CADA ETAPA ES CONVENIENTE EFECTUAR MEDICIONES, CON EL FIN DE VERIFICAR SI SE OBTIENEN LOS RESULTADOS PROYECTADOS, CON LOS AHORROS ESPERADOS.

V. MONITOREAR LOS RESULTADOS OBTENIDOS Y MANTENERLOS ACTUALIZADOS.

PARA LOS PROPOSITOS DE MONITOREAR EL PLAN DE CONSUMO DE ENERGIA ES NECESARIO MEDIRLO O CALCULARLO PERIODICAMENTE.

LA CALIDAD PUEDE DETERMINARSE POR OBSERVACION Y EVALUACION DE LOS COMENTARIOS DE AQUELLOS QUIENES TRABAJAN EN EL AREA ILUMINADA, CAMBIOS EN LA PRODUCTIVIDAD, RANGO DE ERRORES Y OTROS FACTORES PUEDEN PROVEER INDICACIONES DE LOS EFECTOS CAUSADOS POR LA IMPLEMENTACION DE LAS OPCIONES.

EL PLAN DE LA ADMINISTRACION EFICIENTE DE LA ILUMINACION DEBERA ESTAR AL DIA Y REVISARSE CADA SEIS MESES, HACIENDO LOS CAMBIOS QUE SE REQUIERAN.

V. MONITOREAR LOS RESULTADOS OBTENIDOS Y MANTENERLOS ACTUALIZADOS.

LA INDUSTRIA DE ILUMINACION REALIZA PROGRESOS TECNOLOGICOS MUY RAPIDAMENTE, POR ESTA RAZON, LAS PERSONAS A CARGO DEL PLAN DEBERAN HACER UN ESFUERZO PARA ESTAR AL DIA DE LOS ULTIMOS ADELANTOS EN LA TECNOLOGIA DE LA ILUMINACION.

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

CURSOS ABIERTOS

ILUMINACION INTERIOR, DISEÑO Y APLICACIONES

ARQUITECTURA DE LA LUZ
ILUMINACION NATURAL
ILUMINACION ARTIFICIAL
LA LUZ EN LA HOTELERIA

EXP.: ARQ. ENRIQUE QUINTERO

Palacio de Mineria Calle de Tacuba 5 Primer piso Deleg. Cuauhtémoc 06000 México, D.F. APDO. Postal M-2285
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Arquitectura de la luz

La luz, fenómeno físico que nos asombra y conmueve, es sin duda fuente de vida y de creación. No en balde ha sido motivo de adoración en las diferentes culturas que conforman la historia de la humanidad. En la Europa medieval, los *Siglos Oscuros* están definitivamente marcados con un sello de miedo y superchería, mismos que se dejan ver en todas y cada una de las actividades que realizaba el ser humano en aquella época.

Sin embargo, se han superado estas etapas, y es así como en la actualidad todo el fulgor y esplendor de esta manifestación se encuentra al servicio de la especie humana, para maravillarnos aún más y permitirnos continuar con nuestras actividades ya sean de ocio o de trabajo.

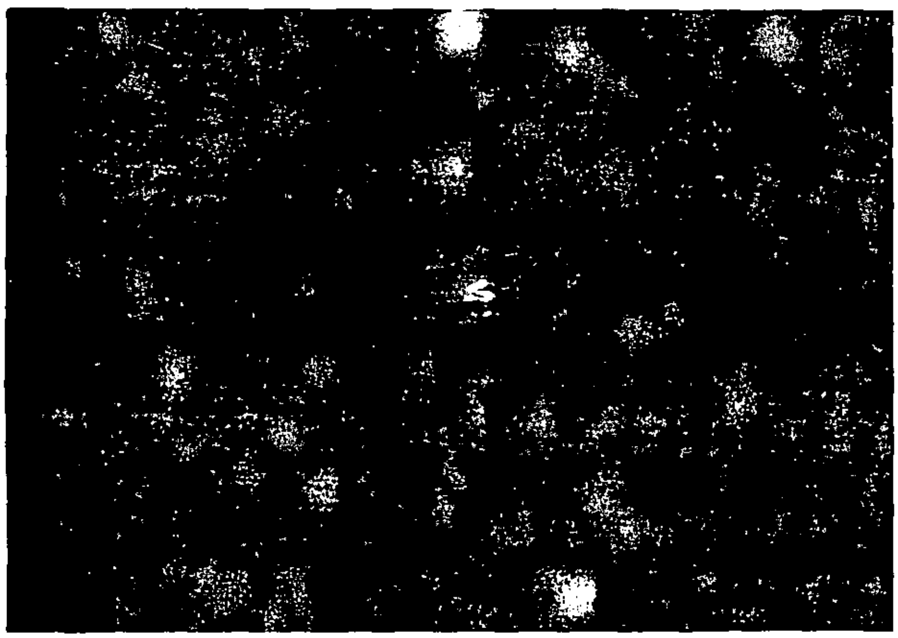
En el campo de la arquitectura, el papel de la luz es preponderante, si tomamos en cuenta que los movimientos del hombre, si bien están directamente relacionados con el día y el exterior, se dirigen también hacia espacios cubiertos y tiempos nocturnos. Es por ello, que surge, cada vez con más fuerza la necesidad de especialistas que vinculen la magia de la luz con la versatilidad de nuestros espacios.

