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

A LOS ASISTENTES A LOS CURSOS

Las autoridades de la Facultad de Ingeniería, por conducto del jefe de la División de Educación Continua, otorgan una constancia de asistencia a quienes cumplan con los requisitos establecidos para cada curso.

El control de asistencia se llevará a cabo a través de la persona que le entregó las notas. Las inasistencias serán computadas por las autoridades de la División, con el fin de entregarle constancia solamente a los alumnos que tengan un mínimo de 80% de asistencias.

Pedimos a los asistentes recoger su constancia el día de la clausura. Estas se retendrán por el periodo de un año, pasado este tiempo la DECFI no se hará responsable de este documento.

Se recomienda a los asistentes participar activamente con sus ideas y experiencias, pues los cursos que ofrece la División están planeados para que los profesores expongan una tesis, pero sobre todo, para que coordinen las opiniones de todos los interesados, constituyendo verdaderos seminarios.

Es muy importante que todos los asistentes llenen y entreguen su hoja de inscripción al inicio del curso, información que servirá para integrar un directorio de asistentes, que se entregará oportunamente.

Con el objeto de mejorar los servicios que la División de Educación Continua ofrece, al final del curso deberán entregar la evaluación a través de un cuestionario diseñado para emitir juicios anónimos.

Se recomienda llenar dicha evaluación conforme los profesores impartan sus clases, a efecto de no llenar en la última sesión las evaluaciones y con esto sean más fehacientes sus apreciaciones.

Atentamente
División de Educación Continua.

Palacio de Mineria Calle de Tacuba 5 Primer piso Deleg. Cuauhtémoc 06000 México, D.F. APDO. Postal M-2285
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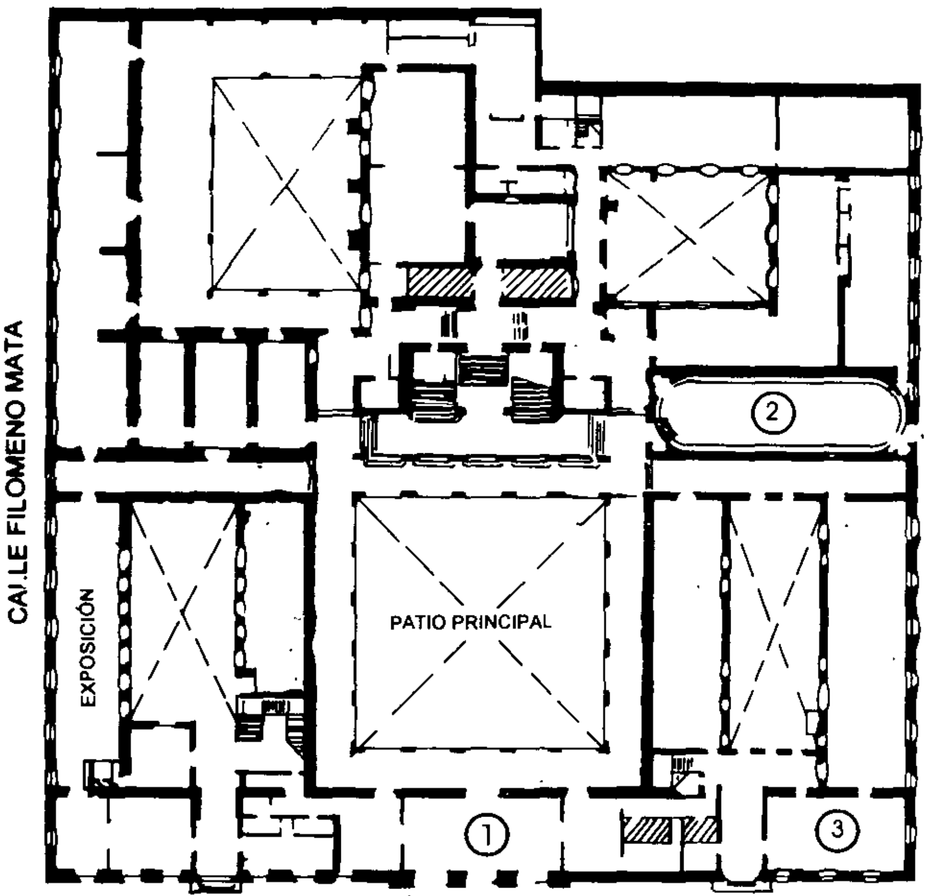

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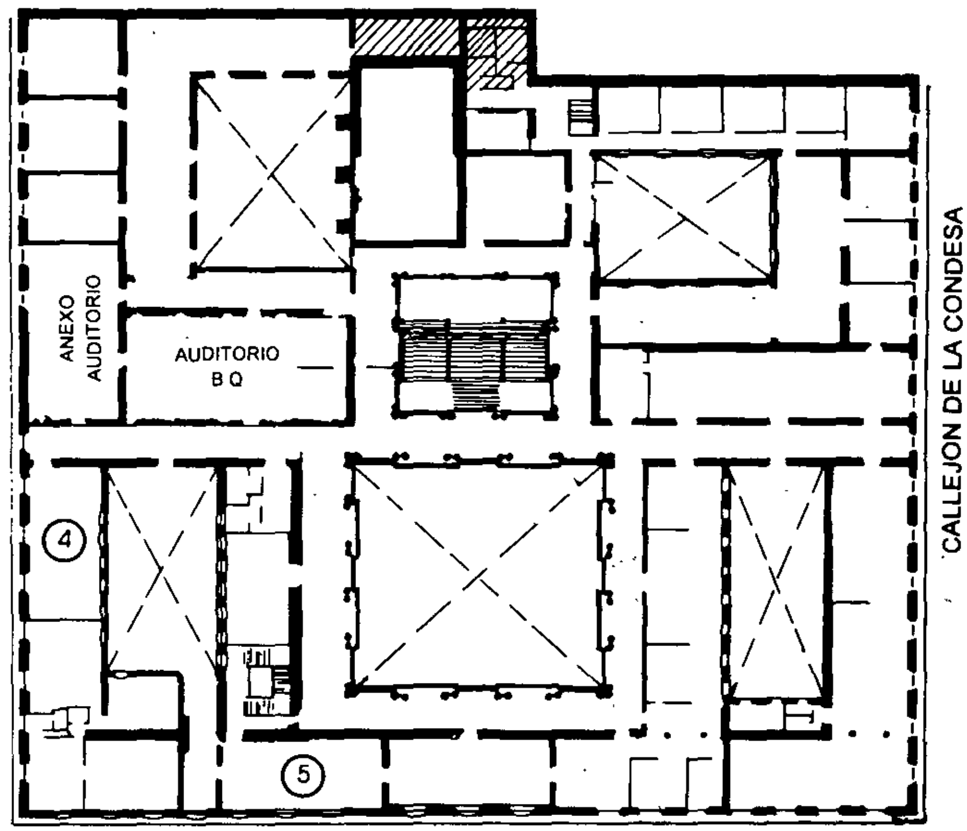

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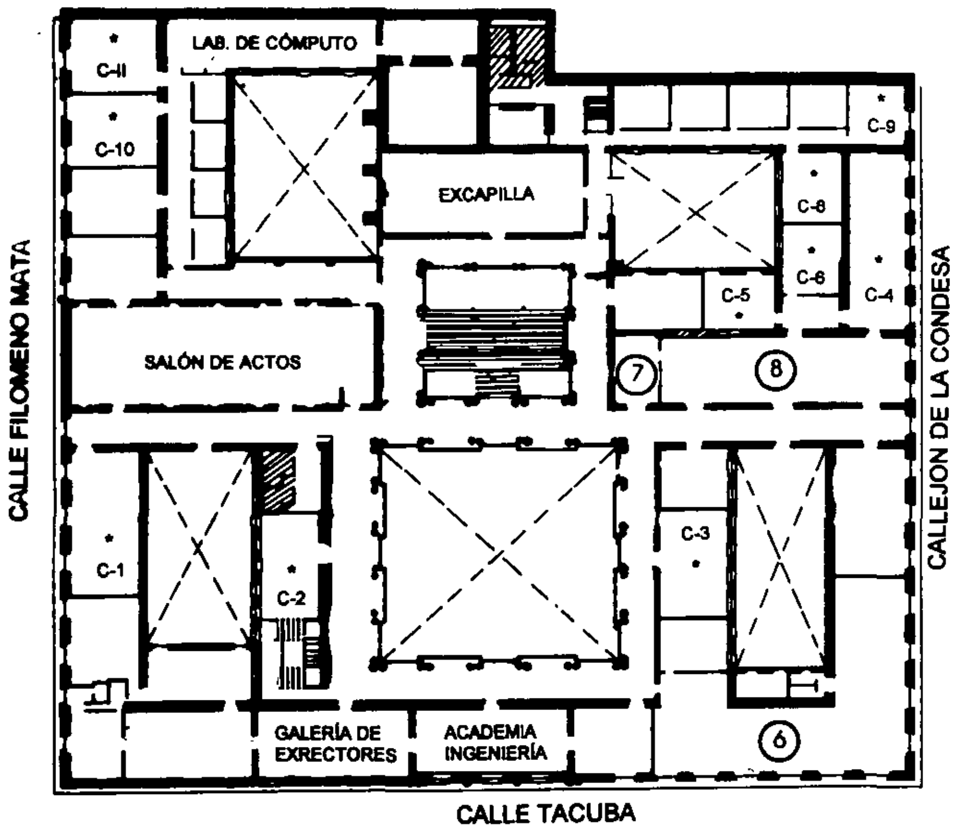

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8. SALA DE DESCANSO

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* AULAS

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FACULTAD DE INGENIERÍA U.N.A.M.
CURSOS ABIERTOS

FACULTAD DE INGENIERÍA UNAM
DIVISIÓN DE EDUCACIÓN CONTINUA

CURSOS ABIERTOS

DIPLOMADO EN INGENIERÍA DE CALDERAS Y RECIPIENTES A PRESIÓN

MÓDULO II: MATERIALES, SOLDADURA Y CALDERAS DE POTENCIA

TEMA

ESPECIFICACIONES DE MATERIALES. SECCIÓN II DEL CODIGO A S M E

EXPOSITOR: ING. ALFREDO SÁNCHEZ FLORES
PALACIO DE MINERÍA
MARZO DEL2003

Palacio de Minería, Calle de Tacuba No. 5, Primer piso, Delegación Cuauhtémoc, CP 06000, Centro Histórico, México D.F.,
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MATERIALES PARA USO EN BAJA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO menos 425 a menos 321 °F
CUERPOS, CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 240 TP304 SA 240 TP304L
BRIDAS CIEGAS	Forja	Forja
	Placa	SA 182 F304 SA 182 F304L
SILLETAS		Idem cuerpo
FALDÓN a 1.2 m. de línea de tangencia		SA 283 C
CUELLOS para Boquillas		Idem cuerpo
COPLES		SA 182 F304L
Apoyos de Platos y Soportes Internos		Idem cuerpo
Mamparas y Colectores		Idem cuerpo
TUBERIA INTERIOR		SA 312 TP304 SA 312TP304L
CONEXIONES SOLDABLES		SA 403 WP-304 SA 403 WP-304L
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 312 TP304 SA 312TP304L
TORNILLERIA INTERIOR		SA 320 B8 y SA 194-8
TORNILLERIA EXTERIOR		SA 194-8

MATERIALES PARA USO EN BAJA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO menos 150 a menos 91 °F
CUERPOS, CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 203 E S5
		SA 203 D S5
BRIDAS CIEGAS	Forja	Idem cuerpo
	Placa	SA 350 LF 3
SILLETAS		Idem cuerpo
FALDÓN a 1.2 m. de línea de tangencia		SA 283 C
CUELLOS para Boquillas		Idem cuerpo
COPLES		SA 350 LF 3
Apoyos de Platos y Soportes Internos		Idem cuerpo
Mamparas y Colectores		Idem cuerpo
TUBERIA INTERIOR		SA 333-3
CONEXIONES SOLDABLES		SA 420 WPL-3
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 333-3
TORNILLERIA INTERIOR		SA 320 L7 y SA 194-4
TORNILLERIA EXTERIOR		SA 194-4

MATERIALES PARA USO EN BAJA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO menos 50 a menos 41 °F
CUERPOS, CABEZAS Y REFUERZOS		SA 516-65 S5
(Plantillas y Collares)		SA 203 B S5
BRIDAS CIEGAS	Forja	Idem cuerpo
	Placa	SA 350 LF 2
SILLETAS		Idem cuerpo
FALDÓN a 1.2 m. de línea de tangencia		SA 283 C
CUELLOS para Boquillas		Idem cuerpo
COPLES		SA 350 LF 2
Apoyos de Platos y Soportes Internos		Idem cuerpo
Mamparas y Colectores		Idem cuerpo
TUBERIA INTERIOR		SA 333-6
CONEXIONES SOLDABLES		SA 420 WPL-6
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 333-6
TORNILLERIA INTERIOR		SA 320 L7 y SA 194-4
TORNILLERIA EXTERIOR		SA 194-4

MATERIALES PARA USO EN MEDIA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO menos 40 a más 60 °F
CUERPOS, CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 516 70 S5
		SA 516 65 S5
BRIDAS CIEGAS	Placa	Idem cuerpo
	Forja	SA 350 LF 2
SILLETAS		Idem cuerpo
FALDÓN a 1.2 m. de línea de tangencia		SA 283 C
CUELLOS para Boquillas		Idem cuerpo
COPLES		SA 350 LF 2
Apoyos de Platos y Soportes Internos		Idem cuerpo
Mamparas y Colectores		Idem cuerpo
TUBERIA INTERIOR		SA 333-6
CONEXIONES SOLDABLES		SA 420 WPL-6
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 312 TP304
TORNILLERIA INTERIOR Y EXTERIOR		SA 193 B7
		SA 194-2H

MATERIALES MAS COMUNES PARA USO EN MEDIA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO EN GRADOS FARHENHEITH	
		-40 a +60	**+61 a +650**
CUERPOS, CABEZAS Y REFUERZOS		SA 516 70 S5	SA 285 C
(Plantillas y Collares)		SA 516 65 S5	SA 515 70
BRIDAS CIEGAS	Placa	Idem cuerpo	Idem cuerpo
	Forja	SA 350 LF 2	SA 105
SILLETAS		Idem cuerpo	Idem cuerpo
FALDÓN a 1.2 m. de línea de tangencia		SA 283 C	SA 283 C
CUELLOS para Boquillas		Idem cuerpo	Idem cuerpo
COPLES		SA 350 LF 2	SA 105
Apoyos de Platos y Soportes Internos		Idem cuerpo	Idem cuerpo
Mamparas y Colectores		Idem cuerpo	Idem cuerpo
TUBERIA INTERIOR		SA 333-6	SA 53-B
CONEXIONES SOLDABLES		SA 420 WPL-6	SA 234 WPA
			SA 234 WPB
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 312 TP304	SA 53-B
			SA 106-B
TORNILLERIA INTERIOR Y EXTERIOR		SA 193 B7	SA 193 B7
		SA 194-2H	SA 194-2H

MATERIALES PARA USO EN ALTA TEMPERATURA

<table>
<tr><th colspan="2" rowspan="2">COMPONENTE</th><th>TEMPERATURA DE DISEÑO</th></tr>
<tr><th>651 a 775 °F</th></tr>
<tr><td colspan="2">CUERPOS, CABEZAS Y REFUERZOS
(Plantillas y Collares)</td><td>SA 515 70</td></tr>
<tr><td rowspan="2">BRIDAS CIEGAS</td><td>Placa</td><td>Idem cuerpo</td></tr>
<tr><td>Forja</td><td>SA 105</td></tr>
<tr><td colspan="2">SILLETAS</td><td>Idem cuerpo</td></tr>
<tr><td colspan="2">FALDÓN a 1.2 m. de línea de tangencia</td><td>SA 283 C</td></tr>
<tr><td colspan="2">CUELLOS para Boquillas</td><td>Idem cuerpo</td></tr>
<tr><td colspan="2">COPLES</td><td>SA 105</td></tr>
<tr><td colspan="2">Apoyos de Platos y Soportes Internos</td><td>Idem cuerpo</td></tr>
<tr><td colspan="2">Mamparas y Colectores</td><td>Idem cuerpo</td></tr>
<tr><td colspan="2">TUBERIA INTERIOR</td><td>SA 53 B</td></tr>
<tr><td colspan="2">CONEXIONES SOLDABLES</td><td>SA 234 WP B</td></tr>
<tr><td colspan="2">CUELLOS DE BOQUILLAS Y
CONEXIONES SOLDABLES</td><td>SA 106-C
SA 106-B</td></tr>
<tr><td colspan="2" rowspan="2">TORNILLERIA INTERIOR Y EXTERIOR</td><td>SA 193 B7</td></tr>
<tr><td>SA 194-2H</td></tr>
</table>

MATERIALES PARA USO EN ALTA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO	
		851 a 1050 °F	
CUERPOS, CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 387 II CL2	
		SA 387 II CL2	
		Clad con	SA 263 SA 264
BRIDAS CIEGAS	Placa	Idem cuerpo	
	Forja	SA 182 F II	
SILLETAS		Idem cuerpo	
FALDÓN a 1.2 m. de línea de tangencia		SA 283 C	
CUELLOS para Boquillas		Idem cuerpo	
COPLES		SA 182 F II	
Apoyos de Platos y Soportes Internos		Idem cuerpo	
Mamparas y Colectores		Idem cuerpo	
TUBERIA INTERIOR		SA 335-PII	
CONEXIONES SOLDABLES		SA 234 WP II	
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 335-PII	
TORNILLERIA INTERIOR Y EXTERIOR		SA 193 B7 y SA 194-2H	

FACULTAD DE INGENIERÍA UNAM
DIVISIÓN DE EDUCACIÓN CONTINUA

CURSOS ABIERTOS

DIPLOMADO CALDERAS Y RECIPIENTES A PRESIÓN

MÓDULO II: MATERIALES, SOLDADURAS Y CALDERAS DE POTENCIA

TEMA

Materiales Para Recipientes A Presión

EXPOSITOR: ING. ALFREDO SANCHEZ FLORES
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MARZO DEL2003

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Materiales para Recipientes a Presión y Calderas

Manuel Cabrera Moreno
Buen Tono 142, Col Industrial
México, D.F. Tel y Fax 759 3550

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3

SECRETARIA DEL TRABAJO Y PREVISION SOCIAL

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COLEGIO DE INGENIEROS MECANICOS Y ELECTRICISTAS (CIME)

ESCUELA SUPERIOR DE INGENIERIA MECANICA Y ELECTRICA (ESIME)

5

DIPLOMADO EN INGENIERIA DE CALDERAS Y RECIPIENTES SUJETOS A PRESION

6

- El proceso de diseño de un recipiente sujeto a presión, ya sea que vaya o no a ser sometido a fuego directo consiste básicamente en el arreglo y disposición de una serie de elementos o formas geométricas, tanto metálicos como no metálicos, de tal manera que soporten las cargas y/o la presión en forma segura, cumpliendo las funciones específicas para las que es diseñado .

7

CONDICIONES BASICAS

- El recipiente debe cumplir los requisitos de SEGURIDAD y funcionales
- Los elementos estructurales que lo conformen deben ser capaces de soportar la presión y las cargas a las que estará sometido.
- Debe ser la construcción más económica.

8

CONCEPTOS BÁSICOS

- DISEÑO ESTRUCTURAL
- TIPOS DE FORMAS GEOMETRICAS Y LAS RELACIONES ENTRE LAS MISMAS
- ANTECEDENTES HISTORICOS QUE SE TENGAN SOBRE LAS MISMAS

9

CONCEPTOS BÁSICOS

- COMPORTAMIENTO DE LAS DISTINTAS FORMAS ESTRUCTURALES
- CONCEPTOS DE DISEÑO
- FACTORES DE SEGURIDAD
- CODIGOS Y ESPECIFICACIONES

10

DISEÑO ESTRUCTURAL

11

HERRAMIENTAS PARA EL DISEÑO MECANICO ESTRUCTURAL

- Conocimiento de las propiedades de los materiales.
- El análisis de la resistencia estructural o mecánica.
- Los códigos, especificaciones y estándares.

12

PASOS LÓGICOS PARA REALIZAR EL DISEÑO

- Requisitos de comportamiento del recipiente.
- La forma y ubicación del recipiente.
- Condiciones de carga y operación.
- Diseño preliminar.

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PASOS LÓGICOS PARA REALIZAR EL DISEÑO

- **Análisis.**
- **Selección de materiales, formas y espesores.**
- **Diseño secundario.**

14

FORMAS GEOMETRICAS Y SUS INTERRELACIONES

15

TIPOS DE FORMAS GEOMETRICAS Y LA TRANSICION ENTRE LAS MISMAS

- **Para este punto, se debe considerar las distintas especificaciones de materiales y en que formas o perfiles se encuentran comercialmente.**
- **El tipo o tipos de refuerzo que se requieren para garantizar la continuidad en la resistencia y comportamiento estructural de los distintos miembros que componen el recipiente.**

16

ANTECEDENTES HISTORICOS QUE SE TENGAN SOBRE LAS FORMAS GEOMETRICAS

17

ANTECEDENTES HISTORICOS QUE SE TENGAN SOBRE EL COMPORTAMIENTO DE LA GEOMETRIA

EN LAS ESTRUCTURAS MECANICAS

- **Es muy importante tener en cuenta los antecedentes históricos que se tengan sobre determinados diseños o configuraciones geométricas.**

18

ANTECEDENTES HISTORICOS QUE SE TENGAN SOBRE EL COMPORTAMIENTO DE LA GEOMETRIA

EN LAS ESTRUCTURAS MECANICAS

- **Los códigos se encargan de resumir los distintos comportamientos que se han observado a lo largo de años de servicio bajo distintas condiciones de operación.**

- **Estas reseñas se presentan como adendas o como interpretaciones en el código ASME.**

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COMPORTAMIENTO DE LAS FORMAS ESTRUCTURALES

20

COMPORTAMIENTO DE LAS FORMAS ESTRUCTURALES

- El comportamiento de los aceros y materiales estructurales está definido por dos de sus propiedades básicas, su resistencia y su ductilidad.
- Estas propiedades normalmente se presentan por medio de gráficas esfuerzo-deformación.

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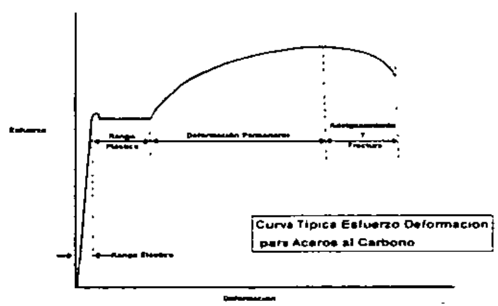
Gráfica # 1



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COMPORTAMIENTO DE LAS DISTINTAS FORMAS ESTRUCTURALES

- **Una gráfica esfuerzo-deformación "comercial" puede o no mostrar las cuatro zonas principales que la componen, que a su vez representan los cuatro estados típicos de comportamiento de los metales.**

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COMPORTAMIENTO DE LAS DISTINTAS FORMAS ESTRUCTURALES

- Estas zonas son:

  El rango elástico

  El rango plástico

  El rango de deformaciones permanentes

  El rango de adelgazamiento-fractura-ruptura

24

COMPORTAMIENTO DE LAS DISTINTAS FORMAS ESTRUCTURALES

- Las gráficas "comerciales", pueden o no mostrar las cuatro áreas, pero todas cuando menos muestran los rangos elásticos y plásticos.

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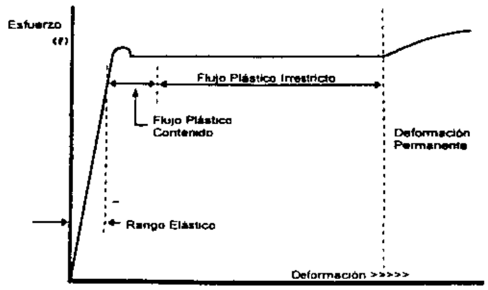
Gráfica Esfuerzo-Deformación "Comercial"



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CRITERIOS DE DISEÑO

27

CONCEPTOS DE DISEÑO

- El comportamiento de las formas geométricas y estructuras metálicas al ser sometidas a cargas o presión, puede estar controlada por uno o más criterios. Estas propiedades se conocen como "límite de utilización estructural" y de entre ellas destacan:

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CONCEPTOS DE DISEÑO

- El Punto de Cedencia Hipotético
- La Máxima Resistencia Plástica
- Las Deformaciones Máximas a las condiciones de servicio
- La Inestabilidad
- La Fatiga
- La Fractura

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DISEÑO

- Como resultado de la combinación de los "límites" anteriores, se desarrollaron sistemas de diseño, entre los cuales están el método del "esfuerzo máximo permisible" y el de "diseño plástico"

30

Diseño por el Método del "Esfuerzo Máximo Permisible"

El método de diseño por "esfuerzo máximo permisible", requiere considerar los siguiente:

- Punto de cedencia hipotético,
- Inestabilidad
- Fatiga y, frecuentemente la
- Máxima resistencia plástica

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"Diseño Plástico"

El método de diseño por "diseño plástico" requiere se consideren, obligatoriamente,

- La Máxima resistencia plástica
- La Inestabilidad

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FACTOR DE SEGURIDAD

33

- El término "factor de seguridad" se ha introducido como un elemento comercial de confiabilidad, a la luz de los registros estadísticos que se han realizado en un gran número de recipientes sujetos a presión bajo las más distintas condiciones de operación.

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El "Factor de Seguridad" no debe considerarse como la posibilidad de sobrecargar o sobrepresurizar un recipiente.

- Para seleccionar un margen de seguridad, considerar:

35

Factor de Seguridad

- Aproximaciones e incertidumbre en el método de análisis
- Calidad de la Mano de Obra
- Presencia de esfuerzos residuales y concentraciones de esfuerzos

36

Factor de Seguridad

- Posibles deficiencias en el material
- Adelgazamiento en las secciones calculadas
- Ubicación y utilización del recipiente

37

Factor de Seguridad

- **Cargas a las que estará sometido. (adicionales a las consideradas en el cálculo).**

38

- Un método preciso para obtener un valor adecuado para el "factor de seguridad" requiere de análisis estadísticos del comportamiento de cada miembro en esa posición específica, ya que pueden presentarse variaciones al cambiar de posición o de tipo de servicio.

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Factor de Seguridad

- **La mayoría de los accidentes que han ocurrido en la industria, involucrando el uso de estructuras metálicas en general, han sido resultado de la combinación de los puntos mencionados, los cuales han sido ignorados o analizados separadamente, por lo que no deben desdeñarse o considerarse exagerados algunos factores de seguridad considerados en los códigos y/o especificaciones.**

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CODIGOS Y ESPECIFICACIONES

41

CODIGOS Y ESPECIFICACIONES

- Esta es la parte esencial que nunca debe olvidar un diseñador.
- Las especificaciones son puntos torales de la construcción.

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CODIGOS Y ESPECIFICACIONES

- Son la principal herramienta que guía al ingeniero hacia procedimientos de diseños seguros y universalmente aceptados, además de ser la mejor referencia en la selección tanto de materiales como de métodos de trabajo y/o proceso. <u>Su utilización es recomendable.</u>

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CODIGOS Y ESPECIFICACIONES

- Los códigos representan un conjunto de reglas de construcción que comprenden los aspectos de seguridad y bases comerciales por lo que su cumplimiento es obligatorio por Ley.
- El seguimiento de las especificaciones y códigos, representan para el comprador, una garantía de que el recipiente cumple con los requisitos básicos de seguridad, funcionamiento y economía.

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MATERIALES

45

MATERIALES

- El uso de materiales metálicos, especialmente los aceros, en la construcción de recipientes sujetos a presión, se atribuye a sus excelentes propiedades mecánicas, a la abundancia de las materias primas para fabricarlo y a su precio competitivo.

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- La principal cualidad del acero y de los materiales metálicos es que pueden producirse con una amplia gama de propiedades físicas y mecánicas, las cuales pueden controlarse con mucha precisión para obtener las características y propiedades deseadas.

47

MATERIALES

- Para la construcción de calderas y recipientes sujetos a presión existe una gran cantidad de aceros y materiales metálicos identificados bajo designaciones estandarizadas por diversas asociaciones, entre las que destacan las de ASTM, AISI, DIN, BSI, JIS, etc.

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MATERIALES

PROPIEDADES IMPORTANTES

- La herramienta principal de que dispone un diseñador para determinar el comportamiento mecánico, son los diagramas esfuerzo-deformación.

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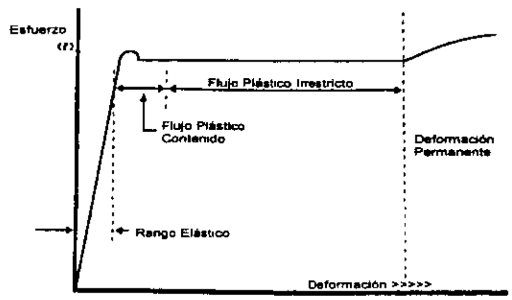
MATERIALES



50

MATERIALES

Las propiedades importantes a considerar son:

- Punto de cedencia
- Punto de fluencia
- Nivel de esfuerzo de cedencia
- Límite proporcional
- Resistencia a la tensión

51

MATERIALES

- Ductilidad
- Módulo de elasticidad
- Módulo de deformacion permanente
- Relación de Poisson
- Módulo de elasticidad cortante
- Soldabilidad
- Maquinabilidad
- Formabilidad

52

MATERIALES

- Resistencia a la corrosión y a la abrasión
- Resistencia a la fatiga
- Tenacidad
- Resistencia a la fractura frágil
- Sensibilidad a las grietas
- Resistencia al impacto

53

MATERIALES

- Resistencia al deslizamiento (creeping)
- Relajación.

54

MATERIALES

FACTORES QUE AFECTAN LAS PROPIEDADES MECANICAS

55

Los factores que afectan las propiedades mecánicas de los aceros y de los materiales metálicos son principalmente:

56

MATERIALES

1. Composición química
2. Tratamiento térmico
3. Historia de su deformación
4. Geometría
5. Temperatura
6. Relación de deformación
7. Estado de esfuerzos

57

MATERIALES

- Los tres primeros dependen exclusivamente del proceso de manufactura del material base.
- Los cuatro restantes dependen de la aplicación, de la funcionalidad del diseño y de los detalles de diseño de cada miembro o componente.

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DETERMINACION DE LAS PROPIEDADES MECANICAS

- Esta es una parte importante del proceso de diseño-fabricación.
- En diseños de alto riesgo, deben tomarse probetas normalizadas y someterlas a las distintas pruebas indicadas en los códigos y/o especificaciones para corroborar que el material recibido cumple con las características mecánicas consideradas en el diseño.

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DETERMINACION DE LAS PROPIEDADES MECANICAS

- La ASTM cuenta con procedimientos escritos, incluyendo la descripción de los aparatos requeridos para la determinación y evaluación de todas y cada una de las propiedades que debe tener un material conforme a una especificación predeterminada y los criterios de aceptación - rechazo.

60

DISPONIBILIDAD DE ACEROS Y MATERIALES METALICOS

- Es importante asegurarse que realmente existen en su forma comercial los materiales considerados en nuestro diseño.

61

DISPONIBILIDAD DE ACEROS Y MATERIALES METALICOS

- Es común encontrar que determinada especificación solo se produce comercialmente hasta o a partir de determinado espesor o diámetro y que en caso de que se nos fabrique deberemos comprar un mínimo de "x" toneladas y este material tendrá un tiempo de entrega de "n" meses.

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DISPONIBILIDAD DE ACEROS Y MATERIALES METALICOS

- Esta situación puede resolverse comparando la concordancia entre las especificaciones ASTM con las DIN o con las JIS, etc., de tal manera que se evalúe en que grado son iguales o en que nos afectan las variantes que se presenten, recalculando los factores esenciàles que puedan afectar el comportamiento de nuestro diseño.

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IMPORTANCIA DE LA SELECCION DE MATERIALES

- Para cumplir los requisitos de seguridad, funcionamiento y economía, existe una amplísima variedad de materiales de donde escoger, siguiendo las especificaciones y los procedimientos de trabajo para los distintos materiales.
- El reto para el diseñador es seleccionar el material más conveniente para un trabajo específico

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IMPORTANCIA DE LA SELECCION DE MATERIALES

La selección debe basarse en:

- El cumplimiento de las condiciones de servicio predeterminadas
- El cumplimiento de las condiciones de seguridad predeterminadas
- El cumplimiento de las expectativas mecánicas de los materiales
- La economía

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SELECCION DE MATERIALES

- En el aspecto económico, considerar el precio del material base, fletes, los costos de fabricación, efectos del peso muerto en los costos de las estructuras y cimentaciones, áreas o espacios de operación y otros factores.

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SELECCION DE MATERIALES

- También considerar que en ocasiones es más económico utilizar materiales base más resistentes, aparentemente más caros pero, que requerirán espesores menores y consecuentemente estructuras y/o cimentaciones más ligeras.

67

SELECCION DE MATERIALES

- Este criterio debe utilizarse al analizar materiales resistentes a la corrosión o a la abrasión, estudiando la posibilidad de utilizar materiales revestidos (clad), soldadura de revestimiento, etc.

68

SELECCION DE MATERIALES

- Bajo ninguna circunstancia, violar el código sobre el que está basado el diseño en aras de la economía o de alguna condición operativa.
- NO ES NEGOCIABLE NI ESTÁ SUJETO A ANÁLISIS NI CONSIDERACIONES DE NINGÚN TIPO LA SEGURIDAD QUE DEBE TENER EL RECIPIENTE DURANTE LA OPERACIÓN.

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SELECCION DE MATERIALES

- Es obligación del diseñador el realizar análisis exhaustivos sobre el comportamiento de distintos materiales para garantizar la funcionalidad y seguridad del recipiente dentro de los marcos de seguridad establecidos.

70

SELECCION DE MATERIALES

- Todos sus hallazgos y decisiones en este sentido debe consignarlos en la MEMORIA DE DISEÑO Y CÁLCULO DEL RECIPIENTE a fin de que, cualquier otra persona debidamente calificada pueda revisarlos y rehacerlos cuando así sea necesario.

71

SELECCION DE MATERIALES

- El diseñador nunca debe olvidar que todo tiene solución, menos la muerte.
- DE UN BUEN DISEÑO DEPENDEN LA FUNCIONALIDAD Y LA ECONOMÍA, PERO TAMBIÉN LA VIDA DE LAS PERSONAS.

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Tablas de Selección de Materiales

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MATERIALES MAS COMUNES PARA USO EN BAJA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO EN GRADOS FAHRENHEIT				
		-425 a -321	-320 a -151	-150 a -81	-80 a -61	-60 a -41
CUERPOS CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 240 TP304	SA 353 (9% Ni) SA 553 TP-I	SA 203 E 55	SA 203 B 55	SA 516-65 65
		SA 240 TP304L	SA 240 TP304 SA 240 TP304L	SA 203 D 55	SA 203 A 55	SA 203 B 65
BRIDAS CIEGAS	Forja	Forja	Forja	Idem cuerpo	Idem cuerpo	Idem cuerpo
	Placa	SA 182 F304 SA 182 F304L	SA 522 (9% Ni) SA 182 F304 SA 182 F304L	SA 350 LF 3	SA 350 LF 3	SA 350 LF 2
SILLETAS		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
FALDÓN a 1.2 m. de línea de tangencia		SA 283 C	SA 283 C	SA 283 C	SA 283 C	SA 283 C
CUELLOS para Boquillas		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
COPLES		SA 182 F304L	SA 182 F304L	SA 350 LF 3	SA 350 LF 3	SA 350 LF 2
Apoyos de Platos y Soportes internos		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
Mamparas y Colectores		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
TUBERIA INTERIOR		SA 312 TP304 SA 312TP304L	SA 333-8 SA 312 TP304 SA 312TP304L	SA 333-3	SA 333-7	SA 333-6
CONEXIONES SOLDABLES		SA 403 WP-304 SA 403 WP-304L	SA 420 WPL-8 SA 312 TP304 SA 312TP304L	SA 420 WPL-3	SA 420 WPL-3	SA 420 WPL-6
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 312 TP304 SA 312TP304L	SA 333-8 SA 312 TP304 SA 312TP304L	SA 333-3	SA 333-7	SA 333-6
TORNILLERIA INTERIOR		SA 320 B8 SA 194-8	SA 320 B8 SA 194-8	SA 320 L7 SA 194-4	SA 320 L7 SA 194-4	SA 320 L7 SA 194-4
TORNILLERIA EXTERIOR		SA 194-8	SA 194-8	SA 194-4	SA 194-4	SA 194-4

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MATERIALES PARA USO EN BAJA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO menos 425 a menos 321 °F
CUERPOS CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 240 TP304 SA 240 TP304L
BRIDAS CIEGAS	Forja	Forja
	Placa	SA 182 F304 SA 182 F304L
SILLETAS		Idem cuerpo
FALDÓN a 1.2 m. de línea de tangencia		SA 283 C
CUELLOS para Boquillas		Idem cuerpo
COPLES		SA 182 F304L
Apoyos de Platos y Soportes internos		Idem cuerpo
Mamparas y Colectores		Idem cuerpo
TUBERIA INTERIOR		SA 312 TP304 SA 312TP304L
CONEXIONES SOLDABLES		SA 403 WP-304 SA 403 WP-304L
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 312 TP304 SA 312TP304L
TORNILLERIA INTERIOR		SA 320 B8 y SA 194-8
TORNILLERIA EXTERIOR		SA 194-8

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MATERIALES PARA USO EN BAJA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO menos 320 a menos 151 °F
CUERPOS CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 353 (9% Ni) SA 553 TP
		SA 240 TP304 SA 240 TP304L
BRIDAS CIEGAS	Forja	Forja
	Placa	SA 522 (9% Ni) SA 182 F304 SA 182 F304L
SILLETAS		Idem cuerpo
FALDÓN a 1.2 m. de línea de tangencia		SA 283 C
CUELLOS para Boquillas		Idem cuerpo
COPLES		SA 182 F304
Apoyos de Platos y Soportes internos		Idem cuerpo
Mamparas y Colectores		Idem cuerpo
TUBERIA INTERIOR		SA 333-8 SA 312 TP304 SA 312 TP304L
CONEXIONES SOLDABLES		SA 420 WPL-8 SA 312 TP304 SA 312 TP304L
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 333-8 SA 312 TP304 SA 312TP304L
TORNILLERIA INTERIOR		SA 320 B8 y SA 194-8
TORNILLERIA EXTERIOR		SA 194-8

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MATERIALES PARA USO EN BAJA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO menos 150 a menos 91 °F
CUERPOS, CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 203 E S5
		SA 203 D S5
BRIDAS CIEGAS	Forja	Idem cuerpo
	Placa	SA 350 LF 3
SILLETAS		Idem cuerpo
FALDÓN a 1.2 m de línea de tangencia		SA 283 C
CUELLOS para Boquillas		Idem cuerpo
COPLES		SA 350 LF 3
Apoyos de Platos y Soportes Internos		Idem cuerpo
Mamparas y Colectores		Idem cuerpo
TUBERIA INTERIOR		SA 333-3
CONEXIONES SOLDABLES		SA 420 WPL-3
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 333-3
TORNILLERIA INTERIOR		SA 320 L7 y SA 194-4
TORNILLERIA EXTERIOR		SA 194-4

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MATERIALES PARA USO EN BAJA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO menos 90 a menos 51 °F
CUERPOS, CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 203 B S5
		SA 203 A S5
BRIDAS CIEGAS	Forja	Idem cuerpo
	Placa	SA 350 LF 3
SILLETAS		Idem cuerpo
FALDON a 1.2 m. de línea de tangencia		SA 283 C
CUELLOS para Boquillas		Idem cuerpo
COPLES		SA 350 LF 3
Apoyos de Platos y Soportes Internos		Idem cuerpo
Mamparas y Colectores		Idem cuerpo
TUBERIA INTERIOR		SA 333-7
CONEXIONES SOLDABLES		SA 420 WPL-3
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 333-7
TORNILLERIA INTERIOR		SA 320 L7
		SA 194-4
TORNILLERIA EXTERIOR		SA 194-4

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MATERIALES PARA USO EN BAJA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO menos 50 a menos 41 °F
CUERPOS, CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 516-65 S5
		SA 203 B S5
BRIDAS CIEGAS	Forja	Idem cuerpo
	Placa	SA 350 LF 2
SILLETAS		Idem cuerpo
FALDON a 1.2 m de línea de tangencia		SA 283 C
CUELLOS para Boquillas		Idem cuerpo
COPLES		SA 350 LF 2
Apoyos de Platos y Soportes Internos		Idem cuerpo
Mamparas y Colectores		Idem cuerpo
TUBERIA INTERIOR		SA 333-6
CONEXIONES SOLDABLES		SA 420 WPL-6
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 333-6
TORNILLERIA INTERIOR		SA 320 L7 y SA 194-4
TORNILLERIA EXTERIOR		SA 194-4

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MATERIALES PARA USO EN MEDIA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO EN GRADOS FAHRENHEIT	
		-40 a +60	+61 a +650
CUERPOS, CABEZAS Y REFUERZOS		SA 516 70 SS	SA 285 C
(Plantillas y Collares)		SA 516 65 SS	SA 515 70
BRIDAS CIEGAS	Placa	Idem cuerpo	Idem cuerpo
	Forja	SA 350 LF 2	SA 105
SILLETAS		Idem cuerpo	Idem cuerpo
FALDON a 1.2 m. de linea de tangencia		SA 283 C	SA 283 C
CUELLOS para Boquillas		Idem cuerpo	Idem cuerpo
COPLES		SA 350 LF 2	SA 105
Apoyos de Platos y Soportes internos		Idem cuerpo	Idem cuerpo
Mamparas y Colectores		Idem cuerpo	Idem cuerpo
TUBERIA INTERIOR		SA 333-6	SA 53-B
CONEXIONES SOLDABLES		SA 420 WPL-6	SA 234 WPA
			SA 234 WPB
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 312 TP304	SA 53-B
			SA 106-B
TORNILLERIA INTERIOR Y EXTERIOR		SA 193 B7	SA 193 B7
		SA 194-2H	SA 194-2H

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MATERIALES PARA USO EN MEDIA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO
		menos 40 a más 60 °F
CUERPOS, CABEZAS Y REFUERZOS		SA 516 70 SS
(Plantillas y Collares)		SA 516 65 SS
BRIDAS CIEGAS	Placa	Idem cuerpo
	Forja	SA 350 LF 2
SILLETAS		Idem cuerpo
FALDON a 1.2 m. de linea de tangencia		SA 283 C
CUELLOS para Boquillas		Idem cuerpo
COPLES		SA 350 LF 2
Apoyos de Platos y Soportes internos		Idem cuerpo
Mamparas y Colectores		Idem cuerpo
TUBERIA INTERIOR		SA 333-6
CONEXIONES SOLDABLES		SA 420 WPL-6
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 312 TP304
TORNILLERIA INTERIOR Y EXTERIOR		SA 193 B7
		SA 194-2H

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MATERIALES PARA USO EN MEDIA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO
		más 61 a más 650 °F
CUERPOS CABEZAS Y REFUERZOS		SA 285 C
(Plantillas y Collares)		SA 515 70
BRIDAS CIEGAS	Placa	Idem cuerpo
	Forja	SA 105
SILLETAS		Idem cuerpo
FALDON a 1.2 m. de linea de tangencia		SA 283 C
CUELLOS para Boquillas		Idem cuerpo
COPLES		SA 105
Apoyos de Platos y Soportes internos		Idem cuerpo
Mamparas y Colectores		Idem cuerpo
TUBERIA INTERIOR		SA 53-B
CONEXIONES SOLDABLES		SA 234 WPA
		SA 234 WPB
CUELLOS DE BOQUILLAS Y		SA 53-B
CONEXIONES SOLDABLES		SA 106-B
TORNILLERIA INTERIOR Y EXTERIOR		SA 193 B7 y SA 194-2H

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MATERIALES PARA USO EN ALTA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO EN GRADOS FAHRENHEITH			
		651 a 775	776 a 850	851 a 1050	1051 a 1150
CUERPOS CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 515 70	SA 204 B SA 204 C Clad con SA 263 SA 264	SA 387 B CL2 SA 387 D CL2 Clad con SA 263 SA 264	SA 204 TP304
BRIDAS CIEGAS	Placa	Idem cuerpo	Idem cuerpo	Idem cuerpo	Forja
	Forja	SA 105	SA 182 F1 (B) SA 182 F2 (C)	SA 182 F B	SA 182 F304 H
SILLETAS		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
FALDON a 1 2 m de linea de tangencia		SA 283 C	SA 283 C	SA 283 C	SA 283 C
CUELLOS para Boquillas		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
COPLES		SA 105	SA 182 F2 (C)	SA 182 F B	SA 182 F304 H
Apoyos de Platos y Soportes Internos		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
Mamparas y Colectores		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
TUBERIA INTERIOR		SA 53 B	SA 335-PI	SA 335-PII	SA 312 TP304 H
CONEXIONES SOLDABLES		SA 234 WP B	SA 234 WP I	SA 234 WP II	SA 403 WP304 H
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 106-C SA 106-B	SA 335 PI	SA 335-PII	SA 312 TP304 H
TORNILLERIA INTERIOR Y EXTERIOR		SA 193 B7 SA 194 2H	SA 193 B7 SA 194 2H	SA 193 B7 SA 194 2H	SA 193 B8 SA 194-8

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MATERIALES PARA USO EN ALTA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO
		651 a 775 °F
CUERPOS CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 515 70
BRIDAS CIEGAS	Placa	Idem cuerpo
	Forja	SA 105
SILLETAS		Idem cuerpo
FALDÓN a 1.2 m. de linea de tangencia		SA 283 C
CUELLOS para Boquillas		Idem cuerpo
COPLES		SA 105
Apoyos de Platos y Soportes Internos		Idem cuerpo
Mamparas y Colectores		Idem cuerpo
TUBERIA INTERIOR		SA 53 B
CONEXIONES SOLDABLES		SA 234 WP B
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 106-C SA 106-B
TORNILLERIA INTERIOR Y EXTERIOR		SA 193 B7 SA 194-2H

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MATERIALES PARA USO EN ALTA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO
		776 a 850 °F
CUERPOS CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 204 B SA 204 C Clad con SA 263 SA 264
BRIDAS CIEGAS	Placa	Idem cuerpo
	Forja	SA 182 F1 (B) SA 182 F2 (C)
SILLETAS		Idem cuerpo
FALDÓN a 1.2 m. de linea de tangencia		SA 283 C
CUELLOS para Boquillas		Idem cuerpo
COPLES		SA 182 F2 (C)
Apoyos de Platos y Soportes Internos		Idem cuerpo
Mamparas y Colectores		Idem cuerpo
TUBERIA INTERIOR		SA 335-PI
CONEXIONES SOLDABLES		SA 234 WP I
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 335 PI
TORNILLERIA INTERIOR Y EXTERIOR		SA 193 B7 y SA 194 2H

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MATERIALES PARA USO EN ALTA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO 801 a 1000 °F	
CUERPOS CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 387 II CL2	
		SA 387 II CL2	
		Clad con	SA 263
			SA 264
BRIDAS CIEGAS	Placa	Idem cuerpo	
	Forja	SA 182 F II	
SILLETAS		Idem cuerpo	
FALDON a 1.2 m. de línea de tangencia		SA 283 C	
CUELLOS para Boquillas		Idem cuerpo	
COPLES		SA 182 F II	
Apoyos de Platos y Soportes internos		Idem cuerpo	
Mamparas y Colectores		Idem cuerpo	
TUBERIA INTERIOR		SA 335-PII	
CONEXIONES SOLDABLES		SA 234 WP II	
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 335-PII	
TORNILLERIA INTERIOR Y EXTERIOR		SA 193 B7 y SA 194-2H	

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MATERIALES PARA USO EN ALTA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO 1001 a 1100 °F	
CUERPOS CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 204 TP304	
		Clad con	SA 263
			SA 264
BRIDAS CIEGAS	Placa	Forja	
	Forja	SA 182 F304 H	
SILLETAS		Idem cuerpo	
FALDON a 1.2 m. de línea de tangencia		SA 283 C	
CUELLOS para Boquillas		Idem cuerpo	
COPLES		SA 182 F304 H	
Apoyos de Platos y Soportes Internos		Idem cuerpo	
Mamparas y Colectores		Idem cuerpo	
TUBERIA INTERIOR		SA 312 TP304 H	
CONEXIONES SOLDABLES		SA 403 WP304 H	
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 312 TP304 H	
TORNILLERIA INTERIOR Y EXTERIOR		SA 193 B8 y SA 194-8	

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MATERIALES POR TIPO DE SERVICIO

SERVICIOS TIPICOS	MATERIAL
Fluidos con corrosividad mediana. Agua fría o caliente	Aceros al Carbono
Aceites sulfurados fríos o calientes hasta 300 °C. Hidrógeno gaseoso, gases con contenido de Azufre	Aleaciones Ferríticas: Aceros al Carbono Molibdeno [illegible] Cromo Molibdeno
Servicio moderadamente corrosivo, componentes en contacto con compuestos sulfurados o que tengan Azufre como impureza	Aceros en configuración ferrítica con contenido de Cromo
Servicio con corrosión no sulfurosa, corrosivos en general	Aceros Austeníticos al Cromo-Níquel
Manejo de compuestos salobres, aguas de mar, compuestos con contenido de halógenos	Aleaciones de Cobre: Admiralty, Latón aluminio, Cupro-Níquel
[illegible] compuestos clorados	Aceros con alta aleación de Níquel-Cromo Molibdeno
Compuestos salobres con sólidos en suspensión. Recipientes sometidos a esfuerzos alternos presión-vacío	Aceros al Titanio
Ambientes severamente corrosivos. Ambientes con diferenciales de temperatura. Ambientes [illegible] ácidos o alcalinos. Recipientes multiusos o multiprocesos	Tecnología Clad. Recubrimientos de Plomo, Hule, Vidrio. Recubrimientos con resinas epóxicas. Recubrimientos con refractarios. Recipientes de [illegible]

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Selección de Materiales

- Es importante que al seleccionar un material en particular se revisen cuidadosamente las especificaciones correspondientes a fin de contemplar en que rango es aplicable, (temperatura, presión, espesores), y que pruebas indica el Código que se deben realizar, (metalográficas, de impacto, tratamiento térmico previo, durante y después de la soldadura, etc.)

