ANALISIS ECONOMICO DE PROYECTOS DE INGENIERIA (Del 12 al 27 de Agosto de 1977)

Fecha	Duración	Tema	Profesor
12 de Agosto	17 a 18 h	Introducción: Decisiones Económicas en la Ingeniería	Ing. Carlos Uriegas Torres
	18 a 20 h	Objeto del Análisis Económico de Proyectos	Ing. Carlos Uriegas Torres
13 de Agosto	20 a 21 h y 9 a 11 a.m.	Modelos Económicos del Sistema "Empresa"	Ing. Vicente Córdova Ibarra
13 de Agosto	11 a 13 h	Evaluación de los Costos	Ing. Hugo Rosales Martínez
	14 a 17 h	Determinación y Representación del Flujo de Efectivo de un Proyecto	Ing. Juan José Vilchis Vivero
19 de Agosto	16 a 19 h	Costo y Valor del Capital	Ing. Carlos Uriegas Torres
19 y 20 de Agosto	19 a 21 h 9 a 11 am	Equivalencia de Flujos de Efectivo	Ing. Hugo Rosales Martínez
20 de Agosto	11 a 14 h	Métodos de Equivalencia del Flujo de Efectivo para la Evaluación de Alternativas	Ing. Juan José Vilchis Vivero
	15 a 18 h	Evaluación de Alternativas mediante la Tasa de Rendimiento Interno	Ing. Vicente Córdova Ibarra
26 de Agosto	17 a 20 h	Evaluación Económica de Proyectos de Ampliación o Expansión	Ing. Juan José Vilchis Vivero
27 de Agosto	20 a 21 h 9 a 12 h	Evaluación Económica de Proyectos de Remplazo de Equipo	Ing. Carlos Uriegas Torres
	12 a 14 h	Depreciación e Impuestos en la Empresa Privada	Ing. Vicente Córdova Ibarra
	15 a 18 h	Análisis Económico de Inversiones Públicas	Ing. Carlos Uriegas Torres

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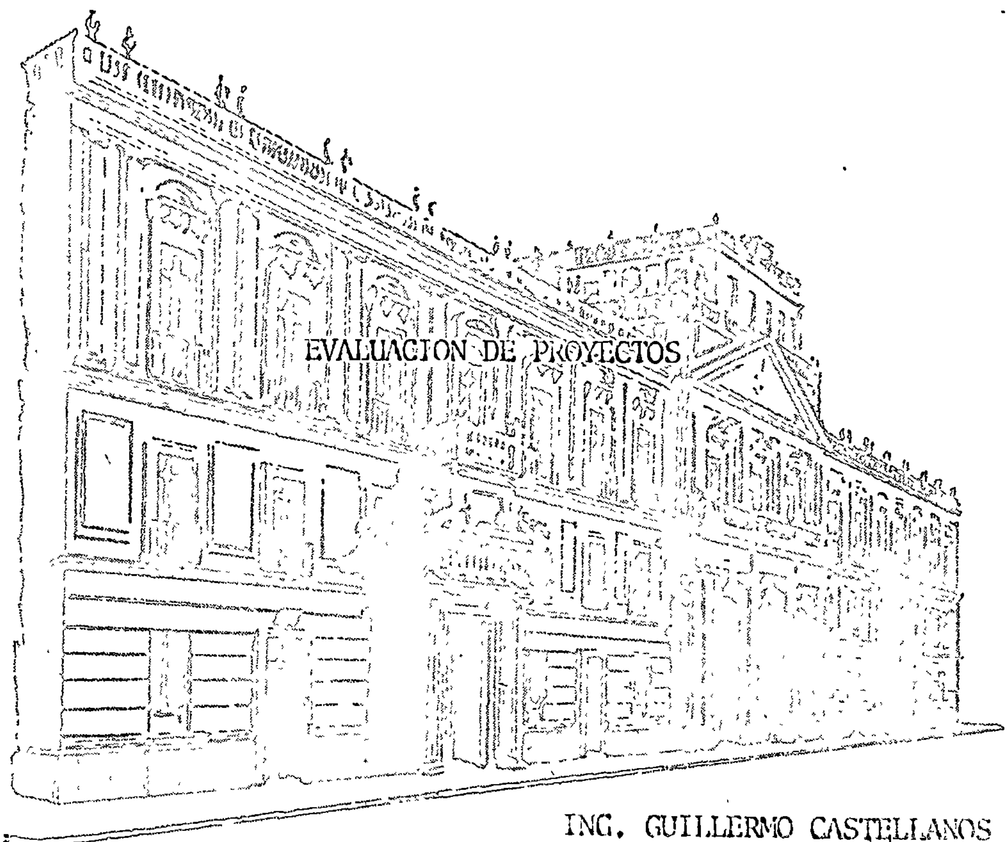
ANALISIS ECONOMICO DE PROYECTOS DE INGENIERIA



EVALUACION DE PROYECTOS

ING. GUILLERMO CASTELLANOS GUZMAN
Marzo 1977.

EVALUCACION DE PROYECTOS

Ing. Guillermo Castellanos Guzmán.

INTRODUCCION

El objetivo básico de todo estudio económico de un proyecto - es evaluarlo, es decir, calificarlo para determinar si es bueno o malo y - compararlo con otros proyectos de acuerdo con una determinada escala de valores a fin de establecer un orden de prelación. Esta tarea exige pre-- cisar las "ventajas" y "desventajas" de la asignación de recursos a un - fin dado. El problema teórico de establecer cual es el criterio de evalua_ ción que se debe utilizar para establecer prelaciones no ha sido aún re-- suelto en definitiva; sin embargo, se distinguen dos grupos principales: - por un lado los patrones de comparación de proyectos conforme al interés del empresario privado y por el otro los que interesan a la comunidad en - su conjunto y que se pueden llamar criterios sociales de evaluación.

Los capítulos en que podemos dividir el estudio de un proyec- to son:

i) Estudio de Mercado. - Estudio de la demanda de los bienes y - servicios a que el proyecto se refiere.

ii) Determinación del tamaño y la localización.- Determinación de la capacidad de producción que ha de instalarse y de la localización de la nueva unidad productora.

iii) Ingeniería del Proyecto.- Descripción técnica del proyecto, investigaciones preliminares, especificación de los equipos y estructuras, selección de los procesos de elaboración, justificación del grado de mecanización adoptado, cantidad y calidad de los insumos requeridos, etc.

iv) Cálculo de las Inversiones.- Cálculo de las inversiones totales en moneda nacional y extranjera que el proyecto exige, considerando la inversión en activos fijos y el capital de trabajo o circulante.

v) Presupuesto de gastos e ingresos anuales y organización de los datos para la evaluación.- Estimación de los costos e ingresos que resultarían del funcionamiento de la empresa incluyendo en forma ordenada aquellos antecedentes que puedan ser necesarios para evaluar el proyecto: efectos sobre la balanza de pagos, presupuestos y disponibilidad de la mano de obra, etc.

vi) Evaluación del Proyecto.- Utilización de criterios de evaluación para poder calificar el proyecto y compararlo con otros para determinar prelaciones.

vii) Financiamiento.- Especificaciones de las fuentes monetarias a que se recurrirá y las formas en que se proyecta canalizar los recursos financieros para llevar a cabo la iniciativa.

viii) Organización y Ejecución.- Solución de problemas relativas a la constitución legal de la empresa y a la organización para el montaje y realización del proyecto.

CRITERIOS DE EVALUACION DE PROYECTOS

Las diferencias sustantivas entre los criterios de evaluación se refieren a las diferentes maneras de considerar, especificar y medir lo que en cada caso se entiende por recursos empleados y beneficios obtenidos; sin embargo, todo cómputo de evaluación debe abordar los conceptos de valoración, homogeneidad y extensión.

La Valoración

Debido a la diferente naturaleza física de los bienes y servicios, la determinación de su cuantía relativa para fines de evaluación se expresa mediante un denominador común, que es la unidad monetaria. La valoración consiste en asignar precios a los bienes y servicios realacionados con un proyecto, los cuales no siempre son los precios de mercado los representativos, sino los que llamaremos precios sociales, que no son más que los precios de mercado corregidos para fines de evaluación.

Homogeneidad

Los cálculos de evaluación abarcan toda la vida útil del proyecto, por lo que habrá que operarse con valores monetarios correspondientes a transacciones realizadas en distintas fechas. Para que tales magnitudes sean comparables, es necesario hacer las homogéneas respecto al tiempo, utilizando para ello equivalencias financieras.

Extensión

La realización de un proyecto provoca una serie de reacciones económicas en cadena hacia atrás o "hacia el origen" y hacia adelante o "hacia el destino" del mismo. El problema de la extensión consiste en considerar y cuantificar estas repercusiones económicas del proyecto, dentro del criterio de evaluación adoptado.

En este aspecto, los criterios de evaluación se dividen en dos grandes grupos, los que miden los efectos que corresponden sólo al proyecto mismo, que se llaman "efectos directos" y los que tratan de medir también los "efectos indirectos", tanto en cuanto a recursos empleados, como a beneficios resultantes.

TIPOS DE COEFICIENTES DE EVALUACION

Las distintas formas de valorar, la posibilidad de incluir o no los efectos indirectos y la posibilidad de seleccionar y definir de distintas maneras los patones de comparación, hacen que existan muchos criterios de evaluación y que se plantee la cuestión de cual de ellos será más adecuado.

I. LA EVALUACION PARA EL EMPRESARIO Y LA EVALUACION SOCIAL

Una buena parte de las controversias registradas en torno a los criterios de prioridad surgen indudablemente de la falta de una distinción clara del objetivo de la evaluación ya que depende de la entidad en favor de quien se evalúa, por lo que han surgido confusiones al valerse de criterios adecuados para seleccionar en función del interés individual y tratar de aplicarlos a casos en que hay que hacerlo en función del interés social.

Estas consideraciones permiten establecer la primera gran distinción entre los criterios de evaluación: por un lado, los que son útiles para la comparación entre los proyectos privados y por el otro, aquéllos que son aplicables desde un punto de vista social. No hay problemas conceptuales en cuanto a lo que el empresario privado entiende por beneficios, ya que su móvil fundamental es el de las utilidades, sea en términos absolutos o por unidad de capital propio (Rentabilidad). Tampoco hay dudas sobre las formas de medición: en cuanto a valoración le interesan los precios de mercado y en cuanto a extensión sólo los beneficios y costos directos del proyecto. El problema es conceptual y prácticamente más difícil en el caso de la evaluación social.

Cabe señalar que quienquiera que sea el realizador o promotor de un proyecto, pertenezca al sector público o al privado, deberá afrontar el problema del financiamiento, lo que hace siempre necesaria una evaluación a precios de mercado. Además, aunque se determine la prelación desde el punto de vista social, muchos proyectos se dejerán a la iniciativa privada, y en ese caso habrá que determinar si serán atractivos o no para el empresario privado y cuales serían los incentivos que podrían despertar su interés.

LA SELECCION ENTRE LOS CRITERIOS PARA EVALUAR

En términos generales puede afirmarse que si se trata de evaluar con criterio social, lo que más importa es el incremento del producto nacional que se obtiene por unidad del complejo de recursos que se emplean en el proyecto. Todas las magnitudes se debieran valorar a precios sociales y habría que tomar en cuenta no sólo los beneficios y recursos directamente relacionados con el proyecto, sino también los indirectos.

Sin embargo, en muchos casos se prefiere medir la productividad del recurso escaso, usando como denominador en el cociente de evaluación el capital, la mano de obra o las divisas invertidas; pero esta evaluación puede resultar incompleta, ya que el proceso de producción envuelve la utilización conjunta de los factores que se complementan e integran en la llamada función de producción.

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La producción en una faena agrícola podría aumentar porque los obreros aprovechan mejor su tiempo, porque se les entrega mejor semilla o porque se pone a su disposición tractores y otras máquinas. Si se omiten todos estos factores y sólo se mide la producción por hombre, no será posible establecer si se obtuvo un producto mayor con la misma suma de factores, uno de los cuales rindió más, o gracias al aumento de los recursos empleados.

Se pueden hacer planteamientos similares en cuanto a los beneficios o efectos del proyecto cuantificados en el numerador del cociente, lo que hace que se presenten limitaciones prácticas y conceptuales para reunir todos estos efectos y sumarlos en unidades homogéneas. De ahí que se propongan a veces coeficientes parciales para medir por separado los efectos. A base de ellos se podría obtener una idea de conjunto que permitiera determinar prelaciones, dando mayor ponderación a aquel factor que se considere más importante en un caso dado, aunque esta ponderación podría llegar a tener un grado de subjetividad del mismo orden que las apreciaciones indispensables para vencer las limitaciones prácticas en la obtención de los datos necesarios para la evaluación integral.

FACTORES ECONOMICOS Y POLITICOS EN LA EVALUACION

Las consideraciones de naturaleza política, suelen desempeñar un papel decisivo en las prioridades de la inversión. Además, hay muchos proyecto destinados a abastecer servicios que no son materia de mercado y cuya demanda no se expresa en términos monetarios, sino en peticiones o gestiones de los grupos interesados, como los servicios de alcantarillado, el alumbrado público, etc.

Conviene tener presente que en las prioridades de inversión pueden influir planteamientos relacionados con la necesidad de dar mejor cohesión social y administrativa a un país.

De todo lo anterior podría desprenderse que al final de cuentas, no son tan importantes los criterios económicos de evaluación ya que a la postre la evaluación económica está supeditada a un criterio político y por consiguiente no habrá justificación para esforzarse en una evaluación cuidadosa; sin embargo, la conclusión correcta es la inversa. Si por razones de orden político, un proyecto A resulta preferible a otro B siendo que conforme a la evaluación económica B es superior a A, es preciso conocer el precio que se paga por esa decisión política; pero ese precio sólo se puede averiguar calculando los coeficientes económicos de prelación.

Por otra parte, no hay que caer en el extremo de suponer que todos los proyectos estarán sujetos a un análisis de tipo político específico. Dado un cierto marco de política económica y realidad institucional, lo más probable es que la decisión respecto a la mayoría de los proyectos se tome simplemente conforme a un criterio económico de evaluación. La importancia de la evaluación económica es pues indudable.

ASIGNACION DE VALORES

Precios de Mercado y Costos Sociales.

El precio de mercado sería representativo del valor real de los bienes y servicios, si funcionaran libremente las leyes de la oferta y la demanda, en condiciones de competencia perfecta, ocupación plena de todos los recursos y completa movilidad de los factores. Si por interferencias, trabas o reglamentaciones de cualquier orden no se cumplen estas condiciones, el sistema de precios estará deformado. De ahí que se considere necesario corregir los precios de mercado para obtener el llamado costo social de los factores.

Las modificaciones fundamentales que se han propuesto hacer los precios de mercado, se podrían agrupar en dos grandes tipos que no se excluyen entre sí. Unas consisten en eliminar de dichos precios las influencias de impuestos y subsidios y las otras en emplear los llamados "costos de oportunidad". El costo de oportunidad de un recurso requerido por un proyecto, es el valor imputable a este recurso, de lo que se dejaría de producir en otra actividad en la que se podría utilizar y de la que se le sustraería para emplearlo en el proyecto.

EFECTOS INDIRECTOS

Cada proyecto establece una cadena de reacciones que tendrá siempre efectos cuantitativos de amplio radio de acción. Si se dispusiera -

de un cuadro muy detallado de insumo-producto, cabría utilizarlo para estimar las consecuencias finales de la introducción de tal o cual alteración representada por un proyecto dado. Pero en la generalidad de los casos, no se contará con tales cuadros. La alternativa está en realizar algún tipo de estimaciones que aún no siendo perfectas, sean por lo menos mejores que las que se obtienen de considerar sólo los efectos directos.

La cuantía de los efectos indirectos en la evaluación social del proyecto, tanto en cuanto a beneficios, como a recursos empleados, variará según el tipo de proyecto de que se trate. En general, los proyectos destinados a producir servicios básicos para la producción, se justificarán por sus efectos en el resto de la economía, más bien que por los resultados del proyecto mismo. Consideraciones similares pueden ser también válidas en cuanto al servicio de transportes.

Ejemplo:

Consideremos dos ciudades A y B, las cuales están ligadas por un camino pavimentado de 100 Km de longitud, en el cual los automóviles circulan a una velocidad media de 70 K/Hr., los autobuses a 65 K/Hr. y los camiones a 60 K/Hr. El tránsito actual es de 2 500 vehículos por día, de los cuales el 50% corresponde a automóviles, el 15% a autobuses y el 35% restante a camiones.

Se pretende estudiar un proyecto carretero entre los mismos puntos A y B con mejores especificaciones y más corto, con objeto de disminuir los costos de transporte. De acuerdo al proyecto, los automóviles podrán circular por este camino a una velocidad media de 90 K/Hr., los autobuses a 85 K/Hr. y los camiones a 70 K/Hr. La longitud de este camino será de 70 Km y se espera que aproximadamente el 40% del tránsito se podrá desviar del camino antiguo al propuesto (dato obtenido con ayuda de estudios de origen y destino).

El tránsito en el camino actual está creciendo a una tasa del 8% anual y se espera que se mantenga hasta el primer año de operación de la obra, a partir del cual se esperan incrementos del 10%, 12%, 13%, 11%, 9% hasta volverse a estabilizar a 8% anual.

El costo horario por vehículo y operadores se ha estimado en $ 6.15 para automóviles, $ 32.97 para autobuses y $ 32.97 para camiones y el costo de tracción por vehículo-kilómetro se ha estimado en $ 0.30 para automóviles, $ 0.54 para autobuses y $ 0.73 para camiones.

Los costos considerados son los siguientes:

Inversión	$ 1 000 000/Km. a realizar en dos años, en el primer año 40% y en el segundo 60%.
Conservación	$ 20 000/Km/año
Reconstrucción al año 9	$ 90 000/Km.
Reconstrucción al año 16	$150 000/Km.

Obtener la relación beneficios-costos del proyectos, considerando - como ventajas los ahorros en tiempo de recorrido y los ahorros en tracción por menor longitud que tendrán los usuarios durante un horizonte económico de 20 años de operación y considerando una tasa de actualización del 12% anual.

Cálculo del ahorro unitario

	Automóviles	Autobuses	Camiones
Tiempo de recorrido			
Camino actual	1.43 Hs.	1.54 Hs.	1.67 Hs.
Camino propuesto	0.78	0.82	1.00
Ahorro	0.65	0.72	0.67
Longitud			
Camino actual	100 Km.	100 Km.	100 Km.
Camino propuesto	70	70	70
Ahorro	30	30	30
Costos			
Horario por vehículo y operadores	6.15	32.97	32.97
De tracción por vehículo-kilómetro	0.30	0.54	0.73
Composición del tránsito	0.50	0.15	0.35

Ahorro unitario anual por tiempo

Automóviles	0.65	x	6.15	x	0.50	x	365	= $	729.55
Autobuses	0.72	x	32.97	x	0.15	x	365	=	1 295.75
Camiones	0.67	x	32.97	x	0.35	x	365	=	2 821.45
			Subtotal						4 846.75

Ahorro unitario anual por costos de tracción

Automóviles	30	x	0.30	x	0.50	x	365	= $	1 642.50
Autobuses	30	x	0.54	x	0.15	x	365	=	886.95
Camiones	30	x	0.73	x	0.35	x	365	=	2 797.80
			Subtotal						5 327.25

Ahorro unitario anual $ 10 174.00

Proyección del Tránsito y Beneficios
(en miles de pesos)

Año	Factor	Tránsito	Beneficios	
0	1.00	1 000	--	
1	1.08	1 080	--	Etapa de construcción
2	1.08	1 166	--	
3	1.08	1 259	12 809	1er. año de operación
4	1.10	1 385	14 090	
5	1.12	1 551	15 781	
6	1.13	1 753	17 835	
7	1.11	1 945	19 788	
8	1.09	2 120	21 569	
9	1.08	2 290	23 294	
10	1.08	2 473	25 158	
11	1.08	2 671	27 17[illegible]	
12	1.08	2 885	29 344	
13	1.08	3 115	31 691	
14	1.08	3 364	34 226	
15	1.08	3 633	36 964	
16	1.08	3 924	39 921	
17	1.08	4 238	43 117	
18	1.08	4 577	46 566	
19	1.08	4 943	50 291	
20	1.08	5 338	54 314	
21	1.08	5 765	[illegible]	
22	1.08	6 226	63 343	

En lo que se refiere a costos se tendrá:

Inversión:	\$ 1 000 000/Km x 70 Km =	\$ 70 000 000	
	Año 1	28 000 000	(40%)
	Año 2	42 000 000	(60%)
Conservación anual	\$ 20 000 x 70 =	1 400 000	
Reconstrucción al año 9	90 000 x 70 =	6 300 000	
Reconstrucción al año 16	150 000 x 70 =	10 500 000	

Determinación de la relación beneficios-costos
(Miles de pesos)

Año	Factor Act.	Beneficios	Beneficios Act.	Costos	Costos Actualizados
0	1.00	--	--	--	--
1	1.12	--	--	28 000	25 000
2	1.25	--	--	42 000	33 600
3	1.40	12 809	9 149	1 400	1 000
4	1.57	14 090	8 974	1 400	892
5	1.76	15 781	8 966	1 400	795
6	1.97	17 835	9 053	1 400	711
7	2.21	19 788	8 954	1 400	633
8	2.47	21 569	8 732	1 400	567
9	2.77	23 294	8 409	1 400	505
10	3.10	25 158	8 115	1 400	451
11	3.48	27 171	7 807	6 300	1 810
12	3.90	29 344	7 524	1 400	359
13	4.36	31 691	7 268	1 400	321
14	4.89	34 226	7 000	1 400	286
15	5.47	36 964	6 757	1 400	256
16	6.13	39 921	6 512	1 400	228
17	6.86	43 117	6 285	1 400	204
18	7.69	46 566	6 055	10 500	1 365
19	8.61	50 291	5 841	1 400	162
20	9.64	54 314	5 634	1 400	145
21	10.80	58 659	5 431	1 400	129
22	12.10	63 343	5 235	1 400	115
Sumas			147 701		68 534

$$\text{Relación beneficios-costos} = \frac{147\ 701}{68\ 534} = 2.15 \quad \text{(mayor que 1)}$$

De esto se deduce que la obra es conveniente, ya que la relación es mayor que la unidad; sin embargo, deberá compararse con otras obras para saber su orden de prioridad.

Beneficio neto actualizado = 147 701 000-68 534 000 = $ 79 167 000

Por tanteos puede calcularse la tasa interna de retorno, variando la tasa de actualización hasta igualar la suma de beneficios actualizados con la suma de costos actualizados.

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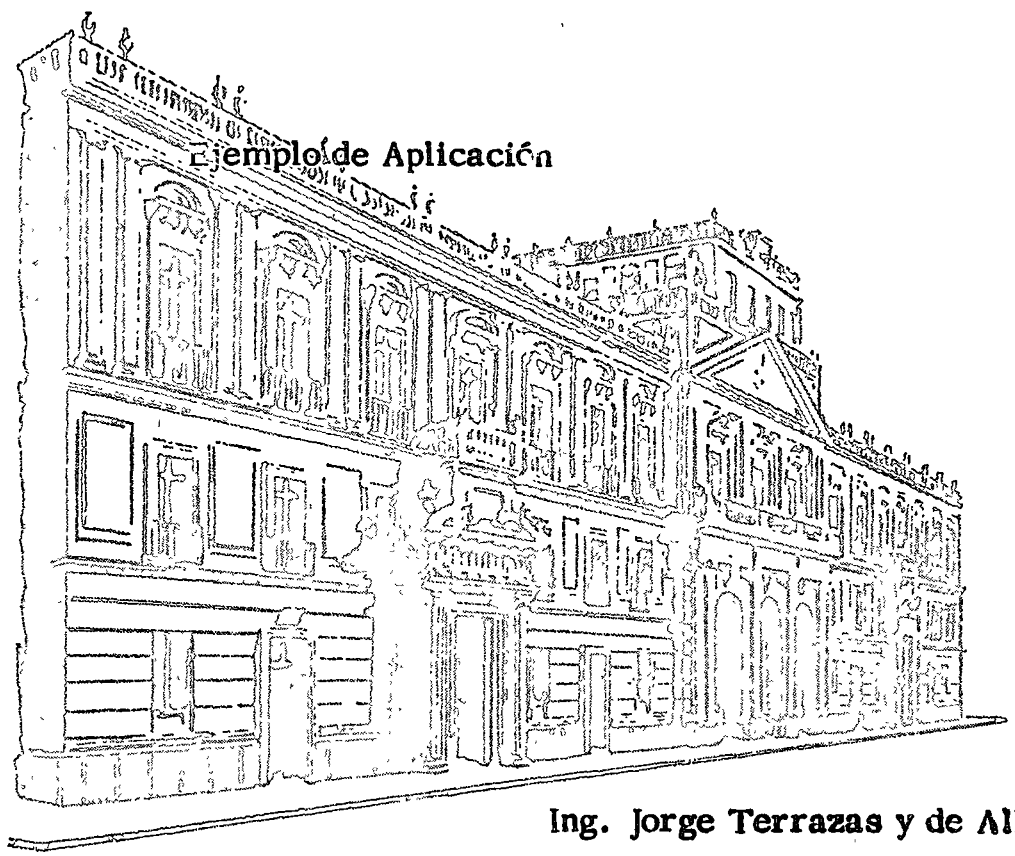
ANALISIS ECONOMICO DE DECISIONES EN LA INDUSTRIA DE LA CONSTRUCCION



Ejemplo de Aplicación

Ing. Jorge Terrazas y de Allende

Puebla, Pue.

Abril, 1977

Ejemplo.

.. A un industrial le es ofrecido un equipo de segunda mano en \$46,000. Estima que le costará unos \$7,000. el traslado, la instalación y el "hechar a andar" dicho equipo; y que tendría costos de operación, conservación y mantenimiento de \$140,000. anuales, durante los 3 años que considera poder utilizarlo y al fin de los cuales podría venderlo en unos \$25,000.

Por otro lado, averigua que una máquina similar, nueva, le cuesta \$150,000. ya instalada, con costos de operación estimados de \$100,000. y Valor de Recuperación al final de los 3 años que la emplearía, de \$50,000:

¿Debe aceptar la oferta del equipo usado o debe adquirirlo nuevo? y en todo caso ¿hasta cuanto podría ofrecer él por el equipo usado?

El industrial estima su tasa interna mínima atractiva de recuperación al momento de tomar su decisión en 17%.

Para calcular el valor límite máximo atractivo (P) al cual le conviene adquirir el equipo usado, procederá de la siguiente manera:

eq. usado: P (en 0), D = 140,000, VR = 25,000 (en 3)

eq. nuevo: 150,000 (en 0), D = 100,000., VR = 50,000 (en 3)

$$VP_{C.}\ \text{eq. usado} = P + 140{,}000\,(P/A,\ 17\%,\ 3) - 25{,}000\,(P/F,\ 17\%,\ 3)$$

$$VP_{C}\ \text{eq. nuevo} = 150{,}000 + 100{,}000\,(P/A,\ 17\%,\ 3) - 50{,}000\,(P/F,\ 17\%,\ 3)$$

El valor límite se obtendrá cuando:

$$VP_C\ \text{eq. nuevo} - VP_C\ \text{eq. usado} = 0$$

o bien: $$VP_C\ \text{eq. nuevo} = VP_C\ \text{eq. usado}$$

numericamente:

$$150{,}000 + 100{,}000\,(P/A,\ 17\%,\ 3) - 50{,}000\,(P/F,\ 17\%,\ 3) - P -$$
$$- 140{,}000\,(P/A,\ 17\%,\ 3) + 25{,}000\,(P/F,\ 17\%,\ 3) = 0$$

$$(\ P = 150{,}000 + (100{,}000 - 140{,}000)\,(P/A,\ 17\%,\ 3)$$
$$- (50{,}000 - 25{,}000)\,(P/F,\ 17\%,\ 3)$$

$$P = 150{,}000 - 40{,}000\,(P/A,\ 17\%,\ 3) - 25{,}000\,(P/F,\ 17\%,\ 3)$$

$$P = 150{,}000 - 88{,}383.^{40} - 15{,}609.^{26}$$

$$P = 46{,}007.^{34}$$

que es el valor de P límite, o el valor de P en el punto de equilibrio, y dado que el valor propuesto (P) para la compra del equipo usado es:

$$P = 46{,}000 + 7000$$
$$P = 53{,}000 > 46{,}007.^{34}$$

luego, la compra del equipo usado no es atractiva en esas condiciones, y deberá procederse a adquirir el equipo nuevo, a menos que, con una contra-oferta, pudiese obtenerse el equipo usado en menos de: ¢ 39,007.^34 (considerando fijo el cargo de ¢ 7,000. de instalación, etc...), de tal forma que el costo total de adquisición de este equipo, resultase menor de ¢ 46,007.^34.

METODO DE LA TASA DE RECUPERACION

Este método de comparación de alternativas, consiste en calcular directamente la tasa de recuperación que se espera obtener de cada una de las alternativas de inversión propuestas, lo que se analiza a partir del flujo de ingresos y de egresos que en cada una de ellas se prevée, y seleccionando aquella que ofrezca la tasa de recuperación más alta, pero teniendo en cuenta la tasa interna mínima atractiva de recuperación de quien debe decidir.

El procedimiento a implementar para lograr lo anterior se basa en el hecho de que, en el proceso de una inversión, los ingresos brutos provenientes de la misma, tienen como finalidad :

-) recuperar todas las erogaciones, costos directos e indirectos, que la inversión implique.

a) proporcionar una recuperación o utilidad.

Ahora bien, al establecer la ecuación :

$$\boxed{\text{Costos} = \text{Ingresos}}$$

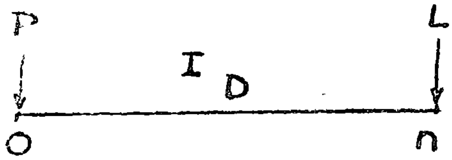
la variable que hace que se verifique la ecuacion anterior es precisamente : la tasa de recuperación, o tasa de interes (i), y desde este punto de vista, podemos decir que :

"la tasa de recuperación (i) es el interes que hace que los costos (o erogaciones totales) sean equivalentes a los ingresos"

Dado que una inversión implicará ingresos y egresos, siempre se podrá calcular algún valor de (i), sin embargo, solo si el importe total de los ingresos es mayor que el de los egresos, el valor de esa tasa de interes será mayor que cero.

Claro está que para establecer la ecuación entre costos e ingresos, ambos deberán estar expresados en el mismo "tiempo", lo cual puede lograrse transportando todo el flujo de efectivo al punto 0 por ejemplo, para obtener el Valor Presente, o traduciéndolo a una serie uniforme equivalente.

Así por ejemplo, para el caso general y traduciendo el flujo de efectivo a una serie de anualidades uniforme equivalente:



La ecuación:

Costos = Ingresos

quedaría:

$$P \cdot {}_{i-n}crf + D = I + L \cdot {}_{i-n}sfdf$$

$$P \cdot {}_{i-n}crf - L \cdot {}_{i-n}sfdf + D = I$$

dado que: ${}_{i-n}sfdf = {}_{i-n}crf - i$

$$\boxed{(P - L)\ {}_{i-n}crf. + L \cdot i + D = I}$$

usando otra notación:

$$\boxed{(P - L)\ (A/P,\ i\%,\ n) + L i + D - I = 0}$$

en la cual, la tasa (i) que verifica la ecuación se determina por iteraciones

De igual manera, solo que transportando el flujo de efectivo al punto 0 a fin de igualar Valores Presentes, se llegaría a:

$$\pm P \pm \sum_{j=1}^{n} F\,(P/F,\ i\%,\ j) \pm A\ (P/A,\ i\%,\ n) = 0$$

en donde el signo se aplicará dependiendo de si se trata de una erogación o de un ingreso.

EJEMPLO:

Se propone invertir en un inmueble en cuya compra inicial se requieren: \$ 450,000, y sobre el cual se espera recibir un ingreso de \$ 75,000 anuales con erogaciones de \$ 30,000 durante 10 años, al cabo de los cuales, se calcula se podrá vender en \$ 200,000. Se pide calcular la tasa de recuperación de la inversión.

$$I = 75{,}000/\text{año}$$

$$P = \$400{,}000 \qquad D = 30{,}000/\text{año} \qquad L = 200{,}000$$

$$0 \text{ ——————————————— } 10$$

Establezcamos la ecuación:

$$\text{Costos} = \text{Ingresos}$$

de acuerdo con la expresión desarrollada:

$$(P-L)\,_{i-n}crf + Li + D = I$$

que para los datos anteriores queda:

$$(400{,}000 - 200{,}000)\,_{i-10}crf + 200{,}000\,(i) + 30{,}000 = 75{,}000$$

Para determinar el valor de (i), hagamos un primer intento con $i = 0\%$ (lo cual equivale a investigar si los ingresos netos son suficientes para recuperar los costos, sin tener en cuenta el factor: "valor del dinero con el tiempo")

$$200{,}000\,_{0-10}crf + 200{,}000\,(0) + 30{,}000 = 75{,}000$$

recordando que: $\underset{i \to 0\%}{crf} \longrightarrow \frac{1}{n}$

entonces: $_{0-10}crf \longrightarrow \frac{1}{n} = \frac{1}{10} = 0.1$

$$\therefore \quad 20{,}000 + 30{,}000 \neq 75{,}000$$
$$50{,}000 < 75{,}000$$

restando \$50,000 en ambos miembros de la desigualdad:

$$0 < 25{,}000$$

lo que quiere decir que considerando una tasa de interes de 0%, los costos anuales < que los beneficios anuales por una diferencia de \$25,000, lo que significa que a una tasa de 0% la inversión se recupera, más una utilidad adicional de \$25,000 anuales.

Esta diferencia de \$25,000, respecto a la inversión inicial, representa un porcentaje de:

$$400{,}000 \text{ ———— } 100$$
$$25{,}000 \text{ ———— } x$$

$$\therefore\; i \approx \frac{25{,}000}{400{,}000} \times 100 = 6.25\,\%$$

Hagamos un 2° intento considerando: $i = 7\%$

$$200{,}000 \; {}_{7-10}crf + 200{,}000\,(0.07) + 30{,}000 = 75{,}000$$
$$28{,}476 \quad + \quad 14{,}000 \quad + 30{,}000 \neq 75{,}000$$
$$72{,}475 < 75{,}000$$
$$0 < 2{,}524$$

$\therefore$ a una tasa de interes del 7%:

$$C.A < BA \quad \text{por } \$\,2{,}524.$$

Hagamos un 3° intento considerando $i = 8\%$

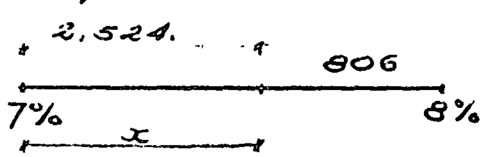
$$200{,}000 \; {}_{8-10}crf + 200{,}000\,(0.08) + 30{,}000 = 75{,}000$$
$$29{,}806 \quad + \quad 16{,}000 \quad + 30{,}000 \neq 75{,}000$$
$$75{,}806 > 75{,}000$$
$$806 > 0$$

$\therefore$ a una tasa de interes del 8%

$$CA > BA \quad \text{por } \$\,806.$$

es decir, impactando una tasa de interes de 8% (como costo del dinero con el tiempo), los costos exceden a los ingresos, la inversión no se alcanza a recuperar por $\$\,806$ anuales.

Interpolando:



$$x \;\text{———}\; 2{,}524$$
$$(8-7) \;\text{———}\; (2{,}524 + 806)$$

$$i = 7.0 + x = 7.0 + \frac{2{,}524}{(2{,}524 + 806)}\,(1.0)$$

$$i = 7.0 + 0.76$$

$\therefore$ la tasa de interes de la inversión propuesta es de:

$$i = 7.76\,\%$$

tasa que habrá que comparar con nuestra tasa interna mínima atractiva de recuperación para juzgar finalmente si la inversión propuesta nos es o no atractiva.

Como mero indicador para el 2° tanteo, conviene indicar que:

si $P > L$, i final $> i$ aprox. (obtenida con $i = 0\%$)
si $P = L$, i final $= i$ (obtenida con $i = 0\%$)
si $P < L$, i final $< i$ aprox. (obtenida con $i = 0\%$)

EJEMPLO

Se quiere calcular la tasa de recuperación de la inversión en un predio cuyo costo inicial es de: \$425,000, y el cual, se espera produzca al ser rentado: \$22,000 anuales netos (ya después de gastos) durante 5 años, al término de los cuales, se considera poder venderlo en: \$625,000. Se establece por otro lado, que la "timar" es de 15%.

$P = 425{,}000$ $\qquad I = 22{,}000/\text{año}$ $\qquad L = 625{,}000$

0 ———————————————— 5

Establezcamos directamente la ecuación:

Costos = Ingresos

$$425{,}000 \; {}_{i-5}crf = 22{,}000 + 625{,}000 \; {}_{i-5}sfdf$$

Para un primer intento con una tasa de interes de 0%, recordemos que:

$${}_{i-n}crf \xrightarrow[i \to 0]{} \frac{1}{n} \qquad\qquad {}_{i-n}sfdf \xrightarrow[i \to 0]{} \frac{1}{n}$$

$$\therefore \quad 425{,}000\,(1/5) = 22{,}000 + 625{,}000\,(1/5)$$
$$85{,}000 < 22{,}000 + 125{,}000$$
$$85{,}000 < 147{,}000$$
$$0 < 62{,}000$$

$\therefore$ considerando $i = 0\%$: C.A. < B.A. por \$62,000

Esta diferencia, con respecto a la inversión inicial de \$425,000 representa un porcentaje de:

$$425{,}000 \;\text{———}\; 100$$
$$62{,}000 \;\text{———}\; x$$

$$\therefore \quad i \backsim \frac{62{,}000}{425{,}000}(100) = 14.59\,\%$$

como $P < L$, la ta[illegible] (i) [illegible] menor que la resultante de 12, [illegible] apr[illegible]ación.

Hagamos por tanto, un 2° [illegible] considerando : $i = 12\%$

$$425{,}000 \; {}_{12-5}crf = 22{,}000 + [illegible]5{,}000 \; {}_{12-5}sfdf$$

$$117{,}899 < 22{,}000 + 98{,}381$$
$$117{,}899 < 120{,}381$$
$$0 < 2{,}482$$

∴ a una tasa de $i = 12\%$: C.A. < B.A. por \$ 2,[illegible]2.

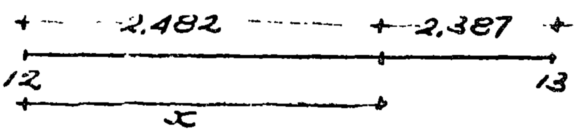
Hagamos un 3° intento considerando $i = 13\%$

$$[illegible]25{,}000 \; {}_{13-5}crf = 22{,}000 + 625{,}000 \; {}_{13-5}sfdf$$

$$120{,}834 > 22{,}000 + 96{,}447$$
$$120{,}834 > 118{,}447$$
$$2{,}387 > 0$$

∴ a una tasa de $i = 13\%$: C.A. > B.A. por \$ 2,387

Para calcular la tasa de recuperación exacta, procedamos a interpolar :



$$x \text{ ——— } 2{,}482$$
$$(13-12) \text{ ——— } (2{,}482 + 2{,}387)$$

$$i = 12 + x = 12 + \frac{2{,}482}{(2{,}482 + 2{,}387)}(1.0)$$

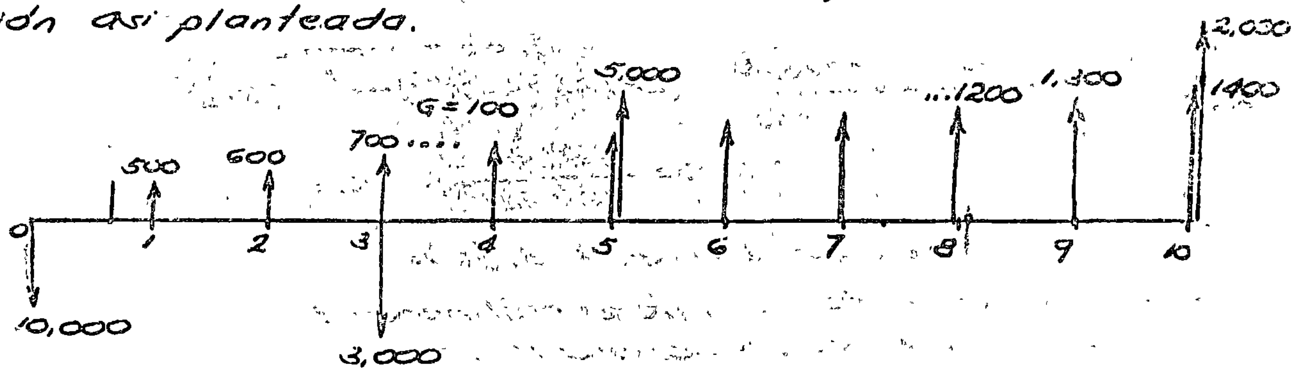
$$i = 12 + 0.51$$
$$i = 12.51\%$$

Dado que la tasa de recuperación esperada de la inversión propuesta : 12.51% es menor que la tasa interna mínima atractiva de recuperación establecida en 15% (al menos en el momento de tener que tomar la decisión) concluimos que la inversión no nos es atractiva.

EJEMPLO

Se propone una inversión que requiere ingresos de: $10,000. al inicio y $3,000 tres meses después; y se preveen ingresos de: $500. al mes primero, $600. a los dos meses y así sucesivamente cantidades con incremento de $100. mensuales hasta el 10° mes. Se recibirán también cantidades globales adicionales de $5,000. en el 5° mes y de $2,000 en el 10° mes.

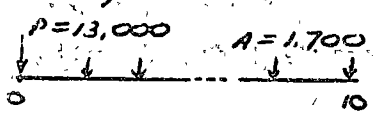
Se pide calcular la tasa de recuperación de la inversión así planteada.



Traduciendo el flujo de efectivo a V.P., dando signo (−) a los egresos y signo (+) a los ingresos e igualando la suma algebraica a 0, se obtiene:

$$0 = -10{,}000 - 3{,}000\ (P/F, i\%, 3) + 5{,}000\ (P/A, i\%, 10)$$
$$+\ 100\ (P/G, i\%, 10) + 5{,}000\ (P/F, i\%, 5) + 2{,}000\ (P/F, i\%, 10)$$

Hagamos una comparación muy burda entre ingresos y egresos solo con el fin de tener una primera orientación para proceder al 1° tanteo:



donde $P = 10000 + 3{,}000 = 13{,}000$

$$y \quad A = 500 + \underbrace{500}_{\substack{prom: \\ 10 \times G \div 2}} + \frac{(5{,}000 + 2{,}000)}{10}$$

$$A = 1{,}700$$

$$P = A\ (P/A, i\%, 10)$$
$$1{,}300 = 1{,}700\ (P/A, i\%, 10)$$
$$7.65 = (P/A, i\%, 10)$$

buscando en las tablas se encuentra para la igualdad anterior, un valor de: $i = 5.2\%$

Procedamos a un primer tanteo con: $i = 5\%$

$0 \neq -10{,}000 - 2{,}591.^{51} + 3{,}860.^{87} + 3{,}164.^{90} + 3{,}917.^{63} + 1{,}227.^{83}$
$0 \neq -420.^{28}$

2° tanteo con $i = 4\%$

$0 \neq -10{,}000 - 2{,}666.^{99} + 4{,}055.^{45} + 3{,}388.^{10} + 4{,}109.^{64} + 1{,}351.^{13}$
$0 \neq +237.^{33}$

Interpolando:

237.33 — 0 — $-420.^{28}$
4% — 5%
x

$$237.33 \text{ ——— } x$$
$$(237.33 + 420.^{28}) \text{ ——— } (5-4)$$

$$x = \frac{237.33}{657.61}(1) = 0.36$$

$$\therefore i = 4 + 0.36 = 4.36\,\%$$

como valor de la tasa de interes real mensual
La tasa efectiva correspondiente seria:

$$\text{tasa efectiva} = {}_{4.36-12}\,spcaf - 1 = (1 + 0.0436)^{12} - 1$$
$$= 1.67 - 1 = 0.67$$

$$\therefore i = 67\%$$

Idéntico resultado se obtendria estableciendo la ecuación de costos e ingresos en base a una serie uniforme equivalente, en cuyo caso, la expresión del flujo de efectivo adquiere la forma:

$$0 = -10{,}000\ (A/P, i\%, 10) - 3{,}000\ (P/F, i\%, 3) \cdot (A/P, i\%, 10) +$$
$$+ 500 + 100\ (A/G, i\%, 10) + 5{,}000\ (P/F, i\%, 5) \cdot (A/P, i\%, 10) +$$
$$+ 2{,}000\ (A/F, i\%, 10)$$

Procediendo a un primer tanteo con $i = 4\%$
$0 \neq -1{,}232.^{91} - 328.^{82} + 500 + 417.^{70} + 506.^{68} + 166.^{58}$
$0 \neq 29.23$

2° tanteo con $i = 5\%$
$0 \neq -1{,}295.05 - 335.^{61} + 500 + 409.^{90} + 507.^{35} + 159.^{01}$
$0 \neq -54.40$

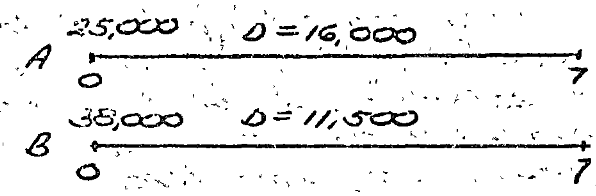
interpolando

29.23 — 0 — $54.^{40}$
4% — 5%
x

se obtiene una tasa real mensual de: $i = 4.36\%$
y una efectiva de: 67%

EJEMPLO

Analicemos dos alternativas de inversión cuya finalidad sea la de reducir costos, en un proceso ya establecido de producción:



La alternativa B implica una sobre-inversión inicial comparativamente más alta con respecto a A de ¢13,000.; pero la cual, se prevee originará ahorros anuales uniformes de ¢ 4,500. Lo anterior implica que se incrementen los ingresos netos anuales durante un horizonte económico de 7 años propuesto, a costa de una inversión adicional inicial de ¢ 13,000.

Dada que no contamos con los datos de la corriente completa de ingresos y egresos que cada alternativa implica a lo largo de 7 años, sólo podemos hacer un análisis COMPARATIVO entre A y B, y analizar si se justifica la inversión adicional en B, con los ahorros que origina.

Establezcamos la igualdad entre los costos anuales adicionales y ahorros anuales, para calcular la tasa (i) que verifique dicha ecuación:

$$\overbrace{(38,000 - 25,000)\ {}_{i-7}crf}^{\text{costo anual adicional}} = \overbrace{16,000 - 11,500}^{\text{ingreso (ahorro) anual adicional}} \quad (1)$$

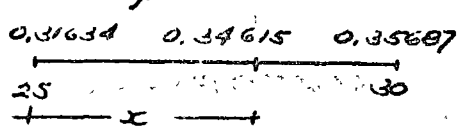
$$13,000\ {}_{i-7}crf = 4,500$$

$${}_{i-7}crf = 0.34615$$

en tablas se observa que: $\quad {}_{25-7}crf = 0.31634$

$${}_{30-7}crf = 0.35687$$

interpolando:



$$i = 25 + \frac{(0.34615 - 0.31634)}{(0.35687 - 0.31634)}(30 - 25)$$

$$i = 25 + 3.68$$

$$i = 28.68\ \%$$

El valor de : 28.68 % es la tasa de interes que hace a los costos equivalentes a los ingresos en la ecuación anterior. Es la tasa de recuperación de la inversión adicional de los $ 13,000, que se recupera con los ahorros de $ 4,500 anuales que origina durante los 7 años.

Faltaria comparar esta tasa con nuestra tasa interna minima atractiva de recuperación, y suponiendo por ejemplo, que esta fuese en ese momento dado, de un 18 %, calificariamos de inmediato la sobre inversión de $ 13,000 que la alternativa B representa, como muy atractiva.

Debe quedar claro, que este análisis solo determina si la inversión adicional que B implica respecto a A, se justifica; es decir, sólo provee del criterio que permite elegir entre ambas alternativas.

La tasa de recuperación calculada, es la tasa de recuperación de la inversión extra, pero de ninguna manera de la inversión total, ya que para estimar esta, seria necesario contar con el dato del flujo de ingresos y egresos generales que cada una de las alternativas A y B implica.

Sin embargo, se trata de un problema de reducción de costos en un proceso ya en operación y plenamente justificado económicamente, y la duda por resolver se refiere exclusivamente a la conveniencia o no de llevar a cabo o no la sobre inversión que B requiere.

Ahora bién; la ecuación (1) puede expresarse :

$$38{,}000\ {}_{i-7}crf + 11{,}500 = 25{,}000\ {}_{i-7}crf + 16{,}000$$

de donde resulta que la tasa de recuperación (i) también establece una equivalencia entre los costos anuales.

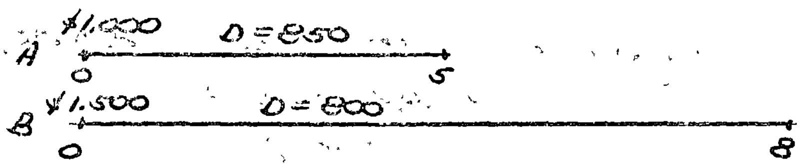
La importancia de lo anterior, radica en el hecho de que en ocasiones, resulta más simple calcular los costos anuales de las alternativas por comparar e igualarlos, que calcular el monto de la inversión adicional y de los ahorros que esta origina, para efectos del cálculo de la tasa de recuperación de la misma.

Esto resulta particularmente util, en la comparación de alternativas con vidas económicas diferentes.

EJEMPLO

Una inversión A requiere un costo inicial de $1.000.; costos anuales uniformes equivalentes, de operación, conservación y mantenimiento de $850. y se le supone una vida económica de 5 años. Una alternativa B, implica $1.500 de costo inicial, costos de operación, conservación y mantenimiento uniformes anuales, de $800 y se le considera una vida económica de 8 años. Se estima la tasa interna mínima atractiva de recuperación en un 8%. El valor de recuperación de ambas alternativas al final de sus respectivos periodos, se considera despreciable.

Gráficamente, las alternativas anteriores se pueden representar:



Expresando los Costos anuales uniformes equivalentes de cada alternativa, e igualándolos, se tiene:

$$1.000\,(A/P,\ i\%,\ 5) + 850 = 1.500\,(A/P,\ i\%,\ 8) + 800$$

1ª aproximación: con $i = 0\%$

$$1.000\,(A/P,\ 0\%,\ 5) + 850 = 1.500\,(A/P,\ 0\%,\ 8) + 800$$

recordando que: $\lim_{i \to 0} crf \longrightarrow \frac{1}{n}$

$$1.000\,(1/5) + 850 \neq 1.500\,(1/8) + 800$$

$$1.050 > 788$$

$$62 > 0$$

$\therefore$ a una tasa de: $i = 0\%$ $\therefore$ $CA_A > CA_B$ por $62

o sea, que la alternativa de inversión extra, tiene menor C.A. a una tasa del 0%, por lo tanto, hay ventaja de $62 anuales si la inversión se considera a 0%.

Expresando esta ventaja como un porcentaje de la inversión adicional inicial de $500 que la alternativa B implica:

$$i \doteq \frac{62}{500} \doteq 12.4\%$$

pero: $P > L$ $\therefore$ $i_{final} > i_{aprox.}$

2ª aproximación: con $i = 15\%$

$$1{,}000\ (A/P,\ 15\%,\ 5) + 850 \neq 1{,}500\ (A/P,\ 15\%,\ 8) + 800$$
$$1{,}148 > 1{,}134$$
$$14 > 0$$

$\therefore$ a una tasa : $i = 15\%$ $\quad CA_A > CA_B$ por ¢14.

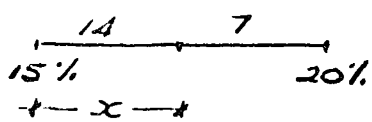
$$i \doteq 15 + \frac{14}{500} \doteq 15 + 2{,}8 \doteq 17{,}8\%$$

3ª aproximación: con $i = 20\%$

$$1{,}000\ (A/P,\ 20\%,\ 5) + 850 \neq 1{,}500\ (A/P,\ 20\%,\ 8) + 800$$
$$1{,}184 < 1{,}191$$
$$0 < 7$$

$\therefore$ a una tasa : $i = 20\%$ $\quad CA_A < CA_B$ por ¢7.

nterpolando:



$$x \text{ — } 14$$
$$(20-15) \text{ — } (14+7)$$

$$\therefore\ i = 15 + x = 15 + \frac{14}{14+7}(20-15) = 15 + \frac{14}{21} \cdot 5 = 18{,}3\%$$

y dado que el valor de esta tasa de recuperación correspondiente a la inversión extra de ¢500, es mayor que la tasa mínima atractiva de recuperación estimada en un 8% en el momento de la toma de decisión, se justifica invertir en la alternativa B.

Hay muchas ocasiones en que un análisis superficial de una situación dada, puede conducirnos a una valorización erronea de la tasa de interes que se está pagando por el capital en esa situación dada.

Veamos un ejemplo, :

Supongamos el que una finca está en venta por ¢240.000. en las siguientes condiciones:

¢40.000 en efectivo y ¢200.000 pagaderos mensualmente durante 15 años a una tasa nominal del 7%. Se requiere pagar además : ¢6.000 de gastos por apertura de crédito.

Ahora bien, si se paga al contado se logra un descuento y en estas condiciones la finca podrá adquirirse por ¢210.000. y logicamente no habrá gastos adicionales por apertura y tramitación de crédito.

Los pagos (A) uniformes mensuales para cubrir los ¢200.000 serán:

número de meses : $15 \times 12 = 180$
tasa real mensual : $7/12\ \%$

$$\therefore\ A = 200{,}000\ (A/P,\ 7/12\ \%,\ 180)$$
$$A = ¢\,1.797.^{66}/\text{mes durante 15 años.}$$

Se presentan entonces al comprador 2 alternativas :

a) Pagar ¢46.000 de inmediato y ¢1.797.^{66} mensualmente durante 15 años
b) Pagar ¢210.000 y terminar la transacción.

Es claro entonces que de cualquier manera debe desembolzar al menos ¢46,000 en forma inmediata, por lo que las alternativas se reducen en última instancia a conseguir ¢164.000 más (para que con los ¢46.000, se completen los ¢210.000 y se compre al contado) o pagar ¢1.797.^{66}/mensuales durante 15 años

Es decir, : ¢164,000 ahora ⇔ ¢1.797.^{66}/mensuales.

La tasa real que al comprador le representa optar por los pagos mensuales es de :

$$164{,}000\ (A/P,\ i\%,\ 180) = 1{,}797.^{66}$$

$$(A/P),\ i\%,\ 180) = \frac{1{,}797.^{66}}{164{,}000} = 0.01096$$

$$i = 0.86\ \%$$

como tasa mensual.

$$i_{efect.} = {}_{0.86-12}spcaf - 1 = (1+0.0086)^{12} - 1$$
$$= 1.10822 - 1$$
$$= 0.10822$$

$\therefore\ i = 10.822\ \%$ que es la tasa real que debe tomar en cuenta el comprador como costo del capital al tomar su decisión, y que es mucho más alta que la tasa de interes del 7% que dadas las condiciones, representaba una tasa de interes solo aparente.

Veamos ahora la sistematización de los principios vertidos en el último tema, en el método que en la literatura de lengua inglesa se denomina: "discounted cash flow method", para el cálculo de la tasa de recuperación de una inversión propuesta y cuya mecánica consiste fundamentalmente en actualizar ("descontar") la corriente neta de efectivo (net cash flow) a distintas tasas de interes, razón por la cual la denominación correcta del método en nuestra terminologia, consideramos sería la de: "método del flujo actualizado de efectivo."

EJEMPLO

Consideremos la posible inversión en un predio el cual se pretende fraccionar y urbanizar para efecto de vender los lotes resultantes y cuyo flujo de efectivo se prevea bajo las siguientes condiciones:

- Compra inicial del predio : $1'650,000.
- Pago de escrituras y gastos notariales : 150,000.
  Erogados en 3 pagos de $50,000 cada uno durante el: 1°, 2° y 3° meses
- Obras de urbanización : 1'500,000.
  Erogados a razón de $250,000 mensuales durante los meses 3°, 4°, 5°, 6°, 7°, 8°
- Trabajos adicionales de acondicionamiento, decoración, etc... : 300,000.
  Erogados a razón de $50,000 durante los mismos meses 3° a 8°.
- Pago global de impuestos, el cual se supone concentrado al final durante el mes 14°: 450,000.
- Gastos de promoción de ventas durante el 9° mes : 50,000.

Suma bruta de egresos : $ 4'100,000.