Por esta razón consideramos oportuno presentar las reflexiones que sobre el tema nos hizo el arquitecto Enrique Quintero L., quien a través de Blitz, Iluminación Corporativa, S.A. de C.V., se dedica exclusivamente a la iluminación, ya sea en el rubro del diseño, del cálculo o de la capacitación.

Quintero: "La utilización de la luz solar en la arquitectura tiene antecedentes muy importantes en nuestra cultura"

Llamamos arquitectura de la luz, al arte y la técnica de la iluminación aplicada a la arquitectura. Esta sigue los métodos utilizados en el proyecto arquitectónico y los resultados que se pueden obtener son realmente sorprendentes.

"El proyecto de iluminación en la arquitectura frecuentemente se vincula con el proyecto eléctrico —explica Quintero—. Sin embargo, el primero va más allá de la simple colocación de luminarias, dado que los efectos de luz y su función están relacionados íntimamente con la actividad estrictamente arquitectónica".



...el papel de la luz es preponderante

Luz diurna y luz nocturna. El proyecto de iluminación se considera como tal, cuando engloba tanto al alumbramiento diurno como al nocturno o artificial, agrupando un todo interdisciplinario, el cual tiene metas tales como ahorrar energía, enfatizar el diseño arquitectónico, adecuar la actividad en el espacio y, sobre todo, dar el carácter propio del estilo.

"La iluminación de día —expliuna referencia confiable, en este rubro se toman promedios con los que se puede satisfacer la media.

Una techumbre suspendida en el aire. En Francia, existe una obra arquitectónica, que se puede considerar como un excelente ejemplo de la utilización de la luz: la Capilla de Ronchamp. Proyectada y construida por el arquitecto suizo-francés Le Corbusier hacia 1955, esta maravillosa obra arquitectónica, basada en temas marinos, fue conceptualizada con base en los efectos de la luz sobre su estructura.

El prefacio que acompañaba a la publicación sobre Ronchamp,

"Observad el juego de las sombras, entrad en el juego..."

realizada por el propio Le Corbusier, reza así:

La clave
es la luz,
y la luz
ilumina formas.
Y estas formas tienen
una potencia emotiva...

La idea se redondeaba en la página siguiente, donde Le Corbusier escribía con convicción:

"Observad el juego de las sombras, entrad en el juego..." y acto seguido, decididamente invitaba al observador a invertir el libro para mirar las imágenes del revés y descubrir el juego de la aquitectura, es decir, redescubrir la luz y el juego.

La cubierta de la capilla de Ronchamp, construida a partir de un cascarón de concreto, está soportada por medio de pilastras del mismo material que dejan una separación entre el muro y la techumbre para que penetre luz natural, dando la impresión de que esta última está suspendida en el aire.

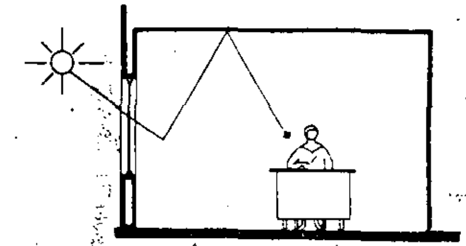
Esta técnica fue utilizada en Santa Sofía de Constantinopla. Al *perforarse* la base de la bóveda con ventanas, la luz "anula" los soportes y la techumbre parece estar suspendida en el aire.

En esta obra de Le Corbusier la luz *acaricia* los muros exteriores. La textura que se le imprimió motiva el juego de brillo y sombra en su superficie. La luz penetra a través de ventanas con vidrios de colores y da una sensación de espiritualidad en el interior que es complementado por la iluminación primitiva de las velas prendidas en racimos.

"Le Curbosier podía ser criticado de barroquismo o de sentir un fanatismo por las máquinas —finaliza Quintero—, pero siempre quedaba aquello que al principio de su carrera había definido como la arquitectura de la manera más bella: *'La arquitectura es el sabio juego, correcto y magnífico, de los volúmenes compuestos bajo la luz'.*" ■

Iluminación natural

En el diseño de iluminación de día y en la artificial se tienen consideraciones distintas; para la luz del Sol, es necesario tener conocimientos de la posición de éste en las diferentes horas del día y considerar también las distintas estaciones del año porque las cantidades de luz están determinadas por las condiciones del tiempo y de los elementos de control. Respecto a la iluminación artificial ésta requiere de técnicas matemáticas de cálculo para determinar cantidades de luz.