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Selección de Materiales

- Todos los requisitos que indique el Código se deben consignar en la Memoria de Diseño y Cálculo del Equipo y también se deben indicar en los Dibujos de Fabricación, en la Especificación de Procedimiento de Soldadura, en la Hoja Viajera, etc.

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Selección de Materiales

NO ES NEGOCIABLE NI ESTÁ SUJETO A ANÁLISIS NI CONSIDERACIONES DE NINGÚN TIPO <u>LA SEGURIDAD QUE DEBE TENER EL RECIPIENTE DURANTE LA OPERACIÓN.</u>

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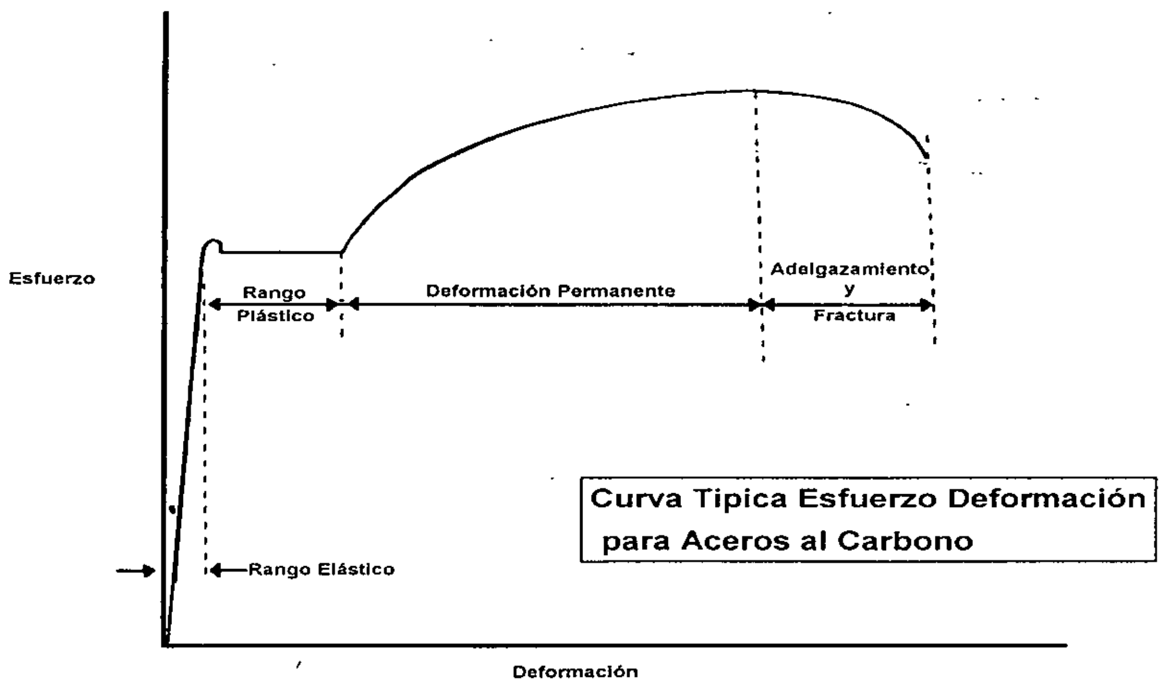
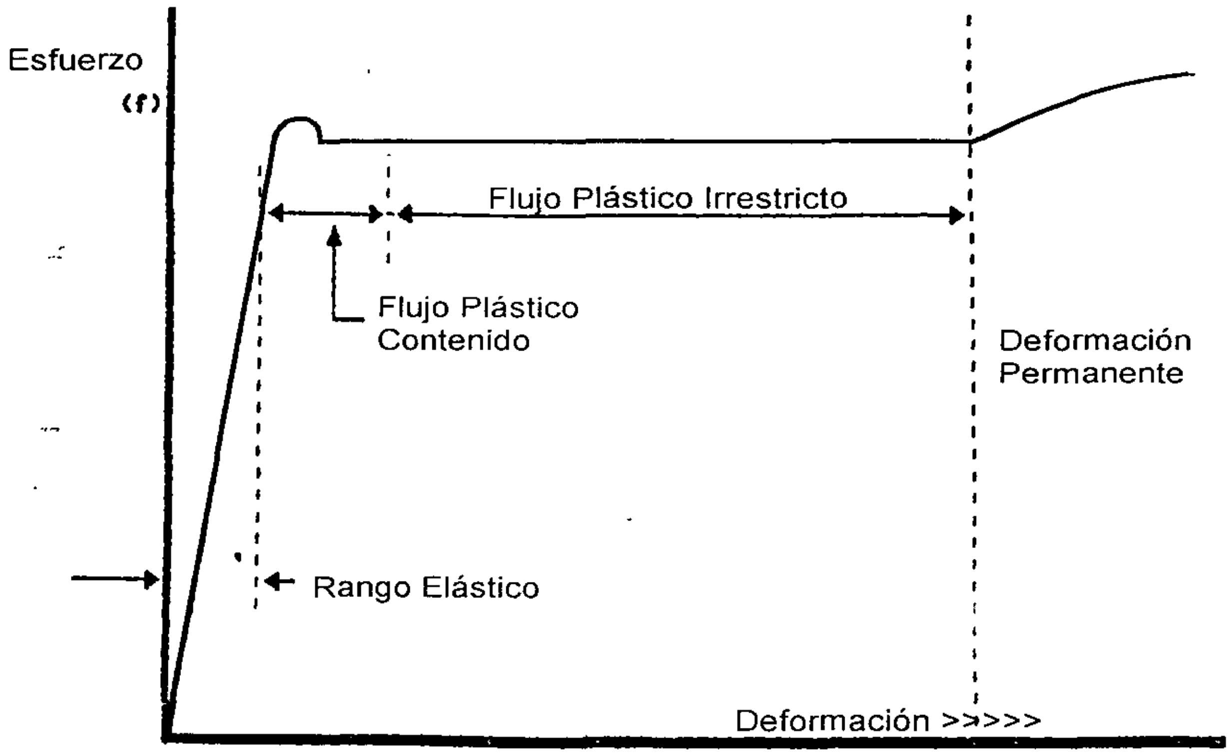
Corolario

DE UN BUEN DISEÑO DEPENDE LA FUNCIONALIDAD Y LA ECONOMÍA, PERO TAMBIÉN LA VIDA DE LAS PERSONAS Y LOS BIENES PATRIMONIALES DE LAS EMPRESAS.

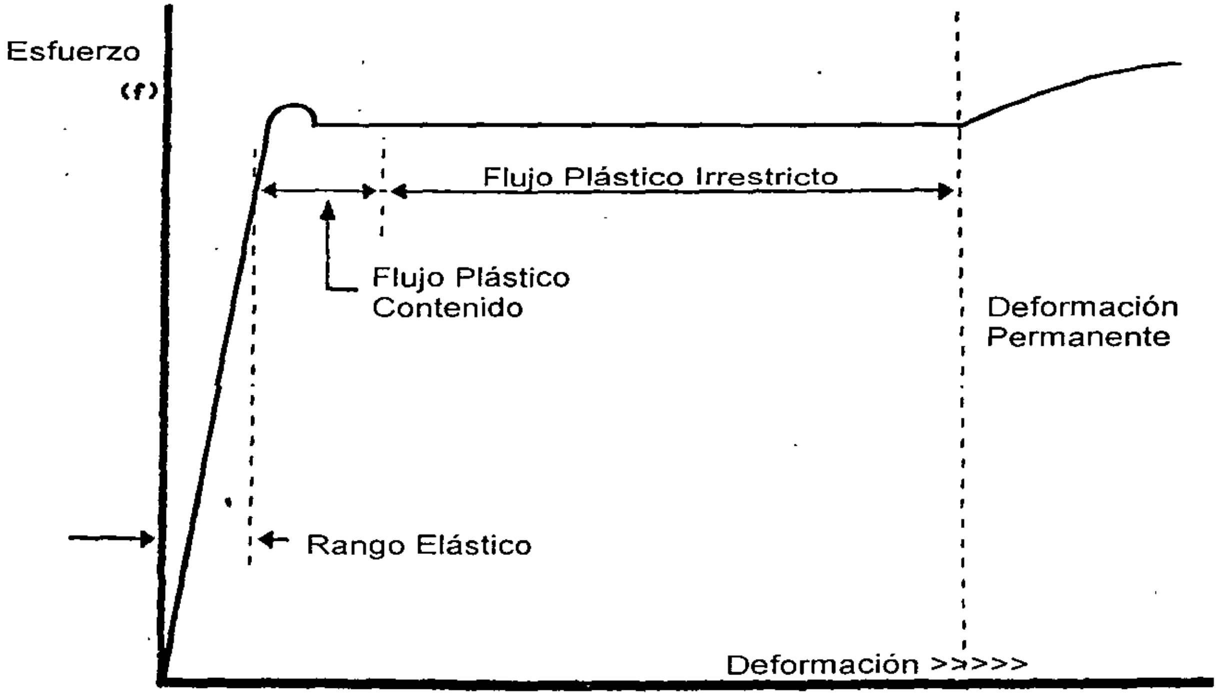
Gráfica # 1


Esfuerzo
Rango
Plástico
Deformación Permanente
Adelgazamiento
y
Fractura
Rango Elástico
Curva Tipica Esfuerzo Deformación
para Aceros al Carbono
Deformación

Gráfica Esfuerzo-Deformación "Comercial"



MATERIALES


Esfuerzo
(f)
Flujo Plástico Irrestricto
Flujo Plástico
Contenido
Deformación
Permanente
Rango Elástico
Deformación >>>>>

MATERIALES POR TIPO DE SERVICIO

SERVICIOS TIPICOS	MATERIAL
Fluidos con corrosividad mediana Agua fría o caliente	Aceros al Carbono
Aceites sulfurados, fríos o calientes hasta 300 °C Hidrógeno gaseoso, gases con contenido de Azufre	Aleaciones Ferríticas, Aceros al Carbono-Molibdeno, o al Cromo-Molibdeno
Servicio moderadamente corrosivo, componentes en contacto con compuestos sulfurados o que tengan Azufre como impureza.	Aceros en configuración ferrítica con contenido de Cromo.
Servicio con corrosión no sulfurosa, corrosivos en general.	Aceros Austeníticos al Cromo-Níquel.
Manejo de compuestos salobres, aguas de mar, compuestos con contenido de Halógenos.	Aleaciones de Cobre, Admiralty, Latón alumínico, Cupro-Níquel.
Acidos Minerales, ácidos y compuestos clorados.	Aceros con alta aleación de Níquel-Cromo-Molibdeno
Compuestos salobres con sólidos en suspensión, Recipientes sometidos a esfuerzos alternos presión-vacío.	Aceros al Titanio.
Ambientes severamente corrosivos Ambientes con diferenciales de temperatura Ambientes altamente ácidos o alcalinos Recipientes multiusos o multiprocesos.	Tecnología Clad Revestimientos de Plomo, Hule, Vidrio Revestimientos con resinas epóxicas Revestimientos con refractarios Recipientes de Carbón-acero.

MATERIALES MAS COMUNES PARA USO EN BAJA TEMPERATURA

COMPONENTE		**TEMPERATURA DE DISEÑO EN GRADOS FARHENHEITH**				
		-425 a -321	**-320 a -151**	**-150 a -91**	**-90 a -51**	**-50 a -41**
CUERPOS, CABEZAS Y REFUERZOS		SA 240 TP304	SA 353 (9% Ni) SA 553 TP-I	SA 203 E S5	SA 203 B S5	SA 516-65 S5
(Plantillas y Collares)		SA 240 TP304L	SA 240 TP304 SA 240 TP304L	SA 203 D S5	SA 203 A S5	SA 203 B S5
BRIDAS CIEGAS	Forja	Forja	Forja	Idem cuerpo	Idem cuerpo	Idem cuerpo
	Placa	SA 182 F304 SA 182 F304L	SA 522 (9% Ni) SA 182 F304 SA 182 F304L	SA 350 LF 3	SA 350 LF 3	SA 350 LF 2
SILLETAS		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
FALDÓN a 1.2 m. de línea de tangencia		SA 283 C	SA 283 C	SA 283 C	SA 283 C	SA 283 C
CUELLOS para Boquillas		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
COPLES		SA 182 F304L	SA 182 F304L	SA 350 LF 3	SA 350 LF 3	SA 350 LF 2
Apoyos de Platos y Soportes Internos		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
Mamparas y Colectores		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
TUBERIA INTERIOR		SA 312 TP304 SA 312TP304L	SA 333-8 SA 312 TP304 SA 312TP304L	SA 333-3	SA 333-7	SA 333-6
CONEXIONES SOLDABLES		SA 403 WP-304 SA 403 WP-304L	SA 420 WPL-8 SA 312 TP304 SA 312TP304L	SA 420 WPL-3	SA 420 WPL-3	SA 420 WPL-6
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 312 TP304 SA 312TP304L	SA 333-8 SA 312 TP304 SA 312TP304L	SA 333-3	SA 333-7	SA 333-6
TORNILLERIA INTERIOR		SA 320 B8	SA 320 B8	SA 320 L7	SA 320 L7	SA 320 L7
		SA 194-8	SA 194-8	SA 194-4	SA 194-4	SA 194-4
TORNILLERIA EXTERIOR		SA 194-8	SA 194-8	SA 194-4	SA 194-4	SA 194-4

MATERIALES MAS COMUNES PARA USO EN MEDIA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO EN GRADOS FARHENHEITH -40 a +60	+61 a +650
CUERPOS, CABEZAS Y REFUERZOS		SA 516 70 S5	SA 285 C
(Plantillas y Collares)		SA 516 65 S5	SA 515 70
	Placa	Idem cuerpo	Idem cuerpo
BRIDAS CIEGAS	Forja	SA 350 LF 2	SA 105
SILLETAS		Idem cuerpo	Idem cuerpo
FALDÓN a 1.2 m. de línea de tangencia		SA 283 C	SA 283 C
CUELLOS para Boquillas		Idem cuerpo	Idem cuerpo
COPLES		SA 350 LF 2	SA 105
Apoyos de Platos y Soportes Internos		Idem cuerpo	Idem cuerpo
Mamparas y Colectores		Idem cuerpo	Idem cuerpo
TUBERIA INTERIOR		SA 333-6	SA 53-B
			SA 234 WPA
CONEXIONES SOLDABLES		SA 420 WPL-6	SA 234 WPB
CUELLOS DE BOQUILLAS Y			SA 53-B
CONEXIONES SOLDABLES		SA 312 TP304	SA 106-B
		SA 193 B7	SA 193 B7
TORNILLERIA INTERIOR Y EXTERIOR		SA 194-2H	SA 194-2H

MATERIALES MAS COMUNES PARA USO EN ALTA TEMPERATURA

COMPONENTE		TEMPERATURA DE DISEÑO EN GRADOS FARHENHEITH			
		651 a 775	776 a 850	851 a 1050	1051 a 1150
CUERPOS, CABEZAS Y REFUERZOS (Plantillas y Collares)		SA 515 70	SA 204 B	SA 387 II CL2	SA 204 TP304
			SA 204 C	SA 387 II CL2	
			Clad con SA 263 SA 264	Clad con SA 263 SA 264	
BRIDAS CIEGAS	Placa	Idem cuerpo	Idem cuerpo	Idem cuerpo	Forja
	Forja	SA 105	SA 182 F1 (B) SA 182 F2 (C)	SA 182 F II	SA 182 F304 H
SILLETAS		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
FALDÓN a 1.2 m. de línea de tangencia		SA 283 C	SA 283 C	SA 283 C	SA 283 C
CUELLOS para Boquillas		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
COPLES		SA 105	SA 182 F2 (C)	SA 182 F II	SA 182 F304 H
Apoyos de Platos y Soportes Internos		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
Mamparas y Colectores		Idem cuerpo	Idem cuerpo	Idem cuerpo	Idem cuerpo
TUBERIA INTERIOR		SA 53 B	SA 335-PI	SA 335-PII	SA 312 TP304 H
CONEXIONES SOLDABLES		SA 234 WP B	SA 234 WP I	SA 234 WP II	SA 403 WP304 H
CUELLOS DE BOQUILLAS Y CONEXIONES SOLDABLES		SA 106-C SA 106-B	SA 335 PI	SA 335-PII	SA 312 TP304 H
TORNILLERIA INTERIOR Y EXTERIOR		SA 193 B7	SA 193 B7	SA 193 B7	SA 193 B8
		SA 194-2H	SA 194-2H	SA 194-2H	SA 194-8

FACULTAD DE INGENIERÍA UNAM
DIVISIÓN DE EDUCACIÓN CONTINUA

CURSOS ABIERTOS

DIPLOMADO EN INGENIERÍA DE CALDERAS Y RECIPIENTES A PRESIÓN

MÓDULO II: MATERIALES, SOLDADURA Y CALDERAS DE POTENCIA

TEMA

ESPECIFICACIONES DE MATERIALES SECCIÓN II DEL CÓDIGO ASME

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PALACIO DE MINERÍA

MODULO II

TEMA 1

ESPECIFICACIONES DE MATERIALES SECCIÓN II DEL CÓDIGO ASME

Analizando la expansion de la industria de fabricacion de calderas y recipientes a presion y la necesidad de incrementar la exportacion de productos terminados, nos encontramos con dos condiciones que se contraponen y perjudican nuestra concurrencia en los mercados exteriores y son las siguientes

Todos los concursos y solicitudes de compra que se reciben en este campo, fijan como condicion ineludible que estos productos esten fabricados bajo especificaciones del codigo "ASME" de la Sociedad Americana de Ingenieros Mecanicos y avalados por su sello estampado en los productos terminados.

El sello "ASME" esta condicionado para el empleo, a la inspeccion durante el proceso de construccion por personal calificado perteneciente a una compañia autorizada de inspeccion que normalmente es una [illegible]

El sello tambien puede utilizarse en las localidades donde el codigo "ASME" tiene reconocimiento oficial

En todo los casos es requisito durante el proceso de manufactura la inspeccion de tercera parte y que el personal a cargo de la inspeccion pertenezca al Consejo Nacional de Inspectores de Calderas y Recipientes a Presion (National Board of Boiler and Pressure Vessel Inspectors) y que este comisionado por el mismo para el caso

La circunstancia que obstaculizaria lo anterior, es que en nuestro pais actualmente no tiene reconocimiento oficial el codigo "ASME", ni las compañias de seguros tienen accion jurisdiccional fuera del pais y tampoco disponemos actualmente de organizacion protocolarizada y calificada de inspectores de calderas y recipientes a presion

Por lo anterior expuesto las compañias fabricantes de calderas y recipientes a presion con capacidad y medios para satisfacer los requisitos de construccion señalados por el codigo "ASME", exigidos por los compradores se ven en la necesidad de contratar los servicios de inspeccion y uso del sello "ASME" en los Estados Unidos de Norteamerica con el consecuente precio en algunos casos prohibitivo

Como ejemplo sobre el particular cabe mencionar que actualmente algunas de las empresas de mayor magnitud dedicadas a la fabricacion de calderas y recipientes a presion en nuestro pais, han adquirido la autorizacion para el uso del sello "ASME", a fin de satisfacer los requisitos del mercado principalmente exterior

La exigencia del comprador con respecto al sello "ASME", es que este representa la aplicacion de una tecnologia avanzada y dinamica con amplia aceptacion mundial, y en materia de seguridad representa tambien el optimo valor

En Mexico desde 1967, la Asociacion Mexicana de Ingenieros Mecanicos y Electricistas (A M I M E) suscribio un acuerdo con "The American Society of Mechanical Engineers" (ASME) para traducir al español el codigo "ASME" para calderas y recipientes a presion sus suplementos e interpretacion de casos, asi como para publicar y distribuir las ediciones de esa fuente de dicho idioma, en la inteligencia de que en la actualidad Mexico es el unico pais distinguido con esa concesion

A la fecha han sido traducidas y publicadas las secciones siguientes del codigo "ASME"

I- Calderas de potencia

IV - Calderas para calefacción

V - Pruebas no destructivas

II - Reglas sugeridas para el cuidado de calderas de potencia

VIII - Recipientes a presion div. 1

IX - Calificaciones de soldadura

Por otra parte desde hace mas de treinta años funciona permanentemente dentro de A M I M E , un grupo de trabajo llamado comite de calderas y recipientes a presion, cuya labor no se ha limitado a la traduccion y edicion de los codigos de calderas "ASME" en lengua española y adaptarlo al metrico decimal, sino que ha hecho tambien labor de difusion en el medio industrial interesado y buscando interrelacion con las autoridades de la Secretaria del Trabajo y Prevision Social, Secretaria de Comercio y Fomento Industrial, Departamento del Distrito Federal, Secretaria de Desarrollo Social, etc a fin de utilizar lo que fuere conveniente de la tecnologia antes mencionada en los codigos y normas nacionales relacionadas con la seguridad industrial

Por su parte los funcionarios de "ASME" han dado su anuencia plena para que el contenido de sus codigos sea utilizado para los usos señalados sin costo alguno

En nuestro pais, la gran mayoria de fabricantes utiliza como su mejor guia las normas "ASME", sin embargo la fabricacion, instalacion y operación que se haga estrictamente de acuerdo con el codigo "ASME", exigen la administracion y vigilancia de la aplicacion de estos codigos por medio de la "Inspeccion Autorizada" que constituya una parte desinteresada entre el fabricante, instalador, el operador y los usuarios

Actualmente el comite de calderas y recipientes a presión de la A M I M E , dirige sus esfuerzos hacia la solucion de esta clase de problemas luchando por el establecimiento de esa inspeccion autorizada en Mexico

En vista de que en los Estados Unidos de Norteamerica este trabajo es practicado por personal de los Departamentos de Inspección de Gobierno, y en su mayor parte por personal de compañias de seguros, y agencia de inspeccion considero conveniente mencionar que dentro del comite de calderas mexicano hemos integrado como parte de la "Inspeccion Autorizada" el comite del sello el cual se aboca a iniciar las actividades de inspección de fabricacion a presión en planta

Consecuentemente en el pasado se ha otorgado el sello AMIME-ASME, a importantes firmas fabricantes de equipo a presion en nuestro pais

Este comite del sello se ha formado de manera analoga al de los E U A , habiendo participado personal de compañias de seguros, ingenieros consultores y funcionarios de gobierno

Es oportuno señalar que del grupo que han formado el comite de calderas y recipientes a presion, tres ingenieros han sustentado examen y fueron aprobados en los E U A , por el National Board and Pressure Vessel Inspectors, como inspectores calificados de calderas y recipientes a presion

El procedimiento que se ha seguido dentro de este grupo para determinar si es o no posible el otorgamiento del sello o certificado de autorizacion, en terminos generales es como a continuación se indica

1 - Se exige al fabricante que proporcione al comité el manual de procedimientos para la fabricacion, junto con una solicitud que previamente se le ha proporcionado

2 - Se estudia la documentacion antes citada y se programa una visita de inspección de comun acuerdo con el solicitante

3 - Se realiza la visita de inspeccion para verificar lo establecido en el manual de procedimientos para fabricacion y si después de haber analizado la materia prima, los diseños, procedimientos de fabricacion y

pruebas se determina que todo esta de acuerdo con el codigo "ASME", o AMIME-ASME entonces sera posible otorgar el uso del sello correspondiente

Finalmente el comite de calderas y recipientes a presión trabaja en el establecimiento de un sello de calidad "AMIME" cuya validez y reconocimiento internacional sea similar al sello "ASME" toda vez que ambos los respalda la misma tecnologia emanada de igual codigo y que el mecanismo y requisito de la inspeccion para su cumplimiento son similares

De esta manera las condiciones que se exigen en esta materia de construccion serian las mismas Los requisitos y condiciones de fabricacion y seguridad estarian tambien asi avalados plenamente por el sello de calidad "AMIME", en esta forma México estara en posibilidades de concursar ventajosamente con sus productos terminados en el mercado internacional

Por lo antes expuesto se puede concluir de la manera siguiente

1 - Es indispensable contar en Mexico con un codigo que norme el diseño, fabricacion inspeccion e instalación de calderas y recipientes a presión que garantice la seguridad, y que este sea el que mejor se adapte al medio y recursos nacionales

2 - Es necesario el reconocimiento de ese codigo que en la fabricacion garantice que la produccion permita resguardar un prestigios nacional de acuerdo con la orientacion tendiente hacia la exportacion

3 - Se ha usado y se sigue usando la tecnologia del codigo AMIME-ASME de calderas y recipientes a presion por parte de las firmas de ingenieria de recomendaciones por los usuarios en sus especificaciones de compra por los fabricantes en sus diferentes procesos y por los inspectores de compañias de inspeccion o de compradores

Los materiales disponibles y fabricados en México, se elaboran para cumplir con requisitos de normas oficiales concordantes con los de las especificaciones de materia de este código

4 - Es necesario agilizar y acelerar los trabajos de preparacion del codigo AMIME-ASME dentro del comite de normas para calderas y recipientes a presion en todas sus secciones

5 - Es conveniente que los propios usuarios las firmas de ingenieria las compañias de seguros y los consultores exijan el cumplimiento de los requisitos establecidos en el codigo AMIME-ASME

6 - Es necesario establecer y ejercer procedimientos para mantener actualizada la forma de evaluacion y calificacion de fabricantes en beneficio de compradores y usuarios

7 - Es recomendable que el comite de calderas y recipientes a presion efectue la calificacion de inspectores de control de calidad en la fabricacion de calderas y recipientes a presion y que la calificacion sea accesible a toda persona que cumpla con los requisitos que el comite determine

8 - Es conveniente que el comite de normas para calderas y recipientes a presion elabore adiciones al codigo AMIME-ASME como parte de adaptacion que corresponda a los recursos industriales propios del medio nacional, una vez que el codigo sea reconocido oficialmente

9 - Es conveniente que el comite de calderas y recipientes a presion organice y realice seminarios con todos los sectores interesados para crear conciencia positiva en la aplicacion y alcance del codigo AMIME-ASME

10 - Este comité considera necesario crear conciencia entre usuarios consultores compañias de seguro y de inspeccion de la importancia del sello calidad AMIME como garantia de seguridad

11 - La tareas derivadas de las reuniones de este comite, hacen necesario que la AMIME las autoridades y la iniciativa privada participen en forma activa en el desarrollo de los trabajos del comite que haran posible

mejor calidad y precios de productos dentro del alcance del codigo para lograr equipos que puedan competir y permitan la participación de Mexico en los mercados internacionales

12 - El comite de calderas y recipientes a presion ha hecho anteriormente estos planteamientos a las autoridades competentes a través del conductos adecuado para obtener el reconocimiento oficial de este codigo, por lo cual consideramos muy factible el logro de este objetivo

SOLDADURA

TEMA 2 SOLDADURAS, SECCIÓN IX DE ASME

La necesidad de productos confiables aunado a la necesidad de conservar los recursos y preservar la seguridad de los trabajadores ha hecho que la calidad de las soldaduras sea cada vez de mayor importancia

La fabricacion de productos metálicos confiables debe comprender

- Diseños documentados
- Buenas Practicas de Manufactura
- Un Sistema de Control de Calidad
- Calificacion de los Procedimientos de Soldadura
- Calificacion de los soldadores

Diseños documentados

- La documentacion de los diseños se consigna, basicamente, en la Memoria de Diseño y Cálculo de cada Equipo, en los dibujos de fabricación y en el control de los materiales empleados

Buenas Practicas de Manufactura

Las Buenas Practicas de Manufactura se obtienen

Apegandose a los ordenamientos del Codigo que se este aplicando

Respetando las Especificaciones emanadas de los Calculos

Usando maquinaria en buen estado

Empleando solo personal calificado

Sistema de Control de Calidad

Un Sistema de Fabricacion confiable requiere del establecimiento de Sistemas de Calidad que contemplen

El establecimiento de un Manual del Sistema de Calidad

El establecimiento de un Manual de Procedimientos de Operacion

Sistema de Control de Calidad

- El establecimiento de Instrucciones de Trabajo

La existencia y aplicacion de Formatos de Control de las distintas operaciones del proceso

Calificacion de los Procedimientos de Soldadura

- La Calificacion del Procedimiento de Soldadura, es el documento donde se consignaran las variables reales empleadas, las pruebas efectuadas y los resultados obtenidos, en un establecimiento en particular

Calificacion de los soldadores

- Este proceso sirve para calificar la habilidad de un soldador, o de un operador de maquina de soldar, para demostrar que es capaz de efectuar depósitos de soldadura con la calidad establecida en el diseño, aplicando procesos especificos, con distintas soldaduras y/o procesos y en distintas posiciones

LOS PROCESOS DE SOLDADURA

- La calificacion de los procedimientos de soldadura, aunadas a un control estricto de los procesos son las herramientas capaces de demostrar que la construccion soldada propuesta tendra las propiedades mecanicas consideradas en los calculos de diseño

Definiciones Importantes

SOLDADURA

- Es la coalescencia localizada de dos o mas metales producida por el calentamiento de los mismos a temperaturas convenientes con y sin el uso de materiales de aporte, con o sin la aplicacion de presión, o por la sola aplicación de presion

SOLDABILIDAD

- Es la capacidad de un material para ser unido a otro mediante soldadura, bajo condiciones y procesos específicos y tener un desempeño satisfactorio en un conjunto estructural predefinido

PROCESOS DE SOLDADURA MAS USUALES

Procesos de Soldadura mas usuales

- SMAW (Shielded Metal Arc Welding)

Es un proceso de soldadura el cual produce la coalescencia por el calentamiento de los metales mediante un arco electrico entre un electrodo de metal recubierto y el metal base

El aporte se obtiene del electrodo y la cubierta protectora de la descomposicion del revestimiento del mismo

Procesos de Soldadura mas usuales

- **SAW (Submerged Arc Welding)**

Es un proceso de soldadura el cual produce la coalescencia por el calentamiento de los metales mediante un arco o arcos electricos formados entre un electrodo de metal desnudo y el metal base

El aporte se obtiene del electrodo y la cubierta protectora de una capa de material fundible aplicada al arco y al metal fundido

· Procesos de Soldadura mas usuales

☞ GTAW (Gas Tungsten Arc Welding)[tig]

Es un proceso de soldadura el cual produce la coalescencia por el calentamiento de los metales mediante un arco eléctrico formado entre un electrodo de tungsteno (no consumible) y el metal base

Puede o no usarse material de aporte y la cubierta protectora se obtiene mediante la aplicación de un gas o mezcla de gases

Procesos de Soldadura más usuales

☞ GMAW (Gas Metal Arc Welding)[mig]

Es un proceso de soldadura el cual produce la coalescencia por el calentamiento de los metales mediante un arco eléctrico formado entre un electrodo metalico (consumible) y el metal base.

El aporte se obtiene del electrodo y la cubierta protectora se obtiene mediante la aplicación de un gas o mezcla de gases y un fundente

Procesos de Soldadura más usuales

☞ FCAW (Flux Cored Arc Welding)

Es un proceso de soldadura el cual produce la coalescencia por el calentamiento de los metales mediante un arco eléctrico formado entre un electrodo metalico continuo (consumible) y el metal base

La cubierta protectora se obtiene de un fundente contenido dentro del electrodo tubular y, opcionalmente mediante la aplicacion externa de un gas o mezcla de gases

Especificacion de Procedimiento de Soldadura

WPS

EPS

PREPARACION DE UN PROCEDIMIENTO CONFORME A LA

SECCION IX DEL CODIGO ASME

Identificación de la Compañía y del Procedimiento

Identificación de Responsables del Procedimiento

QW-482 EPS (WPS)

Versión en Inglés

- *QW-482 SUGGESTED FORMAT FOR WELDING PROCEDURE SPECIFICATION (WPS)*

(See QW-200 1, Section IX, ASME Boiler and Pressure Vessel Code)

Identificación del documento

JUNTAS *(JOINTS)* QW-402

Notas a QW-402 JUNTAS *(JOINTS)*

METALES BASE *(BASE METALS)* QW-403

METALES DE APORTE *(FILLER METALS)* QW-404

POSICION *(POSITION)* QW-405

PRECALENTAMIENTO *(PREHEAT)* QW-406

TRATAMIENTO TERMICO POSTERIOR *(POSTWELD HEAT TREATMENT)* QW-407

GAS *(GAS)* QW-408

CARACTERISTICAS ELECTRICAS *(ELECTRICAL CHARACTERISTIC)* QW-409

Notas a QW-409

TECNICA *(TECHNIQUE)* QW-410

TECNICA *(TECHNIQUE)* QW-410 (continuación)

RESUMEN DE PARAMETROS DEL PROCEDIMIENTO

REGISTRO DE CALIFICACION DE PROCEDIMIENTO DE SOLDADURA

FORMATO SUGERIDO

CALIFICACION DE UN PROCEDIMIENTO CONFORME A LA

SECCION IX DEL CODIGO ASME

Identificacion de la Compañía y del Procedimiento

Identificación de Responsables del Procedimiento

QW-483 RCP (WPQ)

Version en Inglés

Identificación del documento

JUNTAS *(JOINTS)* QW 402

METALES BASE *(BASE METALS)* QW-403

METALES DE APORTE *(FILLER METALS)* QW-404

POSICION *(POSITION)* QW-405

PRECALENTAMIENTO *(PREHEAT)* QW-406

TRATAMIENTO TERMICO POSTERIOR *(POSTWELD HEAT TREATMENT)* QW 407

GAS *(GAS)* QW 408

CARACTERISTICAS ELECTRICAS *(ELECTRICAL CHARACTERISTIC)* QW-409

TECNICA *(TECHNIQUE)* QW 410

Pruebas de Tension *(Tensile Test)* QW-150

Pruebas de Doblez Guiado *(Guided-Bend Tests)* QW-160

Pruebas de Tenacidad *(Toughness Test)* QW-170

Prueba Filete de Soldadura *(Fillet-Weld Test)* QW-180

Otras Pruebas *(Other Tests)*

Registros Indispensables

Certificación

Observaciones

- **El detalle de registro de las pruebas es solamente ilustrativo y puede ser modificado conforme al tipo y número de pruebas requeridas por el Código**

  (Detail of record of tests are illustative only and may be modified to conform to the type and number of tests required by the Code.)

ASEGURAMIENTO DE LA CALIDAD EN SOLDADURA

- Es evidente que casi cualquier persona puede realizar una unión mediante soldadura, pero para hacer uniones soldadas para calderas o recipientes sujetos a presion se requieren muchos otros trabajos adicionales y equipos especializados

ASEGURAMIENTO DE LA CALIDAD EN SOLDADURA

- Para realizar uniones soldadas en recipientes a presion, las empresas u organizaciones que quieran hacerlo deberan de contar con un Sistema de Control tal que, garantice que todas las uniones mediante soldadura satisfagan los requisitos minimos de calidad y eficiencia necesarios en estos equipos

Requisitos Minimos

- ORGANIZACION **Debe contar con una estructura que defina con claridad los limites de autoridad y responsabilidad de cada funcionario**
- PROGRAMA DE ASEGURAMIENTO DE LA CALIDAD **Que defina las especificaciones del producto y describa los controles, procesos y métodos de prueba para garantizar su cumplimiento.**

Requisitos Minimos

- CONTROL DE DISEÑO Tal que incluya, en su caso, la calificacion y prueba de prototipos y garantice el total apego a las especificaciones.
- CONTROL DE ADQUISICIONES Las especificaciones al proveedor deben entregarse por escrito y el recibo de los materiales tambien debe documentarse Ambos documentos deben coincidir

Requisitos Minimos

- PROCEDIMIENTOS E INSTRUCTIVOS Se debe asegurar que todo trabajo se realice mediante instrucciones claras y completas
- CONTROL DE DOCUMENTOS Debe existir un Sistema tal que, permita recolectar y controlar toda la documentación de un equipo haciendo rastreable su utilizacion

Requisitos Minimos

- CONTROL DE PROVEEDORES Se debe contar con un sistema de control que evalue a los proveedores, los cuales deberan de contar con Sistemas de Calidad similares al nuestro
- IDENTIFICACION Y CONTROL DE MATERIALES Se debe contar con un sistema de marcas que permita la identificacion plena de los materiales empleados en el equipo y sus sobrantes

Requisitos Minimos

- CONTROL DE PROCESOS ESPECIALES Se debe garantizar que todos los procesos especiales, incluyendo los de soldadura se efectuen bajo condiciones controladas
- INSPECCION Se debe contar con un sistema de inspección, independiente del area de produccion, que garantice el cumplimiento de las especificaciones en cada etapa

Requisitos Minimos

- CONTROL DE PRUEBAS Y METODOS Todas las pruebas que se lleven a cabo deben efectarse siguiendo métodos escritos y documentar los resultados
- CONTROL DE EQUIPO DE MEDICION Y PRUEBA Se debe contar con un sistema tal que garantice la precisión y calibracion de todas las herramientas usadas en las pruebas

Requisitos Minimos

- MANEJO DE NO CONFORMIDADES Se debe contar con un sistema tal que permita reconocer clasificar y disponer de todos los materiales y equipos no conformes con sus especificaciones

- ACCIONES CORRECTIVAS. Se debe contar con un sistema tal que defina los niveles de autoridad v responsabilidad para ordenar y controlar las correciones

Requisitos Minimos

AUDITORIAS

- Se debe contar con un sistema que permita auditar periodicamente la eficiencia y aplicabilidad de las politicas, los metodos, procedimientos, instructivos y formatos usados en las áreas productivas y el apego de todas las areas de la empresa al Sistema de Calidad de la empresa

Los resultados se deben documentar

MODULO II

TEMA 3.- CALDERAS DE POTENCIA I

INGENIERIA DE CALDERAS

A. COMPONENTES Y ACCESORIOS DE UNA CALDERA
B CIRCULACION
C. ESPECIFICACION Y EVALUACION DE CALDERAS
D DISEÑO TERMICO
E USO EFICIENTE DE LA ENERGIA DE CALDERAS
F CODIGO ASME DE CALDERAS Y RECIPIENTES A PRESION
G COMPARACION DE CODIGOS DE CALDERAS ASME-CODIGO ALEMAN PRESENTACION - PREGUNTAS.

CALDERAS DE POTENCIA

COMPONENTES Y ACCESORIOS

SISTEMA DE PARTES A PRESION AGUA-VAPOR

SISTEMA DE AIRE GASES

SISTEMA DE COMBUSTION

EQUIPOS AUXILIARES

ACCESORIOS

MEDICION CONTROL Y PROTECCION

COMPONENTES DE LA CALDERA

CORAZA - TUBOS - ESPEJOS - REFLECTORES - TIRANTES - BOQUILLAS

DOMOS - CABEZALES - PAREDES - BANCOS GENERADORES - BAJANTES - SOBRECALENTADORES - ATEMPERADORES- RECALENTADORES - ECONOMIZADORES

CUBIERTAS - ESTRUCTURA - CAMARA DE COMBUSTION - DUCTOS - COMPUERTAS - JUNTAS DE EXPANSION - SOPORTES - REFRACTARIO - AISLAMIENTO - CHIMENEA - PRECALENTADORES DE AIRE

EQUIPOS AUXILIARES

QUEMADORES

BOMBAS DE AGUA DE ALIMENTACION

VENTILADOR DE TIRO FORZADO

VENTILADOR DE TIRO INDUCIDO

SOPLADORES DE HOLLIN

BOMBAS DE COMBUSTIBLE

CALENTADORES DE COMBUSTIBLE

CIRCULACION EN CALDERAS

CONCEPTOS BASICOS

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TERMICA O NATURAL
CIRCULACION CONTROLADA
CIRCULACION FORZADA

CRITERIO DE DISEÑO

IMPORTANCIA DE LA CIRCULACION

EMBULLICION NUCLEADA - DNB

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¿VA A ADQUIRIR UNA CALDERA NUEVA ?

ALGUNOS PROBLEMAS CON LAS CALDERAS EN SERVICIO

ALGUNAS SOLUCIONES

ESPECIFICAR ADECUADAMENTE

CAUSAS DE ESPECIFICACION DEFICIENTE

ESPECIFIACION DEMASIADO ABIERTA

ESPECIFICACION DEMASIADA CERRADA

EVALUACION DE CALDERAS

DISEÑO TERMICO

MODOS DE TRANSFERENCIA EN UNA CALDERA

CONDUCTANCIA

TRANSFERENCIA POR RADIACION

TRANSFERENCIA POR CONVECCION

MECANISMOS DE TRANSFERENCIA COMBINADA

OTRAS FORMAS DE TRANSFERENCIA
  CONDENSACION
  EVAPORACION

TRANSFERENCIA DE CALOR
  AL AGUA
  AL VAPOR
  EN EL HORNO
  RADIACION AL AMBIENTE

ABSORCION EN DIFERENTES COMPONENETES

BALANCE TERMICO ES UNA CALDERA

USO EFICIENTE DE LA ENERGIA EN CALDERAS
  USO RACIONAL
  USO EFICIENTE

EL GENERADOR DE VAPOR
IMPORTANCIA ENERGETICA DE LA GENERACION DE VAPOR

DIAGNOSTICO ENERGETICO

GENERACION DE VAPOR

APLICACIONES - CAPACIDADES - CONDICIONES

OPERACION EFICIENTE

OPERACIÓN SEGURA

FACTORES QUE INFLUYEN EN LA SEGURIDAD

EFICIENCIA EN CALDERAS

DIFERENTES CONCEPTOS DE EFICIENCIA
CONTROL Y PROTECCION Vs. EFICIENCIA.

METODOS DE CALCULO

CODIGO ASME - SECCION I

CALDERAS DE POTENCIA

PARTES DEL CONTENIDO

R E Q U I S I T O S

PG	GENERALES PARA TODOS LOS METODOS DE CONSTRUCCION
PW	CALDERAS FABRICADAS MEDIANTE SOLDADURA
PR	CALDERAS FABRICADAS MEDIANTE REMACHADO
PWT	CALDERAS ACOUTUBULARES
PFT	CALDERAS DE TUBO DE HUMO
PFH	OPCIONALES PARA CALENTADOR DE AGUA DE ALIMENTACION DENTRO DEL ALCANCE DE LA SECCION I
PMB	CALDERAS MINIATURA
PEB	CALDERAS ELECTRICAS
PVG	GENERDORES DE FLUIDOS ORGANICOS VAPORIZANDO

PARTE PG - REQUISITOS GENERALES

MATERIALES

DISEÑO

ABERTURAS Y COMPERSACION

TUBERIA EXTERNA A LA CALDERA

TUBERIA EXTERNA A LA CALDERA

VALVULAS DE SEGURIDAD Y DE ALIVIO

FABRICACION

INSPECCION Y PRUEBAS

CERTIFICACION POR MEDIO DEL SELLO Y REPORTE DE DATOS

PARTE PW - CONSTRUCCION SOLDADA

DESEÑO - JUNTAS - TRANSICIONES - ABERTUAS - - CONEXIONES - TIRANTES - NDT - TRATAMIENTO TERMICO

FABRICACION - PROCESOS - CALIFICACION - REGISTROS - PREPARACION DE SUPERFICIES - ALIMENTACION.