Por otro lado, se espera captar los ingresos por concepto de la venta de los lotes, de la siguiente forma:

- $300,000 durante los meses: 7°, 9°, 11°, 12°, 13° : $ 1'500,000
- Durante el mes 14° 5'000,000

Suma bruta de ingresos esperados : $ 6'500,000

Indicando en una escala de tiempos de 14 meses de duración, el flujo de efectivo anterior, adjudicando signo (-) a los egresos y (+) a los ingresos y siguiendo la convención usual de considerar concentrados al final del periodo los movimientos de efectivo supuestos a lo largo de cada uno de ellos, la escala resultante nos queda:

(cantidades en miles)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
terreno	-1'650														
escrituración		-50	-50	-50											
urbanización				-250	-250	-250	-250	-250	-250						
adicionales				-50	-50	-50	-50	-50	-50						
impuestos															-450
promoción										-50					
ingresos								+300		+300		+300	+300	+300	+ 5,000

Sumando algebraicamente las cantidades indicadas en cada uno de los periodos, obtenemos el flujo neto de efectivo (net cash flow):

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
-1'650,000	-50,000	-50,000	-350,000	-300,000	-300,000	-300,000	0	-300,000	+250,000	0	+300,000	+300,000	+300,000	+4'550,000

70

Procedamos a elaborar la siguiente tabla:

m e s	flujo neto de efectivo	Factor de actualización sppwf. al 8%	V. P. al 8%	Factor de actualización sppwf. al 5%	V.P. al 5%
0	-1'650.000	1.000	-1'650,000	1.000	-1'650,000
1	- 50,000	0.92593	- 46,297	0.95238	- 47,619
2	- 50.000	0.85734	- 42,867	0.90703	- 45,351
3	- 350.000	0.79383	- 277,841	0.86384	- 302,344
4	- 300 000	0.73503	- 220,509	0.82270	- 246,810
5	- 300,000	0.68058	- 204,174	0.78353	- 235,059
6	- 300.000	0.63017	- 189.051	0.74622	- 223,866
7	0	———	0	———	0
8	- 300.000	0.54027	- 162,081	0.67684	- 203,052
9	+ 250,000	0.50025	+ 125,063	0.64461	+ 161,153
10	0	~~0.42888~~	0	———	0
11	+ 300,000	0.42888	+ 128,664	0.58468	+ 175,404
12	+ 300,000	0.39711	+ 119,133	0.55684	+ 167,052
13	+ 300,000	0.36770	+ 110,310	0.53032	+ 159,096
14	+ 4'550,000	0.34046	+ 1'549,093	0.50507	+ 2'298,068
	+ 2'400,000		- 760,557		+ 6,671.

La ~~primera~~ segunda columna es la actualización de las cantidades individuales en cada periodo, con una tasa de interes del 0%, por lo que está constituida sencillamente por el flujo neto de efectivo y tiene como interpretación el determinar simplemente si la suma bruta de los ingresos esperados, supera a la suma total de los ingresos presupuestados, sin impactar aun con valor alguno el costo del dinero con el tiempo.

La 3ª y 5ª columnas son los factores de actualización a tasas de 8% y 5% respectivamente, así por ejemplo:

$_{8-0}sppwf = 1.000$ $\quad$ $_{5-0}sppwf = 1.000$

$_{8-1}sppwf = 0.92593$ $\quad$ $_{5-1}sppwf = 0.95238$

$_{8-2}sppwf = 0.85734$ $\quad$ $_{5-2}sppwf = 0.90703$

La 4ª y 6ª columnas son la actualización (Valores Presentes) del flujo neto de efectivo, con un primer tanteo considerando una tasa del 8% y un segundo tanteo a un 5%.

Con los valores "suma algebraica" de las 2 columnas anteriores, se procede a una interpolación a fin de determinar el valor de la tasa de interes que establece y verifica la igualdad en la ecuación de costos e ingresos:

6.671 | 760.557

5% ———————— 8%

—— x ——

$$x \text{ ———— } 6.671$$
$$(8-5) \text{ ———— } 767,228$$

$$i = 5 + \frac{6.671}{767,228} \times 3 = 5 + 0.026$$

$$i = 5.03\ \%$$

Dado que los periodos seleccionados para el análisis del problema y por ende, de la escala de tiempos, fueron mensuales, la tasa obtenida : 5.03 % será la tasa real mensual, por lo que es necesario obtener la tasa efectiva a fin de poder comparar la tasa que brinda la alternativa de inversión ofrecida, con la tasa interna minima atractiva de recuperación o con las tasas de recuperación de otras alternativas de inversión y que estén expresadas, como es normal, en forma de tasa anual.

$$i_{efect.} = {}_{5.03-12}spcaf - 1$$
$$= (1 + 0.0503)^{12} - 1$$
$$= 1.80202 - 1$$
$$= 0.80202$$

$$\therefore\ i = 80.2\ \%$$

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ANALISIS ECONOMICO DE PROYECTOS DE INGENIERIA

A P L I C A C I O N E S

EVALUACION DE UN PROYECTO AGROPECUARIO

M.en I. Guillermo Castellanos G.

Marzo de 1977.

CENTRO DE EDUCACION CONTINUA

EVALUACION DE UN PROYECTO AGROPECUARIO

M. en I. Guillermo Castellanos G.

Sinopsis

El objetivo básico del proyecto consiste en el desarrollo agropecuario de la zona en beneficio directo de 1064 agricultores (36 propietarios y 1028 ejidatarios), para lo cual se utilizarían las aguas del río "A", regularizando su régimen convenientemente.

La superficie bruta del proyecto es de 14 782 ha. La infraestructura y los servicios existentes actualmente corresponden a un incipiente nivel de desarrollo. Las principales actividades económicas son la agricultura y la ganadería con bajos niveles técnicos de explotación y escasa diversificación. El valor de la producción agropecuaria en 1971 se estimó en 6.5 millones de pesos, en tanto que el valor agregado de esa producción fue de 4.2 millones de pesos. La población en 1970 era de 4 338 personas, las cuales prácticamente no cuentan con servicios públicos.

Se definieron y estudiaron diversas alternativas, incluyendo una sin obras de riego, y se hizo una comparación de ellas a través de diversos indicadores, habiéndose seleccionado la alternativa de construir una presa de almacenamiento, para fomentar el desarrollo agropecuario de la zona.

El programa agropecuario se basa en la implantación de un plan de cultivos que permitirá el aprovechamiento integral e intensivo de 9 000 ha. netas bajo riego que comprende el proyecto, las que con cultivos repetidos ascienden a 15 500 ha. Los cultivos mas significativos son el arroz con 8 500 ha (incluyendo el área repetida), las praderas con 3 400 ha, forrajes de corte con 1 000 ha (incluyendo cultivos repetidos). También se proponen cultivos de gramíneas, frutales y hortalizas. Se propone realizar la explotación ganadera en las 3 400 ha. de praderas y en las 500 ha. de forrajes de corte. Se supuso un período de desarrollo en los rendimientos, alcanzando su estabilización en el décimoquinto año de iniciadas las obras, con un valor anual de producción de 109.9 millones de pesos, generando un valor agregado de 96 millones de pesos.

Las obras de ingeniería proyectadas consisten en una presa de almacenamiento con 192 millones de metros cúbicos de capacidad útil y 284.5 millones de metros cúbicos de capacidad total hasta el NAME, las redes de riego y drenaje necesarias y obras complementarias y de mejoramiento social. La presa está compuesta por una cortina de 49 m. de altura máxima sobre el fondo del cauce y 620 m. de longitud en su corona, de materiales graduados, dos obras de toma en túnel con compuertas deslizantes para su control y excedencias con capacidad para descargar 2 061 m^3/seg al paso de la avenida máxima probable. Los sistemas de riego y drenaje comprenden dos canales principales, con longitud de 21.2 y 32.1 km, redes de distribución formadas por un total de 142 km de canales revestidos y redes primarias de drenaje con extensión de 50 km.

Las obras complementarias consisten en edificios para las oficinas del Distrito de Riego y casas para los canaleros, en tanto que las obras de mejoramiento social consisten en la construcción de 316 casas para alojar a los agricultores de la zona y la rehabilitación de 4 poblados que se dotarán de servicios de agua potable y alcantarillado, centros de salud, escuelas, etc.

El presupuesto de las obras proyectadas alcanza la cifra de 249.3 millones de pesos. Se estimaron las cuotas que deberán pagar los usuarios para cubrir totalmente los costos de operación y conservación del distrito y los del programa de asistencia técnica, resultando de - - - - \$ 10.35/miliar de m^3

Se verificó la factibilidad agrológica del proyecto, y el programa de construcción de las obras se estudió a nivel de factibilidad, concluyéndose que el sistema puede quedar terminado en un plazo de 3 -- años y medio.

Con el objeto de determinar la factibilidad económica del proyecto se calcularon diversos indicadores, entre los que destacan la relación beneficio-costo y la tasa de rendimiento interno, definiéndose alternativas de costo y de tasas de actualización. Las principales alternativas de costo del proyecto fueron las de incluir o excluir los correspondientes a las obras de mejoramiento de los poblados. Para el primer indicador se obtuvo 1.68 y 1.93 respectivamente utilizando 12% de tasa de actualización. Las tasas de rendimiento interno resultaron de 18.94% y 21.40% respectivamente. Los índices obtenidos muestran un carácter favorable, por lo que el proyecto resulta altamente recomendable.

La factibilidad financiera se analiza a nivel de parcela agrícola, de unidad ganadera y del proyecto en su conjunto resultando que, desde el punto de vista financiero, el proyecto es factible.

Los conceptos sociales que implica el proyecto podrán ser resueltos satisfactoriamente a través de los programas propuestos en el mismo y con el estudio definitivo de la tenencia actual de la tierra. Por otra parte, existe una favorable aceptación del proyecto que será definitiva en la consecución de los objetivos del mismo.

II.- Costos

A continuación se presentan los costos estimados de obra en millones de pesos:

TOTAL	249.3
1.- PRESA	100.4
Cortina y dique	53.3
Ataguías y obras de toma	13.4
Obra de control y excedencias	24.8
Obra de desvío	8.9
2.- OBRAS MARGEN DERECHA	53.0
Canal principal	12.3
Red de distribución	13.3
Red de drenaje	6.9
Obras de mejoramiento social.- poblados	20.1
Obras complementarias	0.3

3.- OBRAS MARGEN IZQUIERDA	48.2
Canal principal	21.2
Red de distribución	8.2
Red de drenaje	3.2
Obras de mejoramiento social.-poblados y edifs.	15.2
Obras complementarias	0.3
4.- Trabajos preagrícolas	12.3
5.- C[illegible]amento y camino de acceso	6.0
6.- OTROS	29.5
Estudios y proyecto	4.4
Supervisión (10%)	22.0
Indemnizaciones	3.1

Las inversiones iniciales para operación y conservación se estimaron en $ 2.6 millones correspondientes a equipo y maquinaria.

Los cargos anuales de operación y conservación se estimaron en $ 2.2 millones. Por otra parte, los costos anuales de amortización y consumos de la maquinaria serían de $ 0.8 millones, por lo que el total para este rubro sería de $ 3 millones.

En lo relativo a las cuotas de agua, se consideraron los cargos anuales por operación y conservación, haciendo la suposición de que las hectáreas que se siembren con doble cultivo o con cultivo perenne deban pagar una cuota doble que las hectáreas dedicadas a un cultivo anual. Las cuotas resultantes fueron las siguientes:

Cultivos anuales:	$ 155.96/ha.
Cultivos perennes	311.92

Considerando el importe anual de la asistencia técnica que se propone dar a los agricultores y ganaderos, las cuotas por este concepto serán:

Cultivos anuales	$ 50.40/ha
Cultivos perennes	100.80

De lo anterior se obtiene un total de:

Cultivos anuales	$ 206.36/ha
Cultivos perennes	412.72

Se realizó también una estimación de las cuotas en caso de que se cobrara por volumen. Aceptando que la eficiencia de conducción sea del 85%, lo que corresponde a la red de canales revestidos propuesta, el volumen total entregado en las tomas granja asciende a 386.6 millones de metros cúbicos anuales. Dividiendo entre esta cifra los importe de los costos anuales del distrito se obtienen las siguientes cuotas:

Por operación y conservación	$ 7.82/millar de m^3
Asistencia técnica	2.53
Suma	10.35

III.- Justificación técnica de la necesidad de riego.

En el período seco, de noviembre a abril, los valores medios de lluvia mensual varían desde 1 hasta 51 mm. y se estima que la lluvia aprovechable en ese período es nula, en tanto que los usos consuntivos medios durante estos meses son altos, variando de 80 a 272 mm. Por lo anterior, es necesario cubrir esa deficiencia mediante el riego.

En los meses de mayo a octubre, las lluvias mensuales varían de 141 a 319 mm., pero en estos meses, la demanda de los cultivos considerados es aún mayor variando de 158 a 317 mm. A excepción del mes de septiembre, en el resto de los meses la demanda es mayor a la lluvia.

Si se considera la lluvia aprovechable, destaca mas la necesidad de riego ya que los valores varían de 61 a 184 mm, y resultan bastante inferiores a las demandas.

IV.- Adaptación y distribución de cultivos propuestos

Resuelto el problema de drenaje que constituye, el factor que en mayor grado limita la utilización de los suelos del proyecto, tanto en condiciones de temporal como de riego, todos los cultivos propuestos se adaptarán a las condiciones climáticas y agrológicas de la zona.

A continuación se presentan las superficies en hectáreas consideradas para cada cultivo.

	1a. Cosecha	2a. Cosecha.	Total
SUMA	11 000	4 500	15 500
Praderas 1) 2)	3 400	-	3 400
Arroz	5 000	3 500	8 500
Maíz forrajero 1)	500	-	500
Sorgo forrajero 1)	-	500	500
Frijol	400	100	500
Maíz grano	400	200	600
Soya	300	-	300
Chile verde	200	-	200
Aguacate 2)	200	-	200
Cacahuate	200	-	200
Tomate	-	200	200
Cebolla	100	-	100
Mango 2)	100	-	100
Papaya 2)	100	-	100
plátano 2)	100	-	100

1) Para explotaciones pecuarias

2) Cultivos perennes.

V.- TENENCIA DE LA TIERRA

La superficie susceptible de riego asciende a 11 000 ha. netas, las que se deberán distribuir de acuerdo a la Ley Federal de Aguas entre las personas que actualmente se dedican a las actividades agropecuarias en la zona.

En total existen 36 propietarios privados a los que se les asignará una superficie media de 20 ha. a cada una. Las 10 280 ha. -- restantes serán de régimen ejidal en donde se colocarían a los 380 ejidatarios con posesión definitiva y a los 332 ejidatarios sin parcelación definitiva que actualmente radican en la zona. Se han considerado dotaciones de 10 ha. por ejidatario, por lo que aún quedarían 3 160 ha. para reacomodar a los afectados por la zona del vaso de la presa.

VI.- Rendimientos, precios y costos.

En la estimación de los rendimientos se tomaron en consideración las condiciones ecológicas de la región y los elementos físicos y humanos existentes en la zona. En la elaboración de los costos unitarios de los cultivos propuestos se consideró el empleo de maquinaria, semilla mejorada, fertilizantes e insecticidas además del valor de la mano de obra necesaria en las labores de cultivo, de acuerdo con los salarios mínimos regionales.

En el siguiente cuadro se presentan los rendimientos, precios y costos unitarios de los cultivos propuestos, desde el año de su implantación hasta el undécimo año en que se estabilizan.

- Rendimientos y costos -

Cultivo	Precio $/ton.	AÑO 1 ton/ha	AÑO 1 $/ha.	AÑO 6 ton/ha.	AÑO 6 $/ha	AÑO 11 ton/ha	AÑO 11 $/ha.
ANUALES							
Arroz	1 250	2.0	1 603	5.0	1 603	5.0	1 603
Cacahuate	1 600	1.5	1 364	3.0	1 364	3.0	1 364
Cebolla	670	8.0	2 460	15.0	2 460	15.0	2 460
Chile verde	2 200	6.0	2 144	15.0	2 144	15.0	2 144
Frijol	2 100	0.7	1 251	1.5	1 251	1.5	1 251
Maíz	940	1.6	1 182	4.0	1 182	4.0	1 182
Maíz forrajero	-	50.0	-	60.0	-	60.0	-
Sorgo forrajero	-	80.0	-	105.0	-	105.0	-
Soya	1 900	1.2	1 624	2.0	1 624	2.0	1 624
Tomate	1 600	12.0	4 184	20.0	4 184	20.0	4 184
PERENNES							
Aguacate	2 450	-	-	9.0	3 024	14.0	5 795
Mango	850	-	-	10.0	2 599	20.0	4 109
Papaya	600	-	-	30.0	3 655	30.0	3 655
Plátano	500	-	-	20.0	2 150	20.0	2 150
Praderas	-	-	-	75.0	-	75.0	-

VII.- Valores, costos y beneficios de la producción.-

En base a los rendimientos, precios y costos unitarios estimados y a las superficies de los cultivos propuestos, se calcularon los volúmenes, valo--

res, costos y beneficios de la producción agrícola futura. Estos conceptos alcanzan su máximo valor y su estabilización de rendimientos a partir del decimoquinto año de iniciadas las obras del proyecto.

Los cultivos de maíz y sorgo forrajeros y praderas no se incluyen dentro del programa agrícola, por ser insumos de la ganadería y analizarse dentro del programa ganadero.

- MILLONES DE PESOS -

	VALORES			COSTOS			BENEFICIOS		
Año	Anuales	Perennes	Total	Anual	Peren.	Total	Anual	Peren.	Total
4	18.9	-	18.9	10.4	-	10.4	8.5	-	8.5
7	62.2	2.2	64.4	17.2	0.5	17.8	45.0	1.7	46.6
10	73.1	8.1	81.1	17.2	1.4	18.7	55.8	6.6	62.4
15	73.1	11.4	84.4	17.2	1.8	19.0	55.8	9.6	65.4

VIII.-Programa Ganadero

La zona del proyecto presenta condiciones favorables para el desarrollo de la ganadería, especialmente la engorda de bovinos, las que no han sido aprovechadas debido a las deficientes prácticas en que se basan las explotaciones actuales.

El tipo de ganado que se propone es el cebú pura raza ó criollo cruzado con cebú. Aunque la engorda de ganado en base a la adquisición de novillos es la explotación que proporciona los ingresos inmediatos mas altos, ésta tiene problemas en el abastecimiento constante y seguro de los novillos, por lo que la explotación mas segura es la de cria y engorda combinadas.

La superficie de riego destinada a este programa es de 3 900 ha, dentro de la que se propone implantar el cultivo de praderas en 3 400 ha y el de forrajes de corte en las 500 ha. restantes, siendo estas cultivadas con maíz forrajero en verano y sorgo forrajero en invierno.

De acuerdo con las prácticas zootécnicas indispensables que se impondrán, se estima un aumento diario de peso de 0.6 kg. en el ganado de engorda.

La unidad económica de explotación que se propone es de 100 ha, lo que implica la agrupación de pequeños propietarios y ejidatarios en un número no mayor de 10.

Cada unidad estaría compuesta por 2.5 ha. para las instalaciones y construcciones, 85 ha. para el cultivo de las praderas y 12.5 ha para cultivo de maíz y sorgo forrajeros. La relación entre el volumen de producción y la demanda anual por unidad animal determinan la capacidad de carga de la unidad tipo, la cual a partir del cuarto año es de 579 unidades animal.

Las inversiones requeridas para las construcciones, equipo y ganado para la instalación del pie de cría en los cinco primeros años ascienden a $ 858 610.00

La explotación ganadera consiste en la producción de carne para abasto a través de la instalación de un pie de cría. En los primeros años de esta instalación, el pie de cría debe ser menor que el que podría soportar la capacidad de carga, con el fin de tener disponibilidades forrajeras para la engorda de novillos y obtener un flujo de ingresos que permita a los criaderos cubrir sus gastos y obtener beneficios de la explotación.

La venta de ganado en pie en la unidad tipo se inicia desde el primer año de instalación con los novillos de engorda. En el segundo año las ventas están formadas por los novillos de engorda y por las vacas de vientre que se desechan y a partir del tercer año se inicia la venta de productos del pie de cría. En el décimo año se ha estabilizado la explotación del pie de cría y ya no es necesario recurrir a la engorda de novillos.

El precio de la carne en pie "a puerta de rancho" se estima en --- $ 8.00 / kg. A las vaquillas se les considera un valor adicional de ----- de $ 250.00 por estar cargadas y a los sementales se les considera un valor de $ 6 000.00 después de haber prestado servicio por 4 años.

El valor de la producción una vez estabilizada la unidad ganadera asciende a $ 637 650.00 anuales.

Los costos de producción se dividen en fijos y variables. Los primeros corresponden al costo de producción de las praderas, del maíz y del sorgo forrajeros, además de los costos de conservación y mantenimiento de las instalaciones y del equipo. Los costos variables están formados por alimentación suplementaria, programa sanitario, salario de los vaqueros, adquisición de novillos y compra de sementales para reposición. Los costos de producción se estabilizan a partir del décimo año en ---------- $ 193 566.00 anuales.

Los beneficios de la explotación alcanzan su máximo valor en el cuarto año en $ 751 587.00 por la engorda de novillos y se estabiliza en -- $ 444 084.00 anuales a partir del décimo año, por lo que el beneficio por --

hectárea resulta de $ 4 440.84 anuales.

X.- Necesidades de mano de obra

El total de jornadas-hombre que se necesitarán con el plan de cultivos propuesto es de 466 280. Actualmente se estima que se empiean 135 750 por lo que el incremento anual será de 330 529 jornadas-hombre.

Considerando el salario mínimo rural de $ 17.00 diarios, el incremento en el valor de la ocupación será de 5.6 millones de pesos, a partir de la estabilización de la producción.

En la explotación ganadera el valor de los salarios a los vaqueros será de 2.4 millones de pesos a partir del cuarto año de instaladas las unidades ganaderas. Actualmente se pagan 0.3 millones de pesos, por lo que el incremento será de 2.1 millones de pesos.

XI.- FACTIBILIDAD ECONOMICA

Los indicadores utilizados para determinar la factibilidad económica del proyecto son: incremento en el valor agregado, relación producto/capital y ocupación/capital, la relación beneficio/costo y la tasa interna de rendimiento.

a) Valor agregado.-

El incremento del valor agregado se obtuvo a partir de la diferencia del valor agregado en la etapa de estabilización de la producción futura y el correspondiente a la producción actual.

El valor agregado se obtuvo a costo de factores, ya que se han deducido los insumos agropecuarios, considerándose únicamente el valor de la mano de obra, los impuestos e intereses y las utilidades brutas. El valor del incremento resulta ser de 91.9 millones de pesos, que es 21.9 veces mayor que el valor actual.

VALOR AGREGADO (- Millones de $ de 1972)

	Actual	Futuro	Incremento
TOTAL	4.2	96.1	[illegible].9
PRODUCCION AGRICOLA	3.4	73.1	69.7
PRODUCCION GANADERA	0.8	23.0	22.2

b) Relaciones producto/capital y ocupación/capital

La relación producto/capital se obtuvo dividiendo el incremento anual del valor agregado imputable al proyecto entre el costo anual equivalente de la inversión.

Los costos anuales equivalentes resultaron de 19.5 y 23.3 millones de pesos para los casos de no inclusión de poblados a inclusión de poblados respectivamente para una tasa del 12% de interés. Estos valores relacionados con los 91.9 milones de pesos de incremento en el valor agregado dan índices de 4.7 y 3.95 para las dos alternativas, que pueden considerarse como muy favorables.

En el cálculo de la relación ocupación/capital se ha considerado el incremento anual de los salarios de 7.7 millones de pesos que generará el proyecto relacionado con los costos anuales equivalentes de la inversión y resultan valores de 0.39 y 0.33 para las dos alternativas consideradas. Estos índices son bajos, debido al abundante empleo actual de mano de obra que existe en la zona y al bajo salario mínimo de la región.

c) <u>Relación Beneficio/costo</u>

Los valores obtenidos para las dos alternativas fueron de 1.93 y 1.68 que se estiman muy favorables para la realización del proyecto.

Con el fin de tener un amplio margen de seguridad en los resultados, se realizó un análisis de sensibilidad en el que se supuso que los costos de producción así como los de operación y conservación sufrieran un incremento del 15%, permaneciendo lo demás sin modificaciones. Los valores obtenidos fueron de 1.70 y 1.48

Los valores del beneficio neto actualizado resultaron de 180.1 y 151.0 millones de pesos para las alternativas seleccionadas.

	B E N E F I C I O S				C O S T O S						
AÑO	AG.	GAN.	TOT.	ACT.	CONST.	INST. GAN.	FRUT.	OPERAC.	EXT.	TOT.	ACT.
1	-	-	-	-	11.0	-	-	-	-	11.0	[illegible]
2	-	-	-	-	45.4	-	-	-	-	45.4	[illegible]
3	-	-	-	-	104.0	-	-	-	-	104.0	74.0
4	5.0	-	5.0	3.2	52.4	-	-	1.5	0.5	54.4	[illegible]
5	17.1	7.6	24.7	14.0	-	11.2	1.9	3.0	1.0	17.2	9.7
6	30.9	22.6	53.5	27.1	-	10.2	0.4	3.0	1.0	14.7	7.4
7	43.1	25.6	68.7	31.1	-	6.0	0.4	3.0	1.0	10.5	4.7
8	53.0	29.6	82.6	33.4	-	4.5	0.1	3.0	1.0	8.7	3.5
9	58.1	25.8	83.9	30.3	-	2.3	0.1	3.0	1.0	6.4	2.5
10	58.9	22.4	81.3	26.2	-	-	-	3.0	1.0	4.0	[illegible]
11	59.5	18.6	78.2	22.5	-	-	-	3.0	1.0	4.0	[illegible]
12	60.1	15.2	75.3	19.3	-	-	-	3.0	1.0	4.0	1.0
13	60.7	15.8	76.6	17.6	-	-	-	3.0	1.0	4.0	0.9

14	61.3	17.3	78.7	16.1	-	-	-	3.0	1.0	4.0	0.8
15	61.9	17.3	79.3	14.5	-	-	-	3.0	1.0	4.0	0.7
16	2415.4	676.1	3091.5	119.2	-	-	-	118.1	38.[illegible]	156.2	6.2
SUMA	2985.3	894.1	3879.4	374.4	212.7	34.3	3.1	152.6	49.4	491.9	194.2

$$\text{Relación beneficio /costo} = \frac{374.4}{194.2} = 1.93$$

d) <u>Tasa de rendimiento interno</u>

Los valores obtenidos para este indicador de rentabilidad resultaron de 21.4% para la alternativa de no considerar los costos de los poblados y 16.94% para la otra alternativa.

XI.- FACTIBILIDAD FINANCIERA

El costo total de las obras asciende a $ 252.4 millones a invertir en 3años y medio, de los que 11.7 corresponden al primer año, 60.9 al segundo, 119.6 al tercero y 60.2 a los primeros 6 meses del cuarto año.

Los requerimientos de financiamiento agropecuario se estimaron con base en las necesidades del programa y en las modalidades de operación de las instituciones oficiales de crédito.

El financiamiento se ha separado en créditos de avío y refaccionarios, estimándose los recursos bancarios y su recuperación iniciándose al igual que el funcionamiento del distrito en el segundo semestre del 4o. año del proyecto.

Las necesidades de crédito de avío, tanto agrícola como ganadero, están calculados para financiar el 70% de los costos de producción. Los préstamos serían amortizados en el mismo ejercicio en que se otorgan y causan un interés del 10% anual.

El crédito refaccionario estaría destinado a financiar el total de las inversiones en instalación de frutales y de las unidades ganaderas. Se ha supuesto que los préstamos serían otorgados con un plazo de gracia de 5 años, es decir, hasta que se ejercieran totalmente, amortizándose en un período de 6 años con pagos anuales iguales y con tasa de interés del 12% sobre saldos insolutos.

RECURSOS BANCARIOS

– Millones de $ –

AÑO	NECESIDADES ANUAL	NECESIDADES ACUMULADO	RECUPERACIONES ACUMULADAS PAGADO	RECUPERACIONES ACUMULADAS INTERESES	RECUPERACIONES ACUMULADAS TOTAL
4	7.3	7.3	7.3	0.7	8.0
5	30.8	38.1	24.9	4.1	29.0
6	37.6	75.7	51.9	9.6	61.5
7	32.8	108.5	78.2	15.9	94.1
8	32.6	141.1	106.1	22.9	129.0
9	27.9	169.0	131.6	29.9	161.5
10	24.5	193.5	162.3	36.1	198.4
11	23.0	216.5	191.6	41.4	233.0
12	21.2	237.8	219.1	45.8	264.9
13	19.3	257.1	244.7	49.2	293.9
14	18.7	275.8	269.6	51.8	321.4
15	13.3	289.1	289.1	53.1	342.2

Se realizó también un análisis financiero a nivel de parcela agrícola de 10 ha, considerando que en ella se practican los cultivos representativos del programa[1]. Los ingresos estimados se calculan de los valores de producción y los egresos corresponden a los costos de producción de los cultivos, intereses de los créditos, pago del seguro agrícola, consumo familiar, pago de cuotas de agua y amortización de las obras. Los resultados indican una alta rentabilidad de la parcela.

En el caso de la unidad ganadera de 100 ha se considera integrada por 10 parcelas ejidales. Los ingresos están formados por las ventas de ganado y por el valor de la mano de obra que aportarían a la explotación y los egresos estarían constituidos por los costos de producción, intereses, amortización de créditos, seguro agrícola y pecuario, consumo familiar, cuotas de agua y amortización de las obras. Los saldos disponibles presentan resultados positivos con una clara tendencia ascendente que demuestra su factibilidad financiera.

Finalmente respecto a la cuenta de fuentes y usos de fondos del proyecto en su conjunto indican que los saldos son nulos en los tres primeros años y a partir del cuarto año se tienen saldos positivos que para el octavo año son del orden de las inversiones totales en el proyecto y para el décimosexto ascienden a 748.2 millones de pesos, lo que indica la solvencia financiera del proyecto.

FUENTES Y USOS DE FONDOS DEL PROYECTO

- Millones de pesos -

	AÑO 1	AÑO 4	AÑO 8	AÑO 10
FUENTES				
Presupuesto	11.7	60.2	-	-
Valor producción	-	18.9	126.5	109.9
Créds. agrop.	-	7.3	32.6	13.3
Reservas amort.	-	-	10.1	10.1
Saldo año anterior	-	-	150.9	681.2
TOTAL	11.7	86.4	320.2	814.5
USOS				
Inversión fija	11.7	60.2	-	-
Costos produc. 1)	-	8.1	32,2	13.3
Operac. y conserv.	-	1.5	3.0	3.0
Consumo familiar	-	5.3	8.8	18.3
Extensionismo	-	0.5	1.0	1.0
Pago de créditos	-	8.0	35.0	14.6
TOTAL	11.7	83.6	79.9	56.2
Saldo disponible	-	2.7	240.2	758.3
Reservas amortiz.	-	-	10.1	10.1
Saldo año siguiente	-	2.7	230.1	748.2

CONCLUSION

Por lo anteriormente indicado, la conclusión principal de este estudio es que el proyecto resulta altamente recomendable.

EVALUACION DE LA ENSEÑANZA

CURSO: ANALISIS ECONOMICO DE PROYECTOS DE INGENIERIA

FECHA: Del 12 al 27 de Agosto de 1977.

	DOMINIO DEL TEMA	EFICIENCIA EN EL USO DE AYUDAS AUDIOVISUALES	MANT. DEL INTERES (AMENIDAD, FACILIDAD DE EXPRESION, COMUNICACION CON LOS ASISTENTES)	PUNTUALIDAD
Decisiones Económicas en la Ingeniería (Uriegas)				
Objeto del Análisis Económico de Proyectos (Uriegas)				
Modelos Económicos del Sistema "Empresa" (Córdova)				
Evaluación de los Costos (Rosales)				
Determinación y Representación del Flujo de Efectivo de un Proyecto (Vilchis)				
Costo y Valor del Capital (Uriegas)				
Equivalencia de Flujos de Efectivo (Rosales)				
Métodos de Equivalencia del Flujo de Efectivo para la Evaluación de Alternativas (Vilchis)				
Evaluación de Alternativas mediante la Tasa de Rendimiento Interno (Córdova)				
Evaluación Económica de Proyectos de Ampliación o Expansión (Vilchis)				

ESCALA DE EVALUACION DEL 1 AL 10

EVALUACIÓN DE LA ENSEÑANZA

CURSO: ANALISIS ECONOMICO DE PROYECTOS DE INGENIERIA (HOJA 2)

FECHA: Del 12 al 27 de Agosto de 1977.

	DOMINIO DEL TEMA	EFICIENCIA EN EL USO DE AYUDAS AUDIOVISUALES	MANT. DEL INTERES (AMENIDAD, FACILIDAD DE EXPRESION, COMUNICACION CON LOS ASISTENTES)	PUNTUALIDAD
Evaluación Económica de Proyectos de Remplazo de Equipo (Uriegas)				
Depreciación e Impuestos en la Empresa Privada (Córdova)				
Análisis Económico de Inversiones Públicas (Uriegas)				
ESCALA DE EVALUACION DEL 1 AL 10				

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EVALUACION DEL CURSO

	CONCEPTO	EVALUACION
1.	APLICACION INMEDIATA DE LOS CONCEPTOS EXPUESTOS	
2.	CLARIDAD CON QUE SE EXPUSIERON LOS TEMAS	
3.	GRADO DE ACTUALIZACION LOGRADO CON EL CURSO	
4.	CUMPLIMIEN TO DE LOS OBJETIVOS DEL CURSO	
5.	CONTINUIDAD EN LOS TEMAS DEL CURSO	
6	CALIDAD DE LAS NOTAS DEL CURSO	
7	GRADO DE MOTIVACION LOGRADO CON EL CURSO	

ESCALA DE EVALUACION DE 1 A 10

1. ¿Qué le pareció el ambiente del Centro de Educación Continua?

Muy agradable ☐ Agradable ☐ Desagradable ☐

2. Medio de comunicación por el que se enteró del curso:

Periódico Excélsior ☐ Periódico Novedades ☐ Folleto del Curso ☐

Cartel mensual ☐ Radio Universidad ☐ Comunicación carta, teléfono, verbal, etc. ☐

3. Medio de transporte utilizado para venir al Palacio de Minería:

Automóvil particular ☐ Metro ☐ Otro medio ☐

4. ¿Qué cambios haría usted en el programa para tratar de perfeccionar el curso? ______________________________

____

____

5. ¿Recomendaría el curso a otras personas? Si ☐ No ☐

6. ¿Qué curso le gustaría que ofreciera el Centro de Educación Continua? ______________________________

____

____

7. ¿Qué servicios desearía que tuviese el CEC para los asistentes a cursos? ______________________________

____

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8. Otras sugestiones: ______________________________

____

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AMERICAN NATIONAL STANDARD
CODE FOR PRESSURE PIPING

Petroleum Refinery Piping

ANSI B31.3 - 1973

Date of Issuance July 1, 1973

SECRETARIAT

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PUBLISHED BY

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

United Engineering Center 345 East 47th Street New York, N.Y. 10017

Foreword

THE need for a national code for pressure piping became increasingly evident from 1915 to 1925. To meet this need, the American Standards Association initiated project B31 in March 1926, at the request of The American Society of Mechanical Engineers and with that Society the sole administrative sponsor. Because of the wide field involved, Sectional Committee B31 was composed of representatives of some 40 different engineering societies, industries, government bureaus, institutes, and trade associations. After several years work, the first edition was published in 1935 as an American Tentative Standard Code for Pressure Piping

In order to keep the code abreast of current developments in piping design, welding, stress computations, new dimensional and material standards and specifications and increases in the severity of service conditions, revisions, supplements and new editions of the code were published as follows:

B31.1 -- 1942 American Standard Code for Pressure Piping
1942 Procedure established for handling interpretation of code requirements
B31.1a-- 1944 Supplement 1
B31.1b-- 1947 Supplement 2
B31.1 -- 1951 American Standard Code for Pressure Piping
B31.1a-- 1953 Supplement 1 to B31.1 -1951
B31.1 - 1955 American Standard Code for Pressure Piping

In 1952 a new section of the code was published to cover Gas Transmission and Distribution Piping Systems. In 1955 after a review by B31 Executive and Sectional Committees, a decision was made to develop and publish other industry sections as separate code documents of the American Standard Code for Pressure Piping.

The first edition of Petroleum Refinery Piping was Published as ASA B31.3-1959, superseding Section 3 of B31.1-1955. This new Section was revised in 1962 and published as B31.3-1962. It was revised again in 1966 and published as ASA B31.3-1966

In 1967, the American Standards Association was reconstituted and reorganized, and its name was changed to United States of America Standards Institute. In 1969, the Institute changed its name to American National Standards institute, and the sectional committees were named standards committees.

Following approval by the Standards Committee and the secretariat, this revision was approved by the American National Standards Institute on March 20, 1973 and designated ANSI B31.3-1973.

American National Standards Committee B31

Code for Pressure Piping

(Committee Listings as of August 1971)

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Introduction

The Code for Pressure Piping (ANSI B31) consists of a number of Sections, which collectively constitute the Code. Hereinafter in this Introduction and in the text of this Code Section B31.3, when the word "Code" is used without identification to another specific Code Section, it means this Code Section.

The Code for Pressure Piping sets forth engineering requirements deemed necessary for safe design and construction of piping systems. While safety is the basic consideration of this Code, this factor alone will not necessarily govern the final specifications for any pressure piping system. The designer is cautioned that the Code is not a design handbook. The Code does not do away with the need for the engineer or competent engineering judgment.

The Code contains basic reference data and formulas necessary for design. It is intended to state these requirements in terms of basic design principles to the fullest possible extent, supplemented with specific requirements where necessary to obtain uniform interpretation of principle. It contains prohibitions in areas where practices or designs are known to be unsafe. In other areas the code contains warnings or "flags" where caution is known to be necessary, but where it was considered that a direct prohibition would be unwise.

The Code includes:

(1) material specifications and component standards which have been accepted for Code usage.

(2) the designation of proper dimensional standards for the elements comprising piping systems.

(3) requirements for the design of component parts and assembled units, including necessary pipe supporting elements.

(4) requirements for the evaluation and limitation of stresses, reactions, and movements associated with pressure, temperature, and external forces.

(5) requirements for the fabrication, assembly, and erection of piping systems.

(6) requirements for testing and inspecting of elements before assembly or erection and of the completed systems after erection.

The components of piping systems should, as far as practicable, comply with the Specifications and Standards listed in the Code. Compliance with this Code requires that fundamental principles be followed and that materials or practices not specifically approved under this Code, but which are not prohibited by the Code, be qualified for use as set forth in the applicable chapters of the Code.

The specific design requirements of the Code usually revolve around a simplified engineering approach to a subject. It is intended that a designer capable of applying more complete and rigorous analysis to special or unusual problems shall have latitude in the development of such designs and the evaluation of complex or combined stresses. In such cases the designer is responsible for demonstrating the validity of his approach.

This Code shall not be retroactive, or construed as applying to piping systems erected before the date of issuance. After code revisions are approved by ANSI they may be used by agreement between contracting parties beginning with the date of issuance shown on the document title page. Revisions become mandatory as minimum requirements six months after date of issuance except for piping installations or components contracted for or under construction prior to the end of the six month period.

Manufacturers and users of piping are cautioned against making use of revisions and cases that are less restrictive than former requirements without having assurance that they have been accepted by the proper authorities in the jurisdiction where the piping is to be installed.

Attention of users of the Code is directed to the fact that the numbering of the Divisions and the material thereunder may not be consecutive. Such discontinuity is recognized. It is not the result of editorial or printing errors. An attempt has been made, insofar as possible, to follow a uniform outline in the various Sections. Due to the fact that the complete outline may cover phases not applicable to a particular Section, the Code has been prepared with gaps in the numbering. It is believed that in this way, cross referencing between Sections is made easier and use of the Code is facilitated since the same subject, in general, appears under the same number and subnumber in all sections.

The Code is under the direction of the American

National Standards Committee B31, organized under the procedures of the American National Standards Institute, Inc., and is under the administrative sponsorship of The American Society of Mechanical Engineers.

The Committee is a continuing one and is organized to keep the Code up to date in context and in step with the developments in materials, construction, and usage. Revisions are issued periodically. New editions are published at three to four year intervals depending on conditions.

The Standards Committee B31 has established an orderly procedure to consider requests for interpretations and revisions of Code requirements. In order to receive consideration, inquiries shall be in writing and must give full particulars.

When an approved reply to an inquiry involves a change in Code requirements, the ruling is made public through the issuance of a "Case." This is published in *Mechanical Engineering*. A "Case Interpretation and Revision" service is maintained for the benefit of all who use the Code. Suggestions for revisions may originate within the Committee itself or from anyone outside the Committee.

All requests for interpretations or suggestions for revisions should be addressed to the Secretary, Standards Committee B31, in care of The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.

1973 REVISION NOTES

These revision notes outline only the more important changes included in this edition. Also, changes which are strictly editorial (i.e. involving no change in the requirement) are not included. For complete details of all changes, including those listed below, a comparison with the 1966 edition of this Code is required.

Code Reference	*Revision*
300.2	Added definitions of: Solution Annealing Gas Metal-Arc Welding Gas Tungsten-Arc Welding Spiral-Welded Pipe Quench Aging Tungsten Electrodes
300.2	Revised definitions of: Base Metal Engineering Design Heat Affected Zone Inert-Gas Arc Welding Oxygen Cutting Oxygen Gouging Electric Fusion Welded Pipe Preheating Reinforcement of Weld Undercut Welder Welding Procedure
301	General revision
302	General revision, including changes to the bases for allowable stresses to put them on the same basis as ASME Section VIII Division 2 at all temperatures, thus eliminating previous distinctions in stress bases for ferrous and non-ferrous materials. In the 1966 edition, they were on the same basis as Section VIII Division 1, except that ferrous metals were higher below 650F.
304.3	General revisions for clarification of branch connection requirements.
304.3.3(g)	Added extruded outlet header design criteria.
304.3.3(i)	Clarified use of ribs and gussets.
304.4	General revision
304.7	Clarified acceptance criteria for non-standard components.
305.2.1	Removed service limits of API 5LX
306.3	Deleted
308.3	Clarified requirements for joints involving cast iron flanges.
308.5.4	Clarified requirements for joints involving cast iron flanges
308.5.5	Added requirements for depth of tapped holes.
319	General revision, including the following:
319.3.1A(Table)	Corrected data for "25 Cr 20 Ni" and "3½ Nickel" and adds data for "Ni-Fe-Cr".
319.3.1B(Table)	Corrected data for "25 Cr 20 Ni" and "3½ Nickel" and adds data for "Ni-Fe-Cr".
319.3.2B(Table)	Corrected data for "aluminum" and "copper-nickel"
319.3.6 (Table)	Revised to include both inplane and outplane stresses. Expands to include extruded welding tee welding contour insert and branch welding fitting.
319.4.1	Added simplified flexibility formula.
319.4.4	Revised flexibility formulas to include both inplane and outplane stresses.

1973 REVISION NOTES (cont'd)

Code Reference	*Revision*
322.6	Changed "disposal" to "relief".
323	General revision.
326	General revision.
327.2.2	Changed criteria for use of backing rings
327.4	Added Figures 327.4.1A through 327.4.1E showing defects in butt welds. Changed notations in Figures 327.4.4C and 327.4.6D
327.4.2	Added limitation on excess root penetration
327.4.7	Added requirement for welder's identification symbol
327.5.2	Described basis for assignment of P-numbers
327.5.6	Changed requirements for renewal of welder's performance qualification
329.2	Added requirement for temperature of bending
329.3	Required heat treatment after bending for specific conditions
330.1	Added requirement for temperature of forming
330.2	Require heat treatment after forming for specific conditions
331.1.1	Allows alternate heat treatment based on engineering analysis
331.2.1	Establishes recommended preheat temperatures
331.3	Establishes mandatory heat treat requirements
331.3.2	Modifies purpose of hardness testing and requires specific amount of testing
331.3.3	Establishes heat treat for dissimilar welds
331.3.6	Summarized thickness criteria for heat treat requirements.
335.2	Changed title to "Bolted Flanged Joints."
335.2.1	Added requirement for use of a single gasket.
335.2.4	Added B16.5 bolting is adequate provided the lack of complete thread engagement is not more than one thread in any nut.
336.5	General revision
337.1	Added reference to alternate tests
337.2	Editorial revision
337.4.1 (a) & (b)	Added limitation of test stress to 90% of minimum specified yield stress.
337.5	New paragraph to allow alternate tests under specified conditions
Appendix A	General revision and adds data formerly in Appendices C & D
Appendix B	Revises examples to reflect changes in body of code
Appendix C	Deleted
Appendix D	Deleted
Appendix E	Updated

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

Chapter I

SCOPE AND DEFINITIONS

300 GENERAL STATEMENTS

This Petroleum Refinery Piping Code is a section of the American National Standard B31 Code for Pressure Piping. This Section is published as a separate document for simplicity and convenience of Code users. The users of this Code are advised that in some areas legislation may establish governmental jurisdiction over the subject matter covered by this Code.

The owner of a completed piping installation shall have the overall responsibility for compliance with this Code.

This Code recognizes the existence of a wide variety of services within its scope.

The components of piping systems should, as far as practicable, comply with the Specifications and Standards listed in the Code. Compliance with this Code requires that fundamental principles be followed and that materials or practices not specifically approved under this Code, but which are not prohibited by the Code, be qualified for use as set forth in the applicable chapters of the Code.

The specific design requirements of the Code usually revolve around a simplified engineering approach to a subject. It is intended that a designer capable of applying more complete and rigorous analysis to special or unusual problems shall have latitude in the development of such designs and the evaluation of complex or combined stresses. In such cases the designer is responsible for demonstrating the validity of his approach.

It is required that the engineering design specify any special requirements pertinent to the particular service involved. For example, this Code establishes minimum requirements for examination of fabrication and erection, but where service requirements necessitate added quality and more extensive nondestructive examination, these are to be specified in the engineering design and any revision thereto; and when so specified, the Code requires that they be accomplished.

Attention is directed to 336.1 which defines examination and inspection, and to 336.5 which establishes the extent, and by reference the quality, required under various forms of nondestructive examination.

300.1 Scope

300.1.1 This Code prescribes minimum requirements for the materials, design, fabrication, assembly, test and examination of petroleum refinery pressure and vacuum piping systems. Except as excluded in 300.1.4, this Code covers all piping within the property limits of a petroleum refinery, loading terminal, natural gas processing plant (including liquified natural gas facilities), bulk plant, compounding plant, or refinery tank farm, any of which are engaged in the processing or handling of petroleum and related products. It also covers interconnecting lines between separate sections of a refinery.

300.1.2 This Code applies to piping systems handling all fluids, including fluidized solids, and to all types of services including oil, gas, steam, air, water, chemicals, and refrigerants (except as specified or excluded in 300.1.3 and 300.1.4).

300.1.3 Package refrigeration unit piping may be designed and constructed in accordance with ANSI B31.5 except that impact test requirements of 323.2.2 and 323.2.3 shall apply.

300.1.4 This Code excludes the following:

(a) portions of steam, feedwater, blowoff, or other piping within the jurisdiction of Section I (Power Boilers) of the ASME Boiler and Pressure Vessel Code

(b) heater tubes, tube fittings and headers including connection for piping

(c) pressure vessels, heat exchangers, pumps, and other such equipment, including internal piping and connections for piping

(d) piping designed for internal pressures:

(1) at or above 0 psig but less than 5 psig regardless of temperature,

(2) at or above 5 psig but less than 15 psig if the design temperature is in the range of −20F to 650F inclusive

(e) piping located on refinery property which has been set aside for cross-country piping complying with ANSI B31.4, ANSI B31.8, or government regulations, for transmitting oil or gas through, to, or from the refinery.

300.1.5 Piping consists of pipe, flanges, bolting, gaskets, valves, fittings, the pressure containing parts of other components such as expansion joints, swivel joints, and strainers, and devices which serve such purposes as mixing, separating, snubbing, distributing, metering, or controlling flow. It also includes pipe supporting elements.

Piping does not include support structures such as frames of buildings, stanchions, or foundations, nor any equipment such as defined in 300.1.4(b) and (c).

300.2 Definitions

Some of the more common or controversial terms relating to piping are defined below. Terms relating to welding which agree with AWS Standard A3.0 are marked with an asterisk (*) and are shown here for convenience. Other welding terms given are either not included in AWS A3.0 or are required to be here defined with specific reference to piping. For welding terms used in this Code, but not shown here, definitions per AWS A3.0 apply.

Anneal Heat Treatment – See *Heat Treatment.*

**Arc Welding* – A group of welding processes wherein coalescence is produced by heating with an electric arc or arcs, with or without the application of pressure and with or without the use of filler metal.

Assembly – The joining together of two or more piping components by bolting, welding, caulking or threading into their installed location as specified by the engineering design. It is not concerned with the method by which this is done.

**Automatic Welding* – Welding with equipment which performs the entire welding operation without constant observation and adjustment of the controls by an operator. The equipment may or may not perform the loading and unloading of the work.

**Backing Ring* – Backing in the form of a ring generally used in the welding of piping.

Base Metal – The metal to be welded, soldered, brazed or cut.

Braze Welding – A welding process whereby a weld is made using a nonferrous filler metal having a melting point below that of the base metals, but above 800F. The filler metal is not distributed in the joint by capillary attraction. (Bronze welding, formerly used, is a misnomer for this term.)

Brazing – A metal joining process wherein coalescence is produced by use of a nonferrous filler metal having a melting point above 800F, but lower than that of the base metals being joined. The filler metal is distributed between the closely fitted surfaces of the joint by capillary attraction.

**Butt Joint* – A joint between two members lying approximately in the same plane.

Engineering Design – The detailed design developed from process and mechanical requirements and conforming to Code requirements, including all necessary drawings and specifications, governing a piping installation.

Equipment Connection – An integral part of such equipment as pressure vessels, heat exchangers, pumps, designed for attachment to pipe or piping components.

Erection – The complete installation of a piping system, including any field assembly, fabrication, testing, and inspection of the system. It also involves the tools and methods used to prepare for and carry out the complete installation.

Fabrication – Primarily the welding together of piping components into integral pieces ready for assembly. It includes bending, forming, threading or other operations upon these components, if not part of assembly. It may be done in a shop or in the field.

Face of Weld – The exposed surface of a weld on the side from which the welding was done.

Filler Metal – Metal to be added in welding, soldering, brazing or braze welding.

**Fillet Weld* – A weld of approximately triangular cross-section joining two surfaces approximately at right angles to each other in a lap joint, tee joint or corner joint.

**Full Fillet Weld* – A fillet weld whose size is equal to the thickness of the thinner member joined.

**Fusion* – The melting together of filler metal and base metal, or of base metal only, which results in coalescence.

**Gas Metal-Arc Welding (GMAW)*. An arc welding process wherein coalescence is produced by heating with an arc between a continuous filler metal (consumable) electrode and the work. Shielding is obtained entirely from an externally supplied gas or gas mixture. Some methods of this process are called MIG or CO_2 welding.

**Gas Tungsten-Arc Welding (GTAW)*. An arc welding process wherein coalescence is produced by heating with an arc between a single tungsten (nonconsumable) electrode and the work. Shielding is obtained from a gas or gas mixture. Pressure may or may not be used. (This process has sometimes been called TIG welding.)

**Gas Welding* – A group of welding processes wherein coalescence is produced by heating with a gas flame or flames, with or without the application of pressure, and with or without the use of filler metal.

Groove Weld – A weld made in the groove between two members to be joined.

Heat Affected Zones – That portion of the base metal which has not been melted, but whose mechanical properties or microstructures have been altered by the heat of welding or cutting.

Heat Treatment:

Annealing, Full – Heating a metal or alloy to a temperature above the critical temperature range and holding above the range for a proper period of time, followed by cooling to below that range. (A softening treatment is often carried out just below the critical range which is referred to as a subcritical anneal.)

Normalize – A process in which a ferrous metal is heated to a suitable temperature above the transformation range and is subsequently cooled in still air at room temperature.

Solution Annealing – Holding the metal for a sufficient length of time at a temperature at which the chromium carbides, or other carbides present will go into solution, then cooling in air or liquid medium at a sufficient rate to prevent reprecipitation. The alloy is left in a supersaturated unstable state and may subsequently exhibit *Quench Aging.*

Stress-Relief – Uniform heating of a structure or portion thereof to a sufficient temperature to relieve the major portion of the residual stresses, followed by uniform cooling.

Inert-Gas-Arc Welding: See preferred term, Gas Metal-Arc Welding and Gas Tungsten-Arc Welding.

**Joint Design* – The joint geometry together with the required dimensions of the welded joint.

**Joint Penetration* – The minimum depth a groove weld extends from its face into a joint, exclusive of reinforcement.

**Manual Welding* – Welding wherein the entire welding operation is performed and controlled by hand.

Miter – Two or more straight sections of pipe matched and joined on a line bisecting the angle of junction so as to produce a change in direction.

Normalize Heat Treatment – See *Heat Treatment.*

**Oxygen Cutting* – A group of cutting processes wherein the severing or removing of metals is effected by means of the chemical reaction of oxygen with the base metal at elevated temperatures. In the case of oxidation-resistant metals, the reaction is facilitated by use of a chemical flux or metal powder.

**Oxygen-Gouging* – An application of oxygen cutting wherein a bevel or groove is formed.

Package Refrigeration Unit – A refrigeration unit, designed and constructed in accordance with manufacturer's standard design, consisting of the principal refrigeration equipment and the interconnecting piping, including refrigerant piping and other attendant piping.

Petroleum Refinery – An industrial plant for the handling or processing of petroleum. Such a plant may be an individual gasoline recovery plant, a treating plant, or an integrated refinery having various process units and attendant facilities.

Pipe – A tube, usually cylindrical, used for conveying a fluid or transmitting fluid pressure, normally designated "pipe" in the applicable specification. It also includes any similar component designated as "tubing" used for the same purpose. Types of pipe, according to the method of manufacture, are defined as follows:

a. *Electric-Resistance-Welded Pipe.* Pipe produced in individual lengths or in continuous lengths from coiled skelp and subsequently cut into individual lengths, having a longitudinal butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which the pipe is a part, and by the application of pressure.

b. *Furnace Lap-Welded Pipe:* Pipe having a longitudinal lap joint made by the forge welding process wherein coalescence is produced by heating the preformed tube to welding temperature and passing it over a mandrel located between two welding rolls which compress and weld the over-lapping edges.

c. *Furnace Butt-Welded Pipe:*

(1) *Furnace Butt-Welded Pipe, Bell-Welded:* Pipe produced in individual lengths from cut-length skelp, having its longitudinal butt joint forge welded by the mechanical pressure developed in drawing the furnace-heated skelp through a cone-shaped die (commonly known as a "welding bell") which serves as a combined forming and welding die.

(2) *Furnace Butt-Welded Pipe, Continuous-Welded:* Pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round pass welding rolls.

d. *Electric-Fusion-Welded Pipe:* Pipe having a longitudinal butt joint wherein coalescence is produced in the preformed tube by manual or automatic electric-arc welding. The weld may be single or double and may be made with or without the use of filler metal.

e. *Electric Flash-Welded Pipe:* Pipe having a longitudinal butt joint wherein coalescence is produced, simultaneously over the entire area of abutting surfaces, by the heat obtained from resistance to the flow of electric current between the two surfaces, and by the application of pressure after heating is substantially completed. Flashing and upsetting are accompanied by expulsion of metal from the joint.

f. *Double Submerged-Arc-Welded Pipe* Pipe having a longitudinal butt joint produced by at least two passes, one of which is on the inside of the pipe Coalescence is produced by heating with an electric arc or arcs between the bare metal electrode or electrodes and the work. The welding is shielded by a blanket of granular fusible material on the work. Pressure is not used and filler metal for the inside and outside welds is obtained from the electrode or electrodes.

g. *Seamless Pipe:* Pipe produced by piercing a billet followed by rolling or drawing, or both.

h. *Spiral Welded Pipe* – Pipe having a helical seam with either a butt, lap, or lock-seam joint which is welded using either an electrical resistance, electric fusion or double-submerged arc welding process.

Pipe Supporting Elements – Pipe-supporting elements consist of fixtures and structural attachments, as follows:

Fixtures – Fixtures include elements which transfer the load from the pipe or structural attachment to the supporting structure or equipment. They include hanging type fixtures such as hanger rods, spring hangers, sway braces, counterweights, turnbuckles, struts, chains, guides and anchors, and bearing type fixtures such as saddles, bases, rollers, brackets, and sliding supports.

Structural Attachments – Structural attachments include elements which are welded, bolted, or clamped to the pipe, such as clips, lugs, rings, clamps, clevises, straps and skirts.

Postheating – The application of heat to a metal section subsequent to a welding or cutting operation.

**Preheating* – The application of heat to the base metal immediately before welding, brazing, soldering or cutting.

Process Unit – A process unit is an area whose boundaries are designated by the engineering design, devoted to the processing of petroleum and related products. Examples of installations which are not required to be classified as process units are loading terminals, bulk plants, compounding plants, and tank farms.

Quench Aging – Aging induced by rapid coo[illegible] after solution heat treatment.

Refinery – See *Petroleum Refinery*

**Root Opening* – The separation between [illegible] members to be joined, at the root of the joint.

**Root Penetration* – The depth a groove weld extends into the root opening of a joint measured on the center line of the root cross-section

Seal Weld – Any weld used primarily to obtain tightness.

**Semi-Automatic Arc Welding* – Arc welding [illegible] equipment which controls only the filler metal [illegible] The advance of the welding is manually controlled.

**Shielded Metal-Arc Welding* – An arc-welding process wherein coalescence is produced by heating with an electric arc between a covered metal electrode and the work. Shielding is obtained from decomposition of the electrode covering. Pressure is not used and filler metal is obtained from the electrode.

**Size of Weld* –

Groove Weld – The joint penetration (depth [illegible] chamfering plus the root penetration when specified

Fillet Weld – For equal leg fillet welds the leg length of the largest isosceles right-triangle which can be inscribed within the fillet-weld cross-section For unequal leg fillet welds, the leg lengths of the largest right-triangle which can be inscribed within the fillet-weld cross section.

**Slag Inclusion* – Nonmetallic solid material entrapped in weld metal or between weld metal and base metal.

Soldering – A metal joining process wherein coalescence is produced by heating to suitable temperatures and by using a nonferrous alloy fusible at temperatures below 800F and having a melting point below that of the base metals being joined The filler metal is distributed between closely fitted surfaces of the joint by capillary attraction In general, solders are lead-tin alloys and may contain antimony, bismuth, silver, and other elements.