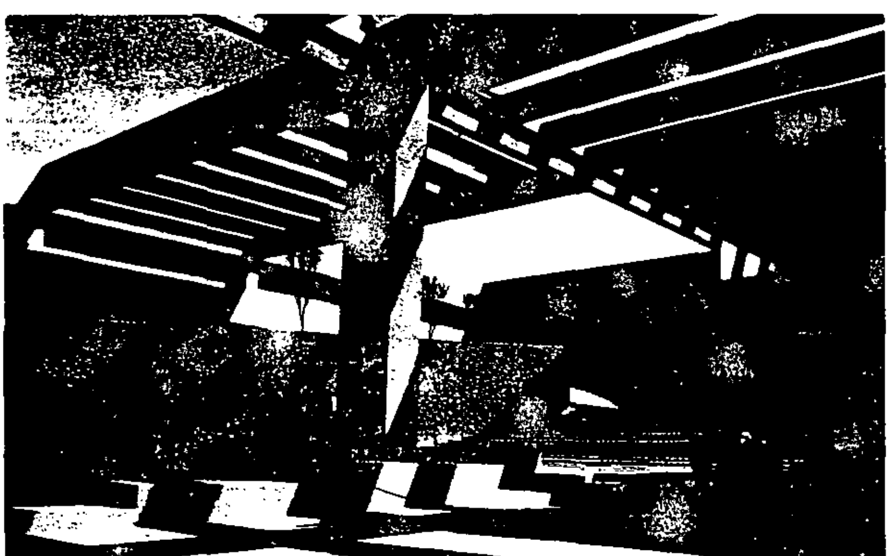
Gráfica No. 1

Nos referiremos primeramente al *diseño de iluminación con luz natural* (DILN). Existen cartas de la posición del Sol en los diferentes puntos de la Tierra y estaciones del año. Estos datos son esenciales para el DILN, y es posible obtenerla en la oficina geográfica de la localidad.

Sin embargo, la utilización práctica de la ubicación de la construcción por medio de maquetas permite observar directamente los efectos de luz solar sobre los volúmenes. Las profundidades logradas y los claro-obscuros obtenidos sobre estas maquetas, se reproducirán en la obra arquitectónica una vez terminada.

La iluminación de día está vinculada con el ahorro de energía y es importante aprovecharla para dar iluminación en el interior.

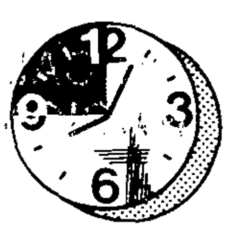
Aprovechar al máximo la luz del Sol no es sencillo, la cantidad que se requiere para un área de trabajo, por ejemplo, debe ser constante, y las condiciones del tiempo pueden variar; de manera que es necesario establecer mecanismos de control, para contrarrestar los cambios climáticos.



La iluminación de día está vinculada con el ahorro de energía

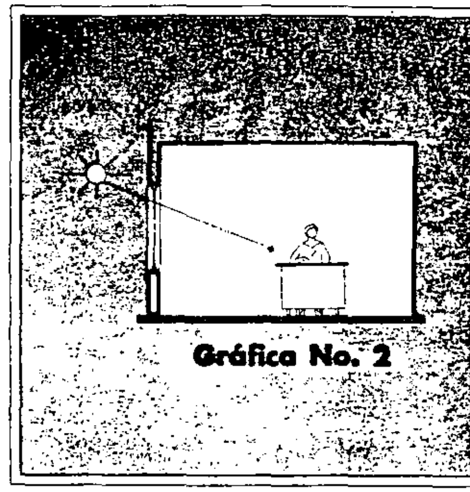
Controles de luz. Los controles de luz los podemos clasificar de la siguiente forma:

• *Persianas y cortinas.* La persiana es una de las formas más antiguas y comunes de controlar la cantidad de luz. Este mecanismo nos ayuda a transformar la iluminación que penetra a través de la ventana en efecto indirecto, como lo indica la gráfica 1.



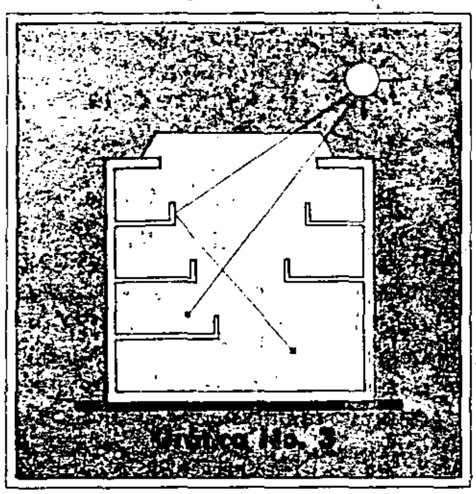
Las persianas construidas en obra tienen el mismo propósito y pueden ser fijas o móviles. En el caso de estar en una sola posición, ésta debe definirse por el deslumbre que moleste y para aprovechar al máximo la posición del Sol con respecto al espacio interno.

El efecto de luz indirecta se acentúa cuando el canto de la persiana es de color claro, o bien podemos dar un efecto más directo, que esté dirigido conforme cambie la inclinación del Sol. Gráfica 2.



Gráfica No. 2

• *Cortinas.* En cuanto a las cortinas pueden ser de diferentes densidades, que dejan pasar determinadas cantidades de luz, siempre difuminadas por el material, bien sea de plástico, tela o metálico.