LA ASME NO "APRUEBA", "CLASIFICA", O RESPALDA NINGUN(A) PARTIDA, CONSTRUCCION, DISPOSITIVO O ACTIVIDAD

LA ASME NO TOMA NINGUNA ACTITUD CON RESPECTO A LA VALIDEZ DE ALGUNOS DERECHOS DE PATENTES DEFENDIDOS EN RELACION CON TALES PARTIDAS MENCIONADAS EN ESTE DOCUMENTO, Y NO SE COMPROMETE PARA DAR SEGURIDAD A ALGUNO QUE UTILIZA UNA NORMA CONTRA RIESGOS POR VIOLACION DE ALGUNA PATENTE DE PRIVILEGIO, NI SE ATRIBUYE NINGUNA RESPONSABILIDAD TAL.
LOS USUARIOS DE ALGUN CODIGO O NORMA ESTAN ADVERTIDOS EXPRESAMENTE QUE LA DETERMINACION Y LA VALIDEZ DE ALGUNOS DERECHOS DE PATENTES Y RIESGO DE VIOLACION DE ESOS DERECHOS ES ENTERAMENTE DE LA RESPONSABILIDAD DE ELLOS

LA PARTICIPACION DE PARTE DE REPRESENTANTE(S) AFILIADAS A LA INDUSTRIA NO ES PARA INTERPRETARSE COMO RESPALDO DEL GOBIERNO O INDUSTRIA DE ESTE CODIGO O CONJUNTO DE NORMAS.

LA ASME ACEPTA LA ESPONSABILIDAD SOLAMENTE PARA AQUELLAS INTERPRETACIONES EMITIDAS DE ACUERDO CON LOS PROCEDIMIENTOS Y POLITICAS DE GOBIERNO DE LA ASME, LAS QUE HACEN IMPOSIBLE LA EMISION DE INTERPRETACIONS POR VOLUNTARIOS INDIVIDUALES.

ELEMENTOS DE SEGURIDAD EN EL PRIMER CODIGO

MATERIALES CON PROPIEDADES CONOCIDAS

FORMULAS DE DISEÑO - FACTOR DE SEGURIDAD MINIMO

METODOS DE CONSTRUCCION RECONOCIDOS

ACCESORIOS Y VALVULAS DE SEGURIDAD APROPIADAS

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SELLO DE CUMPLIMIENTO A CODIGO

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REGLAS TECNICAS "TRD" PARA CALDERAS DE POTENCIA- ALEMANIA

DIFERENCIAS ENTRE LOS DOS CODIGOS

DEFINICION DE CALDERA DE POTENCIA
CODIGO ASME
CODIGO ALEMAN

CLASIFICACION SUGUN "TRD"

GRUPO I - CAPACIDAD MENOR DE 10 LITROS

GRUPO II- CAPACIDAD MAYOR DE 10 LITROS
PRESION MENOR DE 1 BAR
TEMPERATURA MENOR DE 120°C (AGUA CALIENTE-VAPOR)

GRUPO III- CAPACIDAD MAYOR DE 10 LITROS Y MENOR DE 50 LITROS
PRESION MAYOR DE 1 BAR
PRODUCTO PRESION -CAPACIDAD MENOR DE 1000 (AGUA O VAPOR)

GRUPO IV- CALDERA NO CUBIERTA POR GRUPO I, II Y III

ALCANCE DEL CODIGO ASME

JURISDICCION ASME
SECCION I

EL CODIGO "TRD" INCLUYE REQUISITOS PARA

ESTRUCTURA, REFRACTARIO Y ENVOLVENTE

EQUIPO DE COMBUSTION

EQUIPO EN EL CUARTO DE CALDERAS
PRECALENTADORES DE AIRE Y VENTILADORES

SISTEMA DE REMOCION DE GASES Y CHIMENEA

CALENTADORES Y LINEAS DE AGUA DE ALIMENTACION

SOBRECALENTADORES - RECALENTADORES ATEMPERADORES

TUBERIA DE VAPOR Y AGUA CALIENTE DENTRO DEL CUARTO DE CONTROL

TANQUES DE EXPANSION

TODO EL EQUIPO NECESARIO PARA LA OPERACIÓN DE LA CALDERA.

TODO EL MATERIAL USADO PARA LA OPERACIÓN DE LA CALDERA

MATERIAL PERMISIBLES

CODIGO ASME

CODIGO TRD CERTIFICACION DE AGENCIAS DE INSPECCION AUTORIZADAS - MATERIAL - SOLDADURA - APLICACION - PRUEBAS

MAYORES EXIGENCIAS QUE ASME SECCION I

VALORES PERMISIBLES DE ESFUERZOS DE DISEÑO

ASME - EL MENOR DE ESTOS VALORES (APENDICE A-150)

1/4 RESISTENCIA A TENSION MIN. (TEMPERATURA AMBIENTE)

1/4 RESISTENCIA A TENCION (TEMPERATURA DE DISEÑO)

2/3 RESISTENCIA PUNTO DE CEDENCIA (TEMPERATURA AMBIENTE)

2/3 RESISTENCIA PUNTO DE CEDENCIA (TEMPERATURA DE DISEÑO)

CODIGO TRD ESTABLECE USAR EL MENOR DE ESTOS VALORES

RESISTENCIA A TENSION A 20°C/2 4

RESISTENCIA PUNTO DE CEDENCIA A TEMPERATURA DE DISEÑO/1.5

MAYORES EXIGENCIAS DE DISEÑO EN CODIGO TRD QUE EN ASME SECCION I

PLACA DE REFUERZO

ABERTURAS

BOQUILLAS

ESFUERZOS TERMICOS Y CARGAS CICLICAS

DISEÑO DE LA CALDERA REVISADO POR AGENCIA DE INSPECCION AUTORIZADA.

FABRICACION.
ASME REQUIERE CERTIFICACION DE HABILIDAD DE DISEÑO Y FABRICACION A CODIGO Y EXTIENDE CERTIFICADO DE AUTORIZACION Y USO DEL SELLO "S" A FABRICANTES

CODIGO TRD TIENE REQUISITOS SIMILARES CON MENOR FORMALIDAD PARA LA CERTIFICACION QUE EXTIENDE LA AGENCIA AUTORIZADA DE INSPECCION.

OTRAS EXIGENCIAS DEL CODIGO TRD

FORMADO Y DOBLADO

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CALIFICACIONES DE SOLDADURA

CALIFICACION DE PROCEDIMIENTOS DE SOLDADURA

TRATAMIENTO TERMICO

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ANUALMENTE INSPECCION INTERNA 6 MESES DESPUES DE INSPECCION EXTERNA

POR DECRETO EN ALEMANIA

ANUALMENTE INSPECCION EXTERNA

TRIANUALMENTE INSPECCION INTERNA

PRUEBA HIDROSTATICA CADA 9 AÑOS - 1.3 VECES LA PRESION MAXIMA DE TRABAJO

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COMPONENTES Y ACCESORIOS

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SISTEMA DE AIRE GASES

SISTEMA DE COMBUSTION

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ACCESORIOS

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CORAZA - TUBOS - ESPEJOS - DEFLECTORES - TIRANTES - BOQUILLAS

DOMOS - CABEZALES - PAREDES - BANCOS GENERADORES – BAJANTES
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CUBIERTAS - ESTRUCTURA - CAMARA DE COMBUSTION - DUCTOS - COMPUERTAS - JUNTAS DE EXPANSION - SOPORTES - REFRACTARIO - AISLAMIENTO - CHIMENEA - PRECALENTADORES DE AIRE

EQUIPOS AUXILIARES

QUEMADORES

BOMBAS DE AGUA DE ALIMENTACION

VENTILADOR DE TIRO FORZADO

VENTILADOR DE TIRO INDUCIDO

SOPLADORES DE HOLLIN

BOMBAS DE COMBUSTIBLE

CALENTADORES DE COMBUSTIBLE

CIRCULACION EN CALDERAS

CONCEPTOS BASICOS

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IMPORTANCIA DE LA CIRCULACION

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ALGUNAS SOLUCIONES

ESPECIFICAR ADECUADAMENTE

CAUSAS DE ESPECIFICACION DEFICIENTE

ESPECIFICACION DEMASIADO ABIERTA

ESPECIFICACION DEMASIADAOCERRADA

EVALUACION DE CALDERAS

DISEÑO TERMICO

MODOS DE TRANSFERENCIA EN UNA CALDERA

CONDUCTANCIA

TRANSFERENCIA POR RADIACION

TRANSFERENCIA POR CONVECCION

MECANISMOS DE TRANSFERENCIA COMBINADA

OTRAS FORMAS DE TRANSFERENCIA
- CONDENSACION
- EVAPORACION

TRANSFERENCIA DE CALOR
- AL AGUA
- AL VAPOR
- EN EL HORNO
- RADIACION AL AMBIENTE

ABSORCION EN DIFERENTES COMPONENETES

BALANCE TERMICO ES UNA CALDERA

USO EFICIENTE DE LA ENERGIA EN CALDERAS
- USO RACIONAL
- USO EFICIENTE

EL GENERADOR DE VAPOR
IMPORTANCIA ENERGETICA DE LA GENERACION DE VAPOR

DIAGNOSTICO ENERGETICO

GENERACION DE VAPOR

APLICACIONES - CAPACIDADES - CONDICIONES

OPERACION EFICIENTE

OPERACIÓN SEGURA

FACTORES QUE INFLUYEN EN LA SEGURIDAD

EFICIENCIA EN CALDERAS

DIFERENTES CONCEPTOS DE EFICIENCIA
CONTROL Y PROTECCION Vs EFICIENCIA.

METODOS DE CALCULO

CODIGO ASME - SECCION I

CALDERAS DE POTENCIA

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REQUISITOS

PG	GENERALES PARA TODOS LOS METODOS DE CONSTRUCCION
PW	CALDERAS FABRICADAS MEDIANTE SOLDADURA
PR	CALDERAS FABRICADAS MEDIANTE REMACHADO
PWT	CALDERAS ACUOTUBULARES
PFT	CALDERAS DE TUBO DE HUMO
PFH	OPCIONALES PARA CALENTADOR DE AGUA DE ALIMENTACION DENTRO DEL ALCANCE DE LA SECCION I
PMB	CALDERAS MINIATURA
PEB	CALDERAS ELECTRICAS
PVG	GENERDORES DE FLUIDOS ORGANICOS VAPORIZANTES

PARTE PG - REQUISITOS GENERALES

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TUBERIA EXTERNA A LA CALDERA

VALVULAS DE SEGURIDAD Y DE ALIVIO

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FABRICACION - PROCESOS - CALIFICACION - REGISTROS - PREPARACION DE SUPERFICIES - ALIMENTACION

LA ASME NO "APRUEBA", "CLASIFICA", O RESPALDA NINGUN(A) PARTIDA, CONSTRUCCION, DISPOSITIVO O ACTIVIDAD

LA ASME NO TOMA NINGUNA ACTITUD CON RESPECTO A LA VALIDEZ DE ALGUNOS DERECHOS DE PATENTES DEFENDIDOS EN RELACION CON TALES PARTIDAS MENCIONADAS EN ESTE DOCUMENTO, Y NO SE COMPROMETE PARA DAR SEGURIDAD A ALGUNO QUE UTILIZA UNA NORMA CONTRA RIESGOS POR VIOLACION DE ALGUNA PATENTE DE PRIVILEGIO, NI SE ATRIBUYE NINGUNA RESPONSABILIDAD TAL
LOS USUARIOS DE ALGUN CODIGO O NORMA ESTAN ADVERTIDOS EXPRESAMENTE QUE LA DETERMINACION Y LA VALIDEZ DE ALGUNOS DERECHOS DE PATENTES Y RIESGO DE VIOLACION DE ESOS DERECHOS ES ENTERAMENTE DE LA RESPONSABILIDAD DE ELLOS

LA PARTICIPACION DE PARTE DE REPRESENTANTE(S) AFILIADAS A LA INDUSTRIA NO ES PARA INTERPRETARSE COMO RESPALDO DEL GOBIERNO O INDUSTRIA DE ESTE CODIGO O CONJUNTO DE NORMAS.

LA ASME ACEPTA LA RESPONSABILIDAD SOLAMENTE PARA AQUELLAS INTERPRETACIONES EMITIDAS DE ACUERDO CON LOS PROCEDIMIENTOS Y POLITICAS DE GOBIERNO DE LA ASME, LAS QUE HACEN IMPOSIBLE LA EMISION DE INTERPRETACIONS POR VOLUNTARIOS INDIVIDUALES

ELEMENTOS DE SEGURIDAD EN EL PRIMER CODIGO

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INSPECCION Y PRUEBAS - TALLER Y CAMPO

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RELACION CON OTROS CODIGOS

COMPARACION DE CODIGOS DE CALDERAS

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DIFERENCIAS ENTRE LOS DOS CODIGOS

DEFINICION DE CALDERA DE POTENCIA
CODIGO ASME
CODIGO ALEMAN

CLASIFICACION SUGUN "TRD"

GRUPO I - CAPACIDAD MENOR DE 10 LITROS

GRUPO II- CAPACIDAD MAYOR DE 10 LITROS
PRESION MENOR DE 1 BAR
TEMPERATURA MENOR DE 120°C (AGUA CALIENTE-VAPOR)

GRUPO III- CAPACIDAD MAYOR DE 10 LITROS Y MENOR DE 50 LITROS
PRESION MAYOR DE 1 BAR
PRODUCTO PRESION -CAPACIDAD MENOR DE 1000 (AGUA O VAPOR)

GRUPO IV- CALDERA NO CUBIERTA POR GRUPO I, II Y III

ALCANCE DEL CODIGO ASME

JURISDICCION ASME
SECCION I

EL CODIGO "TRD" INCLUYE REQUISITOS PARA:

ESTRUCTURA, REFRACTARIO Y ENVOLVENTE

EQUIPO DE COMBUSTION

EQUIPO EN EL CUARTO DE CALDERAS
PRECALENTADORES DE AIRE Y VENTILADORES

SISTEMA DE REMOCION DE GASES Y CHIMENEA

CALENTADORES Y LINEAS DE AGUA DE ALIMENTACION

SOBRECALENTADORES - RECALENTADORES ATEMPERADORES

TUBERIA DE VAPOR Y AGUA CALIENTE DENTRO DEL CUARTO DE CONTROL

TANQUES DE EXPANSION

TODO EL EQUIPO NECESARIO PARA LA OPERACION DE LA CALDERA.

TODO EL MATERIAL USADO PARA LA OPERACION DE LA CALDERA

MATERIAL PERMISIBLES

CODIGO ASME

CODIGO TRD — CERTIFICACION DE AGENCIAS DE INSPECCION AUTORIZADAS - MATERIAL - SOLDADURA - APLICACION - PRUEBAS

MAYORES EXIGENCIAS QUE ASME SECCION I

VALORES PERMISIBLES DE ESFUERZOS DE DISEÑO

ASME - EL MENOR DE ESTOS VALORES (APENDICE A-150)

1/4 RESISTENCIA A TENSION MIN (TEMPERATURA AMBIENTE)

1/4 RESISTENCIA A TENSION (TEMPERATURA DE DISEÑO)

2/3 RESISTENCIA PUNTO DE CEDENCIA (TEMPERATURA AMBIENTE)

2/3 RESISTENCIA PUNTO DE CEDENCIA (TEMPERATURA DE DISEÑO)

CODIGO TRD ESTABLECE USAR EL MENOR DE ESTOS VALORES

RESISTENCIA A TENSION A 20°C/2 4

RESISTENCIA PUNTO DE CEDENCIA A TEMPERATURA DE DISEÑO/1 5

MAYORES EXIGENCIAS DE DISEÑO EN CODIGO TRD QUE EN ASME SECCION I

PLACA DE REFUERZO

ABERTURAS

BOQUILLAS

ESFUERZOS TERMICOS Y CARGAS CICLICAS

DISENO DE LA CALDERA REVISADO POR AGENCIA DE INSPECCION AUTORIZADA.

FABRICACION
ASME REQUIERE CERTIFICACION DE HABILIDAD DE DISEÑO Y FABRICACION A CODIGO Y EXTIENDE CERTIFICADO DE AUTORIZACION Y USO DEL SELLO "S" A FABRICANTES.

CODIGO TRD TIENE REQUISITOS SIMILARES CON MENOR FORMALIDAD PARA LA CERTIFICACION QUE EXTIENDE LA AGENCIA AUTORIZADA DE INSPECCION

OTRAS EXIGENCIAS DEL CODIGO TRD

FORMADO Y DOBLADO

CUPONES DE PRUEBA DE MATERIALES

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INSPECCIONES EN SERVICIO

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ANUALMENTE INSPECCION INTERNA 6 MESES DESPUES DE INSPECCION EXTERNA

POR DECRETO EN ALEMANIA

ANUALMENTE INSPECCION EXTERNA

TRIANUALMENTE INSPECCION INTERNA

PRUEBA HIDROSTATICA CADA 9 AÑOS - 1 3 VECES LA PRESION MAXIMA DE TRABAJO

FACULTAD DE INGENIERÍA UNAM
DIVISIÓN DE EDUCACIÓN CONTINUA

CURSOS ABIERTOS

DIPLOMADO EN INGENIERÍA DE CALDERAS Y RECIPIENTES A PRESIÓN

MÓDULO II:

MATERIALES, SOLDADURA Y CALDERAS DE POTENCIA

EXPOSITOR: ING. ORLANDO R. RIVERA
PALACIO DE MINERÍA
MARZO DEL2003

SECTION VIII
DIV. 1

CONTENTS

A Detailed Contents Precedes Each Part and the Appendices

SECTION I

PART PG
GENERAL REQUIREMENTS FOR ALL METHODS OF CONSTRUCTION

GENERAL

PG-1 SCOPE

The requirements of Part PG apply to power boilers and high pressure, high-temperature water boilers and to parts and appurtenances thereto and shall be used in conjunction with the specific requirements in the applicable Parts of this Section that pertain to the methods of construction used.

PG-2 SERVICE LIMITATIONS

PG-2.1 The rules of this Section are applicable to the following services:

(a) boilers in which steam or other vapor is generated at a pressure of more than 15 psig (103 kPa);

(b) high-temperature water boilers intended for operation at pressures exceeding 160 psig (1 100 kPa) and/or temperatures exceeding 250°F (121°C).

PG-2.2 For services below those specified in PG-2.1 it is intended that rules of Section IV apply; however, boilers for such services may be constructed and stamped in accordance with this Section provided all applicable requirements are met.

PG-2.3 Coil-type hot water boilers where the water can flash into steam when released directly to the atmosphere through a manually operated nozzle may be exempted from the rules of this Section provided the following conditions are met.

(a) There is no drum, header, or other steam space.

(b) No steam is generated within the coil.

(c) Tubing outside diameter does not exceed 1 in. (25 mm).

(d) Pipe size does not exceed NPS $\frac{3}{4}$ (DN 20).

(e) Nominal water capacity does not exceed 6 gal (23 l).

(f) Water temperature does not exceed 350°F (177°C).

(g) Adequate safety relief valves and controls are provided.

PG-3 REFERENCED STANDARDS

Specific editions of standards referenced in this Section are shown in Appendix A-360

MATERIALS

PG-5 GENERAL

PG-5.1 Material subject to stress due to pressure shall conform to one of the specifications given in Section II and shall be limited to those that are listed in the Tables of Section II, Part D, except as otherwise permitted in PG-8.2, PG-8.3, PG-10, and PG-11. Materials shall not be used at temperatures above those for which stress values are limited, for Section I construction, in the Tables of Section II, Part D. Specific additional requirements described in PG-5 through PG-13 shall be met as applicable.

PG-5.2 Material covered by specifications in Section II is not restricted as to the method of production unless so stated in the specification, and as long as the product complies with the requirements of the specification.

PG-5.3 If, in the development of the art of boiler construction, it is desired to use materials other than those herein described, data should be submitted to the Boiler and Pressure Vessel Committee in accordance with the requirements of Appendix 5 of Section II, Part D. Material not completely identified with any approved Code specifications may be used in the construction of boilers under the conditions outlined in PG-10.

PG-5.4 Materials outside the limits of size or thickness given in the title or scope clause of any specification in Section II may be used if the material is in compliance with the other requirements of the specification, and no similar limitation is given in the rules for construction.

PG-5.5 The use of austenitic alloy steel is permitted for boiler pressure parts that are steam touched in normal operation. Except as specifically provided in PG-9.1.1, PG-12, and PEB-5.3, the use of such austenitic alloys for boiler pressure parts that are water wetted in normal service is prohibited.[1]

PG-6 PLATE

01 **PG-6.1** Steel plates for any part of a boiler subject to pressure, whether or not exposed to the fire or products of combustion, shall be of pressure vessel quality in accordance with one of the following specifications:

SA-202 Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon
SA-204 Pressure Vessel Plates, Alloy Steel, Molybdenum
SA-240 (Type 405 only) Pressure Vessel Plates, Alloy Steel (Ferritic Stainless), Chromium
SA-285 Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
SA-299 Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
SA-302 Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel
SA-387 Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum
SA-515 Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
SA-516 Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
SA/EN-10028-2 Flat Products Made of Steels for Pressure Purposes

PG-7 FORGINGS

PG-7.1 Seamless steel drum forgings made in accordance with SA-266 for Carbon-Steel and SA-336 for Alloy Steel may be used for any part of a boiler for which pressure vessel quality is specified or permitted.

PG-7.2 Forged flanges, fittings, nozzles, valves, and other pressure parts of the boiler shall be of material that conforms to one of the forging specifications as listed in PG-9.

PG-7.3 Drums, shells, or domes may be of seamless drawn construction, with or without integral heads, provided the material conforms to the requirements of the Code for shell material.

PG-8 CASTINGS

PG-8.1 Except for the limited usage permitted by PG-8.2 and PG-8.3, cast material used in the construction of vessels and vessel parts shall conform to one of the specifications listed in PG-9 for which maximum allowable stress values are given in Tables 1A and 1B of Section II, Part D. The allowable stress values shall be multiplied by the applicable casting quality factor given in PG-25 for all cast materials except cast iron.

When cast iron is used as allowed in PG-11.1 for standard pressure parts, it shall conform to one of these standards:

ASME B16.1, Cast Iron Pipe Flanges and Flanged Fittings
ASME B16.4, Cast Iron Threaded Fittings

Material conforming to ASTM A 126 may be used subject to all requirements of the particular standard. Such usage is subject also to all the requirements for the use of cast iron given in PG-8.2 and other paragraphs of this Section.

PG-8.2 Cast Iron

PG-8.2.1 Cast iron shall not be used for nozzles or flanges attached directly to the boiler for any pressure or temperature.

PG-8.2.2 Cast iron as designated in SA-278, Gray Iron Castings for Pressure-Containing Parts for Temperatures up to 650°F (343°C) may be used for boiler and superheater connections under pressure, such as pipe fittings, water columns, valves and their bonnets, for pressures up to 250 psi (1 720 kPa), provided the steam temperature does not exceed 450°F (232°C).

PG-8.3 Cast Nodular Iron. Cast nodular iron as designated in SA-395 may be used for boiler and superheater connections under pressure, such as pipe fittings, water columns, and valves and their bonnets, for pressures not to exceed 350 psi (2 410 kPa), provided the steam temperature does not exceed 450°F (232°C).

[1] Austenitic alloys are susceptible to intergranular corrosion and stress corrosion cracking when used in boiler applications in water wetted service. Factors that affect the sensitivity to these metallurgical phenomena are applied or residual stress and water chemistry. Susceptibility to attack is usually enhanced by using the material in a stressed condition with a concentration of corrosive agents (e.g., chlorides, caustic, or reduced sulfer species). For successful operation in water environments, residual and applied stresses must be minimized and careful attention must be paid to continuous control of water chemistry.

PG-8.4 Nonferrous. Bronze castings shall conform to SB-61 and SB-62 and may be used only for the following:

PG-8.4.1 For flanges and flanged or threaded fittings complying with the pressure and temperature requirements of ANSI B16.15 or B16.24, except that such fittings shall not be used where steel or other material is specifically required. Threaded fittings shall not be used where flanged types are specified.

PG-8.4.2.1 For valves at allowable stress values not to exceed those given in Table 1B of Section II, Part D, with maximum allowable temperatures of 550°F (288°C) for SB-61 and 406°F (208°C) for SB-62.

PG-8.4.2.2 For parts of safety valves or safety relief valves subject to limitations of PG-67.7.

PG-9 PIPES, TUBES, AND PRESSURE CONTAINING PARTS

Pipes, tubes, and pressure containing parts used in boilers shall conform to one of the specifications listed in this paragraph for which maximum allowable stresses are given in Tables 1A and 1B of Section II, Part D. The stress values given in these tables include the applicable joint efficiency factor for welded pipes and tubes.

Open-hearth, electric furnace, or basic oxygen steel shall be used for boiler pressure parts exposed to the fire or products of combustion. When used for internal pressure, the material stress and dimensions shall meet the appropriate requirements of PG-27 and Part PW and be in accordance with the following:

01 **PG-9.1** Boiler parts shall be of the following specifications only:

SA-53 Welded and Seamless Steel Pipe (excluding galvanized)
SA-105 Forgings, Carbon Steel, for Piping Components
SA-106 Seamless Carbon Steel Pipe for High-Temperature Service
SA-178 Electric-Resistance-Welded Carbon Steel Boiler Tubes
SA-181 Forged or Rolled Steel Pipe Flanges, Forged Fittings, and Valves and Parts for General Service
SA-182 Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service (ferritic only)
SA-192 Seamless Carbon Steel Boiler Tubes for High Pressure Service
SA-209 Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes
SA-210 Seamless Medium Carbon Steel Boiler and Superheater Tubes
SA-213 Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater and Heat Exchanger Tubes (ferritic only)
SA-216 Carbon Steel Castings Suitable for Fusion Welding for High-Temperature Service
SA-217 Alloy-Steel Castings for Pressure-Containing Parts Suitable for High-Temperature Service
SA-234 Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures
SA-250 Electric-Resistance-Welded Carbon-Molybdenum Alloy Steel Boiler and Superheater Tubes
SA-266 Carbon Steel Seamless Drum Forgings
SA-268 Seamless and Welded Ferritic Stainless Steel Tubing for General Service
SA-335 Seamless Ferritic Alloy Steel Pipe for High-Temperature Service
SA-336 Alloy Steel Seamless Drum Forgings (ferritic only)
SA-423 Seamless and Electric Welded Low Alloy Steel Tubes
SA-660 Centrifugally Cast Carbon Steel Pipe for High-Temperature Service
SA-731 Seamless, Welded Ferritic, and Martensitic Stainless Steel Pipe

PG-9.1.1 Boiler parts on once-through boilers shall be any of the specifications listed in PG-9.1 or any of the following[2]:

SB-407 Nickel-Iron-Chromium Alloy Seamless Pipe and Tube
SB-408 Nickel-Iron-Chromium Alloy Rod and Bar
SB-409 Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
SB-423 Nickel-Iron-Chromium-Molybdenum Seamless Pipe and Tube
SB-424 Nickel-Iron-Chromium-Molybdenum-Copper Alloy Plate, Sheet, and Strip
SB-425 Nickel-Iron-Chromium-Molybdenum-Copper Alloy Rod and Bar
SB-515 Welded Nickel-Iron-Chromium Alloy Tubes
SB-564 Nickel Alloy Forgings

PG-9.2 Superheater parts shall be of any one of the specifications listed in PG-9.1 or one of the following: 01

SA-182 Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Plates for High-Temperature Service

[2] The maximum recommended feedwater-dissolved solids concentration for once-through boilers is 0.050 ppm

SA-213 Seamless Ferritic and Austenitic Alloy Steel Boiler, Superheater and Heat Exchanger Tubes
SA-240 Stainless and Heat-Resisting Chromium and Chromium-Nickel Steel Plates, Sheet and Strip for Fusion-Welded Unfired Pressure Vessels
SA-249 Welded Austenitic Steel Boiler, Superheater, Heat Exchanger, and Condenser Tubes
SA-312 Seamless and Welded Austenitic Stainless Steel Pipe
SA-336 Alloy Steel Seamless Drum Forgings
SA-351 Ferritic and Austenitic Steel Castings for High-Temperature Service
SA-369 Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service
SA-376 Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service
SA-430 Austenitic Steel Forged and Bored Pipe for High-Temperature Service
SA-479 Stainless and Heat-Resisting Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
SA-731 Seamless, Welded Ferritic, and Martensitic Stainless Steel Pipe
SB-163 Seamless Nickel and Nickel Alloy Condenser and Heat Exchanger Tubes
SB-166 Nickel-Chromium Iron Alloys (UNS N06600, N06601, N06690, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Rod, Bar, and Wire
SB-167 Nickel-Chromium Iron Alloys (UNS N06600, N06601, N06690, N06025, and N06045) Seamless Pipe and Tube
SB-168 Nickel-Chromium Iron Alloys (UNS N06600, N06601, N06690, N06026, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Plate, Sheet, and Strip
SB-366 Factory-Made Wrought Nickel and Nickel Alloy Fittings
SB-407 Nickel-Iron-Chromium Alloy Seamless Pipe and Tube
SB-408 Nickel-Iron-Chromium Alloy Rod and Bar
SB-409 Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
SB-423 Nickel-Iron-Chromium-Molybdenum Seamless Pipe and Tube
SB-424 Nickel-Iron-Chromium-Molybdenum-Copper Alloy Plate, Sheet, and Strip
SB-425 Nickel-Iron-Chromium-Molybdenum-Copper Alloy Rod and Bar
SB-435 N06002, W06230, and R30556 Plate, Sheet, and Strip
SB-514 Welded Nickel-Iron-Chromium Alloy Pipe
SB-515 Welded Nickel-Iron-Chromium Alloy Tubes
SB-516 Welded Nickel-Chromium-Iron Alloy (UNS N06600), UNS N06025, and UNS N06045 Tubes
SB-517 Welded Nickel-Chromium-Iron Alloy (UNS N06600), UNS N06025, and UNS N06045 Pipe
SB-564 Nickel Alloy Forgings
SB-572 Nickel-Molybdenum-Chromium-Iron Alloy Rod
SB-619 Welded Nickel and Nickel-Cobalt Alloy Pipe
SB-622 Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube
SB-626 Welded Nickel and Nickel-Cobalt Alloy Tube

PG-9.3 Copper or copper alloy pipe or tubes shall not be used in the boiler proper for any service where the temperature exceeds 406°F (208°C). Copper and copper alloys shall be seamless, having a thickness not less than ANSI Schedule 40 standard pipe, and shall comply to one of the following specifications: SB-42, Seamless Copper Pipe, Standard Sizes; SB-43, Seamless Red Brass Pipe, Standard Sizes; SB-75, Seamless Copper Tube; or SB-111, Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock.

PG-9.4 Bimetallic tubes, having a core of an acceptable boiler and superheater material, and having an external cladding of another metal alloy, may be used provided the requirements of PG-27.2.1.5 are met for establishing minimum thickness of the core. The permissible variation in wall thickness tolerance of SA-450 or SB-163, as applicable, shall apply to the total wall thickness. The thickness and over and undertolerances of the cladding shall be included in the ordering information. Marking of the bimetallic tubular product shall meet the specification requirements of the core material, but shall also suitably identify the cladding alloy.

PG-9.5 ERW products shall be limited to a maximum thickness of $\frac{1}{2}$ in. for internal pressure applications. For external pressure applications, ERW products shall be limited to a maximum thickness of $\frac{1}{2}$ in. and a maximum size of NPS 24. The thickness and diameter limitations noted above shall be within tolerances stated by the product material specification. 01

PG-10 MATERIAL IDENTIFIED WITH OR PRODUCED TO A SPECIFICATION NOT PERMITTED BY THIS SECTION, AND MATERIAL NOT FULLY IDENTIFIED

PG-10.1 Identified With Complete Certification From the Material Manufacturer. Material identified with a specification not permitted by this Section, or material procured to chemical composition requirements and identified to a single production lot as required by a permitted specification may be accepted as satisfying the requirements of a specification permitted by this Section provided the conditions set forth in PG-10.1.1 or PG-10.1.2 are satisfied.

PG-10.1.1 Recertification by an organization other than the boiler or part manufacturer:

PG-10.1.1.1 All requirements, including but not limited to, melting method, melting practice, deoxidation, quality, and heat treatment, of the specification permitted by this Section, to which the material is to be recertified, have been demonstrated to have been met.

PG-10.1.1.2 A copy of the certification by the material manufacturer of the chemical analysis required by the permitted specification, with documentation showing the requirements to which the material was produced and purchased, and which demonstrates that there is no conflict with the requirements of the permitted specification, has been furnished to the boiler or part manufacturer.

PG-10.1.1.3 A certification that the material was manufactured and tested in accordance with the requirements of the specification to which the material is recertified, excluding the specific marking requirements, has been furnished to the boiler or part manufacturer, together with copies of all documents and test reports pertinent to the demonstration of conformance to the requirements of the permitted specification.

PG-10.1.1.4 The material, and the Certificate of Compliance or the Material Test Report have been identified with the designation of the specification to which the material is recertified and with the notation "Certified per PG-10."

PG-10.1.2 Recertification by the boiler or part manufacturer:

PG-10.1.2.1 A copy of the certification by the material manufacturer of the chemical analysis required by the permitted specification, with documentation showing the requirements to which the material was produced and purchased, which demonstrates that there is no conflict with the requirements of the permitted specification, is available to the Inspector.

PG-10.1.2.2 For applications in which the maximum allowable stresses are subject to a note of Table 1A of Section II, Part D, requiring the use of killed steel, documentation is available to the Inspector that establishes that the material is a killed steel.

PG-10.1.2.3 Documentation is available to the Inspector that demonstrates that the metallurgical structure, mechanical property, and hardness requirements of the permitted specification have been met.

PG-10.1.2.4 For material recertified to a permitted specification that requires a fine austenitic grain size or that requires that a fine grain practice be used during melting, documentation is available to the Inspector that demonstrates that the heat treatment requirements of the permitted specification have been met, or will be met during fabrication.

PG-10.1.2.5 The material has marking, acceptable to the Inspector, for identification to the documentation.

PG-10.1.2.6 When the conformance of the material with the permitted specification has been established, the material has been marked as required by the permitted specification.

PG-10.2 Material Identified to a Particular Production Lot as Required by a Specification Permitted by This Section but That Cannot Be Qualified Under PG-10.1. Any material identified to a particular production lot as required by a specification permitted by this Section, but for which the documentation required in PG-10.1 is not available, may be accepted as satisfying the requirements of the specification permitted by this Section provided that the conditions set forth below are satisfied.

PG-10.2.1 Recertification by an organization other than the boiler or part manufacturer — not permitted.

PG-10.2.2 Recertification by the boiler or part manufacturer.

PG-10.2.2.1 Chemical analyses are made on different pieces from the lot to establish a mean analysis which is to be accepted as representative of the lot. The pieces chosen for analyses shall be selected at random from the lot. The number of pieces selected shall be at least 10% of the number of pieces in the lot, but not less than three. For lots of three pieces or less, each piece shall be analyzed. Each individual analysis in the permitted specification and the mean for each element shall conform to the heat analysis limits of that specification. Analyses need to be made for only those elements required by the permitted specification. However, consideration should be given to making analyses for elements not specified in the specification but which would be deleterious if present in excessive amounts.

PG-10.2.2.2 Mechanical property tests are made in accordance with the requirements of the permitted specification and the results of the tests conform to the specified requirements.

PG-10.2.2.3 For applications in which the maximum allowable stresses are subject to a note of Table 1A of Section II, Part D, requiring the use of killed steel, documentation is available to the Inspector which establishes that the material is a killed steel.

PG-10.2.2.4 When the requirements of the permitted specification include metallurgical structure requirements (i.e., fine austenitic grain size), tests are made and the results are sufficient to establish that those requirements of the specification have been met.

PG-10.2.2.5 When the requirements of the permitted specification include heat treatment, the material is heat treated in accordance with those requirements, either prior to or during fabrication.

PG-10.2.2.6 When the conformance of the material with the permitted specification has been established, the material has been marked as required by the permitted specification.

PG-10.3 Material Not Fully Identified. Material which cannot be qualified under the provisions of either PG-10.1 or PG-10.2, such as material not fully identified as required by the permitted specification or as unidentified material, may be accepted as satisfying the requirements of a specification permitted by this Section provided that the conditions set forth below are satisfied.

PG-10.3.1 Qualification by an organization other than the boiler or part manufacturer — not permitted

PG-10.3.2 Qualification by the boiler or part manufacturer:

PG-10.3.2.1 Each piece is tested to show that it meets the chemical composition for product analysis and the mechanical properties requirements of the permitted specification. Chemical analyses need only be made for those elements required by the permitted specification. However, consideration shall be given to making analyses for elements not specified in the specification but which would be deleterious if present in excessive amounts. For plates, when the direction of final rolling is not known, both a transverse and a longitudinal tension test specimen shall be taken from each sampling location designated in the permitted specification. The results of both tests shall conform to the minimum requirements of the specification, but the tensile strength of only one of the two specimens need conform to the maximum requirement.

PG-10.3.2.2 The provisions of PG-10.2.2.3, PG-10.2.2.4, and PG-10.2.2.5 are met.

PG-10.3.2.3 When the identity of the material with the permitted specification has been established in accordance with PG-10.3.2.1 and PG-10.3.2.2, each piece (or bundle, etc., if permitted in the specification) is marked with a marking giving the permitted specification number and grade, type, or class as applicable and a serial number identifying the particular lot of material. A suitable report, clearly marked as being a "Report on Tests of Nonidentified Material," shall be completed and certified by the boiler or part manufacturer. This report, when accepted by the Inspector, shall constitute authority to use the material in lieu of material procured to the requirements of the permitted specification.

PG-11 MISCELLANEOUS PRESSURE PARTS

Prefabricated or preformed pressure parts for boilers which are subject to allowable working stresses due to internal or external pressure in the boiler and which are furnished by other than the shop of the Manufacturer responsible for the completed boiler shall conform to all applicable requirements of the Code for the completed boiler, including inspection in the shop of the parts manufacturer and the furnishing of Manufacturer's Partial Data Reports as provided for in PG-112.2.4 except as permitted in PG-11.1, PG-11.2, and PG-11.3.

PG-11.1 Cast, Forged, Rolled, or Die Formed Standard Pressure Parts

PG-11.1.1 Pressure parts such as pipe fittings, valves, flanges, nozzles, welding necks, welding caps, manhole frames and covers, and casings of pumps that are part of a boiler circulating system that are wholly formed by casting, forging, rolling, or die forming shall not require inspection, mill test reports, or Partial Data Reports. Standard pressure parts that comply with some ASME Standard[3] shall be made of materials permitted by this Section or of materials specifically listed in an ASME product standard listed elsewhere in this Section but not of materials specifically prohibited or beyond use limitations listed in this Section. Standard pressure

[3] These are pressure parts that comply with some ASME product standard accepted by reference in PG-42. The ASME product standard establishes the basis for the pressure–temperature rating and marking.

parts that comply with a manufacturer's standard[4,5] shall be made of materials permitted by this Section. Such parts shall be marked with the name or trademark of the parts manufacturer and such other markings as are required by the standard. Such markings shall be considered as the parts manufacturer's certification that the product complies with the material specifications and standards indicated and is suitable for service at the rating indicated. The intent of the paragraph will have been met if, in lieu of the detailed marking on the part itself, the parts described herein have been marked in any permanent or temporary manner that will serve to identify the part with the parts manufacturer's written listing of the particular items and such listings are available for examination by the Inspector.

PG-11.1.2 Parts of small size falling within this category for which it is difficult or impossible to obtain identified material or that may be stocked and for which mill test reports or certificates cannot be economically obtained and are not customarily furnished, and that do not appreciably affect the safety of the vessel, may be used for relatively unimportant part or parts stressed to not more than 50% of the stress value permitted by this Section, and listed in Tables 1A and 1B of Section II, Part D, provided they are suitable for the purpose intended and meet the approval of the Inspector. The Manufacturer of the completed vessel shall satisfy himself that the part is suitable for the design conditions specified for the completed vessel.

PG-11.2 Cast, Forged, Rolled, or Die Formed Nonstandard Pressure Parts. Pressure parts such as shells, heads, removable and access opening cover plates, that are wholly formed by casting, forging, rolling, or die forming, may be supplied basically as materials. All such parts shall be made of materials permitted under this Section, and the manufacturer of the part shall furnish mill test reports or other acceptable evidence to that effect. Such parts shall be marked with the name or trademark of the parts manufacturer and with such other markings as will serve to identify the particular parts with accompanying material identification. The Manufacturer of the completed boiler shall satisfy himself that the part is suitable for the design conditions specified for the completed boiler.

PG-11.3 Welded Standard Pressure Parts for Use Other Than the Shell of a Vessel.[6] Pressure parts such as welded standard pipe fittings, caps, valves, and flanges that are fabricated by one of the welding processes recognized by this Section shall not require inspection, mill test reports, or Manufacturers' Partial Data Reports provided.[7]

PG-11.3.1 Standard pressure parts that comply with some ASME product standard[4] shall be made of materials permitted by this Section or of materials specifically listed in an ASME product standard accepted and listed elsewhere in this Section but not of materials specifically prohibited or beyond use limitations listed in this Section. Standard pressure parts that comply with a manufacturer's standard[4,5] shall be made of materials permitted by this Section.

PG-11.3.2 Welding for pressure parts that comply with a manufacturer's standard[4,5] shall comply with the requirements of PW-26 through PW-39. Welding for pressure parts that comply with some ASME product standard[5] shall comply with the requirements of PW-26 through PW-39 or, as a minimum, may comply with the welding requirements of SA-234. Markings where applicable, or certification by the parts manufacturer where markings are not applicable shall be accepted as evidence of compliance with the above welding requirements. Such parts shall be marked as required by PG-11.1.1.

PG-11.3.3 If radiographic examination or heat treatment is required by the applicable rules of this Section, it may be performed either in the plant of the parts manufacturer or in the plant of the Manufacturer of the completed vessel.

If the radiographic examination is done under the control of the parts manufacturer, the completed radiographs, properly identified, with a radiographic inspection report, shall be forwarded to the vessel manufacturer and shall be available to the Authorized Inspector.

PG-11.3.4 If heat treatment is performed at the plant of the parts manufacturer, certification by the parts manufacturer that such treatment was performed shall be accepted as evidence of compliance with applicable Code paragraphs. This certification shall be available to the Authorized Inspector. The Manufacturer of the completed vessel shall satisfy himself that the

[4] These are pressure parts that comply with a parts manufacturer's standard that defines the pressure-temperature rating marked on the part and described in the parts manufacturer's literature. The Manufacturer of the completed vessel shall satisfy himself that the part is suitable for the design conditions of the completed vessel

[5] Pressure parts may be in accordance with an ASME product standard not covered by footnote 4, but such parts shall satisfy the requirements applicable to a parts manufacturer's standard and footnote 6.

[6] Fusion welded pipe, with added filler metal, for use as the shell of the vessel shall be subject to the same requirements as a shell fabricated from plate, including inspection at the point of manufacture and Manufacturers' Partial Data Reports

[7] For requirements for welded water columns, see PW-42

part is suitable for the design conditions specified for the completed vessel.

PG-12 GAGE GLASS BODY AND CONNECTOR MATERIALS

Gage glass body and connector materials shall comply with a Manufacturer's standard that defines the pressure–temperature rating marked on the unit. The materials used may include austenitic stainless steel.

PG-13 STAYS

Threaded stays shall be of steel complying with SA-36 or SA-675.

Seamless steel tubes for threaded stays shall comply with SA-192 or SA-210.

Staybolts, stays, through-rods, or stays with ends for attachment by fusion welding shall comply with SA-36 or SA-675.

DESIGN

PG-16 GENERAL

PG-16.1 The design of power boilers, high-temperature water boilers, and other pressure parts included within the scope of these rules shall conform to the general design requirements in the following paragraphs and in addition to the specific requirements for design given in the applicable Parts of this Section that pertain to the methods of construction used.

PG-16.2 When the pressure parts of a forced-flow steam generator with no fixed steam and waterline are designed for different pressure levels as permitted in PG-21.2, the owner shall provide or cause to be provided a boiler pressure system design diagram, certified by a Professional Engineer experienced in the mechanical design of power plants, which supplies the following information.

PG-16.2.1 The relative location of the various pressure parts within the scope of Section I, with respect to the path of water-steam flow.

PG-16.2.2 A line showing the expected maximum sustained pressure as described in PG-21.2, indicating the expected variation in pressure along the path of water-steam flow.

PG-16.2.3 The maximum allowable working pressure of the various pressure parts.

PG-16.2.4 The location and set pressure of the overpressure protection devices.

Copy of this diagram shall be attached to the Master Data Report per PG-113.

PG-16.3 Minimum Thicknesses. The minimum thickness of any boiler plate under pressure shall be $\frac{1}{4}$ in. (6 mm) except for electric boilers constructed under the rules of Part PEB. The minimum thickness of plates to which stays may be applied in other than cylindrical outer shell plates shall be $\frac{5}{16}$ (8 mm) in. When pipe over NPS 5 (DN 125) is used in lieu of plate for the shell of cylindrical components under pressure, its minimum wall shall be $\frac{1}{4}$ in. (6 mm).

PG-16.4 Undertolerance on Plates. Plate material that is not more than 0.01 in. (0.3 mm) thinner than that calculated from the formula may be used in Code constructions provided the material specification permits such plate to be furnished not more than 0.01 in. (0.3 mm) thinner than ordered.

PG-16.5 Undertolerance on Pipe and Tubes. Pipe or tube material shall not be ordered thinner than that calculated from the applicable formula of this Section. The ordered material shall include provision for the allowed manufacturing undertolerance as given in Section II in the applicable pipe or tube specification.

PG-17 FABRICATION BY A COMBINATION OF METHODS

A boiler and parts thereof may be designed and fabricated by a combination of the methods of fabrication given in this Section, provided the rules applying to the respective methods of fabrication are followed and the boiler is limited to the service permitted by the method of fabrication having the most restrictive requirements.