Solution Heat Treatment – See *Heat Treatment*

Stress-Relief – See *Heat Treatment.*

**Submerged Arc Welding* – An arc welding process wherein coalescence is produced by heating with an electric arc (or arcs) between a bare metal electrode (or electrodes) and the work. The welding is shielded by a blanket of granular, fusible material on the work. Pressure is not used and filler metal is obtained from the electrode and sometimes from a supplementary welding rod.

**Tack Weld* – A weld made to hold parts of a weldment in proper alignment until the final welds are made.

**Throat of a Fillet Weld* – Theoretical – The distance from the beginning of the root of the joint perpendicular to the hypotenuse of the largest right-triangle that can be inscribed within the fillet-weld cross-section. Actual – The shortest distance from the root of a fillet weld to its face.

**Toe of Weld* – The junction between the face of the weld and the base metal.

Tungsten Electrode – A non-filler metal electrode, used in arc welding, made principally of tungsten.

**Undercut* – A groove melted into the base metal adjacent to the toe or root of a weld and left unfilled by weld metal.

Weld – A localized coalescence of metal wherein coalescence is produced by heating to suitable temperatures, with or without the application of pressure, and with or without the use of filler metal. The filler metal shall have a melting point approximately the same as the base metal.

Weld Reinforcement – Weld metal in excess of the specified weld size.

**Welder* – One who is capable of performing a manual or semiautomatic welding operation. (Sometimes erroneously used to denote a welding machine.)

**Welding Operator* – One who operates machine or automatic welding equipment.

Welding Procedure – The materials and detailed methods involved in the production of a weldment, including all essential variables as described in Para. Q-11 of ASME Code Section IX.

**Weldment* – An assembly whose component parts are joined by welding.

321.1.4 *Material*

All equipment for permanent supports and restraints shall be fabricated from material suitable for the service conditions. Unless otherwise permitted below, pipe supporting elements shall be fabricated from steel, wrought iron, or a metal similar to the piping it supports. Cast iron may be used for roller bases, rollers, anchor bases, brackets, and parts of pipe supporting elements upon which the loading will be mainly that of compression. Cast iron is not recommended for pipe supporting elements used with lines subject to impact-type loadings resulting from pulsation or vibration. Malleable or ductile iron may be used for pipe clamps, beam clamps, hanger flanges, clips, bases, and swivel rings. Wood may be used for pipe supporting elements which are primarily in compression if the metal temperature is below ambient temperature.

321.1.5 *Threads*

Screw threads shall conform to ANSI B1.1 unless other threads are required for adjustment under heavy loads. Turnbuckles and adjusting nuts shall have the full length of internal threads engaged. Any threaded adjustment shall be provided with a locknut, unless locked by other means.

321.2 Fixtures

321.2.1 *Anchors and Guides*

(a) A supporting element used as an anchor shall be designed to maintain an essentially fixed position.

(b) To protect terminal equipment or other (weaker) portions of the system, restraints (such as anchors and guides) shall be provided where necessary to control movement or to direct expansion into those portions of the system which are adequate to absorb them. The design, arrangement, and location of restraints shall insure that expansion joint movements occur in the directions for which the joint is designed. In addition to the other thermal forces and moments, the effects of friction in other supports of the system shall be considered in the design of such anchors and guides.

(c) Anchors for expansion joints (such as those of the corrugated, omega, disc, or slip type) shall be designed to withstand the algebraic sum of the forces at the maximum pressure and temperature at which the joint is to be used. These forces are:

1) pressure thrust, which is the product of the effective thrust area times the maximum pressure to which the joint will be subjected during normal operation. (For slip joints the effective thrust area shall be computed using the outside diameter of the pipe. For corrugated, omega or disc type joints the effective thrust area shall be that recommended by the joint manufacturer. If this information is unobtainable, the effective area shall be computed using the maximum inside diameter of the expansion joint bellows.)

2) the force required to compress or extend the joint in an amount equal to the calculated expansion movement.

3) the force required to overcome the static friction of the pipe in expanding or contracting on its supports, from installed to operating position. The length of pipe considered should be that located between the anchor and the expansion joint.

321.2.2 *Inextensible Supports Other Than Anchors and Guides*

(a) *Hanger rods.* Safe loads for threaded hanger rods shall be based on the root area of the threads. Pipe straps or bars of strength and effective area equal to the equivalent hanger rod may be used instead of hanger rods.

(b) *Chains:* Chains may be used for pipe hangers and shall be designed in accordance with 321.2.2(a).

(c) *Sliding supports:* Sliding supports (or shoes) and brackets, shall be designed to resist the forces due to friction in addition to the loads imposed by bearing. The dimensions of the support shall provide for the expected movement of the supported piping.

(d) These supports shall be designed to permit the free movement of piping caused by thermal contraction and expansion.

321.2.3 *Resilient Supports*

(a) Spring supports shall be designed to exert a supporting force, at the point of attachment to the pipe, equal to the load as determined by weight balance calculations. They shall be provided with means to prevent misalignment, buckling, or eccentric loading of the springs, and to prevent unintentional disengagement of the load.

(b) Constant-support spring hangers provide a substantially uniform supporting force throughout the range of travel. The use of this type of spring hanger is advantageous at locations subject to appreciable movement with thermal changes. Hangers of this type should be selected so that their travel range exceeds expected movements.

(c) Means shall be provided to prevent overstressing spring hangers due to excessive deflections. It is recommended that all spring hangers be provided with position indicators.

321.2.4 *Counterweight Supports*

Counterweights shall be provided with stops to limit travel. Weights shall be positively secured. Chains, cables, hangers, rocket arms, or other devices used to attach the counterweight load to the piping, shall be subject to the requirements of 321.2.2.

321.2.5 *Hydraulic Supports*

An arrangement utilizing a hydraulic cylinder may be used to give a constant supporting force. Safety devices and stops shall be provided to support the load in case of hydraulic failure.

321.3 Structural Attachments

321.3.1 *Nonintegral Attachments*

Nonintegral attachments, in which the reaction between the piping and the attachment is by contact, include clamps, slings, cradles, U-bolts, saddles, straps, and clevises. If a clamp is connected to a vertical line to support its weight, it is recommended that shear lugs be welded to the pipe, or that the clamp be located below a fitting or flange, to prevent slippage.

321.3.2 *Integral Attachments*

Integral attachments include welded-on ears, shoes, plates, and angle clips. The material for integral attachments shall be of good weldable quality. Preheating, welding, and postheat treating shall be in accordance with Chapter V. Consideration shall be given to the localized stresses induced in the piping by the integral attachment.

321.4 Structural Connections

The load from piping and pipe supporting elements (including restraints and braces) shall be suitably transmitted to a pressure vessel, building, platform, support structure, foundation, or to other piping.

PART 6: SYSTEMS

322 DESIGN REQUIREMENTS PERTAINING TO SPECIFIC PIPING SYSTEMS

322.3 Instrument Piping

322.3.1 Instrument piping within the scope of this Code includes all piping and piping components used to connect instruments to other piping or equipment, and control piping used to connect air or hydraulically operated control apparatus. It does not include instruments, or permanently sealed fluid filled tubing systems furnished with instruments as temperature-pressure responsive devices.

322.3.2 Instrument piping within the scope of this Code shall meet all the applicable requirements of the Code and the following:

(a) The design pressure and temperature for instrument piping shall be determined in accordance with 301 with consideration of short time conditions as presented in 302. If it presents a more severe condition, the temperature of the piping during periodic operation of the blowdown valve, should be considered as a short-time condition.

(b) Consideration shall be given to the mechanical strength (including fatigue) of small instrument connections to piping or apparatus.

(c) Instrument piping containing fluids which are normally static and subject to freezing shall be protected by steam tracing or other heating methods.

(d) If it will be necessary to blow down (or bleed) instrument piping containing toxic or flammable fluids, consideration shall be given to safe disposal.

322.6 Pressure Relief Piping.

Pressure relief piping within the scope of this Code shall conform to the following requirements.

322.6.1 *Stop Valves in Piping for Pressure-Relieving Safety Devices*

There shall be no intervening stop valves between piping being protected and its protective device or devices, or between the protective device or devices and the point of discharge except:

(a) A full-area stop valve may be installed on the inlet side of a pressure-relieving device. A full-area stop valve may be placed on the discharge side of a pressure-relieving device when its discharge is connected to a common header with other discharge lines from other pressure-relieving devices. Valves of less than full-area may be used on both the inlet side and discharge side of pressure relieving devices as outlined in the foregoing, if the stop valves are of such type and size that the increase in pressure drop will not reduce the relieving capacity below that required nor adversely affect the proper operation of the pressure relieving device. Such stop valves shall be so arranged that they can be locked or sealed in both the open and the closed positions. When these stop valves are to be closed while the equipment is in operation, an authorized person shall be present and shall remain in attendance at a location where the operating pressure can be observed and shall have arrangement provided for relieving the system in the event of overpressure. He shall [illegible] lock or seal the stop valves in the open position, before leaving his station.

(b) When these stop valves are so constructed or positively controlled that the closing of the maximum number of block valves possible at one time will not reduce the pressure-relieving capacity provided by the unaffected relieving devices below the required relieving capacity.

322.6.2 *Discharge Piping from Pressure-Relieving Safety Devices.*

Discharge piping from pressure relieving safety devices within the scope of this Code shall be designed to facilitate drainage. When discharging directly to the atmosphere, discharge shall not impinge on other piping or equipment and shall be directed away from platforms and other areas used by personnel

Chapter III

MATERIALS

323 MATERIALS—GENERAL REQUIREMENTS

323.1 Acceptable Materials and Specifications

323.1.1 *Listed Materials*

The materials used shall conform to the specifications listed in Appendix A, or shall meet the requirements of this Code for materials not so listed.

323.1.2 *Unlisted Materials*

(a) Non-metallic materials such as plastics, glass, carbon, rubber, or ceramics, may be used even if not specifically listed in this Code. If stress data are not available for establishment of allowable stresses, components made of such materials may be qualified per 304.7. Consideration shall be given to the suitability of the material for the service conditions (such as temperature); to the properties of the material with respect to its creep resistance, its resistance to deterioration from the service fluid or environment, its flammability, and its resistance to shocks; and to its proper support and protection from mechanical damage.

(b) Steel materials of unknown specifications may be used at a temperature not to exceed 650 F for structural supports and restraints, with an allowable tensile stress value not exceeding 12,000 psi. For shear and bearing stresses, see 302.3.1 (a).

323.1.3 *Reclaimed Materials*

Reclaimed pipe or other piping components may be used provided they conform to a specification listed in Appendix A, and otherwise meet applicable requirements of this Code. Proof of conformance to the specification shall include sufficient cleaning and reinspection to determine wall thickness and freedom from injurious surface defects.

323.2 Temperature Limitations on Materials

323.2.1 *Upper Temperature Limit*

(a) *Listed Materials:* The use of the materials listed in Appendix A shall be limited to the maximum design temperature for which stress values are shown in the tables except that a material listed in those tables may be used at a higher design temperature provided the design engineer determines that the material is suitable for the service conditions, and no prohibition appears in Appendix A. Some of the factors the design engineer shall consider are:

(1) applicability and reliability of the elevated temperature test data.

(2) creep, stability, and other effects of exposure of the material.

(3) applicability of the allowable stress bases of 302.3 at the proposed higher temperature.

The amount of testing shall be based on a sound scientific program carried out in accordance with recognized elevated temperature technology, and consistent with the conditions anticipated in the intended service. The design engineer is responsible for demonstrating the validity of his approach to the use of the material, and of the stresses to be used.

(b) *Unlisted Materials:* Upper temperature limits and allowable stresses for unlisted materials which conform to all other requirements of this Code shall be in accord with recognized engineering practice, and the allowable stress basis of this Code or a more conservative basis, and also with the provisions of 323.2.1(a) for a listed material above the maximum temperature for which an allowable stress is shown.

323.2.2 *Lower Temperature Limits*

(a) *General*

(1) Except for certain austenitic stainless steels as covered in (b) below, and except as provided in (c) below, the "Minimum Temperatures" listed in Appendix A are the lowest temperatures at which listed materials may be used without testing, other than the tests which may be required by the material specification, to determine that the materials have suitable toughness at the minimum design temperatures at which they will be used.

(2) Steels conforming to Specification A36 or A283 shall not be used for piping having design temperatures below −20F. All other listed carbon, low alloy or high alloy steels may be used for design temperatures below their listed minimum temperatures provided they are either:

i) heat treated to control their microstructure by a method appropriate to the material as outlined in the specification applicable to the product form listed in 323.2.3(b) and impact tested and found to be suitable in accordance with 323.2.3; or,

ii) used only in accordance with the provisions of (c) below.

(3) Listed aluminum alloy, copper or copper alloy, nickel or nickel alloy, and weld metals within the range of composition of those materials may be used in piping for design temperatures down to their listed minimum without additional requirements. They may also be used below those listed temperatures provided the design engineer has suitable low temperature test results, such as tensile elongation and sharp-notch tensile strength (compared to unnotched tensile strength) to provide assurance that the material is suitable at the design temperature.

(4) When materials have been qualified for use at design temperatures below their listed minimum temperatures as provided in (2) and (3), above, the allowable stresses for materials in tension, and design stresses for bolting materials shall not be greater than the values listed in Appendix A for "Min. Temp. to 100F."

(5) Unlisted materials shall be subject to the same minimum temperature limits and toughness testing requirements as listed materials when of comparable composition and product form. All other unlisted materials shall be qualified as required in (a)(2).

(b) *Special Limits on Austenitic Stainless Steels.* Except as provided in (c) below, all listed austenitic stainless steel materials used in piping for design temperatures above the minimum temperatures listed in Appendix A, but below minus 20 F, shall also be impact tested in accordance with the requirements of 323.2.3 whenever any of the following conditions exist:

(1) If they have a carbon content greater than 0.10 percent.

(2) If they are in the form of deposited weld metal regardless of carbon content.

(3) If they are not in the solution heat treated condition.

(c) *Exceptions to Minimum Temperature Limits.* Carbon, low alloy, and high alloy steels may be used for piping at design temperatures not lower than −50 F without impact testing required by (a) or (b) above, if the operating pressure will not be more than 15 percent of the maximum design pressure at ambient temperature, and if the combination of longitudinal stresses due to pressure, deadweight, and displacement strains (See 319.2.1) does not exceed 6,000 psi.

323.2.3 *Impact Testing Methods and Acceptance Criteria*

(a) *General.* The following paragraphs covering impact testing methods and acceptance criteria which shall be used when impact testing is required by the provisions of 323.2.2, by provisions in other parts of this Code, or by the engineering design. Impact tests of component materials and, if welding is employed in their manufacture or in the fabrication or assembly of the piping of deposited weld metal and base metal in heat-affected zones, shall be made by the fabricator in accordance with provisions in (b) through [illegible] below, except that the piping fabricator need not impact test a *material* if:

(1) The material, after being appropriately heat treated as required by 323.2.2(a)(2), was impact tested by the component manufacturer and a certified report of impact tests by the manufacturer has been obtained as evidence that the material including welds used in the component manufacture meets Code requirements, and,

i) the tests were conducted on specimens representative of the material delivered to and used by the fabricator, and the material is not subjected to heat treatment during or after fabrication that will materially reduce its impact properties, or,

ii) the tests were conducted on specimens removed from test pieces of the material which received heat treatment separately in the same manner as the material (including heat treatment by the component manufacturer) so as to be representative of the finished piping.

(2) The material is less than 1/8 inch thick, and thicker material of similar analysis and heat treatment has satisfactorily passed the required impact tests at or below the minimum design temperature.

(b) *Procedure.* Impact testing of each component form of material of *any* specification (including welds in the component) shall be done using procedures and apparatus in accordance with ASTM Specification A 370, and in conformance with impact testing requirements of the following specifications, except that specific requirements of this Code which conflict with requirements of those specifications shall take precedence:

Pipe	ASTM A 333
Tubes	ASTM A 334
Plates	ASTM A 593
Forgings	ASTM A 350
Castings	ASTM A 352
Bolting	ASTM A 320

(c) *Test Specimens.* All impact tests shall be made using standard 0.394 inch (10 millimeters) square cross-section Charpy V-notch specimen bars, except when the material shape and/or thickness does not permit. In such cases, the largest possible standard subsize (3/4, 2/3, 1/2, 1/3, or 1/4) specimens shall be used. Alternatively, for materials less than 0.394 inch (10 millimeters) thick, the largest possible intermediate size as shown in Table 323.2.3 A may be used.

(d) *Location and Orientation of Test Specimens:*

(1) *Materials Impact Tests* — Locations and orientations of specimens shall be as provided in the specifications referenced in (b) above.

(2) *Weld Impact Tests* - Test specimens for impact tests of welds in the fabrication and/or assembly of piping shall be located and oriented as follows:

i) each set of *weld metal* impact specimens shall be taken across the weld with the notch in the weld metal. Each specimen shall be oriented so that the notch is normal to the surface of the material, and one face of the specimen shall be within 1/16 inch of the surface of the material.

ii) each set of *heat affected zone* impact specimens shall be taken across the weld and have sufficient length to locate, after etching, the notch in the heat affected zone. The notch shall be cut approximately normal to the material surface in such a manner as to include as much heat affected zone material as possible in the resulting fracture. Where thickness permits, the axis of the specimen should be inclined to align the root of the notch with the fusion line.

(e) *Number of Impact Tests Required:*

(1) *Of Materials Certified by the Manufacturer* as permitted in 323.2.3(a)(1) — Impact test specimens shall be taken as required by the material specification or in accordance with the provisions of the specification applicable to the product form (i.e., plate, pipe, etc.) listed in 323.2.3(b), whichever is greater.

(2) *Of Materials Qualified by the Fabricator* as required in 323.2.3(a) —

i) [Required if materials are to be assembled by methods other than welding, optional (see ii) if welding is used in fabrication or assembly.] Impact test specimens shall be taken in accordance with the provisions of the specification applicable to the material form (i.e., plate, pipe, etc.) listed in 323.2.3(b), except that,

ii) if materials are to be assembled by welding, the tests of the weld heat affected zones as covered in (3) below and in (d)(2)(ii) above will suffice for the test of the base materials.

(3) *Of Welds Made in Fabrication or Assembly of Piping* — Test pieces [for preparation of impact specimens in accordance with 323.2.3(c) and (d)(2) above] shall be made as follows for each welding procedure, kind of electrode or filler metal (i.e., AWS E-XXXX Classification), and each flux to be used with materials requiring impact testing. All test pieces shall be subjected to heat treatment, including cooling rates and aggregate time at temperature or temperatures essentially the same as that which the finished piping will have received.

i) *When materials certified* by the manufacturer, *or qualified* in accordance with 323.2.3(e)(2)(i) are welded, one test piece shall be made from a piece of such material (i.e., plate, pipe, etc.) for each certified or qualified specification for each range of material thickness that varies more than minus 1/2t or plus 1/4 inch from the tested thickness.

ii) *When materials not certified* by the manufacturer *and not qualified* in accordance with 323.2.3(e)(2)(i) are welded, one test piece shall be made from a piece from each lot of material (i.e., plate, pipe, etc.) which is of the same specification and the same process of production, including heat treatment. For the purposes of this paragraph, "lot" shall mean the quantity of material described under the "*Number of Tests*" provision of the specification applicable to the product form (i.e., plate, pipe, etc.) listed in 323.2.3(b).

iii) unless otherwise specified in the engineering design, test pieces as required in (i) need not be made from material from individual lots at any time, nor from material from each job, provided welds in other certified material in the same thickness ranges and to the same specification (type and grade, not heat or lot) have been tested as required, and the records of those tests are made available.

(f) *Test Temperatures.* For all Charpy impact tests, the test temperature criteria in (1) or (2) below shall be observed. The test piece, as well as the handling tongs, shall be cooled for a sufficient length of time to reach the test temperature.

(1) *For materials of thickness equal to or greater than 0.394 inch* — Where the largest attainable Charpy V-notch specimen has a width along the notch of at least 8 millimeters, the Charpy test using such a specimen shall be conducted at a temperature not warmer than the minimum design temperature. Where the largest possible test specimen has a width along the notch less than 8 millimeters, the test shall be conducted at a temperature lower than the minimum design temperature by the amount shown in Table 323.2.3A for that specimen width.

(2) *For materials with thickness less than 0.394 inch* — Where the largest attainable Charpy V-notch specimen has a width along the notch of at least 80 percent of the material thickness, the Charpy

test of such a specimen shall be conducted at a temperature not warmer than the minimum design temperature. Where the largest possible test specimen has a width along the notch of less than 80 percent of the material thickness, the test shall be conducted at a temperature lower than the minimum design temperature by an amount equal to the difference [referring to Table 323.2.3A] between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to the Charpy specimen width actually tested.

Table 323.2.3A – Charpy Impact Test Temperature Reduction Below Minimum Design Temperature When the Subsize Charpy Impact Width Is Less Than 80 Percent of the Material Thickness

Actual Material Thickness (See 323.2.3(f)(2) or Charpy Impact Specimen Width Along the Notch* Inches	Millimeters	Temperature Reduction Degrees F
0.394	10 (Full size standard bar)	0
0.354	9	0
0.315	8	0
0.295	7.5 (3/4 size bar)	5
0.276	7	8
0.262	6.67 (2/3 size bar)	10
0.236	6	15
0.197	5 (1/2 size bar)	20
0.158	4	30
0.131	3.33 (1/3 size bar)	35
0.118	3	40
0.099	2.5 (1/4 size bar)	50

*Straight line interpolation for intermediate values is permitted.

(g) *Acceptance Criteria*

(1) *Minimum Energy Requirements* – Except for bolting materials, the applicable minimum energy requirement for carbon and low alloy steels with specified minimum tensile strengths less than 100,000 psi shall be those shown in Table 323.2.3B.

(2) *Lateral Expansion Requirements.* Other carbon and low alloy steels having specified minimum tensile strengths greater than 100,000 psi, all bolting materials, and all high alloy steels (P-No. 6, P-No. 7, P-No. 8) shall have a lateral expansion opposite the notch of not less than 0.015 inch (15 mils) for all specimen sizes. The lateral expansion is the increase in thickness of the broken impact specimen over that of the unbroken specimen measured on the compression side, parallel to the line constituting the bottom of the V-notch. See ASTM Specification A 370.

(3) *Weld Impact Test Energy Requirements.* Where two base metals having different required impact energy values are joined by welding, the weld impact test energy requirements shall conform to the requirements of the base material having a specified minimum tensile strength most closely matching the specified minimum tensile strength of the weld metal.

(4) *Retests*

i) *For absorbed energy criteria* – when the average value of the three specimens equals or exceeds the minimum value permitted for a single specimen and the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, a retest of three additional specimens shall be made. The value for each of these retest specimens shall equal or exceed the required average value.

ii) *For lateral expansion criterion* – if the value of lateral expansion for one specimen in a group of three is below 0.015 inch, but not below 0.010 inch, and if the average value for three specimens equals or exceeds 0.015 inch, a retest of three additional specimens may be made, each of which must equal or exceed the specified minimum value of 0.015 inch. If the required values are not obtained in the retest, or if the values in the initial test are below the minimum allowed for retest, in the case of materials with properties enhanced by heat treatment, the material may be reheat treated and retested. After reheat treatment, a set of three specimens shall be made; for acceptance, the lateral expansion of each of the specimens must equal or exceed the specified minimum value of 0.015 inch.

iii) *When an erratic result* is caused by a defective specimen or there is uncertainty in the test procedure, a retest will be allowed.

323.3 Limitations on Specific Materials

323.3.1 *Steel*

(a) Upon prolonged exposure to temperatures above 750 F, the carbide phase of plain carbon steel, plain nickel alloy steel, carbon-manganese alloy steel, manganese-vanadium alloy steel, and carbon-silicon steel may be converted to graphite.

(b) Upon prolonged exposure to temperatures above 850 F, the carbide phase of alloy steels, such as carbon-molybdenum steel, manganese-molybdenum vanadium steel, manganese-chromium-vanadium steel

Table 323.2.3B – Charpy V-Notch Impact Values

Specified Minimum Tensile Strength	No. of Specimens (Note 2)	Energy: Ft-Lbs (1) Fully Deoxidized Steels	Other Than Fully Deoxidized Steels
A. Carbon and Low Alloy Steels			
65,000 psi and less	Average for 3 specimens	13	10
	Minimum for 1 specimen	10	7
Over 65,000 to 75,000 psi inclusive	Average for 3 specimens	15	13
	Minimum for 1 specimen	12	10
Over 75,000 but not including 100,000 psi	Average for 3 specimens	20 (3)	–
	Minimum for 1 specimen	15 (3)	–
		Lateral Expansion (Note 4)	
100,000 psi and over	Minimum for 3 specimens	0.015 in. (15 mils)	
B. Steels in 6, 7, and 8 P-No. Groupings	Minimum for 3 specimens	0.015 in. (15 mils)	

Note 1 – Energy values in this table are for standard-size specimens. For subsize specimens, these values shall be multiplied by the ratio of the actual specimen width along the notch, to the width of a full-size specimen, 0.394 inch (10 millimeters).

Note 2 – See 323.2.3(g)(4) for permissible retests.

Note 3 – The values of lateral expansion opposite the notch and percent shear in the fracture surface shall be recorded in addition to the energy values. These recorded values shall be shown on the certified reports, are for information only, and shall be retained for a period of at least two years.

Note 4 – When the lateral expansion criterion is applicable, in addition to a record of the expansion values, the values of absorbed energy in foot pounds and of the percent shear in the fracture surface shall be recorded on the certified report for information only, and these values shall be retained for a period of at least two years.

and chromium-vanadium steel, may be converted to graphite.

(c) If carbon steel is to be used above a temperature of 900 F, consideration shall be given to the advantages of silicon killed steel (0.1 percent silicon min.).

323.3.2 *Cast and Malleable Iron*

(a) Cast iron shall not be used for pressure-containing parts in hydrocarbon or other flammable fluid service at temperatures above 300 F nor at pressures above 400 psig, except that for service above ground within process unit limits the pressure shall not exceed 150 psig.

(b) Malleable iron shall not be used for pressure-containing parts at temperatures below -20 F, or above 650 F, nor in flammable fluid service above either 300 F or 400 psig.

(c) Cast and malleable iron shall not be used for pressure-containing parts in any toxic service.

323.3.3 *Ductile Iron*

Ductile iron shall not be used for pressure-containing parts at temperatures below -20 F or above 650 F, nor in any lethal fluid service.

Flanged components made of material conforming to ASTM Specification A445 and having dimensions conforming to ANSI B16.5 or API 604 may be used to the pressure-temperature ratings for carbon steel components given in those dimensional standards. Flanged components made of material conforming to ASTM Specification A445 and having dimensions conforming to ANSI B16.1 Class 125 and Class 250 may be used to the pressure-temperature ratings for carbon steel components given in ANSI B16.5 Class 150 and Class 300 respectively. These ratings are applicable to valves providing the valves merit them in other respects.

Welding shall not be employed either in fabrication of ductile iron components or in their assembly as part of a piping system.

323.3.4 *Nonferrous Materials*

The low melting points of copper, copper alloys, and aluminum must be considered before these materials are used as pipe or piping components where fire hazard is involved.

Welding shall not be done on castings of aluminum or aluminum alloys.

323.3.5 *Clad and Lined Materials*

Clad and lined materials may be used in accordance with the following provisions:

(a) If piping components are made from integrally clad plate conforming to ASTM Specifications A 263, A-264, or A-265, pressure design in accordance with rules in 304 may be based upon total thickness of base material and cladding after any allowance for corrosion has been deducted, provided that both the base material and the cladding material are acceptable for Code use under 323.1 above, and provided that the clad plate has been shear tested and meets shear test requirements of the applicable ASTM specification. The allowable stress for each material (base and cladding) shall be taken from Appendix A, or determined in accordance with the rules in 302.3, provided, however, that the allowable stress used for the cladding portion of the design thickness shall never be greater than the allowable stress used for the base portion.

(b) For all other clad or lined piping components, the base material shall be an acceptable code material as defined in 323.1, and the thickness used in pressure design in accordance with 304 shall not include the thickness of the cladding or lining and the allowable stress used shall be that for the base material at the design temperature. For such components, the clad or lining material may be any material that, in the judgment of the user, is suitable for the intended service and for the method of manufacture and assembly of the piping component.

(c) Except for components designed in accordance with provisions of (a) above, fluid service limitations on materials stated in this code shall not restrict their use as cladding or liners in pipe or other components. Limitations on the outer material (including limitations on components and joints) shall govern except that properties of both inner and outer materials, and of any bond between them, shall be considered in establishing temperature limitations.

(d) Fabrication by welding of clad or lined piping components and the inspection and testing of such components shall be done in accordance with applicable provisions of Paragraph UCL 30 through UCL 52 of ASME Code Section VIII, or the provisions of Chapters V and VI of this Code, whichever is more stringent.

323.4 Deterioration of Materials in Service

The selection of materials to resist deterioration in service is outside the scope of this Code. It is the responsibility of the engineer to select materials suitable for the conditions of operation.

325 MATERIALS – MISCELLANEOUS PARTS

325.3 Gaskets

Limitations on gasket materials are covered in 308.4

325.4 Bolting

Limitations on bolting materials are covered in 308.5.

Chapter IV

DIMENSIONAL REQUIREMENTS

326 DIMENSIONAL REQUIREMENTS FOR STANDARD AND NONSTANDARD PIPING COMPONENTS

326.1 Standard Piping Components.

Dimensional standards for piping components are listed in Table 326.1. Also, certain material specifications listed in Appendix A contain dimensional requirements of 326. Dimensions of piping components shall comply with these standards and specifications unless the provisions of 326.2 are met.

326.2 Nonstandard Piping Components.

The dimensions for nonstandard piping components shall be such as to provide strength and performance equivalent to standard components, except as permitted under 304. For convenience, dimensions should conform to those of comparable standard components.

326.3 Threads

The dimensions of all piping connection threads not otherwise covered by a governing component standard or specification, shall conform to the requirements of applicable standards listed in Table 326.1.

Table 326.1 Dimensional Standards*

Standard	Designation
BOLTING	
Square and Hex Bolts and Screws, Including Hex Cap Screws and Lag Screws	ANSI B18.2.1
Square and Hex Nuts	ANSI B18.2.2
FITTINGS, VALVES, FLANGES, AND GASKETS	
Cast Iron Fittings, 2 inch through 48 inch for Water and Other Liquids	ANSI A21.10
Rubber Gasket Joints for Cast Iron Pressure Pipe and Fittings	ANSI A21.11
Gray Iron and Ductile Iron Fittings, 3 inch through 24 inch for Gas	ANSI A21.14
Cast Iron Pipe Flanges and Flanged Fittings, 25, 125, 250, and 800 lb	ANSI B16.1
Malleable-Iron Screwed Fittings, 150 and 300 lb	ANSI B16.3
Cast Iron Screwed Fittings, 125 and 250 lb	ANSI B16.4
Steel Pipe Flanges and Flanged Fittings	ANSI B16.5
Wrought Steel Buttwelding Fittings	ANSI B16.9
Face-to-Face and End-to-End Dimensions of Ferrous Valves	ANSI B16.10
Forged Steel Fittings, Socket-Welding and Threaded	ANSI B16.11
Ferrous Pipe Plugs, Bushings, and Locknuts with Pipe Threads	ANSI B16.14
Cast Bronze Screwed Fittings, 125 and 250 lb	ANSI B16.15
Cast Bronze Solder-Joint Pressure Fittings	ANSI B16.18
Ring-Joint Gaskets and Grooves for Steel Pipe Flanges	ANSI B16.20
Nonmetallic Gaskets for Pipe Flanges	ANSI B16.21
Wrought Copper and Bronze Solder-Joint Pressure Fittings	ANSI B16.22
Bronze Flanges and Flanged Fittings, 150 and 300 lb	ANSI B16.24
Buttwelding Ends for Pipe, Valves, Flanges and Fittings	ANSI B16.25
Cast Bronze Fittings for Flared Copper Tubes	ANSI B16.26
Wrought Steel Buttwelding Short Radius Elbows and Returns	ANSI B16.28
Refrigeration Flare-Type Fittings	ANSI B70.1

Table 326.1 Dimensional Standards (cont'd)

Standard	Designation
FITTINGS, VALVES, FLANGES, AND GASKETS (cont'd)	
Specifications for Threads in Valves, Fittings, and Flanges	API 6A
Flanged Steel Safety Relief Valves	API 526
Steel Venturi Gate Valves, Flanged or Buttwelding End	API 597
Steel Plug Valves	API 599
Steel Gate Valves, Flanged or Buttwelding Ends	API 600
Metallic Gaskets for Refinery Piping, Double-jacketed Corrugated and Spiral Wound	API 601
Compact Design Carbon Steel Gate Valves	API 602
150 lb Light-Wall, Corrosion-Resistant Gate Valve for Refinery Use (½ inch to 12 inch inclusive)	API 603
Flanged Nodular Iron Gate and Plug Valves for Refinery Use	API 604
Large-Diameter Carbon Steel Flanges (Size. 26 inch to 60 inch inclusive; Nominal Pressure Rating: 75, 150, and 300 lb.	API 605
Unions and Pipe Fittings 300 lb. Pressure	AAR M-404
Gate Valves for Ordinary Water Works Service	AWWA C500
Steel Pipe Flanges	AWWA C207
Steel Water Pipe Fittings	AWWA C208
Standard Finishes for Contact Faces of Pipe Flanges and Connecting End Flanges of Valves and Fittings	MSS SP-6
Spot Facing for Bronze, Iron and Steel Flanges	MSS SP-9
Standard Marking System for Valves, Fittings, Flanges and Unions	MSS SP-25
125 lb. Bronze Gate Valves	MSS SP-37
150 lb. Corrosion Resistant Cast Flanged Valves	MSS SP-42
Wrought Stainless Steel Buttwelding Fittings	MSS SP-43
By-Pass and Drain Connection Standard	MSS SP-45
Steel Buttwelding Fittings (26 inches and larger)	MSS SP-48
150 lb. Corrosion Resistant Cast Flanges and Flanged Fittings	MSS SP-51
Pipe Hangers & Supports—Materials and Design	MSS SP-58
Butterfly Valves	MSS SP-67
Cast Iron Gate Valves, Flanged and Threaded Ends	MSS SP-70
Cast Iron Swing Check Valves, Flanged and Threaded Ends	MSS SP-71
General Purpose Ball Valves	MSS SP-72
Silver Brazing Joints for Wrought and Cast Solder Joint Fittings	MSS SP-73
PIPE AND TUBES	
Thickness Design of Cast Iron Pipe	ANSI A21.1
Cast Iron Pipe Centrifugally Cast in Metal Molds, for Water or Other Liquids	ANSI A21.6
Cast Iron Pipe Centrifugally Cast in Metal Molds, for Gas	ANSI A21.7
Cast Iron Pipe Centrifugally Cast in Sand-Lined Molds, for Water or other Liquids	ANSI A21.8
Cast Iron Pipe Centrifugally Cast in Sand-Lined Molds, for Gas	ANSI A21.9
2 Inch and 2¼ Inch Cast Iron Pipe, Centrifugally Cast for Water or other Liquids	ANSI A21.12
Thickness Design of Ductile-Iron Pipe	ANSI A21.50
Ductile Iron Pipe, Centrifugally Cast in Metal Molds or Sand Lined Molds, for Water or Other Liquids	ANSI A21.51
Ductile Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Gas	ANSI A21.52
Wrought Steel and Wrought Iron Pipe	ANSI B36.10
Stainless Steel Pipe	ANSI B36.19

Table 326.1 Dimensional Standards (cont'd)

Standard	Designation
PIPE AND TUBES (cont'd)	
Pipe, Cast Iron: Pressure (Gas and Water)	FS WW-P-360
Pipe, Cast Gray and Ductile Iron, Pressure (For Water and Other Liquids)	FS WW-P-421
MISCELLANEOUS	
Unified Screw Threads	ANSI B1.1
Pipe Threads (Except Dryseal)	ANSI B2.1
Dryseal Pipe Threads	ANSI B2.2
Hose Coupling Screw Threads	ANSI B2.4
Fire-Hose Coupling Screw Thread	ANSI B26
Surface Texture	ANSI B46.1

*Standards incorporated in this Code by reference, and the names and addresses of the sponsoring organizations, are shown in Appendix E. It is not practical to refer to a specific edition of each standard throughout the Code text; but instead, the specific edition references are also shown in Appendix E. Appendix E will be revised at intervals as needed.

Chapter V

FABRICATION, ASSEMBLY AND ERECTION

327 WELDING

327.2 Material.

327.2.1 *Filler Material.*

All filler material shall comply with the requirements of Section IX. ASME Boiler and Pressure Vessel Code.

327.2.2 *Backing Rings.*

Backing rings, when used, shall conform to the following requirements:

(a) *Ferrous Rings.* If ferrous metal backing rings are used they shall be made from material of weldable quality and the sulfur content shall not exceed 0.05 percent.

If two abutting surfaces are to be welded to a third member used as a backing ring and one or two of the three members are ferritic and the other member or members are austenitic, the satisfactory use of such materials shall be determined by the welding procedure as approved by the design engineer and qualified as required in 327.5.

Backing rings may be of the continuous machined or split band type. Some commonly used types are shown in Fig. 327.2.2.

(b) *Nonferrous and Nonmetallic Rings.* Backing rings of nonferrous or nonmetallic material may be used provided the qualification of the welding procedure as required in 327.5 has proved the use of such materials to be satisfactory and provided their use has been approved by the design engineer.

327.2.3 *Consumable Inserts.*

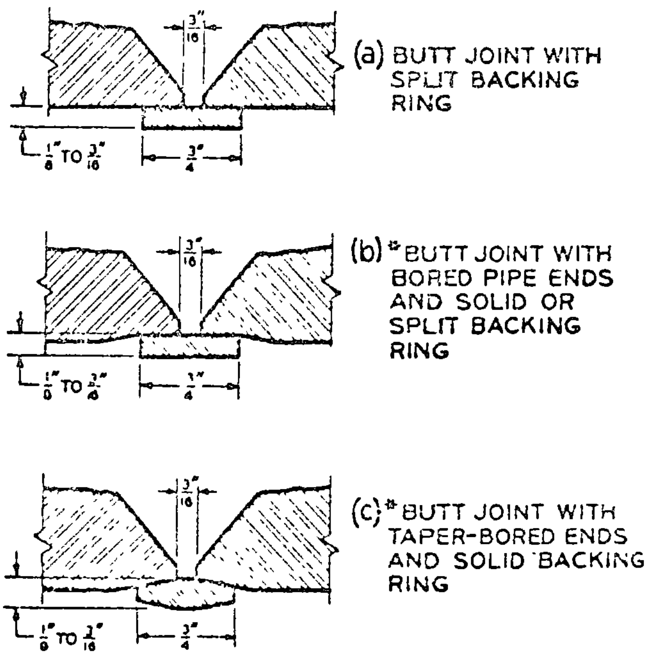
Consumable inserts may be used if satisfactory use of such inserts has been established by the procedure qualification.

327.3 Preparation.

327.3.1 *Butt Welds.*

(a) *End Preparation.*

(1) Oxygen or arc cutting is acceptable only if the cut is reasonably smooth and true and all slag is cleaned from the flame cut surfaces. Discoloration



* REFER TO ANSI B16.25 FOR DETAILED DIMENSIONAL INFORMATION ON PIPE BORE

FIG. 327.2.2—TYPICAL JOINTS WITH BACKING RING

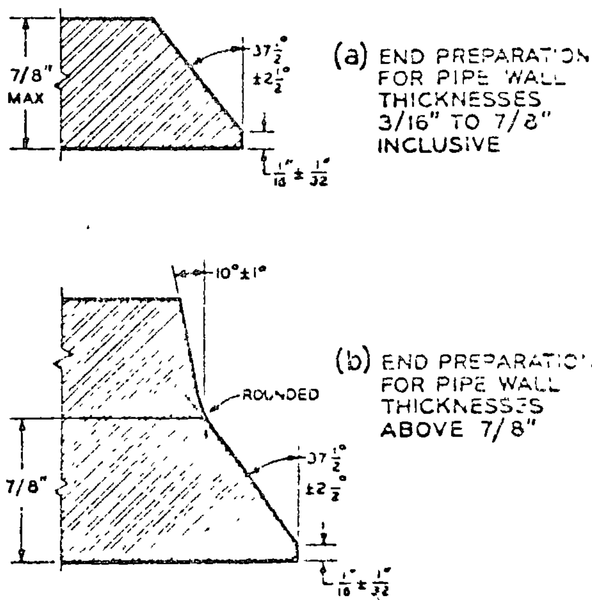


FIG. 327.3.1A—BUTT-WELDING END PREPARATION

which may remain on the flame cut surface is not considered to be detrimental oxidation.

(2) Butt-welding end preparation contained in ANSI B16.25 or any other end preparation which meets the procedure qualification is acceptable. (For convenience the basic bevel angles taken from B16.25 are shown in Fig. 327.3.1A.)

(3) If backing rings are used and the design includes machining the inside of the pipe, the joint designs shown in Fig. 327.2.2(b) or 327.2.2(c) or combinations of these details are preferred.

(4) If piping component ends are bored for accurate fitting machined backing rings, such boring shall not result in a finished wall thickness after welding less than the minimum design thickness plus corrosion and erosion allowances. Where necessary, weld metal may be deposited on the inside of the piping component to provide sufficient material for machining to insure satisfactory seating of rings.

(5) If the piping component ends are upset they may be bored to allow for a completely recessed backing ring, provided the remaining net thickness of the finished ends is not less than the minimum design thickness plus corrosion and erosion allowances.

(b) *Cleaning.*

Surfaces for welding shall be clean and shall be free from paint, oil, rust, scale, or other material which is detrimental to welding.

(c) *Alignment.*

The ends of piping components to be joined shall be aligned as accurately as is practicable within existing commercial tolerances on diameters, wall thicknesses, and out-of-roundness. Alignment shall be preserved during welding. Where ends are to be joined and the internal misalignment exceeds 1/16 inch, it is preferred that the component with the wall extending internally be internally trimmed (see Fig. 327.3.1B),

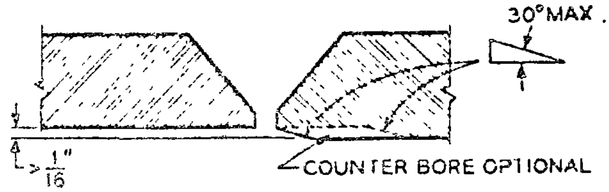


FIG 327.3.1B–INTERNAL MISALIGNMENT

so that adjoining internal surfaces are approximately flush. However, this trimming shall not result in a piping component wall thickness less than the minimum design thickness plus corrosion and erosion allowances.

(d) *Spacing*

The root opening of the joint shall be as given in the procedure specification.

327.3.2 *Fillet Welds.*

Piping components which are to be joined in a manner which includes fillet welding shall be prepared in accordance with applicable provisions and requirements of 327.3.1. For typical details see Fig. 327.4.4A, B and C.

327.4 Procedure.

327.4.1 *General.*

No welding shall be done if there is impingement of any rain, snow, sleet or high wind on the weld area.

327.4.2 *Girth Butt Welds.*

(a) Butt joints may be made with a single vee, double vee, or other suitable type of groove, with or without backing rings

(b) Tack welds shall be made by a qualified welder or shall be removed. Tack welds which are not removed shall be made with an electrode which is the same as or equivalent to the electrode to be used for the first pass. Tack welds which have cracked shall be removed.

(c) If the external surfaces of the two components are not aligned, the weld shall be tapered between the two surfaces.

(d) Welds shall comply with the following limitations as to imperfections, within the capabilities of the type of examination used, and for types of imperfections required to be evaluated as shown in Table 327.4.2.

(1) *Cracks or Side Wall Cold Laps:* None permitted (See Fig. 327.4.1A).

(2) *Incomplete Penetration:* The total joint penetration shall not be less than the thinner of the two components being joined, except that incomplete root penetration is permissible if it does not exceed 1/32 inch or 20 percent of the wall thickness of the thinner component, whichever is smaller. The total length of such incomplete root penetration shall not exceed 1-1/2 inches in any 6 inches of weld length.

Unless otherwise specified by the engineering design, welds on which 100 percent radiography is specified shall have complete joint penetration.

(3) *Weld Reinforcement and Undercutting:* A butt weld shall not have an undercut exceeding the lesser of 1/32 inch or 12½ percent of the wall thickness. The thickness of weld reinforcement shall not exceed the following considering the thinner component being joined

Component Thickness (in.), $\bar{T}$	Reinforcement Thickness, max (in.)
1/2 and under	lesser of 1/8 or 33% $\bar{T}$
Over 1/2 through 1	5/32
Over 1	3/16

For double welded joints this limitation on reinforcement shall apply to each surface of the weld separately.

Within the above limitations, the surface of the weld shall blend into the base metal of the components being welded.

(4) *Porosity* For welds on which 100 percent radiography is specified an individual pocket of porosity shall not exceed the lesser of $\bar{T}/3$ or 1/16 inch in its greatest dimension, $\bar{T}$ being the nominal wall thickness of the thinner component being joined. For welds on which random radiography is specified, an individual pocket of porosity shall not exceed the the lesser of $\bar{T}/2$ or 3/32 inch in its greatest dimension. The total area of porosity under either degree of examination, projected radially through the weld, shall not exceed an area equivalent to three times the area of a single maximum pocket allowable for the degree of examination specified, in any square inch of projected weld area.

(5) *Slag inclusions or other elongated defects:* For welds on which 100 percent radiography is specified, the developed length of any single slag inclusion or elongated defect shall not exceed $\bar{T}/3$, $\bar{T}$ being the nominal wall thickness of the thinner component being joined. The total cumulative developed length of slag inclusions and/or elongated defects shall not exceed $\bar{T}/2$ in any 6-inch length of weld. The width of a slag inclusion shall not exceed 1/16 inch. For welds on which random radiography is specified, the developed length of any single slag inclusion or elongated defect shall not exceed $2\bar{T}$. The total cumulative developed length of slag inclusions and/or elongated defects shall not exceed $4\bar{T}$ in any 6-inch length of weld. The width of a slag inclusion shall not exceed 3/32 inch

(6) *Excess Root Penetration.* For single welded joints, the excess penetration shall be limited to the lesser of 1/8 inch or 25 percent of the nominal wall thickness of the thinner component being joined, down to 1/4 inch wall thickness. For any nominal wall thickness less than 1/4 inch, the excess penetration shall be limited to 1/16 inch.

(7) *Concave Root Surface:* For single-welded joints, concavity of the root surface shall not reduce the total thickness of the joint, including reinforcement, to less than the thickness of the thinner of the components being joined.

Table 327.4.2 Imperfections To Be Evaluated By Various Types Of Examination

Type of Imperfection	TYPE OF EXAMINATION: Visual	Liquid Penetrant or Magnetic Particle*	Ultrasonic or Radiographic: Random	Ultrasonic or Radiographic: 100%
Crack	X	X	X	X
Incomplete Penetration	X		X	X
Lack of Fusion	X		X	X
Weld Undercutting	X			
Weld Reinforcement	X			
Porosity			X	X
Slag Inclusion			X	X
Concave Root Surface	X		X	X

*Evaluation, any necessary repair of imperfections and examination of additional items shall be limited to the requirements of 336.5 unless more stringent requirements are specified by the engineering design.

Different types of imperfections are illustrated in Fig 327.4.1.A thru E inclusive

The methods of examination are described in 336.4 The types and extent of examination required are specified in 336.5

327.4.3 *Longitudinal Butt Welds.*

Any longitudinal butt weld in a piping component not made in accordance with a standard listed in Appendix A shall conform to the following:

(a) The weld shall be single or double butt welded, using a single vee, double vee, or other suitable type of groove.

(b) Tack welds shall either be made by a qualified welder using the same procedure as the completed weld or shall be removed. Tack welds which are not removed should be made with an electrode which is the same as or equivalent to the electrode to be used for the first pass. Tack welds which have cracked shall be removed.

(c) Welds shall comply with the following limitations as to imperfections, for the type of examination used and for types of imperfections required to be evaluated as shown in Table 327.4.2. The methods of examination are described by 336.4. The types and extent of examination required are specified in 336.5

(1) *Cracks and Side Wall Cold Laps:* None permitted

(2) *Incomplete penetration and Lack of Fusion.* None permitted

(3) *Undercutting* Butt welds shall be free from undercutting, and finished weld surfaces shall merge smoothly into the base metal surface at the toe.

(4) *Weld Reinforcement* The thickness of the reinforcement shall be 1/16 inch to 1/8 inch

For double welded joints this limitation on reinforcement shall apply to each surface of the weld separately.

(5) *Excess Root Penetration:* For single-welded joints, the excess penetration shall meet the requirements of 327.4.2(d)(6).

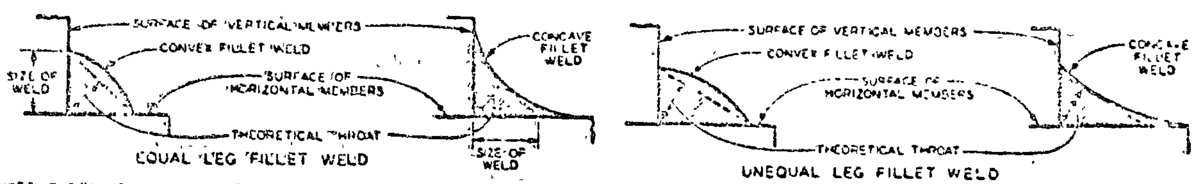
(6) *Porosity:* The weld shall meet requirements of 327.4.2(d)(4).

(7) *Slag Inclusion:* The weld shall meet requirements of 327.4.2(d)(5).

(8) *Concave Root Surface:* The weld shall meet the requirements of 327.4.2(d)(7)

327.4.4 *Fillet Welds:*

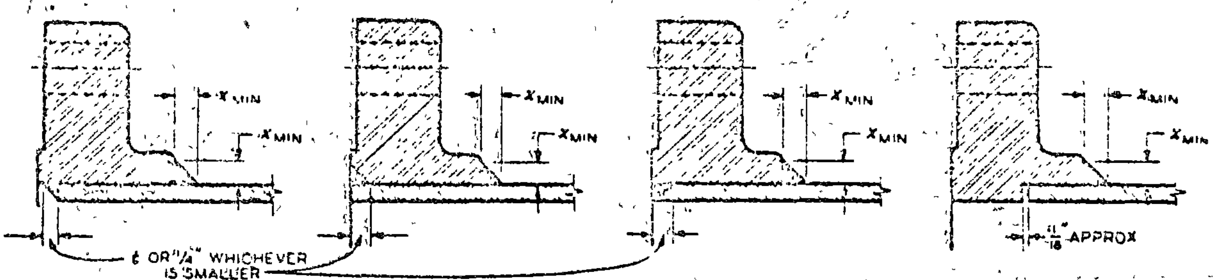
Fillet welds may vary convex to concave. The size of a fillet weld is determined as shown in Fig. 327.4.4A. Typical minimum fillet weld details for slip-on flanges and socket-welding components are shown in Figs. 327.4.4B and 327.4.4C. The limitations on cracks and undercutting set forth in 327.4.2(d) for girth welds are also applicable to fillet welds.



NOTE THE "SIZE" OF AN EQUAL LEG FILLET WELD IS THE LENGTH OF THE LARGEST INSCRIBED RIGHT ISOSCELES TRIANGLE (THEORETICAL THROAT = 0.707 × SIZE)

NOTE THE "SIZE" OF AN UNEQUAL LEG FILLET WELD IS THE LEG LENGTHS OF THE LARGEST RIGHT TRIANGLE WHICH CAN BE INSCRIBED WITHIN THE FILLET WELD CROSS SECTION (e.g., 1/2" × 1")

FIG. 327.4.4A—FILLET WELD SIZE



(a) FRONT AND BACK WELD (b) FACE AND BACK WELD (c) SOCKET WELDING FLANGE

X_{MIN} = 1.4 t OR THE THICKNESS OF THE HUB, WHICHEVER IS SMALLER, BUT NOT LESS THAN 1/8" (SEE DIVISION 304 FOR DEFINITION OF t.)

FIG. 327.4.4B—WELDING DETAILS FOR SLIP-ON AND SOCKET-WELDING FLANGES
SOME ACCEPTABLE TYPES OF FLANGE ATTACHMENT WELDS

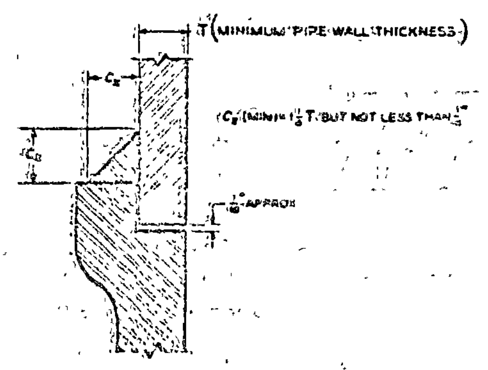
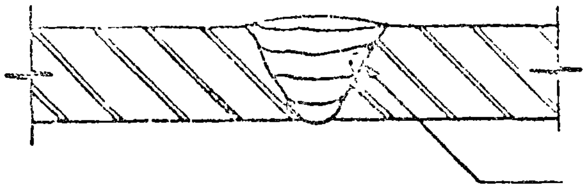


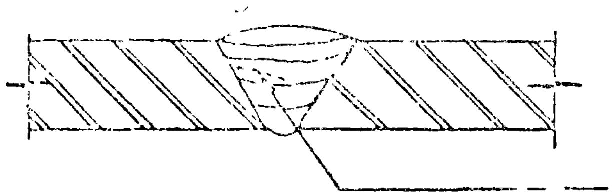
FIG. 327.4.4C—MINIMUM WELDING DIMENSIONS REQUIRED FOR SOCKET-WELDING COMPONENTS OTHER THAN FLANGES



LACK OF FUSION DUE TO SIDE WALL COLD LAP

COLD LAP BETWEEN WELD BEAD AND BASE METAL

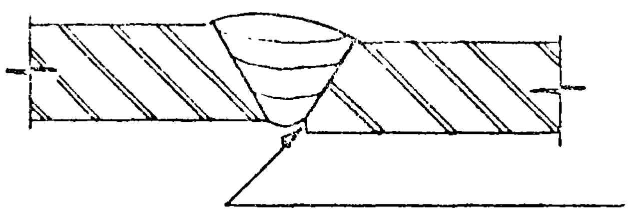
FIG 327 4 1A



LACK OF FUSION DUE TO COLD LAP BETWEEN ADJACENT PASSES

NOTE COLD LAP IS NOT SURFACE CONNECTED

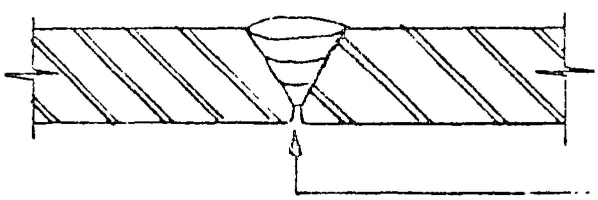
FIG. 327.4 1B



INCOMPLETE PENETRATION DUE TO INTERNAL MISALIGNMENT

NOTE INCOMPLETE FILLING AT ROOT ON ONE SIDE ONLY

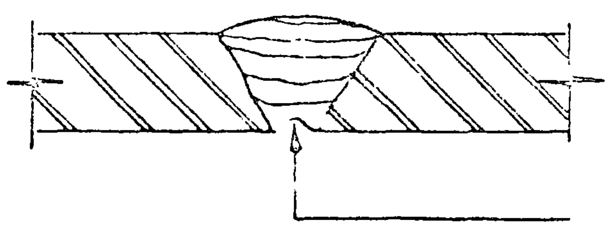
FIG 327 4.1C



INCOMPLETE PENETRATION OF WELD GROOVE

NOTE INCOMPLETE FILLING AT ROOT

FIG. 327 4 1D



CONCAVE ROOT SURFACE (SUCK UP)

ROOT BEAD FUSED TO BOTH INSIDE SURFACES BUT CENTER OF ROOT SLIGHTLY BELOW INSIDE SURFACE OF PIPE (NOT INCOMPLETE PENETRATION)

FIG. 327 4.1E

327.4.5 *Seal Welds.*

If seal welding of threaded joints is performed, all exposed threads shall be covered by the seal weld. Seal welding shall be done by qualified welders. The limitations on cracks and undercutting set forth in 327.4.2(d) for girth welds are also applicable to seal welds.

327.4.6 *Welded Branch Connections.*

(a) Fig. 327.4.6A, 327.4.6B and 327.4.6C show typical details of branch connections, with and without added reinforcement. However, no attempt has been made to show all acceptable types of construction and the fact that a certain type of construction is illustrated does not indicate that it is recommended over other types not illustrated.

(b) Fig. 327.4.6D shows basic types of weld attachments used in the fabrication of branch connections. The location and minimum size of these attachment welds shall conform to the requirements of 327.4.6. Welds shall be calculated in accordance with 304.3.3 but shall not be less than the sizes shown in Fig. 327.4.6D.