Gráfica No. 3

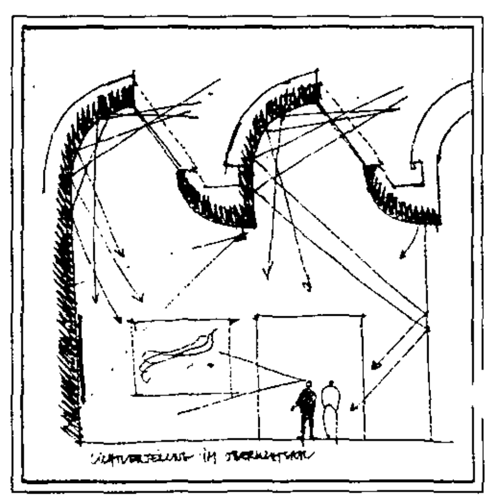
• *Domos y tragaluces.* En algunas ocasiones es difícil dar una entrada de luz a través de ventanas y es necesario introducirla por la cubierta, llegándose al extremo de tener un gran espacio que aparenta estar en el exterior, con ambientación de plantas y elementos que normalmente encontramos afuera de la construcción. De hecho, el mobiliario y los acabados dentro de esta área tendrán que resistir la fuerte radiación del Sol y es conveniente que estén preparados para esto.

El corte transversal de la gráfica 3 indica un gran atrio central que está expuesto a la luz solar por medio de un tragaluz. Este diseño permite que se distribuya en la parte interna del edificio y que pueda aprovechar la fuente de luz natural.

En la ciudad de Hong Kong, en China, existe una gran construcción dedicada a oficinas bancarias que tiene un espejo gigantesco en la parte superior y que coordinado con el movimiento del Sol por medio de motores, refleja la luz en el interior del edificio en una forma constante.

En la gráfica 4 tenemos un ejemplo de tragaluz que fue diseñado para fines religiosos, el haz de luz que se proyecta incide en el lugar de culto a la hora precisa que se realiza. Este efecto es posible gracias a la utilización de computadoras en su diseño, sin embargo, nos preguntamos ¿cómo realizaban los mayas con tanta precisión efectos de luz sobre las pirámides?

Es importante tomar conciencia



de que tenemos la técnica para aprovechar la iluminación natural y no la utilizamos, inclusive un estudio sencillo de las posibilidades de ahorrar energía utilizando luz solar, nos permitirá diseñar arquitectura con volúmenes y estructuras novedosas.

Los tragaluces que son muy utilizados en las áreas fabriles es posible incorporarlos a otros espacios, pues su buen funcionamiento nos invita a utilizarlos en museos como el *ejemplo de la gráfica* 5 y foto que permite la entrada de luz en forma muy general, con el diseño de plafón que podemos apreciar en forma de reflector.

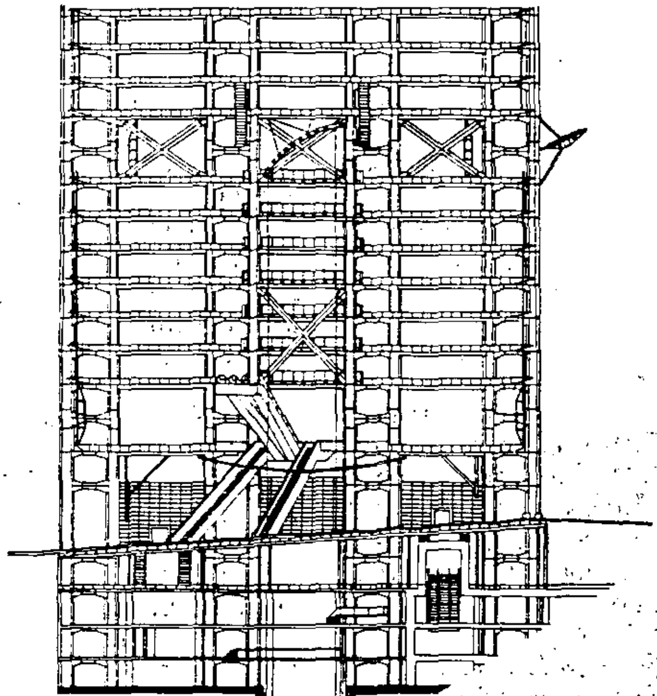
En todas las superficies cercanas al tragaluz se recomienda tener colores claros para que la reflección sea la más alta posible, en algunos casos es posible utillizar un recubrimiento basándonos en el vidrio y yeso que aumenta aún más este efecto. La gráfica 6 nos da un ejemplo sencillo de la utilización de un domo combinado con un murete. Otras variantes constructivas que permiten el aprovechamiento de la luz las podemos encontrar en la gráfica.

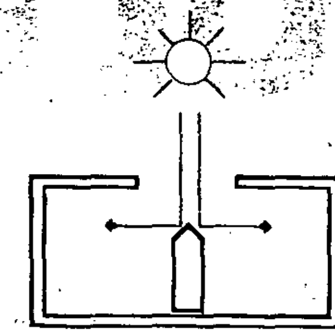
• *Cristales y vitrales.* La utilización de cristales con diferentes transparencias es una técnica que floreció en los vitrales de las construcciones góticas, la combinación de colores, su mezcla para el control y mejoramiento de los tonos cálidos del Sol resultó en esta época un trabajo cuya perfección es difícil igualar en nuestros tiempos.