PG-18 HYDROSTATIC DEFORMATION TEST

Where no rules are given and it is impossible to calculate with a reasonable degree of accuracy the strength of a boiler structure or any part thereof, a full-sized sample shall be built by the Manufacturer and tested in accordance with the Standard Practice for Making a Hydrostatic Test on a Boiler Pressure Part to Determine the Maximum Allowable Working Pressure, given in A-22 or in such other manner as the Committee may prescribe.

ASME BOILER AND PRESSURE VESSEL CODE
AN INTERNATIONALLY RECOGNIZED CODE

SECTION II

Materials

Part A — Ferrous

Material Specifications

1995 EDITION

JULY 1, 1995

ASME BOILER AND PRESSURE VESSEL COMMITTEE
SUBCOMMITTEE ON MATERIALS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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Specifications Listed in Numeric Sequence

SPECIFICATION FOR SEAMLESS CARBON STEEL PIPE FOR HIGH-TEMPERATURE SERVICE

SA-106

(Identical with ASTM A 106-92 except for editorial corrections in 20.4 and the deletion of ASTM caveat 1.5.)

1. Scope

1.1 This specification covers seamless carbon steel pipe for high-temperature service (Note 1) in NPS $^1/_8$ to NPS 48 inclusive, with nominal (average) wall thickness as given in ANSI B36.10. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification. Pipe ordered under this specification shall be suitable for bending, flanging, and similar forming operations, and for welding. When the steel is to be welded, it is presupposed that a welding procedure suitable to the grade of steel and intended use or service will be utilized (Note 2).

NOTE 1—Consideration should be given to possible graphitization of the material at the higher temperatures at which it may be used.

NOTE 2—Grade A rather than Grade B or Grade C pipe should be used for close coiling, or cold bending. The purpose for which the pipe is to be used should be stated in the order. This note is not intended to prohibit the cold bending of Grade B seamless pipe.

1.2 Supplementary requirements (S1 to S4) of an optional nature are provided for seamless pipe intended for use in applications where a superior grade of pipe is required. These supplementary requirements call for additional tests to be made and when desired shall be so stated in the order.

1.3 When these products are to be used in applications conforming to ISO Recommendations for Boiler Construction, the requirements of Specification A 520 (Mechanical Property Requirements Section) shall supplement and supersede the requirements of this specification.

1.4 The values stated in inch-pound units are to be regarded as the standard.

NOTE 3—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.5 DELETED

2. Referenced Documents

2.1 *ASTM Standards:*

A 520 Specification for Supplementary Requirements for Seamless and Electric-Resistance-Welded Carbon Steel Tubular Products for High-Temperature Service Conforming to ISO Recommendations for Boiler Construction

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *ANSI Standard:*

ANSI B36.10 Welded and Seamless Wrought Steel Pipe

2.3 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products

2.5 *Other Standards:*

SSPC-SP6 Surface Preparation Specification No. 6

3. Ordering Information

3.1 Orders for materials under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet or number of lengths),

3.1.2 Name of material (seamless carbon steel pipe),

3.1.3 Grade (Table 1),

3.1.4 Manufacture (hot-finished or cold-drawn),

3.1.5 Size (either NPS and weight class or schedule number, or both, or outside diameter and nominal wall thickness, ANSI B36.10),

3.1.6 Length (specific or random, Section 20),

3.1.7 Optional requirements (Section 9 and S1 to S4),

3.1.8 Test report required (Section on Certification of Specification A 530/A 530M),

3.1.9 Specification designation,

3.1.10 End use of material,

3.1.11 Hydrostatic test in accordance with Specification A 530/A 530M or 13.3 of this specification, or NDE in accordance with Section 14 of this specification.

3.1.12 Special requirements.

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

5. Process

5.1 The steel shall be killed steel made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace. The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting, using electroslag remelting or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

5.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades

5.3 Pipe NPS $1^1/_2$ and under may be either hot finished or cold drawn.

5.4 Unless otherwise specified, pipe NPS 2 and over shall be furnished hot finished. When agreed upon between the manufacturer and the purchaser, cold-drawn pipe may be furnished.

6. Heat Treatment

6.1 Hot-finished pipe need not be heat treated. Cold-drawn pipe shall be heat treated after the final cold draw pass at a temperature of 1200°F (650°C) or higher.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Tables 1 and 2.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified in Section 7. If the secondary melting processes of 5.1 are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 7.

9. Product Analysis

9.1 At the request of the purchaser, analyses of two pipes from each lot (Note 4) of 400 lengths or fraction thereof, of each size up to, but not including, NPS 6, and from each lot of 200 lengths or fraction thereof of each size NPS 6 and over, shall be made by the manufacturer from the finished pipe. The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Section 7.

9.2 If the analysis of one of the tests specified in 9.1 does not conform to the requirements specified in Section 7, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to requirements specified.

NOTE 4—A lot shall consist of the number of lengths specified in Sections 9 and 20 of the same size and wall thickness from any one heat of steel.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

11. Bending Requirements

11.1 For pipe NPS 2 and under a sufficient length of pipe shall stand being bent cold through 90° around a cylindrical mandrel, the diameter of which is 12 times the nominal diameter of the pipe, without developing cracks. When ordered for close coiling (Note 2), the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the nominal diameter of the pipe, without failure.

11.2 For pipe whose diameter equals or exceeds 10 in. (254 mm) a bend test may be conducted instead of the flattening test. The bend test specimens shall be bent at room temperature through 180° without cracking on the outside of the bent portion. The inside diameter of the bend shall be 1 in. (25.4 mm). Substitution of the bend test for the flattening test shall be subject to the approval of the purchaser.

11.3 For pipe whose diameter exceeds 25 in. (635 mm) and whose diameter to wall thickness ratio is 7.0 or less, the bend test described in 11.2 shall be conducted instead of the flattening test.

NOTE 5—Diameter to wall thickness ratio = specified outside diameter/nominal wall thickness.

Example: For 28 in. diameter 5.000 in. thick pipe the diameter to wall thickness ratio = 28/5 = 5.6.

12. Flattening Tests

12.1 For pipe over NPS 2 a section of pipe not less than $2^1/_2$ in. (63.5 mm) in length shall be flattened cold between parallel plates until the opposite walls of the pipe meet. Flattening tests shall be in accordance with Specification A 530/A 530M, except that in the formula used to calculate the "H" value, the following "e" constants shall be used:

0.08 for Grade A
0.07 for Grades B and C

12.2 When low D-to-t ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than 10.

NOTE 6—The "H" values have been calculated for sizes from NPS $2^1/_2$ to 24, inclusive, and are shown in Table X1.1 of this specification.

13. Hydrostatic Test

13.1 Each length of pipe shall be subjected to the hydrostatic test, except as provided for in 13.2, 13.3, and 13.4.

13.2 When specified by the purchaser, pipe may be tested by the nondestructive electric test method in lieu of the hydrostatic test as shown in Section 14.

13.3 When specified in the order, pipe may be furnished without hydrostatic test and without the NDE in Section 14. In this case, each length so furnished shall include the mandatory marking of the letters "NH."

13.4 When the hydrostatic test and the NDE test are omitted and the lengths marked with the letters "NH," the certification, when required, shall clearly state "Not Hydrostatically Tested," the specification number and material grade, as shown on the certification, shall be followed by the letters "NH."

14. Nondestructive Electric Test

14.1 As an alternative to the hydrostatic test, and when specified by the purchaser, each pipe shall be tested with a nondestructive electric test in accordance with Practice E 213, Practice E 309, or Practice E 570. In this case, each length so furnished shall include the mandatory marking of the letters "NDE." It is the intent of this test to reject pipe with imperfections which produce test signals equal to or greater than that of the calibration standard.

14.2 When the nondestructive electric test is performed, the lengths shall be marked with the letters "NDE." The certification, when required, shall state "Nondestructive Electric Tested" and shall indicate which of the tests was applied. Also the letters "NDE" shall be appended to the product specification number and material grade shown on the certification.

14.3 The following information is for the benefit of the user of this specification:

14.3.1 The reference standards defined in 14.3.2 through 14.3.6 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

14.3.2 The ultrasonic testing can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep defects.

14.3.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type

14.3.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

14.3.5 The hydrostatic test referred to in Section 13 has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall defects or defects that extend an appreciable distance into the wall without complete penetration.

14.3.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

14.4 For ultrasonic testing, the calibration reference notches shall be, at the option of the producer, any one of the three common notch shapes shown in Practice E 213. The depth of notch shall not exceed $12^1/_2\%$ of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

14.5 For eddy current testing, the calibration pipe shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection:

14.5.1 *Drilled Hole*—The calibration pipe shall contain depending upon the pipe diameter three holes spaced 120° apart or four holes spaced 90° apart and sufficiently separated longitudinally to ensure separately distinguishable responses. The holes shall be drilled radially and completely through the pipe wall, care being taken to avoid distortion of the pipe while drilling. Depending upon the pipe diameter the calibration pipe shall contain the following hole:

$\leq {}^1/_2$ in.	0 039 in. (1 mm)
$> {}^1/_2 \leq 1^1/_4$ in	0.055 in. (1 4 mm)
$> 1^1/_4 \leq 2$ in	0 071 in. (1.8 mm)
$> 2 \leq 5$ in.	0.087 in. (2 2 mm)
> 5 in.	0 106 in (2.7 mm)

14.5.2 *Transverse Tangential Notch*—Using a round tool or file with a $^1/_4$-in. (6.4-mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding $12^1/_2\%$ of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

14.5.3 *Longitudinal Notch*—A notch 0.031 in. (1.787 mm) or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding $12^1/_2\%$ of the specified wall thickness of the tube or 0.004 in. (0.102 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

14.5.4 *Compatibility*—The discontinuity in the calibration pipe shall be compatible with the testing equipment and the method being used.

14.6 For flux leakage testing, the longitudinal calibration reference notches shall be straight-sided notches machined in a radial plane parallel to the pipe axis. For wall thickness under $^1/_2$ in. (12.7 mm), outside and inside notches shall be used; for wall thickness equal and above $^1/_2$ in. (12.7 mm) , only an outside notch shall be used. Notch depth shall not exceed $12^1/_2\%$ of the specified wall thickness, or 0.004 in.

(0.102 mm), whichever is greater. Notch length shall not exceed 1 in. (25.4 mm), and the width shall not exceed the depth. Outside diameter and inside diameter notches shall be located sufficiently apart to allow separation and identification of the signals.

14.7 Pipe producing a signal equal to or greater than the signal produced by the calibration standard shall be subject to rejection. The area producing the signal may be reexamined.

14.7.1 Test signals produced by imperfections which cannot be identified, or produced by cracks or crack-like imperfections shall result in rejection of the pipe, unless it is repaired and retested. To be accepted, the pipe must pass the same specification test to which it was originally subjected, provided that the remaining wall thickness is not decreased below that permitted by this specification. The OD at the point of grinding may be reduced by the amount so reduced.

14.7.2 Test signals produced by visual imperfections such as those listed below may be evaluated in accordance with the provisions of Section 21:

14.7.2.1 Dinges.

14.7.2.2 Straightener marks.

14.7.2.3 Cutting chips.

14.7.2.4 Scratches.

14.7.2.5 Steel die stamps.

14.7.2.6 Stop marks, or

14.7.2.7 Pipe reducer ripple.

14.8 The test methods described in this section may not be capable of inspecting the end portion of pipes. This condition is referred to as "end effect." The length of the end effect shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser

15. Nipples

15.1 Nipples shall be cut from pipe of the same dimensions and quality described in this specification.

16. Dimensions, Weight, and Permissible Variations

16.1 *Weight*—The weight of any length of pipe shall not vary more than 10% over and 3.5% under that specified. Unless otherwise agreed upon between the manufacturer and the purchaser, pipe in NPS 4 and smaller may be weighed in convenient lots; pipe larger than NPS 4 shall be weighed separately.

16.2 *Diameter*—Variations in outside diameter shall not exceed those specified in Table 5.

16.3 *Thickness*—The minimum wall thickness at any point shall not be more than 12.5% under the nominal wall thickness specified.

NOTE 7—The minimum wall thicknesses on inspection of some of the available sizes are shown in Table X2.1.

17. Lengths

17.1 Pipe lengths shall be in accordance with the following regular practice:

17.1.1 The lengths required shall be specified in the order, and

17.1.2 No jointers are permitted unless otherwise specified.

17.1.3 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft (4.8 to 6.7 m) with 5% 12 to 16 ft (3.7 to 4.8 m), or in double random lengths with a minimum average of 35 ft (10.7 m) and a minimum length of 22 ft with 5% 16 to 22 ft.

18. Workmanship, Finish and Appearance

18.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to assure compliance with 18.2.

18.2 Surface imperfections that penetrate more than $12^1/_2$% of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

18.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

18.2.2 Repaired in accordance with the repair welding provisions of 18.6.

18.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

18.2.4 Rejected.

18.3 To provide a workmanlike finish and basis for evaluating conformance with 18.2 the pipe manufacturer shall remove by grinding the following noninjurious imperfections:

18.3.1 Mechanical marks, abrasions (Note 8) and pits, any of which imperfections are deeper than $^1/_{16}$ in. (1.58 mm).

18.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 18.1 to be deeper than 5% of the nominal wall thickness.

18.4 At the purchaser's discretion, pipe shall be subjected to rejection if surface imperfections acceptable under 18.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

18.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

18.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

18.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

18.7 The finished pipe shall be reasonably straight.

NOTE 8—Marks and abrasions are defined as cable marks, dinges, guide marks, roll marks, ball scratches, scores, die marks, etc.

19. End Finish

19.1 The Pipe shall be furnished to the following practice, unless otherwise specified.

19.1.1 *NPS 1-$^1/_2$* and Smaller—All walls shall be either plain-end square cut, or plain-end beveled at the option of the manufacturer.

19.1.2 *NPS 2 and Larger*—Walls through extra strong weights, shall be plain end-beveled.

19.1.3 *NPS 2 and Larger*—Walls over extra strong weights, shall be plain-end square cut.

NOTE 9—Plain-end beveled is defined as plain-end pipe having a bevel angle of 30°, +5° or −0°, as measured from a line drawn perpendicular to the axis of the pipe with a root face of $^1/_{16}$ in. ± $^1/_{32}$ in. (1.5875 ± 0.7938 mm). Other bevel angles may be specified by agreement between the purchaser and the manufacturer.

20. Number of Tests

20.1 The tensile requirements specified in Section 7 shall be determined on one length of pipe from each lot (Note 4) of 400 lengths or fraction thereof of each size under NPS 6, and from each lot of 200 lengths or fraction thereof of each size NPS 6 and over.

20.2 For pipe NPS 2 and under, the bend test specified in 11.1 shall be made on one pipe from each lot of 400 lengths or fraction thereof of each size. The bend test, where used as permitted by 11.2 or required by 11.3, shall be made on one end of 5% of the pipe from each lot. For small lots, at least one pipe shall be tested.

20.3 The flattening test specified in Section 12 shall be made on one length of pipe from each lot of 400 lengths or fraction thereof of each size over NPS 2, up to but not including NPS 6, and from each lot of 200 lengths or fraction thereof, of each size NPS 6 and over.

20.4 Each length of pipe shall be subjected to the hydrostatic test specified in Section 13.

20.5 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

21. Retests

21.1 If the percentage of elongation of any tension test specimen is less than that prescribed in Table 2 and any part of the fracture is more than $^3/_4$ in. (19.0 mm) from the center of the gage length of a 2-in., or 50-mm, specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed. If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

21.2 Should a crop end of a finished pipe fail in the flattening test, one retest may be made from the failed end. Pipe may be normalized either before or after the first test, but pipe shall be subjected to only two normalizing treatments.

22. Test Specimens and Test Methods

22.1 On NPS 8 and larger, specimens cut either longitudinally or transversely shall be acceptable for the tension test. On sizes smaller than NPS 8, the longitudinal test only shall be used.

22.2 Test specimens for the bend test specified in Section 11 and for the flattening tests shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends.

22.3 Test specimens for the bend test specified in 11.2 and 11.3 shall be cut from one end of the pipe and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either $^1/_2$ by $^1/_2$ in. (12.7 by 12.7 mm) in section or 1 by $^1/_2$ in. (25.4 by 12.7 mm) in section with the corners rounded to a radius not over $^1/_{16}$ in. (1.6 mm) and need not exceed 6 in. (152 mm) in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe respectively.

22.4 All routine check tests shall be made at room temperature

23. Certification

23.1 When test reports are requested, in addition to the requirements of Specification A 530/A 530M, the producer or supplier shall furnish to the purchaser a chemical analysis report for the elements specified in Tables 1 and 2.

24. Product Marking

24.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include heat number, the information as per Table 6, an additional symbol "S" if the pipe conforms in any case to the supplementary requirements specified in S1 to S5, the length and schedule number, and on pipe sizes larger than NPS 4 the weight shall be given. Length shall be marked in feet and tenths of a foot, or metres to two decimal places, depending on the units to which the material was ordered, or other marking subject to agreement. For sizes NPS $1^1/_2$, $1^1/_4$, 1, and $^3/_4$, each length shall be marked as prescribed in Specification A 530/A 530M. These sizes shall be bundled in accordance with standard mill practice and the total bundle footage marked on the bundle tag, individual lengths of pipe need not be marked with footage. For sizes less than NPS $^3/_4$, all required markings may be on the bundle tag and shall include the total footage; individual lengths of pipe need not be marked with footage. If not marked on the bundle tag, all required marking shall be on each length.

24.2 When pipe sections are cut into shorter lengths by a subsequent processor for resale as material, the processor shall transfer complete identifying information, including the name or brand of the manufacturer to each unmarked cut length, or to metal tags securely attached to bundles of unmarked small diameter pipe. The same material designation shall be included with the information transferred, and the processor's name, trademark, or brand shall be added.

24.3 *Bar Coding*—In addition to the requirements in 24.1 and 24.2, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team

25. Government Procurement

25.1 When specified in the contract, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract Marking for the shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

25.2 *Inspection*—Unless otherwise specified in the contract, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the producer may use his own, or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that the material conforms to the prescribed requirements.

TABLE 1
CHEMICAL REQUIREMENTS

	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max[A]	0.25	0.30	0.35
Manganese	0.27–0.93	0.29–1.06	0.29–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035
Silicon, min	0.10	0.10	0.10

[A] For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to a maximum of 1.35 %.

TABLE 2
LIMITS ON UNSPECIFIED ELEMENTS

Element[A]	Composition, %, max		
	Grade A	Grade B	Grade C
Chrome	0.40	0.40	0.40
Copper	0.40	0.40	0.40
Molybdenum	0.15	0.15	0.15
Nickel	0.40	0.40	0.40
Vanadium	0.08	0.08	0.08

[A] These five elements combined shall not exceed 1 %.

TABLE 3
TENSILE REQUIREMENTS

	Grade A (Explanatory Note 2)		Grade B		Grade C	
Tensile strength, min, psi (MPa)	48 000 (330)		60 000 (415)		70 000 (485)	
Yield strength, min, psi (MPa)	30 000 (205)		35 000 (240)		40 000 (275)	
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Elongation in 2 in. or 50 mm, min, %						
Basic minimum elongation transverse strip tests, and for all small sizes tested in full section	35	25	30	16.5	30	16.5
When standard round 2-in. or 50-mm gage length test specimen is used	28	20	22	12	20	12
For longitudinal strip tests	[B,C]		[B,C]		[B,C]	
For transverse strip tests, a deduction for each 1/32-in. (0.8-mm) decrease in wall thickness below 5/16 in. (7.9 mm) from the basic minimum elongation of the following percentage shall be made		1.25[A]		1.00[A]		1.00[A]

[A] The following table gives the computed minimum values:

Wall Thickness		Elongation in 2 in. or 50 mm, min, %	
in.	mm	Grade A, Transverse	Grades B and C, Transverse
5/16 (0.312)	7.9	25.00	16.50
9/32 (0.281)	7.1	23.75	15.50
1/4 (0.250)	6.4	22.50	14.50
7/32 (0.219)	5.6	...	...
3/16 (0.188)	4.8	...	...
5/32 (0.156)	4.0	...	...
1/8 (0.125)	3.2	...	...
3/32 (0.094)	2.4	...	...
1/16 (0.062)	1.6	...	...

NOTE—The above table gives the computed minimum elongation values for each 1/32-in. (0.8-mm) decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

Grade	Direction of Test	Equation
A	Transverse	$E = 40t + 12.50$
B and C	Transverse	$E = 32t + 6.50$

where:

E = elongation in 2 in. or 50 mm, %, and
t = actual thickness of specimen, in.

[B] The minimum elongation in 2 in. (50.8 mm) shall be determined by the following equation:

$$e = 625\,000 A^{0.2}/U^{0.9}$$

where

e = minimum elongation in 2 in. (50.8 mm), %, rounded to the nearest 0.5 %
A = cross-sectional area of the tension test specimen, in.^{2}, based on specified outside diameter or nominal specimen width and specified wall thickness rounded to the nearest 0.01 in.^{2} If the area thus calculated is greater than 0.75 in.^{2}, then the value 0.75 shall be used, and
U = specified tensile strength, psi.

[C] See Table 4 for minimum elongation values for various size tension specimens and grades.

TABLE 4
ELONGATION VALUES

Area, in.^{2} [A]	Tension Test Specimen Wall Thickness, in.[B]				Elongation in 2 in. min., Specified Tensile Strength, psi		
					Grade A	Grade B	Grade C
	½ in. Specimen	¾ in. Specimen	1 in. Specimen	1½ in. Specimen	48 000	60 000	70 000
≥0.75	≥ 1.491	≥ 0.994	≥ 0.746	≥ 0.497	36.0	29.5	25.5
0.74	1.470–1.490	0.980–0.993	0.735–0.745	0.490–0.496	36.0	29.5	25.5
0.73	1.451–1.469	0.967–0.979	0.726–0.734	0.484–0.489	36.0	29.5	25.5
0.72	1.430–1.450	0.954–0.966	0.715–0.725	0.477–0.483	36.0	29.5	25.5
0.71	1.411–1.429	0.941–0.953	0.706–0.714	0.471–0.476	35.5	29.0	25.5
0.70	1.390–1.410	0.927–0.940	0.695–0.705	0.464–0.470	35.5	29.0	25.5
0.69	1.371–1.389	0.914–0.926	0.686–0.694	0.457–0.463	35.5	29.0	25.5
0.68	1.350–1.370	0.900–0.913	0.675–0.685	0.450–0.456	35.5	29.0	25.0
0.67	1.331–1.349	0.887–0.899	0.666–0.674	0.444–0.449	35.5	29.0	25.0
0.66	1.310–1.330	0.874–0.886	0.655–0.665	0.437–0.443	35.0	29.0	25.0
0.65	1.291–1.309	0.861–0.873	0.646–0.654	0.431–0.436	35.0	28.5	25.0
0.64	1.270–1.290	0.847–0.860	0.635–0.645	0.424–0.430	35.0	28.5	25.0
0.63	1.251–1.269	0.834–0.846	0.626–0.634	0.417–0.423	35.0	28.5	25.0
0.62	1.230–1.250	0.820–0.833	0.615–0.625	0.410–0.416	35.0	28.5	25.0
0.61	1.211–1.229	0.807–0.819	0.606–0.614	0.404–0.409	34.5	28.5	24.5
0.60	1.190–1.210	0.794–0.806	0.595–0.605	0.397–0.403	34.5	28.5	24.5
0.59	1.171–1.189	0.781–0.793	0.586–0.594	0.391–0.396	34.5	28.0	24.5
0.58	1.150–1.170	0.767–0.780	0.575–0.585	0.384–0.390	34.5	28.0	24.5
0.57	1.131–1.149	0.754–0.766	0.566–0.574	0.377–0.383	34.0	28.0	24.5
0.56	1.110–1.130	0.740–0.753	0.555–0.565	0.370–0.376	34.0	28.0	24.5
0.55	1.091–1.109	0.727–0.739	0.546–0.554	0.364–0.369	34.0	28.0	24.9
0.54	1.070–1.090	0.714–0.726	0.535–0.545	0.357–0.363	34.0	27.5	24.0
0.53	1.051–1.069	0.701–0.713	0.526–0.534	0.351–0.356	33.5	27.5	24.0
0.52	1.030–1.050	0.687–0.700	0.515–0.525	0.344–0.350	33.5	27.5	24.0
0.51	1.011–1.029	0.674–0.686	0.506–0.514	0.337–0.343	33.5	27.5	24.0
0.50	0.990–1.010	0.660–0.673	0.495–0.505	0.330–0.336	33.5	27.0	23.5
0.49	0.971–0.989	0.647–0.659	0.486–0.494	0.324–0.329	33.0	27.0	23.5
0.48	0.950–0.970	0.634–0.646	0.475–0.485	0.317–0.323	33.0	27.0	23.5
0.47	0.931–0.949	0.621–0.633	0.466–0.474	0.311–0.316	33.0	27.0	23.5
0.46	0.910–0.930	0.607–0.620	0.455–0.465	0.304–0.310	33.0	27.0	23.5
0.45	0.891–0.909	0.594–0.606	0.446–0.454	0.297–0.303	32.5	26.5	23.0
0.44	0.870–0.890	0.580–0.593	0.435–0.445	0.290–0.296	32.5	26.5	23.0
0.43	0.851–0.869	0.567–0.579	0.426–0.434	0.284–0.289	32.5	26.5	23.0
0.42	0.830–0.850	0.554–0.566	0.415–0.425	0.277–0.283	32.0	26.5	23.0
0.41	0.811–0.829	0.541–0.553	0.406–0.414	0.271–0.276	32.0	26.0	23.0
0.40	0.790–0.810	0.527–0.540	0.395–0.405	0.264–0.270	32.0	26.0	22.5
0.39	0.771–0.789	0.514–0.526	0.386–0.394	0.257–0.263	31.5	26.0	22.5
0.38	0.750–0.770	0.500–0.513	0.375–0.385	0.250–0.256	31.5	26.0	22.5
0.37	0.731–0.749	0.487–0.499	0.366–0.374	0.244–0.249	31.5	25.5	22.5
0.36	0.710–0.730	0.474–0.486	0.355–0.365	0.237–0.243	31.0	25.5	22.0
0.35	0.691–0.709	0.461–0.473	0.346–0.354	0.231–0.236	31.0	25.5	22.0
0.34	0.670–0.690	0.447–0.460	0.335–0.345	0.224–0.230	31.0	25.0	22.0
0.33	0.651–0.669	0.434–0.446	0.326–0.334	0.217–0.223	30.5	25.0	22.0
0.32	0.630–0.650	0.420–0.433	0.315–0.325	0.210–0.216	30.5	25.0	21.5
0.31	0.611–0.629	0.407–0.419	0.306–0.314	0.204–0.209	30.5	25.0	21.5
0.30	0.590–0.610	0.394–0.406	0.295–0.305	0.197–0.203	30.0	24.5	21.5
0.29	0.571–0.589	0.381–0.393	0.286–0.294	0.191–0.196	30.0	24.5	21.5
0.28	0.550–0.570	0.367–0.380	0.275–0.285	0.184–0.190	29.5	24.5	21.0
0.27	0.531–0.549	0.354–0.366	0.266–0.274	0.177–0.183	29.5	24.0	21.0
0.26	0.510–0.530	0.340–0.353	0.255–0.265	0.170–0.176	29.0	24.0	21.0
0.25	0.491–0.509	0.327–0.339	0.246–0.254	0.164–0.169	29.0	23.5	20.5
0.24	0.470–0.490	0.314–0.326	0.235–0.245	0.157–0.163	29.0	23.5	20.5
0.23	0.451–0.469	0.301–0.313	0.226–0.234	0.151–0.156	28.5	23.5	20.5
0.22	0.430–0.450	0.287–0.300	0.215–0.225	0.144–0.150	28.5	23.0	20.0
0.21	0.411–0.429	0.274–0.286	0.206–0.214	0.137–0.143	28.0	23.0	20.0
0.20	0.390–0.410	0.260–0.273	0.195–0.205	0.130–0.136	27.5	22.5	19.5
0.19	0.371–0.389	0.247–0.259	0.186–0.194	0.124–0.129	27.5	22.5	19.5
0.18	0.350–0.370	0.234–0.246	0.175–0.185	0.117–0.123	27.0	22.0	19.5
0.17	0.331–0.349	0.221–0.233	0.166–0.174	0.111–0.116	27.0	22.0	19.0
0.16	0.310–0.330	0.207–0.220	0.155–0.165	0.104–0.110	26.5	21.5	19.0
0.15	0.291–0.309	0.194–0.206	0.146–0.154	0.097–0.103	26.0	21.5	18.5
0.14	0.270–0.290	0.180–0.193	0.135–0.145	0.091–0.096	26.0	21.0	18.5
0.13	0.251–0.269	0.167–0.179	0.126–0.134	0.084–0.090	25.5	21.0	18.0
0.12	0.230–0.250	0.154–0.166	0.115–0.125	0.077–0.083	25.0	20.5	18.0
0.11	0.211–0.229	0.141–0.153	0.106–0.114	0.071–0.076	24.5	20.0	17.5
0.10	0.190–0.210	0.127–0.140	0.095–0.105	0.064–0.070	24.0	19.5	17.0
0.09	0.171–0.189	0.114–0.126	0.086–0.094	0.057–0.063	23.5	19.5	17.0
0.08	0.150–0.170	0.100–0.113	0.075–0.085	0.050–0.056	23.0	19.0	16.5
0.07	0.131–0.149	0.087–0.099	0.066–0.074	0.044–0.049	22.5	18.5	16.0
0.06	0.110–0.130	0.074–0.086	0.055–0.065	0.037–0.043	22.0	18.0	15.5
0.05	0.091–0.109	0.061–0.073	0.046–0.054	0.031–0.036	21.0	17.0	15.0
0.04	0.070–0.090	0.047–0.060	0.035–0.045	0.024–0.030	20.0	16.5	14.5
0.03	0.051–0.069	0.034–0.046	0.026–0.034	0.017–0.023	19.0	15.5	13.5
0.02	0.030–0.050	0.020–0.033	0.015–0.025	0.010–0.016	17.5	14.5	12.5
≤0.01	≤ 0.029	≤ 0.019	≤ 0.014	≤ 0.009	15.0	12.5	11.0

[A] 1 in.^{2} = 645.16 mm^2
[B] 1 in. = 25.4 mm

TABLE 5
VARIATIONS IN OUTSIDE DIAMETER

NPS Designator	Permissible Variations in Outside Diameter			
	Over		Under	
	in.	mm	in.	mm
to 1½, incl	1/64 (0.015)	0.40	1/64 (0.015)	0.40
er 1½ to 4, incl	1/32 (0.031)	0.79	1/32 (0.031)	0.79
er 4 to 8, incl	1/16 (0.062)	1.59	1/32 (0.031)	0.79
er 8 to 18, incl	3/32 (0.093)	2.38	1/32 (0.031)	0.79
er 18 to 26, incl	1/8 (0.125)	3.18	1/32 (0.031)	0.79
er 26 to 34, incl	5/32 (0.156)	3.97	1/32 (0.031)	0.79
er 34 to 48, incl	3/16 (0.187)	4.76	1/32 (0.031)	0.79

TABLE 6
MARKING

Hydro	NDE	Marking
Yes	No	Test Pressure
No	Yes	NDE
No	No	NH
Yes	Yes	Test Pressure/NDE

SUPPLEMENTARY REQUIREMENTS FOR PIPE REQUIRING SPECIAL CONSIDERATION

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Test

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest.

S3. Flattening Test

S3.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Metal Structure and Etching Test

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate sections of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Carbon Equivalent

S5.1 The steel shall conform to a carbon equivalent (CE) of 0.50 maximum as determined by the following formula:

$$CE = \%C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Ni + \%Cu}{15}$$

S5.2 A lower CE maximum may be agreed upon between the purchaser and the producer.

S5.3 The CE shall be reported on the test report.

S6. Heat Treated Test Specimens

S6.1 At the request of the purchaser, one tensile test shall be performed by the manufacturer on a test specimen from each heat of steel furnished which has been either stress relieved at 1250°F or normalized at 1650° F, as specified by the purchaser. The results of this test shall meet the requirements of Table 3.

S7. Internal Cleanliness—Government Orders

S7.1 The internal surface of hot finished ferritic steel pipe and tube shall be manufactured to a free of scale condition equivalent to the visual standard listed in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

APPENDIX
(Nonmandatory Information)

X1. CALCULATED H VALUES FOR SEAMLESS PIPE

X1.1 Table X1.1 lists values for H to be used for the test of Section 11.

TABLE X1.1
CALCULATED "H" VALUES FOR SEAMLESS PIPE

Inch-Pound Units

NPS Designator	Outside Diameter, in.	Wall Thickness, in.	Schedule Number	Distance, in Inches, Between Plates "H" by Equation: $H = -\frac{(1+e)t}{e+t/D}$ Grade A	Grades B & C
2½	2 875	0 203	40	1 456	1 545
		0 276	80	1 694	1 779
		0 375	160	1 925	2 002
3	3 500	0 216	40	1 646	1 755
		0 300	80	1 955	2 062
		0 438	160	2.306	2 398
3½	4 000	0 226	40	1 788	1 912
		0 318	80	2 153	2 276
4	4 500	0 237	40	1 929	2 067
		0 337	80	2 350	2 489
		0 438	120	2 687	2 818
		0 531	160	2 896	3 022
5	5 563	0 258	40	2 205	2 372
		0 375	80	2 747	2 920
		0 500	120	3.179	3 346
		0.625	160	3 509	3 667
6	6 625	0 280	40	2 473	2 669
		0 432	80	3 213	3 419
		0 562	120	3 682	3 884
		0 719	160	4 116	4 307
8	8 625	0 250	20	2 477	2 702
		0 277	30	2 668	2 902
		0 322	40	2 964	3 210
		0 406	60	3 451	3 711
		0 500	80	3 914	4 181
		0 593	100	4 305	4 573
		0 719	120	4 750	5 013
		0 812	140	5 036	5 293
		0.906	160	5 288	5 538
10	10 750	0 250	20	2 615	2 868
		0 307	30	3 054	3 333
		0 365	40	3 459	3 757
		0.500	60	4 268	4 592
		0 593	80	4 738	5.070
		0.719	100	5 320	5.621
		0.843	120	5 747	6 077
		1 000	140	6.242	6 564
		1 125	160	6 580	6.892
12	12.750	0 250	20	2 711	2 985
		0 330	30	3 366	3.683
		0.406	40	3 921	4 266
		0.562	60	4 892	5.271
		0 687	80	5 542	5.934
		0 843	100	6 231	6.627
		1.000	120	6 817	7 209
		1 125	140	7 222	7.607
		1 312	160	7 747	8 119
14	14 000	0 250	10	2.759	3.045
		0.312	20	3.294	3.617
		0 375	30	3 792	4.146
		0 438	40	4.669	5.125
		0 593	60	5.234	5 647
		0.750	80	6.064	6 494
		0 937	100	6 887	7 322
		1 093	120	7.479	7.902
		1 250	140	7.974	8 397
		1 406	160	8.416	8 827
16	16 000	0 250	10	2.284	3.124
		0 312	20	3 387	3.730
		0 375	30	3.915	4 294
		0.500	40	4 854	5 284
		0 656	60	5.855	6.324
		0 843	80	6.861	7 352
		1 031	100	7 709	8 206
		1 218	120	8 426	8.919
		1 438	140	9.141	9.625
		1 593	160	9 579	10.050
18	18.000	0 250	10	2.876	3.189
		0.312	20	3.462	3 823
		0 438	30	4 535	4.963
		0 562	40	5.457	5 941
		0.750	60	6 656	7 185
		0.937	80	7.663	8.214
		1.156	100	8 657	9 216
		1.375	120	9 495	10 043
		1 562	140	10.115	10 660
		1.781	160	10.665	11 198
20	20.000	0.250	10	2.919	3 242
		0.375	20	4.101	4 521
		0 500	30	5.143	5.632
		0 593	40	5.841	6.367
		0 812	60	7 272	7 856
		1.031	80	8.464	9.072
		1.281	100	9 601	10.221
		1.500	120	10.452	11 069
		1.750	140	11.284	11.889
		1.968	160	11.913	12.504
24	24.000	0.250	10	2.986	3.326
		0.375	20	4.236	4.886
		0.562	30	5.869	6.437
		0.687	40	6.831	7.454
		0.968	60	8.690	9.390
		1.218	80	10 061	10.793
		1.531	100	11 449	12.244
		1.812	120	12.585	13.332
		2.062	140	13.424	14.150
		2.343	160	14.248	14.958

TABLE X1.1 (CONT'D)

SI Units

NPS Designator	Outside Diameter, mm	Wall Thickness, mm	Schedule Number	Distance, in mm, Between Plates "H" by Equation $H = -\frac{(1+e)t}{e+t/D}$	
				Grade A	Grades B & C
2½	73.0	5.16	40	37.0	39.2
		7.01	80	43.0	45.2
		9.52	160	48.9	50.8
3	88.9	5.49	40	41.8	44.6
		7.62	80	49.6	52.4
		11.13	160	58.8	60.9
3½	101.6	5.74	40	45.4	48.6
		8.08	80	54.7	57.8
4	114.3	6.02	40	49.0	52.5
		8.56	80	59.7	63.2
		11.13	120	67.0	71.6
		13.49	160	73.6	76.8
5	141.3	6.55	40	56.0	60.2
		9.52	80	69.8	74.2
		12.70	120	80.8	85.0
		15.88	160	89.1	93.1
6	168.3	7.11	40	62.8	67.8
		10.97	80	81.6	86.8
		14.27	120	93.5	98.6
		18.24	160	104.6	109.4
8	219.1	6.35	20	63.0	68.6
		7.04	30	67.8	73.7
		8.18	40	75.3	81.5
		10.31	60	87.7	94.3
		12.70	80	99.4	106.2
		15.06	100	109.4	116.2
		18.24	120	120.6	127.3
		20.62	140	127.9	134.4
		23.01	160	134.3	140.7
10	273.0	6.35	20	66.4	72.8
		7.80	30	77.6	84.7
		9.27	40	87.9	95.4
		12.70	60	108.4	116.6
		15.06	80	120.4	128.8
		18.24	100	135.1	142.8
		21.41	120	146.0	154.4
		25.40	140	158.6	166.7
		28.58	160	167.1	175.1
12	323.8	6.35	20	68.9	75.8
		8.38	30	85.5	93.6
		10.31	40	99.6	108.4
		14.27	60	124.3	133.9
		17.35	80	140.8	150.7
		21.41	100	158.3	168.3
		25.40	120	173.2	183.1
		28.58	140	183.4	193.2
		33.32	160	196.8	206.2

NPS Designator	Outside Diameter, mm	Wall Thickness, mm	Schedule Number	Distance, in mm, Between Plates "H" by Equation $H = -\frac{(1+e)t}{e+t/D}$	
				Grade A	Grades B & C
14	355.6	6.35	10	70.1	77.3
		7.92	20	83.7	91.8
		9.52	30	96.3	105.3
		11.13	40	118.6	130.2
		15.06	60	132.9	143.4
		19.05	80	154.0	165.0
		23.80	100	174.9	186.0
		27.76	120	190.0	200.7
		31.75	140	202.5	213.3
		35.71	160	213.8	224.2
16	406.4	6.35	10	71.7	79.4
		7.92	20	89.0	94.7
		9.52	30	99.4	109.1
		12.70	40	123.3	143.2
		16.66	60	148.7	160.6
		21.41	80	174.3	186.7
		26.19	100	195.8	208.4
		30.94	120	214.0	226.6
		36.53	140	232.2	244.5
		40.46	160	243.3	255.3
18	457.2	6.35	10	73.0	81.0
		7.92	20	87.9	97.1
		11.13	30	115.2	126.1
		14.27	40	139.5	150.9
		19.05	60	169.1	182.5
		23.80	80	194.6	208.6
		29.36	100	219.9	234.1
		34.92	120	241.2	255.1
		39.67	140	256.9	270.7
		45.24	160	270.9	284.4
20	508.0	6.35	10	74.1	82.4
		9.52	20	104.2	114.8
		12.70	30	130.6	143.0
		15.06	40	148.4	161.7
		20.62	60	184.7	199.5
		26.19	80	215.0	230.4
		32.54	100	243.9	259.6
		38.10	120	265.5	281.2
		44.45	140	286.6	302.0
		49.99	160	302.6	317.6
24	609.6	6.35	10	75.8	84.5
		9.52	20	107.6	119.0
		14.27	30	149.1	163.5
		17.35	40	173.5	189.3
		24.59	60	220.7	238.5
		30.94	80	255.6	274.1
		38.89	100	290.8	311.0
		46.02	120	319.7	338.6
		52.37	140	341.0	359.4
		59.51	160	361.9	379.9

X2. MINIMUM WALL THICKNESSES

X2.1 Table X2.1 lists minimum wall thicknesses for nominal pipe wall thickness.

TABLE X2.1
TABLE OF MINIMUM WALL THICKNESSES ON INSPECTION FOR NOMINAL (AVERAGE) PIPE WALL THICKNESS

NOTE 1—The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:
t_n = nominal (average) wall thickness, in. and
t_m = minimum wall thickness, in.

The wall thickness is expressed to three decimal places, the fourth decimal place being carried forward or dropped, in accordance with Practice E 29.

NOTE 2—This table covers some wall thicknesses associated with standard pipe sizes but is not meant to imply that these are the only thicknesses obtainable under this specification.

Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)	
in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.068	1.73	0.060	1.52	0.281	7.14	0.246	6.25	0.864	21.94	0.756	19.20
0.083	2.11	0.073	1.85	0.294	7.47	0.257	6.53	0.875	22.22	0.766	19.46
0.088	2.24	0.077	1.96	0.300	7.62	0.262	6.65	0.906	23.01	0.793	20.14
0.091	2.31	0.080	2.03	0.307	7.80	0.269	6.83	0.938	23.82	0.821	20.85
0.095	2.41	0.083	2.11	0.308	7.82	0.270	6.86	0.968	24.59	0.847	21.51
0.109	2.77	0.095	2.41	0.312	7.92	0.273	6.93	1.000	25.40	0.875	22.22
0.113	2.87	0.099	2.51	0.318	8.07	0.278	7.06	1.031	26.19	0.902	22.91
0.119	3.02	0.104	2.64	0.322	8.18	0.282	7.16	1.062	26.97	0.929	23.60
0.125	3.18	0.109	2.77	0.330	8.38	0.289	7.34	1.094	27.79	0.957	24.31
0.126	3.20	0.110	2.79	0.337	8.56	0.295	7.49	1.125	28.58	0.984	24.99
0.133	3.38	0.116	2.95	0.344	8.74	0.301	7.64	1.156	29.36	1.012	25.70
0.140	3.56	0.122	3.10	0.358	9.09	0.313	7.95	1.219	30.96	1.066	27.08
0.141	3.58	0.123	3.12	0.365	9.27	0.319	8.10	1.250	31.75	1.094	27.79
0.145	3.68	0.127	3.23	0.375	9.52	0.328	8.33	1.281	32.54	1.121	28.47
0.147	3.73	0.129	3.28	0.382	9.70	0.334	8.48	1.312	33.32	1.148	29.16
0.154	3.91	0.135	3.43	0.400	10.16	0.350	8.89	1.375	34.92	1.203	30.56
0.156	3.96	0.136	3.45	0.406	10.31	0.355	9.02	1.406	35.71	1.230	31.24
0.172	4.37	0.150	3.81	0.432	10.97	0.378	9.60	1.438	36.53	1.258	31.95
0.179	4.55	0.157	3.99	0.436	11.07	0.382	9.70	1.500	38.10	1.312	33.32
0.188	4.78	0.164	4.17	0.438	11.12	0.383	9.73	1.531	38.89	1.340	34.04
0.191	4.85	0.167	4.24	0.469	11.91	0.410	10.41	1.562	39.67	1.367	34.72
0.200	5.08	0.175	4.44	0.500	12.70	0.438	11.13	1.594	40.49	1.395	35.43
0.203	5.16	0.178	4.52	0.531	13.49	0.465	11.81	1.635	41.53	1.431	36.35
0.210	5.33	0.184	4.67	0.552	14.02	0.483	12.27	1.750	44.45	1.531	38.89
0.216	5.49	0.189	4.80	0.562	14.27	0.492	12.50	1.781	45.24	1.558	39.57
0.218	5.54	0.191	4.85	0.594	15.09	0.520	13.21	1.812	46.02	1.586	40.28
0.219	5.56	0.192	4.88	0.600	15.24	0.525	13.34	1.875	47.62	1.641	41.68
0.226	5.74	0.198	5.03	0.625	15.88	0.547	13.89	1.969	50.01	1.723	43.76
0.237	6.02	0.207	5.26	0.656	16.66	0.574	14.58	2.000	50.80	1.750	44.45
0.250	6.35	0.219	5.56	0.674	17.12	0.590	14.99	2.062	52.37	1.804	45.82
0.258	6.55	0.226	5.74	0.688	17.48	0.602	15.29	2.125	53.98	1.859	47.22
0.276	7.01	0.242	6.15	0.719	18.26	0.629	15.98	2.200	55.88	1.925	48.90
0.277	7.04	0.242	6.15	0.750	19.05	0.656	16.66	2.344	59.54	2.051	52.10
0.279	7.09	0.244	6.19	0.812	20.62	0.710	18.03	2.500	63.50	2.188	55.58
0.280	7.11	0.245	6.22	0.844	21.44	0.739	18.77				

SPECIFICATION FOR FORGINGS, CARBON STEEL, FOR GENERAL-PURPOSE PIPING

E95

SA-181/SA-181M

(Identical with ASTM Specification A 181/A 181M-93a)

1. Scope

1.1 This specification covers nonstandard as-forged fittings, valve components, and parts for general service.

1.2 Two grades of material are covered, designated as Classes 60 and 70, respectively, and are classified in accordance with their chemical composition and mechanical properties as specified in 5.1 and 6.1.