The notations and symbols used in this paragraph and in Fig. 327.4.6D are as follows:

$\bar{T}_h$ = Nominal thickness of header, inches

t_c = the smaller of 0.7 t_n or 1/4 inch.

t_n = nominal thickness of branch wall, inches.

t_r = nominal thickness of reinforcing ring or saddle, inches, made from plate
= minimum thickness of reinforcing ring or saddle, inches, made from pipe.

t_{min} = the smaller of t_n or t_r

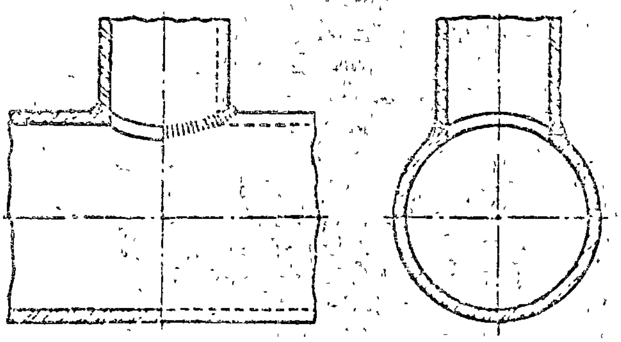


FIG. 327.4.6A—TYPICAL WELDED BRANCH CONNECTION, WITHOUT ADDITIONAL REINFORCEMENT

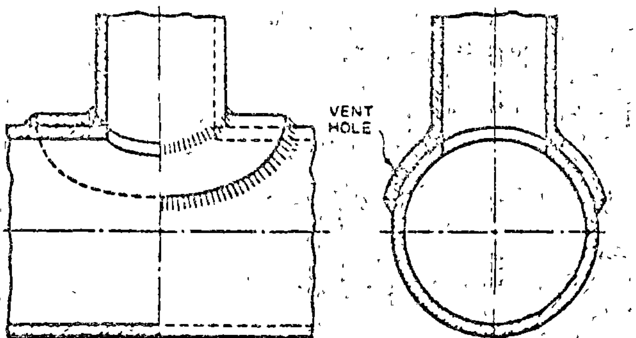


FIG. 327.4.6B—TYPICAL WELDED BRANCH CONNECTION WITH ADDITIONAL REINFORCEMENT

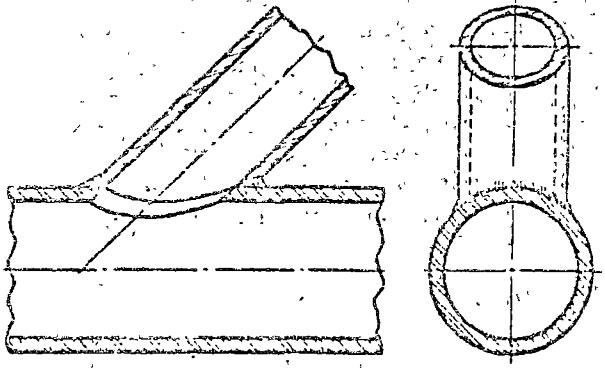


FIG. 327.4.6C—TYPICAL WELDED ANGULAR BRANCH CONNECTION WITHOUT ADDITIONAL REINFORCEMENT

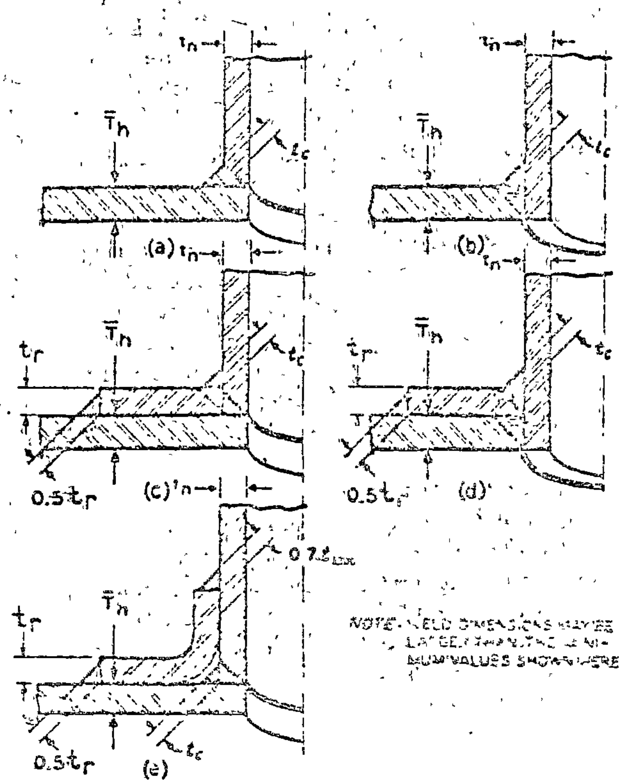


FIG. 327.4.6D—SOME ACCEPTABLE TYPES OF WELDED BRANCH ATTACHMENT DETAILS SHOWING MINIMUM ACCEPTABLE WELDS

(c) Branch connections (including specially made integrally reinforced branch connection fittings) which abut the outside surface of the run wall, or which are inserted through an opening cut in the run wall, shall have opening and branch contour to provide a good fit and shall be attached by means of fully penetrated groove welds. The fully penetrated groove welds shall be finished with cover fillet welds having a minimum throat dimension not less than t_c [See Fig. 327.4.6D(a) and 327.4.6D(b).]. The limitation as to imperfection of these groove welds shall be as set forth in 327.4.2(d) for girth welds.

(d) In branch connections having reinforcement pads or saddles, the reinforcement shall be attached by welds at the outer edge and at the branch periphery as follows:

(1) If the weld joining the added reinforcement to the branch is a fully penetrated groove weld, it shall be finished with a cover fillet weld having a minimum throat dimension not less than t_c; the weld at the outer edge, joining the added reinforcement to the run, shall be a fillet weld with a minimum throat dimension of $0.5t_r$ [See Fig. 327.4.6D(c) and 327.4.6D(d).]

(2) If the weld joining the added reinforcement to the branch is a fillet weld, the throat dimension shall not be less than $0.7t_{min}$ [See Fig. 327.4.6D(e).] The weld at the outer edge joining the outer reinforcement to the run shall also be a fillet weld with a minimum throat dimension of $0.5t_r$.

(e) If rings or saddles are used, a vent hole shall be provided (at the side and not at the crotch) in the ring or saddle to reveal leakage in the weld between branch and main run and to provide venting during welding and heat treating operations. Rings or saddles may be made in more than one piece if the joints between the pieces have adequate strength and if each piece is provided with a vent hole. A good fit shall be provided between reinforcing rings or saddles and the parts to which they are attached.

327.4.7 *Weld Identification.*

Each qualified welder or welding operator shall have an identification symbol assigned to him and, unless specified otherwise by the design engineer because of service conditions, each pressure weld shall be permanently marked with this identification symbol. If more than one welder welds a joint, each shall apply his symbol in a manner to indicate the part of the joint he welded.

327.4.8 *Heat Treatment*

Heat treatment for welds shall be in accordance with 331.

327.5 Qualification.

327.5.1 *General*

Qualification of the welding procedures to be used, and of the performance of welders and welding operators, is required, and shall comply with the requirements of the ASME Boiler and Pressure Vessel Code (Section IX) except as modified by 327.5. For braze welding qualification requirements, see Part of Section IX.

327.5.2 *P-Numbers*

To reduce the number of welding procedure qualifications required, P-numbers are assigned groupings of material on the basis of hardenability characteristics where this can be logically done.

These groupings do not imply that base materials or filler metals of different analysis within a group may be indiscriminately substituted for a material which was used in the qualification test without consideration of the compatibility of the base materials and filler metals from the standpoint of metallurgical properties, postheat treatment, design and service requirements, and mechanical properties.

The P-numbers for most materials appear in Appendix A in a separate column of the stress tables.

327.5.3 *Welding Responsibility.*

Each employer is responsible for the welding done by personnel of its organization, and shall conduct the required qualification test to qualify the welding procedures, and the welders or welding operators.

327.5.4 *Qualification by Others.*

To avoid duplication of qualification tests of welders or welding operators, the welders or welding operators qualified as required above by one employer may be accepted by another employer (subject to the approval of the Code Examiner) on piping using the same or an equivalent procedure wherein the essential variables are within the limits established in Section IX, ASME Boiler and Pressure Vessel Code. An employer accepting such qualification tests by another employer shall obtain a copy (from the previous employer) of the performance qualification test record, showing the name of the employer by whom the welders or welding operators were qualified, the dates of such qualification, and the date the welder last welded pressure piping components under such qualification.

327.5.5 *Test Joint.*

Test joints for both procedure qualification and performance qualification shall be made as groove welds in pipe in one or more of the specified basic qualification test positions.

327.5.6 *Performance Requalification.*

Renewal of a Performance Qualification is required (1) when a welder has not used the specific process (e.g., metal arc, gas) to weld either ferrous or nonferrous pressure piping components for a period of three months or more, or (2) when there is a specific reason to question his ability to make welds that meet the Performance Qualification requirements. Renewal of qualification under stipulation (1) may be made in only a single pipe wall thickness. Evaluation of requalification under stipulation (2) may be made by radiographic examination.

327.6 Qualification Records

The employer shall maintain a record, certified by him, and available to the purchaser or his agent and the inspector, of the procedures used and the welders or welding operators employed by him, showing the date and results of procedure and performance qualifications, and the identification symbol assigned to each performance qualification.

327.7 Defect Repairs.

All defects in welds requiring repair, shall be removed by flame or arc gouging, grinding, chipping, or machining. All repair welds shall be preheated and postheated as originally required, and the basic principles of the same welding procedure initially used shall be employed as far as applicable. This recognizes that the cavity to be welded may not be of the same contour or dimensions as the original joint.

Preheating may be required on certain alloy materials of the air hardening type in order to prevent surface checking or cracking adjacent to the flame or arc gouged surface.

328 BRAZING

328.1 Materials.

328.1.1 *Filler Metal.*

The filler metal used in brazing shall be a nonferrous metal or alloy having a melting point above 800F and below that of the metal being joined. The filler metal shall melt and flow freely within the desired temperature range and in conjunction with a suitable flux or controlled atmosphere, shall wet and adhere to the surfaces to be joined.

328.1.2 *Flux.*

Fluxes that are fluid and chemically active at the brazing temperature shall be used when necessary to prevent oxidation of the filler metal and the surfaces to be joined and to promote free flowing of the filler metal.

328.2 Preparation and Procedure.

328.2.1 *Surface Preparation.*

The surfaces to be brazed shall be clean and free from grease, oxides, paint, scale, and dirt of any kind. Any suitable chemical or mechanical cleaning method may be used to provide a clean wettable surface for brazing.

328.2.2 *Joint Clearance.*

The clearance between surfaces to be joined shall be no larger than is necessary to allow complete capillary distribution of the filler metal.

328.2.3 *Heating.*

The joint shall be brought to brazing temperature in as short a time as possible to minimize oxidation without localized underheating or overheating.

328.2.4 *Brazing Qualifications.*

The qualification of brazing, brazers and brazing operators shall be in accordance with the requirements of Part C, Section IX, ASME Boiler and Pressure Vessel Code.

329 BENDING

329.1 Bend Radius and Flattening

Pipe may be bent to any radius which will result in arc surfaces free of cracks and substantially free of buckles. Flattening of a bend, as measured by the difference between the maximum and the minimum diameter at any cross-section, shall not exceed 8 percent and 3 percent of the nominal outside diameter for internal and external pressure respectively. This shall not prohibit the use of bends designed as creased or corrugated.

329.2 Procedure

Pipe may be bent by any hot or cold method permissible by radii and material characteristics of the pipe being bent.

Cold bends of ferritic materials shall be made at temperatures below the lower critical temperature. Hot bends shall be made at temperatures above the upper critical temperature.

Hot bending shall be done within a temperature range consistent with material characteristics and end use requirements.

329.3 Heat Treatment

(a) After hot bending heat treatment for all thicknesses of P-3, P-4, P-5, P-6, P-10A and P-10B materials is required. Times and temperatures shall be in accordance with 331.

(b) After cold bending, heat treatment for temperature and duration in accordance with 331 shall be required only as follows:

(1) Where the maximum calculated fiber elongation of the outside fibers of the bend exceeds 50 percent of the minimum specified elongation for P1 through P7 materials unless it has been demonstrated that the selection of the pipe and the procedure for making the bend provide assurance that, in the as bent condition, the outside fibers have retained a minimum elongation capability of 10 percent.

(2) Where required by the engineering design.

(3) Where impact tested material is required when the calculated fiber elongation of the bend exceeds 5 percent.

330 FORMING

330.1 Procedure

Piping components may be formed by any suitable hot or cold pressing, rolling, forging, hammering, spinning, drawing, or other method.

Cold forming of ferrous materials shall be done at temperatures below the lower critical temperature. Hot forming shall be done at temperatures above the upper critical temperature.

Hot forming shall be done within a temperature range consistent with material characteristics and end use requirements.

330.2 Heat Treatment

(a) After hot forming, heat treatment is required for all thicknesses of P-3, P-4, P-5, P-6, P-10A and P-10B materials. Times and temperatures shall be in accordance with 331.

(b) After cold forming, heat treatment for temperature and duration in accordance with 331 shall be required as follows:

(1) Where maximum calculated fiber elongation exceeds 50 percent of the minimum specified elongation for P-1 through P-7 materials, unless it has been demonstrated that the selection of the pipe and the procedure for forming provide assurance that, in the as-formed condition, the most severely formed portion has retained a minimum elongation capability of 10 percent.

(2) Where required by the engineering design.

(3) Where impact tested material is required.

331 HEAT TREATMENT

331.1.1 *General*

Preheating and heat treatment are means used to avert or relieve the detrimental effects of the high temperature and severe thermal gradients inherent in welding. In addition, heat treatment is used to relieve residual stresses created during bending or forming operations.

The requirements of this section represent basic practices which are acceptable for most applications of welding, bending and forming. However they are not necessarily suitable for all service conditions. The engineering design must specify more stringent requirements for heat treatment and/or hardness limitations when service conditions warrant them. Similarly, the engineering design may specify less stringent conditions for heat treatment and/or hardness requirements when:

(a) Service conditions warrant less stringent requirements, and

(b) The overall variables of the welding or forming process are such that the finished product will be suitable for the intended service.

When the engineering design stipulates requirements less stringent than those contained in 331 the design engineer must demonstrate to the satisfaction of the owner the adequacy of these requirements by comparable service experience or appropriate tests. In citing comparable service experience adequate consideration must be given to overall service conditions including factors such as frequency of thermal cycling, flexibility stress levels, probability of brittle failure and the effects of service temperature. In addition, appropriate welding procedure qualification tests shall be carried out.

The engineering design shall stipulate the details of examination and/or other production quality control operations required to insure that the final welds are of adequate quality. Such operations shall be applied at least to the extent specified in this Code.

331.1.2 *Heating and Cooling Method*

Heating may be accomplished by a suitable method which will provide the required metal temperature, metal temperature uniformity, and temperature control such as an enclosed furnace, local fuel firing, electric resistance, electric induction, or exothermic chemical reaction. Cooling may be accomplished in a furnace, in air, with the aid of local thermal control through the application of heat or insulation, or in any other manner required to achieve the desired cooling rate.

331.2 Preheating

331.2.1 *General*

The necessity for preheating of welds, and the temperature to be used, shall be established by the engineering design and demonstrated by the procedure qualification. However recommended minimum preheat temperatures for the various P-number materials

Table 331.2.1 – Recommended Preheat Temperatures

* Base Metal P Number	* Weld Metal Analysis A Number	Material Group	Nom. Wall, In.	Min. specified tensile strength (base metal), psi	Min. Temp., F
1	1	Carbon Steel	< 1 ≥ 1 all	≤ 71,000 all > 71,000	50 175 175
3	2	Alloy Steels Cr. 3/4% max. Total Alloy 2% max.	≤ 1/2 ≥ 1/2 all	≤ 71,000 all > 71,000	50 175 175
4	3	Alloy Steels Cr. > 3/4% to 2% Total Alloy 2-3/4% max.	all	all	300
5	4	Alloy Steels Cr. > 2% to 10% Total Alloy 10% max.	all	all	350
6	5	High Alloy Steels Martensitic Cr. 11% 15%	all	all	300 (600 max interpass)
7	6	High Alloy Steels Ferritic Cr. 11%-30%	all	all	50
8	7,8	High Alloy Steels Austenitic	all	all	50
9A, 9B, 9C		Nickel Alloy Steels	all	all	200
10A		Mn V Steel	all	all	175
10B		Cr-V Steel	all	all	300
11A SG-1		9% Ni Steel			None
P21-P52			all	all	50

* P Number from Appendix A
A Number from ASME Section IX, Table Q-11.3

are listed in Table 331.2.1. If the ambient temperature is less than 32F, preheating to a temperature warm to the hand is required for all materials.

331.2.2 *Preheating Dissimilar Metals*

When welding dissimilar metals having different preheat recommendations, the preheat temperature shall be established by the engineering design as demonstrated by the qualified welding procedure; however the higher preheat temperature shown in Table 331.2.1 for the two metals is recommended.

331.2.3 *Temperature Measurement*

The preheat temperature, required according to the welding procedure, shall be checked by use of temperature-indicating crayons, thermocouple pyrometers, or other suitable methods to assure that the required preheat temperature is obtained prior to and maintained during the welding operation.

331.2.4 *Types of Welds*

These preheat recommendations apply to all welds including butt welds, fillet welds, socket welds, and seal welds of threaded joints.

331.3 Heat Treatment

331.3.1 *Requirements for Heat Treatment*

Heat treatment in accordance with Table 331.3.1 shall be applied as required below. The design engineer may specify more stringent requirements, including heat treatment for lesser thicknesses, or he may specify less stringent requirements, including none, in accordance with 331.1.1.

(a) Piping shall be heat treated after welding as required for material groups and thicknesses in Table 331.3.1. The heat treatment to be used in production welding shall be stated in the welding procedure specification and used in the qualification of the welding procedure.

(b) Piping shall be heat treated after bending or forming as required by 329.3 or 330.2.

(c) Normalizing, or normalizing and tempering, or annealing may be applied in lieu of the required heat treatment after welding, bending, or forming provided that mechanical properties of the affected weld and base metal meet specification requirements after such heat treatment.

331.3.2 *Hardness Tests*

Hardness tests of production welds and of hot formed and hot bent piping are intended as a check to determine if heat treatment has been performed satisfactorily. Where a hardness limit is given in Table 331.3.1, a minimum of 10 percent of welds and of hot formed and hot bent materials in each heat treatment batch which are furnace heat treated, and 100 percent of those which are locally heat treated shall be hardness tested. The hardness limit applies to weld and to heat affected zone. The test of the heat affected zone shall be made at a point as near as practicable to the edge of the weld.

331.3.3 *Dissimilar Welds*

(a) Heat treatment of welded joints between dissimilar ferritic metals or between ferritic metals with dissimilar ferritic weld metal, shall be at the higher temperature range of those ranges required in Table 331.3.1 for each material joined.

(b) Dissimilar joints including both a ferritic and an austenitic weld or component shall be heat treated according to the requirements for the ferritic material, unless otherwise specified by the engineering design.

331.3.4 *Temperature Measurement*

Heat treatment temperature shall be checked by the use of thermocouple pyrometers or other suitable methods to assure that the requirements stated in the procedure specification are accomplished.

331.3.5 *Interrupted Welds*

If welding is interrupted before completion, or the weldment is allowed to cool prior to heat treatment, adequate heat treatment or controlled rate of cooling shall be applied to assure that no detrimental effect to the piping shall result. The preheat temperature in the welding procedure must be applied before welding is resumed

331.3.6 *Thickness Effect on Heat Treatment Requirements*

When components are joined by welding, the thickness to be used in applying the preheat recommendations and heat treatment requirements of Tables 331.2.1 and 331.3.1 shall be that of the thicker component measured at the joint, except as follows:

(a) In the case of branch connections, metal (other than weld metal) added as reinforcement, whether integral or attached, will not be considered in determining heat treatment requirements. However, heat treatment is required when the thickness through the weld in any plane through the branch is greater than two times the limiting material thickness requiring heat treatment even though the thickness of the components at the joint is less than the limiting thickness. Thickness through the weld for the details shown in Fig. 327.4.6D shall be computed using the the following formulas:

detail (a) = $t_n + t_c$

detail (b) = $\bar{T}_h + t_c$

detail (c) = Greater of $t_n + t_r$ or $t_r + t_c$

detail (d) = $\bar{T}_h + t_r + t_c$

detail (e) = $t_n + t_c$

Table 331.3.1 – Requirements for Heat Treatment[1]

* Base Metal P Number**	* Weld Metal Analysis A Number	Material Group	Nom. Wall, In.	Min. specified tensile Strength (base metal), psi	Metal Temp., F	Hrs/In Nom. Wall	Min. Time, Hrs.	Brinell Hardness, Max
1	1	Carbon Steel	≤ 3/4	all	None			
			> 3/4		1100-1200	1	1	
3	2	Alloy Steels Cr. 3/4% max. Total alloy 2% max.	≤ 3/4	≤ 71,000	None			
			> 3/4	all	1100-1325	1	1	225
			all	> 71,000	1100-1325	1	1	225
			preheated <175F	all	1100-1325	1	1	225
4	3	Alloy Steels Cr. >3/4% to 2% Total Alloy 2-3/4% max.	≤ 1/2	< 71,000	None			
			≥ 1/2	all	1300-1375	1	2	225
			all	> 71,000	1300-1375	1	2	225
			All not preheated to 300F	all	1300-1375	1	2	225
5	4	Alloy Steels Cr. >2% to 10% Total Alloy 10% max.	≤ 1/2 & < 3% Cr & ≤ 0.15% C & preheated ≥350F	all	None			
			≥1/2 or >3% Cr or >0.15% C or preheated <350F	all	1300-1400	1	2	241
6	5	High Alloy Steels Martensitic Cr. 11% 15%	all	all	1350-1450	1	2	241
		(A240 GR. 429)	all	all	1150-1225	1	2	241
7	6	High Alloy Steels Ferritic Cr. 11% 30%	all	all	None			
8	7,8	High Alloy Steels Austenitic	all	all	None			
9A 9B 9C		Nickel Alloy Steels	≤ 3/4	all	None			
			> 3/4	all	1100-1175	1/2	1	
10A		Mn-V Steel	≤ 3/4	≤ 71,000	None	–	–	–
			> 3/4	all	1100-1300	1	1	225
			all	> 71,000	1100-1300	1	1	225
10B		Cr-V Steel	≤ 1/2	≤ 71,000	None	–		–
			> 1/2	all	1100-1350	1	1	225
			all	>71,000	1100-1350	1	1	225
			all preheated ≤300F	all	1100-1350	1	1	225
11A SG-1		9% Ni Steel	≤ 2	all	None			
			> 2	all	1025-1085 (cooling rate ≥300F/Hr to 600F)	1	1	

P Number from Appendix A.
* A Number from ASME Section IX, Table Q-11.3.
** Special P Numbers (SP 1, SP 2, SP 3) require special consideration in procedure qualification. The required thermal treatment shall be established by the engineering design as demonstrated by the procedure qualification.

(b) In the case of fillet welds for attachment of external non pressure containing parts such as lugs or other pipe supporting elements, the throat of the fillet weld shall govern.

(c) For fillet welds used in slip-on and socket welding flanges and connections, and for seal welds of threaded joints, the necessity for heat treatment shall be governed by the base metal thickness in accordance with Table 331.3.1, except as follows:

(1) Not required for P-1 materials when weld throat thickness is 5/8 inch or less, regardless of base metal thickness.

(2) Not required for P-3, P-4, P-5, P10A or P10B materials with weld throat thickness 1/2 inch or less, regardless of base metal thickness, providing recommended minimum preheat is applied and minimum specified tensile strength of base metal is less than 71,000 psi.

(3) Not required for ferritic materials when welds are made with filler metal which is not air hardening. Austenitic welding materials may be used for welds to ferritic materials when the effects of service conditions such as differential thermal expansion due to elevated temperature or corrosion will not adversely affect the weldment.

331.3.7 *Local Heat Treatment*

In local heat treatment a circumferential band must be heated until the specified temperature range exists over the complete circumference of the pipe section, with a gradual diminishing of the temperature outward from the edge of the band which includes the weld or the bent or formed section.

(a) In local heat treatment of butt welded joints, the minimum width of the circumferential band, centered on the weld, shall extend one inch beyond the edges of the weld.

(b) In local heat treatment of welded branch connections, the width of the heated circumferential band shall extend at least one inch beyond the edge of the weld joining the branch or attachment to the run pipe.

(c) In local heat treatment of bent or formed sections, the minimum width of the circumferential band shall extend to one inch on each side of the bent or formed area.

335 ASSEMBLY

335.1 General

The assembly of the various piping components, whether done in a shop or as field erection shall be done so that the completely erected piping conforms with the requirements of this Code and with the specified requirements of the engineering design.

335.2 Bolted Flanged Joints

335.2.1 All flanged joints except in lined pipe and components wherein the lining serves as a gasket, shall be fitted up using a single gasket between contact faces. The contact faces shall bear uniformly on the gasket, and the flange bolts shall be tightened to relatively uniform bolt stress.

335.2.2 In bolting gasketed flanged joints the gasket shall be properly compressed in accordance with the design principles applicable to the type of gasket used.

335.2.3 Steel-to-cast iron flanged joints shall be assembled with care to prevent damage to the cast iron flange (See 308.5.4)

335.2.4 All bolts shall extend completely through their nuts except that bolting conforming to ANSI B16.5 that fails to do so shall be considered adequate provided the lack of complete thread engagement is not more than one thread in any nut.

335.3 Cast Iron Bell and Spigot Joints

Bell and spigot joints in cast iron piping shall be assembled using poured lead or other joint compound suitable for the service. Assembly of cast iron bell and spigot piping shall comply with AWWA Std. C600.

335.4 Threaded Pipe Joints

335.4.1 Threaded joints which are to be seal welded shall be made up without any thread compound.

335.4.2 Any compound or lubricant used on threads shall be suitable for the service conditions, and shall not react unfavorably with either the service fluid or the piping material.

Chapter VI

336 EXAMINATION AND INSPECTION

336.1 General

336.1.1 *Examination and Inspection*

This Code distinguishes between "examination" and "inspection." "Examination" applies to quality control functions performed by personnel employed by the piping manufacturer, fabricator, or erector. References in this Code to "examiner" are to personnel performing quality control examinations. "Inspection" applies to functions performed for the owner by the Authorized Inspector or his delegates. References in this Code to "The Inspector" are to the Authorized Inspector or his delegates.

336.1.2 *Required Examination and Inspection*

Prior to initial operation, a piping installation, including its components and workmanship, shall be examined to assure compliance with the design, material, fabrication, and assembly requirements of this Code, and of the engineering design. It is the owner's responsibility, exercised through the Authorized Inspector, to verify that all required examinations and testing have been completed and to inspect the piping to the extent necessary to satisfy himself that it conforms to all applicable requirements of this Code and the engineering design. This verification shall include, but shall not be limited to, certifications and records pertaining to materials, components, heat treatment, examination and testing, and qualifications of operators and procedures. The Authorized Inspector may delegate performance of inspection, but is responsible to insure that a person to whom he delegates an inspection function is qualified to perform that function.

336.1.3 *Responsibility for Examination*

Inspection does not relieve the erector, the manufacturer, or the fabricator of responsibility for providing materials, components, and workmanship in accordance with requirements of this Code and the engineering design; performing all required examinations, and preparing suitable records of examinations and tests performed, for the Inspector's use.

336.2 Qualifications of the Authorized Inspector

The Authorized Inspector shall be designated by the owner and shall be the owner, an employee of the owner, an employee of an engineering or scientific organization, or of a recognized insurance or inspection company acting as the owner's agent. He shall not represent nor be an employee of the piping erector, the manufacturer, or the fabricator unless the owner is also the erector, the manufacturer, or the fabricator. He shall have a minimum of ten years experience in the design, fabrication, or inspection of industrial pressure piping. Satisfactory completion of work toward an engineering degree shall be considered equivalent experience, year for year, up to five years.

336.3 Rights of the Authorized Inspector

The Authorized Inspector and his delegates shall have access to any place where work concerned with the piping is being performed. This includes manufacture, fabrication, heat treatment, assembly, erection, examination, and testing of the piping. They shall have the right to audit any examinations, to inspect the piping using any examination method specified by the engineering design, and to review all certifications and records necessary to satisfy the owner's responsibility as stated in 336.1.2.

336.4 Examination Methods

Examinations required by this Code (see 336.5) by the engineering design, and by the Inspector, shall be performed in accordance with the methods outlined below.

336.4.1 *General Requirements for Examinations*

(a) The methods of examination covered in the following paragraphs shall be performed by qualified personnel in accordance with qualified written procedures that conform to the designated method.

(b) *Personnel Qualification.* Personnel performing examinations other than visual (336.4.2) shall be qualified in accordance with applicable portions of SNT-TC-1A, "Recommended Practice for Nondestructive Testing Personnel Qualification and Certification."

(c) *Procedure Qualification.* Procedures shall be qualified as required in paragraph T-150, Article 1, Section V of the ASME Code.

(d) *Limitations on Defects.* Limitations on defects shall be in accordance with the engineering design, but shall at least meet the requirements in Chapter V and the supplementary requirements given in the subdivision for the specific type of examination.

(e) *Repairs* Repairs shall be in accordance with 327.7.

336.4.2 *Visual Examination*

(a) Visual examination is observation of the portion of components, joints and other piping elements that are or can be exposed to view before, during, or after manufacture, fabrication, assembly, erection, inspection, or testing. This examination includes verification of Code and engineering design requirements for materials and components, dimensions, joint preparation, alignment, welding or joining, supports, assembly, and erection.

(b) Visual examination shall be performed in accordance with Article 9, Section V of the ASME Code.

336.4.3 *Magnetic Particle Examination*

(a) *Method* Magnetic particle examination shall be performed in accordance with Article 7, Section V of the ASME Code.

(b) *Limitations on Defects* Limitations on defects shall be as stated in 327.4.

336.4.4 *Liquid Penetrant Examination*

(a) *Method.* Liquid penetrant examination shall be performed in accordance with Article 6, Section V of the ASME Code.

(b) *Limitations on Defects:* Limitations on defects shall be as stated in 327.4.

336.4.5 *Radiographic Examination*

(a) *Definitions:* The following definitions shall apply to radiography required by this Code or by the engineering design:

(1) *"Random radiography"* applies only to girth butt welds. It is radiographic examination in accordance with the method outlined in (b) of the complete circumference of a specified percentage of the girth butt welds in a designated lot of piping.

(2) *"100 percent Radiography"* also applies only to girth butt welds unless otherwise specified in the engineering design. It is radiographic examination in accordance with the method outlined in (b) of the complete circumference of all the girth butt welds in a designated lot of piping. If the engineering design specifies that 100 percent radiography shall include welds other than girth butt welds, the examination shall include the full length of all such welds in the designated lot of piping.

(3) *"Spot Radiography"* is the practice of making a single exposure radiograph using a procedure within the method outlined in (b) at a point within a specified extent of welding. Required coverage for a single spot radiograph is:

1) For longitudinal welds, at least six inches of weld length.

2) For girth, miter and branch welds

a) in piping 2½ inches and smaller nominal pipe size, a single elliptical exposure which encompasses the entire weld circumference

b) in piping larger than 2½ inch nominal pipe size, at least 25 percent of the inside circumference, or 6 inches, whichever is less.

(b) *Method.* Radiography of castings is covered by 302.3.3(c). Radiography of other components and of welds shall be in accordance with Article 3, Section V of the ASME Code, with the following exceptions for double wall exposure:

1. The penetrameter thickness may be 2 percent of two times the nominal wall thickness.

2. The penetrameter may have 3 holes of 2, 3, and 4 times the penetrameter thickness, but in no case less than 1/16 inch diameter except that when Gamma Rays are used as a source of radiation, the minimum hole diameter need not be less than 3/32 inch

3. The penetrameter may be placed on the side nearest the radiation source or on the film side if the technique employed is shown (or proven) to be adequate

(c) *Limitations on Defects* Limitations on defects in castings shall be as stated in 302.3.3 for the required casting quality factor. Limitations on defects in other components and welds shall be as stated in 327.4 for the degree of radiography involved

336.4.6 *Ultrasonic Examination*

(a) *Method* Ultrasonic examination of welds shall be in accordance with Article 5, Section V of the ASME Code, except the following shall be substituted for Subparagraph T-535.1 (d) (2):

As a minimum the transfer method shall be used.

1. once in every 10 welded joints.

2. for sizes over 2 inches NPS, once in 5 feet of welding.

3. for sizes over 18 inches NPS, once in each welded joint.

Each type of material and each size and wall thickness shall be considered separately in applying the transfer method. In addition, the transfer method shall be used at least twice on each type of weld joint

(b) *Limitations on Defects* Limitations on defects shall be as stated in 327.4. The following requirements supplement, for this method of examination only, the limitation on defects specified in 327.4. Linear-type discontinuities are unacceptable if the primary reference response exceeds the reference level and discontinuities have lengths which exceed the following:

1/4 inch for $\overline{T}$ up to 3/4 inch
1/3 inch for $\overline{T}$ from 3/4 to 2-1/4 inch
3/4 inch for $\overline{T}$ over 2-1/4 inch

where $\bar{T}$ is the thickness of the weld being examined. If the weld joins two members having different thicknesses at the weld, $\bar{T}$ is the thinner of these two thicknesses.

336.5 Type and Extent of Required Examination[1]
The intent of these examinations is to provide the examiner and the Inspector with reasonable assurance that the requirements of this Code and the engineering design have been met. Required examination ordinarily will provide this assurance. When a required examination reveals that the item (a type of piping component, or a weld) examined fails to meet applicable quality requirements, the item shall be repaired or replaced to meet requirements of this Code. Also, two additional examinations of the same type shall be made of the same kind of item (if a weld, by the same welder or welding operator) that was deficient in quality. If the second group of items examined meets applicable quality requirements, all items represented by these additional examinations shall be accepted. For each of the second group of items which fails to meet applicable quality requirements, two additional items shall be examined. If all of the third groups of items examined meet applicable quality requirements, the items which were deficient shall be repaired or replaced to meet the requirements of the Code and all items represented by the examined items shall be accepted. If any of the third group of items examined fail to meet applicable quality requirements, all comparable items may be replaced or they shall be fully examined and repaired as necessary to meet applicable quality requirements. For P numbers 3, 4, and 5 materials, examination shall be performed after completion of any heat treatment.

336.5.1 *Required Examination for Piping Not Covered by 336.5.2*

(a) *Visual Examination*

Piping shall be visually examined in accordance with 336.4.2 to the extent specified herein or to any greater extent specified in the engineering design. The following shall be included:

1. Sufficient material and components, selected at random to satisfy the examiner that they conform to specifications and are free from damage.

2. At least 5 percent of fabrication. Each welder's or welding operator's work shall be represented though not necessarily each type of weld for each welder or welding operator. Limitations on defects are those of 327.4.

3. 100 percent of fabrication for longitudinal welds, other than those in components made to material specifications recognized in this code. Limitations on defects are those of 327.4.3. See 336.6.1 (a) for examination of longitudinal welds having a joint factor "E" of 0.90

4. Random examination of the assembly of threaded, bolted and other joints to satisfy the examiner that they conform to requirements of 335

5. Random examination during erection of piping, including checking of alignments, supports, and cold spring

6. Examination of erected piping for evidence of damage that would require repair or replacement and for other evident deviations from the intent of the design

(b) *Other Examination*

1. When piping is intended for service at temperatures above 360 F or pressures above 150 psig a minimum of 5 percent of circumferential butt welds shall be examined fully by random radiography in accordance with 336.4.5 or ultrasonic examination in accordance with 336.4.6. The welds to be examined shall be selected to insure that the work product of each individual welder or welding operator doing the production welding is included. In-process examination as provided in (c), may be substituted for all or part of the radiographic or ultrasonic examination on a weld-for-weld basis if specified in the engineering design and approved by the owner.

2. Any weld designated as requiring weld quality assurance in accordance with 319.4.5 shall be examined radiographically to standards in 336.4.5 for 100 percent radiography or ultrasonically in accordance with 336.4.6 or by in-process examination supplemented by appropriate non-destructive examination.

3. All examined welds which do not meet the requirements specified in 327.4.2 (d) or 327.4.3 (c) shall be repaired to meet those requirements and reexamined in the repaired areas.

(c) *In-Process Examination*

In-Process Examination consists of the following visual examinations of:

1. joint preparation and cleanliness
2. preheating
3. fit-up and internal alignment prior to welding
4. weld position, electrode, other variables specified by the welding procedure.
5. condition of the root pass after cleaning, external and internal where accessible, aided by liquid penetrant or magnetic particle examination where specified in the engineering design
6. slag removal and weld condition between passes.
7. appearances of the finished weld.

[1] See 336.1.1 for definition of examination.

(d) *Certification and Records for Components and Materials*

The examiner shall assure himself by examination of certifications and records that the materials and components are of the specified grades and that they have received required heat treatment, examination and testing. The examiner shall provide the Inspector with a certification that all the quality control requirements of this Code and of the engineering design have been carried out.

336.5.2 *Required Examination*[1] *for Piping for Low Hazard Service only*

Piping and piping elements shall be visually examined in accordance with 336.4.2 to the extent necessary to satisfy the examiner that components, materials and workmanship conform to the requirements of this Code and the engineering design when all the following apply.

1. The design pressure does not exceed 150 psig.
2. The design temperature does not exceed 360 F.
3. The fluid handled is nonflammable and nontoxic.

336.6 Supplementary Examination

Any of the methods of examination described in 336.4 may be specified by the engineering design to supplement the examination required by 336.5. The extent of supplementary examination to be performed and any limitations on defects that differ from those in the applicable part of 327 shall be specified in the engineering design. For P-numbers 3, 4, and 5 materials, examination shall be performed after completion of any postheat treatment.

Another type of examination which may be specified by the engineering design is spot radiography as described in 336.6.1.

336.6.1 *Spot Radiography*

(a) *Longitudinal Welds.* Spot radiography for longitudinal welds made in accordance with 327.4.3 which are required to have a joint factor "E" of 0.90 (See Table 302.3.4) require examination by radiography of at least one foot in each 100 feet of weld for each welder using the method of 336.4.5. Limitations on defects are those of the 100 percent radiographic requirements of 327.4.3.

(b) *Girth Welds and Other Welds.* It is recommended that the extent of examination be not less than one shot on one weld in each 20 welds for each welder. Unless otherwise specified, limitations on defects are those of 327.4 for the type of joint examined.

(c) *Progressive Examination:* If the specified spot radiograph is free of unacceptable indications all welds represented by it are considered acceptable if free of visual defects. If a radiograph shows an unacceptable indication, two other spots shall be examined among the welds represented by the first radiograph. If these are free of unacceptable indications, the extent of defects indicated on the first radiograph shall be explored, and the weld shall be repaired and reexamined visually. If either of the additional radiographs shows unacceptable indications, all welds represented shall be either:

1. fully examined, repaired as necessary and re-examined where repaired in accordance with the requirements of this paragraph, 336.5.1 or the engineering design, or
2. completely replaced and examined by spot radiography.

(d) *Welds to be Examined.* The locations of welds and the points at which they are to be examined by spot radiography shall be selected or approved by the Inspector.

336.6.2 *Hardness Tests*

The extent of hardness testing required shall be in accordance with 331.3.2 unless more extensive requirements are specified by the engineering design.

336.6.3 *Supplementary Examination to Verify Code Requirements*

Any method of examination may be used to resolve doubtful indication. Limitations on defects shall be those for required examination.

337 PRESSURE TESTS

337.1 Tests, General

Prior to initial operation, installed piping shall be pressure tested to assure tightness except as permitted in 337.5.2.

In the event repairs or additions are made following the pressure test, the affected piping shall be retested, except that in the case of minor repairs or additions the owner may waive retest requirements, when precautionary measures are taken to assure sound construction. The pressure test shall be maintained for a sufficient time to determine if there are any leaks but not less than ten minutes.

When conducting pressure tests at low metal temperatures the possibility of brittle fracture shall be considered.

Alternate tests to those required by 337.2, 337.3, and 337.4 may be applied under the conditions described in 337.5.

[1] See 336.1.1 for definition of examination

337.2 Test Fluid

337.2.1 *Hydrostatic Test*

The test shall be hydrostatic, using water, except if there is a possibility of damage due to freezing, or if the operating fluid or piping material would be adversely affected by water, any other suitable liquid may be used. If a flammable liquid is used, its flash point shall not be less than 120 F, and consideration shall be given to the test environment.

337.2.2 *Pneumatic Test*

(a) If hydrostatic testing is not considered practicable by the owner, a pneumatic test in accordance with 337.4.3 may be substituted using air or another nonflammable gas.

(b) A preliminary pneumatic test at not more than 25 psig may be made prior to hydrostatic test in order to locate major leaks.

337.3 Test Preparation

All joints, including welds, are to be left uninsulated and exposed for examination during the test. If a joint has been previously tested in accordance with this Code, it may be insulated or covered.

Piping designed for vapor or gas shall be provided with additional temporary supports, if necessary, to support the weight of the test liquid.

Expansion joints shall be provided with temporary restraint if required for the additional pressure load under test or shall be isolated from the test.

Equipment which is not to be subjected to the pressure test shall be either disconnected from the piping or isolated by blinds or other means during the test. Valves may be used provided that the valve (including the closure mechanism) is suitable for the proposed test pressure.

A flanged joint at which a blank is inserted to blank off other equipment during the test need not be tested.

If a pressure test is to be maintained for a period of time and the test liquid in the system is subject to thermal expansion, precautions shall be taken to avoid excessive pressure.

337.4 Test Pressure

337.4.1 *Hydrostatic Testing of Internal Pressure Piping*

(a) Except as required by 337.4.1(b) the hydrostatic test pressure at any point in the system shall be as follows.

(1) Not less than 1-1/2 times the design pressure.

(2) For a design temperature above 650 F, the minimum test pressure shall be as calculated by equation 20.

$$P_T = \frac{1.5\, P S_T}{S} \quad \ldots\ldots\ldots\ldots (20)$$

in which:

P_T = minimum hydrostatic pressure, psig.

P = internal design pressure, psig.

S_T = allowable stress at 650 F, psi (See Table 1, Appendix A)

S = allowable stress at design temp., psi (See Table 1, Appendix A).

(b) Under certain design conditions the stress resulting from the test pressure required by 337.4.1(a) could exceed 90 percent of the minimum specified yield strength at test temperature. A check shall be made to determine if this condition exists. In such cases, the test pressure shall be reduced so that the stress does not exceed 90 percent of the minimum specified yield strength.

(c) If the maximum operating conditions of piping attached to a vessel are the same as those of the vessel, the piping and vessel may be tested together at the test pressure of the vessel. However, if the piping may be subjected to higher operating conditions and requires a higher test than the connected equipment or if the piping is designed for lesser operating conditions than the connected equipment and could be overstressed by a systems test, then it shall be isolated and tested separately.

337.4.2 *Hydrostatic Testing of External Pressure Piping*

Lines in vacuum service shall be tested at a minimum internal pressure of 15 psig unless limited to a lower pressure by the design. In jacketed lines the jacket shall be tested in accordance with 337.4.1 on the basis of the jacket pressure. The internal line shall be tested on the basis of the internal or external pressure whichever is critical unless limited by the engineering design. Lines in external pressure service shall be subjected to an internal pressure test at not less than the external design pressure.

337.4.3 *Pneumatic Testing*

If piping is tested pneumatically, the test pressure shall be 110 percent of the design pressure. Any pneumatic test shall include a preliminary check at not more than 25 psig. The pressure shall be increased gradually [illegible] providing [illegible] the piping to equalize strains [illegible] to check for leaks.

337.5 Special Alternate Tests

337.5.1

[illegible] circumstances [illegible] hydrostatic [illegible] pneumatic tests in 337.4.1 and 337.4.3 [illegible] considered practical by the owner, alternate tests [illegible] permitted by this paragraph may be employed, if all of the following conditions are met

(1) Hydrostatic tests would be damaging to linings, internal insulation, or interfere with a process which will be hazardous, corrosive, or inoperative in the presence of moisture or the possibility of brittle fracture exists from low metal temperature during test

(2) Pneumatic tests required by paragraph 337.4.3 would introduce considerable hazard from stored energy in the system or the possibility of brittle fracture exists from low metal temperature during test.

(b) Under the above conditions, the following shall be applied

(1) The system or joints to be tested shall be subjected to a pneumatic test at normal plant air pressure of at least 90 psig for a length of time sufficient for an examination for leaks, but in no case for less than ten minutes. A preliminary check shall be made and pressure shall be applied gradually as required in 337.4.3 All joints which have not been tested in accordance with 337.4.1 or 337.4.3 shall be examined for leakage. Leak detection shall be by a method and sensitivity specified by the engineering design.

(2) Welds, including those used in the manufacture of welded pipe and fittings, which have not been subjected to pressure tests in accordance with 337.4.1 or 337.4.3 shall be non-destructively examined as follows before leak testings:

a. Butt welds shall be 100 percent radiographed

b. All welds, including structural attachment welds, in magnetic materials shall be magnetic particle examined.

c. All welds, including structural attachment welds, in nonmagnetic materials shall be dye penetrant examined.

d. When post weld heat treatment is required the above examinations shall be performed after the treatment.

e. Examination methods shall be in accordance with 336.1 and limitations on defects shall be in accordance with 327.4.

(3) A flexibility analysis of the system shall be made in accordance with paragraphs 319.4.2(c) and (d).

337.5.2

At the option of owner, systems or joints may be leak tested by examining every joint for leaks while at normal operating conditions during or prior to initial operation, when all the following conditions:

1. The fluid handled is air, inert gas, water, steam, or other nonflammable, nontoxic fluid

2 The design pressure does not exceed 150 psig

3. The design temperature does not exceed 360 F.

A preliminary check shall be made at not more than 25 psig The pressure shall be increased gradually in steps providing sufficient time to allow the piping to equalize strains during test, and to check for leaks.

337.6 Test Records

Records shall be made of each piping installation during the testing. These records shall include:

1. date of test
2. identification of piping tested
3. test fluid
4. test pressure
5. approval by inspector

These records need not be retained after completion of the piping installation, if a certification by The Inspector that all piping has been pressure tested as required by this Code is retained.

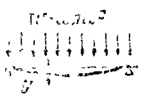
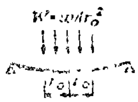
TABLE X.—FORMULAS FOR FLAT PLATES

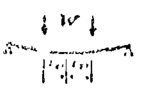
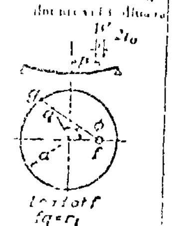
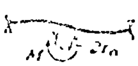
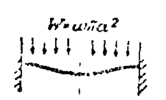
Notation: W = total applied load (lb.); w = unit applied load (lb. per sq. in.); t = thickness of plate (in.); s = unit stress at surface of plate (lb. per sq. in.); y = vertical deflection of plate from original position (in.); θ = slope of plate measured from horizontal; E = modulus of elasticity; m = reciprocal of ν, Poisson's ratio. q denotes any given point on the surface of plate, r denotes the distance of q from the center of a circular plate. Other dimensions and corresponding symbols are indicated on figures. Positive sign for s indicates tension at upper surface and equal compression at lower surface; negative sign indicates reverse condition. Positive sign for y indicates upward deflection, negative sign downward deflection. Subscripts r, t, a, and b used with s denote respectively radial direction, tangential direction, direction of dimension a, and direction of dimension b. All dimensions are in inches. All logarithms are to the base e ($\log_e x = 2.3026 \log_{10} x$). (See pp. 240 and 242 for stress, slope, and deflection coefficients.)

Manner of loading, Case No.	Formulas for stress and deflection
	Circular and solid (A)
1. Edges supported, uniform load over entire surface	(At q) $s_r = -\frac{3W}{8\pi mt^2}\left[(3m+1)\left(1-\frac{r^2}{a^2}\right)\right]$ $s_t = -\frac{3W}{8\pi mt^2}\left[(3m+1)-(m+3)\frac{r^2}{a^2}\right]$ $y = -\frac{3W(m^2-1)}{8\pi Em^2t^3}\left[\frac{(5m+1)a^2}{2(m+1)}+\frac{r^4}{2a^2}-\frac{(3m+1)r^2}{m+1}\right]$ (At center) Max $s_r = s_t = -\frac{3W}{8\pi mt^2}(3m+1)$ Max $y = -\frac{3W(m-1)(5m+1)a^2}{16\pi Em^2t^3}$ (At edge) $\theta = \frac{3W(m-1)a}{2\pi Emt^3}$
2. Edges supported, uniform load over concentric circular area of radius r_0 $W = w\pi r_0^2$	(At q, $r < r_0$) $s_r = -\frac{3W}{2\pi mt^2}\left[m+(m+1)\log\frac{a}{r_0}-(m-1)\frac{r_0^2}{4a^2}-(3m+1)\frac{r^2}{4r_0^2}\right]$ $s_t = -\frac{3W}{2\pi mt^2}\left[m+(m+1)\log\frac{a}{r_0}-(m-1)\frac{r_0^2}{4a^2}-(m+3)\frac{r^2}{4r_0^2}\right]$ $y = -\frac{3W(m^2-1)}{16\pi Em^2t^3}\left[4a^2-5r_0^2+\frac{r^4}{r_0^2}-(8r^2+4r_0^2)\log\frac{a}{r_0}-\frac{2(m-1)r_0^2(a^2-r^2)}{(m+1)a^2}+\frac{8m(a^2-r^2)}{m+1}\right]$ (At q, $r > r_0$) $s_r = -\frac{3W}{2\pi mt^2}\left[(m+1)\log\frac{a}{r}-(m-1)\frac{r_0^2}{4a^2}+(m-1)\frac{r_0^2}{4r^2}\right]$ $s_t = -\frac{3W}{2\pi mt^2}\left[(m-1)+(m+1)\log\frac{a}{r}-(m-1)\frac{r_0^2}{4a^2}-(m-1)\frac{r_0^2}{4r^2}\right]$ $y = -\frac{3W(m^2-1)}{16\pi Em^2t^3}\left[\frac{(12m+4)(a^2-r^2)}{m+1}-\frac{2(m-1)r_0^2(a^2-r^2)}{(m+1)a^2}-(4r^2+4r_0^2)\log\frac{a}{r}\right]$ (At center) Max $s_r = s_t = -\frac{3W}{2\pi mt^2}\left[m+(m+1)\log\frac{a}{r_0}-(m-1)\frac{r_0^2}{4a^2}\right]$ Max $y = -\frac{3W(m^2-1)}{16\pi Em^2t^3}\left[\frac{(12m+4)a^2}{m+1}-4r_0^2\log\frac{a}{r_0}-\frac{(7m+3)r_0^2}{m+1}\right]$ For r_0 very small (concentrated load) Max $y = -\frac{3W(m-1)(3m+1)a^2}{4\pi Em^2t^3}$ (At edge) $\theta = \frac{3W(m-1)a}{2\pi Emt^3}$
3. Edges supported, uniform load on concentric circular ring of radius r_0	(At q, $r < r_0$) Max $s_r = s_t = -\frac{3W}{2\pi mt^2}\left[\frac{1}{2}(m-1)+(m+1)\log\frac{a}{r_0}-(m-1)\frac{r_0^2}{2a^2}\right]$ $y = -\frac{3W(m^2-1)}{2\pi Em^2t^3}\left[\frac{(3m+1)(a^2-r^2)}{2(m+1)}-(r^2+r_0^2)\log\frac{a}{r_0}+(r^2-r_0^2)-\frac{(m-1)r_0^2(a^2-r^2)}{2(m+1)a^2}\right]$ (At q, $r > r_0$) $s_r = -\frac{3W}{2\pi mt^2}\left[(m+1)\log\frac{a}{r}+(m-1)\frac{r_0^2}{2r^2}-(m-1)\frac{r_0^2}{2a^2}\right]$ $s_t = -\frac{3W}{2\pi mt^2}\left[(m-1)+(m+1)\log\frac{a}{r}-(m-1)\frac{r_0^2}{2r^2}-(m-1)\frac{r_0^2}{2a^2}\right]$ $y = -\frac{3W(m^2-1)}{2\pi Em^2t^3}\left[\frac{(3m+1)(a^2-r^2)}{2(m+1)}-(r^2+r_0^2)\log\frac{a}{r}-\frac{(m-1)r_0^2(a^2-r^2)}{2(m+1)a^2}\right]$ (At center) Max $y = -\frac{3W(m^2-1)}{2\pi Em^2t^3}\left[\frac{(3m+1)a^2-(m-1)r_0^2}{2(m+1)}-r_0^2\left(\log\frac{a}{r_0}+1\right)\right]$
4. Edges supported, uniform load over small eccentric circular area of radius r_0	(At point of load, p) Max $s_r = s_t = -\frac{3W}{2\pi mt^2}\left[m+(m+1)\log\frac{a-p}{r_0}-(m-1)\left(\frac{r_0^2}{4(a-p)^2}\right)\right]$ (At q) $s_r = (\text{Max } s_r)\left[\frac{(m+1)\log\frac{a_1}{r_1}}{1+(m+1)\log\frac{a_1}{r_0}}\right]$ $s_t = (\text{Max } s_t)\left[\frac{(m+1)\log\frac{a_1}{r_1}+(m-1)}{m+(m+1)\log\frac{a_1}{r_0}}\right]$ Where $y = K_0(r^4-b_0a^2r^2+c_0a^4)+K_1(r^3-b_1ar^3+c_1a^2r)\cos\phi+K_2(r^4-b_2ar^4+c_2a^2r^2)\cos 2\phi$ Where $K_0 = \frac{2(m+1)W(p^2-b_0a^2p^2+c_0a^4)}{9(5m+1)K\pi a^4}$; $K_1 = \frac{2(3m+1)W(p^3-b_1ap^3+c_1a^2p)}{3(5m+1)K\pi a^4}$; $K_2 = \frac{(4m+1)W(p^4-b_2ap^4+c_2a^2p^2)}{(9m+1)(5m+1)K\pi a^4}$ $K = \frac{m^2Et^3}{12(m^2-1)}$; $b_0 = \frac{3(2m+1)}{2(m+1)}$; $b_1 = \frac{3(4m+1)}{2(3m+1)}$; $b_2 = \frac{2(5m+1)}{4m+1}$; $c_0 = \frac{4m+1}{2(m+1)}$; $c_1 = \frac{4m+1}{2(3m+1)}$; $c_2 = \frac{m+1}{4m+1}$
5. Edges supported, load on small concentric circular area of radius r_0	(At $r = r_0$) Max $s_r = \frac{3W}{4\pi t^2}\left[1+\left(\frac{m+1}{m}\right)\log\frac{2(a-r_0)}{Kc}\right]$ where $K = \frac{1.10t^3}{(r_0+0.75t)^3}$ (See also p. 216)
6. Edges fixed, uniform load over entire surface $W = w\pi a^2$	(At q) $s_r = \frac{3W}{8\pi mt^2}\left[(3m+1)\frac{r^2}{a^2}-(m+1)\right]$ $s_t = \frac{3W}{8\pi mt^2}\left[(m+3)\frac{r^2}{a^2}-(m+1)\right]$ $y = -\frac{3W(m^2-1)}{16\pi Em^2t^3}\left[\frac{(a^2-r^2)^2}{a^2}\right]$ (At edge) Max $s_r = \frac{3W}{4\pi t^2} = \frac{3wa^2}{4t^2}$ (At center) $s_r = s_t = -\frac{3W(m+1)}{8\pi mt^2}$ Max $y = -\frac{3W(m^2-1)a^2}{16\pi Em^2t^3}$

TABLE X.—FORMULAS FOR FLAT PLATES

Notation: W = total applied load (lb.); w = unit applied load (lb. per sq. in.); t = thickness of plate (in.); s = unit stress at surface of plate (lb. per sq. in.); y = vertical deflection of plate from original position (in.); θ = slope of plate measured from horizontal; E = modulus of elasticity; m = reciprocal of ν, Poisson's ratio. q denotes any given point on the surface of plate; r denotes the distance of q from the center of a circular plate. Other dimensions and corresponding symbols are indicated on figures. Positive sign for s indicates tension at upper surface and equal compression at lower surface, negative sign indicates reverse condition. Positive sign for y indicates upward deflection, negative sign downward deflection. Subscripts r, t, a, and b used with s denote respectively radial direction, tangential direction, direction of dimension a, and direction of dimension b. All dimensions are in inches. All logarithms are to the base e ($\log_e x = 2.3026 \log_{10} x$). (See pp. 240 and 242 for stress, slope, and deflection coefficients.)