Sin embargo, nos dejan plasmadas en su composición fórmulas consideradas secretas, pues por medio de aparatos sensibles al color (kelvinómetros) se puede lograr descifrar las cantidades de cada color utilizando en los diferentes vitrales, que dependía de la orientación, de la altura y recinto a iluminar.

Una de las primeras reglas en esta técnica consiste en colocar en la parte superior los colores más obscuros, los de menor transparencia y bajar con degradados de tonos hasta tener en la parte in-

Banco de Hong Kong, en China





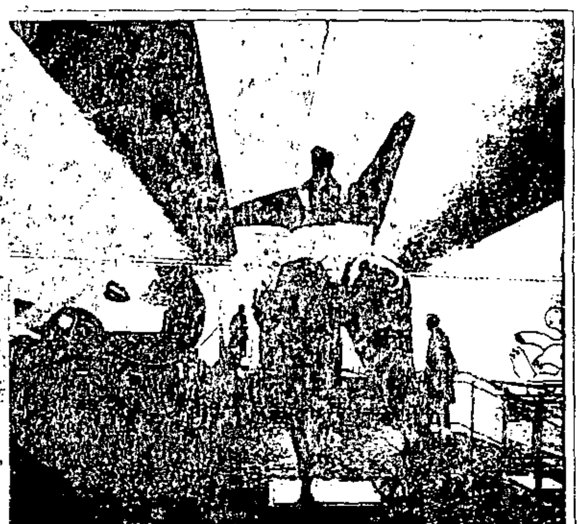
Gráfica No. 6

Gráfica No. 7

ferior un 90% de penetración de luz.

Respecto a los colores, para restar tonos cálidos a la luz del Sol se utilizarán colores morados, azules, tonos que encontramos en el lado izquierdo del espectro visible de energía electromagnética del Sol, y por el contrario, si se desea elevar el color cálido, se escogerán los del lado derecho del espectro, rojos, naranjas, amarillos.

En cuanto a los cristales, actualmente tenemos una gran variedad con diferentes características: con filtros a la radiación ultravioleta e infrarroja, y también con diferentes grados de transparencia.



Cuando los interiores tienen materiales muy sensibles, ya sean tapices, muebles o pintura, obras de arte muy finas, es conveniente utilizar cristales con filtros. En algunas orientaciones de la construcción en donde no es posible evitar la entrada directa del Sol, y requerimos de vista panorámica, la utilización de cristales que atenúan la luz natural resuelven buena parte del problema.

• *Pérgolas.* Mucho se ha hablado de la inutilidad de las pérgolas, sin embargo su utilización como persianas horizontales es muy eficiente. Existe un paseo en el Parque México en la colonia Roma que utiliza una pérgola, que junto con enredaderas atenúan la luz del Sol, provocando con sombras y manchas de luz un ambiente muy agradable; dan frescura al paseo y enmarcan el espacio desde el punto de vista arquitectónico.

La pérgola se puede extender al espacio interior alternada con domos corridos y teniendo la posibilidad de funcionar con movimiento a través de motores y rieles para dar diferentes niveles de iluminación.

Es posible conectar sensores a este sistema móvil de pérgola y mantener cantidades de luz, uniformemente. ■

Arq. Enrique Quintero López

Iluminación artificial

Las fuentes de luz artificial tienen la posibilidad de lograr mayor control de la luz natural, pues para esta función no dependen de las condiciones climáticas.

Para hacer posible la iluminación artificial, actualmente contamos con una gran variedad de fuentes luminosas, que nos permiten iluminar a diferentes alturas y lograr efectos muy precisos de acentos. Contamos también con unidades de control de luz (atenuadores o *dimmer)* que, conectados a una unidad computarizada, controla con programas de tiempo e intensidad toda la iluminación de un gran complejo arquitectónico.

Toda esta tecnología de iluminación artificial es necesario coordinarla con la iluminación natural para poder integrar este proyecto en un todo congruente, y *es importante dar a este estudio un enfoque de ahorro de energía.*

Aspectos del proyecto. Los aspectos básicos a considerar para iniciar el proyecto de iluminación, son los siguientes:

. *Aspecto funcional.* Son las consideraciones que deben tomarse en cuenta desde el punto de vista "actividad del hombre". Para cada una se requiere una cantidad de luz y un tratamiento específico. En Estados Unidos de Norteamérica existe una sociedad dedicada al estudio de la iluminación, la misma emite tablas con cantidades de luz y detalles específicos para todos los espacios donde tiene actividades el hombre; esta información es considerada básica para el inicio del proyecto de iluminación.

En México existe la Sociedad de Ingenieros en Iluminación que tiene tablas y estudios acerca de los niveles de iluminación para las diferentes actividades; estos datos están actualizados y adaptados para este país.

. *Aspecto formal.* Se refiere a las características de diseño del sistema de iluminación; éste debe adaptarse al estilo arquitectónico y contribuir a la ambientación general, interior y exterior de la arquitectura.