1.3 Class 60 was formerly designated Grade I and Class 70 was formerly designated Grade II.

1.4 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
A 788 Specification for Steel Forgings, General Requirements
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
E 165 Test Methods for Liquid Penetrant Inspection Method
E 709 Guide for Magnetic Particle Examination

2.2 *ASME Boiler and Pressure Vessel Code:*

Section IX, Welding Qualifications
Section VIII, Pressure Vessels, Div. 1

2.3 *Military Standard:*

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.4 *AIAG Standard:*

AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

3. Ordering Information

3.1 Orders for material under this specification shall include the following information, as necessary, to describe adequately the desired material:

3.1.1 Description of item requirements,

3.1.2 Material class (see 1.2),

3.1.3 Specification designation,

3.1.4 Requirements pertaining to sketch (see 4.4)

3.1.5 Weld repair of specially designed parts (see 11.2),

3.1.6 Use of the short circuit gas metal arc welding (GMAW) process for repair welds (see 11.4),

3.1.7 Making repair welds exceeding the limits specified herein (see 11.7), and

3.1.8 Requirements pertaining to chemical and mechanical test results (see Sections 15 and 16).

4. Materials and Manufacture

4.1 The steel shall be made by the open-hearth, basic-oxygen, or electric-furnace process and shall be fully killed.

4.2 A sufficient discard shall be made from source material to secure freedom from injurious piping and undue segregation.

4.3 The material shall be forged as close as practicable to the specified shape and size.

4.4 Except for flanges of all types, hollow, cylindrically shaped parts may be machined from hot-rolled or forged bar, provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Other parts, excluding flanges of all types, up to and including NPS 4 may be machined from hot-rolled or forged bar. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

4.5 Except as permitted in 4.4, the finished product shall be a forging as defined in the Terminology section (exclusively) of Specification A 788.

4.6 When specified in the order, the manufacturer shall submit for approval of the purchaser a sketch showing the shape of the rough forging before machining.

4.7 Forgings shall be protected against sudden or too rapid cooling from the rolling or forging while passing through the critical range.

4.8 Heat treatment is neither required nor prohibited, but when applied, heat treatment shall consist of tempering, annealing, normalizing, or normalizing and tempering.

5. Chemical Composition

5.1 *Cast or Heat Analysis*— An analysis of each cast or heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The analysis shall be made from a test sample taken preferably during the pouring of the cast or heat. The chemical composition thus determined shall conform to the requirements in Table 1.

5.2 *Product Analysis:*

5.2.1 The purchaser may make a product analysis on forgings supplied to this specification by any of the commonly accepted methods that will positively identify the material. Samples for analysis may be taken from midway between center and surface of solid forgings, midway between inner and outer surfaces of hollow forgings, midway between center and surface of full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 1 within the permissible variations of Table 2.

5.2.2 Test Methods, Practices, and Terminology A 751 shall apply.

6. Mechanical Properties

6.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

6.2 Testing shall be performed in accordance with Test Methods and Definitions A 370.

7. Test Specimens

7.1 The tension test specimens shall be machined to the form and dimensions of the standard 2-in. [50 mm] gage length tension test specimen shown in Fig. 4 of Test Methods and Definitions A 370, except as specified in 7.2.

7.2 In the case of small sections which will not permit the taking of standard test specimen specified in 7.1, the tension test specimen shall be as large as feasible and its dimensions shall be proportional to those shown in Fig. 4 of Test Methods and Definitions A 370. The gage length for measuring elongation shall be four times the diameter of the specimen.

7.3 For the purpose of determining conformance to Table 3, specimens shall be obtained from the production forgings, or from separately forged test blanks prepared from the stock used to make the finished product. Such test blanks shall receive approximately the same working as the finished product.

8. Number of Tests

8.1 One tension test shall be made from each heat.

8.2 If any test specimen is defectively machined, it may be discarded and another specimen substituted.

9. Retests

9.1 When one or more representative test specimens do not conform to specification requirements for the tested characteristic, only a single retest for each nonconforming characteristic may be performed to establish product acceptability. Retests shall be performed on twice the number of representative specimens that were originally nonconforming. When any retest specimen does not conform to specification requirements for the characteristic in question, the lot represented by that specimen shall be rejected, heat-treated or reheat-treated in accordance with 4.6, and tested in accordance with Sections 6, 7, and 8.

10. Workmanship, Finish, and Appearance

10.1 The forgings shall be free of injurious imperfections as defined below and shall have a workmanlike finish. At the discretion of the inspector representing the purchaser, finished forgings shall be subject to rejection if surface imperfections acceptable under 10.3 are not scattered but appear over a large area in excess of what is considered a workmanlike finish.

10.2 *Depth of Injurious Imperfections* — Selected typical linear and other typical surface imperfections shall be explored for depth. When the depth encroaches on the minimum wall thickness of the finished forging, such imperfections shall be considered injurious.

10.3 *Machining or Grinding Imperfections Not Classified as Injurious* — Surface imperfections not classified as injurious shall be treated as follows:

10.3.1 Forgings showing seams, laps, tears, or slivers not deeper than 5% of the nominal wall thickness or $\frac{1}{16}$ in. [1.6 mm], whichever is less, need not have these imperfections removed. If the imperfections require removal, they shall be removed by machining or grinding.

10.3.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining provided the depth does not exceed the limitations set forth in 10.2 and if not deeper than $\frac{1}{16}$ in. [1.6 mm]. If such imperfections are deeper than $\frac{1}{16}$ in. [1.6 mm] but do not encroach on the minimum wall thickness of the forging they shall be removed by grinding to sound metal.

10.3.3 When imperfections have been removed by grinding or machining, the outside dimension at the point of grinding or machining may be reduced by the amount removed. Should it be impracticable to secure a direct measurement, the wall thickness at the point of grinding, or at imperfections not required to be removed, shall be determined by deducting the amount removed by grinding, from the nominal finished wall thickness of the forging, and the remainder shall not be less than the minimum specified or required wall thickness.

11. Repair by Welding

11.1 Repair welding, by the manufacturer, is permissible for parts made to dimensional standards such as those of ANSI or equivalent standards.

11.2 Prior approval of the purchaser shall be required to weld repair special parts made to the purchaser's requirements.

11.3 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

11.4 The composition of the weld deposits shall be similar to the base metal and in accordance with the procedure qualification for the applicable material. Welding shall be accomplished with a weld procedure designed to produce low hydrogen in the weldment. Short-circuit gas metal arc welding is permissible only with the approval of the purchaser.

11.5 Unacceptable imperfections shall be removed by mechanical means or thermal cutting or gouging methods. Cavities prepared for welding shall be examined by one of the following methods to verify removal of the imperfection:

11.5.1 Magnetic particle examination in accordance with Test Method A 275 or Guide E 709.

11.5.2 Liquid penetrant examination in accordance with Test Method E 165.

11.6 Weld repaired area(s) shall be blended uniformly to the base metal and shall be examined by the same method used for 11.5.

11.7 Repair by welding shall neither exceed 10 % of the surface area of the part, nor $33^1/_3$ % of the wall thickness of the finished product at the location of repair, without prior approval of the purchaser.

12. Marking of Forgings

12.1 Identification marks consisting of the manufacturer's symbol or name (Note), designation of service rating, Specification number, grade, and size shall be legibly forged or stamped on each forging, and in such a position as not to injure the usefulness of the forgings. The specification number marked on the forgings need not include specification year of issue and revision letter.

NOTE — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

12.2 *Bar Coding* — In addition to the requirements in 12.1, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG standard B-5 02.00 Primary Metals Identification Tag Application. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

13. Packaging, Marking, and Loading for Shipment

13.1 Packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

13.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, when level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.

15. Certificate of Compliance

15.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. The specification designation included on certificates of compliance shall include year of issue and revision letter, if any.

15.2 When specified in the purchase order or contract, a report of the test results shall be furnished.

16. Reports of Testing

16.1 Upon request of the purchaser in the contract or order, a report of the test results and chemical analyses shall be furnished. The specification designation included on reports of testing shall include year of issue and revision letter, if any.

17. Rejection

17.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

18. Rehearing

18.1 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon between the manufacturer and the purchaser.

TABLE 1 Chemical Requirements

Element	Composition, % Classes 60 and 70[A]
Carbon, max	0.35
Manganese, max	1.10[B]
Phosphorus, max	0.05
Silicon, max	[A]
Sulfur, max	0.05

[A] It may be necessary to add silicon to the composition for Class 70 and for the heavier thicknesses of Class 60 flanges in order to meet the required tensile properties. The silicon content shall not exceed 0.35 %.

[B] Manganese may be increased to 1.35 % max provided the carbon is reduced 0.01 % for each 0.06 % increase in manganese over the limit shown in the table.

TABLE 2 Permissible Variations in Product Analysis

NOTE—Product cross-sectional area is defined as either:
(a) maximum cross-sectional area of rough machined forging (excluding boring),
(b) maximum cross-sectional area of the unmachined forging, or
(c) maximum cross-sectional area of the billet, bloom or slab.

Area taken at right angles to the axis of the original ingot or billet.

	Permissible Variations over the Maximum Limit or Under the Minimum Limit, %				
	200 in.^{2} [1290 cm^2] and Under	Over 200 to 400 in.^{2} [1290 to 2580 cm^2] incl	Over 400 to 800 in.^{2} [2580 to 5160 cm^2] incl	Over 800 to 1600 in.^{2} [5160 to 10 320 cm^2]	Over 1600 in.^{2} [10 320 cm^2]
Manganese					
Up to and Including 0.90	0.04	0.05	0.06	0.07	0.08
0.91 and over	0.06	0.07	0.08	0.08	0.09
Phosphorus	0.008	0.010	0.010	0.015	0.015
Sulfur	0.010	0.010	0.010	0.015	0.015
Silicon	0.03	0.04	0.04	0.05	0.06

TABLE 3 Tensile Requirements

	Class 60	Class 70
Tensile strength, min, ksi [MPa]	60 [415]	70 [485]
Yield strength,[A] min, ksi [MPa]	30 [205]	36 [250]
Elongation in 2 in. [50 mm], min, %	22	18
Reduction of area, min, %	35	24

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

SUPPLEMENTARY REQUIREMENTS

S1. Carbon Equivalent

S1.1 The maximum carbon equivalent based on heat analysis shall be as follows:

	Maximum Carbon Equivalent Value	
Class	Maximum Section Thickness Less Than or Equal to 2 in.	Maximum Section Thickness Greater Than 2 in.
60	0.45	0.46
70	0.47	0.48

S1.2 Determine the carbon equivalent (CE) as follows:

$$CE\ p\ C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S1.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

S1.4 When this Supplementary Requirement is invoked, all elements in the carbon equivalent formula shall be analyzed and the amounts reported.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, FOR INTERMEDIATE- AND HIGHER-TEMPERATURE SERVICE

SA-515/515M

(Identical with ASTM Specification A 515/A 515M-93)

1. Scope

1.1 This specification covers carbon-silicon steel plates primarily for intermediate- and higher-temperature service in welded boilers and other pressure vessels.

1.2 Material under this specification is available in four grades having different strength levels as follows:

Grade U.S. [SI]	Tensile Strength, ksi [MPa]
60 [415]	60-80 [415-550]
65 [450]	65-85 [450-585]
70 [485]	70-90 [485-620]

1.3 The maximum thickness of plates is limited only be the capacity of the composition to meet the specified mechanical property requirements; however, current practice normally limits the maximum thickness of plates furnished under this specification as follows:

Grade U.S. [SI]	Maximum Thickness, in. [mm]
60 [415]	8 [200]
65 [450]	8 [200]
70 [485]	8 [200]

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Document

2.1 *ASTM Standard:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 20/A 20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, marking, loading, etc.

3.2 Specification A 20/A 20M also establishes the rules for the ordering information that should be complied with when purchasing material to this specification.

3.3 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. These include:

3.3.1 Vacuum treatment,

3.3.2 Additional or special tension testing,

3.3.3 Impact testing, and

3.3.4 Nondestructive examination.

3.4 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A 20/A 20M

3.5 If the requirements of this specification are in conflict with the requirements of Specification A 20/A 20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice* — The steel shall be killed and made to a coarse austenitic grain size practice.

5. Heat Treatment

5.1 Plates 2 in. [50 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both

5.2 Plates over 2 in. [50 mm] in thickness shall be normalized

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A 20/A 20M.

7. Mechanical Requirements

7.1 *Tension Test Requirements* — The material as represented by the tension-test specimens shall conform to the requirements shown in Table 2.

TABLE 1
CHEMICAL REQUIREMENTS

Elements	Composition, %		
	Grade 60 [Grade 415]	Grade 65 [Grade 450]	Grade 70 [Grade 485]
Carbon, max[A],			
1 in [25 mm] and under	0.24	0.28	0.31
Over 1 to 2 in [25 to 50 mm], incl	0.27	0.31	0.33
Over 2 to 4 in. [50 to 100 mm], incl	0.29	0.33	0.35
Over 4 to 8 in. [100 to 200 mm], incl	0.31	0.33	0.35
Over 8 in [200 mm]	0.31	0.33	0.35
Manganese, max:			
Heat analysis	0.90	0.90	1.20
Product analysis	0.98	0.98	1.30
Phosphorus, max[A]	0.035	0.035	0.035
Sulfur, max[A]	0.035	0.035	0.035
Silicon			
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45

[A] Applies to both heat and product analyses

TABLE 2
TENSILE REQUIREMENTS

	Grade		
	60 [415]	65 [450]	70 [485]
Tensile strength, ksi [MPa]	60–80 [415–550]	65–85 [450–585]	70–90 [485–620]
Yield strength, min, ksi [MPa]	32 [220]	35 [240]	38 [260]
Elongation in 8 in [200 mm], min, %	21[A]	19[A]	17[A]
Elongation in 2 in. [50 mm], min, %	25[A]	23[A]	21[A]

[A] See Specification A 20/A 20M.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order. A list of standardized supplementary requirements for use at the option of the purchaser is included in ASTM Specification A 20/A 20M. Those which are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment.

S2. Product Analysis.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test.

S6. Drop-Weight Test.

S7. High-Temperature Tension Test.

S8. Ultrasonic Examination in accordance with Specification A 435/A 435 M,

S9. Magnetic Particle Examination.

S11. Ultrasonic Examination in accordance with Specification A 577/A 577M,

S12. Ultrasonic Examination in accordance with Specification A 578/A 578M.

S14. Bend Test, and

S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below is an additional optional supplementary requirement suitable for this specification.

S61. Austenitic Grain Size

S61.1 The material shall have a carburized austenitic grain size of 1 to 5

ASME BOILER AND PRESSURE VESSEL CODE
AN INTERNATIONALLY RECOGNIZED CODE

SECTION II

Materials

Part B — Nonferrous Material Specifications

1995 EDITION

JULY 1, 1995

ASME BOILER AND PRESSURE VESSEL COMMITTEE
SUBCOMMITTEE ON MATERIALS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
United Engineering Center 345 East 47th Street New York, N.Y. 10017

SPECIFICATION FOR SEAMLESS COPPER PIPE, STANDARD SIZES

E95

SB-42

(Identical with ASTM Specification B 42-93 for the alloys covered except for the deletion of para. 4.1.6 and Supplementary Requirements for government procurement. Certification has been made mandatory.)

1. Scope

1.1 This specification covers seamless copper pipe in all nominal or standard pipe sizes, both regular and extra stong, suitable for use in plumbing, boiler feed lines, and for similar purposes.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards:*

B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing

B 170 Specification for Oxygen-Free Electrolytic Copper Refinery Shapes

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast

E 8 Test Methods for Tension Testing of Metallic Materials

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 53 Test Methods for Chemical Analysis of Copper

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)

E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes

E 478 Test Methods for Chemical Analysis of Copper Alloys

E 527 Practice for Numbering Metals and Alloys (UNS)

3. Terminology

3.1 *Definitions:*

3.1.1 *lengths* — straight pieces of the product.

3.1.1.1 *standard* — uniform lengths recommended in a Simplified Practice Recommendation or established as a Commercial Standard.

3.1.2 *tube, seamless* — a tube produced with a continuous periphery in all stages of the operations.

3.1.2.1 *pipe* — a seamless tube conforming to the particular dimensions commercially known as Nominal or Standard Pipe Sizes.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *capable of* — as used in this specification, the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Type of copper, if required,

4.1.2 Temper (see 6.1),

4.1.3 Pipe size, regular or extra-strong, (see 10.2),

4.1.4 Length (see 10.3),

4.1.5 Total length of each size,

4.1.6 Mill test report, if required (see 20.1),

4.1.7 Hydrostatic test, if required, and

4.1.8 Pneumatic test, if required.

5. Chemical Composition

5.1 The material shall conform to the following chemical requirements:

Copper (incl silver), min, %	99.9
Phosphorus, max, %	0.04

5.2 The pipe may be produced from the following coppers, and unless otherwise specified, anyone of them may be furnished:

Copper UNS No.	Previously Used Designation	Type of Copper
C10200	OF	Oxygen-free without residential deoxidants
C12000	DLP	Phosphorized, low residual phosphorus
C12200	DHP	Phosphorized, high residual phosphorus

5.3 When the copper is specified, the material shall conform to the chemical requirements specified in Table 1.

5.4 These specification limits do not preclude the possible presence of other elements. Limits for unnamed elements may be established by agreement between manufacturer or supplier and purchaser.

5.4.1 The major element that is not analyzed shall be determined by difference between the sum of those elements analyzed and 100%. By agreement between manufacturer and purchaser, analysis may be required and limits established for elements not specified.

6. Temper

6.1 All pipe shall normally be furnished in the O61 (annealed), H55 (light drawn), or H80 (hard drawn temper, as prescribed in Practice B 601, and shall have the properties shown in Table 2.

6.2 When pipe is required for bending, it shall be so specified in the purchase order, and the pipe shall be furnished in the temper agreed upon between the manufacturer or supplier and the purchaser.

7. Expansion Test

7.1 Pipe ordered in the annealed (O) condition, selected for test, shall withstand an expansion of 25% of the outside diameter when expanded in accordance with Test Method B 153. The expanded pipe shall show no cracking or rupture visible to the unaided eye. Pipe ordered in the drawn (H) condition is not subject to this test.

NOTE 1 — The term "unaided eye," as used herein, permits the use of corrective spectacles necessary to attain normal vision.

7.2 As an alternative to expansion test for pipe over 4 in. (102 mm) in diameter in the annealed condition, a section 4 in. in length shall be cut from the end of one of the lengths for a flattening test. This 4-in. specimen shall be flattened so that a gage set at three times the wall thickness will pass over the pipe freely thoughout the flattened part. The pipe so tested shall develop no cracks or flaws visible to the unaided eye (Note 1) as a result of this test. In making the flattening test the elements shall be slowly flattened by one stroke of the press.

8. Microscopical Examination

8.1 The pipe shall be made from copper that is free of cuprous oxide as determined by microscopical examination at a 75X magnification. When Copper UNS No. C12200 is supplied, microscopical examination for cuprous oxide is not required.

9. Nondestructive Testing

9.1 The material shall be tested in the final size but may be tested prior to the final anneal or heat treatment, when these thermal treatments are required, unless otherwise agreed upon by the manufacturer or supplier and purchaser.

9.2 *Eddy-Current Test* — Each piece of material from $\frac{1}{8}$ in. up to and including $2\frac{1}{2}$ in. nominal outside diameter, or within the capabilities of the eddy-current tester, shall be subjected to an eddy-current test. Testing shall follow the procedures of Practice E 243, except for determination of "end effect." The material shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of the material for the intended application.

9.2.1 Notch-depth standards rounded to the nearest 0.001 in. (0.025 mm) shall be 10% of the nominal wall thickness. The notch depth tolerance shall be ±0.0005 in. (0.013 mm). Alternatively, when a manufacturer uses speed insensitive equipment that can select a maximum imbalance signal, a maximum imbalance signal of 0.3% may be used.

9.2.2 Material that does not actuate the signaling device of the eddy-current test shall be considered as conforming to the requirements of this test. Material with discontinuities indicated by the testing unit may be reexamined or retested, at the option of the manufacturer, to determine whether the discontinuity is cause for rejection. Signals that are found to have been caused by minor mechanical damage, soil or moisture shall not be cause for rejection of the material provided the dimensions of the material are still within prescribed limits and the material is suitable for its intended application.

9.3 *Hydrostatic Test* — When specified, the material shall stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 6000 psi (41 MPa), determined by the following equation for thin hollow cylinders under tension. The material need not be tested at a hydrostatic pressure of over 1000 psi (6.9 MPa) unless so specified.

$$P = 2St/(D - 0.8t)$$

where:

P = hydrostatic pressure, psi (or MPa),
t = wall thickness of the material, in. (or mm),
D = outside diameter of the material in. (or mm), and
S = allowable stress of the material, psi (or MPa).

9.4 *Pneumatic Test* — When specified, the material shall be subjected to an internal air pressure of 60 psi (415 kPa) minimum for a 5 s without showing evidence of leakage. The test method used shall permit easy visual detection of any leakage, such as by having the material under water or by the pressure-differential method. Any evidence of leakage shall be cause for rejection.

10. Dimensions and Permissible Variations

10.1 For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the limiting values for any dimensions may be cause for rejection.

10.2 *Standard Dimensions, Wall Thickness, and Diameter Tolerances* — The standard dimensions, wall thickness, and diameter tolerances shall be in accordance with Table 3.

10.3 *Length and Length Tolerances* — The standard length of copper pipe is 12 ft (3.66 m) with a tolerance of $\pm\frac{1}{2}$ in. (13 mm).

10.4 *Roundness:*

10.4.1 For drawn unannealed pipe in straight lengths, the roundness tolerances shall be as follows:

t/d (ratio of Wall Thickness to Outside Diameter)	Roundness Tolerances as Percent of Outside Diameter (Expressed to the Nearest 0.001 in. (0.025 mm))
0.01 to 0.03, incl	1.5
Over 0.03 to 0.05, incl	1.0
Over 0.05 to 0.10, incl	0.8
Over 0.10	0.7

10.4.2 Compliance with the roundness tolerance shall be determined by taking measurements on the outside diameter only, irrespective of the manner in which the pipe dimensions are specified.

10.4.3 The deviation from roundness is measured as the difference between major and minor diameters as determined at any one cross section of the tube.

10.5 *Squareness of Cut* — The departure from squareness of the end of any pipe shall not exceed the following:

Outside Diameter in. (mm)	Tolerance
Up to $\frac{5}{8}$ (15.9), incl	0.010 in. (0.25 mm)
Over $\frac{5}{8}$ (15.9)	0.016 in./in. (0.016 mm/mm) of diameter

11. Workmanship, Finish, and Appearance

11.1 The material shall be free of defects of a nature that interfere with normal commercial applications. It shall be well cleaned and free of dirt.

12. Sampling

12.1 *Sampling* — The lot size, portion size, and selection of sample pieces shall be as follows:

12.1.1 *Lot Size* — The lot size shall be as follows:

Pipe Size, in	Lot Weight, lb (kg)
Up to $1\frac{1}{2}$, incl	5 000 (2270) or fraction thereof
Over $1\frac{1}{2}$ to 4, incl	10 000 (4550) or fraction thereof
Over 4	40 000 (18 100) or fraction thereof

12.1.2 *Portion Size* — Sample pieces shall be taken for test purposes from each lot according to the following schedule:

Number of Pieces in Lot	Number of Sample Pieces to be Taken[A]
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2% of total number of pieces in the lot, but not to exceed 10 sample pieces

[A] Each sample piece shall be taken from a separate tube

13. Number of Tests and Results

13.1 *Chemical Analysis* — Samples for chemical anyalysis shall be taken in accordance with Practice E 55. Drillings, millings, etc., shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 12.1.2 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g

13.1.1 Instead of sampling in accordance with Practice E 55, the manufacturer shall have the option of determining conformance to chemical composition as follows: Conformance shall be determined by the manufacturer by analyzing samples taken from the semi-finished product. If the manufacturer determines the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product. The number of samples taken for determination of chemical composition shall be as follows:

13.1.1.1 When samples are taken at the time the castings are poured, at least one sample shall be taken for each group of castings poured simultaneously from the same source of molten metal.

13.1.1.2 When samples are taken from the semi-finished product, a sample shall be taken to represent each 10 000 lb (4550 kg) or fraction thereof, except that not more than one sample shall be required per piece.

13.1.1.3 Due to the discontinuous nature of the processing of castings into wrought products, it is not practical to identify specific quanitity of finished material.

13.1.1.4 In the event that heat identification or traceability is required, the purchaser shall specify the details desired.

13.2 *Retests:*

13.2.1 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

13.2.2 If a bend test specimen fails, due to conditions of bending more severe than required by the specification, a retest shall be permitted on a new sample piece or on the remaining portion of the first sample piece.

13.2.3 If the results of the test on one of the specimens fail to meet the specified requirements, two additional specimens shall be taken from different sample pieces and tested. The results of the tests on both of these specimens shall meet the specified requirements. Failure of more than one specimen to meet the specified requirements for a particular property shall be cause for rejection of the entire lot.

13.2.4 If the chemical analysis fails to conform to the specified limits, analysis shall be made on a new composite sample prepared from additonal pieces selected in accordance with 12.1. The results of this retest shall comply with the specified requirements.

14. Test Methods

14.1 The properties enumerated in this specification shall, in case of disagreement, be determined in accordance with the following applicable test methods:

Test	ASTM Designation[A]
Chemical analysis	B 170[B], E 53, E 62, E 478
Tension	E 8
Expansion (pin test)	B 153
Eddy current	E 243

[A] See 2.1

[B] Reference to Specification B 170 is to the suggested chemical methods in the annex thereof. When Committee E-1 has tested and published methods for assaying the low level impurities in copper, the Specification B 170 annex will be eliminated.

14.2 Tension test specimens shall be of the full section of the pipe and shall conform to the requirements of the Specimens for Pipe and Tube section, of Test Methods E 8, unless the limitations of the testing machine preclude the use of such a specimen. Test specimens conforming to Type No. 1 of Fig. 13, Tension Test Specimens for Large-Diameter Tubular Products, of Test Methods E 8 may be used when a full section specimen cannot be tested.

14.3 Whenever tension test results are obtained from both full size and machined test specimens and they differ, the results obtained from full test specimens shall be used to determine conformance to the specification requirements.

14.4 Tension test results on material covered by this specification are not seriously affected by variations in speed of testing. A considerable range of testing speed is permissible; however, the rate of stressing to the yield strength should not exceed 100 ksi (700 MPa)/min. Above the yield strength the movement per minute of the testing machine head under load should not exceed 0.5 in./in. (0.5 mm/mm) of gage length (or distance between grips for full-section specimens).

15. Significance of Numerical Limits

15.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E 29.

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength Yield strength	nearest ksi (nearest 5 MPa)

16. Inspection

16.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with the specified requirements.

17. Rejection and Rehearing

17.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or supplier may make claim for a rehearing.

18. Packaging and Package Marking

18.1 The material shall be separated by size, composition, and temper, and prepared for shipment in such a manner as to ensure acceptance by common carrier for transportation and to afford protection from the normal hazaards of transportation.

18.2 Each shipping unit shall be legibly marked with the purchase order number, metal or alloy designation, temper, size, total length or piece count or both, and name of supplier. The specification number shall be shown, when specified.

19. Certification

19.1 The manufacturer shall furnish to the purchaser a certificate stating that each lot has been sampled, tested, and inspected in accordance with this specification and has met the requirements.

20. Mill Test Report

20.1 When specified on the purchase order, the manufacturer shall furnish to the purchaser a test report showing results of tests required by the specification.

21. Keywords

21.1 copper pipe; extra strong; regular; standard sizes

TABLE 1
CHEMICAL REQUIREMENTS

Copper UNS No.	Copper (incl Silver), min, %	Phosphorus, %
C10200	99.95	. .
C12000	99.90	0.004 to 0.012
C12200	99.9	0.015 to 0.040

TABLE 2
TENSILE REQUIREMENTS

Temper Designation		Pipe Size Nominal or Standard, in.	Tensile Strength, min, ksi[B]	Yield Strength,[A] min, ksi[B]
Standard	Former			
O61	annealed	all	30	9
H80	hard drawn	$^1/_8$–2, incl	45	40
H55	light drawn	2–12, incl	36	30

[A]At 0.5% extension under load.
[B]ksi = 1000 psi.

TABLE 3 STANDARD DIMENSIONS, WEIGHTS, AND TOLERANCES

NOTE—All tolerances are plus and minus except as otherwise indicated.

Nominal or Standard Pipe Size, in	Outside Diameter, in.	Average Outside Diameter Tolerances,[A] in All Minus	Wall Thickness, in.	Tolerance,[B] in	Theoretical Weight, lb/ft
			Regular		
1/8	0.405	0.004	0.062	0.004	0.253
1/4	0.540	0.004	0.082	0.005	0.447
3/8	0.675	0.005	0.090	0.005	0.627
1/2	0.840	0.005	0.107	0.006	0.934
3/4	1.050	0.006	0.114	0.006	1.27
1	1.315	0.006	0.126	0.007	1.78
1 1/4	1.660	0.006	0.146	0.008	2.63
1 1/2	1.900	0.006	0.150	0.008	3.13
2	2.375	0.008	0.156	0.009	4.12
2 1/2	2.875	0.008	0.187	0.010	5.99
3	3.500	0.010	0.219	0.012	8.56
3 1/2	4.000	0.010	0.250	0.013	11.2
4	4.500	0.012	0.250	0.014	12.7
5	5.562	0.014	0.250	0.014	15.8
6	6.625	0.016	0.250	0.014	19.0
8	8.625	0.020	0.312	0.022	30.9
10	10.750	0.022	0.365	0.030	45.2
12	12.750	0.024	0.375	0.030	55.3
			Extra Strong		
1/8	0.405	0.004	0.100	0.006	0.363
1/4	0.540	0.004	0.123	0.007	0.611
3/8	0.675	0.005	0.127	0.007	0.829
1/2	0.840	0.005	0.149	0.008	1.23
3/4	1.050	0.006	0.157	0.009	1.67
1	1.315	0.006	0.182	0.010	2.46
1 1/4	1.660	0.006	0.194	0.010	3.39
1 1/2	1.900	0.006	0.203	0.011	4.10
2	2.375	0.008	0.221	0.012	5.67
2 1/2	2.875	0.008	0.280	0.015	8.66
3	3.500	0.010	0.304	0.016	11.6
3 1/2	4.000	0.010	0.321	0.017	14.1
4	4.500	0.012	0.341	0.018	16.9
5	5.562	0.014	0.375	0.019	23.2
6	6.625	0.016	0.437	0.027	32.2
8	8.625	0.020	0.500	0.035	48.4
10	10.750	0.022	0.500	0.040	61.1

[A] The average outside diameter of a tube is the average of the maximum and minimum outside diameters as determined at any one cross section of the pipe

[B] Maximum deviation at any one point

APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one meter per second squared ($N = kg \cdot m/s^2$). The derived SI unit for pressure or stress in the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since 1 ksi = 6 894 757 Pa the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2.

ASME BOILER AND PRESSURE VESSEL CODE
AN INTERNATIONALLY RECOGNIZED CODE

SECTION II

Materials

Part C — Specifications for Welding Rods, Electrodes, and Filler Metals

1995 EDITION

JULY 1, 1995

ASME BOILER AND PRESSURE VESSEL COMMITTEE
SUBCOMMITTEE ON NONDESTRUCTIVE TESTING

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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CONTENTS

SPECIFICATION FOR CARBON STEEL ELECTRODES FOR SHIELDED METAL ARC WELDING

SFA-5.1

(Identical with AWS Specification A5.1-91)

1. Scope

This specification prescribes requirements for the classification of carbon steel electrodes for shielded metal arc welding

SECTION A — GENERAL REQUIREMENTS

2. Classification

2.1 The welding electrodes covered by this specification are classified according to the following:

(1) Type of current (see Table 1)

(2) Type of covering (see Table 1)

(3) Welding position (see Table 1)

(4) Mechanical properties of the weld metal in the as-welded or aged condition (see Tables 2 and 3)

2.2 Materials classified under one classification shall not be classified under any other classification of this specification, except that E7018M may also be classified as E7018 provided the electrode meets all of the requirements of both classifications.

3. Acceptance

Acceptance[1] of the welding electrodes shall be in accordance with the provisions of the ANSI/AWS A5.01, *Filler Metal Procurement Guidelines.*[2]

[1] See A3 (in the Appendix) for further information concerning acceptance, testing of the material shipped, and ANSI/AWS A5.01 *Filler Metal Procurement Guidelines*

[2] AWS standards can be obtained from the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.

4. Certification

By affixing the AWS specification and classification designations to the packagings, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[3]

5. Units of Measure and Rounding-Off Procedure

5.1 U.S. Customary Units are the standard units of measure in this specification. The SI Units are given as equivalent values to the U.S. Customary Units. The standard sizes and dimensions in the two systems are not identical, and for this reason, conversion from a standard size or dimension in one system will not always coincide with a standard size or dimension in the other. Suitable conversions, encompassing standard sizes of both, can be made, however, if appropriate tolerances are applied in each case.

5.2 For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the "nearest unit" of the last right-hand place of figures used in expressing the limiting value in accordance with the round-off method of ASTM Practice E29 for *Using Significant Digits in Test Data to Determine Conformance with Specifications.*[4]

[3] See A4 (in the Appendix) for further information concerning certification and the testing called for to meet this requirement

[4] ASTM standards can be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

TABLE 1
ELECTRODE CLASSIFICATION

AWS Classification	Type of Covering	Welding Position[a]	Type of Current[b]
E6010	High cellulose sodium	F,V,OH,H	dcep
E6011	High cellulose potassium	F,V,OH,H	ac or dcep
E6012	High titania sodium	F,V,OH,H	ac or dcen
E6013	High titania potassium	F,V,OH,H	ac, dcep or dcen
E6019	Iron oxide titania potassium	F,V,OH,H,	ac, dcep or dcen
E6020	High iron oxide	H-fillets F	ac or dcen ac, dcep or dcen
E6022[c]	High iron oxide	F,H	ac or dcen
E6027	High iron oxide, iron powder	H-fillets F	ac or dcen ac, dcep or dcen
E7014	Iron powder, titania	F,V,OH,H	ac, dcep or dcen
E7015[d]	Low hydrogen sodium	F,V,OH,H	dcep
E7016[d]	Low hydrogen potassium	F,V,OH,H	ac or dcep
E7018[d]	Low hydrogen potassium, iron powder	F,V,OH,H	ac or dcep
E7018M	Low hydrogen iron powder	F,V,OH,H	dcep
E7024[d]	Iron powder, titania	H-fillets,F	ac, dcep or dcen
E7027	High iron oxide, iron powder	H-fillets F	ac or dcen ac, dcep or dcen
E7028[d]	Low hydrogen potassium, iron powder	H-fillets,F	ac or dcep
E7048[d]	Low hydrogen potassium, iron powder	F,OH,H,V-down	ac or dcep

Notes:

a. The abbreviations indicate the welding positions as follows:
F = Flat
H = Horizontal
H-fillets = Horizontal fillets
V-down = Vertical with downward progression
V = Vertical
OH = Overhead
} For electrodes 3/16 in. (4.8mm) and under, except 5/32 in. (4.0mm) and under for classifications E7014, E7015, E7016, E7018, and E7018M.

b. The term "dcep" refers to direct current electrode positive (dc, reverse polarity). The term "dcen" refers to direct current electrode negative (dc, straight polarity).

c. Electrodes of the E6022 classification are intended for single-pass welds only.

d. Electrodes with supplemental elongation, notch toughness, absorbed moisture, and diffusible hydrogen requirements may be further identified as shown in Tables 2, 3, 10, and 11.

TABLE 2
TENSION TEST REQUIREMENTS[a,b,c]

AWS Classification	Tensile Strength ksi	Tensile Strength MPa	Yield Strength at 0.2% Offset ksi	Yield Strength at 0.2% Offset MPa	Elongation in 2 in. (50.8 mm) Percent
E6010	60	414	48	331	22
E6011	60	414	48	331	22
E6012	60	414	48	331	17
E6013	60	414	48	331	17
E6019	60	414	48	331	22
E6020	60	414	48	331	22
E6022[d]	60	414	not specified		not specified
E6027	60	414	48	331	22
E7014	70	482	58	399	17
E7015	70	482	58	399	22
E7016	70	482	58	399	22
E7018	70	482	58	399	22
E7024	70	482	58	399	17[e]
E7027	70	482	58	399	22
E7028	70	482	58	399	22
E7048	70	482	58	399	22
E7018M	note g	482	53-72[f]	365-496[f]	24

Notes:
a. See Table 4 for sizes to be tested.
b. Requirements are in the as-welded condition with aging as specified in 11.3.
c. Single values are minimum
d. A transverse tension test, as specified in 11.2 and Figure 9 and a longitudinal guided bend test, as specified in Section 12, Bend Test, and Figure 10, are required.
e. Weld metal from electrodes identified as E7024-1 shall have elongation of 22 % minimum.
f. For 3/32 in. (2.4mm) electrodes, the maximum for the yield strength shall be 77 ksi (531 MPa).
g. Tensile strength of this weld metal is a nominal 70 ksi (482 MPa).

SECTION B — TESTS, PROCEDURES, AND REQUIREMENTS

6. Summary of Tests

The tests required for each classification are specified in Table 4. The purpose of these tests is to determine the chemical composition, mechanical properties, and soundness of the weld metal, moisture content of the low hydrogen electrode covering; and the usability of the electrode. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Sections 8 through 17

The supplemental tests for absorbed moisture, in Section 16, Absorbed Moisture Test, and diffusible hydrogen, in Section 17, Diffusible Hydrogen Test, are not required for classification of the low hydrogen electrodes except for E7018M, where these are required. See Notes j and n of Table 4.

7. Retest

If the results of any tests fail to meet the requirement, that test shall be repeated twice. The results of both tests shall meet the requirement. Specimens for retest may be taken from the original test assembly or from a new test assembly. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement.

8. Weld Test Assemblies

8.1 One or more of the following five weld test assemblies are required.

(1) The weld pad in Fig. 1 for chemical analysis of the undiluted weld metal

(2) The groove weld in Fig. 2 for mechanical properties and soundness of the weld metal

(3) The fillet weld in Fig. 3 for the usability of the electrode

(4) The groove weld in Fig. 4 for transverse tensile

TABLE 3
CHARPY V-NOTCH IMPACT REQUIREMENTS

AWS Classification	Limits for 3 out of 5 Specimens[a] Average, Min.	Single Value, Min.
E6010, E6011, E6027, E7015, E7016[b], E7018[b], E7027, E7048	20 ft-lb at -20°F (27 J at -29°C)	15 ft-lb at -20°F (20 J at -29°C)
E6019 E7028	20 ft-lb at 0°F (27 J at -18°C)	15 ft-lb at 0°F (20 J at -18°C)
E6012, E6013, E6020, E6022, E7014, E7024[b]	Not Specified	Not Specified
	Limits for 5 out of 5 Specimens[c] Average, Min.	Single Value, Min.
E7018M	50 ft-lb at -20°F (67 J at -29°C)	40 ft-lb at -20°F (54 J at -29°C)

Notes:

a. Both the highest and lowest test values obtained shall be disregarded in computing the average. Two of these remaining three values shall equal or exceed 20 ft-lb (27 J).

b. Electrodes with the following optional supplemental designations shall meet the lower temperature impact requirements specified below:

AWS Classification	Electrode Designation	Charpy V-Notch Impact Requirements, Limits for 3 out of 5 specimens (Refer to Note a above) Average, Min.	Single Value, Min.
E7016 E7018	E7016-1 E7018-1	20 ft-lb at -50°F (27 J at -46°C)	15 ft-lb at -50°F (20 J at -46°C)
E7024	E7024-1	20 ft-lb at 0°F (27 J at -18°C)	15 ft-lb at 0°F (20 J at -18°C)

c. All five values obtained shall be used in computing the average. Four of the five values shall equal, or exceed, 50 ft-lb (67 J).

and longitudinal bend tests for welds made with the E6022 single pass electrode

(5) The groove weld in Fig. 5 for mechanical properties and soundness of weld metal made with the E7018M electrode

The sample for chemical analysis may be taken from a low dilution area either in the groove weld in Fig. 2 or 5 or in the fractured all-weld-metal tension test specimen, thereby avoiding the need to make a weld pad. In case of dispute, the weld pad shall be the referee method.

8.2 Preparation of each weld test assembly shall be as prescribed in 8.3 through 8.5. The base metal for each assembly shall be as required in Table 5 and shall meet the requirements of the ASTM specification shown there or an equivalent specification. Testing of the assemblies shall be as prescribed in Sections 9 through 14.

Electrodes other than low hydrogen electrodes shall be tested without "conditioning." Low hydrogen electrodes, if they have not been adequately protected against moisture pickup in storage, shall be held at a temperature of 500 to 800°F (260 to 427°C) for a minimum of one hour prior to testing.

TABLE 4
REQUIRED TESTS[a,b]

AWS Classification	Current and Polarity[a]	Electrode Size[c] in.	Electrode Size[c] mm	Chemical[d] Analysis	Radiographic Test[e] All-Weld-Metal Tension Test[f]	Impact Test[g]	Fillet Weld Test[h]	Moisture Test[f]
E6010	dcep	3/32, 1/8	2.4, 3.2	NR	NR[b]	NR[b]	NR[b]	NR
		5/32, 3/16	4.0, 4.8	NR	F	F	V & OH	NR
		7/32	5.6	NR	NR[b]	NR[b]	NR[b]	NR
		1/4	6.4	NR	F	F	H	NR
		5/16	8.0	NR	F	NR[b]	NR[b]	NR
E6011	ac and dcep	3/32, 1/8	2.4, 3.2	NR	NR[b]	NR[b]	NR[b]	NR
		5/32, 3/16	4.0, 4.8	NR	F	F	V & OH	NR
		7/32	5.6	NR	NR[b]	NR[b]	NR[b]	NR
		1/4	6.4	NR	F	F	H	NR
E6012	ac and dcen	5/16	8.0	NR	F	NR[b]	NR[b]	NR
		1/16 to 1/8 inc.	1.6 to 3.2 inc.	NR	NR[b]	NR	NR[b]	NR
		5/32, 3/16	4.0, 4.8	NR	F[l]	NR	V & OH	NR
		7/32	5.6	NR	NR[b]	NR	NR[b]	NR
		1/4, 5/16	6.4, 8.0	NR	F[l]	NR	H	NR
E6013	ac, dcep, and dcen	1/16 to 1/8 inc.	1.6 to 3.2 inc.	NR	NR[b]	NR	NR[b]	NR
		5/32, 3/16	4.0, 4.8	NR	F[l]	NR	V & OH	NR
		7/32	5.6	NR	NR[b]	NR	NR[b]	NR
		1/4, 5/16	6.4, 8.0	NR	F[l]	NR	H	NR
E6019	ac, dcep, and dcen	5/64 to 1/8 inc.	2.0 to 3.2 inc.	NR	NR[b]	NR[b]	NR[b]	NR
		5/32, 3/16	4.0, 4.8	NR	F[l]	F[l]	V & OH	NR
		7/32	5.6	NR	NR[b]	NR[b]	NR[b]	NR
		1/4, 5/16	6.4, 8.0	NR	F[l]	F[l]	H	NR
E6020	For H-fillets, ac and dcen; For flat position ac, dcep, and dcen	1/8	3.2	NR	NR[b]	NR	NR[b]	NR
		5/32, 3/16	4.0, 4.8	NR	F[l]	NR	H	NR
		7/32	5.6	NR	NR[b]	NR	NR[b]	NR
		1/4						
		5/16	6.4	NR	F[l]	NR	H	NR
			8.0	NR	F[l]	NR	NR[b]	NR
E6022	ac and dcen	1/8	3.2	NR	NR	NR	NR	NR
		5/32 to 7/32 inc.	4.0 to 5.6 inc.	NR	NR[i,k]	NR	NR	NR
E6027	For H-fillets, ac and dcen; For flat position ac, dcep, and dcen	1/8	3.2	NR	NR[b]	NR[b]	NR[b]	NR
		5/32, 3/16	4.0, 4.8	NR	F[l,m]	F[l]	H	NR
		7/32	5.6	NR	NR[b]	NR[b]	NR[b]	NR
		1/4						
		5/16	6.4	NR	F[l,m]	F[l]	H	NR
			8.0	NR	F[l,m]	NR[b]	NR[b]	NR

(Continued)

TABLE 4 (CONT'D)
REQUIRED TESTS[a,b]

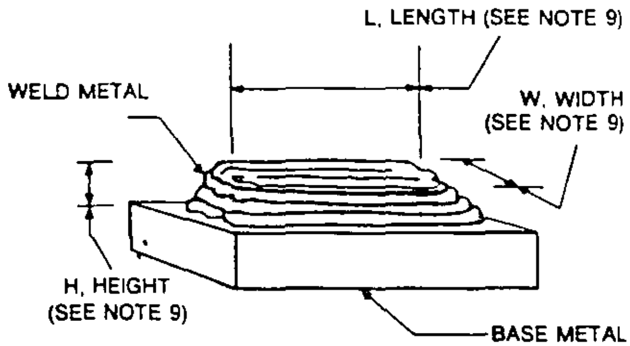
AWS Classification	Current and Polarity[a]	Electrode Size[c] in.	Electrode Size[c] mm	Chemical[d] Analysis	Radiographic Test[e] All-Weld-Metal Tension Test[f]	Impact Test[g]	Fillet Weld Test[h]	Moisture Test[f]
E7014	ac, dcep, and dcen	3/32, 1/8	2.4, 3.2	NR[b]	NR[b]	NR	NR[b]	NR
		5/32	4.0	F[l]	F[l]	NR	V & OH	NR
		3/16	4.8	NR[b]	F[l]	NR	H	NR
		7/32	5.6	NR[b]	NR[b]	NR	NR[b]	NR
		1/4	6.4	F[l]	F[l]	NR	H	NR
		5/16	8.0	NR[b]	F[l]	NR	H	NR
E7015	dcep	3/32, 1/8	2.4, 3.2	NR[b]	NR[b]	NR[b]	NR[b]	NR[b]
		5/32	4.0	F	F	F	V & OH	Req'd.
		3/16	4.8	NR[b]	F	F	H	NR[b]
		7/32	5.6	NR[b]	NR[b]	NR[b]	NR[b]	NR[b]
		1/4	6.4	F	F	F	H	Req'd.
		5/16	8.0	NR[b]	F	NR[b]	NR[b]	NR[b]
E7016	ac and dcep	3/32, 1/8	2.4, 3.2	NR[b]	NR[b]	NR[b]	NR[b]	NR[b]
		5/32	4.0	F	F	F	V & OH	Req'd.
		3/16	4.8	NR[b]	F	F	H	NR[b]
		7/32	5.6	NR[b]	NR[b]	NR[b]	NR[b]	NR[b]
		1/4	6.4	F	F	F	H	Req'd.
		5/16	8.0	NR[b]	F	NR[b]	NR[b]	NR[b]
E7018	ac and dcep	3/32, 1/8	2.4, 3.2	NR[b]	NR[b]	NR[b]	NR[b]	NR[b]
		5/32	4.0	F	F	F	V & OH	Req'd.
		3/16	4.8	NR[b]	F	F	H	NR[b]
		7/32	5.6	NR[b]	NR[b]	NR[b]	NR[b]	NR[b]
		1/4	6.4	F	F	F	H	Req'd.
		5/16	8.0	NR[b]	F	NR[b]	NR[b]	NR[b]
E7018M[n]	dcep	3/32 to 5/32 inc.	2.4 to 4.0 inc.	F	V	V	NR	Req'd.
		3/16 to 5/16 inc.	4.8 to 8.0 inc.	F	F	F	NR	Req'd.
E7024	ac, dcep, and dcen	3/32, 1/8	2.4, 3.2	NR[b]	NR[b]	NR[b,o]	NR[b]	NR
		5/32	4.0	F[l]	F[l,m]	F[o]	H	NR
		3/16	4.8	NR[b]	F[l,m]	F[o]	H	NR
		7/32	5.6	NR[b]	NR[b]	NR[b,o]	NR[b]	NR
		1/4	6.4	F[l]	F[l,m]	F[o]	H	NR
		5/16	8.0	NR[b]	FC[l,m]	NR[b,o]	NR[b]	NR
E7027	For H-fillets ac and dcen; For flat position ac, dcep, and dcen	1/8	3.2	NR[b]	NR[b]	NR[b]	NR[b]	NR
		5/32	4.0	F[l]	F[l,m]	F[l]	H	NR
		3/16	4.8	NR[b]	F[l,m]	F[l]	H	NR
		7/32	5.6	NR[b]	NR[b]	NR[b]	NR[b]	NR
		1/4	6.4	F[l]	F[l,m]	F[l]	H	NR
		5/16	8.0	NR[b]	F[l,m]	NR[b]	NR[b]	NR

(Continued)

TABLE 4 (CONT'D)
REQUIRED TESTS[a,b]

AWS Classification	Current and Polarity[a]	Electrode Size[c] in.	Electrode Size[c] mm	Chemical[d] Analysis	Radiographic Test[e] All-Weld-Metal Tension Test[f]	Impact Test[g]	Fillet Weld Test[h]	Moisture Test[f]
E7028	ac and dcep	1/8	3.2	NR[b]	NR[b]	NR[b]	NR[b]	NR[b]
		5/32	4.0	F	F[m]	F		Req'd.
		3/16	4.8	NR[b]	F[m]	F	H	NR[b]
		7/32	5 6	NR[b]	NR[b]	NR[b]	NR[b]	NR[b]
		1/4	6 4	F	F[m]	F	H	Req'd.
		5/16	8 0	NR[b]	F[m]	NR[b]	NR[b]	NR[b]
E7048	ac and dcep	1/8	3.2	NR[b]	NR[b]	NR[b]	NR[b]	NR[b]
		5/32	4.0	F	F	F	V-down & OH	Req'd.
		3/16	4.8	NR[b]	F	F	V-down & H	NR[b]

a. NR means "not required". The abbreviations, F,H, H-fillets, V-down, V, and OH, are defined in Note a of Table 1. The terms "dcep" and "dcen", are defined in Note b of Table 1.
b. Standard electrode sizes not requiring this specific test can be classified provided at least two other sizes of that classification have passed the tests required for them, or the size to be classified meets specification requirements by having been tested in accordance with Figures 1, 2, and 3 and Table 6.
c. Electrodes manufactured in sizes not shown shall be tested to the requirements of the nearest standard size. 6.0 mm electrode shall be tested to the requirements of 1/4 in. (6.4 mm) electrode.
d. See Section 9, Chemical Analysis.
e. See Section 10, Radiographic Test.
f. See Section 11, Tension Test.
g. See Section 13, Impact Test.
h. See Section 14, Fillet Weld Test.
i. A radiographic test is not required for this classification.
j. The moisture test given in Sections 15 through 15.9 is the required test for measurement of moisture content of the covering. In Section 16, Absorbed Moisture Test, and Section 17, Diffusible Hydrogen Test, are supplemental tests required only when their corresponding optional supplemental designators are to be used with the classification designators.
k. A transverse tension test (see 11.2 and Figure 9) and a longitudinal guided bend test (see Section 12, Bend Test, and Figure 10) are required for classification of 5/32, 3/16, and 7/32 in. (4.0, 4.8, and 5.6 mm) E6022 electrodes. Welding shall be in the flat position. See Note d of Table 2.
l. When dcep and dcen are shown, only dcen need be tested.
m. Electrodes longer than 18 in. (450 mm) will require a double length test assembly in accordance with Note 2 of Figure 2, to ensure uniformity of the entire electrode.
n. Tests in Section 16 Absorbed Moisture Test, and in Section 17, Diffusible Hydrogen Test, are required tests for all sizes of E7018M.
o. Electrodes identified as E7024-1 shall be impact tested See Note b of Table 3.