Manner of loading and Case No.	Formulas for stress and deflection
	Circular and solid  (A)
1. Edge supported, uniform load over entire surface. $W = w\pi a^2$ 	(At q) $s_r = -\frac{3W}{8\pi m t^2}\left[(3m+1)\left(1-\frac{r^2}{a^2}\right)\right]$ $\quad s_t = -\frac{3W}{8\pi m t^2}\left[(3m+1)-(m+3)\frac{r^2}{a^2}\right]$ $y = -\frac{3W(m^2-1)}{8\pi E m^2 t^3}\left[\frac{(5m+1)a^2}{2(m+1)}+\frac{r^4}{2a^2}-\frac{(3m+1)r^2}{m+1}\right]$ (At center) Max $s_r = s_t = -\frac{3W}{8\pi m t^2}(3m+1)$ $\quad$ Max $y = -\frac{3W(m-1)(5m+1)a^2}{16\pi E m^2 t^3}$ (At edge) $\theta = \frac{3W(m-1)a}{2\pi E m t^3}$
2. Edge supported, uniform load over concentric circular area of radius r_0. $W = w\pi r_0^2$ 	(At q, $r < r_0$) $s_r = -\frac{3W}{2\pi m t^2}\left[m+(m+1)\log\frac{a}{r_0}-(m-1)\frac{r_0^2}{4a^2}-(3m+1)\frac{r^2}{4r_0^2}\right]$ $\quad s_t = -\frac{3W}{2\pi m t^2}\left[m+(m+1)\log\frac{a}{r_0}-(m-1)\frac{r_0^2}{4a^2}-(m+3)\frac{r^2}{4r_0^2}\right]$ $y = -\frac{3W(m^2-1)}{16\pi E m^2 t^3}\left[4a^2-5r_0^2+\frac{r^4}{r_0^2}-(8r^2+4r_0^2)\log\frac{a}{r_0}-\frac{2(m-1)r_0^2(a^2-r^2)}{(m+1)a^2}+\frac{8m(a^2-r^2)}{m+1}\right]$ (At q, $r > r_0$) $s_r = -\frac{3W}{2\pi m t^2}\left[(m+1)\log\frac{a}{r}-(m-1)\frac{r_0^2}{4a^2}+(m-1)\frac{r_0^2}{4r^2}\right]$ $\quad s_t = -\frac{3W}{2\pi m t^2}\left[(m-1)+(m+1)\log\frac{a}{r}-(m-1)\frac{r_0^2}{4a^2}-(m-1)\frac{r_0^2}{4r^2}\right]$ $y = -\frac{3W(m^2-1)}{16\pi E m^2 t^3}\left[\frac{(12m+4)(a^2-r^2)}{m+1}-\frac{2(m-1)r_0^2(a^2-r^2)}{(m+1)a^2}-(8r^2+4r_0^2)\log\frac{a}{r}\right]$ (At center) Max $s_r = s_t = -\frac{3W}{2\pi m t^2}\left[m+(m+1)\log\frac{a}{r_0}-(m-1)\frac{r_0^2}{4a^2}\right]$ $\quad$ Max $y = -\frac{3W(m^2-1)}{16\pi E m^2 t^3}\left[\frac{(12m+4)a^2}{m+1}-4r_0^2\log\frac{a}{r_0}-\frac{(7m-3)r_0^2}{m+1}\right]$ For r_0 very small (concentrated load) Max $y = -\frac{3W(m-1)(3m+1)a^2}{4\pi E m^2 t^3}$ (At edge) $\theta = \frac{3W(m-1)a}{\pi E m t^3}$

Manner of loading and Case No.	Formulas for stress and deflection
3. Edge supported, uniform load on concentric circular ring of radius r_0 	(At q, $r < r_0$) Max $s_r = s_t = -\frac{3W}{2\pi m t^2}\left[\frac{1}{2}(m-1)+(m+1)\log\frac{a}{r_0}-(m-1)\frac{r_0^2}{2a^2}\right]$ $y = -\frac{3W(m^2-1)}{2\pi E m^2 t^3}\left[\frac{(3m+1)(a^2-r^2)}{2(m+1)}-(r^2+r_0^2)\log\frac{a}{r_0}+(r^2-r_0^2)-\frac{(m-1)r_0^2(a^2-r^2)}{2(m+1)a^2}\right]$ (At q, $r > r_0$) $s_r = -\frac{3W}{2\pi m t^2}\left[(m+1)\log\frac{a}{r}+(m-1)\frac{r_0^2}{2r^2}-(m-1)\frac{r_0^2}{2a^2}\right]$ $\quad s_t = -\frac{3W}{2\pi m t^2}\left[(m-1)+(m+1)\log\frac{a}{r}-(m-1)\frac{r_0^2}{2r^2}-(m-1)\frac{r_0^2}{2a^2}\right]$ $y = -\frac{3W(m^2-1)}{2\pi E m^2 t^3}\left[\frac{(3m+1)(a^2-r^2)}{2(m+1)}-(r^2+r_0^2)\log\frac{a}{r}-\frac{(m-1)r_0^2(a^2-r^2)}{2(m+1)a^2}\right]$ (At center) Max $y = -\frac{3W(m^2-1)}{2\pi E m^2 t^3}\left[\frac{(3m+1)a^2-(m-1)r_0^2}{2(m+1)}-r_0^2\left(\log\frac{a}{r_0}+1\right)\right]$
4. Edge supported, uniform load over small eccentric circular area of radius r_0. $W = w\pi r_0^2$  $l = r_1$ of f; $fq = r_1$; $fg = a_1$	(At point of load, f) Max $s_r = s_t = -\frac{3W}{2\pi m t^2}\left[m+(m+1)\log\frac{a-p}{r_0}-(m-1)\left(\frac{r_0^2}{4(a^2-p^2)}\right)\right]$ (At g) $s_r = (\text{Max } s_r)\left[\frac{(m+1)\log\frac{a_1}{r_1}}{1+(m+1)\log\frac{a_1}{r_0}}\right]$ $\quad s_t = (\text{Max } s_t)\left[\frac{(m+1)\log\frac{a_1}{r_1}+(m-1)}{m+(m+1)\log\frac{a_1}{r_0}}\right]$ Where $y = K_0(r^4-b_0ar^2+c_0a^4)+K_1(r^4-b_1ar^3+c_1a^2r)\cos\phi+K_2(r^4-b_2ar^3+c_2a^2r^2)\cos 2\phi$ $K_0 = \frac{2(m+1)W(p^4-b_0ap^2+c_0a^4)}{9(5m+1)K\pi a^6}$; $K_1 = \frac{2(3m+1)W(p^4-b_1ap^3+c_1a^3p)}{3(9m+1)K\pi a^6}$, $K_2 = \frac{(4m+1)^2W(p^4-b_2ap^3+c_2a^2p^2)}{(9m+1)(5m+1)K\pi a^6}$ Where $K = \frac{m^2Et^3}{12(m^2-1)}$; $b_0 = \frac{3(2m+1)}{2(m+1)}$, $b_1 = \frac{3(4m+1)}{2(3m+1)}$, $b_2 = \frac{2(5m+1)}{4m+1}$, $c_0 = \frac{4m+1}{2(m+1)}$; $c_1 = \frac{6m+1}{2(3m+1)}$, $c_2 = \frac{6m+1}{4m+1}$ (Ref. 1)
5. Edge supported, central couple (trunnion loading) 	(At $r = r_0$) Max $s_r = \frac{3M}{4\pi t^2 r_0}\left[1+\left(\frac{m+1}{m}\right)\log\frac{2(a-r_0)}{Ka}\right]$ $\quad$ where $K = \frac{0.49r_0^2}{(r_0+0.7a)^2}$ (Ref. 2) (See also p. 216)
6. Edge fixed. Uniform load over entire surface. $W = w\pi a^2$ 	(At q) $s_r = \frac{3W}{8\pi m t^2}\left[(3m+1)\frac{r^2}{a^2}-(m+1)\right]$ $\quad s_t = \frac{3W}{8\pi m t^2}\left[(m+3)\frac{r^2}{a^2}-(m+1)\right]$ $\quad y = -\frac{3W(m^2-1)}{16\pi E m^2 t^3}\left[\frac{(a^2-r^2)^2}{a^2}\right]$ (At edge) Max $s_r = \frac{3W}{4\pi t^2}$, $s_t = \frac{3W}{4\pi m t^2}$ (At center) $s_r = s_t = -\frac{3W(m+1)}{8\pi m t^2}$ $\quad$ Max $y = -\frac{3W(m^2-1)a^2}{16\pi E m^2 t^3}$

APPENDIX A

TABLE OF CONTENTS

TABLE 1 – ALLOWABLE STRESSES IN TENSION FOR MATERIALS

APPENDIX A

TABLE OF CONTENTS

TABLE 1 – ALLOWABLE STRESSES IN TENSION FOR MATERIALS

TABLE 2 – DESIGN STRESSES FOR BOLTING MATERIALS

SPECIFICATION INDEX* FOR APPENDIX A

Spec	Page	Spec	Page	Spec	Page	Spec	Page	Spec	Page	Spec	Page
ASTM		ASTM		ASTM		ASTM		ASTM		API	
A36	80	A225	82	A358	84,	B11	92	B165	92	5L	76,78,
A47	76,	A234	80,84	A369	80	B12	100	B166	94,102		
A48	76,	A240	86	A376	84,	B21	100	B167	92	5LS	76,
A53	76,	A245	80,	A377	76,	B26	98	B168	94,		
[illegible]	80,	A268	84,86,	A381	78,	B42	92	B169	92	5LX	76,78,
[illegible]	76	A278	76,	A387	82,	B43	92	B209	96,98	American National Standard	
[illegible]	76	A283	80,	A395	76,	B61	92	B210	96		
A?76	76,	A285	80,	A403	88	B62	92	B211	100	A21.6	76
A13?	76,78,	A299	80,	A409	86,	B68	92	B221	96	A21.8	76
A135	76	A302	82	A410	[illegible]	B75	92	B241	96		
A139	78	A306	100	A420	80,84	B88	92	B247	98	Federal	
A155	78,82,	A307	100	A426	82	B96	92	B283	92	WW-P-421c	76
A167	86,88	A312	84,86	A430	84	B98	100	B333	94		
A181	80,	A320	100	A437	100	B127	92	B334	94		
A182	84,88	A325	100	A445	76,	B13?	92	B335	102		
A193	100	A333	76,80,82	A451	84,86	B143	92	B336	102		
A194	100	A335	80,	A452	86,	B147	92	B361	98		
A197	76,	A338	76,	A453	100	B148	92	B366	94		
A202	82,	A350	80,84	A494	94	B149	92	B407	92		
A203	82,	A351	88,90	A515	80,	B150	100				
A204	82,	A352	80,84	A516	80,	B152	92				
A211	78,80	A353	82	A524	76	B160	94,100				
A216	80	A354	100	A587	76	B161	92				
A217	84	A357,	82	A593	80,82	B162	92,94				
						B16?	94,100,102				

*Specifications incorporated in this code by reference, and the names and addresses of the sponsoring organizations are shown in Appendix E. It is not practical to refer to a specific edition of each standard throughout the code text, but instead the specific edition references are also shown in Appendix E. Appendix E will be revised at intervals as needed.

APPENDIX A

NOTES

PETROLEUM REFINERY PIPING

SPECIAL NOTE FOR THE 1973 EDITION All allowable Stress Values in these tables for use in the range from Minimum Temperature to 100F have been established on the revised stress bases set forth in 302.3.2(a) and (b). Not all Allowable Stress Values for temperatures above 100F have been updated to those new bases. Some have been completely developed on the new bases. Some have been developed on the new bases only below the temperature range where creep or rupture stress limits would govern, and some are still on the stress bases of 302.3.2(c) and (d) of the 1966 Edition of the Code. The Section Committee is continuing to evaluate data on the materials in the latter categories and to develop up-dated allowable stress values in the elevated temperature ranges. They will be issued in Addenda to the Code.

1. Above 900F consider the advantages of killed steel (see 323.3.1).
2. Conversion of carbides to graphite may occur after prolonged exposure to temperatures over 750F (see 323.3.1).
3. Conversion of carbides to graphite may occur after prolonged exposure to temperatures over 850F (see 323.3.1).
4. In shaded areas, allowable stress values which are printed in *italics* exceed 2/3 of the expected yield strength at temperature. Allowable stress values which are printed in **BOLD TYPE** are equal to 90 percent of expected yield strength at temperature. See 302.3.2(b)(4) and 302.3.2(b) (Note 3).
5. A quality factor of 92 percent is included for structural grade.
6. The higher S values at 1050F and above for this material shall be used only when assurance is provided that the steel has a predominant grain size not finer than No. 6 per ASTM E112. Otherwise, the lower values shall be used.

6a. For temperatures above 1000F, these stress values may be used only if the material has been heat treated at a temperature of 2000F minimum.

6b. For temperatures above 1000F these stress values may be used only if the material has been heat treated by heating to a minimum temperature of 1900F and quenching in water or rapidly cooling by other means.

7. There are restrictions on the use of this material in 323.3.
8. For use in code piping at the stated allowable stresses the tensile and yield strengths listed in these tables must be verified by tensile tests at the mill: such tests shall be specified in the purchase order.
9. Pressure–temperature ratings of cast [illegible] forged parts as published in standards referenced in this Code section may be used for parts meeting requirements of these standards. Allowable stresses for castings and forgings, where listed, are for use in design of special components not furnished in accordance with such standards.
10. Material for use in code piping bought to these specifications shall have a minimum yield strength of 10,000 psi at 0.5 percent extension under load.
11. Properties of this material vary with thickness or size. Stresses are based on minimum properties for the thickness listed.
12. To use this material at temperatures below -20F the special requirements of 323.[illegible] must be met.
13. Stresses shown are for the lowest strength base material permitted by the specification to be used in the manufacture of this grade of [illegible]. If a higher strength base material is used, the higher allowable stresses for that material may be used in design.
14. The appropriate joint factor shall be applied to these allowable stress values when [illegible] a longitudinal welded joint is used, unless the joint has been 100 percent radiographed as required by the specifications for [illegible] welds.
15. For welded construction with work hardened grades, use the stresses for annealed material

for welded construction with precipitation hardened grades, use the special allowable stresses for welded construction given in the tables.

16. SE values shown in this table for welded pipe include the joint factor for the longitudinal weld as required by Table 302.3.4. For some code computations, particularly with regard to expansion, flexibility, structural attachments, supports, and restraints (Part 5, Chapter II), the longitudinal joint factor E need not be considered. To determine the allowable stress S for use in code computations not utilizing the joint factor E, divide the value (SE) shown in this table by the longitudinal joint factor (E) tabulated herein for each material.

17. These specifications do not include requirements or rules for spot radiographic inspection. If this higher joint factor is to be used, material shall be purchased to the special requirements of 327.4.3 with spot radiography in accordance with Table 302.3.4; and the user must take appropriate steps to insure that required inspection and repair is accomplished.

18. These specifications do not include requirements for 100% radiographic inspection. If this higher joint factor is to be used, the material shall be purchased to the special requirements of 327.4.3 with 100 percent radiography in accordance with Table 302.3.4.

19. These specifications include requirements for random radiographic inspection for mill quality control. If the 0.90 joint factor is to be used, the welds shall meet the requirements of 327.4.3 with spot radiography in accordance with Table 302.3.4. This shall be a matter of special agreement between purchaser and manufacturer.

20. These stress values (at all temperatures) apply only when the carbon content is 0.04 percent or higher.

21. These casting quality factors are applicable only when proper supplementary examination has been specified. Refer to 302.3.3.

22. Stress values shown include the casting quality factor shown in this table. Higher stress values can be used if special inspection is accomplished (see 302.3.3).

23. The unstabilized grades of stainless steel have increasing tendency to intergranular carbide precipitation as the carbon content increases above 0.03 percent.

24. Impact requirements for seamless fittings shall be governed by those listed in this table for the particular basic material specifications in the grades permitted (A312, A240, and A182). When Specification A270 materials are used in the manufacture of these fittings, the notes, minimum temperatures, and allowable stresses for comparable grades of A240 materials shall apply.

25. The allowable stress to be used for this gray cast iron material at its upper temperature limit of 450F, is the same as that shown in the 400F column.

26. The minimum temperature shown is that design temperature for which the material is normally suitable, but the use of a material at a design temperature below -20F is established by rules elsewhere in this Code, including any necessary impact test requirements.

27. This material shall not be welded.

28. These steels are intended for use at high temperatures, however, they may have low ductility and/or low impact properties at room temperature after being used above the temperature indicated by the single bar (|).

29. If there is no entry in the column headed "Steel Making Process," any process acceptable under the material specification is acceptable under this code. If there is an entry in the "Steel Making Process" column, only the processes listed in these tables are acceptable under this code. The key to symbols used is as follows: EA = Electric Arc; EI or IF = Electric Induction Furnace; EF = Electric Furnace; BO = Basic Oxygen.

30. For pipe sizes 8 in. and larger and for wall thicknesses of Sch. 140 or heavier, the minimum specification tensile strength is 70,000 psi.

31. This material is grouped in P 7 because its hardenability is low.

32. If over 5 in. thick, the minimum specification tensile strength shall be 70,000 psi.

33. Because of thermal instability, this material is not recommended for service above 600F.

34. There are restrictions on the use of this material in the text of the code.

35. A single bar (|) in the stress tables indicates there are conditions other than stress which affect usage above or below the temperature as described in other referenced notes. A double bar (||) after a tabled stress indicates that use of

the material is prohibited above that temperature. At temperatures where there are no allowable stresses, the material may be used in accordance with 323.2 unless prohibited by a double bar (||).

36. The specification permits this material to be furnished without solution heat treatment or with other than a solution heat treatment. When the material has not been solution heat treated, the minimum temperature shall be -20F unless the material is impact tested per 323.2.3.

37. See 327.5.2 for Description of P-Number groupings.

38. If the chemical composition of this grade is such as to render it hardenable, qualification under P-number 6 is required.

39. For temperatures above 800F, these stress values apply only when the carbon content is 0.04 percent or higher.

40. The allowable stress values for austenitic stainless steels in these tables may not be applicable if the material has been given a final heat treatment other than that required by the material specification and any overriding requirements of this code called for by Notes 6a or 6b.

41. This material when used below -20F requires impact testing if the carbon content is above 0.10 percent.

42. This is a product specification. No design stresses are necessary. Limitations on metal temperature for materials covered by this specification are:

Grades 1 and 2	-20 to 900F
Grade 2H	-50 to 1100F
Grade 3	-20 to 1100F
Grade 4	-150 to 1100F
Grade 6	-20 to 800F
Grade 8F	-20 to 800F
(see Note 41)	-325 to -20F
Grades 8M and 8T	-325 to 1500F
Grades 8 and 8C	-425 to 1500F

43. For use in code piping at the stated allowable stresses, the required minimum tensile and yield properties must be verified by tensile test at the mill. If such tests are not mandatory in the ASTM Specification, they shall be specified in the purchase order.

44. After use above the temperature indicated by a single bar (|), use at a lower temperature shall be based on the stress values allowed for the annealed condition of the material.

45. Stresses shown in the table are applicable for "die" forgings only.

46. The Allowable Stress Values in these tables are for materials in tension. Allowable stress values in shear shall be 0.80 times the tabulated values and allowable stress values in bearing shall be 1.60 times the tabulated values. [See 302.3.1(a)].

47. Yield strengths listed are not included in ASTM specifications. The value shown is based on yield strengths of materials with similar characteristics.

48. The letter "a" indicates alloys which are not recommended for welding and which, if welded, must be individually qualified. The letter "b" indicates copper base alloys which must be individually qualified.

49. In accordance with the specification, when fittings are to be used for service at temperatures above 750F, the purchaser shall specify silicon killed steel.

50. When the section welded is less than 3/8 in. thick, the tensile strength is permitted to be as low as 21,600 psi; and a factor of 90 percent shall be applied to the allowable stress values shown.

51. These stress values are established from a consideration of strength only and will be satisfactory for average service. For bolted joints where freedom from leakage over a long period of time without retightening is required, lower stress values may be necessary as determined from the flexibility of the flange and bolts and corresponding relaxation properties.

52. At temperature over 1000F, these stress values apply only when the carbon is 0.04 percent or higher.

53. For use at temperatures below -20F to -50F inclusive, this material must be quenched and tempered.

54. The stress values given for this material are not applicable when either welding or thermal cutting is employed.

55. For stress-relieved tempers (T351, T3510, T3511, T451, T4510, T4511, T651, T6510,

T6511) stress values for material in the basic temper shall be used.

56. These stresses do not apply to steel bolts made by the Bessemer steel process.

57. The maximum operating temperature is arbitrarily set at 500F because harder temper adversely effects design stress in the creep rupture temperature ranges.

58. Pipe produced to this specification is not intended for high temperature service. The stress values apply to either non-expanded or cold expanded material in the as-rolled, normalized, or normalized and tempered condition.

59. Design stresses for the cold drawn temper are based on hot rolled properties until required data on cold drawn are submitted.

60. Special groupings SP-1, SP-2, and SP-3 of carbon steels are not included in group P-1 because of possible high carbon-high manganese combinations which would require special consideration in qualification. Qualification of any high carbon high manganese grade may be extended to other grades in its group.

61. Annealed at approximately 1800F.

62. Annealed at approximately 2100F.

63. No heat treatment necessary; properties are equal to those of solution annealed material.

64. Stress relief heat treatment is required for service above 450F.

65. The minimum temperature shown is for the heaviest wall permissible by the specification. The minimum temperature for lighter walls shall be as shown in the following table:

Impact Test Temp. (F) for Plate Thicknesses Shown

Spec. & Grade	1" Max.	2" Max.	Over 2" to 3"
A203 - A	-90	-90	-75
A203 - B	-90	-90	-75
A203 - D	-150	-150	-125
A203 - E	-150	-150	-125
A410	-125	-100	-85

APPENDIX A

TABLE 1

ALLOWABLE STRESS IN TENSION FOR MATERIALS (16, 46)

(NUMBERS IN PARENTHESES REFER TO STRESS TABLE NOTES; SEE PAGES [illegible] THROUGH 75)

Material	Specification	(23) Steel Making Process	(37) P No.	Grade	Class	Factor (E)	Tensile Strength Min PSI	Yield Strength Min PSI	Notes	(26) Min Temp	[illegible]	[illegible]	[illegible]
[illegible]													
Centrifugally Cast Pipe													
	FS WW P421c								7, 9, 25	-20	[illegible]		[illegible]
	ASTM A377								7, 9, 25	20	[illegible]	[illegible]	[illegible]
	ANSI 21.6								7, 9, 25	-20	[illegible]		[illegible]
	ANSI 21.8								7, 9, 25	-20	[illegible]		[illegible]
[illegible]													
[illegible]	ASTM A47			32510			50000	32500	7, 9	-20	[illegible]		[illegible]
[illegible]	ASTM A47			35018			53000	35000	7, 9	-20			[illegible]
[illegible]	ASTM A48			20			20000		7, 9, 25	-20	[illegible]		
[illegible]	ASTM A48			25			25000		7, 9, 25	-20		[illegible]	
	ASTM A48			30			30000		7, 9, 25	-20	[illegible]		[illegible]
[illegible]	ASTM A48			35			35000		7, 9, 25	-20	[illegible]		[illegible]
[illegible]	ASTM A48			40			40000		7, 9, 25	-20	[illegible]		[illegible]
	ASTM A48			45			45000		7, 9, 25	-20	[illegible]		[illegible]
[illegible]	ASTM A48			50			50000		7, 9, 25	-20		[illegible]	[illegible]
[illegible]	ASTM A48			60			60000		7, 9, 25	-20	[illegible]	[illegible]	[illegible]
	ASTM A126			A			21000		7, 9, 25	-20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A126			B			31000		7, 9, 25	-20	[illegible]		[illegible]
[illegible]	ASTM A126			C			41000		7, 9, 25	-20		[illegible]	[illegible]
[illegible]	ASTM A197						40000	30000	7, 9	-20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A278			20			20000		7, 9, 25	-20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A278			25			25000		7, 9, 25	-20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A278			30			30000		7, 9, 25	-20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A278			35			35000		7, 9, 25	-20	[illegible]	[illegible]	
[illegible]	ASTM A278			40			40000		7, 9, 64	-20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A278			50			50000		7, 9, 64	-20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A278			60			60000		7, 9, 64	-20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A278			70			70000		7, 9, 64	-20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A278			80			80000		7, 9, 64	-20	[illegible]	[illegible]	[illegible]
Malleable	ASTM A339								7, 9	-20	[illegible]	[illegible]	
Ductile	ASTM A395					.80	60000	40000	7, 9, 22	-20	[illegible]	[illegible]	[illegible]
[illegible] Ductile	ASTM A445					.80	60000	40000	7, 9, 22	-20	[illegible]	152	143
CARBON STEEL (1, 2)													
Seamless Pipe													
	ASTM A53	OH, EF, BO	1	A	Type S		48000	30000	1, 2	-20	16000	[illegible]	[illegible]
	ASTM A53	OH, EF, BO	1	B	Type S		60000	35000	1, 2	-20	20000	[illegible]	[illegible]
	ASTM A106		1	A			48000	30000	2	-20	[illegible]	[illegible]	
	ASTM A106		1	B			60000	35000	2	-20	20000	[illegible]	[illegible]
	ASTM A106		1	C			70000	40000	2	-20	23300	[illegible]	[illegible]
	ASTM A120	OH, EF, BO, AB	1						34	-20	12000	[illegible]	
	ASTM A333		1	1			55000	30000	1, 2	-50	18300	[illegible]	[illegible]
	ASTM A333		1	6			60000	35000	2	-50	20000		
	ASTM A524		1	I			60000	35000	2	-20	20000		
	ASTM A524		1	II			55000	30000	2	-20	18300		
	API 5L	OH, EF, BO	1	A			48000	30000	1, 2	-20	16000	[illegible]	[illegible]
	API 5L	OH, EF, BO	1	B			60000	35000	1, 2	-20	20000	[illegible]	[illegible]
	API 5LX	OH, EF, BO	SP2	X42			60000	42000	58, 60	-20	20000	[illegible]	[illegible]
	API 5LX	OH, EF, BO	SP3	X46			63000	46000	58, 60	-20	21000	[illegible]	
	API 5LX	OH, EF, BO	SP3	X52			66000	52000	58, 60	-20	22000	[illegible]	[illegible]
	API 5LX	OH, EF, BO	SP3	X52			72000	52000	58, 60	-20	23500	[illegible]	[illegible]
Furnace Butt Welded Pipe													
	ASTM A53	OH, BO, EF	1		F	.60	45000	25000	34	-20	9000	[illegible]	[illegible]
	ASTM A120	OH, BO, EF	1			.60			34	-20	7200	[illegible]	
	API 5L		1	A 25	I & II	.60	45000	25000	34	-20	9000	[illegible]	[illegible]
Electric Resistance Welded & Electric Flash Welded Pipe													
	ASTM A53	OH, BO, EF	1	A	Type E	.85	48000	30000	1, 2	-20	13600	[illegible]	[illegible]
	ASTM A53	OH, BO, EF	1	B	Type E	.85	60000	35000	1, 2	-20	17000	[illegible]	[illegible]
	ASTM A120	OH, BO, EF	1			.85			34	-20	10200	[illegible]	
	ASTM A135		1	A		.85	48000	30000	1, 2	-20	13600	[illegible]	[illegible]
	ASTM A135		1	B		.85	60000	35000	1, 2	-20	17000	[illegible]	[illegible]
	ASTM A333		1	1		.85	55000	30000	1, 2	-50	[illegible]	[illegible]	[illegible]
	ASTM A333		1	6		.85	60000	35000	1, 2	-50	17000		
	ASTM A587		1			.85	48000	30000	1, 2	-20	13600		
	API 5L		1	A25	I & II	.85	45000	25000	1, 2	-20	[illegible]	[illegible]	[illegible]
	API 5L	OH, BO, EF	1	A		.85	48000	30000	1, 2	-20	13600	[illegible]	[illegible]
	API 5L	OH, BO, EF	1	B		.85	60000	35000	1, 2	-20	[illegible]	[illegible]	
	API 5LX		SP2	X42		.85	60000	42000	58, 60	-20	[illegible]	[illegible]	[illegible]
	API 5LX		SP3	X46		.85	63000	46000	58, 60	-20	[illegible]		[illegible]
	API 5LX		SP3	X52		.85	66000	52000	58, 60	-20	[illegible]	[illegible]	[illegible]
	API 5LX		SP3	X52		.85	72000	52000	58, 60	-20	[illegible]	[illegible]	[illegible]
Electric Fusion Welded Pipe (Straight Seam)													
A285 GR A	ASTM A134		1			.80	45000	25000	5, 34	-20	[illegible]	[illegible]	
A285 GR B	ASTM A134		1			.80	49000	30000	5, 34	20	[illegible]	[illegible]	
A285 GR C	ASTM A134		1			.80	52000	33000	5, 34	20	[illegible]	12	[illegible]
[illegible] GR D	ASTM A134		1			.80	55000	30000	5, 34	20	[illegible]	[illegible]	[illegible]
A283 GR A	ASTM A134		1			.80	45000	24000	5, 34	-20	[illegible]		[illegible]
A283 GR B	ASTM A134		1			.80	50000	27000	5, 34	-20	[illegible]	[illegible]	
[illegible] GR C	ASTM A134		1			.80	55000	30000	5, 34	-20	[illegible]	[illegible]	[illegible]
A283 GR D	ASTM A134		1			.80	60000	33000	5, 34	20	[illegible]	[illegible]	[illegible]
A285 GR A	ASTM A134		1			.80	45000	24000	34	20	[illegible]	[illegible]	[illegible]
A283 GR B	ASTM A134		1			.80	50000	27000	34	-20	[illegible]	[illegible]	[illegible]

APPENDIX [illegible]

TABLE [illegible]

ALLOWABLE STRESSES IN TENSION FOR MATERIALS (16) (45)

(NUMBERS IN PARENTHESIS REFER TO STRESS TABLE NOTES; SEE PAGES 72 THROUGH 75)

ALLOWABLE STRESSES, SE (PSI) (46)

Metal Temperature Degrees F (35)

400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification	Material
																						IRON
																						Centrifugally Cast [illegible]
6000																					FS AN P421c	
6000																					AST [illegible] 7	
6000																					ANSI 21.6	
6000																					ANSI 21.8	
																						Castings
10000	10000	10000	10000																		ASTM A47	Malleable
10600	10600	10600	10600																		ASTM A47	Malleable
2000																					ASTM A48	Gray
2500																					ASTM A48	Gray
3000																					ASTM A48	Gray
3500																					ASTM A48	Gray
4000																					ASTM A48	Gray
4500																					ASTM A48	Gray
5000																					ASTM A48	Gray
6000																					ASTM A48	Gray
2000																					ASTM A126	Gray
3000																					ASTM A126	Gray
4000																					ASTM A126	Gray
8000	8000	8000	8000																		ASTM A197	Cupola Malleable
2000																					ASTM A278	Gray
2500																					ASTM A278	Gray
3000																					ASTM A278	Gray
3500																					ASTM A278	Gray
4000	4000	4000	4000																		ASTM A278	Gray
5000	5000	5000	5000																		ASTM A278	Gray
6000	6000	6000	6000																		ASTM A278	Gray
7000	7000	7000	7000																		ASTM A278	Gray
8000	8000	8000	8000																		ASTM A278	Gray
10000	10000	10000	10000																		ASTM A235	Malleable
13500	12650	11850	11350																		ASTM A395	Ductile
13500	12650	11850	11350																		ASTM A[illegible]	Ferritic [illegible]
																						CARBON STEEL
																						Seamless Pipe
13800	13100	12350	12000	11650	10700	9300	7900	6500	4500	2500	1600	1000									ASTM A53	
17250	16350	15500	15000	14350	12950	10800	8650	6500	4500	2500	1600	1000									ASTM A53	
16000	16000	13900	13500	13300	10700	9300	7900	6500	4500	2500	1600	1000									ASTM A106	
20000	18900	17300	17000	16500	12950	10800	8650	6500	4500	2500	1600	1000									ASTM A106	
22900	21600	19700	19100	19200	14750	12000															ASTM A106	
																					ASTM A120	
17200	16200	14800	14500	14400	12050	10200	8350	6500	4500	2500	1600	1000									ASTM A333	
																					ASTM A333	
																					ASTM A524	
																					ASTM A524	
13800	13100	12350	12000	11650	10700	9300	7900	6500	4500	2500	1600	1000									API 5L	
17250	16350	15500	15000	14350	12950	10800	8650	6500	4500	2500	1600	1000									API 5L	
17250																					API 5LX	
19150																					API 5LX	
19000																					API 5LX	
20350																					API 5LX	
																						Furnace Butt Welded Pipe
7800																					ASTM A53	
																					ASTM A120	
7800																					API 5L	
																						Electric Resistance Welded & Electric Flash Welded Pipe
	[illegible]	10500	10200	9900	9100	7900	6700	5500	3800	2150	1350	850									ASTM A53	
[illegible]	13900	13150	12750	12200	11000	9200	7350	5500	3800	2150	1350	850									ASTM A53	
																					ASTM A1[illegible]	
11750	11100	10500	10200	9900	9100	7900	6700	5500	3800	2150	1350	850									ASTM A[illegible]	
14650	13900	13150	12750	12200	11000	9200	7350	5500	3800	2150	1350	850									ASTM [illegible]	
[illegible]	13750	12600	12300	12250	10250	8650	7100	5500	3800	2150	1350	850									ASTM A[illegible]	
																					ASTM A5[illegible]	
																					ASTM A5[illegible]	
11050																					API 5L	
11750	11100	10500	10200	9900	9100	7900	6700	5500	3800	2150	1350	850									API 5L	
[illegible]	13900	13150	12750	12200	11000	9200	7350	5500	3800	2150	1350	850									API 5L	
14650																					API 5LX	
15000																					API 5LX	
16100																					API 5LX	
17300																					API 5LX	
																						Electric Fusion Welded Pipe [illegible]
																					ASTM [illegible]	[illegible]
																					ASTM [illegible]	[illegible]
																					ASTM [illegible]	[illegible]
																					ASTM [illegible]	[illegible]
																					ASTM [illegible]	[illegible]
																					ASTM [illegible]	
																					[illegible]	
																					ASTM [illegible]	[illegible]
10950	10400	9450	9300	9200	8200	7700	6200	5200													ASTM [illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]													ASTM A[illegible]	[illegible]

TABLE 1

ALLOWABLE STRESSES IN TENSION FOR MATERIALS (35, 36)

(NUMBERS IN PARENTHESIS REFER TO STRESS TABLE NOTES ON PAGES 72 THROUGH 79)

Material	Specification	(29) Steel Making Process	(37) "P" No	Grade	Class	Factor (E)	Tensile Strength Min PSI	Yield Strength Min PSI	Notes	(29) Min Temp	Min Temp To 650	[illegible]	[illegible]
Carbon Steel (Cont)													
Electric Fusion Welded Pipe (Straight Seam) (Cont)													
[illegible]	ASTM A139		1			80	55000	30000	34	−20	14650	[illegible]	[illegible]
	ASTM A139		1	A		80	[illegible]	30000	34	−20	12[illegible]	[illegible]	[illegible]
	ASTM A139		1	B		80	60000	35000	34	−20	160[illegible]		[illegible]
[illegible] A	ASTM A155		1	C45	2	85	45000	24000	1, 2	−20	127[illegible]		[illegible]
[illegible]	ASTM A155		1	C50	2	85	50000	27000	1, 2	−20	14[illegible]		[illegible]
[illegible]	ASTM A155		1	C55	2	85	55000	30000	1, 2	−20	15[illegible]	[illegible]	[illegible]
[illegible]	ASTM A155		1	CMS 75	2	85	75000	40000	2	−20	21[illegible]	[illegible]	[illegible]
[illegible]	ASTM A155		1	CMS 75	2	85	75000	42000	2	−20	21[illegible]	[illegible]	[illegible]
[illegible]	ASTM A155		1	KC 55	2	85	55000	30000	1, 2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A155		1	KC 60	2	85	60000	32000	1, 2	−20	17[illegible]		[illegible]
[illegible]	ASTM A155		1	KC 65	2	85	65000	35000	1, 2	−20	184[illegible]	[illegible]	[illegible]
[illegible]	ASTM A155		1	KC 70	2	85	70000	38000	1, 2	−20	[illegible]		[illegible]
[illegible]	ASTM A155		1	KCF 55	2	85	55000	30000	1, 2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A155		1	KCF 60	2	85	60000	32000	1, 2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A155		1	KCF 65	2	85	65000	35000	1, 2	−20	1845[illegible]	[illegible]	[illegible]
[illegible]	ASTM A155		1	KCF 70	2	85	70000	38000	1, 2	−20	198[illegible]	[illegible]	[illegible]
[illegible]	ASTM A155		1	C45	2	90	45000	24000	1, 2, 17	−20	13[illegible]		[illegible]
[illegible]	ASTM A155		1	C50	2	90	50000	27000	1, 2, 17	−20	15[illegible]		[illegible]
[illegible]	ASTM A155		1	C55	2	90	55000	30000	1, 2, 17	−20	[illegible]		[illegible]
[illegible]	ASTM A155		1	CMS 75	2	90	75000	40000	2, 17	−20	225[illegible]		[illegible]
[illegible]	ASTM A155		1	CMS 75	2	90	75000	42000	2, 17	−20	[illegible]	[illegible]	
[illegible]	ASTM A155		1	KC 55	2	90	55000	30000	1, 2, 17	−20	[illegible]		
[illegible]	ASTM A155		1	KC 60	2	90	60000	32000	1, 2, 17	−20	[illegible]		[illegible]
[illegible]	ASTM A155		1	KC 65	2	90	65000	35000	1, 2, 17	−20	19[illegible]		
[illegible]	ASTM A155		1	KC 70	2	90	70000	38000	1, 2, 17	−20	2[illegible]		
[illegible]	ASTM A155		1	KCF 55	2	90	55000	30000	1, 2, 17	−20	[illegible]		[illegible]
[illegible]	ASTM A155		1	KCF 60	2	90	60000	32000	1, 2, 17	−20	[illegible]		[illegible]
[illegible]	ASTM A155		1	KCF 65	2	90	65000	35000	1, 2, 17	−20	[illegible]		
[illegible]	ASTM A155		1	KCF 70	2	90	70000	38000	1, 2, 17	−20	[illegible]		[illegible]
[illegible] A	ASTM A155		1	C45	1	1.00	45000	24000	1, 2	−20	150[illegible]		[illegible]
[illegible]	ASTM A155		1	C50	1	1.00	50000	27000	1, 2	−20	167[illegible]		[illegible]
[illegible]	ASTM A155		1	C55	1	1.00	55000	30000	1, 2	−20	18[illegible]		
[illegible]	ASTM A155		1	CMS 75	1	1.00	75000	40000	2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A155		1	CMS 75	1	1.00	75000	42000	2	−20	25[illegible]		
[illegible]	ASTM A155		1	KC 55	1	1.00	55000	30000	1, 2	−20	18[illegible]		[illegible]
[illegible] 60	ASTM A155		1	KC 60	1	1.00	60000	32000	1, 2	−20	20[illegible]		[illegible]
[illegible]	ASTM A155		1	KC 65	1	1.00	65000	35000	1, 2	−20	21[illegible]	[illegible]	
[illegible] 70	ASTM A155		1	KC 70	1	1.00	70000	38000	1, 2	−20	2[illegible]		
[illegible] 55	ASTM A155		1	KCF 55	1	1.00	55000	30000	1, 2	−20	18[illegible]		
A515 GR 60	ASTM A155		1	KCF 60	1	1.00	60000	32000	1, 2	−20	20000		[illegible]
A516 GR 65	ASTM A155		1	KCF 65	1	1.00	65000	35000	1, 2	−20	21700	[illegible]	[illegible]
A516 GR 70	ASTM A155		1	KCF 70	1	1.00	70000	38000	1, 2	−20	23[illegible]	[illegible]	
	ASTM A381		SP1	Y35		85	60000	35000	60	−20	17[illegible]		
	ASTM A381		SP2	Y42		85	68000	42000	60	−20	19250	[illegible]	[illegible]
	ASTM A381		SP3	Y46		85	70000	46000	60	−20	19550		[illegible]
	ASTM A381		SP3	Y48		85	72000	48000	60	−20	20[illegible]	[illegible]	[illegible]
	ASTM A381		SP3	Y50		85	72000	50000	60	−20	20[illegible]	[illegible]	
	ASTM A381		SP3	Y52		85	75000	52000	60	−20	[illegible]		[illegible]
	ASTM A381		SP1	Y35		90	60000	35000	19, 60	−20	18[illegible]	[illegible]	[illegible]
	ASTM A381		SP2	Y42		90	68000	42000	19, 60	−20	20[illegible]		[illegible]
	ASTM A381		SP3	Y46		90	70000	46000	19, 60	−20	2[illegible]	[illegible]	[illegible]
	ASTM A381		SP3	Y48		90	72000	48000	19, 60	−20	21[illegible]	[illegible]	
	ASTM A381		SP3	Y50		90	72000	50000	19, 60	−20	21700	[illegible]	[illegible]
	ASTM A381		SP3	Y52		90	75000	52000	19, 60	−20	22[illegible]		
	ASTM A381		SP1	Y35		1.00	60000	35000	19, 60	−20	2[illegible]		[illegible]
	ASTM A381		SP2	Y42		1.00	68000	42000	19, 60	−20	22[illegible]	[illegible]	[illegible]
	ASTM A381		SP3	Y46		1.00	70000	46000	[illegible]	−20	23[illegible]	[illegible]	[illegible]
	ASTM A381		SP3	Y48		1.00	72000	48000	19, 60	−20	[illegible]	[illegible]	[illegible]
	ASTM A381		SP3	Y50		1.00	72000	50000	19, 60	−20	24[illegible]	[illegible]	[illegible]
	ASTM A381		SP3	Y52		1.00	78000	52000	19, 60	−20	26000	[illegible]	[illegible]
	API 5L	OH, BO, EF	1	A		85	48000	30000	1, 2	−20	13[illegible]		[illegible]
	API 5L	OH, BO, EF	1	B		85	60000	35000	1, 2	−20	[illegible]		[illegible]
	API 5LX	OH, BO, EF	SP2	X42		85	60000	42000	38, 60	−20	[illegible]	[illegible]	[illegible]
	API 5LX	OH, BO, EF	SP3	X46		85	62000	46000	38, 60	−20	[illegible]	[illegible]	[illegible]
	API 5LX	OH, BO, EF	SP3	X52		85	66000	52000	38, 60	−20	18[illegible]	[illegible]	[illegible]
	API 5LX	OH, BO, EF	SP3	X52		85	72000	52000	38, 60	−20	20400	[illegible]	[illegible]
Spiral Welded Pipe													
A285 GR A	ASTM A134		1			80	45000	25000	5, 34	−20	[illegible]	[illegible]	
A285 GR B	ASTM A134		1			80	49000	30000	5, 34	−20	117[illegible]	[illegible]	
A285 GR C	ASTM A134		1			80	52000	33000	5, 34	−20	12750	[illegible]	
A285 GR D	ASTM A134		1			80	53000	33000	5, 34	−20	12[illegible]	[illegible]	
A283 GR A	ASTM A134		1			80	45000	24000	5, 34	−20	[illegible]	[illegible]	
A283 GR B	ASTM A134		1			80	50000	27000	5, 34	−20	122[illegible]	[illegible]	
A283 GR C	ASTM A134		1			80	55000	30000	5, 34	−20	13[illegible]	[illegible]	
A283 GR D	ASTM A134		1			80	60000	33000	5, 34	−20	147[illegible]	[illegible]	
A[illegible] GR A	ASTM A134		1			80	45000	24000	34	−20	[illegible]	[illegible]	
A245 GR B	ASTM A134		1			80	50000	27000	34	−20	[illegible]	[illegible]	
A245 GR C	ASTM A134		1			80	55000	30000	34	−20	[illegible]	[illegible]	
	ASTM A139		1	A		80	48000	30000	34	−20	[illegible]		
	ASTM A139		1	B		80	60000	35000	34	−20	[illegible]		
A245 GR A	ASTM A211		1			75	45000	25000	5, 34	−20	[illegible]		
A245 GR B	ASTM A211		1			75	49000	30000	5, 34	−20	[illegible]	[illegible]	

APPENDIX A

TABLE 1

ALLOWABLE STRESSES IN TENSION FOR MATERIALS (16, 45)

(NUMBERS IN PARENTHESES REFER TO STRESS TABLE NOTES; SEE PAGES 72 THROUGH 75)

ALLOWABLE STRESSES, SE (PSI) (46)

Metal Temperature Degrees F (35)

400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification	Material
																						CARBON [illegible] (Cont)
																					Electric Fusion Welded Pipe [illegible] (Cont)	
13750	12950	11850	11600	11500	9650	8150	6700	5200													ASTM A[illegible]	[illegible]
																					ASTM A[illegible]	
																					ASTM A[illegible]	
11650	11050	10050	9850	9750	8700	7650	6600	5500	3800	2100	1350	850									ASTM A[illegible]	A[illegible]
13100	12400	11300	11150	11050	9500	8150	6850	5500	3800	2100	1350	850									ASTM A[illegible]	A[illegible]
[illegible]	13750	12600	12300	12250	10250	8650	7100	5500	3800	2100	1350	850									ASTM A[illegible]	A[illegible]
19450	18350	16750	16500	[illegible]	13300	10700	8100	5500	3800	2100	1350	850									ASTM A[illegible]	A[illegible]
20400	19300	17600	17350	17150																	ASTM A[illegible]	A[illegible]
14600	13750	12600	12200	12250	10250	8650	7100	5500	3800	2100	1350	850									ASTM A[illegible]	A[illegible]
15550	14700	13450	13200	13100	11000	9200	7350	5500	3800	2100	1350	850									ASTM A[illegible]	A[illegible]
[illegible]	16050	14700	14450	14300	11750	9700	7600	5500	3800	2100	1350	850									ASTM A[illegible]	A[illegible]
18350	17300	15900	15650	15550	12550	10200	7350	5500	3800	2100	1350	850									ASTM A[illegible]	A[illegible]
13600	12750	12600	12300	12250	10250	8700	7100														ASTM A[illegible]	A[illegible]
15550	14700	13450	13200	13100	11000	9200	7350														ASTM A[illegible]	A[illegible]
17000	16050	14700	14450	14300	11750	9700	7600														ASTM A[illegible]	A[illegible]
18450	17450	15900	15650	15550	12550	10200	7850														ASTM A[illegible]	A[illegible]
12350	11700	11600	10450	10350	9200	8100	6950	5950	4050	2250	1450	900									ASTM A[illegible]	A[illegible]
12550	11750	11950	11800	11700	10050	8650	7250	5850	4050	2250	1450	900									ASTM A[illegible]	A[illegible]
15500	14500	13300	13050	12950	10850	9200	7500	5850	4050	2250	1450	900									ASTM A[illegible]	A[illegible]
20600	19450	17750	17450	17300	14100	11350	8600	5850	4050	2250	1450	900									ASTM A[illegible]	A29[illegible]
[illegible]	[illegible]	18650	18350	[illegible]																	ASTM A[illegible]	A[illegible]
15500	[illegible]	13300	13050	[illegible]	10850	9200	7500	5850	4050	2250	1450	900									ASTM A[illegible]	A[illegible]
16500	15550	14200	13950	13850	11650	9700	7800	5850	4050	2250	1450	900									ASTM A[illegible]	A515 [illegible]
18000	17000	15550	15300	15100	12450	10250	8050	5950	4050	2250	1450	900									ASTM A[illegible]	A515 G[illegible]
19550	18350	16850	16550	16500	13450	10800	8300	5850	4050	2250	1450	900									ASTM A[illegible]	A515 G[illegible]
15500	14600	13300	13050	12950	10850	9200	7500														ASTM A[illegible]	A516 GR [illegible]
16350	15550	14200	13950	13850	11650	9700	7800														ASTM A[illegible]	A516 GR [illegible]
18000	17000	15550	15300	15100	12450	10250	8050														ASTM A[illegible]	A[illegible]
19550	18350	16350	16550	16500	13250	10800	8300														ASTM A[illegible]	A516 [illegible]
13750	13000	11900	11600	11500	10250	9600	7750	6500	4500	2500	1600	1000									ASTM A[illegible]	A2[illegible]
15500	14600	13500	13100	13000	11150	9600	8050	6500	4500	2500	1600	1000									ASTM A[illegible]	A245 GR [illegible]
17200	16200	14800	14500	14300	12650	10200	8350	6500	4500	2500	1600	1000									ASTM A155	A245 GR C
22900	21600	19700	19400	19200	15650	12600	9950	6500	4500	2500	1600	1000									ASTM A155	A299 [illegible]
24600	22700	20700	20400	20200																	ASTM A[illegible]	A299 [illegible]
17200	16200	14800	14500	14400	12050	10200	8350	6500	4500	2500	1600	1000									ASTM A[illegible]	A515 G[illegible]
18300	17300	15800	15500	15400	12950	10800	8650	6500	4500	2500	1600	1000									ASTM A[illegible]	A515 G[illegible]
20000	18900	17300	17000	16900	13850	11400	8950	6500	4500	2500	1600	1000									ASTM A155	A515 GR
21700	20500	18700	18400	18300	14750	12000	9250	6500	4500	2500	1600	1000									ASTM A155	A515 G[illegible]
17200	16200	14800	14500	14400	12050	10200	8350														ASTM A155	A516 [illegible]
18300	17300	15800	15500	15400	12950	10800	8650														ASTM A155	A516 G[illegible]
20000	18900	17300	17000	16900	13850	11400	8950														ASTM A[illegible]	A516 G[illegible]
21700	20500	18700	18400	18300	14750	12000	9250														ASTM A155	A516 GR [illegible]
13650	[illegible]	13200	12750																		ASTM A3[illegible]	
16750	15750	14900	14450																		ASTM A[illegible]	
17150	16250	15350	14900																		ASTM A[illegible]	
17650	16700	15750	15300																		ASTM A3[illegible]	
[illegible]	17000	16100	15700																		ASTM A3[illegible]	
18400	17400	16500	15900																		ASTM A3[illegible]	
15550	14700	14000	13500																		ASTM A381	
[illegible]	16700	15800	15300																		ASTM A381	
18200	17200	16250	15550																		ASTM A3[illegible]	
18700	17750	16650	16200																		ASTM A3[illegible]	
18600	18000	17100	16600																		ASTM A3[illegible]	
19500	18400	17400	16900																		ASTM A3[illegible]	
17250	16350	15500	15000																		ASTM A381	
19700	18550	17500	17000																		ASTM A381	
[illegible]	19100	18050	17500																		ASTM A381	
[illegible]	19650	18500	[illegible]																		ASTM A3[illegible]	
[illegible]	20000	19000	18500																		ASTM A3[illegible]	
[illegible]	[illegible]	19400	18500																		ASTM A381	
11750	11100	10500	10200	9900	9100	7900	6700	5500	3800	2150	1350	850									API 5L	
11650	13900	13150	12750	12200	11000	9200	7350	5500	3800	2150	1350	850									API 5L	
[illegible]																					API 5LX	
15400																					API 5LX	
16100																					API 5LX	
																					API 5LX	
17600																					API 5LX	
																						[illegible]
																					ASTM A[illegible]	A24[illegible]
																					ASTM A134	A24[illegible]
																					ASTM A134	A24[illegible]
																					ASTM A134	A2[illegible]
																					ASTM A134	A2[illegible]
																					ASTM A[illegible]	A2[illegible]
																					ASTM A[illegible]	A2[illegible]
																					ASTM A[illegible]	A[illegible]
																					ASTM A[illegible]	A[illegible]
																					ASTM A[illegible]	A[illegible]
																					ASTM A[illegible]	A2[illegible]
																					[illegible]	
																					ASTM A[illegible]	
																					ASTM A[illegible]	A2[illegible]

APPENDIX A

TABLE 1

ALLOWABLE STRESSES [illegible]

(NUMBERS IN PARENTHESES [illegible] THROUGH [illegible])

Material	Specification	(29) Steel Making Process	(37) "P" No	Grade	Class	Factor (E)	Tensile Strength Min PSI	Yield Strength Min Psi	Notes	(29) Min. Temp	Min Temp To 100	200	300
CARBON STEEL (Cont.)													
[illegible] Pipe (Cont.)													
[illegible]	ASTM A211		1			.75	52000	33000	5, 34	−20	[illegible]	[illegible]	
[illegible]	ASTM A211		1			.5	55000	40000	5, 34	−20	[illegible]	[illegible]	
	API 5LS	OH, BO, EF	1	A		.85	48000	30000	55	−20	[illegible]	[illegible]	
	API 5LS	OH, BO, EF	1	B		.85	60000	35000	55	−20	[illegible]	[illegible]	
Plates & Sheets													
[illegible]	ASTM A245		1	A		.92	45000	25000	2, 5	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A245		1	B		.92	49000	30000	2, 5	−20	[illegible]	[illegible]	[illegible]
	ASTM A245		1	C		.92	52000	33000	2, 5	−20	[illegible]		[illegible]
[illegible]	ASTM A245		1	D		.92	55000	40000	2, 5	−20	[illegible]		[illegible]
[illegible]	ASTM A283		1	A		.92	45000	24000	2, 5, 34	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A283		1	B		.92	50000	27000	2, 5, 34	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A283		1	C		.92	55000	30000	2, 5, 34	−20	[illegible]		[illegible]
[illegible]	ASTM A283		1	D		.92	60000	33000	2, 5, 34	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A285		1	A			45000	24000	1, 2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A285		1	B			50000	27000	1, 2	−20	16700	[illegible]	[illegible]
	ASTM A285		1	C			55000	30000	1, 2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A299		3	1" Thick & Under			75000	42000	2, 11	−20	[illegible]	[illegible]	[illegible]
	ASTM A299		3	Over 1" to 2" Thick			75000	40000	2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A593		1	A516 55			55000	30000	2	−50	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A593		1	A516 60			60000	32000	2	−50	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A593		1	A516 65			65000	35000	2	−50	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A593		1	A516 70			70000	38000	2	−50	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A515		1	55			55000	30000	2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A515		1	60			60000	32000	2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A515		1	65			65000	35000	2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A515		1	70			70000	38000	2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A516		1	55			55000	30000	2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A516		1	60			60000	32000	2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A516		1	65			65000	35000	2	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A516		1	70			70000	38000	2	−20	[illegible]	[illegible]	[illegible]
Forgings & Seamless Fittings													
Forgings & Fittings	ASTM A105		1	I			60000	30000	1, 2, 9	−20	[illegible]	[illegible]	[illegible]
Forgings & Fittings	ASTM A105		1	II			70000	36000	1, 2, 9	−20	[illegible]	[illegible]	[illegible]
Forgings & Fittings	ASTM A181		1	I			60000	30000	1, 2, 9	−20	[illegible]		[illegible]
Forgings & Fittings	ASTM A181		1	II			70000	36000	1, 2, 9	−20	[illegible]	[illegible]	[illegible]
Fittings	ASTM A234		1	WPA			48000	30000	1, 2, 13	−20	[illegible]	[illegible]	[illegible]
Fittings	ASTM A234		1	WPB			60000	35000	1, 2, 13	−20	[illegible]	[illegible]	[illegible]
Fittings	ASTM A234		1	WPC			70000	40000	1, 2, 13	−20	[illegible]	[illegible]	[illegible]
Forgings & Fittings	ASTM A350		1	LF 1			60000	30000	1, 2, 9	−50	[illegible]	[illegible]	[illegible]
Forgings & Fittings	ASTM A350		1	LF 2			70000	36000	2, 9	−50	[illegible]	[illegible]	[illegible]
Forgings & Fittings	ASTM A420		1	WPL-1			55000	30000	2, 13	−50	[illegible]	[illegible]	[illegible]
Castings													
	ASTM A216		1	WCA		.80	60000	30000	2, 9, 22	−20	16000	[illegible]	[illegible]
	ASTM A216		1	WCB		.80	70000	36000	2, 9, 22	−20	[illegible]	[illegible]	[illegible]
	ASTM A216		1	WCC		.80	70000	40000	2, 9, 22	−20	[illegible]	[illegible]	[illegible]
	ASTM A352		1	LCB		.80	65000	35000	2, 9, 22	−50	17350	[illegible]	[illegible]
Structural													
NOTE: [illegible] such as pipe, castings, forgings, etc., listed elsewhere in Appendix A may also be used as structural materials													
	ASTM A36		1			.92	58000	36000	2, 5, 34	−20	17800	[illegible]	[illegible]
LOW AND INTERMEDIATE ALLOY STEEL													
Seamless Pipe													
3½ Ni	ASTM A333		9B	3			65000	35000		−150	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A333		4	4			60000	35000		−150	[illegible]	[illegible]	[illegible]
2½ Ni	ASTM A333		9A	7			65000	35000		−100	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A333	SG1	11A	8			100000	75000		−320	[illegible]	[illegible]	
[illegible]	ASTM A333		9A	9			63000	46000		−100	21000		
C-½ Mo	ASTM A335	OH, EF	3	P1			55000	30000	3	−20	[illegible]	[illegible]	
[illegible]	ASTM A335	OH, EF	3	P2			55000	30000	3	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A335	EF	5	P5			60000	30000		−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A335	EF	5	P5b			60000	30000		−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A335	EF	5	P5c			60000	30000		−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A335	EF	5	P7			60000	30000		−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A335	EF	5	P9			60000	30000		−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A335	EF	4	P11			60000	30000		−20	[illegible]	[illegible]	
[illegible]	ASTM A335	OH, EF	4	P12			60000	30000	3	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A335	EF	3	P15			60000	30000	3	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A335	EF	5	P21			60000	30000		−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A335	EF	5	P22			60000	30000		−20	[illegible]	[illegible]	
[illegible]	ASTM A369	OH, EF	3	FP1			55000	30000	3	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A369	OH, EF	3	FP2			55000	30000	3	−20	[illegible]		
[illegible]	ASTM A369	EF	4	FP3b			60000	30000		−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A369	EF	5	FP5			60000	30000		−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A369	EF	5	FP7			60000	30000		−20			
[illegible]	ASTM A369	EF	5	FP9			60000	30000		−20	[illegible]		
[illegible]	ASTM A369	EF	4	FP11			60000	30000		−20	[illegible]	[illegible]	
[illegible]	ASTM A369	OH, EF	4	FP12			60000	[illegible]	3	−20		[illegible]	
[illegible] 2 Mo	ASTM A369	EF	5	FP21			60000	30000		−20	[illegible]	[illegible]	
2¼ Cr 1 Mo	ASTM A369	EF	5	FP22			60000	30000		−20	[illegible]	[illegible]	[illegible]

ALLOWABLE STRESSES IN TENSION FOR MATERIALS (16, 65)

(NUMBERS IN PARENTHESIS REFER TO STRESS TABLE NOTES SEE PAGES 72 THROUGH 75)

ALLOWABLE STRESSES, PSI (62)

Metal Temperature Degrees F (35)