Los colores que emiten las fuentes luminosas también estarán considerados para concordar con la arquitectura. La iluminación de los callejones de Guanajuato, están resueltos con faroles acordes con esta arquitectura y la fuente luminosa, sodio en alta presión, da a ambientación en tonos amarilos que destaca a piedra de las fachadas.

• *Aspectos sicológicos.* Es difícil medir este punto, sin embargo sabemos que existe e influye en el diseño, con la iluminación podemos enfatizar el aspecto sicológico y reafirmar al espacio en su actividad. Daremos algunos ejemplos: en el pasillo de un hotel, se requiere iluminación de baja intensidad, y este efecto provoca que las personas transiten haciendo el menor ruido posible; la iluminación, básicamente de puntos, establece comportamientos de euforia en las personas; la luz indirecta relaja, etcétera.

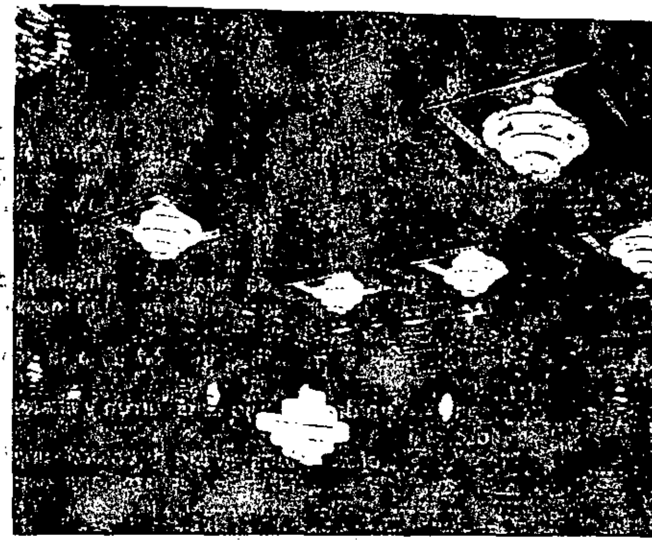
Dos maneras distintas de concebir la iluminación de un mismo objeto

En las fuentes luminosas los colores utilizados provocan diferentes estados de ánimo. En hospitales de Houston en Estados Unidos, se han hecho experimentos con diferentes colores para distintos tipos de pacientes. En algunos con padecimientos cardiacos, por ejemplo, los colores verde pastel proyectados en forma indirecta ayudan al restablecimiento. En enfermedades mentales se comprobó que colores azules y naranjas contribuyen a la mejoría.

Consideraciones del proyecto. Existen consideraciones que el proyecto de iluminación contempla, como:

Mantenimiento. Para que el proyecto de iluminación, una vez ejecutado, sea eficiente se requiere de un programa de mantenimiento que contemple el reemplazo de lámparas y de limpieza de luminarias. Este programa puede estar estructurado de manera que se puedan reemplazar lotes de lámparas a un mismo tiempo, según la duración real indicada por el fabricante para mantener niveles de iluminación estables.

El ahorro de energía está ligado también al mantenimiento, un sistema que se encuentre en óptimas condiciones consumirá menos energía. En el hotel Nikko de esta ciudad, en el salón de convenciones, se encuentra instalado un sistema de candiles monumentales de forma helicoidal, que por su diseño dificultaba la limpieza y el reemplazo de lámparas, de manera que para darles mantenimiento fue necesario dotarlos de un sistema de polipastos eléctricos; de esta forma el candil baja a 20 centímetros del suelo y puede realizarse el mantenimiento adecuado.



Hotel Nikko de la ciudad de México, salón de convenciones

• *Ahorro de energía.* Actualmente este tema, por el costo real de la energía eléctrica es muy importante. En países europeos donde el costo de la electricidad es muy

[illegible]

[illegible] luminoso. El flujo luminoso [illegible] el lumen, lleva consigo el concepto de relación [illegible] similar a aquella con la cual otras cantidades fluyen, como [illegible] por minuto, metros cúbicos por hora, etcétera. Ejemplo: una lámpara incandescente de 100 watts emite luz a razón de 1750 lúmenes, mientras que el flujo luminoso de una lámpara fluorescente de 40 watts es de cerca de 3,200 lúmenes.

Candela. Es la unidad utilizada para medir la intensidad luminosa, la potencia en candelas indica la capacidad de una fuente luminosa para producir iluminación en una dirección determinada.

Iluminación. Se denomina iluminación (E) a la densidad de flujo luminoso incidente.

Lux. Cuando la unidad de flujo es el lumen y el área está expresada en metros cuadrados.

Temperatura de color. La temperatura de color de una fuente luminosa es aquella a la cual debe operarse un cuerpo negro radiante para tener la misma apariencia de color que la fuente luminosa. La temperatura de color es solamente una especificación de la apariencia de color, y está medida en grados Kelvin (K).

Reflexión. Se caracteriza por el hecho de que el rayo llega a la superficie y sale de ella con ángulos iguales, o sea que el de incidencia es igual al de reflexión.

Transmisión. Este concepto se refiere al paso de la luz a través de un medio, de cuyas características dependerá que la luz se modifique en cuanto al color, intensidad y dirección.