Notes:
1. Base metal of any convenient size, of any type specified in Table 5, shall be used as the base for the weld pad.
2. The surface of the base metal on which the filler metal is to be deposited shall be clean.
3. The pad shall be welded in the flat position with successive layers to obtain undiluted weld metal.
4. One pad shall be welded for each type of current shown in Table 4 except for those classifications identified by note L in Table 4
5. The number and size of the beads will vary according to the size of the electrode and the width of the weave, as well as the amperage employed
6. The preheat temperature shall not be less than 60°F (16°C) and the interpass temperature shall not exceed 300°F (150°C).
7. The slag shall be removed after each pass.
8. The test assembly may be quenched in water between passes to control interpass temperature
9. The minimum completed pad size shall be at least four layers in height (H) with length (L) and width (W) sufficient to perform analysis. The sample for analysis shall be taken at least 1/4 in (6.4 mm) above the original base metal surface

FIG. 1 — PAD FOR CHEMICAL ANALYSIS OF UNDILUTED WELD METAL

8.3 Weld Pad. A weld pad, when required, shall be prepared as specified in Fig 1. Base metal of any convenient size of the type specified in Table 5 shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple layers to obtain undiluted weld metal. The preheat temperature shall not be less than 60°F (16°C) and the interpass temperature shall not exceed 300°F (150°C). The slag shall be removed after each pass. The pad may be quenched in water between passes. The dimensions of the completed pad shall be as shown in Fig 1. Testing of this assembly shall be as specified in Section 9, Chemical Analysis.

8.4 Groove Weld

8.4.1 Mechanical Properties and Soundness. A test assembly shall be prepared and welded as specified in Figs. 2 or 5 using base metal of the appropriate type specified in Table 5. Testing of this assembly shall be as specified in Section 11, Tension Test, and Section 13, Impact Test. The assembly shall be tested in the as-welded or aged condition.

8.4.2 Transverse Tension and Bend Tests. A test assembly shall be prepared and welded as specified in Fig. 4 using base metal of the appropriate type specified in Table 5. Testing of this assembly shall be as specified in 11.2 through 11.4 and Section 12, Bend Test. The assembly shall be tested in the aged condition.

8.5 Fillet Weld. A test assembly shall be prepared and welded as specified in Table 4 and Fig. 3 using base metal of the appropriate type specified in Table 5. The welding positions shall be as specified in Table 6 and Figs. 3 and 6 according to the size and classification of electrode. Testing of the assembly shall be as specified in Section 14, Fillet Weld Test.

9. Chemical Analysis

9.1 The sample for analysis shall be taken from weld metal obtained with the electrode. The sample shall come from a weld pad or from a low dilution area in the fractured all-weld-metal tension specimen or the groove weld in Figs. 2 or 5 Areas where arc starts or craters exist shall be avoided.

The top surface of the pad described in 8.3 and shown in Fig. 1 shall be removed and discarded, and a sample for analysis shall be obtained from the underlying metal by any appropriate mechanical means. The sample shall be free of slag and shall be taken at least $^{1}/_{4}$ in (6.4 mm) from the nearest surface of the base metal.

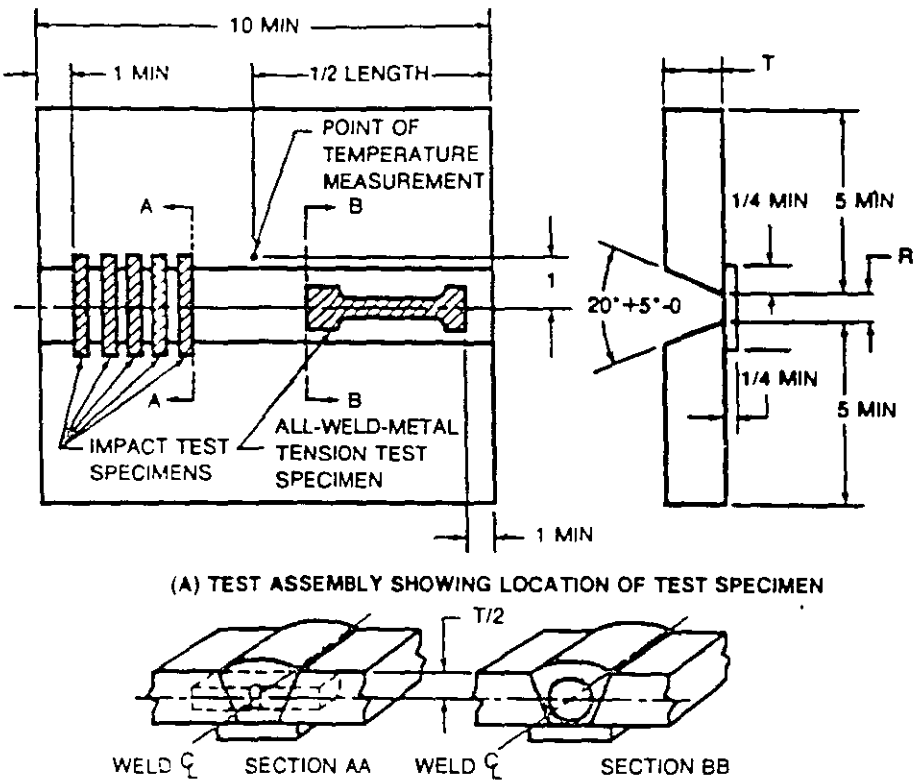
The low dilution area in the fractured tension test specimen or in the groove weld in Figs. 2 or 5 shall be prepared for analysis by any suitable mechanical means

9.2 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM Standard Method E350, *Chemical Analysis of Carbon Steel, Low Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron.*

9.3 The results of the analysis shall meet the requirements of Table 7 for the classification of electrode under test.

10. Radiographic Test

10.1 When required in Table 4, the groove weld described in 8.4.1 and shown in Fig. 2 or 5 shall be radiographed to evaluate the soundness of the weld



(A) TEST ASSEMBLY SHOWING LOCATION OF TEST SPECIMEN

(B) ORIENTATION AND LOCATION OF IMPACT TEST SPECIMEN

(C) LOCATION OF ALL-WELD-METAL TENSION TEST SPECIMEN

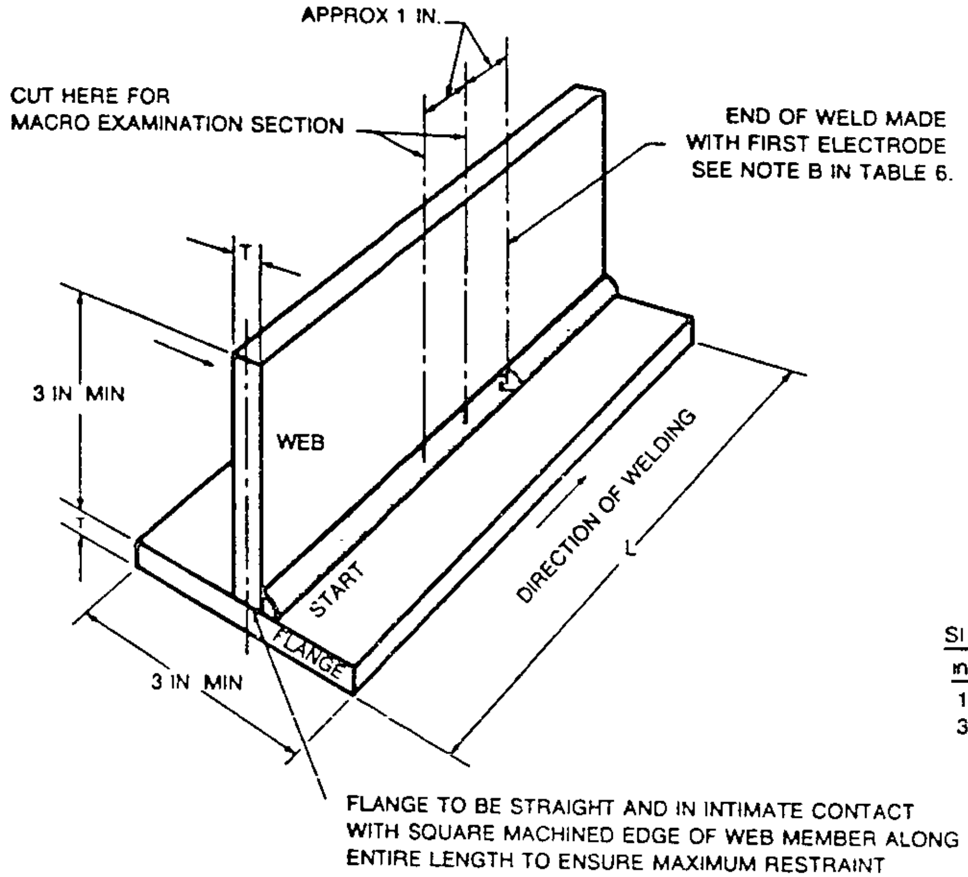
SI Equivalents	
in	mm
1/4	6.4
1	25
5	127
10	254

Electrode Size in	mm	(T) Plate Thickness in.	mm	(R) Root Opening in	mm	Passes Per Layer	Total Layers
3/32	2.4	1/2	13	3/8	10	2	not specified
1/8	3.2	1/2	13	1/2	13	2	5 to 7
5/32	4.0	3/4	20	5/8	16	2	7 to 9
3/16	4.8	3/4	20	3/4	20	2	6 to 8
7/32	5.6	3/4	20	7/8	23	2	6 to 8
1/4	6.4	1	25	1	25	2	9 to 11
5/16	8.0	1-1/4	32	1-1/8	28	2	10 to 12

Notes:

1. All dimensions except angles are in inches.
2. For electrodes longer than 18 in. (450 mm), a 20 in (500 mm) minimum length test assembly shall be welded.
3. Base metal shall be as specified in Table 5.
4. The surfaces to be welded shall be clean.
5. Prior to welding, the assembly may be preset to yield a welded joint sufficiently flat to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint within 5 deg of plane. A welded test assembly that is more than 5 deg out of plane shall be discarded. Straightening of the test assembly is prohibited.
6. Welding shall be in the flat position, using each type of current specified in Table 4 except for classifications identified by Note L in Table 4.
7. The preheat temperature shall be 225°F (105°C) minimum. The interpass temperature shall not be less than 225°F (105°C) nor more than 350°F (175°C).
8. The joint root may be seal welded with 3/32 or 1/8 in. (2.4 or 3.2 mm) electrodes using stringer beads.
9. In addition to the stops and starts at the ends, each pass shall contain a stop and start in between the ends.
10. The completed weld shall be at least flush with the surface of the test plate

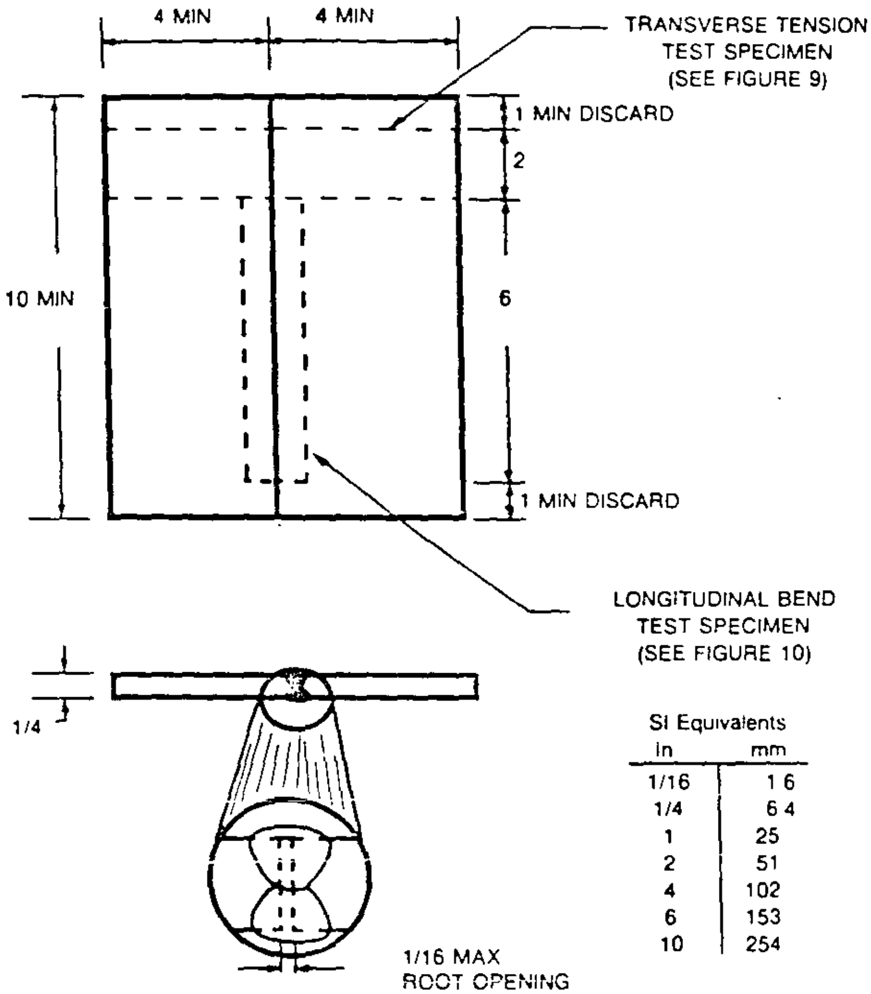
FIG. 2 — GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS EXCEPT FOR E6022 AND E7018M ELECTRODES



SI Equivalents	
in.	mm
1	25
3	76

Notes
1. See Table 6 for values of T and L
2. Base metal shall be as specified in Table 5.
3. The surfaces to be welded shall be clean
4. An assembly shall be welded in each position specified in Table 6 and shown in Figure 6 using each type of current specified in Table 4
5. The preheat shall be 60°F (16°C) minimum.
6. A single pass fillet weld shall be made on one side of the joint. The first electrode shall be consumed to a stub length no greater than 2 in. (50 mm)
7. Welding in the vertical position shall be with upward progression, except for the E7048 classification where progression shall be downward.
8. Weld cleaning shall be limited to slag chipping, brushing, and needle scaling. Grinding or filing of the weld face in prohibited.

FIG. 3 — FILLET WELD TEST ASSEMBLY

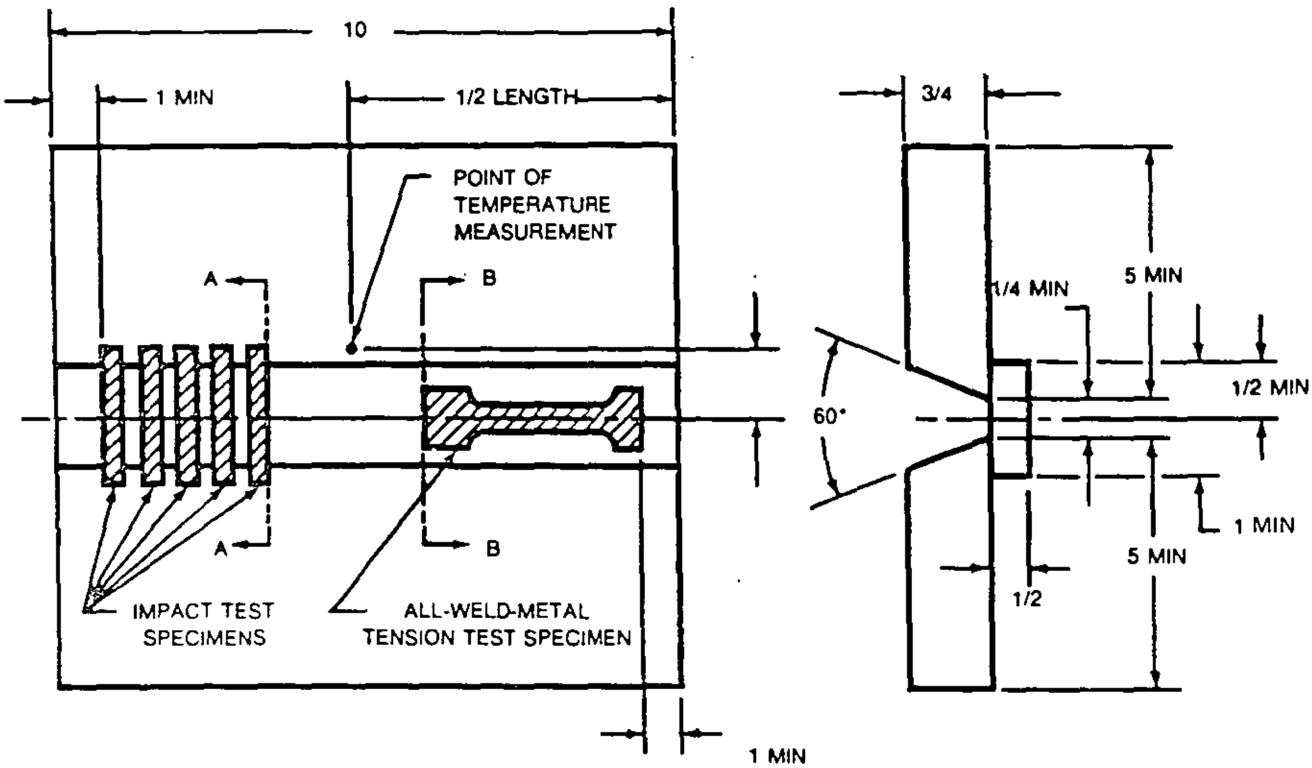


SI Equivalents

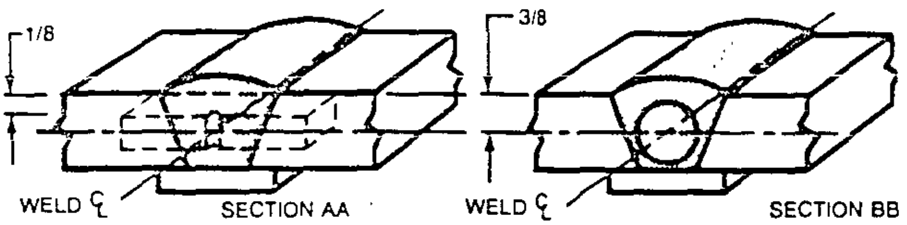
in	mm
1/16	1.6
1/4	6.4
1	25
2	51
4	102
6	153
10	254

Notes:
1. All dimensions are in inches
2. Base metal shall be as specified in Table 5.
3. The surfaces to be welded shall be clean.
4. Prior to welding, the assembly may be preset to yield a welded joint sufficiently flat to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint within 5 deg of plane. A welded test assembly that is more than 5 deg out of plane shall be discarded. Straightening of the test assembly is prohibited.
5. The assembly shall be welded in the flat position, using the type of current specified in Table 4.
6. The preheat temperature shall be 60°F (16°C) min. The interpass temperature shall not exceed 350°F (180°C).
7. In addition to the stops and starts at the ends, each pass shall contain a stop and start in between the ends.
8. Back gouging may be done to ensure sound weld metal through the entire thickness of test assembly
9. The completed weld shall be at least flush with the surface of the test plate.

FIG. 4 — TEST ASSEMBLY FOR TRANSVERSE TENSION AND LONGITUDINAL GUIDED BEND TESTS FOR WELDS MADE WITH E6022 ELECTRODES



(A) TEST ASSEMBLY LOCATIONS OF TEST SPECIMENS



(B) ORIENTATION AND LOCATION OF IMPACT TEST SPECIMEN

(C) LOCATION OF ALL-WELD-METAL TENSION TEST SPECIMEN

SI Equivalents

in.	mm
1/8	3.2
1/4	6.4
3/8	9.5
1/2	12.7
3/4	19.1
1	25.4
5	127
10	254

Notes:
1. All dimensions except angles are in inches.
2. Base metal shall be as specified in Table 5.
3. The surfaces to be welded shall be clean.
4. Prior to welding, the assembly may be preset to yield a welded joint sufficiently flat to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint within 5 deg of plane. A welded test assembly that is more than 5 deg out of plane shall be discarded. Straightening of the test assembly is prohibited.
5. The assembly shall be welded in the vertical position with progression upward for electrodes 5/32 in. (4.0 mm) and less in size, and in the flat position for electrodes 3/16 in. (4.8 mm) and greater in size, using the type of current specified in Table 4 for the electrode and welding technique recommended by the electrode manufacturer.
6. The preheat temperature and the interpass temperature shall be 200-250°F (93-121°C).
7. The welding heat input shall be 30 to 40 kJ/in. (12 to 16 kJ/cm) for the 3/32 in. (2.4 mm) size electrodes and 50 to 60 kJ/in. (20 to 24 kJ/cm) for the 1/8 in. (3.2 mm) size and larger electrodes.
8. In addition to the stops and starts at the ends, each pass shall contain a stop and start in between the ends.
9. The completed weld shall be at least flush with the surface of the test plate. Maximum weld reinforcement shall be 3/16 in. (4.8 mm). Peening of weld beads is not permitted.

FIG. 5 — GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS OF WELD METAL MADE WITH E7018M ELECTRODES

TABLE 5
BASE METAL FOR TEST ASSEMBLES

AWS Classification	Base Metal Type	ASTM Specification[a]	UNS Number[b]
All	Carbon steel	A131 Grade B	K02102
		A285 Grade A	K01700
		A285 Grade B	K02200
All except E7018M	Carbon steel	A285 Grade C	K02801
		A283 Grade D	—
		A36	K02600
		A29 Grade 1015	G10150
		A29 Grade 1020	G10200

Notes:

a. Equivalent steel may be used.

b. SAE/ASTM Unified Numbering System for Metals and Alloys.

metal. In preparation for radiography, the backing shall be removed, and both surfaces of the weld shall be machined or ground smooth. The finished surface of the weld may be flush with the plate or have a reasonably uniform reinforcement not exceeding $^3/_{32}$ in. (2.4 mm). Both surfaces of the test assembly in the area of the weld shall be smooth enough to avoid difficulty in interpreting the radiograph.

10.2 The weld shall be radiographed in accordance with ASTM Method E142, *Controlling Quality of Radiographic Testing*. The quality level of inspection shall be 2-2T.

10.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows the following.

(1) No cracks, no incomplete fusion or incomplete joint penetration

(2) No slag inclusions longer than $^1/_4$ in. (6.4 mm) or $^1/_3$ of the thickness of the weld, whichever is greater, or no groups of slag inclusions in line that have an aggregate length greater than the thickness of the weld in a length 12 times the thickness of the weld, except when the distance between the successive inclusions exceeds 6 times the length of the longest inclusions in the group.

(3) No rounded indications in excess of those permitted by the radiographic standards in Fig. 7 according to the grade specified in Table 8.

One in. (25 mm) of the weld measured from each end of the assembly shall be excluded from radiographic evaluation.

10.4 A rounded indication is an indication (on the radiograph) whose length is no more than three times its width. Rounded indications may be circular, elliptical, conical, or irreguair in shape, and they may have "tails." The size of a rounded indication is the largest dimension of the indication, including any tail that may be present.

The indication may be porosity or slag. Indications whose largest dimension does not exceed $^1/_{64}$ in. (0.4 mm) shall be disregarded. Test assemblies with porosity indications larger than the largest rounded indications permitted in the radiographic standards do not meet the requirements of this specification.

11. Tension Test

11.1 One all-weld-metal tension test specimen shall be machined from the groove weld described in 8.4.1 as shown in Fig. 2 or 5. The dimensions of the specimen shall be as shown in Fig. 8

11.2 For E6022 electrodes, one traverse tension test specimen shall be machined from the groove weld described in 8.4.2 and Fig. 4. The dimensions of the specimen shall be as shown in Fig. 9.

11.3 The tension specimens for all electrodes except the low hydrogen classifications shall be aged at 200 to 220°F (95 to 105°C) for 48 ±2 hours, and cooled in air to room temperature. All specimens shall be tested in the manner described in the tension testing section of AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

TABLE 6
REQUIREMENTS FOR PREPARATION OF FILLET WELD TEST ASSEMBLIES

AWS Classification	Electrode Size in.	Electrode Size mm	Assembly Size[a] Thickness (T) in.	Thickness (T) mm	Length[b] (L), Min. in.	Length (L), Min. mm	Welding Position	Fillet Weld Size in.	Fillet Weld Size mm
E6010 and E6011	3/32	2.4	1/8	3.2	10	250	V & OH	5/32 max.	4.0
	1/8	3.2	3/16	4.8	12	300	V & OH	3/16 max.	4.8
	5/32	4.0	3/8	9.5	12	300	V & OH	1/4 max	6.4
	3/16	4.8	3/8	9.5	12	300	V & OH	5/16 max.	8.0
	7/32	5.6	1/2	12.7	12 or 16[c]	300 or 400[c]	H	1/4 min.	6.4
	1/4	6.4	1/2	12.7	16	400	H	1/4 min.	6.4
	5/16	8.0	1/2	12.7	16	400	H	1/4 min.	6.4
E6012, E6013 and E6019	1/16-5/64	1.6-2.0	1/8	3.2	6	150	V & OH	1/8 max.	3.2
	3/32	2.4	1/8	3.2	10	250	V & OH	1/8 max.	3.2
	1/8	3.2	3/16	4.8	12	300	V & OH	3/16 max.	4.8
	5/32	4.0	3/8	9.5	12	300	V & OH	1/4 max.	6.4
	3/16	4.8	1/2	12.7	12	300	V & OH	3/8 max.	9.5
	7/32	5.6	1/2	12.7	12 or 16[c]	300 or 400[c]	H	1/4 min.	6.4
	1/4	6.4	1/2	12.7	16	400	H	5/16 min.	8.0
	5/16	8.0	1/2	12.7	16	400	H	5/16 min.	8.0
E7014	3/32	2.4	1/8	3.2	12	300	V & OH	5/32 max.	4.0
	1/8	3.2	3/16	4.8	12	300	V & OH	3/16 max.	4.8
	5/32	4.0	3/8	9.5	12	300	V & OH	5/16 max.	8.0
	3/16	4.8	3/8	9.5	12	300	H	1/4 min.	6.4
	7/32	5.6	3/8	9.5	12 or 16[c]	300 or 400[c]	H	1/4 min.	6.4
	1/4	6.4	1/2	12.7	16	400	H	5/16 min.	8.0
	5/16	8.0	1/2	12.7	16	400	H	5/16 min.	8.0
E7015 and E7016	3/32	2.4	1/8	3.2	10	250	V & OH	5/32 max.	4.0
	1/8	3.2	1/4	6.4	12	300	V & OH	3/16 max.	4.8
	5/32	4.0	3/8	9.5	12	300	V & OH	5/16 max.	8.0
	3/16	4.8	3/8	9.5	12	300	H	3/16 min.	4.8
	7/32	5.6	1/2	12.7	12 or 16[c]	300 or 400[c]	H	1/4 min.	6.4
	1/4	6.4	1/2	12.7	16	400	H	5/16 min.	8.0
	5/16	8.0	1/2	12.7	16	400	H	5/16 min.	8.0

(Continued)

TABLE 6 (CONT'D)
REQUIREMENTS FOR PREPARATION OF FILLET WELD TEST ASSEMBLIES

AWS Classification	Electrode Size		Assembly Size[a] Thickness (T)		Assembly Size[a] Length[b](L), Min.		Welding Position	Fillet Weld Size	
	in.	mm	in.	mm	in.	mm		in.	mm
E7018	3/32	2.4	1/8	3.2	10 or 12[d]	250 or 300[d]	V & OH	3/16 max.	4.8
	1/8	3.2	1/4	6.4	12	300	V & OH	1/4 max.	6.4
	5/32	4.0	3/8	9.5	12	300	V & OH	5/16 max.	8.0
	3/16	4.8	3/8	9.5	12	300	H	1/4 min.	6.4
	7/32	5.6	1/2	12.7	12 or 16[c]	300 or 400[c]	H	1/4 min.	6.4
	1/4	6.4	1/2	12.7	16	400	H	5/16 min.	8.0
	5/16	8.0	1/2	12.7	16	400	H	5/16 min.	8.0
E6020	1/8	3.2	1/4	6.4	12	300	H	1/8 min.	3.2
	5/32	4.0	3/8	9.5	12	300	H	5/32 min.	4.0
	3/16	4.8	3/8	9.5	12 or 16[c]	300 or 400[c]	H	3/16 min.	4.8
	7/32	5.6	1/2	12.7	16	400	H	1/4 min.	6.4
	1/4	6.4	1/2	12.7	16	400	H	5/16 min.	8.0
	5/16	8.0	1/2	12.7	16	400	H	5/16 min.	8.0
E6027, E7024, E7027 and E7028	3/32[e]	2.4[e]	1/4	6.4	10	250	H	5/32 min.	4.0
	1/8	3.2	1/4	6.4	12	300	H	5/32 min.	4.0
	5/32	4.0	3/8	9.5	12	300	H	3/16 min.	4.8
	3/16	4.8	3/8	9.5	12 or 16[c]	300 or 400[c]	H	1/4 min.	6.4
	7/32	5.6	1/2	12.7	16 or 26[f]	400 or 650[f]	H	1/4 min.	6.4
	1/4	6.4	1/2	12.7	16 or 26[f]	400 or 650[f]	H	5/16 min.	8.0
	5/16	8.0	1/2	12.7	16 or 26[f]	400 or 650[f]	H	5/16 min.	8.0
E7048	1/8	3.2	1/4	6.4	12	300	V-down & OH	1/4 max.	6.4
	5/32	4.0	3/8	9.5	12	300	V-down & OH	5/16 max.	8.0
	3/16	4.8	3/8	9.5	12 or 16[c]	300 or 400[c]	H & V-down	1/4 min.	6.4

Notes:

a. See Figure 3.

b. When the end of the bead with the first electrode will be less than 4 in. (100 mm) from the end of the test assembly, a starting tab or a longer test assembly shall be used.

c. For 14 in. (350 mm) electrodes, the minimum length of the test assembly shall be 12 in. (300 mm); for 18 in. (460 mm) electrodes, the minimum length of the test assembly shall be 16 in. (400 mm).

d. For 12 in. (300 mm) electrodes, the minimum length of the test assembly shall be 10 in. (250 mm); for 14 in. (350 mm) electrodes, the minimum length of the test assembly shall be 12 in. (300 mm).

e. E7024 only.

f. For 18 in. (460 mm) electrodes, the minimum length of the test assembly shall be 16 in. (400 mm); for 28 in. (700 mm) electrodes, the minimum length of the test assembly shall be 26 in. (650 mm).

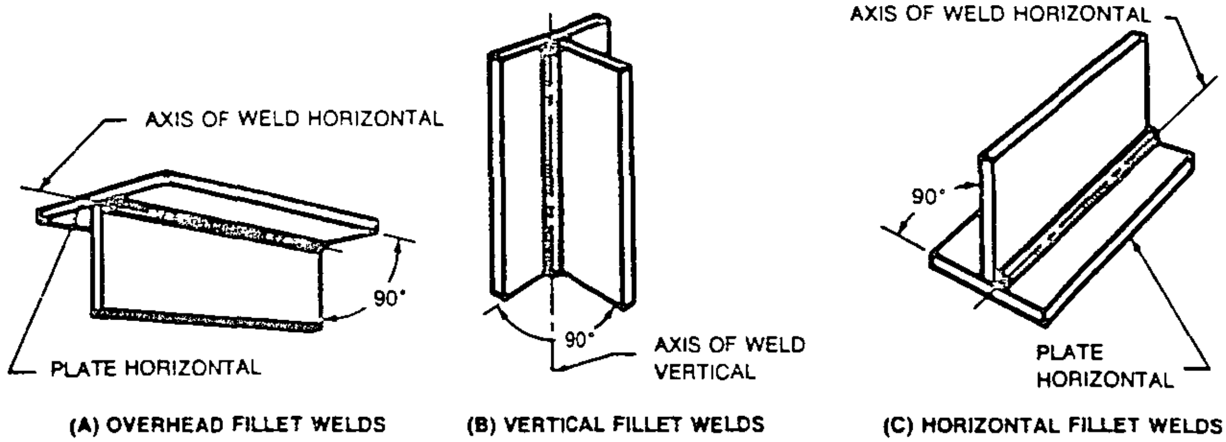


FIG. 6 — WELDING POSITIONS FOR FILLET WELD TEST ASSEMBLIES

11.4 The results of the tension test shall meet the requirements specified in Table 2.

12. Bend Test (For E6022 Electrodes Only)

12.1 One longitudinal face bend specimen, as required in Table 4, shall be machined from the groove weld test assembly described in 8.4.2 and shown in Fig. 4. Dimensions of the specimen shall be as shown in Fig. 10.

12.2 The bend specimen shall be aged at 200 to 220°F (95 to 105° C) for 48 ±2 hours then air cooled to room temperature and tested as required in 12.3.

12.3 The specimen shall be tested in the manner described in the bend testing section of AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. The specimen shall be bent uniformly through 180 degrees over a $^3/_4$ in. (19 mm) radius in any suitable jig. Three standard jigs are shown in Fig. 11. Positioning of the face bend specimen shall be such that the weld face of the last side welded is in tension.

12.4 Each specimen, after bending, shall conform to the $^3/_4$ in. (19 mm) radius, with an appropriate allowance for springback and the weld metal shall not contain openings in excess of 1/8 in. (3.2 mm) on the convex surface.

13. Impact Test

13.1 Five Charpy V-notch impact test specimens, Fig. 12, shall be machined from the test assembly shown in Fig. 2 or 5, for those classifications for which impact testing is required in Table 4.

13.2 The five specimens shall be tested in accordance with the fracture toughness testing section of AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. The test temperature shall be that specified in Table 3 for the classification under test.

13.3 In evaluating the test results for all the classifications that require impact testing, except E7018M, the lowest and highest values obtained shall be disregarded. Two of the three remaining values shall equal, or exceed, the specified 20 ft-lb (27J) energy level. One of the three may be lower, but not lower than 15 ft-lb (20J). The average of the three shall not be less than the required 20 ft-lb (27J) energy level.

13.4 In evaluating the results for E7018M, all five values shall be used. Four of the five values shall equal, or exceed, the specified 50 ft-lb (67J) energy level. One of the five may be lower, but not lower than 40 ft-lb (54J). The average of the five shall not be less than the required 50 ft-lb (67J) energy level.

14. Fillet Weld Test

14.1 The fillet weld test, when required in Table 4, shall be made in accordance with 8.5 and Fig. 3. The entire face of the completed fillet weld shall be examined visually. It shall be free of cracks, overlap, slag, and porosity, and shall be substantially free of undercut. An infrequent short undercut up to $^1/_{32}$ in. (0.8 mm) depth shall be allowed. After the visual examination, a specimen, approximately 1 in. (25 mm) in length, shall be removed as shown in Fig. 3. One cross-sectional surface of the specimen shall be polished, etched, and then examined as required in 14.2.

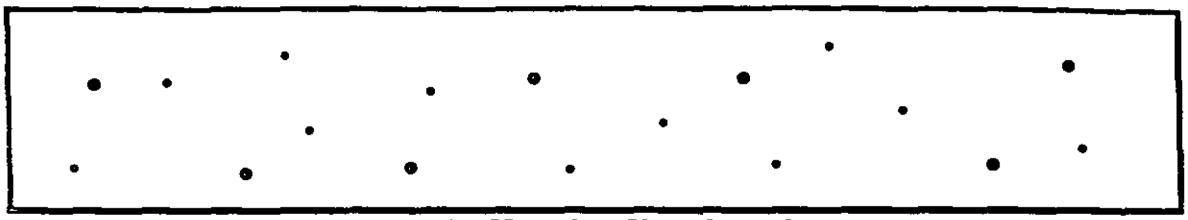
TABLE 7
CHEMICAL COMPOSITION REQUIREMENTS FOR WELD METAL

AWS Classification	UNS[a] Number	Weight, Percent[b]									Combined Limit for Mn + Ni + Cr + Mo + V
		C	Mn	Si	P	S	Ni	Cr	Mo	V	
E6010 E6011 E6012 E6013 E6019 E6020 E6022 E6027	W06010 W06011 W06012 W06013 W06019 W06020 W06022 W06027	Not Specified									
E7016 E7018 E7027	W07016 W07018 W07027	Not Specified	1.60	0.75	Not Specified		0.30	0.20	0.30	0.08	1.75
E7014 E7015 E7024	W07014 W07015 W07024	Not Specified	1.25	0.90	Not Specified		0.30	0.20	0.30	0.08	1.50
E7028 E7048	W07028 W07048	Not Specified	1.60	0.90	Not Specified		0.30	0.20	0.30	0.08	1.75
E7018M	W07018	0.12	0.40 to 1.60	0.80	0.030	0.020	0.25	0.15	0.35	0.05	Not Specified

Notes:

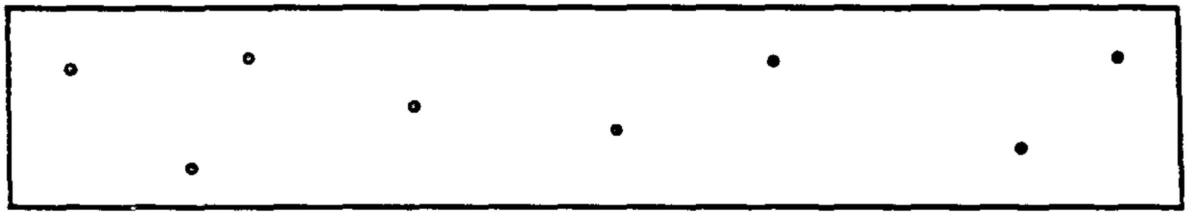
a. SAE/ASTM Unified Numbering System for Metals and Alloys

b. Single values are maximum.



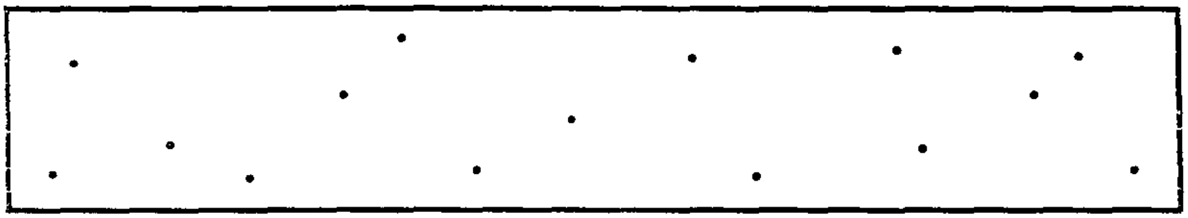
(A) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in. (0.4 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH. MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 18, WITH THE FOLLOWING RESTRICTIONS:
MAXIMUM NUMBER OF LARGE 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM 1/32 in. (0.8 mm) TO 3/64 in. (1.2 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 5.
MAXIMUM NUMBER OF SMALL 1/64 in. (0.4 mm) TO 1/32 in. (0.8 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 10.



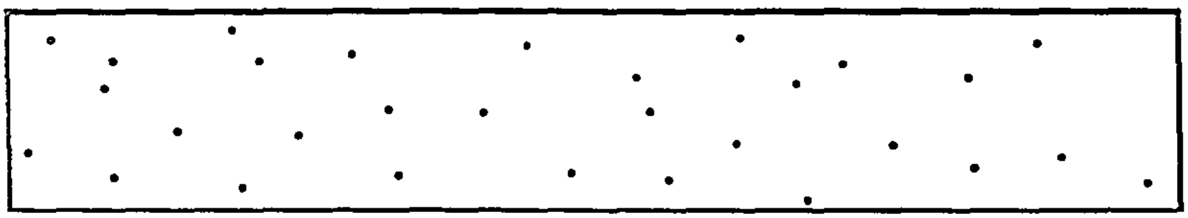
(B) LARGE ROUNDED INDICATIONS

SIZE 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 8



(C) MEDIUM ROUNDED INDICATIONS

SIZE 1/32 in. (0.8 mm) TO 3/64 in. (1.2 mm) IN DIAMETER OR IN LENGTH
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 15.

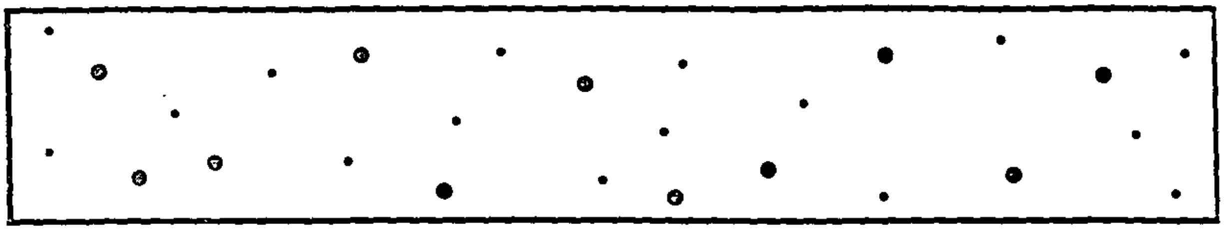


(D) SMALL ROUNDED INDICATIONS

SIZE 1/64 in. (0.4 mm) TO 1/32 in. (0.8 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 30.

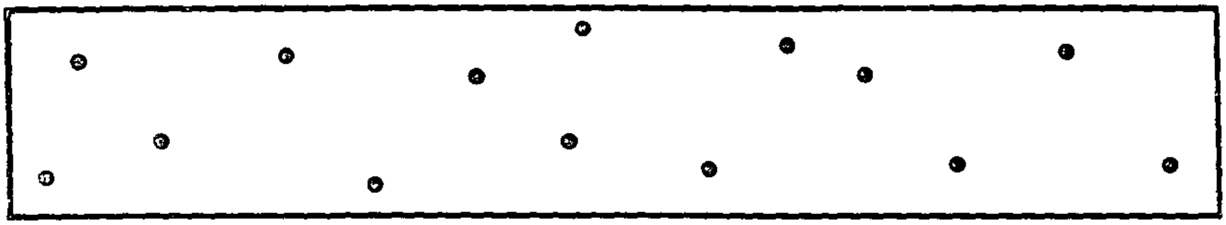
Notes:
1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.
3. Indications whose largest dimension does not exceed 1/64 in. (0.4 mm) shall be disregarded.