400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification	Material
																						CARBON STEEL (cont.)
																						Spiral Welded Pipe (Cont.)
																					ASTM A211	A245 [illegible]
																					ASTM A211	A245 Gr [illegible]
																					API 5LS	
																					API 5LS	
																						Plates & Sheets
12300	11500	11150	10950	10700	9850																ASTM A245	Sheets
12950	12250	11600	11250	10900	10550																ASTM A245	Sheets
13750	13050	12100	11950	11550	11200																ASTM A245	Sheets
14500	14150	13500	13150	12600	11600																ASTM A245	Sheets
11950	11310	10700	10350	10150	9450																ASTM A285	Plates
13200	12550	11950	11500	11150	10250																ASTM A2[illegible]	Plates
[illegible]	13900	13050	12650	12200	11100																ASTM A2[illegible]	Plates
15900	15050	14200	13500	13200	11900																ASTM A2[illegible]	Plates
13700	13000	11800	11600	11500	10250	9000	7750	6500	4500	2500	1500	1000									ASTM A2[illegible]	Plates
15400	14600	13300	13100	13000	11150	9600	8050	6500	4500	2500	1600	1000									ASTM A2[illegible]	Plates
17200	16200	13900	14500	14100	12050	10500	8350	6500	4500	2500	1600	1000									ASTM A299	Plates
[illegible]	22700	20700	[illegible]	20200	15650	12600	9550	6500	4500	2500	1600	1000									ASTM A299	Plates
22900	21600	19700	19400	19300	15650	12600	9550	6500	4500	2500	1600	1000									ASTM A3[illegible]	Plates
17200	16200	[illegible]	14500	[illegible]	12050	10200	8350														ASTM A5[illegible]	Plates
18300	17300	15500	15500	15400	12950	10800	8650														ASTM A5[illegible]	Plates
[illegible]	[illegible]	17400	17000	16800	13850	11800	8950														ASTM A5[illegible]	Plates
21700	20500	18700	18400	18300	14750	12000	9250														ASTM A5[illegible]	Plates
17200	16200	14800	14500	14400	12050	10300	8350	6500	4500	2500											ASTM A5[illegible]	Plates
18300	17300	15800	15500	15700	12950	10800	8650	6500	4500	2500											ASTM A5[illegible]	Plates
[illegible]	18300	17300	17600	16800	12950	10900	8650	6500	4500	2500											ASTM A5[illegible]	Plates
21700	20500	18700	18400	18600	14750	12000	9250	6500	4500	2500											ASTM A5[illegible]	Plates
17200	16200	15800	14500	14400	12050	10200	8350														ASTM A5[illegible]	Plates
18300	17300	15800	15500	15400	12950	10600	8650														ASTM A5[illegible]	Plates
20200	18900	17300	17000	16800	13850	11800	8950														ASTM A5[illegible]	Plates
21700	20500	18700	18400	18300	14750	12000	9250														ASTM A5[illegible]	Plates
																						Forgings & Seamless Fittings
17200	16200	14800	14500	14400	12950	10800	8650	6500	4500	2500	1600	1000									ASTM A1[illegible]	Forgings
20600	19400	17800	17400	17300	14750	12000	9250	6500	4500	2500	1600	1000									ASTM A[illegible]	Forgings [illegible]
17200	16200	14800	14500	14400	12950	10800	8650	6500	4500	2500	1600	1000									ASTM [illegible]	Forgings [illegible]
20600	19400	17800	17400	17300	14750	12000	9250	6500	4500	2500	1600	1000									ASTM A[illegible]	[illegible]
15400	14600	13300	13100	13000	10700	9800	7900	6500	4500	2500	1600	1000									ASTM A2[illegible]	Fittings
20000	18900	17300	17000	16500	12950	10800	8650	6500	4500	2500	1600	1000									ASTM A234	Fittings
22900	21600	19700	19400	19200	14750	12000															ASTM A234	Fittings
17200	16200	14800	14500	14400	12950	10800	8650	6500	4500	2500	1600	1000									ASTM A[illegible]	F[illegible]
20600	19400	17800	17400	17300	14750	12000	9250	6500	4500	2500	1600	1000									ASTM A3[illegible]	[illegible]
17200	16200	14800	14500	14400	12050	10200	8350	6500	4500	2500	1600	1000									ASTM A420	Fittings
																						Castings
13750	12950	11850	11600	11500	10350	8650	6900	5200	3600	2000	1300	800									ASTM A2[illegible]	
16500	15500	14250	13900	13950	11800	9600	7400	5200	3600	2000	1300	800									ASTM A[illegible]	
18300	17300	15750	15500	15350	11800	9600	7400	5200	3600	2000											ASTM A2[illegible]	
16000	15100	13850	13600	13450	11100	9100	7150	5200	3600	2000	1300	800									ASTM A352	
																						Structural
16900	16900	16900	16900	16900																	ASTM A36	
																						LOW AND INTERMEDIATE ALLOY STEEL
																						Seamless Pipe
18700	17750	16750	16250	15500	13850	11400	8950	6500	4500	2500	1600	1000									ASTM A3[illegible]	[illegible]
17250	16350	15500	15000																		ASTM A3[illegible]	[illegible]
16250	16250	16250	16250																		ASTM A3[illegible]	[illegible]
																					ASTM A3[illegible]	[illegible]
																					ASTM A3[illegible]	[illegible]
17800	17200	16800	16600	16300	13750	13150	13150	12500	10000	6250	4000	2400									ASTM A[illegible]	[illegible]
17800	17300	16800	16600	16300	13750	13450	13150	12500	10000	6250	4000	2400									ASTM A[illegible]	[illegible]
16500	15700	15200	15000	14700	13100	12800	12000	10350	7600	5600	4150	3050	2000	1300							ASTM A[illegible]	[illegible]
16500	15900	15200	15000	14700	13100	12800	12000	10350	7600	5600	4150	3050	2000	1300							ASTM A[illegible]	[illegible]
16500	15900	15200	15000	14700	13100	12800	12000	10350	7600	5600	4150	3050	2000	1300							ASTM A[illegible]	[illegible]
16500	15900	15200	15000	14700	13100	12500	11500	9500	7000	5000	3500	2500	1800	1200							ASTM A[illegible]	[illegible]
16500	15900	15200	15000	14700	13100	12800	12500	12000	10800	8500	5500	3500	2200	1500							ASTM A[illegible]	[illegible]
17500	17200	16700	16200	15600	15200	15300	14500	12800	11000	7800	5500	4000	[illegible]	1200							ASTM A[illegible]	[illegible]
17500	17200	16700	16300	15600	15200	15000	14500	12500	11000	7500	5000	2800	1450	1000							ASTM A[illegible]	[illegible]
17000	16450	15850	15600	15300	15000	14400	13750	12500	10000	6250	4000	2400									ASTM A[illegible]	[illegible]
17500	17200	16700	16200	15600	15200	15000	14000	12000	9000	7000	5500	4000	2700	1500							ASTM A[illegible]	[illegible]
17500	17200	16700	16200	15600	15200	15000	14500	12800	11000	7800	5800	4200	3000	2000							ASTM A[illegible]	[illegible]
17800	17300	16800	16600	16300	13750	13450	13150	12500	10000	6250	4000	2400									ASTM A[illegible]	[illegible]
17800	17300	16800	16600	16300	13750	13150	13150	12500	10000	6250	4000	2400									ASTM [illegible]	[illegible]
17500	17200	16700	16200	15600	15000	14700	14000	12500	10000	6200	4200	2750	1750	1200							ASTM A[illegible]	[illegible]
16500	15900	15200	15000	14700	13100	12800	12000	10350	7600	5600	4150	3050	2000	1300							ASTM [illegible]	[illegible]
16500	15900	15200	15000	14700	13100	12500	11500	9500	7000	5000	3500	2500	[illegible]	1200							ASTM [illegible]	[illegible]
16500	15900	15200	15000	14700	13100	12500	12500	12000	10800	8500	5500	3500	[illegible]	1500							ASTM [illegible]	[illegible]
17500	17200	16700	16200	15600	15200	15000	14500	12800	11000	7800	5500	4000	[illegible]	[illegible]							[illegible]	[illegible]
17500	17200	16700	16200	15600	15200	15000	14500	12500	11000	7500	5000	2400	[illegible]	[illegible]							ASTM [illegible]	[illegible]
17500	17200	16700	16200	15600	15200	15000	14000	12000	9000	7000	5500	4000	2700	1500							[illegible]	[illegible]
17500	17200	16700	16200	15600	15200	15000	[illegible]	12800	11000	7800	5800	4200	3000	2000							ASTM [illegible]	[illegible]

TABLE 1

[illegible]

Material	Specification	(27) Steel Making Process	(32) P No	Grade	Class	Factor (E)	Tensile Strength Min PSI	Yield Strength Min PSI	Notes	(26) Min Temp	Min Temp To 100	200	300
[illegible] DIATE ALLOY STEEL (Cont.)													
[illegible] Cast Pipe													
[illegible]	ASTM A426		3	CP1		1.00	55000	30000	3, 21	−20	183[illegible]	[illegible]	[illegible]
[illegible]	ASTM A426		3	CP2		1.00	55000	30000	3, 21	−20	18350	[illegible]	[illegible]
[illegible]	ASTM A426		5	CP5		1.00	60000	[illegible]	21	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A426		5	CP5b		1.00	60000	30000	21	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A426		5	CP7		1.00	60000	30000	21	−20	18750	17550	[illegible]
[illegible]	ASTM A426		5	CP9		1.00	60000	30000	21	−20	18750	[illegible]	[illegible]
[illegible]	ASTM A426		4	CP11		1.00	60000	30000	21	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A426		4	CP12		1.00	60000	30000	3, 21	−20	18750	[illegible]	[illegible]
[illegible]	ASTM A426		3	CP15		1.00	60000	30000	3, 21	−20	18750	[illegible]	[illegible]
[illegible]	ASTM A426		5	CP21		1.00	60000	30000	21	−20	18750	[illegible]	[illegible]
[illegible]	ASTM A426		5	CP22		1.00	60000	30000	21	−20	18750	[illegible]	[illegible]
[illegible] Seamless Welded Pipe													
[illegible]	ASTM A333		9B	3		.85	65000	35000		−150	[illegible]	17600	[illegible]
[illegible]	ASTM A333		9A	7		.85	65000	35000		−100	[illegible]		
[illegible]	ASTM A333		11A	8		.85	100000	75000		−320	[illegible]		
[illegible]	ASTM A333			9		.85	63000	46000		−100	[illegible]		
[illegible] Fusion Welded Pipe													
[illegible]	ASTM A155		3	CM65	2	.85	65000	37000	3	−20	15450	[illegible]	[illegible]
[illegible]	ASTM A155		3	CM70	[illegible]	.85	70000	40000	3	−20	[illegible]	[illegible]	[illegible]
[illegible]	ASTM A155		3	CM75	2	.85	75000	43000	3	−20	[illegible]	[illegible]	[illegible]
[illegible] Mo A387 GR A	ASTM A155		3	½ Cr	2	.85	55000	33000	3	−20	[illegible]	[illegible]	[illegible]
[illegible] Mo A387 GR B	ASTM A155		4	1 Cr	2	.85	55000	33000	3	−20	15550	[illegible]	[illegible]
[illegible] Mo A387 GR C	ASTM A155		4	1¼ Cr	2	.85	60000	35000		−20	17000	[illegible]	[illegible]
2¼ Cr [illegible] Mo A387 GR D	ASTM A155		5	2¼ Cr	2	.85	60000	30000		−20	17000	[illegible]	[illegible]
[illegible] A357	ASTM A155		5	5 Cr	2	.85	60000	30000		−20	17000	[illegible]	[illegible]
[illegible] A204 GR A	ASTM A155		3	CM65	2	.90	65000	37000	3, 17	−20	19550	[illegible]	[illegible]
C Mo A204 GR B	ASTM A155		3	CM70	2	.90	70000	40000	3, 17	−20	20950	[illegible]	[illegible]
C Mo A204 GR C	ASTM A155		3	CM75	2	.90	75000	43000	3, 17	−20	22500	[illegible]	[illegible]
½ Cr ½ Mo A387 GR A	ASTM A155		3	½ Cr	2	.90	55000	33000	3, 17	−20	[illegible]	[illegible]	[illegible]
1 Cr ½ Mo A387 GR B	ASTM A155		4	1 Cr	2	.90	55000	33000	3, 17	−20	[illegible]	[illegible]	[illegible]
1¼ Cr ½ Mo A387 GR C	ASTM A155		4	1¼ Cr	2	.90	60000	35000	17	−20	[illegible]	[illegible]	[illegible]
2¼ Cr 1 Mo A387 GR D	ASTM A155		5	2¼ Cr	2	.90	60000	30000	17	−20	18000	[illegible]	[illegible]
5 Cr ½ Mo A357	ASTM A155		5	5 Cr	2	.90	60000	30000	17	−20	[illegible]	[illegible]	[illegible]
C Mo A204 GR A	ASTM A155		3	CM65	1	.90	65000	37000	3	−20	[illegible]	[illegible]	[illegible]
C Mo A204 GR B	ASTM A155		3	CM70	1	1.00	70000	40000	3	−20	[illegible]	[illegible]	[illegible]
C Mo A204 GR C	ASTM A155		3	CM75	1	1.00	75000	43000	3	−20	[illegible]	[illegible]	[illegible]
½ Cr ½ Mo A387 GR A	ASTM A155		3	½ Cr	1	1.00	55000	33000	3	−20	18300	[illegible]	[illegible]
1 Cr ½ Mo A387 GR B	ASTM A155		4	1 Cr	1	1.00	55000	33000	3	−20	18300	[illegible]	[illegible]
1¼ Cr ½ Mo A387 GR C	ASTM A155		4	1¼ Cr	1	1.00	60000	35000		−20	20000	[illegible]	[illegible]
2¼ Cr 1 Mo A387 GR D	ASTM A155		5	2¼ Cr	1	1.00	60000	30000		−20	20000	[illegible]	[illegible]
5 Cr ½ Mo A357	ASTM A155		5	5 Cr	1	1.00	60000	30000		−20	20000	18200	[illegible]
Plates													
Cr Mn Si	ASTM A202		4	A			75000	45000		−20	25000	[illegible]	[illegible]
Cr Mn Si	ASTM A202		4	B			85000	47000		−20	28350	[illegible]	[illegible]
2¼ Ni	ASTM A203		9A	A			65000	37000	12	−20	21700	[illegible]	[illegible]
2¼ Ni	ASTM A203		9A	B			70000	40000	12	−20	23300	[illegible]	[illegible]
3½ Ni	ASTM A203		9B	D			65000	37000	12	−20	21700	[illegible]	[illegible]
3½ Ni	ASTM A203		9B	E			70000	40000	12	−20	[illegible]	[illegible]	[illegible]
C ½ Mo	ASTM A204		3	A			65000	37000	3	−20	21700	[illegible]	[illegible]
C ½ Mo	ASTM A204		3	B			70000	40000	3	−20	23300	[illegible]	[illegible]
C ½ Mo	ASTM A204		3	C			75000	43000	3	−20	[illegible]	[illegible]	[illegible]
Mn V	ASTM A225		10A	A			70000	40000		−20	23300	[illegible]	[illegible]
Mn V	ASTM A225		10A	B			75000	43000		−20	[illegible]	[illegible]	[illegible]
2¼ Ni	ASTM A593		9A	A203A	3		65000	37000	65	−75	21700	[illegible]	[illegible]
2¼ Ni	ASTM A593		9A	A203B	4		70000	40000	65	−75	23300	[illegible]	[illegible]
3½ Ni	ASTM A593		9B	A203D	3		65000	37000	65	−125	21700	[illegible]	[illegible]
3½ Ni	ASTM A593		9B	A203E	4		70000	40000	65	−125	23300	[illegible]	[illegible]
[illegible] Cu Al	ASTM A593		4	A410	3		60000	30000	65	−85	18750	[illegible]	[illegible]
Mn ½ Mo	ASTM A302		3	A			75000	45000	3	−20	[illegible]	[illegible]	[illegible]
Mn ½ Mo	ASTM A302		3	B			80000	50000	3	−20	[illegible]	[illegible]	[illegible]
Mn ½ Mo ½ Ni	ASTM A302		3	C			80000	50000		−20	26700	[illegible]	[illegible]
Mn ½ Mo ¾ Ni	ASTM A302		3	D			80000	50000		−20	[illegible]	[illegible]	[illegible]
9 Ni	ASTM A353	SG1	11A				100000	75000		−320	31350	[illegible]	[illegible]
5 Cr ½ Mo	ASTM A357		5				60000	30000		−20	[illegible]	[illegible]	[illegible]
½ Cr ½ Mo	ASTM A387		3	A			55000	33000	3	−20	18300	[illegible]	[illegible]
1 Cr ½ Mo	ASTM A387		4	B			55000	33000	3	−20	18300	[illegible]	[illegible]
1¼ Cr ½ Mo	ASTM A387		4	C			60000	35000		−20	[illegible]	[illegible]	[illegible]
2¼ Cr 1 Mo	ASTM A387		5	D			60000	30000		−20	[illegible]	[illegible]	[illegible]
5 Cr ½ Mo	ASTM A387		5	E			60000	30000		−20	[illegible]	[illegible]	[illegible]
[illegible] Cu Al	ASTM A410		4				60000	30000		−20	20000	[illegible]	[illegible]

TABLE 1

ALLOWABLE STRESSES [illegible] (CONTINUED)

(NUMBERS IN PARENTHESES REFER TO [illegible] NOTES — SEE [illegible])

ALLOWABLE STRESS [illegible]

Metal Temperature Degrees F (35)

LOW AND INTERMEDIATE ALLOY STEEL (Cont.)

Centrifugally Cast Pipe

400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification	Material
16300	15600	14900	14550	14200	13850	13500	13150	12500	10000	6250	4000	2400									ASTM A426	C ½ Mo
16300	15600	14900	14550	14200	13850	13500	13150	12500	10000	6250	4000	2400									ASTM A426	½ Cr ½ Mo
16700	15350	14300	14100	13650	13250	12300	12400	11500	10000	7100	5700	3300	2200	1500							ASTM A426	5 Cr ½ Mo
16700	15350	14500	14100	13650	13250	12800	12400	10900	9000	5500	3500	2500	1800	1200							ASTM A426	5 Cr ½ Mo [illegible]
[illegible]	15600	14450	14000	13550	13100	12500	11500	9500	7000	5000	3500	2500	1600	1200							ASTM A426	7 Cr ½ Mo
[illegible]	15450	14600	[illegible]	[illegible]	[illegible]	12950	12500	[illegible]	10800	8500	5500	3300	2700	1500							ASTM A426	9 Cr 1 Mo
17150	16600	16050	15800	15550	[illegible]	15000	[illegible]	13100	11000	7800	5500	4000	2500	1200							ASTM A426	1¼ Cr ½ Mo
[illegible]	[illegible]	[illegible]	[illegible]	17350	[illegible]	14750	[illegible]	13100	11000	7800	5000	2900	1550	1000							ASTM A426	1 Cr ½ Mo
[illegible]	[illegible]	15850	[illegible]	[illegible]	[illegible]	14400	[illegible]	12500	10000	6250	4000	2400									ASTM A426	[illegible] Si [illegible] Mo
[illegible]	[illegible]	15450	15150	[illegible]	[illegible]	13900	13200	12000	9000	7000	5500	4000	2700	[illegible]							ASTM A426	3 Cr 1 Mo
17150	16600	16050	15800	15500	[illegible]	15000	14400	13100	11000	7800	5500	4200	3000	2000							ASTM A426	2¼ Cr 1 Mo

Electric Resistance Welded Pipe

400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification	Material
[illegible]	[illegible]	[illegible]	13800	[illegible]	[illegible]	9700	7600	5500	3800	2150	1350	850									ASTM A333	[illegible]
																					ASTM A333	[illegible]
																					ASTM A333	[illegible]
																					ASTM A333	2 Ni 1 Cu

Electric Fusion Welded Pipe

400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification	Material
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13300	12250	10500	8500	5500	3300	2050									ASTM A155	C ½ Mo [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13350	12750	10350	9500	5300	3400	2050									ASTM A155	C ½ Mo [illegible]
[illegible]	[illegible]	[illegible]	20250	19500	[illegible]	[illegible]	[illegible]	11050	8500	5300	3400	2050									ASTM A155	C ½ Mo [illegible]
[illegible]	[illegible]	15850	15550	15450	14700	14450	11200	10400	8500	5300	3400	2050									ASTM A155	½ Cr ½ Mo [illegible]
[illegible]	[illegible]	15550	15150	14600	14200	13000	13500	11900	9350	6350	4250	2400	1300	850							ASTM A155	1 Cr ½ Mo A[illegible]
17000	[illegible]	16550	16050	15550	15070	14850	14150	12750	9350	6650	4650	3300	2100	1000							ASTM A155	1¼ Cr ½ Mo A[illegible]
[illegible]	[illegible]	[illegible]	13750	13250	[illegible]	12750	12300	10900	9350	6650	4050	3550	2550	1700							ASTM A155	[illegible]
[illegible]	[illegible]	12900	12750	[illegible]	11150	10900	10550	9750	8500	6200	4300	2800	1850	1250							ASTM A155	5 Cr ½ Mo [illegible]
[illegible]	[illegible]	18650	18350	[illegible]	14500	14100	12950	11250	9000	5600	3600	2150									ASTM A155	C [illegible]
[illegible]	[illegible]	20150	19600	19550	[illegible]	15200	13500	11450	9000	5600	3600	2150									ASTM A155	C [illegible] A201 [illegible]
[illegible]	[illegible]	21700	21400	20950	16950	16200	14300	11700	9000	5600	3600	2150									ASTM A155	C [illegible] A201 [illegible]
[illegible]	[illegible]	[illegible]	16150	[illegible]	12400	12100	11850	11250	9000	5550	3600	2150									ASTM A155	[illegible]
[illegible]	[illegible]	16450	16000	15500	15050	14350	14300	12600	9900	6750	4500	2500	1400	900							ASTM A155	1 Cr ½ Mo [illegible]
[illegible]	18000	17550	17000	16450	15950	15750	15200	13500	9900	7000	4950	3600	2250	1100							ASTM A155	1¼ Cr ½ Mo [illegible]
[illegible]	[illegible]	15050	14600	14050	13700	13500	13050	11500	9900	7000	5200	3800	2700	1800							ASTM A155	2¼ Cr 1 Mo [illegible]
[illegible]	[illegible]	13700	13500	13250	11800	11500	11150	10350	9000	6550	4700	2950	2000	1350							ASTM A155	5 Cr ½ Mo A357
[illegible]	21300	20700	20400	20600	16250	15650	14400	12500	10000	6250	4000	2400									ASTM A155	C ½ Mo A204 [illegible]
[illegible]	[illegible]	22400	22100	21700	17500	16900	15000	12750	10000	6250	4000	2400									ASTM A155	C ½ Mo A204 [illegible]
[illegible]	24600	24100	23300	23300	18750	18600	15900	13000	10000	6250	4000	2400									ASTM A155	C ½ Mo A204 [illegible]
[illegible]	18300	18300	18300	18200	13750	13450	13150	12500	10000	6250	4000	2400									ASTM A155	½ Cr ½ Mo A387 Gr A
[illegible]	19300	18300	17800	17200	16700	16500	15900	14000	11000	7500	5000	2800	1550	1000							ASTM A155	1 Cr ½ Mo A387 Gr [illegible]
[illegible]	20000	19500	18900	18300	17700	17500	16900	15000	11000	7800	5500	4000	2500	1200							ASTM A155	1¼ Cr ½ Mo A387 Gr [illegible]
17500	17200	16700	16200	15600	15200	15000	14500	12600	11000	7800	5800	4200	3000	2000							ASTM A155	2¼ Cr 1 Mo A387 Gr [illegible]
16500	15900	15200	15000	14700	13100	12800	12400	11500	10000	7300	5200	3300	2200	1500							ASTM A155	5 Cr ½ Mo A357

Plates

400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification	Material
[illegible]	[illegible]	19300	18750	[illegible]	15650	12600	9550	6500	4500	2500	1600	1000									ASTM A202	Cr Mn Si
[illegible]	23200	21900	21250	[illegible]	17700	17800	9900	6500	4500	2500	1600	1000									ASTM A202	Cr Mn Si
[illegible]	[illegible]	16250	16250	[illegible]	13850	11100	8950	6500	4500	2500	1600	1000									ASTM A203	2¼ Ni
17500	17500	17500	17500	16600	14750	12000	9250	6500	4500	2500	1600	1000									ASTM A203	2¼ Ni
[illegible]	16250	16250	16250	15500	13850	11400	8950	6500	4500	2500	1600	1000									ASTM A203	3½ Ni
[illegible]	[illegible]	17500	17500	16600	14750	12000	9250	6500	4500	2500	1600	1000									ASTM A203	3½ Ni
[illegible]	21300	20700	20400	20000	16250	15650	14400	12500	10000	6250	4000	2400									ASTM A204	C ½ Mo
[illegible]	[illegible]	22400	22100	21700	17500	16900	15000	12750	10000	[illegible]	4000	2400									ASTM A204	C ½ Mo
[illegible]	24500	24100	23800	[illegible]	17500	16900	15000	12750	[illegible]	6250	4000	2400									ASTM A204	C ½ Mo
20650	19750	18850	18400	17950	17500																ASTM A225	Mn-V
[illegible]	[illegible]	20200	19700	19250	18750																ASTM A225	Mn V
[illegible]	[illegible]	16250	16250	15500	13850	11400	8950	6500	4500	2500	1600	1000									ASTM A353	2¼ Ni
[illegible]	17500	17500	17500	16600	14750	12000	9250	6500	4500	2500	1600	1000									ASTM A393	2¼ Ni
[illegible]	[illegible]	16250	16250	15500	13850	11400	8950	6500	4500	2500	1600	1000									ASTM A393	3½ Ni
[illegible]	[illegible]	[illegible]	17500	[illegible]	14750	12000	9250	6500	4500	2500	1600	1000									ASTM A393	3½ Ni
16700	16000	15350	15000																		ASTM A393	Ni Cr ½ Mo [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18750	18000	15900	13000	10000	6250	4000	2400									ASTM A302	Mn Mo
[illegible]	[illegible]	[illegible]	26700	[illegible]	20000	19100	16800	13250	10000	6250	4000	2400									ASTM A302	Mn Mo
[illegible]	26700	26700	26700	26700																	ASTM A302	Mn Mo Ni
[illegible]	26700	26700	26700	26700																	ASTM A302	Mn [illegible] Ni
[illegible]	[illegible]	23550	23200																		ASTM A[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	15000	14700	13100	12800	12000	10350	7600	5600	4150	3050	2000	1300							ASTM A357	5 Cr ½ Mo
[illegible]	[illegible]	[illegible]	18300	15200																	ASTM A357	[illegible]
[illegible]	[illegible]	[illegible]	17800	17200	16700	16500	15900	14000	11000	7500	5000	2800	1550	1000							ASTM A387	1 Cr ½ Mo
20600	[illegible]	19500	18900	[illegible]	17700	17500	16900	15000	11000	7800	5500	4000	2500	1200							ASTM A387	1¼ Cr ½ Mo
[illegible]	17200	16700	16200	15600	15200	15000	14700	12500	11000	7800	5800	4200	3000	2000							ASTM A387	2¼ Cr 1 Mo
17500	17200	16700	16200	15600	15200	15000	14300	12000	9000	7000	5500	4000	2700	1500							ASTM A387	3 Cr 1 Mo
17700	16000	15350	15000																		ASTM A410	Ni Cr Cu Al

TABLE 1

ALLOWABLE [illegible] STRESSES [illegible] FOR [illegible] (14, 33, 47)

[illegible]

Material	Specification	(29) Steel Making Process	(57) "P" No	Grade	Class	Factor (E)	Tensile Strength Min PSI	Yield Strength Min PSI	Notes	(2) Min Temp	Max Temp To 100	[illegible]
[illegible] INTERMEDIATE ALLOY STEEL (Cont.)												
[illegible] Fittings												
[illegible]	ASTM A182		3	F1			70000	40000	3, 9	−20	23300	[illegible]
[illegible] Mo	ASTM A182		5	F2			60000	30000	9	−20	20000	[illegible]
[illegible]	ASTM A182		5	F5a			90000	65000	9	−20	30000	[illegible]
[illegible]	ASTM A182		6	F6			85000	55000	9, 28	−20	28300	[illegible]
[illegible]	ASTM A182		5	F7			60000	36000	9	−20	20000	[illegible]
[illegible]	ASTM A182		5	F9			100000	70000	9	−20	33300	[illegible]
[illegible]	ASTM A182		4	F11			70000	40000	9	−20	23300	[illegible]
[illegible]	ASTM A182		4	F12			70000	40000	3, 9	−20	23300	[illegible]
[illegible]	ASTM A182		5	F21			70000	40000	9	−20	23300	[illegible]
[illegible]	ASTM A182		5	F22			70000	40000	9	−20	23300	[illegible]
[illegible]	ASTM A234		3	WP1			55000	30000	3, 13, 49	−20	18300	[illegible]
[illegible]	ASTM A234		5	WP5			60000	30000	13, 49	−20	20000	[illegible]
[illegible]	ASTM A234		4	WP11			60000	30000	13, 49	−20	20000	[illegible]
[illegible]	ASTM A234		4	WP12			60000	30000	3, 13, 49	−20	20000	[illegible]
[illegible]	ASTM A234		5	WP22			60000	30000	13, 49	−20	20000	[illegible]
[illegible]	ASTM A350		9B	LF3			70000	40000	9	−150	23300	[illegible]
[illegible]	ASTM A350		4	LF4			60000	30000	9, 13	−150	20000	[illegible]
[illegible]	ASTM A420		9B	WPL3			65000	35000	13	−150	[illegible]	[illegible]
[illegible]	ASTM A420		4	WPL4			60000	35000	13	−150	[illegible]	[illegible]
[illegible]												
[illegible]	ASTM A217		3	WC1		80	65000	35000	3, 9, 22	−20	[illegible]	[illegible]
[illegible]	ASTM A217		4	WC4		80	70000	40000	3, 9, 22	−20	[illegible]	[illegible]
[illegible]	ASTM A217		4	WC5		80	70000	40000	3, 9, 22	−20	[illegible]	[illegible]
[illegible]	ASTM A217		4	WC6		80	70000	40000	9, 22	−20	[illegible]	[illegible]
[illegible]	ASTM A217		5	WC9		80	70000	40000	9, 22	−20	[illegible]	[illegible]
[illegible]	ASTM A217		5	C5		80	90000	60000	9, 22	−20	[illegible]	[illegible]
[illegible]	ASTM A217		5	C12		80	90000	60000	9, 22	−20	[illegible]	[illegible]
[illegible]	ASTM A352		3	LC1		80	65000	35000	3, 9, 22	−75	[illegible]	[illegible]
[illegible]	ASTM A352		9A	LC2		80	65000	40000	9, 22	−100	[illegible]	[illegible]
[illegible]	ASTM A352		9B	LC3		80	65000	40000	9, 22	−150	[illegible]	[illegible]
[illegible] STEEL (40) [illegible]									40			
[illegible] Pipe and Tubes												
[illegible] Tubes	ASTM A268	EF	10E	TP329			90000	70000	28	−20	30000	[illegible]
[illegible]	ASTM A268	EF	7	TP405			60000	30000	28	−20	20000	[illegible]
[illegible]	ASTM A268	EF	6	TP409			60000	30000	28	−20	[illegible]	[illegible]
[illegible]	ASTM A268	EF	6	TP410			60000	30000	28	−20	[illegible]	[illegible]
[illegible]	ASTM A268	EF	7	TP430			60000	35000	28, 38	−20	[illegible]	[illegible]
[illegible]	ASTM A268	EF	7	TP430-Ti			60000	30000	28, 38	−20	[illegible]	[illegible]
[illegible]	ASTM A268	EF	10	TP443			70000	40000	28	−20	[illegible]	[illegible]
[illegible]	ASTM A268	EF	10E	TP446			70000	40000	28	−20	[illegible]	[illegible]
[illegible]	ASTM A312	EF	8	TP304			75000	30000	6a, 20, 23, 30	−425	[illegible]	[illegible]
[illegible] Pipe	ASTM A312	EF	8	TP304H			75000	30000	23	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A312	EF	8	TP304L			70000	25000		−425	[illegible]	[illegible]
[illegible] Pipe	ASTM A312	EF	8	TP309			75000	30000	28, 41, 52	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A312	EF	8	TP310			75000	30000	6, 28, 41, 52	−325	[illegible]	[illegible]
[illegible]	ASTM A312	EF	8	TP310			75000	30000	6, 28, 41, 52	−325	[illegible]	[illegible]
[illegible] 2 Mo Pipe	ASTM A312	EF	8	TP316			75000	30000	20	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A312	EF	8	TP316H			75000	30000	23	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A312	EF	8	TP316L			70000	25000		−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A312	EF	8	TP317			75000	30000	20, 23	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A312	EF	8	TP321			75000	30000	6a, 20	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A312	EF	8	TP321H			75000	30000		−325	[illegible]	[illegible]
[illegible] Cb Pipe	ASTM A312	EF	8	TP347			75000	30000	6a, 20	−425	[illegible]	[illegible]
[illegible] Cb Pipe	ASTM A312	EF	8	TP347H			75000	30000		−325	[illegible]	[illegible]
[illegible] Cb Pipe	ASTM A312	EF	8	TP348			75000	30000	6a, 20	−325	[illegible]	[illegible]
[illegible] Cb Pipe	ASTM A312	EF	8	TP348H			75000	30000		−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A376	EF	8	TP304			75000	30000	6b, 20, 23, 30, 36	−425	[illegible]	[illegible]
[illegible] Pipe	ASTM A376	EF	8	TP304H			75000	30000	23	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A376	EF	8	TP316			75000	30000	6b, 20, 23, 36	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A376	EF	8	TP316H			75000	30000	23	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A376	EF	8	TP321			75000	30000	6a, 20, 36	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A376	EF	8	TP321H			75000	30000		−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A376	EF	8	TP347			75000	30000	6a, 20, 36	−425	[illegible]	[illegible]
[illegible] Pipe	ASTM A376	EF	8	TP347H			75000	30000		−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A376	EF	8	TP348			75000	30000	6a, 20, 36	−325	[illegible]	[illegible]
[illegible] 2Mo Pipe	ASTM A376	EF	8	16-8-2H			75000	30000	6b, 23, 12	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A430	EF	8	FP304			70000	30000	6b, 23, 36	−425	[illegible]	[illegible]
[illegible] Pipe	ASTM A430	EF	8	FP304H			70000	30000	23, 36	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A430	EF	8	FP316			70000	30000	6b, 23, 36	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A430	EF	8	FP316H			70000	30000	23, 36	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A430	EF	8	FP321			70000	30000	6a, 36	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A430	EF	8	FP321H			70000	30000	36	−325	[illegible]	[illegible]
[illegible] Cb Pipe	ASTM A430	EF	8	FP347			70000	30000	6a, 36	−425	[illegible]	[illegible]
[illegible] Pipe	ASTM A430	EF	8	FP347H			70000	30000	36	−325	[illegible]	[illegible]
[illegible] 2Mo Pipe	ASTM A430	EF	8	FP 16-8-2H			70000	30000	6b, 23, 36	−325	[illegible]	[illegible]
Centrifugally Cast Pipe												
[illegible]	ASTM A451		8	CPF8		90	70000	[illegible]	20, 22, 23	−425	[illegible]	[illegible]
[illegible] 2Mo	ASTM A451		8	CPF8M		90	70000	[illegible]	20, 22, 23	[illegible]	[illegible]	[illegible]
[illegible] Cb	ASTM A451		8	CPF8C		90	70000	30000	6a, 20, 22	−325	[illegible]	[illegible]
[illegible] 2Mo Cb	ASTM A451		8	CPF10MC		90	70000	30000	6a, 12, 20, 22	−325	[illegible]	[illegible]
[illegible]	ASTM A451		8	CPH8		90	65000	28000	12, 20, 22, 26	−325	[illegible]	[illegible]

For shaded areas see Note 4

ALLOWABLE STRESSES IN TENSION FOR MATERIALS (1, 10, 36)

(NUMBERS IN PARENTHESIS REFER TO STRESS TABLE NOTES SEE PAGES 72 THROUGH 75)

ALLOWABLE STRESSES ST [illegible] (36)

Metal Temperature in Degrees F (35)

400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification	Material
																						LOW AND INTERMEDIATE ALLOY STEEL (...)
																						Forgings and Fittings
23300	23000	[illegible]	22130	21700	17500	16900	15000	12750	13000	6250	4000	2400									ASTM A182	C-½Mo
16300	15400	15200	[illegible]	[illegible]	13100	12800	12000	10350	7500	[illegible]	4150	3050	2000	1300							ASTM A182	5Cr-½Mo
24050	22100	20700	[illegible]	17500	16000	14500	12800	10350	7600	[illegible]	4150	3050	2000	1300							ASTM A182	5Cr-½Mo
18850	[illegible]	17600	[illegible]	17100	16550	15700	11400	12300	8800	6400	4400	2900	1750	1000							ASTM A182	13Cr
[illegible]	18500	[illegible]	[illegible]	17600	13200	12500	11500	9500	7000	5000	3500	2500	1800	1700							ASTM A182	7Cr-½Mo
[illegible]	25200	[illegible]	22200	[illegible]	20000	17700	15400	13100	10800	8500	5500	[illegible]	2200	1500							ASTM A182	9Cr-1Mo
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15500	15000	14300	13100	11000	[illegible]	5500	4000	2500	1700							[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15500	13850	17200	13100	11100	7500	5000	2900	1550	1000							ASTM A182	1Cr-½Mo
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17000	13000	13700	12000	9000	7000	5500	3000	2200	1500							ASTM A182	1Cr-½Mo
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17500	17500	17000	14000	11000	7000	5000	4200	3000	2000							ASTM A182	2¼Cr-1Mo
[illegible]	[illegible]	[illegible]	15600	15000	17500	13450	13150	12700	10000	6250	4000	2400									ASTM A234	C-½Mo
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17500	[illegible]	12000	10350	7600	[illegible]	4150	3050	2000	1300							ASTM A234	5Cr-½Mo
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14500	17500	11300	7500	5500	4000	2500	1700							ASTM A234	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15000	[illegible]	14500	17500	11000	7500	5000	2900	1550	1000							ASTM A234	1Cr-½Mo
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15300	13200	[illegible]	14300	12800	11000	7000	5000	4200	3000	2000						ASTM A234	2¼Cr-1Mo
[illegible]	[illegible]	15750	17500	16000	[illegible]	12000	9250	6500													ASTM A352	3½Ni
																					ASTM A350	Ni-Cr-Cu-Al
[illegible]	[illegible]	16700	16270	15500	[illegible]	14400	8950	6500	4500	2500	1600	1000									ASTM A420	3½Ni
[illegible]	[illegible]	[illegible]	[illegible]																		ASTM A420	Ni-Cr-Cu-Al
																						Castings
[illegible]	[illegible]	[illegible]	15450	[illegible]	13000	[illegible]	14500	10500	8000	5000	3200	1900									ASTM A217	C-½Mo
[illegible]	17650	[illegible]	[illegible]	17000	14000	13600	12650	11700	8000	5000	3200	1900									ASTM A217	Ni-Cr-½Mo
[illegible]	[illegible]	17850	17300	[illegible]	[illegible]	[illegible]	12650	11290	8800	6250	4400	3200									ASTM A217	Ni-Cr-1Mo
[illegible]	[illegible]	17550	17300	16750	14650	13600	12650	11200	8800	6250	4400	3200	2000	950							ASTM A217	1¼Cr-½Mo
[illegible]	16300	16650	17500	16750	14600	13500	12650	11200	8500	6250	4650	3360	2400	1600							ASTM A217	2¼Cr-1Mo
[illegible]	18600	16000	16900	17300	16250	15200	14600	8300	6100	4700	3300	2450	1600	1050							ASTM A217	5Cr-½Mo
[illegible]	15600	[illegible]	[illegible]	17600	16800	13550	13850	12000	8600	6500	4400	2650	1760	1200							ASTM A217	9Cr-1Mo
[illegible]	[illegible]	[illegible]	15350	15200	13000	12500	11500	10000	8000	5000	3200	1900									ASTM A352	C-½Mo
[illegible]	14200	[illegible]	13900																		ASTM A352	2½Ni
14950	[illegible]	13400	13300																		ASTM A352	3½Ni
																						STAINLESS STEEL (...)
																						Seamless Pipe and Tubes
																					ASTM A268	26Cr-1Mo Tubes
[illegible]	17400	16600	16600	16500	11650	11100	10400	9650	8400	6000											ASTM A268	[illegible] Tubes
																					ASTM A268	[illegible] Tubes
[illegible]	17400	16800	16600	16500	11650	11100	10400	9650	8400	6400	4400	2900	1750	1000							ASTM A268	13Cr Tubes
17800	17400	16300	16600	16500	11650	11100	10400	9650	8500	6500	4500	3200	2400	1750							ASTM A268	15Cr Tubes
																					ASTM A268	18Cr Ti Tubes
[illegible]	19300	18450	15000	17500	16900	16200	15100	13000	6800	4500											ASTM A268	20Cr Tubes
[illegible]	19450	18450	15000	17500	16900	16200	15100	13000	6800	[illegible]											ASTM A268	27Cr Tubes
19700	17150	16400	16150	15950	15550	15150	14900	14650	14350	13750	12150	9750	7700	6050	4700	3700	2900	2300	[illegible]	1400	ASTM A312	18Cr 8Ni Pipe
[illegible]	17450	16400	16150	15950	15550	15150	14900	14650	14350	13750	12150	9750	7700	6050	4700	3700	2900	2300	[illegible]	1400	ASTM A312	18Cr 8Ni Pipe
15750	14350	[illegible]	12700	13450	13200	13000	12900	11900	[illegible]	7300	6300	5100	4000	3250	2600	2100	1700	1100	1000	900	ASTM A312	18Cr 8Ni Pipe
[illegible]	20600	19200	[illegible]	18300	[illegible]	17500	14600	11850	12500	10500	8500	6500	5000	3800	2900	2300	1750	1300	950	750	ASTM A312	25Cr-12Ni Pipe
[illegible]	20000	[illegible]	[illegible]	15500	15000	17200	14600	13350	12500	12000	7100	5500	3600	2500	1450	750	450	350	250	200	ASTM A312	25Cr-20Ni Pipe
[illegible]	20000	19200	19000	[illegible]	18000	17200	11700	13850	12500	[illegible]	9750	8500	7250	6000	4750	3500	2350	1600	1100	750	ASTM A312	[illegible]
[illegible]	17950	17000	16650	[illegible]	16050	15300	15700	15550	15400	[illegible]	14500	12400	9000	7400	5450	4100	3050	2250	1700	1250	ASTM A312	16Cr-12Ni-2Mo Pipe
[illegible]	17350	[illegible]	16650	16300	[illegible]	15350	15700	15550	15400	15200	14500	12400	9500	7100	5450	4100	3050	2250	1700	1250	ASTM A312	16Cr-12Ni-2Mo Pipe
[illegible]	[illegible]	[illegible]	13200	12800	[illegible]	12350	12100	11700	11500	12200	10850	10250	8300	6400	4700	3500	2500	1850	1350	1000	ASTM A312	[illegible]
[illegible]	17350	17000	[illegible]	[illegible]	16050	15550	15700	15550	15400	15300	14500	12400	9500	7400	5450	4100	3050	2250	1700	1250	ASTM A312	[illegible]
[illegible]	17250	16300	[illegible]	[illegible]	15650	15450	15350	15250	15150	[illegible]	9600	6900	5000	3600	2550	1700	1100	750	500	300	ASTM A312	[illegible]
18600	17250	16350	[illegible]	[illegible]	15650	15450	15350	15250	15150	[illegible]	11700	9050	6500	5350	4100	3150	2450	1850	1450	1100	ASTM A312	[illegible]
[illegible]	19400	[illegible]	[illegible]	[illegible]	18150	18300	15400	11900	11800	14200	12100	9100	6100	4400	3300	2200	1500	1200	900	750	ASTM A312	[illegible]
[illegible]	19700	19500	[illegible]	[illegible]	[illegible]	18300	18200	18150	18100	[illegible]	17100	14250	10500	7900	5900	4350	3200	2450	1850	1300	ASTM A312	[illegible]
[illegible]	17700	[illegible]	[illegible]	18100	18450	[illegible]	15400	11900	14800	[illegible]	12100	9100	6100	4400	3300	2200	1500	1200	900	750	ASTM A312	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18150	[illegible]	15200	15150	18100	19250	17100	14250	10500	7900	5900	4350	3200	2450	1850	1300	ASTM A312	[illegible]
[illegible]	[illegible]	15810	15150	15950	15630	15150	14900	14650	14350	13750	12150	9750	7700	6050	4700	3700	2900	2300	1800	1400	ASTM A376	16Cr 8Ni Pipe
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15150	14900	14650	14350	13750	12150	9750	7700	6050	4700	3700	2900	2300	[illegible]	1400	ASTM A376	16Cr 8Ni Pipe
[illegible]	[illegible]	17000	[illegible]	[illegible]	[illegible]	[illegible]	15700	15550	15400	[illegible]	[illegible]	12400	9500	7400	5450	4100	3050	2250	1700	1250	ASTM A376	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15700	15550	15400	[illegible]	[illegible]	[illegible]	9500	7400	5450	4100	3050	2250	1700	1250	ASTM A376	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15630	15420	15350	15250	15150	[illegible]	9600	6900	5000	3600	2550	1700	1100	750	500	200	ASTM A376	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15650	15410	15350	15250	15150	[illegible]	11700	9050	6500	5350	4100	3150	2450	1350	1450	1100	ASTM A376	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18150	18300	15400	[illegible]	[illegible]	[illegible]	12100	9100	6100	4400	3300	2200	1500	1200	[illegible]	750	ASTM A376	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18150	18100	[illegible]	17100	14250	10500	7900	5900	4350	3200	2450	[illegible]	1300	ASTM A376	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15450	15300	15400	[illegible]	14800	[illegible]	12100	9100	6100	4400	3300	2200	1500	1200	900	750	ASTM A376	[illegible]
																					ASTM A376	[illegible]
[illegible]	17700	16400	[illegible]	[illegible]	15550	15150	14900	14650	14350	[illegible]	12150	9750	7700	6050	4700	3700	2900	[illegible]	[illegible]	1400	ASTM A451	18Cr 8Ni Pipe
[illegible]	17400	[illegible]	[illegible]	[illegible]	15550	15150	14900	14650	14350	13750	12150	9750	7700	6050	4700	3700	2900	2300	[illegible]	1400	ASTM A430	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15400	[illegible]	[illegible]	[illegible]	12400	9500	7400	5450	4100	3050	2250	1700	1250	ASTM A430	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15400	[illegible]	[illegible]	[illegible]	12400	9500	7400	5450	4100	3050	2250	1700	1250	ASTM A430	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15150	[illegible]	9600	6900	5000	3600	2550	1700	1100	750	500	300	ASTM A430	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15650	15450	15350	15250	15150	[illegible]	11700	9050	6900	5350	4100	3150	2450	1850	1450	1100	ASTM A430	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9100	6100	4400	3300	2200	1500	1200	[illegible]	750	ASTM A430	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10500	7900	5900	4350	3200	2450	[illegible]	[illegible]	1300	ASTM A430	[illegible]
																					ASTM A430	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ASTM A451	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ASTM A451	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11700	[illegible]	7200	4500	3150	2400	1800	1400	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	16200	15750	[illegible]	11100	14730	[illegible]	11250	[illegible]	[illegible]	7650	5350	4500	3350	2600	2100	1550	1200	[illegible]	700	ASTM A451	[illegible]

[illegible]

AP[illegible]X A

TABLE 1

ALLOWABLE STRESSES IN [illegible] FOR MATERIALS (4, 15, [illegible])

[illegible]

Material	Specification	(29) Steel Making Process	(37) "P" No.	Grade	Class	Factor (E)	Tensile Strength Min PSI	Yield Strength Min PSI	Notes	(26) Min Temp	[illegible] To 100	200
[illegible] (Cont)												
[illegible] (Cont)									40			
[illegible]	ASTM A351		8	[illegible] or [illegible]		.90	70000	30000	8, 12, 20, 22, 28, 41	−325	[illegible]	[illegible]
[illegible]	ASTM A351		8	[illegible]20		.90	65000	28000	20, 22, 28, 41	−325	[illegible]	[illegible]
[illegible]	ASTM A452		8	TP304H		.85	75000	30000	22, 23	−325	17000	[illegible]
[illegible]	ASTM A452		8	TP316H		.85	75000	30000	22, 23	−325	[illegible]	[illegible]
[illegible]	ASTM A452		8	TP347H		.85	75000	30000	22	−325	17000	[illegible]
[illegible] and Pipe and Tubes												
[illegible]	ASTM A268	EF	7	TP405		.85	60000	30000	23	−20	17000	[illegible]
[illegible]	ASTM A268	EF	6	TP409		.85	60000	30000	28	−20	[illegible]	
[illegible]	ASTM A268	EF	6	TP410		.85	60000	30000	2[illegible]	−20	17000	1625[illegible]
[illegible]	ASTM A268	EF	7	TP430		.85	60000	35000	23, 38	−20	17000	1625[illegible]
[illegible]	ASTM A268	EF		TP430 Ti		.85	60000	30000	28, 33	−20	[illegible]	
[illegible]	ASTM A268	EF	10	TP443		.85	70000	40000	2[illegible]	−20	[illegible]	[illegible]
[illegible]	ASTM A268	EF	10E	TP446		.85	70000	40000	2[illegible]	−20	[illegible]	[illegible]
[illegible] Tubes	ASTM A268	EF	10F	TP329		.85	90000	70000	28	−20	25500	
[illegible]	ASTM A312	EF	8	[illegible]		.85	75000	30000	20, 23	−325	[illegible]	[illegible]
[illegible]	ASTM A312	EF	8	TP304H		.85	75000	30000	23	−325	[illegible]	[illegible]
[illegible]	ASTM A312	EF	8	TP304H		.85	70000	25000		−325	[illegible]	
[illegible]	ASTM A312	EF	8	TP309		.85	75000	30000	28, 41, 52	−325	[illegible]	[illegible]
[illegible]	ASTM A312	EF	8	TP310		.85	75000	30000	6, 28, 41, 52	−325	[illegible]	[illegible]
[illegible]	ASTM A312	EF	8	TP310		.85	75000	30000	6, 28, 41, 52	−325	[illegible]	[illegible]
16Cr [illegible] Pipe	ASTM A312	EF	8	TP316		.85	75000	30000	20, 23	−325	17000	[illegible]
16Cr 12Ni Mo Pipe	ASTM A312	EF	8	TP316H		.85	75000	30000	23	−325	17000	[illegible]
[illegible]	ASTM A312	EF	8	TP316L		.85	70000	25000		−325	14[illegible]	[illegible]
[illegible] Pipe	ASTM A312	EF	8	TP317		.85	75000	30000	20, 23	−325	17000	[illegible]
[illegible]	ASTM A312	EF	8	TP321		.85	75000	30000	6a, 23	−325	17000	[illegible]
18Cr 10Ni Ti Pipe	ASTM A312	EF	8	TP321H		.85	75000	30000		−325	17000	[illegible]
[illegible]	ASTM A312	EF	8	TP347		.85	75000	30000	6a, 20	−425	17000	17[illegible]
[illegible] Pipe	ASTM A312	EF	8	TP347H		.85	75000	30000		−325	17000	[illegible]
[illegible]	ASTM A312	EF	8	TP348		.85	75000	30000	6a, 20	−325	[illegible]	[illegible]
[illegible] Pipe	ASTM A312	EF	8	TP348H		.85	75000	30000		−325	[illegible]	[illegible]
Type 304 A240	ASTM A358	EF	8	304	2	.85	75000	30000	6b, 20, 23, 36	−425	17000	[illegible]
Type 316 A240	ASTM A358	EF	8	316	2	.85	75000	30000	6b, 20, 23, 36	−325	17000	[illegible]
Type 347 A240	ASTM A358	EF	8	347	2	.85	75000	30000	6a, 20, 36	−425	[illegible]	[illegible]
Type 321 A240	ASTM A358	EF	8	321	2	.85	75000	30000	6a, 20, 36	−325	17000	[illegible]
Type 309S A240	ASTM A358	EF	8	309S	2	.85	75000	30000	6b, 28, 36, 52	−325	[illegible]	[illegible]
Type 310S A240	ASTM A358	EF	8	310S	2	.85	75000	30000	6, 28, 36, 52	−325	17[illegible]	[illegible]
Type 316 A240	ASTM A358	EF	8	310S	2	.85	75000	30000	6, 28, 36, 52	−325	17[illegible]	[illegible]
Type 348 A240	ASTM A358	EF	8	348	2	.85	75000	30000	6a, 20, 36	−325	[illegible]	[illegible]
Type 304 A240	ASTM A358	EF	8	304		.90	75000	30000	6b, 17, 20, 23, 36	−425	[illegible]	[illegible]
Type 316 A240	ASTM A358	EF	8	316		.90	75000	30000	6b, 17, 20, 23, 36	−325	15[illegible]	[illegible]
Type 347 A240	ASTM A358	EF	8	347		.90	75000	30000	6a, 17, 20, 36	−425	15000	[illegible]
Type 321 A240	ASTM A358	EF	8	321		.90	75000	30000	6a, 17, 20, 36	−325	15[illegible]	
Type 309S A240	ASTM A358	EF	8	309S		.90	75000	30000	6b, 17, 28, 36, 52	−325	15[illegible]	
Type 310S A240	ASTM A358	EF	8	310S		.90	75000	30000	6, 17, 28, 36, 52	−325	[illegible]	[illegible]
Type 310S A240	ASTM A358	EF	8	310S		.90	75000	30000	6, 17, 28, 36, 52	−325	15[illegible]	
Type 348 A240	ASTM A358	EF	8	348		.90	75000	30000	6a, 17, 20, 36	−325	15300	[illegible]
Type 304 A240	ASTM A358	EF	8	304	1	1.00	75000	30000	6b, 20, 23, 36	−425	20000	[illegible]
Type 316 A240	ASTM A358	EF	8	316	1	1.00	75000	30000	6b, 20, 23, 36	−325	[illegible]	[illegible]
Type 347 A240	ASTM A358	EF	8	347	1	1.00	75000	30000	6a, 20, 36	−425	[illegible]	[illegible]
Type 321 A240	ASTM A358	EF	8	321	1	1.00	75000	30000	6a, 20, 36	−325	20[illegible]	[illegible]
Type 309 A240	ASTM A358	EF	8	309S	1	1.00	75000	30000	6a, 28, 36, 52	−325	[illegible]	[illegible]
Type 310 A240	ASTM A358	EF	8	310S	1	1.00	75000	30000	6, 28, 36, 52	−325	[illegible]	[illegible]
Type 310 A240	ASTM A358	EF	8	310	1	1.00	75000	30000	6, 28, 36, 52	−325	[illegible]	[illegible]
Type 348 A240	ASTM A358	EF	8	348	1	1.00	75000	30000	6a, 20, 36	−325	20[illegible]	[illegible]
[illegible] 8Ni Pipe	ASTM A409	EF	8	TP304		.85	75000	30000	6b, 20, 23, 36	−425	[illegible]	[illegible]
23Cr 12Ni Pipe	ASTM A409	EF	8	TP309		.85	75000	30000	6b, 28, 36, 41, 52	−325	17000	[illegible]
25Cr 20Ni Pipe	ASTM A409	EF	8	TP310		.85	75000	30000	6b, 28, 36, 41, 52	−325	[illegible]	[illegible]
18Cr 10Ni Ti Pipe	ASTM A409	EF	8	TP321		.85	75000	30000	6a, 20, 36	−325	17000	[illegible]
18Cr 10Ni Cb Pipe	ASTM A409	EF	8	TP347		.85	75000	30000	6a, 20, 36	−425	[illegible]	[illegible]
16Cr 12Ni 2Mo Pipe	ASTM A409	EF	8	TP316		.85	75000	30000	6b, 20, 23, 36	−325	[illegible]	17[illegible]
18Cr 13Ni 3Mo Pipe	ASTM A409	EF	8	TP317		.85	75000	30000	6b, 20, 23, 36	−325	17000	[illegible]
18Cr 10Ni Cb Pipe	ASTM A409	EF	8	TP348		.85	75000	30000	6a, 20, 36	−325	17000	1700[illegible]
Plates and Sheets												
16Cr 6Ni	ASTM A167	EA or EL	8	301			75000	30000	6b, 12, 23	−325	[illegible]	[illegible]
18Cr 8Ni	ASTM A167	EA or EL	8	302			75000	30000	6b, 12, 20, 23	−325	20000	[illegible]
18Cr 8Ni	ASTM A167	EA or EL	8	302B			75000	30000	6b, 12, 20, 23	−325	[illegible]	
18Cr 8Ni	ASTM A167	EA or EL	8	304			75000	30000	6b, 20, 23, 36	−425	[illegible]	[illegible]
18Cr 8Ni	ASTM A167	EA or EL	8	304L			70000	25000	36	−425	16000	[illegible]
18Cr 10Ni	ASTM A167	EA or EL	8	305			70000	25000	6b, 12, 23	−325	16700	
20Cr 10Ni	ASTM A167	EA or EL	8	308			75000	30000	6b, 23, 36	−325	20000	[illegible]
23Cr 12Ni	ASTM A167	EA or EL	8	309			75000	30000	6b, 12, 28, 52	−325	20000	[illegible]
23Cr 12Ni	ASTM A167	EA or EL	8	309S			75000	30000	6b, 28, 36, 52	−325	[illegible]	
25Cr 20Ni	ASTM A167	EA or EL	8	310			75000	30000	6, 12, 28, 52	−325	[illegible]	
25Cr 20Ni	ASTM A167	EA or EL	8	310			75000	30000	6, 12, 28, 52	−325	[illegible]	
25Cr 20Ni	ASTM A167	EA or EL	8	310S			75000	30000	6b, 28, 36, 52	−325	[illegible]	
16Cr 12Ni 2Mo	ASTM A167	EA or EL	8	316			75000	30000	6b, 20, 23, 36	−325	[illegible]	
16Cr 12Ni 2Mo	ASTM A167	EA or EL	8	316L			70000	25000	36	−325	[illegible]	
18Cr 13Ni 3Mo	ASTM A167	EA or EL	8	317			75000	30000	6b, 20, 23, 36	−325	20[illegible]	