Refracción. Se llama así al cambio de dirección de los rayos luminosos al pasar de un medio a otro.

elevado, se han desarrollado sistemas de iluminación, luminaria y lámpara con un alto grado de eficiencia. En México el costo de la energía está en un punto tal que va a ser imposible sostener el subsidio gubernamental por mucho tiempo, por lo que es de vital importancia que en los proyectos de iluminación, se tengan consideraciones de ahorro de energía.

Ahorro de energía. Para el ahorro de energía en iluminación se pueden considerar los siguientes puntos importantes.

1. *Fuentes de iluminación eficientes.* Con las técnicas actuales podemos elegir de una gama muy amplia de lámparas de alta eficiencia, de muy buen rendimiento de color, semejante a la luz solar, y son lámparas de muchas horas de vida.

Para conocer estos avances que actualmente tenemos en México es conveniente contactar a algunas de las fábricas establecidas en el país; en sus catálogos encontraremos fuentes de luz que nos ayuden con el ahorro de energía en nuestros proyectos.

2. *Luminaria óptima.* Nos referimos a un buen diseño de luminaria, donde el reflector y sus curvas fotométricas son las correctas y están avaladas por algún laboratorio especializado.

En México contamos con un laboratorio de este tipo en el Departamento del Distrito Federal.

El difusor es igualmente importante, aquéllos geométricamente diseñados nos elevan la cantidad de luz emitida y dan un control de ella para cada uso específico.

3. *Cálculo de iluminación.* Para ubicar correctamente las luminarias y elegir la lámpara adecuada, el cálculo de iluminación es muy necesario; nos da la cantidad de equipos que se van a requerir sin excedernos, esto contribuye a lograr un ahorro extra.

El proyecto de iluminación dentro de la arquitectura y la ingeniería es muy importante, existen algunas construcciones de arquitectos famosos, de reconocido prestigio, que descuidaron este aspecto.

Como ejemplo podríamos citar el museo Guggenhgeim en la ciudad de Nueva York, edificio proyectado y construido por el arquitecto Frank Lloyd Wright, considerado como el mejor en Estados Unidos. Tiene grandes errores en su concepto de iluminación, reflectores que provocan molestos deslumbres directos, luz fluorescente con distorsión en el color, etcétera. La luz en espacio museográfico es vital, de manera que la carencia de un buen diseño de iluminación en este museo es muy notorio.

El proyecto de iluminación arquitectónica en su realización utiliza el mismo método que usa el arquitecto, la investigación de entorno y el tipo de actividad, etcétera.

La integración del proyecto de iluminación en la arquitectura da al producto final carácter y funcionalidad al grado de tener una importancia básica en el resultado del diseño arquitectónico. ■

Arq. Enrique Quintero López

La tecnología de iluminación artificial se debe coordinar con la iluminación natural

La luz en la hotelería

La arquitectura de la luz en los servicios turísticos, hoteles, restaurantes y discotecas tiene un rango muy amplio de creatividad, a pesar de estar considerado como un trabajo muy técnico.

El huésped desea encontrar en un hotel un "segundo hogar", con la ambientación que se tiene en casa, teniendo acceso además a una serie de actividades de recreación cercanas y a la mano. La luz en un hotel es más importante de lo que se piensa y finalmente representa uno de sus mayores atractivos.

Si bien cada cadena hotelera ostenta características especiales de diseño arquitectónico, comentaremos en términos generales las áreas más importantes y cómo se resuelven desde el punto de vista de calidad y cantidad de luz.

Lobby de acceso. Está área, a la cual accede en primera instancia el cliente, debe reflejar la imagen del hotel y la calidad de los servicios que puede encontrar el huésped. Con frecuencia encontramos en este espacio diseños monumentales de plafones luminosos o candiles, destacándose el del hotel Hyatt Singapur considerado el más grande del mundo. Esta luminaria está compuesta de tubos de cristal de tonos agua y azules con bombillas incandescentes de cinco y diez watts.

En cuanto a las cantidades o niveles de iluminación, la Sociedad Mexicana de Ingenieros en Iluminación nos indica que deberá estar en promedio entre los 450-600 LX.

La recepción requiere de iluminación de trabajo en el mostrador (400-500 LX) y en la parte posterior, donde comúnmente se ubican los casilleros de llaves y recados.

Las cantidades de luz oscilan entre los 500-600 LX y en este lugar encontramos logotipos del hotel y señalamientos importantes que la luz puede destacar con reflectores de acento.

Salón de convenciones. El acondicionamiento y el equipo de iluminación en un salón de convenciones resulta uno de los trabajos más atractivos en el diseño de iluminación, pues requiere de una gran variedad de efectos con luz para satisfacer todas las actividades y eventos que se realizan en este espacio.

Los distintos sistemas de iluminación abarcan efectos ambientales, luz general, efectos de acento y como parte del diseño de interiores, candiles y arbotantes.

La mayoría de estos salones de convenciones dividen sus espacios en forma modular y temporal y la iluminación se adapta a este requerimiento. Para la correcta combinación de circuitos, logrando gran variedad de efectos se utilizan controles computarizados con atenuadores.