FIG. 7 — RADIOGRAPHIC ACCEPTANCE STANDARDS FOR ROUNDED INDICATIONS
(Grade 1)



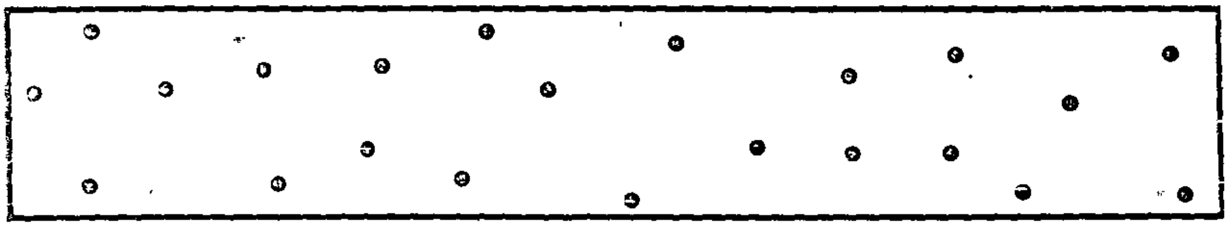
(E) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in. (0.4 mm) TO 5/64 in. (2.0 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 27, WITH THE FOLLOWING RESTRICTIONS:
MAXIMUM NUMBER OF LARGE 1/16 in. (1.6 mm) TO 5/64 in. (2.0 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 8.
MAXIMUM NUMBER OF SMALL 1/64 in. (0.4 mm) TO 3/64 in. (1.2 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 16.



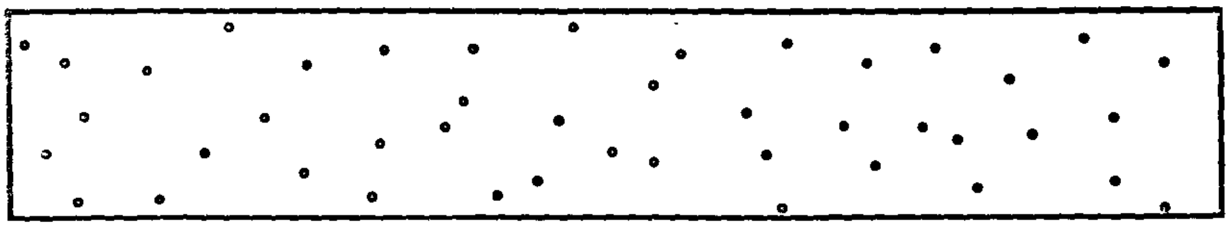
(F) LARGE ROUNDED INDICATIONS

SIZE 1/16 in. (1.6 mm) TO 5/64 in. (2.0 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 14.



(G) MEDIUM ROUNDED INDICATIONS

SIZE 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 22



(H) SMALL ROUNDED INDICATIONS

SIZE 1/64 in. (0.4 mm) TO 3/64 in. (1.2 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 44.

Notes:

1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.
3. Indications whose largest dimension does not exceed 1/64 in. (0.4 mm) shall be disregarded.

FIG. 7 — RADIOGRAPHIC ACCEPTANCE STANDARDS FOR ROUNDED INDICATIONS (Grade 2) (CONT'D)

TABLE 8
RADIOGRAPHIC SOUNDNESS REQUIREMENTS

AWS Classification	Radiographic Standard[a,b]
E6019 E6020 E7015 E7016 E7018 E7018M E7048	Grade 1
E6010 E6011 E6013 E7014 E7024 E6027 E7027 E7028	Grade 2
E6012 E6022	Not specified

Notes:

a. See Figure 7.

b. The radiographic soundness obtainable under actual industrial conditions employed for the various electrode classifications is discussed in A6.10.1 in the Appendix

14.2 Scribe lines shall be placed on the prepared surface, as shown in Fig. 13, and the fillet weld size, fillet weld leg, and convexity shall be determined to the nearest $^1/_{64}$ in. (0.4 mm) by actual measurement (see Fig. 13). These measurements shall meet the requirements of Table 6 with respect to minimum or maximum fillet weld size and the requirements of Table 9 with respect to maximum convexity and maximum difference between fillet weld legs according to the fillet weld size measured.

14.3 The remaining two sections of the test assembly shall be broken through the fillet weld by a force exerted as shown in Fig. 14. When necessary to facilitate fracture through the fillet, one or more of the following procedures may be used.

(1) A reinforcing bead, as shown in Fig. 14, may be added to each leg of the weld.

(2) The position of the web on the flange may be changed, as shown in Fig. 14

(3) The face of the fillet may be notched, as shown in Fig. 14.

Tests in which the weld metal pulls out of the base metal during bending are invalid tests. Specimens in which this occurs shall be replaced, specimen for specimen, and the test completed. In this case, the doubling of specimens as required for retest in Section 7, Retest, does not apply.

14.4 The fractured surfaces shall be visually examined without magnification The fracture surface shall be free of cracks Incomplete fusion at the weld root shall not be greater than 20% of the total length of the weld. There shall be no continuous length of incomplete fusion greater than 1 in. (25 mm) as measured along the weld axis except for electrodes of the E6012, E6013, and E7014 classifications. Fillet welds made with electrodes of these classifications may exhibit incomplete fusion through the entire length of the fillet weld, provided that at no point this incomplete fusion exceeds 25 percent of the smaller leg of the fillet weld.

15. Moisture Test

15.1 The moisture content of the covering on the low hydrogen electrodes, when required in Table 4, shall be determined by any suitable method In case of dispute, the method described in 15.3 through 15.9 shall be the referee method.

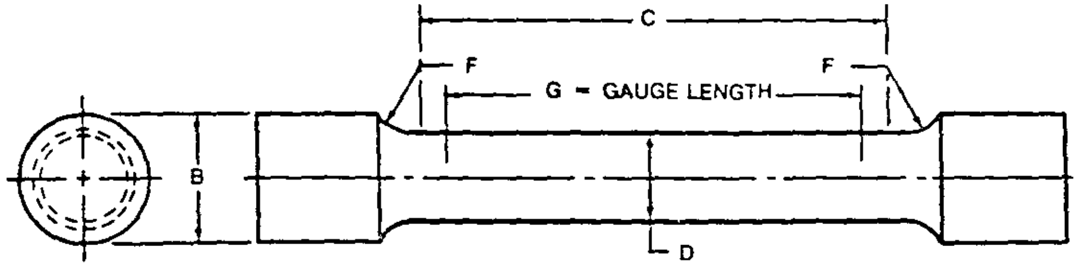
15.2 The electrodes shall be tested without conditioning, unless the manufacturer recommends otherwise If the electrodes are conditioned, that fact, along with the method used for conditioning, and the time and temperature involved in the conditioning, shall be noted on the test record. The moisture content shall not exceed the limit specified in Table 10.

15.3 This method (the referee method) consists of heating a sample of the covering in a nickel or clay boat placed inside a combustion tube in order to remove the moisture from the covering. A stream of oxygen is used to carry the moisture to an absorption tube where the moisture is collected. The moisture content of the covering is determined by the increase in weight of the absorption tube and is expressed as a percentage of the original weight of the sample of the covering.

15.4 The apparatus shall be as shown in Fig. 15[5] and shall consist of the following:

(1) A tube furnace with a heating element long enough to heat at least 6 in. (150 mm) of the middle portion of the combustion tube to 2000°F (1093°C).

[5] Modifications of the type described in Appendix A8, which give equivalent results, also meet the requirements of this specification.

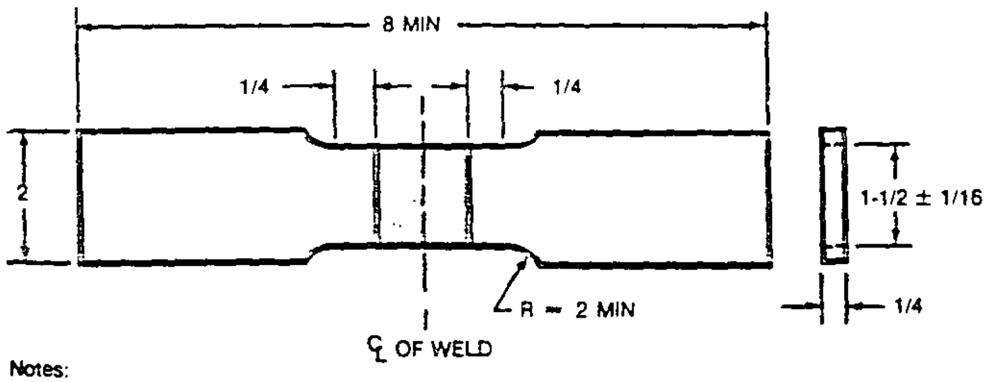


Dimensions of Specimen, in					
Test Plate Thickness	D	G	C	B	F, Min.
1/2	0.250 ± 0.005	1.000 ± 0.005	1-1/4	3/8	3/16
3/4 and larger	0.500 ± 0.010	2.000 ± 0.005	2-1/4	3/4	3/8

Dimensions of Specimen, mm					
Test Plate Thickness	D	G	C	B	F, Min
12.7	6.40 ± 0.13	25.40 ± 0.13	32	9.5	4.8
19 and larger	12.70 ± 0.25	50.80 ± 0.13	57	19	9.5

Notes:
1. Dimensions G and C shall be as shown, but ends may be of any shape to fit the testing machine holders as long as the load is axial.
2. The diameter of the specimen within the gauge length shall be slightly smaller at the center than at the ends. The difference shall not exceed one percent of the diameter.
3. When the extensometer is required to determine yield strength, dimension C may be modified. However, the percent of the elongation shall be based on dimension G.
4. The surface finish within the C dimension shall be no rougher than 63 μ in. (1.6 μ m)

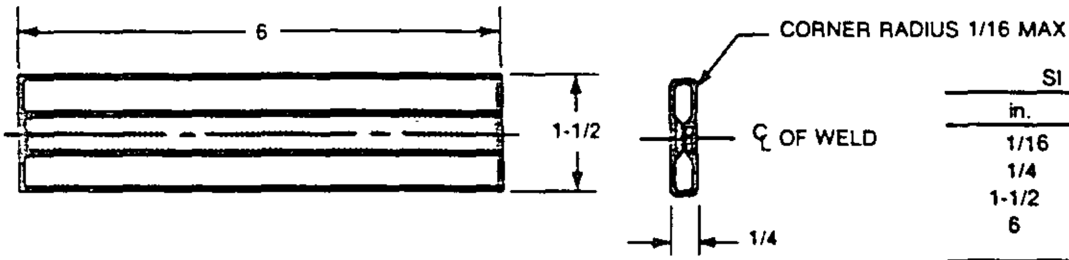
FIG. 8 — ALL-WELD-METAL TENSION TEST SPECIMEN DIMENSIONS



SI Equivalents	
in	mm
1/4	6.4
1-1/2 ± 1/16	38.1 ± 1.6
2	51
8	203

Notes:
1. All dimensions are in inches.
2. Weld reinforcement shall be ground or machined smooth and flush with the surfaces of the specimen. Grinding or machining marks shall be parallel of the longest dimension of the specimen.

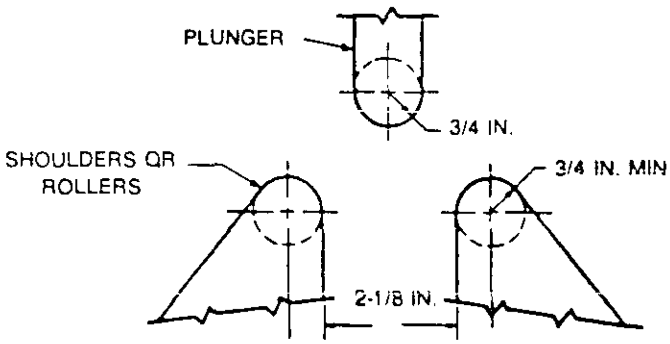
FIG. 9 — TRANSVERSE TENSION TEST SPECIMEN (E6022)



SI Equivalents	
in.	mm
1/16	1.6
1/4	6.4
1-1/2	38
6	152

Notes:
1. All dimensions are in inches.
2. Weld reinforcement shall be ground or machined smooth and flush with the surfaces of the specimen. Grinding or machining marks shall be parallel to the length of the weld.

FIG. 10 — LONGITUDINAL GUIDED—BEND TEST SPECIMEN (E6022)

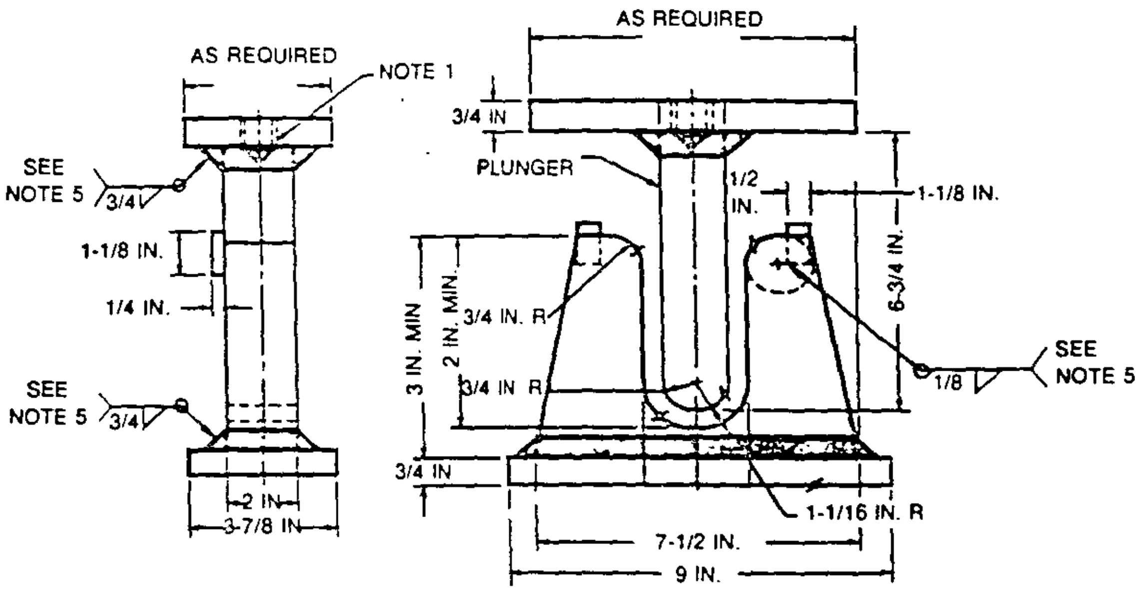


in.	mm
1/16	1.6
3/4	19
2-1/8	54

(A) BOTTOM EJECTING GUIDED-BEND TEST JIG

Notes
1. Either hardened and greased shoulders or hardened rollers free to rotate shall be used.
2. The shoulders or rollers shall have a minimum bearing length of 2 in. (51 mm) for placement of the specimen.
3. The shoulders or rollers shall be high enough above the bottom of the testing jig so that the specimen will clear the shoulders or rollers when the plunger is in the low position.
4. The plunger shall be fitted with an appropriate base and provision for attachment to the testing machine and shall be designed to minimize deflection or misalignment.
5. The shoulder or roller supports may be made adjustable in the horizontal direction so that specimens of various thickness may be tested in the same jig
6. The shoulder or roller supports shall be fitted to a base designed to maintain the shoulders or rollers centered and aligned with respect to the plunger, and to minimize deflection or misalignment.

FIG. 11 — BEND TEST JIGS

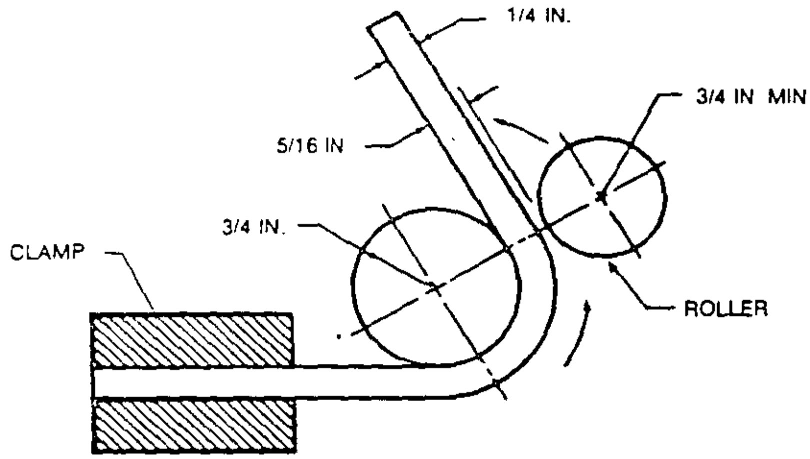


SI Equivalents	
in.	mm
1/16	1.6
1/8	3.2
1/4	6.4
1/2	12.7
3/4	19
1-1/16	27
1-1/8	29
2	51
3	76
3-7/8	98
6-3/4	171
7-1/2	191
9	229

(B) BOTTOM GUIDED-BEND TEST JIG

Notes:

1. A tapped hole of appropriate size, or other suitable means for attaching plunger to testing machine shall be made.
2. Either hardened and greased shoulders or hardened rollers free to rotate shall be used in the die.
3. The plunger and base shall be designed to minimize deflection and misalignment.
4. The specimen shall be forced into the die by applying the load on the plunger until the curvature of the specimen is such that a 1/8 in. (3.0 mm) diameter wire cannot be placed between the specimen and all points in the curvature of the die member of the jig.
5. Weld size indicated is a recommendation. The actual size is the responsibility of the user to ensure rigidity and design adequacy.



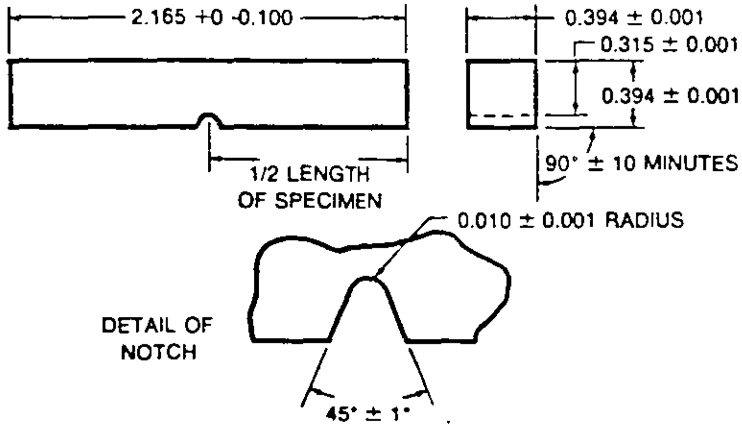
SI Equivalents	
in.	mm
1/4	6.4
5/16	7.9
3/4	19

(C) WRAP-AROUND GUIDED BEND TEST JIG

Notes:

1. Dimensions not shown are the option of the designer, except that the minimum width of the components shall be 2 in. (51 mm).
2. It is essential to have adequate rigidity so that the jig will not deflect during testing. The specimen shall be firmly clamped on one end so that is does not slide during the bending operation.
3. Test specimens shall be removed from the jig when the outer roll has traversed 180° from the starting point.

FIG. 11 — BEND TEST JIGS (CONTINUED)



SI Equivalents

in	mm
0.001	0.025
0.010	0.255
0.040	1.0
0.10	2.5
0.315	8.0
0.394	10.0
1.082	27.5
2.165	55.0

Notes:

1. All dimensions except angles are in inches.
2. The notched surface and the surface to be struck shall be parallel within 0.002 in. (0.05 mm) and have at least 63 μ in. (1.6 μm) finish. The other two surfaces shall be square with the notched or struck surface within ± 10 minutes of the degree and have at least 125μin (3.2 μm) finish.
3. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.
4. The geometry of the notch shall be measured on at least one specimen in a set of five specimens Measurement shall be done at minimum 50 times magnification on either a shadowgraph or a metallograph.
5. The correct location of the notch shall be verified by etching before or after machining
6. If a specimen does not break upon being struck, the value for energy absorbed shall be reported as the capacity of the impact testing machine followed by a plus sign (+)

FIG. 12 — CHARPY V-NOTCH IMPACT TEST SPECIMEN

(2) An oxygen purifying train consisting of a needle valve, a flow meter, a 96% sulfuric acid wash bottle, a spray trap, and an anhydrous magnesium perchlorate drying tower

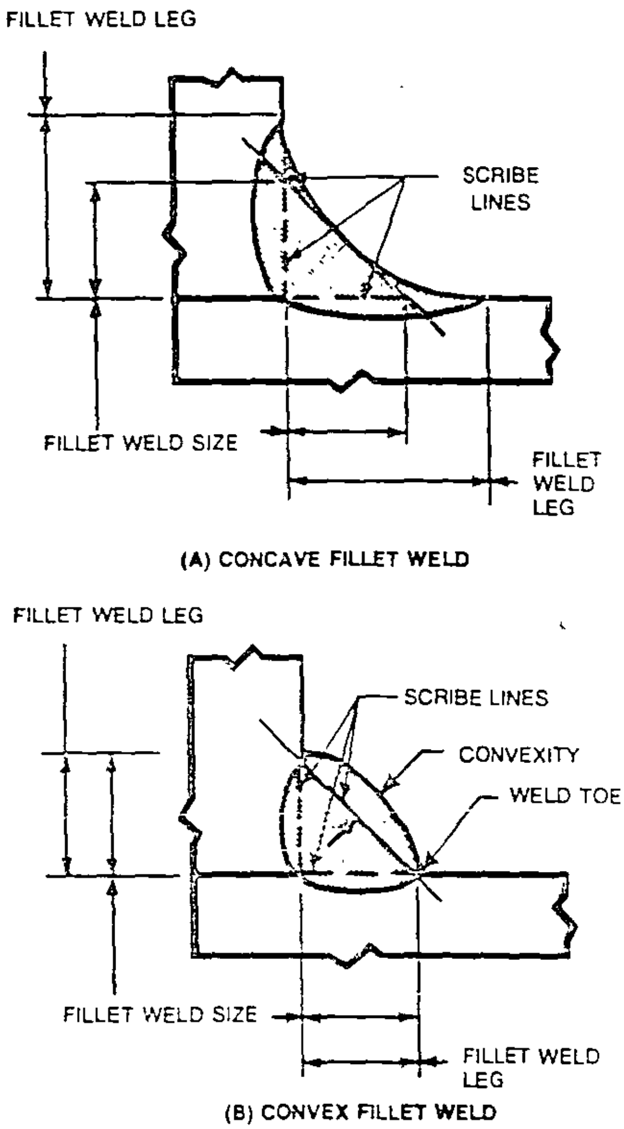
(3) A fused silica combustion tube of at least $^7/_8$ in. (22 mm) inside diameter with plain ends and a devitrification point above 2000°F (1093°C). (A high-temperature ceramic tube can be used, but a higher value will be obtained for the blanks.) A plug of glass wool fine enough to filter the gases shall be inserted far enough into the exit end of the combustion tube to be heated to a temperature of 400 to 500°F (204 to 260°C).

(4) A water absorption train consisting of a U-tube (Schwartz-type) filled with anhydrous magnesium perchlorate and a concentrated sulfuric acid gas-sealing bottle.

15.5 In conducting this test, a sample of approximately 4 grams of covering shall be prepared as a composite of the covering from the middle of three electrodes taken from the same package. The covering shall be removed by bending the electrode or by pinching the covering with clean, dry pliers or forceps. Immediately upon removal, the sample of covering shall be transferred to a dried, stoppered vial or sample bottle

15.6 The furnace shall be operated at 1800°F ± 25°F (982°C ± 14°C) with an oxygen flow of 200 to 250 ml per minute. The empty boat (see 15.3) shall be placed in the hot zone of the combustion tube, for drying, and the absorption U-tube assembly shall be attached to the system for "conditioning." After 30 minutes, the absorption U-tube shall be removed and placed in the balance case. The boat shall be removed and placed in a desiccator in which anhydrous magnesium perchlorate is used as a desiccant. After a cooling period of 20 minutes, the absorption U-tube shall be weighed.

15.7 In the blank determination, the procedure for an actual moisture determination shall be followed step-by-step with a single exception of omitting the sample. The boat shall be removed from the desiccator and exposed to the atmosphere for a period approximating the time required to transfer a sample from the balance pan to the boat. The combustion tube shall be opened, the weighed absorption U-tube attached, the boat placed in the hot zone of the combustion tube, and the tube closed. After a heating period of 30 minutes, the ab-



Note

1. Fillet weld size is the leg lengths of the largest isosceles right triangle which can be inscribed within the fillet weld cross section
2. Convexity is the maximum distance from the face of a convex fillet weld perpendicular to a line joining the weld toes.
3. Fillet weld leg is the distance from the joint root to the toe of the fillet weld.

FIG. 13 — DIMENSIONS OF FILLET WELDS

sorption U-tube shall be removed and placed in the balance case. The boat shall be transferred to the desiccator. After the 20 minute cooling period, the absorption U-tube shall be weighed and the gain in weight shall be taken as the blank value.

15.8 Immediately after weighing the absorption U-tube above, the sample of the covering shall be weighed and quickly transferred to the boat. The combustion tube shall be opened, the weighed absorption U-tube attached, the boat with sample transferred to the hot zone of the combustion tube, and the tube closed. After heating for 30 minutes, the absorption U-tube shall be removed and placed in the balance case. If another sample is to be run, the boat shall be taken from the combustion tube, the sample removed, and the boat transferred to the desiccator. The absorption U-tube shall be weighed after the 20 minute cooling period. Another determination may be started immediately, since it is not necessary to repeat the blank determination, provided the same combustion boat can be used.

15.9 The calculation shall be made according to the following formula:

$$\text{Percent Moisture} = \frac{A - B}{\text{Weight of Sample}} \times 100$$

where:

A = gain in weight of absorption tube in moisture determination

B = gain in weight of absorption tube in blank determination

16. Absorbed Moisture Test

16.1 In order for a low hydrogen electrode to be designated as low-moisture-absorbing with the "R" suffix designator or classified as E7018M, sufficient electrodes shall be exposed to an environment of 80°F (26.7°C)/80% relative humidity for a period of not less than 9 hours by any suitable method. In case of dispute, the exposure method described in 16.2 through 16.6 shall be the referee method. The moisture content of the electrode covering on the low-moisture-absorbing, low hydrogen electrodes (E7015R, E7016R, E7016-1R, E7018R, E7018-1R, E7018M, E7028R, E7048R) shall be determined by any suitable method. In case of dispute, the method described in 15.3 through 15.9 shall be the referee method for determination of moisture content. The moisture content of the exposed covering shall not exceed the maximum

TABLE 9
DIMENSIONAL REQUIREMENTS FOR FILLET WELD USABILITY TEST SPECIMENS

Measured Fillet Weld Size		Maximum Convexity		Maximum Difference Between Fillet Weld Legs	
in.	mm	in.	mm	in.	mm
1/8	3.2	3/64	1.2	1/32	0.8
5/32	4.0	3/64	1.2	3/64	1.2
3/16	4.8	1/16	1.6	1/16	1.6
7/32	5.6	1/16	1.6	5/64	2.0
1/4	6.4	1/16	1.6	3/32	2.4
9/32	7.1	1/16	1.6	7/64	2.8
5/16	8.0	5/64	2.0	1/8	3.2
11/32	8.7	5/64	2.0	9/64	3.6
3/8	9.5	5/64	2.0	5/32	4.0

specified moisture content for the designated electrode and classification in Table 10

16.2 An electrode sample of each size of E7018M or the smallest and the largest sizes of "R" designated electrode shall be exposed. If the electrodes are conditioned prior to exposure, that fact, along with the method used for conditioning, and the time and temperature involved in conditioning, shall be noted on the test record. Conditioning of electrodes after exposure is not permitted.

16.3 The electrode sample shall be exposed in a suitably calibrated and controlled environmental chamber for nine hours minimum at 80°F, minus 0, plus 5°F (26.7°C, minus 0, plus 2.8°C) and 80% RH, minus 0, plus 5%.

16.4 The environmental chamber shall meet the following design requirements

(1) The apparatus shall be an insulated humidifier which produces the temperature of adiabatic saturation through regenerative evaporation or vaporization of water.

(2) The apparatus shall have an average air speed within the envelope of air surrounding the covered electrode of 100 to 325 fpm (0.5 to 1.7 m/sec.).

(3) The apparatus shall have a drip-free area where the covered electrode up to 18 in. (450 mm) in length can be positioned with length as perpendicular as practical to the general air flow

(4) The apparatus shall have a calibrated means of continuously measuring and recording the dry bulb temperature and either the wet bulb temperature or the differential between the dry bulb and wet bulb temperature over the period of time required.

(5) The apparatus shall have an air speed of at least 900 fpm (4.5 m/s) over the wet bulb sensor unless the wet bulb sensor can be shown to be insensitive to air speed or has a known correction factor that will provide for an adjusted wet bulb reading equal to the temperature of adiabatic saturation.

(6) The apparatus shall have the wet bulb sensor located on the suction side of the fan so that there is an absence of heat radiation on the sensor.

16.5 The exposure procedure shall be as follows.

(1) The electrode sample in unopened packages, or from reconditioned lots, shall be heated to a temperature, minus 0, plus 10°F (6°C) above the dew point of the chamber at the time of loading.

(2) The electrode sample shall be loaded into the chamber without delay after the packages are opened.

(3) The electrodes shall be placed in the chamber in a vertical or horizontal position on 1 in. (25 mm) centers, with the length of the electrode perpendicular as practical to the general air flow.

(4) Time, temperature, and humidity shall be continuously recorded for the period that the electrodes are in the chamber.

(5) Counting of the exposure time shall start when the required temperature and humidity in the chamber are established.

(6) At the end of the exposure time, the electrodes shall be removed from the chamber and a sample of the electrode covering taken for moisture determination, as specified in Section 15, Moisture Test.

16.6 The manufacturer shall control other test variables which are not defined, but which must be controlled to ensure a greater consistency of results.

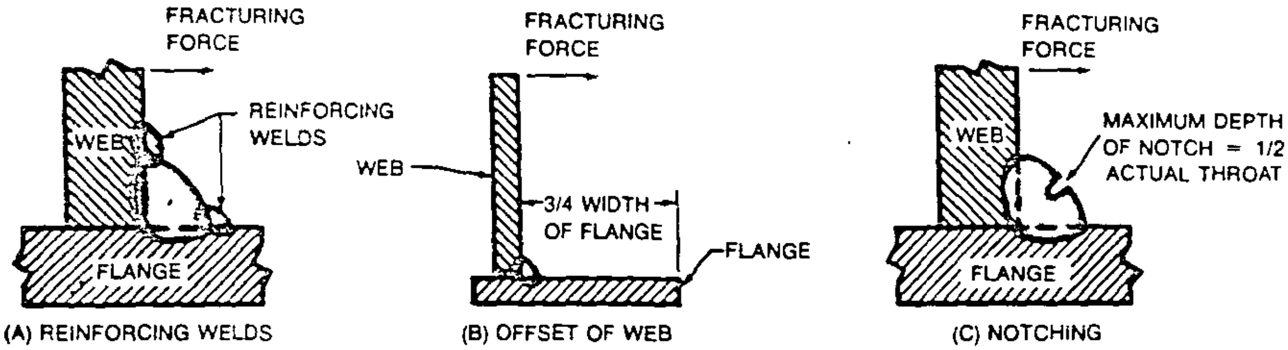


FIG. 14 — ALTERNATIVE METHODS FOR FACILITATING FRACTURE OF THE FILLET WELD

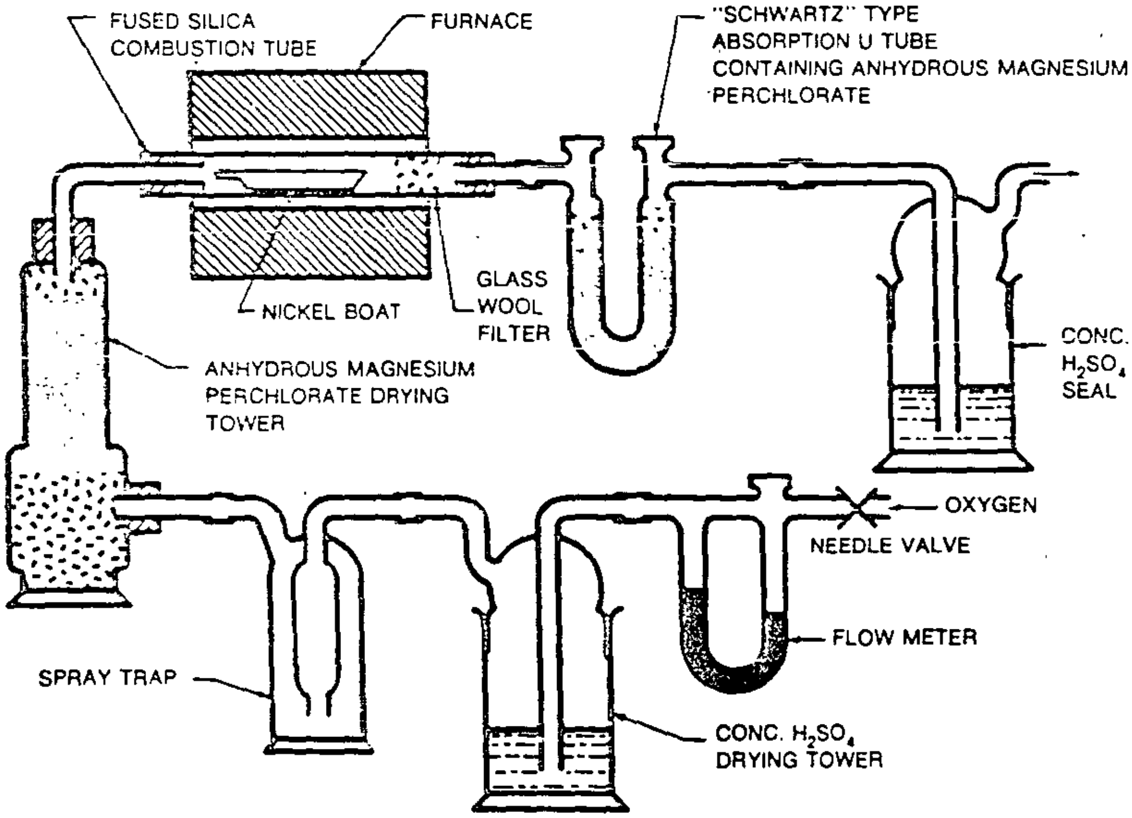


FIG. 15 — SCHEMATIC OF TRAIN FOR MOISTURE DETERMINATIONS

TABLE 10
MOISTURE CONTENT LIMITS IN ELECTRODE COVERINGS

AWS Classification	Electrode Designation	Limit of Moisture Content, % by Wt., Max. As-Received or Conditioned[a]	As-Exposed[b]
E7015	E7015	0.6	Not specified
E7016	E7016, E7016-1	0.6	Not specified
E7018	E7018, E7018-1	0.6	Not specified
E7028	E7028	0.6	Not specified
E7048	E7048	0.6	Not specified
E7015	E7015R	0.3	0.4
E7016	E7016R, E7016-1R	0.3	0.4
E7018	E7018R, E7018-1R	0.3	0.4
E7028	E7028R	0.3	0.4
E7048	E7048R	0.3	0.4
E7018M	E7018M	0.1	0.4

Notes:

a. As-received or conditioned electrode coverings shall be tested as specified in Section 15, Moisture Test.

b. As-exposed electrode coverings shall have been exposed to a moist environment as specified in 16.2 through 16.6 before being tested as specified in 16.1.

TABLE 11
DIFFUSIBLE HYDROGEN LIMITS FOR WELD METAL

AWS Classification	Diffusible Hydrogen Designator	Diffusible Hydrogen Content, Average mL(H_2)/100g Deposited Metal, Max.[a,b]
E7018M	None	4.0
E7015, E7016, E7018, E7028, E7048	H16	16.0
E7015, E7016, E7018, E7028, E7048	H8	8.0
E7015, E7016, E7018, E7028, E7048	H4	4.0

Notes:

a. Diffusible hydrogen testing in Section 17, Diffusible Hydrogen Test, is required for E7018M. Diffusible hydrogen testing of other low hydrogen electrodes is only required when diffusible hydrogen designator is added as specified in Figure 16.

b. Some low hydrogen classifications may not meet the H4 and H8 requirements.

TABLE 12
STANDARD SIZES AND LENGTHS

Standard Sizes,[a] (Core Wire Diameter)			Standard Lengths[a,b]					
			E6010, E6011, E6012, E6013, E6022, E7014, E7015, E7016, E7018 E7018M		E6020, E6027, E7024 E7027, E7028, E7048		E6019	
in.		mm	in.	mm	in.	mm	in.	mm
1/16[c]	(0.063)	1.6[c]	9	230	—	—	—	—
5/64[c]	(0.072)	2.0[c]	9 or 12	230 or 300	—	—	9 or 12	230 or 300
3/32[c]	(0.094)	2.4[c]	12 or 14	300 or 350	12 or 14	300 or 350	12 or 14	300 or 350
1/8	(0.125)	3.2	14	350	14	350	14	350
5/32	(0.156)	4.0	14	350	14	350	14 or 18	350 or 450
3/16	(0.188)	4.8	14	350	14 or 18	350 or 460	14 or 18	350 or 450
7/32[c]	(0.219)	5.6[c]	14 or 18	350 or 460	18 or 28	460 or 700	18	450
1/4[c]	(0.250)	6.4[c]	18	460	18 or 28	460 or 700	18	450
5/16[c]	(0.313)	8.0[c]	18	460	18 or 28	460 or 700	18	450

Notes:
a. Lengths and sizes other than these shall be as agreed to by purchaser and supplier.
b. In all cases, end-gripped electrodes are standard.
c. These diameters are not standard sizes for all classifications (see Table 4).

17. Diffusible Hydrogen Test

The smallest and largest sizes of the electrode of each classification to be designated by an optional supplemental diffusible hydrogen designator and all sizes of E7018M, shall be tested according to one of the methods given in ANSI/AWS A4.3 *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*. Testing shall be done without "conditioning" of the electrode, unless the manufacturer recommends otherwise. If the electrodes are conditioned, that fact, along with the method used for conditioning, and the time and temperature involved in conditioning, shall be noted on the test record. The diffusible hydrogen designator may be added to the classification according to the average test value as compared to the requirements of Table 11.

For purposes of certifying compliance with diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of 10 grains of water vapor per pound (1.43 g/kg) of dry air at the time of welding. The actual atmospheric conditions shall be reported along with the average value for the test according to ANSI/AWS A4.3 (See Appendix, A9.2).

When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification, provided the actual test results satisfy the diffusible hydrogen requirements for the applicable designator. Likewise, if the acutal test results for an electrode meet the requirements for the lower or lowest hydrogen designator, as specified in Table 11, the electrode also meets the requirements for all higher hydrogen designators in Table 11 without the need to retest.

SECTION C — MANUFACTURE, IDENTIFICATION, AND PACKAGING

18. Method of Manufacture

The electrodes classified according to this specification may be manufactured by any method that will produce electrodes that meet the requirements of this specification.

19. Standard Sizes and Lengths

19.1 Standard sizes (diameter of the core wire) and lengths of electrodes are shown in Table 12.

19.2 The diameter of the core wire shall not vary more than ± 0.002 in. (± 0.05 mm) from the diameter specified. The length shall not vary more than ± 1/4 in. (± 10 mm) from that specified.

20 Core Wire and Covering

20.1 The core wire and covering shall be free of defects that would interfere with uniform deposition of the electrode.

Mandatory Classification Designators:*

Designates an electrode. This designator may be deleted from the product imprint required for identification of the electrode.

Designates the tensile strength (minimum), in ksi, of the weld metal when produced in accordance with the test assembly preparation procedure of this specification. See Table 2.

Designates the welding position in which electrodes are usable, the type of covering, and the kind of welding current for which the electrodes are suitable. See Table 1.

E XX YY
E XX YY M
E XX YY -1 HZ R

Designates an electrode (E7018M) intended to meet most military requirements (greater toughness, lower moisture content — both as-received and after exposure — and mandatory diffusible hydrogen limits for weld metal). See Table 3, 10 and 11.

Optional Supplemental Designators:

Designates that the electrode meets the requirements of the absorbed moisture test (an optional supplemental test for all low hydrogen electrodes except the E7018M classification, for which the test is required). See Table 10.

Designates that the electrode meets the requirements of the diffusible hydrogen test (an optional supplemental test of the weld metal from low hydrogen electrodes, as-received or conditioned — with an average value not exceeding "Z" mL of H_2 per 100g of deposited metal, where "Z" is 4, 8, or 16). See Table 11.

Designates that the electrode (E7016, E7018, or E7024) meets the requirements for improved toughness — and ductility in the case of E7024 — (optional supplemental test requirements shown in Tables 2 and 3). See notes to Tables 2 and 3.

Note:
* The combination of these designators constitutes the electrode classification.

FIG. 16 — ORDER OF ELECTRODE MANDATORY AND OPTIONAL SUPPLEMENTAL DESIGNATORS

20.2 The core wire and the covering shall be concentric to the extent that the maximum core-plus-one-covering dimension shall not exceed the minimum core-plus-one-covering dimension by more than

(1) 7% of the mean dimension in sizes $^3/_{32}$ in (2.4 mm) and smaller;

(2) 5% of the mean dimension in sizes $^1/_8$ in. (3.2 mm) and $^5/_{32}$ in. (4.0 mm);

(3) 4% of the mean dimension in sizes $^3/_{16}$ in (4.8 mm) and larger.

Concentricity may be measured by any suitable means.

21. Exposed Core

21.1 The grip end of each electrode shall be bare (free of covering) for a distance of not less than $^1/_2$ in. (12 mm), nor more than $1^1/_4$ in. (30 mm) for $^5/_{32}$ in. (4.0 mm) and smaller sizes, and not less than $^3/_4$ in. (19 mm) nor more than $1^1/_2$ in. (40 mm) for $^3/_{16}$ in. (4.8 mm) and larger sizes, to provide for electrical contact with the electrode holder.

21.2 The arc end of each electrode shall be sufficiently bare and the covering sufficiently tapered to permit easy striking of the arc. The length of the bare portion (measured from the end of the core wire to the location where the full cross-section of the covering is obtained) shall not exceed $^1/_8$ in. (3 mm) or the diameter of the core wire, whichever is less. Electrodes with chipped coverings near the arc end, baring the core wire no more than the lesser of $^1/_4$ in. (6 mm) or twice the diameter of the core wire, meet the requirements of this specification, provided no chip uncovers more than 50% of the circumference of the core.

22. Electrode Identification

All electrodes shall be identified as follows:

22.1 At least one imprint of the electrode designation (classification plus any optional designators) shall

Appendix
Guide to AWS Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding

(This Appendix is not a part of ANSI/AWS A5.1-91, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*, but is included for information purpose only.)

A1. Introduction

This guide was designed to correlate the covered electrode classification with the intended applications so the specification can be used effectively. Such correlations are intended as examples rather than complete listings of the base metals for which each filler metal is suitable.

A2. Classification System

A2.1 The system for electrode classification in the specification follows the established pattern used in other AWS filler metal specifications. The letter "E" at the beginning of each classification designation stands for an electrode. The first two digits, 60, for example, designate tensile strength of at least 60 ksi of the weld metal, produced in accordance with the test assembly preparation section of the specification. The third digit designates position usability that will allow satisfactory welds to be produced with the electrode. Thus, the "1," as in E6010, means that the electrode is usable in all positions (flat, horizontal, vertical, and overhead). The "2," as in E6020, designates that the electrode is suitable for use in flat position and for making fillet welds in the horizontal position. The "4," in E7048, designates that the electrode is suitable for use in vertical welding with downward progression and for other positions (see Table 1). The last two digits taken together designate the type of current with which the electrode can be used and the type of covering on the electrode, as listed in Table 1.

A2.2 Optional designators are also used in this specification in order to identify electrodes that have met the mandatory classification requirements and certain supplementary requirements as agreed to between the supplier and the purchaser. A "-1" designator following classification identifies an electrode which meets optional supplemental impact requirements at a lower temperature than required for the classification (see Note b to Table 3). An example of this is the E7024-1 electrode which meets the classification requirements of E7024 and also meets the optional supplemental requirements for fracture toughness and improved elongation of the weld metal (see Note c to Table 2). Certain low hydrogen electrodes also may have optional designators

A letter "R" is a designator used with the low hydrogen electrode classifications. The letter "R" is used to identify electrodes that have been exposed to a humid environment for a given length of time and tested for moisture absorption in addition to the standard moisture test required for classification of low hydrogen electrodes. See Section 16, Absorbed Moisture Test, and Table 10.

An optional supplemental designator "HZ" following the four digit classification designators or following the "-1" optional supplemental designator, if used, indicates an average diffusible hydrogen content of not more than "Z" ml/100g of deposited metal when tested in the "as-received" or conditioned state in accordance with ANSI/AWS A4.3, *Standard Methods for Determination of Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*. Electrodes that are designated as meeting the lower or lowest hydrogen limits, as specificed in Table 11, are also understood to be able to meet any higher hydrogen limits even though these are not necessarily designated along with the electrode classification. Therefore, as an example, an electrode designated as "H4" also meets "H8" and "H16" requirements without being designated as such. See Section 17, Diffusible Hydrogen Test, and Table 11.

A2.3 Table A1 shows the classification for similar electrodes from Canadian Standards Association Specification W48.1-M1980, *Mild Steel Covered Arc Welding Electrodes*.

applied to the electrode covering in the order specified in Fig. 16 within 2-$^1/_2$ in. (65 mm) of the grip end of the electrode

22.2 The numbers and letters of the imprint shall be of bold block type of a size large enough to be legible

22.3 The ink used for imprinting shall provide sufficient contrast with the electrode covering so that, in normal use, the numbers and letters are legible both before and after welding

22.4 The prefix letter "E" in the electrode classification designation may be omitted from the imprint

23. Packaging

23.1 Electrodes shall be suitably packaged to protect them from damage during shipment and storage under normal conditions. In addition, E7018M electrodes shall be packaged in hermetically sealed containers. Hermetically sealed containers shall be capable of passing the test specified in 23 2.