[illegible] See Note [illegible]

ALLOWABLE STRESSES ... [illegible]

NUMBERS IN PARENTHESES REFER TO ... [illegible]

ALLOWABLE STRESSES ... [illegible]

Metal Temperature Degrees F (35)

400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification	[illegible]
																					STAINLESS STEELS [illegible] Centrifugally Cast Pipe	
18000	15000	17350	16600	16300	16200	15750	12250	12000	11250	9450	7650	5850	4500	3350	2600	2100	1550	1200	800	700	ASTM A451	[illegible]
[illegible]	16500	16200	15750	15400	15100	14700	11500	11250	10700	9900	9800	7650	6550	5100	4300	3150	2150	1350	1000	700	ASTM A451	[illegible]
15300	14850	14050	13850	13550	13200	12850	12700	12450	12700	11700	10300	8300	6500	5150	4000	3150	2150	1950	1500	1200	ASTM A452	[illegible]
16400	15300	14400	13700	13850	13600	13500	13350	13300	13100	13000	12300	10500	8350	6300	4600	3500	2600	1350	1450	1050	ASTM A452	[illegible]
17200	16900	16900	16100	15800	15700	15550	15450	15400	15100	15350	14550	12100	8950	6700	5000	3700	2700	2100	1550	1100	ASTM A452	[illegible]
																					Electric Fusion Welded Pipe and Tubes	
15450	14500	14300	[illegible]	13050	9900	9450	8850	8200	7150	3400											ASTM A[illegible]	[illegible]
																					ASTM A[illegible]	[illegible]
15150	[illegible]	14700	14100	[illegible]	9900	9450	8850	8200	7150	5450	3750	2450	1500	850							ASTM A265	[illegible]
15150	[illegible]	[illegible]	[illegible]	[illegible]	9900	9450	8550	8200	7200	5500	3650	2400	2050	1500							ASTM A268	[illegible]
																					ASTM A[illegible]	[illegible]
17550	16550	15700	15300	14900	14350	13750	12850	11050	3600	3200											ASTM A[illegible]	[illegible]
17350	16550	[illegible]	15300	14800	14350	13750	12850	11050	5500	3800											ASTM A2[illegible]	[illegible]
																					ASTM A265	[illegible]
[illegible]	[illegible]	14000	13550	13550	13200	12650	12700	12450	12200	[illegible]	10300	8300	6500	5150	4000	3150	2450	[illegible]	1500	1200	ASTM A[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	13850	13550	13200	12850	12700	12450	12200	11700	[illegible]	8300	6700	5150	4000	3150	2450	1950	1500	1200	ASTM A312	[illegible]
15400	13500	[illegible]	[illegible]	[illegible]	11750	[illegible]	10900	10000	[illegible]	6600	5350	4350	3400	2650	2200	1900	1450	[illegible]	850	720	ASTM A312	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7250	5550	4250	3350	2550	1950	1500	1100	750	650	ASTM A312	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9300	[illegible]	3750	3050	[illegible]	1250	650	350	300	200	[illegible]	ASTM A312	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9350	8300	7200	6150	5050	4000	3000	2000	1350	950	650	ASTM A312	[illegible]
[illegible]	[illegible]	[illegible]	14200	13850	[illegible]	[illegible]	13350	13300	13100	13000	12300	10500	8350	6300	4600	3500	2600	1950	1450	1050	ASTM A312	[illegible]
[illegible]	15200	[illegible]	14300	[illegible]	13600	13550	13350	13200	13100	13000	12300	10500	8350	6300	4600	3500	2600	1950	1450	1050	ASTM A312	[illegible]
[illegible]	12250	11950	11200	10850	10700	10600	10200	10050	9500	3500	9250	8700	7450	5450	4000	2950	2100	1600	1150	850	ASTM A312	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13600	13500	13350	13200	13100	13000	12300	10500	8350	6300	4600	3500	2600	1700	1450	1050	ASTM A312	[illegible]
15500	13700	13900	13650	13450	13300	13150	13050	12950	12900	11750	8150	5850	4250	3050	2150	1450	950	650	400	250	ASTM A312	[illegible]
15550	[illegible]	13900	13650	13450	13300	13150	13050	12900	12900	11900	9650	7700	5900	4550	3500	2700	2100	1550	1250	950	ASTM A312	[illegible]
17000	16300	16000	16100	15900	15700	15550	11100	10650	12350	[illegible]	10300	7750	5200	3750	2800	1850	1250	1000	750	650	ASTM A312	[illegible]
17000	16900	16400	[illegible]	15900	15700	15550	15450	15400	15300	15350	14550	12100	8950	6700	5000	3700	2700	2100	1550	1100	ASTM A312	[illegible]
17000	16550	16400	[illegible]	15900	15700	15550	14100	12650	12350	11900	10300	7750	5200	3750	2400	1850	1250	1000	750	650	ASTM A312	[illegible]
17000	16950	16400	16100	15900	15700	15550	15150	15400	15400	15350	14550	12100	8950	6700	5000	3700	2700	2100	1550	1100	ASTM A312	[illegible]
15900	14900	14300	13850	13650	13200	12850	12700	12450	12200	11700	10300	8300	6550	5150	4000	3150	2450	1950	1500	1200	ASTM A358	[illegible]
16400	15200	14400	14200	13850	13600	13500	13350	13200	13100	13000	12300	10500	8350	6300	4600	3500	2600	1950	1450	1050	ASTM A358	Type 316 A2[illegible]
17000	16950	16400	16100	15900	15700	15550	11100	10650	12350	11900	10100	7750	5200	3750	2600	1350	1250	1000	750	650	ASTM A358	Type [illegible]
15300	14200	13700	13650	13450	13300	13150	13050	12950	12900	11700	8150	5850	4250	3050	2150	1450	950	650	400	250	ASTM A358	Type [illegible]
17000	17000	16350	16000	15550	15300	14900	12400	11750	10650	8950	7250	5550	4250	3250	2450	1950	1500	1100	750	650	ASTM A358	Type [illegible]
17000	17000	16350	16000	15550	15300	14900	12400	11750	10650	9350	6000	4250	3050	2100	1250	650	350	300	200	150	ASTM A358	Type [illegible]
17000	17000	16350	16000	15550	15300	14900	12400	11750	10650	9350	8300	7200	6150	5050	4000	3000	2000	1350	950	650	ASTM A358	Type 310 [illegible]
17000	16950	16400	16100	15900	15700	15550	15100	12650	12350	11900	10300	7750	5200	3750	2800	1850	1250	1000	750	650	ASTM A358	Type [illegible]
16850	15700	14300	14550	14300	14000	13650	13300	13200	12900	12350	10950	8750	6950	5450	4250	3350	2600	2050	1600	1250	ASTM A358	Type 304 A2[illegible]
17300	16150	15300	15000	14650	14450	14250	14150	14000	13850	13750	13050	11150	8800	6650	4900	3700	2750	2000	1550	1100	ASTM A358	Type 316 A2[illegible]
18000	17900	17350	17050	16750	16600	16450	13350	13400	13050	12600	10300	8200	5500	3950	2950	2000	1350	1100	800	700	ASTM A358	Type 347 A2[illegible]
16750	15550	14700	14450	14200	14100	13900	13800	13700	13650	12550	8650	6200	4500	3250	2300	1550	1000	700	450	250	ASTM A358	Type 321 A[illegible]
18000	16000	17300	16900	16750	16200	15750	13150	13150	11250	9150	7650	5850	4500	3400	2600	2050	1550	1150	850	700	ASTM A358	Type [illegible]
18000	18000	17350	16300	16450	16200	15750	13150	12150	11250	9900	6400	4500	3750	2250	1300	700	400	300	200	200	ASTM A358	Type [illegible]
18000	16900	17300	16900	16450	16200	15750	13150	12150	11250	9900	8750	7650	6500	5400	4250	3150	2100	1450	1000	700	ASTM A358	Type 316 [illegible]
18000	17900	17350	17050	16750	16600	16450	13850	13100	13050	12600	10900	8200	5500	3950	2950	2000	1350	1100	800	700	ASTM A358	Type 348 A2[illegible]
18700	17450	15400	16250	15750	15550	15850	13900	13650	14350	13750	12150	9750	7700	6050	4700	3700	2900	2300	1800	14[illegible]	ASTM A358	Type 304 A2
17750	17050	17000	15650	16300	16050	15850	15700	15550	15100	15300	13500	12400	9800	7100	5150	4100	3050	2250	1700	1250	ASTM A358	Type 316 A2[illegible]
20000	19800	19300	18950	18600	18450	18300	15700	13700	13500	14000	12100	9100	6100	4100	3300	2200	1500	1200	900	[illegible]	ASTM A358	Type 347 [illegible]
[illegible]	17350	16650	16050	15800	15650	15450	15350	15350	15150	15500	9600	6900	5000	3600	2550	1700	1100	750	500	300	ASTM A358	Type [illegible]
20000	20000	19200	18900	18500	18000	17500	14600	13850	12500	10500	8500	6500	5000	3600	2500	2300	1750	1300	900	750	ASTM A3[illegible]	Type [illegible]
20000	20000	19200	18400	18300	18000	17500	14600	13850	12500	11000	7100	5000	3000	2500	1450	750	450	350	250	200	ASTM A3[illegible]	Type [illegible]
20000	20000	19200	18800	18500	18000	17500	14600	13850	12500	11000	9750	8500	7250	6000	4750	3500	2350	1600	1100	750	ASTM A3[illegible]	Type 310 [illegible]
20000	19950	19300	18950	18600	18450	18300	15400	13900	13500	14000	12100	9100	6100	4400	3300	2200	1500	1200	900	7[illegible]	ASTM A376	Type 348 [illegible]
15900	14950	14000	13850	13550	13200	12850	12700	12450	12200	11700	11200	8300	6500	5150	4000	3150	2450	1950	1500	1200	ASTM A409	[illegible]
17000	17000	16350	16000	15550	15300	14900	12400	11750	10650	8950	7250	5550	4250	3250	2450	1950	1500	1100	750	650	ASTM A409	[illegible]
	7700	16350	16000	15550	15300	14900	12400	11750	10650	9350	6000	4250	3050	2100	1250	650	350	300	200	150	ASTM A409	[illegible]
[illegible]	[illegible]	[illegible]	13650	13450	13200	13150	13050	12950	12900	11800	8150	5850	4250	3050	2200	1450	950	650	400	250	ASTM A409	[illegible]
[illegible]	[illegible]	[illegible]	16100	[illegible]	15700	15550	13100	12650	12350	11900	10300	7750	5200	3750	2300	1850	1250	1000	750	650	ASTM A409	[illegible]
16400	15200	14400	14200	[illegible]	[illegible]	13500	13350	13200	13100	13000	12300	10500	8350	6300	4600	3500	2600	1950	1450	1050	ASTM A409	[illegible]
16400	15200	14400	14200	[illegible]	13600	13500	13350	13200	13100	13000	12300	10500	8350	6300	4600	3500	2600	1950	1450	1050	ASTM A409	[illegible]
17000	16250	16400	16100	15900	15700	15550	13100	12650	12350	11900	10300	7750	5200	[illegible]	2800	1850	1250	1000	750	650	ASTM A430	[illegible]
																					[illegible] Tubes	
13650	12500	11600	11300	10900	10400																ASTM A[illegible]	[illegible]
18700	17450	16400	16150	15750	15550	15150	14900	14650	14350	13750											ASTM A[illegible]	[illegible]
18700	17450	16400	16150	15750	15550	15150	14900	14650	14350	13750											ASTM A[illegible]	[illegible]
18700	17450	[illegible]	16150	15750	15550	15150	14900	14650	14350	13750	12150	9750	7700	6050	4700	3700	2400	2300	1500	14[illegible]	ASTM A[illegible]	[illegible]
15750	14750	13750	13700	13450	13250	13000	12800	11900	9900	7800	6300	5100	4000	3250	2600	2100	1700	1100	1000	900	ASTM A[illegible]	[illegible]
																					ASTM A[illegible]	[illegible]
13650	12500	[illegible]	11200	10900	10400	10000	9700	9300	9100	8800	8500	7500	5750	4500	3500	2450	1800	1400	1000	750	ASTM A[illegible]	[illegible]
20000	20000	19000	18500	[illegible]	18000	17500	14600	13850	12500	10500	8500	6500	5000	3600	2500	2300	1750	1300	900	750	ASTM A[illegible]	[illegible]
20000	20000	19200	18400	18000	18000	17700	14600	13850	12500	10500	9500	6500	5000	3900	2500	2300	1750	1300	900	750	ASTM A[illegible]	[illegible]
20000	20000	19200	18400	18300	18000	17500	14600	13350	12500	15600	7100	5000	3600	2500	1450	750	450	350	250	200	ASTM A[illegible]	[illegible]
21000	20000	19200	18800	18300	18000	17500	14600	13850	12500	11000	9750	8500	7250	6000	4750	3500	2350	1600	1100	750	ASTM A[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19450	17350	[illegible]	[illegible]	[illegible]	16950	15850	13700	15550	15500	15500	13500	12400	9600	7400	5450	4100	3050	2250	1700	1250	ASTM A[illegible]	[illegible]

[illegible] shaded areas see Note 2

APPENDIX A

TABLE 1

ALLOWABLE STRESSES IN TENSION FOR [illegible]

(NUMBERS IN PARENTHESIS REFER TO STRESS TABLE NOTES [illegible] THROUGH 70)

Material	Specification	(29) Steel Making Process	(27) P No	Grade	Class	Factor (E)	Tensile Strength Min PSI	Yield Strength Min PSI	Notes	(20) Min Temp	Min Temp To 100
STAINLESS STEEL (4) (10) (Cont.)											
Plates and Sheets (Cont.)											
[illegible]	ASTM A167	EA or EL	8	317L			75000	30000	36	−325	[illegible]
[illegible]	ASTM A167	EA or EL	8	321			75000	30000	6a 20, 36	−325	[illegible]
18Cr [illegible]	ASTM A167	EA or EL	8	347			75000	30000	6a 20, 36	−425	[illegible]
[illegible] Cb	ASTM A167	EA or EL	8	348			75000	30000	6a, 20 36	−325	[illegible]
[illegible]	ASTM A240		8	302			75000	30000	6b, 12, 20, 23	−325	[illegible]
[illegible]	ASTM A240		8	304			75000	30000	6b 20, 23 36	−425	[illegible]
[illegible]	ASTM A240		8	304L			70000	25000	6b, 36	−425	[illegible]
[illegible]	ASTM A240		[illegible]	305			70000	25000	6b 12, 23	−325	[illegible]
[illegible]	ASTM A240		8	309S			75000	30000	6b, 2[illegible] 36 52	−325	[illegible]
[illegible]	ASTM A240		8	310S			75000	30000	6b 28 36 52	−325	[illegible]
[illegible]	ASTM A240		8	316			75000	30000	6b, 20 23, 36	−325	[illegible]
[illegible]	ASTM A240		8	316L			70000	25000	36	−325	[illegible]
[illegible]	ASTM A240		8	317			75000	30000	6a, 20 23, 36	−325	[illegible]
[illegible]	ASTM A240		8	317L			75000	30000	36	−325	[illegible]
[illegible]	ASTM A240		8	321			75000	30000	6a, 20, 36	−325	[illegible]
[illegible] Cb	ASTM A240		8	347			75000	30000	6a 20, 36	−425	[illegible]
[illegible] Cb	ASTM A240		8	348			75000	30000	6a, 20, 36	−325	[illegible]
[illegible]	ASTM A240		7	405			60000	25000	28	−20	[illegible]
[illegible]	ASTM A240		6	410			65000	30000	28	−20	[illegible]
[illegible]	ASTM A240		7	410S			60000	30000	28, 31	−20	[illegible]
[illegible]	ASTM A240		6	430A			65000	30000	28	−20	[illegible]
17Cr	ASTM A240		7	430B			65000	30000	28	−20	[illegible]
18Cr Ti Al	ASTM A240			XM8			5000	30000	28	−20	[illegible]
Forgings and Seamless Fittings											
[illegible]	ASTM A182		8	F304			5000	30000	9, 20, 23, 32	−425	[illegible]
[illegible]	ASTM A182		8	F304H			75000	30000	9, 23, 32	−325	[illegible]
[illegible] 8Ni	ASTM A182		8	F304L			5000	25000	9	−425	[illegible]
[illegible]	ASTM A182		8	F310			75000	30000	6, 9, 28, 41, 52	−425	[illegible]
25Cr 20Ni	ASTM A182		8	F310			75000	30000	6, 9, 28, 41 52	−425	[illegible]
[illegible]	ASTM A182		8	F316			75000	30000	9, 20, 23, 32	−325	[illegible]
[illegible]	ASTM A182		8	F316H			75000	30000	9, 23, 32	−325	[illegible]
[illegible] 12Ni 2Mo	ASTM A182		8	F316L			65000	25000	9	−325	[illegible]
[illegible] Ti	ASTM A182		8	F321			75000	30000	6a, 9, 20 32, 36	−325	[illegible]
[illegible] 10Ni Ti	ASTM A182		8	F321H			75000	30000	9, 32	−325	[illegible]
18Cr 10Ni Cb	ASTM A182		8	F347			75000	30000	6a 9, 20 32, 36	−425	[illegible]
[illegible] Cb	ASTM A182		8	F347H			75000	30000	9, 32	−325	[illegible]
18Cr 10Ni Cb	ASTM A182		8	F348			75000	30000	6a, 9, 20, 32, 36	−325	[illegible]
18Cr 10Ni Cb	ASTM A182		8	F348H			75000	30000	9, 32	−325	[illegible]
29Ni 8Cr	ASTM A182		8	F10			80000	30000	9, 12, 20, 23	−325	[illegible]
18Cr 8Ni	ASTM A403	Refer to	8	WP304			75000	30000	6b, 13, 20, 23, 24, 30	−425	20000
18Cr 8Ni	ASTM A403	Basic Material	8	WP304H			75000	30000	13, 23, 24	−325	20000
18Cr 8Ni	ASTM A403	Specification	8	WP304L			65000	25000	13, 24	−425	16650
23Cr 12Ni	ASTM A403	Listing in	8	WP309			75000	30000	13, 24 28, 41, 52	−325	[illegible]
25Cr 20Ni	ASTM A403	these Tables	8	WP310			75000	30000	6, 13 24, 28, 41, 52	−325	[illegible]
25Cr 20Ni	ASTM A403	Refer to	8	WP310			75000	30000	6, 13, 24, 28, 41, 52	−325	[illegible]
16Cr 12Ni 2Mo	ASTM A403	Basic Material	8	WP316			75000	30000	6b, 13, 20, 23, 24	−325	[illegible]
16Cr 12Ni 2Mo	ASTM A403	Specification	8	WP316H			75000	30000	13, 23, 24	−325	[illegible]
16Cr 12Ni 2Mo	ASTM A403	Listing in	8	WP316L			65000	25000	13, 24	−325	[illegible]
18Cr 13Ni 3Mo	ASTM A403	these Tables	8	WP317			75000	30000	6b, 13, 20, 23, 24	−325	20000
18Cr 10Ni Ti	ASTM A403	Refer to	8	WP321			75000	30000	6a, 13, 20, 24, 36	−325	[illegible]
18Cr 10Ni Ti	ASTM A403	Basic Material	8	WP321H			75000	30000	13, 24	−325	[illegible]
18Cr 10Ni Cb	ASTM A403	Specification	8	WP347			75000	30000	6a, 13, 20, 24, 36	−425	[illegible]
18Cr 10Ni Cb	ASTM A403	Listing in	8	WP347H			75000	30000	13, 24	−325	[illegible]
18Cr 10Ni Cb	ASTM A403	these Tables	8	WP348			75000	30000	6a, 13, 20, 24, 36	−325	[illegible]
Welded Fittings											
18Cr 8Ni	ASTM A403	Refer to	8	WP304		1.00	75000	30000	6b 12, 13, 14, 20, 23	−425	[illegible]
18Cr 8Ni	ASTM A403	Basic Material	8	WP304H		1.00	75000	30000	12, 13, 14, 23	−325	[illegible]
18Cr 8Ni	ASTM A403	Specification	8	WP304L		1.00	70000	25000	12, 13 14	−425	[illegible]
23Cr 12Ni	ASTM A403	Listing in	8	WP309		1.00	75000	30000	12, 13, 14 28 52	−325	[illegible]
25Cr 20Ni	ASTM A403	these Tables	8	WP310		1.00	75000	30000	6, 12, 13 14 28 52	−325	[illegible]
25Cr 20Ni	ASTM A403	Refer to	8	WP310		1.00	75000	30000	6 12 13 14 28 52	−325	[illegible]
18Cr 8Ni Cb Ta	ASTM A403	Basic Material	8	WP347		1.00	75000	30000	6a, 12 13, 14 20	−425	[illegible]
18Cr 8Ni Cb Ta	ASTM A403	Specification	8	WP347H		1.00	75000	30000	12, 13 14 20	−325	[illegible]
18Cr 12Ni 2Mo	ASTM A403	Listing in	8	WP316		1.00	75000	30000	6b 12, 13 14 20, 23	−325	[illegible]
18Cr 12Ni 2Mo	ASTM A403	these Tables	8	WP316H		1.00	75000	30000	12, 13, 14 23	−325	[illegible]
18Cr 12Ni 2Mo	ASTM A403	Refer to	8	WP316L		1.00	70000	25000	6b, 12 13 14	−325	[illegible]
19Cr 13Ni 3Mo	ASTM A403	Basic Material	8	WP317		1.00	75000	30000	6b 12 13 14 20 23	−325	[illegible]
18Cr 10Ni Ti	ASTM A403	Specification	8	WP321		1.00	75000	30000	6a 12 13 14, 20	−325	[illegible]
18Cr 10Ni Ti	ASTM A403	Listing in	8	WP321H		1.00	75000	[illegible]	12 13, 14	−325	[illegible]
18Cr 10Ni Cb	ASTM A403	these Tables	8	WP348		1.00	75000	30000	6a, 12, 13, 14 20	−325	20000
Castings											
12Cr	ASTM A351		6	CA15		.80	90000	65000	9 12, 28	−20	24000
18Cr 8Ni	ASTM A351		8	CF3		.80	70000	30000	9 22	−425	[illegible]
18Cr 8Ni	ASTM A351		8	CF3A		.80	77500	[illegible]	9, 22, 33	−425	[illegible]
17Cr 10Ni 2Mo	ASTM A351		8	CF3M		.80	70000	[illegible]	9, 22	−425	[illegible]
18Cr 8Ni	ASTM A351		8	CF8		.80	70000	30000	6b, 9 22, 23 39	−425	[illegible]
18Cr 8Ni	ASTM A351		8	CF8A		.80	77500	35000	6b, 9, 22 23 33	−425	[illegible]
20Cr 10Ni Cb	ASTM A351		8	CF8C		.80	70000	30000	6a, 9 22 39	−325	[illegible]
18Cr 10Ni 2Mo	ASTM A351		8	CF8M		.80	70000	30000	6b 9 22 23 39	−425	[illegible]
15Cr 15Ni 2Mo Cb	ASTM A351		8	CF10MC		.80	70000	30000	6a, 9 12 22	−325	[illegible]
25Cr 13Ni	ASTM A351		8	CH8		.80	65000	28000	6b 9, 12, 22 28, 39	−325	[illegible]

For [illegible] see Note 4

ALLOWABLE STRESSES IN TENSION FOR MATERIALS [illegible]

(NUMBERS IN PARENTHESES REFER TO NOTES [illegible])

ALLOWABLE STRESS VALUES (psi)

400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification	Grade
																					STAINLESS STEEL (Cont'd)	
																					Plates and Sheets (Cont'd)	
18600	17300	16200	[illegible]	[illegible]	15400	[illegible]	[illegible]	14200	13800	13500	13100	12300	8800	6400	4700	3500	2500	1750	1350	1000	ASTM A167	[illegible]
15000	17250	16350	[illegible]	[illegible]	15650	[illegible]	[illegible]	15250	15150	13500	9600	6900	5000	[illegible]	2550	1700	1100	750	500	[illegible]	ASTM A167	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15400	[illegible]	[illegible]	[illegible]	12100	9100	6100	4100	3200	2200	1500	1200	900	750	ASTM A167	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12100	9100	6100	4400	3300	2200	1500	1200	900	750	ASTM A167	[illegible]
15700	17450	[illegible]	16150	[illegible]	15550	[illegible]	14150	14900	14650	13720											ASTM A[illegible]	[illegible]
18000	17450	[illegible]	[illegible]	[illegible]	[illegible]	17150	14900	14650	14350	13750	12150	9750	7700	6050	4700	3700	2900	2300	1800	1400	ASTM A240	[illegible]
15750	14650	13950	13700	[illegible]	13250	13000	12800	[illegible]	[illegible]	7300	6300	5100	4000	3250	2600	2100	1700	1100	1000	900	ASTM A240	[illegible]
																					ASTM A240	[illegible]
[illegible]	[illegible]	19200	[illegible]	[illegible]	18000	17500	[illegible]	[illegible]	12700	10500	8500	6500	5000	3400	2300	2300	1750	1300	[illegible]	[illegible]	ASTM A240	[illegible]
20000	20000	19200	[illegible]	[illegible]	18000	17500	16000	13850	12700	11000	7100	5000	3600	2500	1450	750	450	350	250	200	ASTM A240	[illegible]
[illegible]	[illegible]	17000	16650	[illegible]	16150	[illegible]	17700	15?00	15400	15000	14500	12?00	9500	7?00	5450	4100	3050	2250	1700	1250	ASTM A240	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10650	[illegible]	[illegible]	6300	4000	3500	2500	1850	1350	[illegible]	ASTM A240	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15?00	15350	15000	[illegible]	[illegible]	12?00	[illegible]	[illegible]	5150	4100	3050	2250	1700	1250	ASTM A240	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13500	13400	[illegible]	9800	6300	4700	3500	2500	[illegible]	1350	[illegible]	ASTM A240	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13350	15250	15150	[illegible]	9600	6900	5000	3600	2550	1700	1100	750	500	300	ASTM A240	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12100	9100	6100	4400	3300	2200	1500	1200	900	750	ASTM A240	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12100	9100	6100	4400	3300	2200	1500	1200	900	750	ASTM A240	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16000	13650	8?00	4000										ASTM A240	[illegible]
7500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11250	10450	8800	6800	[illegible]	2900	1750	1000						ASTM A240	[illegible]
17800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11100	10400	9850	8400	6400	[illegible]	[illegible]	1750	1000						ASTM A240	[illegible]
17950	17500	[illegible]	16000	[illegible]	[illegible]	[illegible]	[illegible]	11250	10450	9200	6500	4500	3200	2400	1750						ASTM A240	[illegible]
17800	[illegible]	[illegible]	16000	[illegible]	12650	12200	11250	10450	9200	6500	4500	3200	2400	1750							ASTM A240	[illegible]
																					ASTM A240	[illegible]
																					Forgings and Seamless [illegible]	
[illegible]	[illegible]	16300	16150	15900	15550	15150	14900	14650	14350	13750	12150	9750	7700	6050	4700	3700	2900	2300	1800	1400	ASTM A182	[illegible]
[illegible]	[illegible]	16350	16150	15900	15550	15150	15100	14650	14350	13750	12150	9750	7700	6050	4700	3700	2900	2300	1800	1400	ASTM A182	[illegible]
[illegible]	[illegible]	[illegible]	13700	[illegible]	13250	13000	12800	[illegible]	[illegible]	7300	6300	5100	4000	3250	2600	2100	1700	1100	1000	900	ASTM A182	[illegible]
[illegible]	20000	[illegible]	[illegible]	[illegible]	[illegible]	17500	16000	13850	12500	11000	7100	5000	3600	2500	1450	750	450	350	250	200	ASTM A182	[illegible]
20000	20000	19200	[illegible]	[illegible]	[illegible]	17500	16000	13850	12500	11000	9750	8500	7250	6000	4750	3500	2350	1600	1100	750	ASTM A182	[illegible]
19250	17950	17000	16650	16500	16050	15850	15700	15550	15400	15300	14500	12100	9800	7400	5450	4100	3050	2250	1700	1250	ASTM A182	[illegible]
19250	17950	[illegible]	[illegible]	16600	16050	15850	15700	15550	15400	15300	14500	12100	9800	7400	5450	4100	3050	2250	1700	1250	ASTM A182	[illegible]
15500	14400	[illegible]	13300	[illegible]	12600	12350	12100	11800	11500	11200	10650	10250	8700	6400	4700	3500	2500	1850	1350	1000	ASTM A182	[illegible]
15000	17250	16350	16050	15900	15650	15450	15350	15250	15150	13500	9600	6900	5000	3600	2550	1700	1100	750	500	300	ASTM A182	[illegible]
18600	17250	16350	16050	15900	15550	15450	15350	15250	15150	15150	14000	11700	9050	6950	5350	4100	3150	2450	1850	1450	ASTM A182	[illegible]
20000	19900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12100	9100	6100	4400	3300	2200	1500	1200	900	750	ASTM A182	[illegible]
20000	19900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17100	14250	10500	7900	5900	4350	3200	2450	1800	1300	ASTM A182	[illegible]
20000	19900	19300	18950	18600	18450	18300	18200	18150	18100	18050	17100	14250	10500	7900	5900	4350	3200	2450	1800	1300	ASTM A182	[illegible]
																					ASTM A182	[illegible]
18600	17450	16400	16150	15950	15550	15150	14900	14650	14350	13750	12150	9750	7700	6050	4700	3700	2900	2300	1800	1400	ASTM A403	[illegible]
18700	17450	16400	16150	15950	15550	15150	14900	14650	14350	13750	12150	9750	7700	6050	4700	3700	2900	2300	1800	1400	ASTM A403	[illegible]
15750	14700	13950	13700	13500	13250	13000	12800	11500	9900	7300	6300	5100	4000	3250	2600	2100	1700	1100	1000	900	ASTM A403	[illegible]
20000	20000	19200	18900	18300	18000	17500	16000	13850	12500	10500	8500	6500	5000	3800	2900	2300	1750	1300	900	750	ASTM A403	[illegible]
20000	20000	19200	18600	18300	18000	17500	16000	13850	12500	11000	7100	5000	3600	2500	1450	750	450	350	250	200	ASTM A403	[illegible]
20000	20000	19200	18900	18300	18000	17500	16000	13850	12500	11000	9750	8500	7250	6000	4750	3500	2350	1600	1100	750	ASTM A403	[illegible]
19250	17950	17000	16650	16500	16050	15850	15700	15550	15400	15300	14500	12400	9800	7400	5450	4100	3050	2250	1700	1250	ASTM A403	[illegible]
19250	17950	17000	16650	16500	16050	15850	15700	15550	15400	15300	14500	12400	9800	7400	5450	4100	3050	2250	1700	1250	ASTM A403	[illegible]
15500	14400	13700	13300	12950	12600	12350	12100	11800	11500	11200	10650	10250	8300	6400	4700	3500	2500	1850	1350	1000	ASTM A403	[illegible]
19250	17950	17000	16650	16500	16050	15850	15700	15550	15400	15300	14500	12400	9800	7400	5450	4100	3050	2250	1700	1250	ASTM A403	[illegible]
18600	17250	16350	16050	15900	15650	15450	15350	15250	15150	13500	9600	6900	5000	3600	2550	1700	1100	750	500	300	ASTM A403	[illegible]
18600	17250	16350	16050	15900	15600	15450	15350	15250	15150	15150	14000	11700	9050	6950	5350	4100	3150	2450	1850	1450	ASTM A403	[illegible]
20000	19900	19300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14900	14800	14000	12100	9100	6100	4400	3300	2200	1500	1200	900	750	ASTM A403	[illegible]
20000	19900	19300	18950	18600	18450	18300	18200	18150	18100	18050	17100	14250	10500	7900	5900	4350	3200	2450	1800	1300	ASTM A403	[illegible]
20000	19900	19300	18950	18600	18450	18300	15400	14900	14800	14000	12100	9100	6100	4400	3300	2200	1500	1200	900	750	ASTM A403	[illegible]
																					Welded [illegible]	
[illegible]	17450	16400	16150	15950	15550	15150	14900	14650	14350	13750	12150	9750	7700	6050	4700	3700	2900	2300	1800	1400	ASTM A[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15550	15150	14900	14650	14350	13750	12150	9750	7700	6050	4700	3700	2900	2300	1800	1400	ASTM A[illegible]	[illegible]
[illegible]	[illegible]	13950	13700	[illegible]	13250	13000	12800	[illegible]	9900	7300	6300	5100	4000	3250	2600	2100	1700	1100	1000	900	ASTM A[illegible]	[illegible]
[illegible]	20000	[illegible]	[illegible]	[illegible]	[illegible]	17500	16000	13850	12500	10500	8500	6500	5000	3800	2900	2300	1750	1300	[illegible]	[illegible]	ASTM A[illegible]	[illegible]
20000	20000	19200	18600	18300	18000	17500	16000	13850	12500	11000	7100	5000	3600	2500	1450	750	450	350	250	200	ASTM A[illegible]	[illegible]
20000	20000	19200	18900	18300	18000	17500	16000	13850	12500	11000	9750	8500	7250	6000	4750	3500	2350	1600	1100	750	ASTM A[illegible]	[illegible]
20000	19900	19300	18950	18600	18450	18300	15400	14900	14800	14000	12100	9100	6100	4400	3300	2200	1500	1200	900	750	ASTM A[illegible]	[illegible]
20000	19900	19300	18950	18600	18450	18300	18200	18150	18100	18050	17100	14250	10500	7900	5900	4350	3200	2450	1800	1300	ASTM A[illegible]	[illegible]
19250	17950	17000	16650	16500	16050	15850	15700	15550	15400	15300	14500	12100	9800	7400	5450	4100	3050	2250	1700	1250	ASTM A[illegible]	[illegible]
19250	17950	17000	16650	16500	16050	15850	15700	15500	15400	15300	14500	12100	9800	7400	5450	4100	3050	2250	1700	1250	ASTM A[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	13300	[illegible]	[illegible]	12350	12100	11800	11500	11200	10650	10250	8300	6400	4700	3500	2500	1850	1350	1000	ASTM A[illegible]	[illegible]
19250	17950	17000	16650	16500	16050	15850	15700	15550	15400	15300	14500	12100	9800	7400	5450	4100	3050	2250	1700	1250	ASTM A[illegible]	[illegible]
15000	17250	16350	16050	15900	15650	15450	15350	15250	15150	13500	9600	6900	5000	3600	2550	1700	1100	750	500	300	ASTM A[illegible]	[illegible]
18600	17250	16350	16050	15900	15650	15450	15350	15250	15150	15150	14000	11700	9050	6950	5350	4100	3150	2450	1850	1450	ASTM A[illegible]	[illegible]
20000	19900	19300	18950	18600	18450	18300	15400	14900	14800	14000	12100	9100	6100	4400	3300	2200	1500	1200	900	750	ASTM A[illegible]	[illegible]
																					[illegible]	
20000	19150	17900	17300	16500	15700	14650	12800	8800	6100	4000	2650	1750	1200	800							ASTM A351	[illegible]
13400	13150	12500	12200	12100	11900	11120															ASTM A351	[illegible]
																					ASTM A351	[illegible]
[illegible]	12500	12300	[illegible]	[illegible]	[illegible]	11200	10600														ASTM A351	[illegible]
14100	13150	12500	12200	[illegible]	11900	11850	10300	10150	9900	8650	7500	6000	4600	3600	2600	1950	1450	1100	800	600	ASTM A351	[illegible]
																					ASTM A351	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13700	11200	11100	11000	[illegible]	13400	[illegible]	[illegible]	4600	2900	2150	[illegible]	[illegible]	[illegible]	[illegible]	ASTM A351	[illegible]
15500	14500	13700	13400	13100	12850	12500	11200	11100	11100	10500	8200	7500	6400	5450	4250	3260	2400	1900	1500	1200	ASTM A351	[illegible]
																					ASTM A351	[illegible]
17950	14900	14400	14000	13700	13450	13100	10500	10000	9400	8100	6800	5200	4000	3000	2300	1850	1400	1050	750	600	ASTM A351	[illegible]

ALLOWABLE STRESSES IN [illegible]
(NUMBERS IN PARENTHESIS REFER TO [illegible] THROUGH [illegible])

Material	Specification	(29) Steel Making Process	(57) P No.	Grade	Class	Factor (E)	Tensile Strength Min PSI	Yield Strength Min PSI	Notes	Min Temp	Temp To 100	200	300
[illegible] STEEL (4) [illegible] (Cont.)													
[illegible]									40				
[illegible]	ASTM A351		8	CH10		[illegible]	70000	[illegible]	65, 9, 12, 22, [illegible]	−325	[illegible]		
[illegible]	ASTM [illegible]		8	CH20 [illegible]		[illegible]	70000	30000	66, 9, 12, 22, [illegible] 39	[illegible]	[illegible]		
[illegible]	ASTM [illegible]		8	CF20		80	65000	[illegible]	66, 9, 22, 26, 39, 4[illegible]	[illegible]	[illegible]		
[illegible]	ASTM A351		8	CN7M		80	62500	25000	6[illegible], 9, 12, 22	−325	[illegible]		
[illegible]	ASTM A351		8	HK30		60	65000	35000	12, 22, 28	−325	[illegible]		
[illegible]	ASTM A351		8	HK40		80	67500	35000	12, 22, 28	−325	[illegible]		
[illegible]	ASTM [illegible]		8	HT30		.60	65000	28000	12, 22	−325	14950		

For shaded areas see Note 4

APPENDIX A

TABLE A-1

ALLOWABLE STRESSES IN TENSION FOR MATERIALS (1)(3)(4a)

(NUMBERS IN PARENTHESES REFER TO SPECIAL NOTES. SEE NOTES SEE PAGES 72 THROUGH 7?)

ALLOWABLE STRESSES, SE (PSI) (46)

Metal Temperature Degrees F (35)

0	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification	Material
																						STAINLESS STEEL (4) (40) (Cont.) Castings (Cont.)
16?00	16000	15?00	15050	14650	14400	14000	10900	10650	10000	8400	6800	5200	4000	3000	2300	1650	1400	1050	700	600	ASTM A351	25Cr 13Ni
?0	16000	15300	15050	14650	14400	11000	10700	10650	10000	8400	6800	5200	4000	3000	2300	1850	1400	1050	700	600	ASTM A351	25Cr 13Ni
?50	14950	14400	14000	13700	13450	13100	10250	10000	9550	8800	7800	6800	5600	4800	3800	2600	1900	1300	900	600	ASTM A351	25Cr 20Ni
																					ASTM A351	28Ni 20Cr 2Mo-3Cu
																					ASTM A351	25Cr-20Ni
																					ASTM A351	25Cr 20Ni
																					ASTM A351	35Ni 15Cr Mo

For shaded areas see Note 4

ALLOWABLE STRESSES IN TENSION [illegible]
(NUMBERS IN PARENTHESES REFER TO [illegible])

Material	Specification	Grade	Class	Temper	P No.	Size Range	Factor (E)	Tensile Strength Min.	Yield Strength Min.	Notes	Min Temp	Temp To 100	150	[illegible]
COPPER AND COPPER ALLOY														
Seamless Pipe & Tubes														
Copper pipe	ASTM B42	OF,DLP,DHP	102,120,122	Drawn	31	[illegible] Incl		45000	[illegible]	8,35,44	−325	[illegible]	[illegible]	[illegible]
Copper pipe	ASTM B42	OF,DLP,DHP	102,120,122	Drawn	31	2½"-12" Incl		[illegible]	[illegible]	8,35,44	−325	12000	[illegible]	[illegible]
Red brass pipe	ASTM B43	85%	230	Annealed	32			[illegible]	[illegible]	8	−325	8000	[illegible]	[illegible]
Copper tube	ASTM B75	OF,DLP,DHP	102,120,122	Annealed	31			30000	9000	8,47	−325	6000	[illegible]	[illegible]
Copper tube	ASTM B75	OF,DLP,DHP,DPA	102,120,122,142	Annealed	31			[illegible]	9000	8	−325	6000	5100	[illegible]
Copper tube	ASTM B75	OF,DLP,DHP,DPA	102,120,122,142	Light Dr.	31			36000	30000	8,35,44	−325	12000	9000	[illegible]
Copper tube	ASTM B75	OF,DLP,DHP,DPA	102,120,122,142	Hard Dr.	31			[illegible]	40000	8,35,44	−325	15000	[illegible]	[illegible]
Copper tube	ASTM B88	(Water Tube)		Annealed	31			30000	[illegible]	8,47	−325	6000	[illegible]	[illegible]
Copper tube	ASTM B88	(Water Tube)		Drawn	31			36000	30000	8,44,47	−325	12000	9000	[illegible]
[illegible]														
Copper [illegible]	ASTM B11	ETP,FRTP	110,[illegible]		a			[illegible]	[illegible]	8,10,57	−325	6700	5750	[illegible]
Copper	ASTM B11	DHP	122		31			[illegible]	[illegible]	8,10	−325	6700	5750	[illegible]
[illegible]	ASTM B11	ATP,DPA	[illegible] 142		31			[illegible]	[illegible]	8,10	−325	6700	5750	[illegible]
Copper [illegible]	ASTM B96	A,C	655,653		33			[illegible]	12000		−325	12000	12[illegible]	[illegible]
Copper	ASTM B152	DHP	122	Annealed	31			30000	10000	8,47	−325	6700	5750	[illegible]
Aluminum [illegible] Bronze	ASTM B169	D	614	Soft	35	½"-2" Incl		70000	30000	11	−325	20000	20000	[illegible]
[illegible]														
[illegible]	ASTM B283		377		a			58000	23000	5,9,57	−325	15300	12500	[illegible]
[illegible]	ASTM B283		464		32			64000	26000	5,9	−325	17[illegible]	1575[illegible]	[illegible]
[illegible]	ASTM B283		365		a			62000	22000	8,9,35,57	−325	16[illegible]	15250	[illegible]
[illegible] (A)	ASTM B283		675		32			[illegible]	34000	8,9	−325	22650	1090[illegible]	[illegible]
Al-Silicon Bronze	ASTM B283		639		35			83000	41000	8,9	−325	27300	17500	[illegible]
[illegible]	ASTM B283		110		a			33000	11000	8,9,57	−325	7300	6700	[illegible]
High Silicon Bronze (A)	ASTM B283		655		33			52000	18000	8,9	−325	12000	10000	[illegible]
Castings														
[illegible]	ASTM B61		922		a		80	34000	16000	9,22,57	−325	8500	8500	[illegible]
Composition Bronze	ASTM B62		836		a		80	30000	14000	9,22,57	−325	7000	7500	[illegible]
[illegible]	ASTM B[illegible]		864		a		80	60000	20000	9,22,57	−325	13650	10150	[illegible]
[illegible] Bronze	ASTM B62		867		a		80	80000	32000	9,22,57	−325	17000	14600	[illegible]
Tin Bronze	ASTM B143		905		b		80	40000	18000	9,22,57	−325	9600	9600	[illegible]
Tin Bronze	ASTM B143		903		b		80	40000	18000	9,22,57	−325	9600	8000	[illegible]
Leaded [illegible]	ASTM B143		922		a		80	34000	16000	9,22,57	−325	8500	8500	[illegible]
Leaded [illegible]	ASTM B143		923		a		80	36000	16000	9,22,57	−325	8500	7200	[illegible]
Leaded [illegible] Bronze	ASTM B147		864		a		80	60000	20000	9,22,57	−325	10650	10200	[illegible]
No. 1 [illegible]	ASTM B147		865		b		80	65000	25000	9,22,57	−325	13500	11500	[illegible]
High Strength [illegible]	ASTM B147		862		b		80	90000	45000	9,22,57	−325	24000	15600	[illegible]
High Strength [illegible]	ASTM B147		863		b		80	110000	60000	9,22,57	−325	29300	18250	[illegible]
Aluminum Bronze	ASTM B148	A	952		b		80	65000	25000	9,22,57	−325	13300	[illegible]	[illegible]
Aluminum Bronze	ASTM B148	B	953		b		80	65000	25000	9,22,57	−325	13300	[illegible]	[illegible]
Aluminum Bronze	ASTM B148	C	954		b		80	75000	30000	9,24,57	−325	16000	15000	[illegible] 13750 [illegible] 12500
Aluminum Bronze	ASTM B148	D	955		b		80	90000	40000	9,22,57	−325	21300	18000	[illegible] 15000 [illegible]
Silicon Al-Bronze	ASTM B148	E	956		b		80	60000	28000	9,22,57	−325	14950		
Leaded Ni-Brass	ASTM B149		973		a		80	30000	15000	9,22,57	−325	8000		
Leaded Ni-Bronze	ASTM B149		976		a		80	30000	17000	9,22,57	−325	8000	6000	[illegible] 5500 [illegible]
Leaded Ni-Bronze	ASTM B149		978		a		80	45000	22000	9,22,57	−325	11700	8300	7500 6750 [illegible]
NICKEL AND NICKEL ALLOY (3)														
Seamless Pipe & Tubes														
Nickel	ASTM B161		Annealed		41	5" O.D. & Under		55000	15000		−325	10000	10000	[illegible] 10000 [illegible]
Nickel	ASTM B161		Annealed		41	Over 5" O.D.		55000	12000		−325	8000	8000	[illegible] 8000 [illegible]
Nickel	ASTM B161		Stress Rel'd		41			65000	40000		−325	21600	1570[illegible]	[illegible]
Low Carbon Nickel	ASTM B161		Annealed		41	5" O.D. & Under		50000	12000		−325	8000	[illegible]	[illegible] 7500 [illegible]
Low Carbon Nickel	ASTM B161		Annealed		41	Over 5" O.D.		50000	10000		−325	6650	6500	[illegible] 6350 [illegible]
Low Carbon Nickel	ASTM B161		Stress Rel'd		41			60000	30000		−325	20000	[illegible]	[illegible]
Nickel-Copper	ASTM B165		Annealed		42	5" O.D. & Under		70000	28000		−325	18650	17550	16[illegible] 157[illegible]
Nickel-Copper	ASTM B165		Annealed		42	Over 5" O.D.		70000	25000		−325	16650	15650	147[illegible] 142[illegible]
Nickel-Copper	ASTM B165		Stress Rel'd		42			85000	55000		−325	28300	20700	[illegible]
Ni-Cr-Fe	ASTM B167		Hot Fin. or Hot Fin. Annealed		43	5" O.D. & Under		80000	30000		−325	20000	20000	[illegible]
Ni-Cr-Fe	ASTM B167		Hot Fin. or Hot Fin. Annealed		43	Over 5" O.D.		75000	25000		−325	16700	16700	[illegible]
Ni-Cr-Fe	ASTM B167		Cold Drawn Ann		43	5" O.D. & Under		80000	35000		−325	23350	23350	[illegible]
Ni-Cr-Fe	ASTM B167		Cold Drawn Ann		43	Over 5" O.D.		80000	30000		−325	20000	20000	[illegible]
Ni-Fe-Cr	ASTM B407		Cold Drawn Ann		45			75000	30000	61	−325	20000	20000	[illegible]
Ni-Fe-Cr	ASTM B407		Cold Drawn Sol Annealed		45			70000	25000	62	−325	16650	16650	[illegible]
Ni-Fe-Cr	ASTM B407		Hot Finished		45			75000	25000	63	−325	16650	[illegible]	[illegible]
Plates & Sheets														
Nickel-Copper	ASTM B127		Hot Rolled Plate Annealed		42			70000	28000		−325	18650	17500	[illegible]
Nickel-Copper	ASTM B127		Hot Rolled Plate As Rolled		42			75000	40000		−325	25000	2425[illegible]	[illegible] 22[illegible]
Nickel	ASTM B162		Hot Rolled Plate Annealed		41			55000	15000		−325	10000	10000	[illegible]
Nickel	ASTM B162		Hot Rolled Plate As Rolled		41			55000	20000		−325	13300	1335[illegible]	[illegible]
Low Carbon Nickel	ASTM B162		Hot Rolled Plate Annealed		41			50000	12000		−325	8000	7850	[illegible]

For shaded areas see Note 4

[illegible]

ALLOWABLE STRESSES IN TENSION FOR MATERIALS [illegible]

(NOS. REFER TO [illegible] FOOTNOTES [illegible])

ALLOWABLE [illegible]

Metal Temperature (Deg. F.)

[illegible]	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification No. / Material
																							COPPER AND COPPER ALLOYS
																							Seamless Pipe & Tube
[illegible]																							[illegible]
[illegible]																							[illegible]
[illegible]000	2000																						[illegible] Pipe
2500	[illegible]	750																					[illegible] Copper Tube
[illegible]	1500	750																					ASTM B75 Copper Tube
3500																							ASTM B75 Copper Tube
[illegible]																							[illegible] Copper Tube
[illegible]	1500	750																					[illegible] Copper Tube
2500	1500	750																					[illegible] Copper Tube
																							Plates & Sheets
[illegible]	1500	750																					[illegible] Copper Plate
[illegible]	1500	750																					[illegible]
3000	1500	750																					[illegible] Copper
3000	1500	750																					[illegible]
																							ASTM B152 Copper
19200	15100	19000																					ASTM B169 Aluminum Bronze
																							Forgings
2000																							[illegible]
[illegible]																							[illegible]
[illegible]																							[illegible]
[illegible]																							[illegible]
10000																							ASTM B283 [illegible]
2500	1500	750																					[illegible] Copper
3000																							[illegible] Hi Silicon Bronze
																							Castings
8250	7250	7200	5000																				ASTM B61 Steam Bronze
7000	5800																						ASTM B62 Composition Bronze
																							[illegible]
																							[illegible]
[illegible]																							[illegible] Tin Bronze
5600																							[illegible] Tin Bronze
5200																							[illegible]
5600																							[illegible]
																							[illegible]
																							[illegible]
																							[illegible]
																							[illegible]
[illegible]	9600	8000																					[illegible]
[illegible]	9600	8000																					[illegible]
11500	10300	8500																					[illegible]
																							ASTM B148 [illegible]
12000	10800	9600																					[illegible]
																							[illegible]
																							[illegible]
																							[illegible]
																							[illegible]
																							NICKEL AND NICKEL ALLOYS
																							Seamless Pipe & Tube
10000	10000	10000	10000	10000																			ASTM B161 Nickel
8000	8000	8000	8000	8000																			ASTM B161 Nickel[1]
15000	14500	14500																					ASTM B161 Nickel
7500	7500	7500	7500	7500	7450	7400	7300	7200	5800	4500	3700	3000	2400	2000	1500	1200							ASTM B161 Low Carbon Nickel
6200	6200	6200	6200	6200	6200	6200	6050	5900	5800	4500	3700	3000	2400	2000	1500	1200							ASTM B161 Low Carbon Nickel
13500	13500	13500																					ASTM B161 Low Carbon Nickel
[illegible]	14800	14800	14800	14800	14800	14800	14600	14200															ASTM B165 Nickel-Copper
[illegible]	13200	13200	13200	13200	13200	13200	13000	12700															ASTM B165 Nickel-Copper
19200	19200	19200																					ASTM B165 Nickel-Copper
20000	20000	20000	20000	20000	20000	20000	20000	20000	19600	16000	10600	7000	4500	3000	2200	2000							ASTM B167 Ni-Cr-Fe
16700	16700	16700	16700	16700	16700	16700	16700	16700	16500	15900	10000	7000	4500	3000	2200	2000							ASTM B167 Ni-Cr-Fe
23350	23350	23350	23350	23350	23350	23350	23350	23350															ASTM B167 Ni-Cr-Fe
20000	20000	20000	20000	20000	20000	20000	20000	20000															ASTM B167 Ni-Cr-Fe
[illegible]	20000	20000	20000	20000	20000	20000	20000	20000	18400	18200	17900	17800	17000	[illegible]	9500	6800	4200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ASTM B407 Ni-Fe-Cr
[illegible]	15350	[illegible]	14750	[illegible]	14400	14300	14200	14000	[illegible]	13100	12900	12800	12700	12700	10000	7000	6000	4600	3600	2500	[illegible]	[illegible]	ASTM B407 Ni-Fe-Cr
[illegible]	15350	14900	14750	14600	14400	14300	14200	14000	13200	13100	12900	14800	12700	12700	10000	7000	6000	4600	3600	2300	2100	[illegible]	ASTM B407 Ni-Fe-Cr
																							[illegible]
14800	14800	14800	14800	14800	14800	14800	14800	14200	11000	8000													ASTM B127 Nickel-Copper
[illegible]	21200	21200	[illegible]	[illegible]	21200	21200	20900	20100	8200	4000													[illegible]
[illegible]	10000	10000	[illegible]	[illegible]																			[illegible]
[illegible]	12500	12500	[illegible]	[illegible]																			[illegible]
[illegible]	[illegible]	7500	[illegible]	[illegible]	7350	7400	7300	7200	[illegible]	4500	3700	3000	[illegible]	2000	1500	1200							ASTM B162 Low Carbon Nickel

[1] [illegible]

TABLE A-1 [illegible]

ALLOWABLE STRESSES [illegible]

(NUMBERS IN PARENTHESES REFER TO [illegible])

Material	Specification	Grade	Class	Temper	(27) P-No.	Size Range in.	[illegible] (%)	Tensile Strength Min psi	Yield Strength Min psi	Notes	(26) Min Temp	Min Temp To 100	150	[illegible]	250	[illegible]	[illegible]
[illegible] ALLOYS (3) (Cont)																	
[illegible] (Cont)																	
Low C [illegible] Ni [illegible]	ASTM B162		Hot Rolled Plate As Rolled		41			5[illegible]000	[illegible]000		−325	8000	7850	[illegible]	7[illegible]00	[illegible]	
[illegible] Fe	ASTM B168		Hot Rolled Plate Annealed		43			80[illegible]00	35000		−325	23350	23350	2[illegible]	2[illegible]50	2[illegible]	[illegible]
Ni-Cr-Fe	ASTM B168		Hot Rolled Plate As Rolled		43			85000	35000		−325	23350	20600	[illegible]	[illegible]	[illegible]	[illegible]
Ni-Mo	ASTM B333		Sol Ann Sheet		44	Up to 3/16"		115000	50000		−325	33300	33100	[illegible]	[illegible]	[illegible]	[illegible]
Ni-Mo	ASTM B333		Sol Ann Plate		44	3/16"-3[illegible]"		100000	[illegible]000		−325	30000	30000	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Mo	ASTM B333		Sol Ann Plate		44	Over [illegible]"		[illegible]00	45000		[illegible]325	30000	30000	[illegible]			
Ni-[illegible]	ASTM B[illegible]		Sol Ann Sheet		44	Up to 3/16		[illegible]0	[illegible]000		−325	33300	33[illegible]	[illegible]			
Ni-[illegible]	ASTM B[illegible]		Sol Ann Plate		44	3/16-3/4"		10[illegible]00	45000		−325	30000	30[illegible]	[illegible]			
Ni-[illegible]	ASTM B[illegible]		Sol Ann Plate		44	Over 3/4"		[illegible]0	45000		−325	30000	30[illegible]	[illegible]			
Forgings & Seamless Fittings																	
Ni [illegible]	ASTM B[illegible]		Annealed		41			55000	15000	9	−325	[illegible]000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ni [illegible]	ASTM B[illegible]		Hot Finished		41			6[illegible]00	[illegible]000	9	−325	10000	10000	[illegible]	[illegible]	[illegible]	
[illegible] Nickel	ASTM B[illegible]		Annealed		41			50000	[illegible]000	9	[illegible]325	[illegible]650	6550	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	ASTM B[illegible]		Ann Forged		42			70000	25000	[illegible]	[illegible]25	16650	16650	[illegible]	[illegible]		
Ni-[illegible]	ASTM B[illegible]		Hot Finished		42			80000	40000	[illegible]	−325	26700	19450	[illegible]	[illegible]	[illegible]	
[illegible]	ASTM B[illegible]		Annealed		43			80000	35000	[illegible]	−325	23350	2[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ni-[illegible]	ASTM B[illegible]		Hot Finished		43			85000	35000	9	[illegible]	23350	2[illegible]		2[illegible]	[illegible]	
[illegible]	ASTM B366	WPN			41			550[illegible]	[illegible]	[illegible]	325	[illegible]000	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	ASTM B[illegible]	WPNL			41			50000	[illegible]000	13	[illegible]325	5650	6700	[illegible]	[illegible]	[illegible]	
[illegible] Cu [illegible]	ASTM B366	WPNC			42			70000	25000	13	−325	16650	15650	[illegible]	[illegible]	[illegible]	
Ni-[illegible] Fe	ASTM B366	WPNCI			43			75000	25000	13	−325	16700	16700	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Ni [illegible]	ASTM B366	[illegible]			44			90000	45000	13	−325	30000	30000	[illegible]	[illegible]		
Ni-Mo	ASTM B366	WPHC			44			90000	45000	13	−325	30000	30000	3[illegible]	3[illegible]		[illegible]
[illegible]ing																	
[illegible]	ASTM [illegible]						80	72000	46000	9,22,27	−325	19200	13160	[illegible]3160	13100	[illegible]	[illegible]
Ni-[illegible]	ASTM A4[illegible]						80	72000	46000	9,22,27	−325	19200	[illegible]	13100	[illegible]	[illegible]	13[illegible]