En el salón constelaciones del Hotel Nikko se encuentra un buen ejemplo de lo que se puede lograr en salones de convenciones.

Restaurantes. Existen en los hoteles dos tipos diferentes de restaurantes. En el primero, por lo general la iluminación es natural para los desayunos y cuenta con algunos refuerzos de luz artificial, para comida y cena, que se resuelven con dos sistemas de iluminación. En el segundo, restaurante de especialidades donde la gastronomía es superior, la iluminación es más ambiental con efectos de luz de mayor contraste. Entre más fino es un restaurante el nivel de iluminación, decir la cantidad de luz es menor y los acentos luminosos sobre las mesas es más recomendado.

Discoteca. Es una de las zonas más creativas en cuanto a trabajo de iluminación, pues de hecho se trata de un espacio de luz y sonido,

La luz tiene un rango muy amplio de creatividad a pesar de estar considerada como algo muy técnico. Representa uno de los mayores atractivos en un hotel

Los espacios exteriores de un hotel significan una carta de presentación

aunque de mayor complejidad técnica a resolver.

La pista de baile, como un laboratorio completo de iluminación contiene elementos móviles de Par 36, luces estroboscópicas, fibra óptica y rayo laser. El control de efectos de luz, realizado mediante sofisticados elementos de «dimeo», se coordina con el sonido y el video.

Habitaciones. En la habitación de hotel, ya sea sencilla o master suite, se refleja el confort y la calidad de servicio y dependiendo de éste serán las «estrellas» con que sea catalogado el hotel. La iluminación representa un gran porcentaje de ese confort.

La luz de lectura debe presentarse en circuitos separados y abarcar exclusivamente el área necesaria. En algunos casos se utilizan pequeños reflectores en bajo voltaje dirigidos, o bien, lámparas con pantalla.

La mesita que se usa para comer o trabajar requiere de una cantidad de luz que permita más de dos actividades y puede estar en 450-500 LX.

Es conveniente, en caso de usar lámpara suspendida, que ésta se ubique a una altura que no deslumbre directamente.

Baños. En los baños encontramos, para los lavabos, en la mayoría de los hoteles, incluyendo a los de gran turismo, una iluminación fluorescente colocada en un gabinete en la parte superior que aparentemente es la adecuada; sin embargo el color o tipo de tubo fluorescente instalado es, en la mayoría de los casos deficiente. Las mujeres que se maquillan en estos lugares se quejan de la luz, pues no refleja fielmente los colores.

Otro aspecto negativo de esta iluminación es que sea cenital, pues los rostros muestran sombras desagradables. La mejor forma de iluminar el rostro en un espejo es lateralmente, en ambos lados y con una fuente luminosa que refleje correctamente los colores, que puede ser fluorescente, sea tubular o compacto con un buen rendimiento de color.

Pasillos. Los efectos de luz actúan en el hombre de manera inconsciente, modificando su comportamiento. La luz tenue e indirecta hace reaccionar con lentitud a las personas y hablar en voz baja. Este tratamiento de luz es recomendable para los pasillos, ya sea en arbotantes indirectos o en casillos con iluminación de luz rebotada.

En el diseño de los pasillos se marcan «ritmos» para evitar que éstos se sientan largos y aburridos. La luz en distintas intensidades es un excelente recurso y se puede indicar la proximidad de un vestíbulo de elevadores con un nivel más intenso de luz.

Jardinería y áreas exteriores. Los espacios exteriores en un hotel significan la carta de presentación externa de la cadena hotelera. Los jardines se enfatizan con unidades de iluminación fabricadas con materiales especiales para la corrosión y podemos, actualmente dar efectos con lámparas de bajo voltaje en MR-16 o bien Par 36. Estas unidades que se integran al follaje y los árboles, deben considerar un aspecto: la seguridad.

Por seguridad en las albercas se requiere instalar unidades de bajo voltaje que estén debidamente selladas para evitar filtraciones. Un recurso novedoso es la utilización de fibra óptica que es un elemento que transmite únicamente luz, por lo tanto resulta muy segura en su instalación y uso y tiene la posibilidad de cambiar de colores y de estar sumergida en el agua.

El proyecto de iluminación en hoteles es considerado como el más completo, pues además existen áreas de oficinas, bodegas y lavandería, que completan un rango muy amplio de aplicaciones de iluminación arquitectónica y técnica.

Finalmente, siendo las consideraciones de ahorro y energía una de las prioridades actuales, las nuevas fuentes luminosas ahorradoras de energía combinadas con luminarias eficientes y un proyecto adecuado de iluminación permiten optimizar la energía sin sacrificar la calidad ni la cantidad de iluminación. ■

Arq. Enrique Quintero López

El arquitecto Enrique Quintero López trabaja como asesor especializado en proyectos de iluminación. Asimismo imparte cursos en diferentes universidades e instituciones de la ciudad de México. Entre los reconocimientos de que ha sido objeto se encuentra el de *Lighttolier* por el diseño de su sala de exhibición en Polanco y el *Premio Internacional de Iluminación Edwin F. Guth* por la obra «Tienda Hermanos Vásquez» en la ciudad de México.