For shaded areas see Note 4

TABLE [illegible]

ALLOWABLE STRESSES [illegible] FOR MATERIALS (4, [illegible], 46)

(NUMBERS IN PARENTHESIS REFER TO [illegible] TABLE NOTES, SEE PAGES [illegible] THROUGH 75)

ALLOWABLE STRESS [illegible]

Metal Temperature Degrees F (35)

400	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification Material
																							NICKEL AND NICKEL ALLOYS (Cont.)
																							Plates and Sheets (Cont.)
7500	7500	7500	7500	7500	7450	7400	7300	7200	5800	4800	3700	3000	2400	2000	1500	1200							ASTM B162 [illegible]
23350	23350	23350	23350	23350	23350	23350	23350	23350															ASTM B16[illegible] Ni-C[illegible]
[illegible]	20000	20000	20000	20000	20000	20000	20000	20000	19750	19500	17000	14500	10000	7200	6000	5500							ASTM B1[illegible] Ni-Cr-[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33300	33100															AS[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]															A[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25650	[illegible]															ASTM [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]															A[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30000															AS[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25400	26200															AS[illegible]
																							Forgings & Seamless Fittings
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																			A[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																			ASTM B[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6050	5950	5800	4500	3700	3000	2400	2000	1500	1200							AST[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]															A[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16400	14500	10000	4000													ASTM B1[illegible]
23350	[illegible]	[illegible]	[illegible]	[illegible]	23350	23350	23350	23350															ASTM B16[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20000	19700	19500	17000	14500	10000	7200	6000	5500							AST[illegible]
[illegible]	[illegible]	[illegible]	8000	8000																			AST[illegible]
6200	6200	[illegible]	[illegible]	[illegible]	6200	6200	6050	5900	5800	4500	3700	3000	2400	2000	1500	1200							ASTM [illegible]
[illegible]	13200	[illegible]	[illegible]	[illegible]	[illegible]	13200	13000	12700															ASTM B[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	16700	[illegible]	[illegible]	16700	16700	16500	15900	[illegible]	7000	4500	3000	2200	2000							[illegible] Ni-Cr-Fe
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28500															[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28400	28200															[illegible] Ni-Mo-[illegible]
																							Castings
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																	ASTM A[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12400	12400	12000	11700	11700	11700											ASTM A[illegible]

Table [illegible]

ALLOWABLE STRESSES IN TENSION FOR MATERIALS [illegible]

(NUMBERS IN PARENTHESES REFER TO [illegible] THROUGH 75)

Material	Specification	Grade	Class	Temper	(37) P No	Size	[illegible]	Factor (E)	Tensile Strength Min [illegible]	Yield Strength Min [illegible]	Notes	(25) Min Temp	Min Temp To 100	150	200	250	300	350
ALUMINUM ALLOY																		
Seamless Pipe & Tubes																		
	ASTM B210	1060		O	21				8500	2500	43	−452	1650					
	ASTM B241	1060		O	21				8500	2500	43	−452	1550					
	ASTM B241	1060		O	21				8500	2500	43	−452	1650					
	ASTM B210	1060		H112	21				8500	2500	15,43	−452	1650					
	ASTM B221	1060		H112	21				8500	2500	15,43	−452	1650					
	ASTM B241	1060		H112	21				8500	2500	15,43	−452	1650					
	ASTM B210	1060		H14	21				12000	10000	15,43	−452	4000	3000	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B210	3003		O	21				14000	5000	43	−452	3350	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B221	3003		O	21				14000	5000	43	−452	3350	[illegible]	[illegible]		[illegible]	[illegible]
	ASTM B241	3003		O	21				14000	5000	43	−452	3350	3350	3350	3	[illegible]	[illegible]
	ASTM B210	3003		H14	21				20000	17000	15,43	−452	6650	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B210	3003		H18	21				27000	24000	15,43	−452	9000	[illegible]	[illegible]		250	[illegible]
	ASTM B210	3003		H112	21				14000	5000	15,43	−452	3000	[illegible]	[illegible]	[illegible]		
	ASTM B221	3003		H112	21				14000	5000	15,43	−452	3350	3350	[illegible]	[illegible]		
	ASTM B241	3003		H112	21				14000	5000	15,43	−452	3350	3350	3350	[illegible]		
	ASTM B210	3003 CLAD		O	21				13000	4500	43	−452	3000	3000	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B221	3003 CLAD		O	21				13000	4500	43	−452	3000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B241	3003 CLAD		O	21				13000	4500	43	−452	3000	3000	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B210	3003 CLAD		H112	21				13000	4500	15,43	−452	3000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B221	3003 CLAD		H112	21				13000	4500	15,43	−452	3000	3000	3000	[illegible]	[illegible]	[illegible]
	ASTM B241	3003 CLAD		H112	21				13000	4500	15,43	−452	3000	3000	3000	[illegible]	[illegible]	[illegible]
	ASTM B210	3003 CLAD		H14	21				19000	16000	15,43	−452	6350	[illegible]	[illegible]		[illegible]	[illegible]
	ASTM B210	3003 CLAD		H18	21				26000	23000	15,43	−452	8700	6100	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B210	5050		O	21				18000	6000	43	−452	4000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B210	5052		O	22				25000	10000	43	−452	6650	6250	6250	[illegible]	[illegible]	[illegible]
	ASTM B221	5052		O	22				25000	10000	43	−452	6650	6250	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B241	5052		O	22				25000	10000	43	−452	6650	6250	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B210	5083		O	25				39000	16000	43	−452	10650					
	ASTM B221	5083		O	25				39000	16000	43	−452	10650					
	ASTM B241	5083		O	25				39000	16000	43	−452	10650					
	ASTM B241	5083		H112	25				39000	16000	15,43	−452	10650					
	ASTM B210	5154		O	22				30000	11000	43	−452	7350	7350				
	ASTM B221	5154		O	22				30000	11000	43	−452	7350	7350				
	ASTM B210	5154		H34	22				39000	29000	15,43	−452	13000	9700				
	ASTM B210	5456		O	25				41000	19000	43	−452	12700					
	ASTM B221	5456		O	25				41000	19000	43	−452	12700					
	ASTM B241	5456		O	25				41000	19000	43	−452	12700					
	ASTM B210	6061		T4	23				30000	16000	15,43	−452	10000	10000	10000	[illegible]	[illegible]	
	ASTM B221	6061		T4	23				26000	16000	15,43	−452	8650	8650	8650	[illegible]	[illegible]	[illegible]
	ASTM B241	6061		T4	23				26000	16000	15,43	−452	8650	8650	8650	[illegible]	[illegible]	[illegible]
	ASTM B210	6061		T6	23				42000	35000	15,43	−452	14000	14000	14000	13[illegible]	[illegible]	[illegible]
	ASTM B221	6061		T6	23				38000	35000	15,43	−452	12650	12650	12650	122[illegible]		[illegible]
	ASTM B241	6061		T6	23				38000	35000	15,43	−452	12650	12650	12650	122[illegible]		[illegible]
	ASTM B210	6061		Welded	23				24000		15,50	−452	6000	5900	[illegible]	[illegible]	[illegible]	4[illegible]
	ASTM B221	6061		Welded	23				24000		15,50	−452	6000	5900	5700	[illegible]	[illegible]	4200
	ASTM B241	6061		Welded	23				24000		15,50	−452	6000	5900	5700	[illegible]	[illegible]	4200
	ASTM B210	6063		T4	23				22000	10000	15,43	−452	6650	5100	4900	45[illegible]	[illegible]	3100
	ASTM B221	6063		T4	23				18000	9000	15,43	−452	6000					
	ASTM B210	6063		T6	23				33000	28000	15,43	−452	11000	11000	[illegible]	[illegible]		[illegible]
	ASTM B221	6063		T6	23				30000	25000	15,43	−452	10000	10000	9500	[illegible]		[illegible]
	ASTM B241	6063		T6	23				30000	25000	15,43	−452	10000	10000	[illegible]	[illegible]	[illegible]	
	ASTM B210	6063		Welded	23				17000		15	−452	4250	4200	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B221	6063		Welded	23				17000		15	−452	4250	4200	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B241	6063		Welded	23				17000		15	−452	4250	4200	[illegible]	[illegible]	[illegible]	[illegible]
Plates & Sheets																		
	ASTM B209	1060		O	21				8000	2500	43	−452	1650					
	ASTM B209	1060		H112	21				9000	4000	11,15,43	−452	2650					
	ASTM B209	1060		H12	21				11000	9000	15,43	−452	3650	2550	2550	[illegible]	[illegible]	1600
	ASTM B209	1060		H14	21				12000	10000	15,43	−452	4000					
	ASTM B209	1100		O	21				11000	3500	43	−452	2350	2350	2300	[illegible]	[illegible]	1600
	ASTM B209	1100		H112	21	2.0" Max Th			13000	5000	11,15,43	−452	3350	2500	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	1100		H12	21				14000	11000	15,43	−452	4650	3400	[illegible]	[illegible]	[illegible]	2400
	ASTM B209	1100		H14	21				16000	14000	15,43	−452	5350	3900	2650	[illegible]	[illegible]	[illegible]
	ASTM B209	3003		O	21				14000	5000	43	−452	3350	3350	3350	[illegible]	[illegible]	[illegible]
	ASTM B209	3003		H112	21				14500	6000	11,15,43	−452	4000	4000	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	3003		H12	21				17000	12000	15,43	−452	5650	4000	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	3003		H14	21				20000	17000	15,43	−452	6650	4650	[illegible]	[illegible]		[illegible]
	ASTM B209	3003 CLAD		O	21				13000	4500	11,43	−452	3000	2900	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	3003 CLAD		H112	21				14500	6000	11,15,43	−452	4000	3500	[illegible]	[illegible]		[illegible]
	ASTM B209	3003 CLAD		H12	21				16000	11000	11,15,43	−452	5350	3800	[illegible]	[illegible]	[illegible]	2500
	ASTM B209	3003 CLAD		H14	21				19000	16000	11,15,43	−452	6350	4600	4350	[illegible]	[illegible]	[illegible]
	ASTM B209	3004		O	22				22000	8500	43	−452	5650	5650	5650	[illegible]	[illegible]	[illegible]
	ASTM B209	3004		H112	22				23000	9000	15,43	−452	6000	6000	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	3004		H32	22				28000	21000	15,43	−452	9350	7000	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	3004		H34	22				32000	25000	15,43	−452	10650	8000	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	3004 CLAD		O	22				21000	8000	11,43	−452	5350	5250	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	3004 CLAD		H112	22				22000	8500	11,15,43	−452	5650	5500	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	3004 CLAD		H32	22				27000	20000	11,15,43	−452	9000	7500	[illegible]			[illegible]
	ASTM B209	3004 CLAD		H34	22				31000	24000	11,15,43	−452	10330	7500	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	5050		O	21				18000	7000	43	−452	4000	4000	4000	[illegible]	[illegible]	[illegible]

ALLOWABLE STRESS [illegible]

(NUMBERS IN PARENTHESES [illegible])

ALLOWABLE STRESS [illegible]

Metal Temperature Degrees F [illegible]

00	450	500	5[illegible]0	600	[illegible]	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	[illegible]	1350	[illegible]	1450	1500	Specification Material

Material	Specification	Grade	Class	Temper	P-No.	Size Range	Factor (E)	Min. Tensile	Min. Yield	Notes	Min. Temp	Min. Temp to 100	150	200	250	300	350
ALUMINUM ALLOY (Cont.)																	
[illegible] (Cont.)																	
	ASTM B209	5050		H112	21			[illegible]	[illegible]	15,43	−452	5350	5000	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	5050		H32	21			[illegible]	[illegible]	15,43	−452	7350	5550	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	5050		H34	21			[illegible]	26000	15,43	−452	[illegible]	6250	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	5052		0	22			[illegible]	9500	43	−452	6350	6350	[illegible]	635[illegible]	[illegible]	[illegible]
	ASTM B209	5052		H112	22			25000	9500	11,15,43	−452	6350	6350	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	5052		H32	22			31000	23000	15,43	−452	10300	7750	7650	7[illegible]	6400	5600
	ASTM B209	5052		H34	22			34000	26000	15,43	−452	11300	8500	8400	7700	[illegible]	6100
	ASTM B209	5083		0	25	3.0" Max Th		40000	17000	1,43	−452	11350	1135[illegible]				
	ASTM B209	5083		H112	25			39000	17000	11,15,43	−452	11350	1135[illegible]				
	ASTM B209	5086		0	25			35000	14000	43	−452	9350	9150[illegible]				
	ASTM B209	5086		H112	25	2.0" Max Th		35000	14000	11,15,43	−452	[illegible]	9150[illegible]				
	ASTM B209	5086		H32	25			40000	28000	15,43	−452	[illegible]	[illegible]				
	ASTM B209	5086		H34	25			44000	34000	15,43	−452	14650	1050[illegible]				
	ASTM B209	5154		0	22			30000	11000	43	−452	7350	[illegible]				
	ASTM B209	5154		H112	22			30000	11000	11,15,43	−452	7350	7350[illegible]				
	ASTM B209	5154		H32	22			36000	26000	15,43	−452	12000	9[illegible]				
	ASTM B209	5154		H34	22			39000	29000	15,43	−452	13000	970[illegible]				
	ASTM B209	5456		0	25	3.0" Max Th		42000	18000	1,43	−452	12000	1015[illegible]				
	ASTM B209	5456		H321	25	1.5" Max Th		44000	31000	11,15,43	−452	14650	1600[illegible]				
	ASTM B209	6061		T4	23			30000	16000	15,43	−452	10[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	6061		T6	23			42000	35000	15,43	−452	14000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	6061		Welded	23			24000		15,50	−452	6000	5900	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	6061 CLAD		T4	23			27000	14000	15,43	−452	9000	6500	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B209	6061 CLAD		T6	23			38000	32000	15,43	−452	12650	9200	9000	[illegible]	[illegible]	[illegible]
	ASTM B209	6061 CLAD		Welded	23			24000		15	−452	6000	5900	[illegible]	5400	[illegible]	42[illegible]
[illegible]																	
	ASTM [illegible]	[illegible]		H112	23			14000	5000	9,15,55	−452	3350					
	ASTM [illegible]	6061		T6	23			38000	35000	9,15,55	−452	12650					
	ASTM [illegible]	6061		Welded	23			[illegible]		9,15,45,50	−452	6000	5900	5700	5400	[illegible]	4200
	ASTM B361	WP 1060		0	21			[illegible]	2500	11,13,43	−452	1650					
	ASTM B361	WP 1060		H112	21			8500	2500	11,13,15,43	−452	1650					
	ASTM B361	WP 1100		0	21			13000	3000	[illegible]	−452	2000					
	ASTM B361	WP 1100		H112	21			11000	3000	[illegible]	−452	2000					
	ASTM B361	WP 3003		0	21			14000	5000	[illegible]	−452	3350	3350	[illegible]	3250	[illegible]	[illegible]
	ASTM B361	WP 3003		H112	21			13000	[illegible]	11,13,15,43	−452	3000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B361	WP 3003 CLAD		0	21			13000	4500	11,13,43	−452	3000	3000	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B361	WP 3003 CLAD		H112	21			[illegible]	[illegible]	11,13,15,43	−452	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B361	WP 5052		0	22			25000	[illegible]	11,13,43	−452	6350	6350	[illegible]	[illegible]	[illegible]	[illegible]
	ASTM B361	WP 5052		H112	22			25000	9500	11,13,15,43	−452	6350	6350	6350	6350	[illegible]	4650
	ASTM B361	WP 5154		0	22			30000	11000	11,13,43	−452	7350	7350[illegible]				
	ASTM B361	WP 5154		H112	22			30000	11000	11,13,15,43	−452	7350	7350[illegible]				
	ASTM B361	WP 6061		T4	23			26000	16000	11,13,15,43	−452	8650	8650	[illegible]	[illegible]	[illegible]	
	ASTM B361	WP 6061		T6	23			38000	35000	11,13,15,43	−452	12650	12650	[illegible]	[illegible]	[illegible]	
	ASTM B361	WP 6061		Welded	23			24000		11,13,15,50	−452	6000	5900	5700	5400	[illegible]	4200
	ASTM B361	WP 6063		T4	23			18000	9000	11,13,15,43	−452	6000					
	ASTM B361	WP 6063		T6	23			30000	25000	11,13,15,43	−452	10000	10000	9850	[illegible]	[illegible]	
	ASTM B361	WP 6063		Welded	23			17000		11,13,15	−452	4250	4200	4000	3800	3600	2750
Castings																	
	ASTM B26	S5A		F	–			17000	6000	9,27,43	−452	4000	4000	3700	3400	[illegible]	2850
	ASTM B26	SG70A		T6	–		.80	30000	20000	9,27,43	−452	8000	5900	5500	4550		
	ASTM B26	SG70A		T71	–		.80	25000	18000	9,27,43	−452	6700	4800	4650	4400	[illegible]	3600

TABLE 3

ALLOWABLE STRESS IN TENSION FOR MATERIALS

(NUMBERS IN PARENTHESES REFER TO STRESS TABLE NOTES SEE PAGES THROUGH)

ALLOWABLE STRESSES (PSI)

Metal Temperature Degrees F

400	450	600	650	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	Specification	Material
																								ALUMINUM Plates & Sheets Cont.
																							ASTM B209	
3100																							ASTM B209	
3100																							ASTM B209	
3100																							ASTM B209	
[illegible]																							ASTM B209	
4000																							ASTM B209	
3500																							ASTM B209	
[illegible]																							ASTM B209	
																							ASTM B209	
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																							ASTM B209	
																							ASTM B209	
																							ASTM B209	
2000																							ASTM B209	
2500																							ASTM B209	
3200																							ASTM B209	
3600																							ASTM B209	
[illegible]																							ASTM B209	
3200																								
																								Forgings
																							ASTM B247	
																							ASTM B247	
																							ASTM B247	
3200																							ASTM B247	
																							ASTM B247	
																							ASTM B361	
																							ASTM B361	
																							ASTM B361	
[illegible]																							ASTM B361	
3100																							ASTM B361	
3700																							ASTM B361	
[illegible]																							ASTM B361	
3500																							ASTM B361	
3500																							ASTM B361	
																							ASTM B361	
																							ASTM B361	
																							ASTM B361	
																							ASTM B361	
3200																							ASTM B361	
																							ASTM B361	
1400																							ASTM B361	
																								Castings
																							ASTM B26	
2500																							ASTM B26	
																							ASTM B26	
2800																								

APPENDIX A
TABLE 2

DESIGN STRESSES FOR BOLTING MATERIALS (13, 40)

NUMBERS IN PARENTHESIS REFER TO [illegible] NOT[illegible]

Material	Specification	Grade	Temper	Size Range	Tensile Strength Min Psi	Yield Strength Min Psi	Notes	(20) Min Temp	Min Temp To 100	[illegible]	[illegible]	[illegible]	[illegible]
CARBON STEEL													
	A306	45			45000	22500		−20	11250	11250	11250	11250	[illegible]
	A306	50			50000	25000		−20	12500	12500	12500	12500	[illegible]
	A306	55			55000	27500		−20	13750	13750	13750	13750	[illegible]
	A306	60			60000	30000		−20	15000	15000	15000	15000	[illegible]
	A306	65			65000	32500		−20	16250	16250	16250	16250	[illegible]
	A306	70			70000	35000		−20	17500	17500	17500	17500	[illegible]
	A306	80			80000	40000		−20	20000	20000	20000	20000	[illegible]
	A307	B			60000			−20	13750	13750	13750	13750	
	A325				105000			−20	19250	19250	19250	19250	
	A194	1, 2					[illegible]	−20					
	A194	2H					[illegible]	−50					
ALLOY STEEL													
5 Cr	A193	B5		4" & Under	100000	80000		−20	20000	20000	20000	20000	[illegible]
Cr-Mo	A193	B7		2½" & Under	125000	105000	[illegible]	−20	25000	25000	25000	25000	[illegible]
Cr-Mo	A193	B7		Over 2½" To 4"	115000	95000	[illegible]	−20	23000	23000	23000	23000	[illegible]
Cr-Mo-V	A193	B16		2½" & Under	125000	105000		−20	25000	25000	25000	25000	[illegible]
Cr-Mo-V	A193	B16		Over 2½" To 4"	110000	95000		−20	22000	22000	22000	22000	[illegible]
	A354	BB			100000	85000		−20	20000	20000	20000	20000	[illegible]
	A354	BC			115000			−20	23000	23000	23000	[illegible]	
	A354	BD			150000			−20	30000	30000	30000	[illegible]	
5 Cr	A194	3					42						
C-Mo	A194	4					42						
Cr-Mo	A320	L7,L7A,L7B,L7C		2½" & Under	125000	105000		−150	25000	25000	25000	[illegible]	
3½ Ni	A320	L9		2½" & Under	125000	105000		−225	25000	25000	25000	[illegible]	
3½ Ni	A320	L9		Over 2½" To 4"	105000	80000		−225	21000	21000	21000	[illegible]	
3½ Ni	A320	L10		4" & Under	70000	40000		−150	17500	17500	17500	[illegible]	
Ni-Cr-Mo	A320	L43		4" & Under	125000	105000		−150	25000	25000	25000	[illegible]	
STAINLESS STEEL													
12 Cr	A193	B6		4" & Under	110000	85000		−20	20000	20000	19250	[illegible]	
304 Soln Trtd	A193	B8			75000	30000	[illegible]	−425	15000	15000	13000	[illegible]	
347 Soln Trtd	A193	B8C			75000	30000	[illegible]	−425	15000	15000	15000	[illegible]	
316 Soln Trtd	A193	B8M			75000	30000	[illegible]	−325	15000	15000	15000	[illegible]	
321 Soln Trtd	A193	B8T			75000	30000		−325	15000	15000	15000	[illegible]	
12 Cr	A194	6					[illegible]						
304 Soln Trtd	A194	8					[illegible]						
347 Soln Trtd	A194	8C					[illegible]						
303 Soln Trtd	A194	8F					[illegible]						
316 Soln Trtd	A194	8M					42						
321 Soln Trtd	A194	8T					[illegible]						
304 Soln Trtd	A320	B8			75000	30000	[illegible]	−425	15000	15000	13000	[illegible]	
347 Soln Trtd	A320	B8C			75000	30000	[illegible]	−425	15000	15000	[illegible]		
303 Soln Trtd	A320	B8F			75000	30000	41	−325	15000	15000	15000	[illegible]	
316 Soln Trtd	A320	B8M			75000	30000	[illegible]	−325	15000	15000	15000	[illegible]	
321 Soln Trtd	A320	B8T			75000	30000	5, 12	−325	15000	15000	15000	[illegible]	[illegible]
12 Cr	A437	B4B			145000	100000	[illegible]	−20	36000	35000	34000	[illegible]	[illegible]
12 Cr	A437	B4C			115000	80000	[illegible]	−20	26000	26000	[illegible]	[illegible]	[illegible]
14 Cr-24 Ni	A453	660A/B			130000	85000	[illegible]	−20	21250	21250	20700	[illegible]	[illegible]
19 Cr-9 Ni	A453	651 A		3" & Under	100000	70000	28	−20	17500	17500	16650	16650	[illegible]
19 Cr-9 Ni	A453	651 A		Over 3"	100000	60000		−20	15000	15000	13750	13750	[illegible]
19 Cr-9 Ni	A453	651 B		3" & Under	95000	60000		−20	15000	15000	13750	13750	[illegible]
19 Cr-9 Ni	A453	651 B		Over 3"	95000	50000		−20	12500	12500	11450	11350	[illegible]
ALUMINUM & ALUMINUM BASE ALLOYS													
	B211	2014	T6	1/8" To 8"	65000	55000	54,55	−325	13000	13000	11600	10400	[illegible]
	B211	2024	T4	1/8" To Under ½"	62000	45000	54,55	−325	11250	[illegible]	[illegible]	[illegible]	[illegible]
	B211	2024	T4	½" To 4½"	62000	42000	54,55	−325	10500	10150	[illegible]	[illegible]	[illegible]
	B211	2024	T4	Over 4½" To 6½"	62000	40000	54,55	−325	10000	9700	[illegible]	[illegible]	[illegible]
	B211	2024	T4	Over 6½" To 8"	58000	38000	54,55	−325	9500	9200	8950	8500	7400
	B211	6061	T6	1/8" To 8"	42000	35000	54,55	−325	8400	8200	7900	7500	6300
COPPER & COPPER BASE ALLOY													
Copper	B12	102,110,120,122,125			30000	10000		−325	2500	2200	2000	[illegible]	[illegible]
Arsenical Copper	B12	141,142	Soft		31000	10000		−325	2500	2200	2000	[illegible]	[illegible]
Naval Brass	B21	463,482,485	Soft		50000	20000		−325	5000	5000	[illegible]	[illegible]	[illegible]
Copper Silicon	B98	655,661	Soft		52000	15000		−325	3750	3500	[illegible]	[illegible]	[illegible]
Copper Silicon	B98	655,661	Quarter Hard		55000	24000		−325	6000	6000	[illegible]	[illegible]	[illegible]
Copper Silicon	B98	655,661	Half Hard		70000	38000		−325	9500	9500	[illegible]	[illegible]	[illegible]
Copper Silicon	B98	651	Soft		40000	12000		−325	3000	[illegible]	[illegible]	[illegible]	[illegible]
Copper Silicon	B98	651	Bolt	Up To ½"	85000	55000		−325	13500	[illegible]	[illegible]	[illegible]	[illegible]
Copper Silicon	B98	651	Bolt	Over ½" To 1"	75000	45000		−325	11200	[illegible]	[illegible]	[illegible]	[illegible]
Copper Silicon	B98	651	Bolt	Over 1"	75000	40000		−325	10000	10000	[illegible]	[illegible]	[illegible]
Aluminum Bronze	B150	642		Up To ½"	80000	40000		−325	10000	10000	[illegible]	[illegible]	[illegible]
Aluminum Bronze	B150	642		Over ½" To 1"	75000	35000		−325	9400	[illegible]	[illegible]	[illegible]	[illegible]
Aluminum Bronze	B150	642		Over 1"	72000	35000		−325	8800	8400	[illegible]	[illegible]	[illegible]
Aluminum Bronze	B150	630		½" To 1"	100000	50000		−325	12500	[illegible]	[illegible]	[illegible]	[illegible]
Aluminum Bronze	B150	630		Over 1" To 2"	90000	45000		−325	11250	[illegible]	[illegible]	[illegible]	[illegible]
Aluminum Bronze	B150	630		Over 2" To 4"	85000	42500		−325	10600	10500	[illegible]	[illegible]	[illegible]
Aluminum Bronze	B150	614		Up To ½"	80000	40000		−325	10000	9950	[illegible]	[illegible]	[illegible]
Aluminum Bronze	B150	614		Over ½" To 1"	75000	35000		−325	8750	[illegible]	[illegible]	[illegible]	[illegible]
Aluminum Bronze	B150	614		Over 1" To 2"	70000	32000		−325	8000	8000	[illegible]	[illegible]	[illegible]
NICKEL & NICKEL BASE ALLOY													
Nickel	B160	200	Cold Drawn		65000	40000		−325	10000	[illegible]	[illegible]	[illegible]	[illegible]
Nickel	B160	200	Annealed		55000	15000		−325	3750	3750	[illegible]	[illegible]	[illegible]
Nickel	B160	200	Hot Finished		60000	15000		−325	3750	[illegible]	[illegible]	[illegible]	[illegible]
Low Carbon Nickel	B160	201	Ann. Hot Fin.		50000	10000		−325	2500	[illegible]	[illegible]	[illegible]	[illegible]
Nickel Copper	B164	400,405	Annealed		70000	25000		−325	6250	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

TABLE 2

DESIGN STRESSES FOR [illegible] MATERIALS (16, [illegible])

(NUMBERS IN PARENTHESES REFER TO [illegible] TABLE NOTES SEE PAGES 72 THROUGH 75)

ALLOWABLE STRESSES [illegible] (PSI) (4)

Metal Temperature Degrees F (55)

400	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300	1350	1400	1450	1500	[illegible]	[illegible]
																								CARBON STEEL
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																		A106	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																		A106	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																		A106	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																		A106	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																		A106	
[illegible]	[illegible]	[illegible]	17500	17500	17500																		[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	20000	[illegible]																		A106	
[illegible]	[illegible]	[illegible]																					[illegible]	
[illegible]	19750	19250	19250	19250	19250																		[illegible]	
																							[illegible]	
																							[illegible]	
																								ALLOY STEEL
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4150	3050	2000	1300							[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12500	[illegible]	4500											[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12500	[illegible]	4500											[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25000	[illegible]	[illegible]	[illegible]	11000	6250	2750									[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22000	22000	22000	21000	[illegible]	15300	11000	6250	2750									[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23000																		[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																		[illegible]	
[illegible]	[illegible]	[illegible]	30000	[illegible]	[illegible]																		[illegible]	
																							[illegible]	
																							[illegible]	
[illegible]	25000	[illegible]	20000	[illegible]	[illegible]	20000	20000	20000	16250	12500	8500	4500											A320	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20000																		A320	[illegible]
[illegible]	21000	[illegible]	[illegible]	[illegible]	[illegible]																		[illegible]	[illegible]
[illegible]	17500	[illegible]	17500	[illegible]	[illegible]																		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	20000	[illegible]	20000																		A320	[illegible]
																								STAINLESS STEEL
[illegible]	17750	17150	17150	16550	16550	16100	15550	14500	13600	[illegible]													[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8300	8000	7750	[illegible]	7250	7050	[illegible]	[illegible]	5750	[illegible]	3250	2450	1500	[illegible]	[illegible]	750	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11800	11750	11650	11450	[illegible]	11100	10800	10500	10000	9000	[illegible]	3600	2700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	12650	[illegible]	[illegible]	[illegible]	[illegible]	11800	11750	11650	11450	11300	[illegible]	10500	[illegible]	[illegible]	[illegible]	5800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12650	12650	12200	12200	[illegible]	[illegible]	11800	11750	11650	11450	[illegible]	11100	10800	10500	10000	[illegible]	5000	3600	2700	[illegible]	1550	[illegible]	1000	[illegible]	[illegible]
																							[illegible]	[illegible]
																							[illegible]	[illegible]
																							[illegible]	[illegible]
																							A194	[illegible]
																							A194	[illegible]
																							A194	[illegible]
[illegible]	10000	10000	10000	[illegible]	[illegible]	8650	8300	8000	7750	7500	7250	7050	[illegible]	[illegible]	5750	4500	3250	2450	[illegible]	[illegible]	1000	750	A320	[illegible]
[illegible]	12650	12200	12200	[illegible]	[illegible]	11800	11750	11650	11150	[illegible]	11100	10800	10500	[illegible]	8000	5000	3600	2700	2000	[illegible]	[illegible]	1000	A320	[illegible]
[illegible]	[illegible]	10000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]															[illegible]	[illegible]
[illegible]	12650	12200	12200	11900	[illegible]	11800	11750	[illegible]	11450	11300	[illegible]	10800	10500	[illegible]	[illegible]	6800	5300	4000	3000	2350	1850	1500	A320	[illegible]
[illegible]	[illegible]	12200	[illegible]	11900	[illegible]	11800	11750	11650	11450	[illegible]	11100	10800	10500	[illegible]	8000	5000	3600	2700	2000	1550	1200	1000	[illegible]	[illegible]
[illegible]	31400	30500	[illegible]	29700	[illegible]																		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	24200	23500	22900																		[illegible]	[illegible]
[illegible]	20350	[illegible]	[illegible]	20200	[illegible]	20100	20000	19950	19900	[illegible]	19800	19750											A453	[illegible]
[illegible]	14050	13400	13400	12700	12400	12150	11850	11600	11300	[illegible]	10950	10700											A453	[illegible]
[illegible]	[illegible]	11500	11500	[illegible]	[illegible]	10400	10150	9950	9750	[illegible]	9400	9150											A453	[illegible]
[illegible]	[illegible]	11500	11500	[illegible]	10650	[illegible]	10150	9950	9750	9550	9400	9150											A453	[illegible]
[illegible]	[illegible]	9500	9500	9000	8800	8650	8450	8300	8150	[illegible]	7850	7650											A453	[illegible]
																								ALUMINUM & ALUMINUM BASE ALLOYS
[illegible]																							[illegible]	
[illegible]																							B211	
[illegible]																							B211	
[illegible]																							B211	
[illegible]																							B211	
[illegible]																							B211	
																								COPPER & COPPER BASE ALLOY
[illegible]																							B12	[illegible]
[illegible]																							B12	[illegible]
																							[illegible]	[illegible]
																							[illegible]	[illegible]
																							[illegible]	[illegible]
																							[illegible]	[illegible]
																							[illegible]	[illegible]
																							[illegible]	[illegible]
																							[illegible]	[illegible]
																							[illegible]	[illegible]
[illegible]	9500	[illegible]	9200	[illegible]																			B150	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																			B150	[illegible]
[illegible]	[illegible]	8200	[illegible]	[illegible]																			B150	[illegible]
[illegible]	[illegible]	[illegible]	10500	[illegible]	[illegible]	[illegible]																	B150	[illegible]
[illegible]	[illegible]	[illegible]	9400	[illegible]	6680	6000																	[illegible]	[illegible]
[illegible]	[illegible]	9400	8990	[illegible]	7150	5800																	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]																					[illegible]	[illegible]
[illegible]	[illegible]	8200																					[illegible]	[illegible]
[illegible]	[illegible]	[illegible]																					B150	[illegible]
																								NICKEL & NICKEL [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																			[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																			[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2300	2100	2250	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1700							[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]																			[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]														[illegible]	[illegible]

APPENDIX A
TABLE 2

[illegible] STRESSES FOR BOLTING MAT[illegible]

(NUMBERS [illegible] REFER TO STRESS TA[illegible] NOTES SEE PAGES [illegible])

Material	Specification	Grade	Temper	Size Range	Tensile Strength Min PSI	Yield Strength Min PSI	[illegible]	Max Temp	To 100	150	200	250	[illegible]
NICKEL AND NICKEL BASE ALLOY (Cont)													
Nickel-Copper	B164	400	Hot Finished	All Except Hex Over 2 1/8"	80000	[illegible]		325	10000	[illegible]			[illegible]
Nickel-Copper	B164	400	Hot Finished	Hex Over 2 1/8"	[illegible]	[illegible]		325	7[illegible]	7[illegible]			[illegible]
Nickel-Copper	B164	405	Hot Finished	Rd To 3" Incl	[illegible]	[illegible]		325	[illegible]	[illegible]			
Nickel-Copper	B164	400	Cold Dr Rel		8[illegible]	[illegible]	5[illegible]	325	12[illegible]	[illegible]			[illegible]
Nickel-Copper	B164	400	Cold Dr Eq	Rd To 3 1/2" Incl	[illegible]	70000	5[illegible]	325	17500	17[illegible]			[illegible]
Nickel-Copper	B164	400	[illegible] Eq	All Exc Rd [illegible]	[illegible]	[illegible]	[illegible]	325	[illegible]	[illegible]			[illegible]
Nickel-Copper	B164	400	Cold Drawn		[illegible]	52[illegible]	[illegible]	325	[illegible]				[illegible]
Nickel-Copper	B164	405	Cold Drawn		[illegible]	[illegible]	[illegible]	325	12[illegible]	[illegible]			
[illegible]	B166	600	Annealed		[illegible]	[illegible]		325	[illegible]	[illegible]			
[illegible]	B166	600	[illegible]	Rd Over 3	[illegible]	[illegible]		325	[illegible]	[illegible]			
Ni-Cr-Fe	B166	600	Hot Finished	Rd To 3"	[illegible]	[illegible]		325	[illegible]				
Ni-Cr-Fe	B166	600	Cold Drawn		90000	40000	[illegible]	325	10000	[illegible]			
Ni-Mo	B335		Annealed		100000	46000		325	[illegible]	[illegible]			
Ni-Mo-Cr	B336		Annealed		100000	16000		325	[illegible]	[illegible]			

ALLOWABLE STRESSES

Metal Temperature Degrees F

[illegible]	400	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	1250	1300
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8400	8300		[illegible]								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6100	[illegible]	6200	5100	[illegible]								
[illegible]	[illegible]	[illegible]																
[illegible]	[illegible]	[illegible]																
[illegible]	[illegible]	[illegible]																
[illegible]	[illegible]	[illegible]																
[illegible]	[illegible]	[illegible]																
[illegible]	[illegible]	[illegible]																
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	7200	[illegible]	[illegible]	[illegible]	[illegible]	6900		[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8700	8600	[illegible]	[illegible]	7600	[illegible]		[illegible]		
[illegible]	[illegible]	[illegible]																
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						

APPENDIX B

SAMPLE CALCULATIONS FOR BRANCH REINFORCEMENT

The following examples are intended to illustrate the application of the rules and definitions in 304.3.3 for welded branch connections.

a. An 8 in. run (header) in an oil piping system has a 4 in. branch at right angles (Figure 304.3.3C page [illegible]). Both pipes are schedule 40 API 5L Grade A seamless. The design conditions are 300 psig at 400 F. The fillet welds at the crotch are minimum size in accordance with 327.4.6(b). A corrosion allowance of 0.10 in. is specified. Is additional reinforcement necessary?

SOLUTION

From Appendix A Table 1 SE = 13800 psi.

$T_h = (0.322)(0.875) = 0.282$ in.

$T_b = (0.237)(0.875) = 0.207$ in.

$L_4 = 2.5(0.237 - 0.10) = 0.343$ in.

$d_2 = d_1 = 4.500 - 2(0.207 - 0.10) = 4.286$ in.

$$t_h = \frac{(300)\ (8.625)}{(2)\ (13800) + (2)\ (0.4)\ (300)} = 0.093 \text{ in.}$$

$$t_b = \frac{(300)\ (4.500)}{(2)\ (13800) + (2)\ (0.4)\ (300)} = 0.0485 \text{ in.}$$

Minimum leg dimension of fillet weld $= \dfrac{(0.7)\ (0.237 - 0.10)}{0.707} = 0.136$ in.

Thus, the required area, $A_1 = (0.093)(4.286) = 0.399$ sq. in.

The reinforcement area in run wall, $A_2 = (4.286)(0.282 - 0.093 - 0.10)$	= 0.381 sq. in.
in branch wall, $A_3 = (2)(0.343)(0.207 - 0.0485 - 0.10)$	= 0.040 sq. in.
in fillet welds, $A_4 = (2)(\tfrac{1}{2})(0.136)^2$	= 0.018 sq. in.
The total reinforcement area	= 0.439 sq. in.

This is more than 0.399 sq. in. so that no additional reinforcement is required to sustain the internal pressure.

b. There is an 8 in. branch at right angles to an 18 in. header. (Figure 304.3.3C). Both run and branch are of schedule 80 ASTM A335 Grade P11 seamless pipe. The connection is reinforced by a ring 14 in. outside diameter (measured along the run) cut from a piece of 18 in. schedule 80 ASTM A335 Grade P12 seamless pipe and opened slightly to fit over the run pipe. The fillet welds have the minimum dimensions permitted in 327.4.6(b). A corrosion allowance of 0.10 in. is specified. What is the maximum permissible normal operating pressure if the normal operating temperature is 1005F?

SOLUTION.

From Appendix A Table 1 SE = 7570 psi for Grade P11 and SE = 7250 psi for Grade P12, both at 1005F.

Leg Dimensions of Welds

$$\frac{t_c}{0.707} = \frac{0.250}{0.707} = 0.354 \text{ in.}$$

$$\frac{(0.5)\ (0.937)\ (0.875)}{0.707} = 0.580 \text{ in.}$$

$T_h = (0.937)(0.875) = 0.820$ in.

$T_b = (0.500)(0.875) = 0.438$ in.

$t_r = (0.937)(0.875) = 0.820$ in.

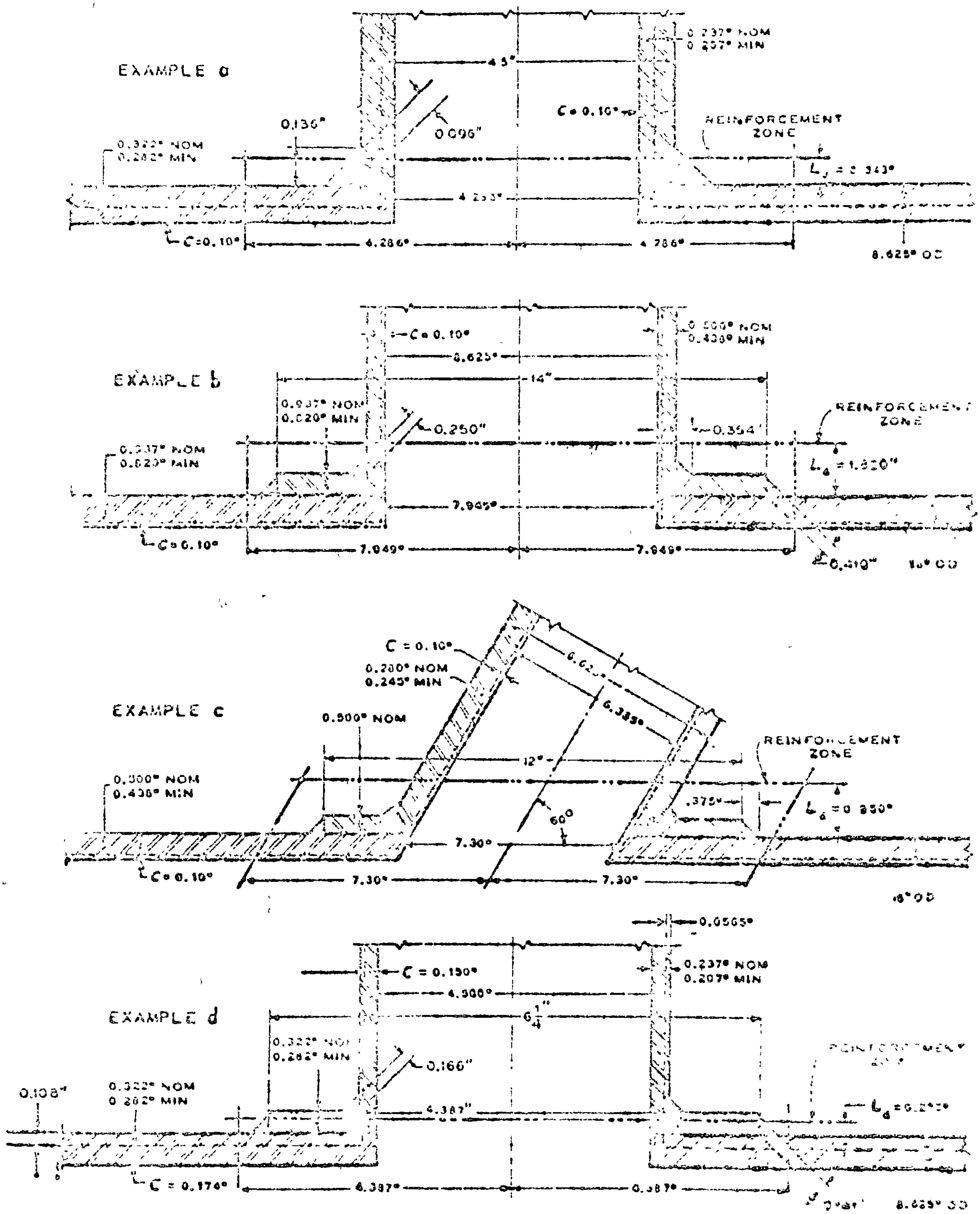

FIG 304.3.3C – ILLUSTRATIONS FOR EXAMPLES IN APPENDIX B

L_4 = 2.5 (0.500 − 0.10) + 0.820 = 1.820 in.
(This is smaller than 2-1/2 (0.937 − 0.10) = 2.094 in.)

d_2 = d_1 = 8.625 − 2(0.438 − 0.10) = 7.949 in.

$$t_h = \frac{18P}{(2)(7570) + (2)(0.7)(P)}$$

$$t_b = \frac{(8.625)(P)}{(2)(7570) + (2)(0.7)(P)}$$

Using the symbol $q = \frac{P}{15140 + 1.4P}$, we can briefly write

t_h = 18q and t_b = 8.625 q.

The required area, A_1 = 7.949 t_h = 143.08q

The reinforcement area

in run wall, A_2	= (7.949) (0.820 − 18q − 0.10)	=	5.723 − 143.08q
in branch wall, A_3	= (2) (1.820) (0.438 − 8.625q − 0.10)	=	1.230 − 31.395q
in ring, A_4	= (0.820) (14 − 8.625) (7250/7570)	=	4.221
in fillet welds, A_4	= (2) (1/2) (0.354)^2 + (2) (1/2) (0.580)^2	=	0.461
The total reinforcement area		=	11.635 − 174.475q

At the maximum permissible normal operating pressure, the required area and the reinforcement area are equal; thus:

143.08q = 11.635 − 174.475q; 317.555q = 11.635; q = 0.0366

But also, $q = \frac{P}{15140 + 1.4P}$

Thus, P = (0.0366) (15140 + 1.4P) = 554.12 + 0.0512P

0.9488P = 554.12

P = 584 psig which is the maximum permissible normal operating pressure.

c. A 6 in. schedule 40 branch has its axis at a 60° angle to the axis of a 16 in. schedule 40 run (header) in an oil piping system (Figure 304.3.3C). Both pipes are API 5L Grade A seamless. The connection is reinforced with a ring 12 in. outside diameter (measured along the run) made from 1/2 in. ASTM A285 Grade C plate. All fillet welds are equivalent to 45° fillet welds with 3/8 in. legs. Corrosion allowance = 0.10 in. The design pressure is 500 psig at 700 F. Is the design adequate for the internal pressure?

SOLUTION:

The allowable stress values from Appendix A Table 1 are: for pipe, SE = 11650 psi; for ring, SE = 14400 psi.

T_h = (0.500) (0.875) = 0.438 in.

T_b = (0.280) (0.875) = 0.245 in.

t_r = 0.500 in.

L_4 = 2.5 (0.280 − 0.10) + 0.500 = 0.950. This is smaller than 2.5 (0.500 − 0.10) = 1.000 in.

$$t_h = \frac{(500)(16)}{(2)(11650) + (2)(0.4)(500)} = 0.338 \text{ in.}$$

$$t_b = \frac{(500)(6.625)}{(2)(11650) + (2)(0.4)(500)} = 0.140 \text{ in.}$$

$$d_2 = d_1 = \frac{6.625 - 2(0.245 - 0.10)}{\sin 60^\circ} = \frac{6.335}{0.866} = 7.30 \text{ in.}$$

The required area, A_1 = (0.338) (7.30) (2 − 0.866) = 2.80 sq. in.

The reinforcement area

in run wall, A_2	$= (7.30)(0.438 - 0.338 - 0.10)$	$= 0$ sq. in.
in branch wall, A_3	$= (2)\dfrac{(0.950)}{0.866}(0.245 - 0.140 - 0.10)$	$= 0.011$ sq. in.
in ring, A_4	$= 0.500\left(12 - \dfrac{6.625}{0.866}\right)$	$= 2.175$ sq. in.
in fillet welds, A_4	$= (4)(1/2)(3/8)^2$	$= 0.281$ sq. in.
Total reinforcement area		$= 2.467$ sq. in.

This total is less than 2.80 sq. in., so that additional reinforcement in the amount of 0.333 sq. in. is required to sustain internal pressure. Increase pad diameter to 13 in. Then the reinforcement area in ring is 2.675 sq. in. The total reinforcement area now = 2.967 sq. in. which is adequate.

d. An 8 in. run (header) in an oil piping system has a 4 in. branch at right angles (Figure 304.3.3C). Both pipes are schedule 40 API 5L Grade A seamless. The design conditions are 350 psig at 400 F. It is assumed that the piping system is to remain in service until all metal thickness, in both branch and header, in excess of that required by equation (3) of 304.1.2 has corroded away per 304.3.3(c)(1). What reinforcing is required for this connection?

SOLUTION:

The allowable stress value from Appendix A Table 1 is $SE = 13800$ psi.

$$t_h = \frac{(350)(8.625)}{(2)(13800) + (2)(0.4)(350)} = 0.108 \text{ in.}$$

$$t_b = \frac{(350)(4.500)}{(2)(13800) + (2)(0.4)(350)} = 0.0565 \text{ in.}$$

$$d_1 = 4.500 - (2)(0.0565) = 4.387 \text{ in.}$$

Required reinforcing area, $A_1 = (0.108)(4.387) = 0.474$ sq. in.

Try fillet welds only

$$L_4 = (2.5)(0.0565) = 0.141 \text{ in.}$$

or

$$(2.5)(0.108) = 0.270 \text{ in.} \qquad \text{use } 0.141 \text{ in.}$$

Due to limitation in the height at the reinforcing zone, no practical fillet weld size will supply enough reinforcement area; therefore, the connection must be reinforced by a ring. Try a ring of 6¼ in. outside diameter (measured along the run). Assume the ring to be cut from a piece of 8 in. schedule 40 API 5L Grade A seamless pipe and welded to the connection with minimum size fillet welds.

Min pad thickness, $t_r = (0.322)(0.875) = 0.282$ in. (Mfg. Tolerance)

New $L_4 = (2.5)(0.0565) + 0.282 = 0.423$ in.

or

$(2.5)(0.108) = 0.270$ in. use 0.270 in.

Reinforcement area in the ring:

$X_1 = 0.282\,(6.25 - 4.5) - (0.282 - 0.270)\,(6.25 - 4.5)^* = 0.473$ sq. in.

Leg Dimension of Weld:

$$\frac{(0.5)(0.282)}{0.707} = 0.199 \text{ in.}$$

Reinforcement area in fillet welds:

$X_2 = (2)(1/2)(0.199)^2 = 0.040$ sq. in.

*The subtractive term accounts for that portion of the ring and fillets lying outside the reinforcement zone

Total Reinforcement Area, $A_4 + X_1 + X_2 = 0.513$ sq. in

This total reinforcement area is greater than the required reinforcing area, therefore a reinforcing ring [illegible] 6½ in. outside diameter cut from a piece of 8 in. schedule 40 API 5L Grade A seamless pipe and welded to the connection with minimum size fillet welds would provide adequate reinforcing for this connection

e. (Not illustrated) A 1 1/2 in 3000 lb forged steel socket welding coupling has been welded at right angles to a 8 in schedule 40 header in oil service using a weld conforming to Example A of Figure 327.4.5D. The header is A53 Grade B seamless pipe. The design pressure is 400 psi and the design temperature is 450F. The corrosion allowance is 0.10 in. Is additional reinforcement required?

SOLUTION

No. According to 304.3.3(b) the design is adequate to sustain the internal pressure and no calculations are necessary. It is presumed, of course, that calculations have shown the run pipe to be satisfactory for the service conditions according to Equations 2 and 3

APPENDIX E

Includes referenced standards revisions effective August 12, 1970

Standards incorporated in this Code by reference, and the names and addresses of the sponsoring organizations are shown in this Appendix. It is not practical to refer to a specific edition of each standard throughout the Code text; but instead, the specific edition reference dates, are also shown here. Updated standards incorporated in this Code by reference will be covered by a separately published list supplementing this Appendix E, which is to be attached to this Code. It will be designated "B31.3a Reference Standards, supplementing Appendix E, ANSI B31.3-1973". This list will be published separately because it is subject to interim revisions, between Code editions.

ASTM Specifications

A36-69	A350-65	B127-61
A47-68	A351-69	B132-52
A48-64	A352-68a	B143-61
A53-69a	A353-67a	B147-63
A105-68	A354-66	B148-63T
A106-68	A357-67	B149-52
A120-69	A358-65	B150-66
A126-66	A369-65	B152-68
A134-68	A376-64	B160-61
A135-69	A377-66	B161-61
A139-68	A381-68	B162-61
A155-69	A387-69	B164-61
A167-69	A395-68	B165-61
A181-68	A403-67	B166-63
A182-69	A409-66	B167-64
A193-69	A410-69	B168-63
A194-69	A420-64	B169-66a
A197-47(1965)	A426-66	B209-69
A202-69	A430-70	B210-68
A203-69	A437-68a	B211-69
A204-69	A445-66	B221-69
A211-68	A451-66	B241-69
A216-69	A452-65	B247-69
A217-69	A453-65	B283-69
A225-69	A494-62	B333-62
A234-65	A515-69	B334-65
A240-69	A516-69	B335-62
A245-64	A524-68	B336-62
A268-68	A587-68	B361-64
A278-64	A593-69	B366-66
A283-67	B11-66a	B407-65T
A285-69	B12-66a	E71-64
A299-69	B21-66a	E109-63
A300-68	B26-68	E112-63
A302-69a	B42-66	E114-63
A306-64	B43-66	E125-63
A307-68	B61-63	E138-63
A312-69	B62-63	E142-68
A320-68	B68-68	E155-64
A325-68	B75-68	E165-65
A333-70	B88-66a	E186-67
A335-65	B96-69	E272-67
A338-61(1967)	B98-69	E280-68
		E310-69

American National Standards

A21.1–1967
A21.6–1962
A21.7–1962
A21.8–1962
A21.9–1962
A21.10–1964
A21.11–1964
A21.12–1965
A21.14–1968
A21.50–1965
A21.51–1965
A21.52–1965
A58.1–1969
B1.1–1960
B2.1–1968
B2.2–1968
B2.4–1966
B16.1–1967
B16.3–1963
B16.4–1963
B16.5–1968
B16.9–1964
B16.10–1957
B16.11–1966
B16.14–1965
B16.15–1964
B16.18–1963
B16.18a–1967
B16.20–1963
B16.21–1962
B16.22–1963
B16.24–1962
B16.25–1964
B16.26–1967
B16.28–1964
B18.2.1–1965
B18.2.2–1965
B26–1925(R1953)
B36.10–1970
B36.19–1965
B46.1–1962
Z70.1–1969

MSS Standard Practices

SP-6 –1963
SP-9 –1970
SP-25–1964
SP-37–1959
SP-42–1959
SP-43–1959
SP-45–1953
SP-48–1969
SP-51–1957 (R1965)
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SP-73–1970

API Standards

5L, 25th Edn., 1970
5LX, 17th Edn, 1970
5LS, 5th Edn, 1970

6A, 6th Edn. 1968 + Supplement 1, Feb. 1969**
526, 2nd Edn. 1969
527, 1st Edn. 1968
599, 1st Edn. 1970
600, 6th Edn. 1969
601, 2nd Edn. 1962
602, 1st Edn. 1964
603, 1st Edn. 1962
604, 2nd Edn. 1965
605, 1st Edn. 1967

AWWA Standards

C207–1955
C208–1959
C500–1961
C504–1970
C600–1964

[illegible]	AWS Standard
ASME Boiler and [illegible] Vessel Code	A 3.0 – 1969
Section VIII [illegible] and Addenda through Summer 1970	AAR Specifications
Section VIII [illegible] and Addenda through Summer 1970	M-404 – 1942
Section IX [illegible] and [illegible] through Summer 1970	Federal Specifications
	WW-P-421C, Sept. 1967

*The issue date shown immediately [illegible] the hyphen after the number of the standard (e.g., A-21.1-1967, C 207-1955, and A 36-69) is the [illegible] date of the issue (edition) of the standard. Any additional number shown following the issue d[illegible] prefixed by the letter "R", is the latest date of reaffirmation [illegible] SP 51-1957 (R1965).

This publication, a consolidation [illegible] Standards 6A, 6B, 6BX, 6C, 6CM, and 6E, covers wel[illegible] fittings, and flanges. Only that [illegible] of this standard which covers the material formerly in Standard [illegible] (i.e., threads in valves, fittings, and [illegible]es) is specifically applicable to this code.

Specifications and standards of [illegible] organizations appear in the above list:

AAR	Association of American Railroads 59 East Van B[illegible], Chicago, Illinois 60605
API	American Petroleum Institute 1801 K Street NW, Washington, D.C. 20006
ANSI	American National Standards Institute, Inc. 1430 Broadway, New York, New York 10018
ASME	The American Society of Mechanical Engineers 345 East 47th Street, New York, New York 10017
ASTM	American Society for Testing and Materials 1916 Race Street, Philadelphia, Pennsylvania 19103
AWS	American Welding Society 2501 N.W. 7th Street, Miami, Florida 33125
AWWA	American Water Works Association 2 Park Avenue, New York, New York 10016
MSS	Manufacturers Standardization Society of the Valve and Fittings Industry 1815 North [illegible] Drive, Arlington, Virginia 22209
- - -	Federal Specifications [illegible] Superintendent of Documents United States Government Printing Office Washington, D.C. [illegible]

INDEX

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20.	RICARDO SOSA TORRES	PEMEX Av. Marina Nacional # 365 Col. Anáhuac México, D. F. Tel. 545-74-60 Ext. 2481
21.	RAUL TAJONAR CHAVEZ Flamencos # 42 Col. Sn. José Insurgentes México 10, D. F.	DESPACHO PARTICULAR Insurgentes Sur # 1657-101 Col. Guadalupe Inn México 20, D. F. Tel. 598-20-19
22.	J. IGNACIO TAKAMI CAMPOS Paseo de las Alamedas # 143 Fracc. Alamedas Edo. de México Tel. 9159421750	IMSS. Durango # 291-4° Piso Col. Roma México 7, D. F. Tel. 553-21-11
23.	ING. RAMON UGALDE BURGOS Las Flores # 208 Col. Tlacopac San Angel México 20, D. F. Tel. 563-06-24	
24.	GLORIA DE LOS A. VELEZ M. Reforma # 51-15° Piso Col. San Rafael México 4, D. F. Tel. 535-54-83	SARH. Reforma # 69 Col. San Rafael México 4, D. F. Tel. 535-54-94

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(DEL 12, 13, 19, 26 y 27 DE AGOSTO DE 1977.

	NOMBRE Y DIRECCION	EMPRESA Y DIRECCION
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