23.2 For the test, a representative container shall be immersed in water that is at a temperature of at least 50°F (27°C) above that of the packaged material (room temperature). The container shall be immersed so that the surface under observation is approximately 1 in (25 mm) below the water level and the greatest dimension is parallel to the water surface. A container with a stream of bubbles that lasts for 30 seconds or more does not meet the requirements of this specification

23.3 Standard package weights shall be as agreed upon between purchaser and supplier.

24. Marking of Packages

24.1 The following product information (as a minimum) shall be legibly marked on the outside of each unit package.

(1) AWS specification and classification designations (year of issue may be excluded)

(2) Supplier's name and trade designation

(3) Size and net weight

(4) Lot, control, or heat number

24.2 The following precautionary information (as a minimum) shall be prominently displayed in legible print on all packages of electrodes, including individual unit packages enclosed within a larger package.

WARNING:

•Protect yourself and others. Read and understand this information. FUMES AND GASES can be dangerous to your health. ARC RAYS can injure eyes and burn skin. ELECTRIC SHOCK can kill.

- Before use, read and understand the manufacturer's instructions, Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone, and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch electrical parts
- See American National Standard Z49.1, *Safety in Welding and Cutting*, published by the American Welding Society, 550 North LeJeune Road, P O. Box 351040, Miami, Florida, 33135; *OSHA Safety and Health Standards*, 29 CFR 1910, available from the U.S. Government Printing Office, Washington, D C. 20402.

DO NOT REMOVE THIS INFORMATION

TABLE A1
CANADIAN ELECTRODE CLASSIFICATIONS SIMILAR TO AWS CLASSIFICATIONS (For Information Only)

Canadian Electrode Classification[a]	AWS Classification
E41000	—
E41010	E6010
E41011	E6011
E41012	E6012
E41013	E6013
E41022	E6022
E41027	E6027
E48000	—
E48010	—
E48011	—
E48012	—
E48013	—
E48014	E7014
E48015	E7015
E48016	E7016
E48018[b]	E7018
E48022	—
E48024	E7024
E48027	E7027
E48028	E7028
E48048	E7048

Notes:

a. From CSA Standard W48.1-M1980, *Mild Steel Covered Arc Welding Electrodes*, published by Canadian Standards Association, 178 Rexdale Boulevard, Rexdale, Ontario, Canada M9W 1R3.

b. Also includes E48018-1 designated electrode.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*, as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this Specification, shall be clearly stated in the purchase order, according to the provisions of ANSI/AWS A5.01. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing normally is performed on material of that classification, as specified in Schedule F, Table 1, of ANSI/AWS A5.01. Testing in accordance with any other Schedule in that Table must be specifically required by the purchase order. In such cases, acceptance of the material shipped shall be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance Program" in ANSI/AWS A5.01.

A5. Ventilation During Welding

A5.1 The following five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators are exposed during welding:

(1) Dimensions of the space in which welding is done (with special regard to the height of the ceiling)

(2) Number of welders and welding operators working in that space

(3) Rate of evolution of fumes, gases, or dust, according to the materials and processes used

(4) The proximity of the welders or welding operators to the fumes as they issue from the welding zone, and to the gases and dusts in the space in which they are working

(5) The ventilation provided to the space in which the welding is done

A5.2 American National Standard Z49.1, *Safety in Welding and Cutting* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the Section of that document entitled "Health Protection and Ventilation."

A6. Welding Consideration

A6.1 Weld metal properties may vary widely, according to the size of the electrode and amperage used, size of the weld beads, base metal thickness, joint geometry, preheat and interpass temperatures, surface condition, base metal composition, dilution, etc. Because of the profound effect of these variables, a test procedure was chosen for this specification which would represent good welding practice and minimize variation of the most potent of these variables.

A6.2 It should be recognized, however that production practices may be different. The differences encountered may alter the properties of the weld metal For instance, interpass temperatures may range from subfreezing to several hundred degrees. No single temperature or reasonable range of temperatures can be chosen for classification tests which will be representative of all of the conditions encountered in production work.

Properties of production welds may vary accordingly, depending on the particular welding conditions Weld metal properties may not duplicate, or even closely approach, the values listed and prescribed for test welds. For example, ductility in single pass welds in thick base metal made outdoors in cold weather without adequate preheating may drop to little more than half that required herein and normally obtained This does not indicate that either the electrodes or the welds are below standard. It indicates only that the particular production conditions are more severe than the test conditions prescribed by this specification

A6.3 Hydrogen is another factor to be considered. Weld metals, other than those from low hydrogen electrodes (E7015, E7016, E7018, E7018M, E7028, and E7048), contain significant quantities of hydrogen for some period of time after they have been made. This hydrogen gradually escapes. After two to four weeks at room temperature or in 24 to 48 hours at 200 to 220°F (95 to 105°C), most of it has escaped As a result of this change in hydrogen content, the ductility of the weld metal increases towards its inherent value, while the yield, tensile, and impact strengths remain relatively unchanged This specification requires aging of the test specimens at 200 to 220°F (95 to 105°C) for 48 hours before subjecting them to the tension or bend test This is done to minimize discrepancies in testing.

A6.4 When weldments are given a postweld heat treatment, the temperature and time at temperature are very important The tensile and yield strengths generally are decreased as postweld heat treatment temperature and time at temperature are increased.

A6.5 Welds made with electrodes of the same classification and the same welding procedure will have significantly different tensile and yield strengths in the as-welded and postweld heat-treated conditions. Comparison of the values for as-welded and postweld heat-treated [1150°F (620°C) for one hour] weld metal will show the following:

A6.5.1 The tensile strength of the postweld heat-treated weld metal will be approximately 5 ksi (34.5 MPa) lower than that of the weld metal in the as-welded condition.

A6.5.2 The yield strength of the postweld heat-treated weld metal will be approximately 10 ksi (69 MPa) lower than that of the weld metal in the as-welded condition.

A6.6 Conversely, postweld heat-treated welds made with the same electrodes and using the same welding procedure except for variation in interpass temperature and postweld heat treatment time can have almost identical tensile and yield strengths. As an example, almost identical tensile and yield strengths may be obtained in two welds, one using an interpass temperature of 300°F (150°C) and postweld heat-treated for 1 hour at 1150°F (620°C), and the other using an interpass temperature of 200°F (93°C) and postweld heat-treated for 10 hours at 1150°F (620°C).

A6.7 Electrodes which meet all the requirements of any given classification may be expected to have similar characteristics. Certain minor differences continue to exist from one brand to another due to differences in preferences that exist regarding specific operating characteristics. Furthermore, the only differences between the present E60XX and E70XX classifications are the differences in chemical composition and mechanical properties of the weld metal, as shown in Tables 2, 3, and 7. In many applications, electrodes of either E60XX or E70XX classifications may be used.

A6.8 Since the electrodes within a given classification have similar operating characteristics and mechanical properties, the user can limit the study of available electrodes to those within a single classification after determining which classification best suits the particular requirements.

A6.9 This specification does not establish values for all characteristics of the electrodes falling within a given classification, but it does establish values to measure those of major importance. In some instances, a particular characteristic is common to a number of classifications and testing for it is not necessary. In other instances, the characteristics are so intangible that no adequate tests are available. This specification does not necessarily provide all the information needed to determine which classification will best fulfill a particular need. Therefore, a discussion of each classification is included in Appendix A7 to supplement information given elsewhere in the specification.

A6.10 Some important tests for measuring major electrode characteristics are as follows:

A6.10.1 Radiographic Test. Nearly all of the carbon steel electrodes covered by this specification are capable of producing welds that meet most radiographic soundness requirements. However, if incorrectly applied, unsound welds may be produced by any of the electrodes. For electrodes of some classifications, the radiographic requirements in Table 8 are not necessarily indicative of the average radiographic soundness to be expected in production use. Electrodes of the E6010, E6011, E6019, and E6020 classifications can be expected to produce acceptable radiographic results.

Under certain conditions, notably in welding long, continuous joints in relatively thick base metal, low hydrogen electrodes of the E7015, E7016, E7018, and E7018M classifications will often produce even better results. On the other hand, in joints open to the atmosphere on the root side, at the ends of joints, in joints with many stops and starts, and in welds on small diameter pipe or in small, thin, irregularly shaped joints, the low hydrogen electrodes tend to produce welds of poor radiographic soundness. E6013 electrodes usually produce the best radiographic soundness in welding small, thin parts.

E6027, E7024 and E7028 electrodes produce welds which may be either quite good or rather inferior in radiographic soundness. The tendency seems to be in the latter direction. Of all types, the E6022 and E6012 electrodes generally produce welds with the least favorable radiographic soundness.

A6.10.2 Fillet Weld Test. This test is included as a means of demonstrating the usability of an electrode. This test is concerned with the appearance of the weld (i.e., weld face contour and smoothness, undercut, overlap, size, and resistance to cracking). It also provides an excellent and inexpensive method of determining the adequacy of fusion at the weld root (one of the important considerations for an electrode).

A6.10.3 Toughness. Charpy V-notch impact requirements are included in the specification. All classes of electrodes in this specification can produce weld metal of sufficient toughness for many applications. The inclusion of impact requirements for certain electrode classifications allows the specification to be used as a guide in selecting electrodes where low-temperature toughness is required. There can be considerable variation in the weld metal toughness unless particular attention is given to the welding procedure and the preparation and testing of the specimens. The impact energy values are for Charpy V-notch specimens and should not be confused with values obtained with other toughness tests.

A6.11 Electrode Covering Moisture Content and Conditioning

A6.11.1 Hydrogen can have adverse effects on welds in some steels under certain conditions. One source of this hydrogen is moisture in the electrode coverings. For this reason, the proper storage, treatment, and handling of electrodes are necessary.

A6.11.2 Electrodes are manufactured to be within acceptable moisture limits, consistent with the type of covering and strength of the weld metal. They are then normally packaged in a container which has been designed to provide the degree of moisture protection considered necessary for the type of covering involved.

A6.11.3 If there is a possibility that the noncellulosic electrodes may have absorbed excessive moisture, they may be restored by rebaking. Some electrodes require rebaking at a temperature as high as 800°F (425°C) for approximately 1 to 2 hours. The manner in which the electrodes have been produced and the relative humidity and temperature conditions under which the electrodes are stored determine the proper length of time and temperature used for conditioning. Some typical storage and drying conditions are included in Table A2.

A6.11.4 Cellulose coverings for E6010 and E6011 electrodes need moisture levels of 3% to 7% for proper operation; therefore, storage or conditioning above ambient temperature may dry them too much and adversely affect their operation (see Table A2).

A6.12 Core Wire. The core wire for all the electrodes classified in this specification is usually a mild steel having a typical composition which may differ significantly from that of the weld metal produced by the covered electrodes.

A6.13 Coverings

A6.13.1 Electrodes of some classifications have substantial quantities of iron powder added to their coverings. The iron powder fuses with the core wire and the other metal in the covering, as the electrode melts, and is deposited as part of the weld metal, just as is the core wire. Relatively high currents can be used since a considerable portion of the electrical energy passing through the electrode is used to melt the thicker covering containing iron powder. The result is that

Table A2
Typical Storage and Drying Conditions for Covered Arc Welding Electrodes

AWS Classifications	Storage Conditions[a] Ambient Air	Storage Conditions[a] Holding Ovens	Drying Conditions[b]
E6010, E6011	Ambient temperature	Not recommended	Not recommended
E6012, E6013, E6019, E6020, E6022, E6027, E7014, E7024 E7027	80 ± 20°F (30 ± 10°C) 50 percent max relative humidity	20°F (12°C) to 40°F (24°C) above ambient temperature	1 hour at temperature 275 ± 25°F (135 ± 15°C)
E7015, E7016, E7018, E7028, E7018M, E7048	Not Recommended[c]	50°F (30°C) to 250°F (140°C) above ambient temperature	500 to 800°F (260 to 427°C) 1 to 2 hours at temperature

Notes:
a. After removal from manufacturer's packaging.
b. Because of inherent differences in covering composition, the manufacturers should be consulted for the exact drying conditions.
c. Some of these electrode classifications may be designated as meeting low moisture absorbing requirements. This designation does not imply that storage in ambient air is recommended.

more weld metal may be obtained from a single electrode with iron powder in its covering than from a single electrode of the same diameter without iron powder.

A6.13.2 Due to the thick covering and deep cup produced at the arcing end of the electrode, iron powder electrodes can be used very effectively with a "drag" technique. This technique consists of keeping the electrode covering in contact with the workpiece at all times, which makes for easy handling. However, a technique using a short arc length is preferable if the $^3/_{32}$ in. (2.4 mm) or $^1/_8$ in. (3.2 mm) electrodes are to be used in other than flat or horizontal fillet welding positions or for making groove welds.

A6.13.3 The E70XX electrodes were included in this specification to acknowledge the higher strength levels obtained with many of the iron powder and low hydrogen electrodes, as well as to recognize the industry demand for electrodes with 70 ksi (482 MPa) minimum tensile strength. Unlike the E70XX-X classification in AWS A5.5, *Specification for Low Alloy Steel Covered Arc Welding Electrodes*, these electrodes do not contain deliberate alloy additions, nor are they required to meet minimum tensile properties after postweld heat treatment.

A6.13.4 E70XX low hydrogen electrodes have mineral coverings which are high in limestone and other ingredients that are low in moisture and hence "low in hydrogen content." Low hydrogen electrodes were developed for welding low alloy high-strength steels, some of which were high in carbon content. Electrodes with other than low hydrogen coverings produce "hydrogen-induced cracking" in those steels. These underbead cracks occur in the base metal, usually just below the weld bead.

Weld metal cracks also may occur. These usually are caused by the hydrogen absorbed from the arc atmosphere. Although these cracks do not generally occur in carbon steels which have a low carbon content, they may occur whenever other electrodes are used on higher carbon or alloy steels. Low hydrogen electrodes are also used to weld high-sulphur and enameling steels. Electrodes with other than low hydrogen coverings give porous welds on high-sulphur steels. With enameling steels, the hydrogen that escapes after welding with other than low hydrogen electrodes produces holes in the enamel.

A6.14 Amperage Ranges. Table A3 gives amperage ranges which are satisfactory for most classifications. When welding vertically upward, currents near the lower limit of the range are generally used.

A7. Description and Intended Use of Electrodes

A7.1 E6010 Classification

A7.1.1 E6010 electrodes are characterized by a deeply penetrating, forceful, spray type arc and readily

TABLE A3
TYPICAL AMPERAGE RANGES

Electrode Diameter in.	Electrode Diameter mm	E6010 and E6011	E6012	E6013	E6019	E6020	E6022	E6027 and E7027	E7014	E7015 and E7016	E7018M and E7018	E7024 and E7028	E7048
1/16	1.6	—	20 to 40	20 to 40	—	—	—	—	—	—	—	—	—
5/64	2.0	—	25 to 60	25 to 60	35 to 55	—	—	—	—	—	—	—	—
3/32*	2.4*	40 to 80	35 to 85	45 to 90	50 to 90	—	—	—	80 to 125	65 to 110	70 to 100	100 to 145	— —
1/8	3.2	75 to 125	80 to 140	80 to 130	80 to 140	100 to 150	110 to 160	125 to 185	110 to 160	100 to 150	115 to 165	140 to 190	80 to 140
5/32	4.0	110 to 170	110 to 190	105 to 180	130 to 190	130 to 190	140 to 190	160 to 240	150 to 210	140 to 200	150 to 220	180 to 250	150 to 220
3/16	4.8	140 to 215	140 to 240	150 to 230	190 to 250	175 to 250	170 to 400	210 to 300	200 to 275	180 to 255	200 to 275	230 to 305	210 to 270
7/32	5.6	170 to 250	200 to 320	210 to 300	240 to 310	225 to 310	370 to 520	250 to 350	260 to 340	240 to 320	260 to 340	275 to 365	—
1/4	6.4	210 to 320	250 to 400	250 to 350	310 to 360	275 to 375	— —	300 to 420	330 to 415	300 to 390	315 to 400	335 to 430	— —
5/16	8.0	275 to 425	300 to 500	320 to 430	360 to 410	340 to 450	— —	375 to 475	390 to 500	375 to 475	375 to 470	400 to 525	— —

* This diameter is not manufactured in the E7028 classification.

removable, thin, friable slag which may not seem to completely cover the weld bead. Fillet welds usually have a relatively flat weld face and have a rather coarse, unevenly spaced ripple. The coverings are high in cellulose, usually exceeding 30% by weight. The other materials generally used in the covering include titanium dioxide, metallic deoxidizers such as ferromanganese, various types of magnesium or aluminum silicates, and liquid sodium silicate as a binder. Because of their covering composition, these electrodes are generally described as the high-cellulose sodium type.

A7.1.2 These electrodes are recommended for all welding positions, particularly on multiple pass applications in the vertical and overhead welding positions and where welds of good soundness are required. They frequently are selected for joining pipe and generally are capable of welding in the vertical position with either uphill or downhill progression.

A7.1.3 The majority of applications for these electrodes is in joining carbon steel. However, they have been used to advantage on galvanized steel and on some low alloy steels. Typical applications include shipbuilding, buildings, bridges, storage tanks, piping, and pressure vessel fittings. Since the applications are so widespread, a discussion of each is impractical. Sizes larger than $^3/_{16}$ in. (4.8 mm) generally have limited use in other than flat or horizontal-fillet welding positions.

A7.1.4 These electrodes have been designed for use with deep (electrode positive). The maximum amperage that can generally be used with the larger sizes of these electrodes is limited in comparison to that for other classifications due to the high spatter loss that occurs with high amperage.

A7.2 E6011 Classification

A7.2.1 E6011 electrodes are designed to be used with ac current and to duplicate the usability characteristics and mechanical properties of the E6010 classification. Although also usable with deep (electrode positive), a decrease in joint penetration will be noted when compared to the E6010 electrodes. Arc action, slag, and fillet weld appearance are similar to those of the E6010 electrodes.

A7.2.2 The coverings are also high in cellulose and are described as the high-cellulose potassium type. In addition to the other ingredients normally found in E6010 coverings, small quantities of calcium and potassium compounds usually are present.

A7.2.3 Sizes larger than $^3/_{16}$ in. (4.8 mm) generally have limited use in other than flat or horizontal-fillet welding positions.

A7.3 E6012 Classification

A7.3.1 E6012 electrodes are characterized by low penetrating arc and dense slag, which completely covers the bead. This may result in incomplete root penetration in fillet welded joints. The coverings are high in titania, usually exceeding 35% by weight, and usually are referred to as the "titania" or "rutile" type. The coverings generally also contain small amounts of cellulose and ferromanganese, and various siliceous materials such as feldspar and clay with sodium silicate as a binder. Also, small amounts of certain calcium compounds may be used to produce satisfactory arc characteristics on dcen (electrode negative).

A7.3.2 Fillet welds tend to have a convex weld face with smooth even ripples in the horizontal welding position, and widely spaced rougher ripples in the vertical welding position which become smoother and more uniform as the size of the weld is increased. Ordinarily, a larger size fillet must be made in the vertical and overhead positions using E6012 electrodes compared to welds with E6010 and E6011 electrodes of the same diameter.

A7.3.3 The E6012 electrodes are all-position electrodes and usually are suitable for welding in the vertical position with either the upward or downward progression. However, more often the larger sizes are used in the flat and horizontal positions than in the vertical and overhead positions. The larger sizes are often used for single pass, high-speed, high current fillet welds in the horizontal welding position. Their ease of handling, good fillet weld face, and ability to bridge wide root openings under conditions of poor fit, and to withstand high amperages make them very well suited to this type of work. The electrode size used for vertical and overhead position welding is frequently one size smaller than would be used with an E6010 or E6011 electrode.

A7.3.4 Weld metal from these electrodes is generally lower in ductility and may be higher in yield strength [1 to 2 ksi (690 to 1380 kPa)] than weld metal from the same size of either the E6010 or E6011 electrodes.

A7.4 E6013 Classification

A7.4.1 E6013 electrodes, although very similar to the E6012 electrodes, have distinct differences. Their flux covering makes slag removal easier and gives a smoother arc transfer than E6012 electrodes. This is particularly the case for the small diameters [$^1/_{16}$, $^5/_{64}$, and $^{3}/_{32}$ in. (1.6, 2.0, and 2.4 mm)]. This permits satisfactory operation with lower open-circuit ac voltage. E6013 electrodes were designed specifically for light sheet metal work. However, the larger diameters are used on many of the same applications as E6012 electrodes and provide low penetrating arc. The smaller diameters provide a less penetrating arc than is obtained with E6012 electrodes. This may result in incomplete penetration in fillet welded joints.

A7.4.2 Coverings of E6013 electrodes contain rutile, cellulose, ferromanganese, potassium silicate as a binder, and other siliceous materials. The potassium compounds permit the electrodes to operate with ac at low amperages and low open-circuit voltages.

A7.4.3 E6013 electrodes are similar to the E6012 electrodes in usability characteristics and bead appearance. The arc action tends to be quieter and the bead surface smoother with a finer ripple. The characteristics of E6013 electrodes vary slightly from brand to brand. Some are recommended for sheet metal applications where their ability to weld satisfactorily in the vertical welding position with downward progression is an advantage.

Others, with a more fluid slag, are used for horizontal fillet welds and other general purpose welding. These electrodes produce a flat fillet weld face rather than the convex weld face characteristic of E6012 electrodes. They are also suitable for making groove welds because of their concave weld face and easily removed slag. In addition, the weld metal is definitely freer of slag and oxide inclusions than E6012 weld metal and exhibits better soundness. Welds with the smaller diameter E6013 electrodes often meet the Grade 1 radiographic requirements of this specification.

A7.4.4 E6013 electrodes usually cannot withstand the high amperages that can be used with E6012 electrodes in the flat and horizontal welding positions. Amperages in the vertical and overhead positions, however, are similar to those used with E6012 electrodes.

A7.5 E7014 Classification

A7.5.1 E7014 electrode coverings are similar to those of E6012 and E6013 electrodes, but with the addition of iron powder for obtaining higher deposition efficiency. The covering thickness and the amount of iron powder in E7014 are less than in E7024 electrodes (see A7.10).

A7.5.2 The iron powder also permits the use of higher amperages than are used for E6012 and E6013 electrodes. The amount and character of the slag permit E7014 electrodes to be used in all positions.

A7.5.3 The E7014 electrodes are suitable for welding carbon and low alloy steels. Typical weld beads are smooth with fine ripples. Joint penetration is approximately the same as that obtained with E6012 electrodes (see 7.3.1), which is advantageous when welding over a wide root opening due to poor fit. The face of fillet welds tends to be flat to slightly convex. The slag is easy to remove. In many cases, it removes itself.

A7.6 Low Hydrogen Electrodes

A7.6.1 Electrodes of the low hydrogen classifications (E7015, E7016, E7018, E7018M, E7028, and E7048) are made with inorganic coverings that contain minimal moisture. The covering moisture test, as specified in Section 15, Moisture Test, converts hydrogen-bearing compounds in any form in the covering into water vapor that is collected and weighed. The test thus assesses the potential hydrogen available from an electrode covering. All low hydrogen electrodes, in the as-manufactured condition or after conditioning, are expected to meet a maximum covering moisture limit of 0.6% or less, as required in Table 10.

A7.6.2 The potential for diffusible hydrogen in the weld metal can be assessed more directly, but less conveniently, by the diffusible hydrogen test, as specified in Section 17, Diffusible Hydrogen Test. The results of this test, using electrodes in the as-manufactured condition or after conditioning, permit the addition of an optional supplemental diffusible hydrogen designator to the classification designation according to Table 11. See also A9.2 in this Appendix.

A7.6.3 In order to maintain low hydrogen electrodes with minimal moisture in their coverings, these electrodes should be stored and handled with considerable care. Electrodes which have been exposed to humidity may absorb considerable moisture and their low hydrogen character may be lost. Then conditioning can restore their low hydrogen character. See Table A2.

A7.6.4 Low hydrogen electrode coverings can be designed to resist moisture absorption for a considerable time in a humid environment. The absorbed moisture test (see Section 16, Absorbed Moisture Test), assesses this characteristic by determining the covering moisture after nine hours exposure to 80°F (27°C), 80% relative humidity air. If, after this exposure, the covering moisture does not exceed 0.4%, then the optional supplemental designator, "R", may be added to the electrode classification designation, as specified in Table 10. See also A9.3 in this Appendix.

A7.6.5 E7015 Classification

A7.6.5.1 E7015 electrodes are low hydrogen electrodes to be used with dcep (electrode positive). The slag is chemically basic.

A7.6.5.2 E7015 electrodes are commonly used for making small welds on thick base metal, since they are less susceptible to cracking (see A6.13.4). They are also used for welding high sulphur and enameling steels. Welds made with E7015 electrodes on high sulphur steels may produce a very tight slag and a very rough or irregular bead appearance in comparison to welds with the same electrodes in steels of normal sulphur content.

A7.6.5.3 The arc of E7015 electrodes is moderately penetrating. The slag is heavy, friable, and easy to remove. The weld face is convex, although a fillet weld face may be flat.

A7.6.5.4 E7015 electrodes up to and including the $^5/_{32}$ in. (4.0 mm) size are used in all welding positions. Larger electrodes are used for groove welds in the flat welding position and fillet welds in the horizontal and flat welding positions.

A7.6.5.5 Amperages for E7015 electrodes are higher than those used with E6010 electrodes of the same diameter. The shortest possible arc length should be maintained for best results with E7015 electrodes. This reduces the risk of porosity. The necessity for preheat is reduced; therefore, better welding conditions are provided.

A.7.6.6 E7016 Classification

A7.6.6.1 E7016 electrodes have all the characteristics of E7015 electrodes, plus the ability to operate on ac. The core wire and coverings are very similar to those of E7015, except for the use of a potassium silicate binder or other potassium salts in the coverings to facilitate their use with ac. Most of the preceding discussion on E7015 electrodes applies equally well to the E7016 electrodes. The discussion in A6.13.4 also applies.

A7.6.6.2 Electrodes designated as E7016-1 have the same usability and weld metal composition as E7016 electrodes except that the manganese content is set at the high end of the range. They are intended for welds requiring a lower transition temperature than is normally available from E7016 electrodes.

A7.6.7 E7018 Classification

A7.6.7.1 E7018 electrode coverings are similar to E7015 coverings, except for the addition of a relatively high percentage of iron powder. The coverings on these electrodes are slightly thicker than those of the E7016 electrodes.

A7.6.7.2 E7018 low hydrogen electrodes can be used with either ac or dcep. They are designed for the same applications as the E7016 electrodes. As is common with all low hydrogen electrodes, a short arc length should be maintained at all times.

A7.6.7.3 In addition to their use on carbon steel, the E7018 electrodes are also used for joints involving high-strength, high carbon, or low alloy steels (see also A6.13). The fillet welds made in the horizontal and flat welding positions have a slightly convex weld face, with a smooth and finely rippled surface. The electrodes are characterized by a smooth, quiet arc, very low spatter, and medium arc penetration. E7018 electrodes can be used at high travel speeds.

A7.6.7.4 Electrodes designated as E7018-1 have the same usability and weld metal composition as E7018 electrodes, except that the manganese content is set at the high end of the range. They are intended for welds requiring a lower transition temperature than is normally available from E7018 electrodes.

A7.6.8 E7018M Electrodes

A7.6.8.1 E7018M electroces are similar to E7018-1H4R electrodes, except that the testing for mechanical properties and for classification is done on a groove weld that has a 60 degree included angle and, for electrodes up to $^5/_{32}$ in. (4.0 mm), welded in the vertical position with upward progression. The impact test results are evaluated using all five test values and higher values are required at $-20°F$ ($-29°C$). The maximum allowable moisture-in-coating values in the "as-received" or reconditioned state are more restrictive than that required for E7018R. This classification closely corresponds to MIL-7018-M in MIL-E-22200/10 specification, with the exception that the absorbed moisture limits on the electrode covering and the diffusible hydrogen limits on the weld metal are not as restrictive as those in MIL-E-22200/10.

A7.6.8.2 E7018M is intended to be used with dcep type current in order to produce the optimum mechanical properties. However, if the manufacturer desires, the electrode may also be classified as E7018 provided all the requirements of E7018 are met.

A7.6.8.3 In addition to their use on carbon steel, the E7018M electrodes are used for joining carbon steels to high strength low alloy steels and higher carbon steels. Fillet welds made in the horizontal and flat welding positions have a slightly convex weld face, with a smooth and finely rippled surface. The electrodes are characterized by a smooth, quiet arc, very low spatter, and medium arc penetration.

A7.6.9 E7028 Classification

A7.6.9.1 E7028 electrodes are very much like E7018 electrodes. However, E7028 electrodes are suitable for fillet welds in the horizontal welding position and groove welds in the flat welding position only, whereas E7018 electrodes are suitable for all positions.

A7.6.9.2 The E7028 electrode coverings are much thicker. They make up approximately 50% of the weight of the electrodes. The iron content of E7028 electrodes is higher (approximately 50% of the weight of the coverings). Consequently, on fillet welds in the horizontal position and groove welds in the flat welding position, E7028 electrodes give a higher deposition rate than the E7018 electrodes for a given size of electrode.

A7.6.10 E7048 Classification. Electrodes of the E7048 classification have the same usability, composition, and design characteristics as E7018 electrodes, except that E7048 electrodes are specifically designed for exceptionally good vertical welding with downward progression (see Table 1).

A7.7 E6019 Classification

A7.7.1 E6019 electrodes, although very similar to E6013 and E6020 electrodes in their coverings, have distinct differences. E6019 electrodes, with a rather fluid slag system, provide deeper arc penetration and produce weld metal that meets a 22% minimum elongation requirement, meets the Grade 1 radiographic standards, and has an average impact strength of 20 ft-lb (27J) when tested at 0°F (−18°C).

A7.7.2 E6019 electrodes are suitable for multipass of up to 1 in. (25 mm) thick steel. They are designed for use with ac, dcen, or dcep. While $^{3}/_{16}$ in. (4.8 mm) and smaller diameter electrodes can be used for all welding positions (except vertical welding position with downward progression), the use of larger diameter electrodes should be limited to the flat or horizontal fillet welding position. When welding in the vertical welding position with upward progression, weaving should be limited to minimize undercut.

A7.8 E6020 Classification

A7.8.1 E6020 electrodes have a high iron oxide covering. They are characterized by a spray type arc, produce a smooth and flat, or slightly concave weld face and have an easily removable slag.

A7.8.2 A low viscosity slag limits their usability to horizontal fillets and flat welding positions. With arc penetration ranging from medium to deep (depending upon welding current), E6020 electrodes are best suited for thicker base metal.

A7.9 E6022 Classification. Electrodes of the E6022 classification are recommended for single pass, high-speed, high current welding of groove welds in the flat welding position, lap joints in the horizontal welding position, and fillet welds on sheet metal. The weld face tends to be more convex and less uniform, especially since the welding speeds are higher.

A7.10 E7024 Classification

A7.10.1 E7024 electrode coverings contain large amounts of iron powder in combination with ingredients similar to those used in E6012 and E6013 electrodes. The coverings on E7024 electrodes are very thick and usually amount to about 50% of the weight of the electrode, resulting in higher deposition efficiency.

A7.10.2 The E7024 electrodes are well suited for making fillet welds in the flat or horizontal position. The weld face is slightly convex to flat, with a very smooth surface and an extremely fine ripple. These electrodes are characterized by a smooth, quiet arc, very low spatter, and low arc penetration. They can be used with high travel speeds. Electrodes of these classifications can be operated on ac, dcep, or dcen.

A7.10.3 Electrodes designated as E7024-1 have the same general usability characteristics as E7024 electrodes. They are intended for use in situations requiring greater ductility and a lower transition-temperature than normally is available from E7024 electrodes.

A7.11 E6027 Classification

A7.11.1 E6027 electrode coverings contain large amounts of iron powder in combination with ingredients similar to those found in E6020 electrodes. The coverings on E6027 electrodes are also very thick and usually amount to about 50% of the weight of the electrode.

A7.11.2 The E6027 electrodes are designed for fillet or groove welds in the flat position with ac, dcep, or dcen, and will produce flat or slightly concave weld face on fillet welds in the horizontal position with either ac or dcen.

A7.11.3 E6027 electrodes have a spray-type arc. They will operate at high travel speeds. Arc penetration is medium. Spatter loss is very low. E6027 electrodes produce a heavy slag which is honeycombed on the underside. The slag is friable and easily removed.

A7.11.4 Welds produced with E6027 electrodes have a flat to slightly concave weld face with a smooth, fine, even ripple, and good wetting along the sides of the joint. The weld metal may be slightly inferior in radiographic soundness to that from E6020 electrodes. High amperages can be used, since a considerable portion of the electrical energy passing through the electrode is used to melt the covering and the iron powder it contains. These electrodes are well suited for thicker base metal.

A7.12 E7027 Classification. E7027 electrodes have the same usability and design characteristics as E6027 electrodes, except they are intended for use in situations requiring slightly higher tensile and yield strengths than are obtained with E6027 electrodes. They must also meet chemical composition requirements (see Table 7). In other respects, all previous discussions for E6027 electrodes also apply to E7027 electrodes.

A8. Modification of Moisture Test Apparatus

A8.1 Some laboratories have modified test apparatus for determining the moisture content of electrode coverings. The following are some of the modifications which have been successfully used:

A8.1.1 This specification recommends that only nickel boats be used rather than clay boats because lower blank values can be obtained. Some laboratories use zirconium silicate combustion tubes in preference to fused silica or mullite because zirconium silicate will not devitrify or allow the escape of combustible gases at temperatures up to 2500°F (1370°C). Some combustion tubes are reduced at the exit end and a separate dust trap is used. This dust trap consists of a 200 mm drying tube filled with glass wool which is inserted between the Schwartz absorption U-tube and the combustion tube. A suitable 300°F (149°C) heater is mounted around the dust trap to keep the evolved water from condensing in the trap. The dust trap is filled with glass wool which can be easily inspected to determine when the glass wool should be replaced. An extra spray trap may be installed downstream of the absorption U-tube to ensure that the concentrated sulfuric acid in the gas sealing bottle is not accidently drawn into the absorption U-tube.

A8.1.2 On the entrance end of the combustion tube, a pusher rod can be used consisting of a $^1/_8$ in. (3.2 mm) stainless steel rod mounted in a $^1/_4$ in. (6.4 mm) copper tee fitting. This is used at the entrance of the combustion tube and permits gradual introduction of the sample into the tube while oxygen is passing over the sample. In this way, any free moisture will not be lost, which can happen if the sample is introduced directly into the hot zone before closing the end of the tube.

A9. Special Tests

A9.1 It is recognized that supplementary tests may be necessary to determine the suitability of these welding electrodes for applications involving properties not considered in this specification. In such cases, additional tests to determine specific properties, such as hardness, corrosion resistance, mechanical properties at higher or lower service temperatures, wear resistance, and suitability for welding combinations of different carbon and low alloy steels, may need to be conducted.

A9.2 Diffusible Hydrogen Test. Hydrogen induced cracking of weld metal and the heat-affected zone generally are not problems with carbon steels containing 0.30%, or less, carbon. Nevertheless, the welding electrodes of the specification are sometimes used to join higher carbon steels or low alloy steels, where hydrogen induced cracking may be a serious problem.

The coating moisture test has proven to be a satisfactory test over many years as a means of assessing the degree of care needed to avoid hydrogen induced cracking. This is, however, an indirect test. Moisture itself does not cause cracking, but the diffusible hydrogen that forms from the moisture in the arc can cause cracking.

Since entry of diffusible hydrogen into the weld pool can be affected by the form of the moisture in the coating (for example, chemically bonded versus surface absorbed), there is a fundamental utility for considering diffusible hydrogen for low hydrogen electrodes. Accordingly, the use of optional designators for diffusible hydrogen is introduced to indicate the maximum average value obtained under a clearly defined test condition in ANSI/AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Weld Metal Produced by Arc Welding*.

The user of this information is cautioned that actual welding conditions may result in different diffusible hydrogen values than those indicated by the designator.

The use of a reference atmospheric condition during welding is necessitated because the arc always is imperfectly shielded. Moisture from the air, distinct from that in the covering, can enter the arc and subsequently

TABLE A4
DISCONTINUED ELECTRODE CLASSIFICATIONS[a]

AWS Classification	Last A5.1 (ASTM A-233) Publication Date	AWS Classification	Last A5.1 (ASTM A-233) Publication Date
E4511	1943	E9020	1945
E4521	1943	E9030	1945
E7010[b]	1945	E10010[b]	1945
E7011[b]	1945	E10011[b]	1945
E7012	1945	E10012	1945
E7020[b]	1945	E10020	1945
E7030	1945	E10030	1945
E8010[b]	1945	E4510	1958
E8011[b]	1945	E4520	1958
E8012	1945	E6014	1958
E8020[b]	1945	E6015	1958
E8030	1945	E6016	1958
E9010[b]	1945	E6018	1958
E9011[b]	1945	E6024	1958
E9012	1945	E6028	1958
		E6030	1958

Notes:
a. See A10 (in the Appendix) for information on discontinued classifications.
b. These electrode classifications were transferred from the ASTM A233-45T to the new AWS A5.5-48T. They were later discontinued from that specification and replaced with the new "G" classifications in order to permit a single classification system with weld metal chemistry requirements in AWS A5.5-58T.

the weld pool, contributing to the resulting observed diffusible hydrogen. This effect can be minimized by maintaining as short an arc length as possible consistent with a steady arc. Experience has shown that the effect of arc length is minor at the H16 level, but it is very significant at the H4 level. An electrode meeting the H4 requirement under the reference atmospheric conditions may not do so under conditions of higher humidity at the time of welding. This is especially true if a long arc is maintained.

The reference atmospheric condition during welding of the test assembly is 10 grains of water vapor per pound (1.43g/kg) of dry air. This corresponds to 70°F (21°C) and 10% RH on a standard psychrometric chart at 29.92 in. Hg (760 mm) barometric pressure. Actual conditions, measured using a sling psychrometer, that equal or exceed this reference condition provide assurance that the conditions during welding weill not diminish the final results of the test.

A9.3 Absorbed Moisture Test. The development of low hydrogen electrode coverings that resist moisture absorption during exposure to humid air is a recent improvement in covered electrode technology. Not all commercial low hydrogen electrodes possess this characteristic. To assess this characteristic, the absorbed moisture test described in Section 16, Absorbed Moisture Test, was devised. The exposure conditions selected for the test are arbitrary. Other conditions may yield quite different results.

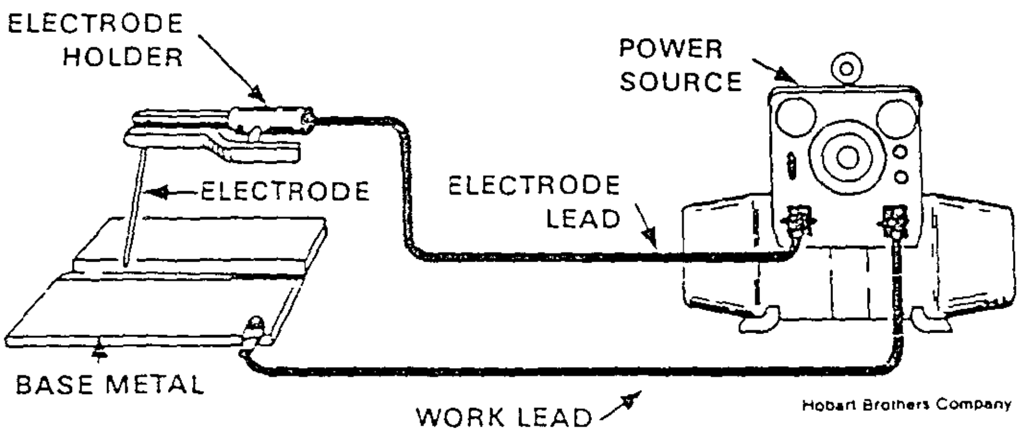
A task group of the AWS A5A Subcommittee evaluated this test and concluded that it can successfully differentiate moisture resistant electrodes from those which are not. The task group also observed considerable variab ility of covering moisture results after exposure of electrodes in cooperative testing among several laboratories. The precision of the test is such that, with moisture resistant electrodes from a single lot, the participating laboratories could observe exposed covering moisture values ranging, for example, from 0.15% or less to 0.35% or more. The cause of this variability is uncertain at present, but is considered by the task group to be related to variations in the exposure conditions. Because of this variability, the task group concluded that it is not realistic to set a limit for covering moisture of exposed moisture resistant electrodes lower than 0.4% at this time.

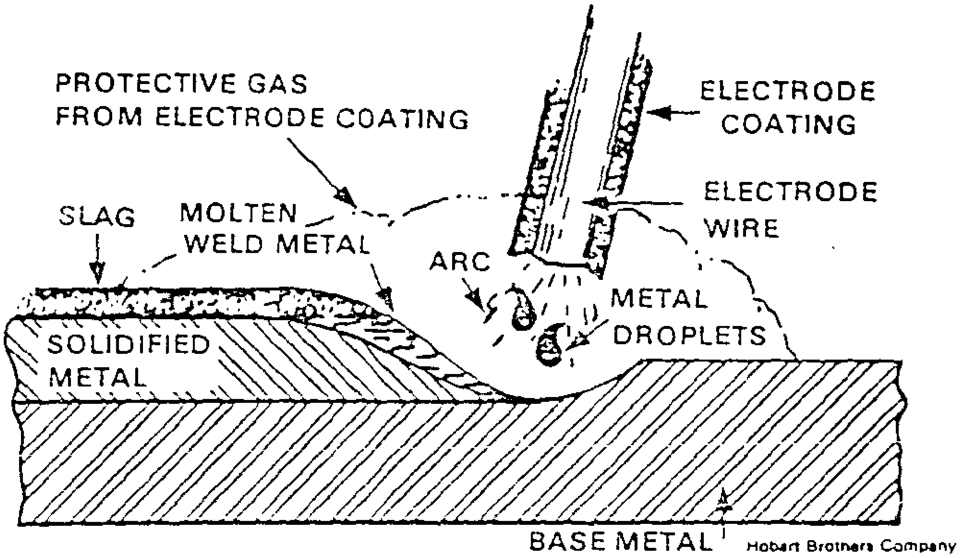
A10. Discounted Classifications

A number of electrode classifications have been discontinued during the numerous revisions of this specification, reflecting either changes in commercial practice, or changes in the scope of filler metals classified in the specification. These discontinued electrode classifications are listed in Table A4, along with the year they were last published in this specification.

WELDING

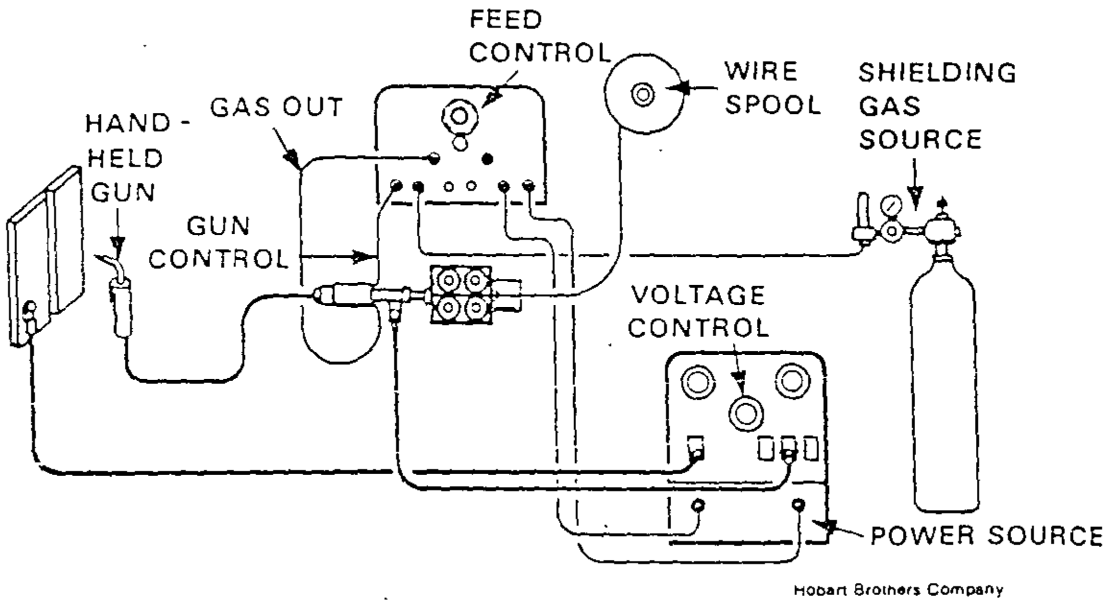
SHIELDED METAL ARC WELDING (SMAW)

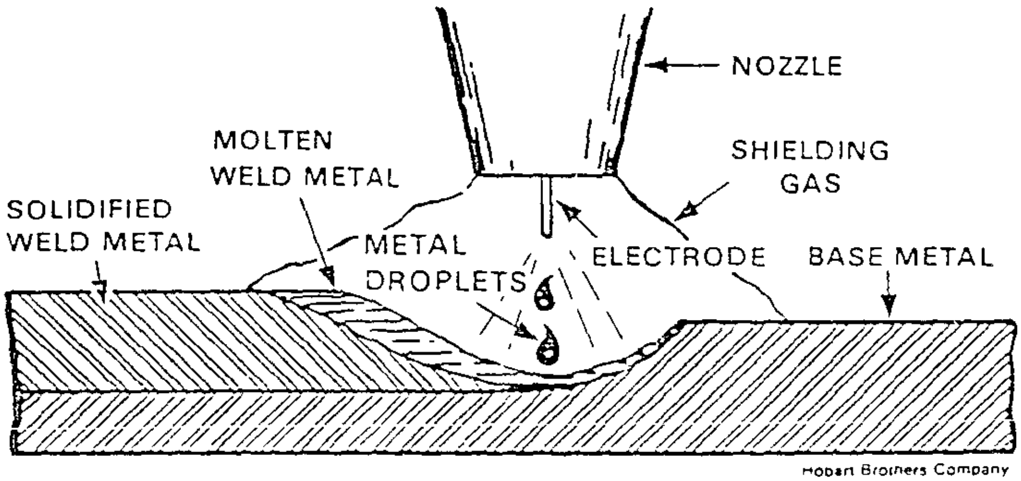




SHIELDED METAL ARC WELDING

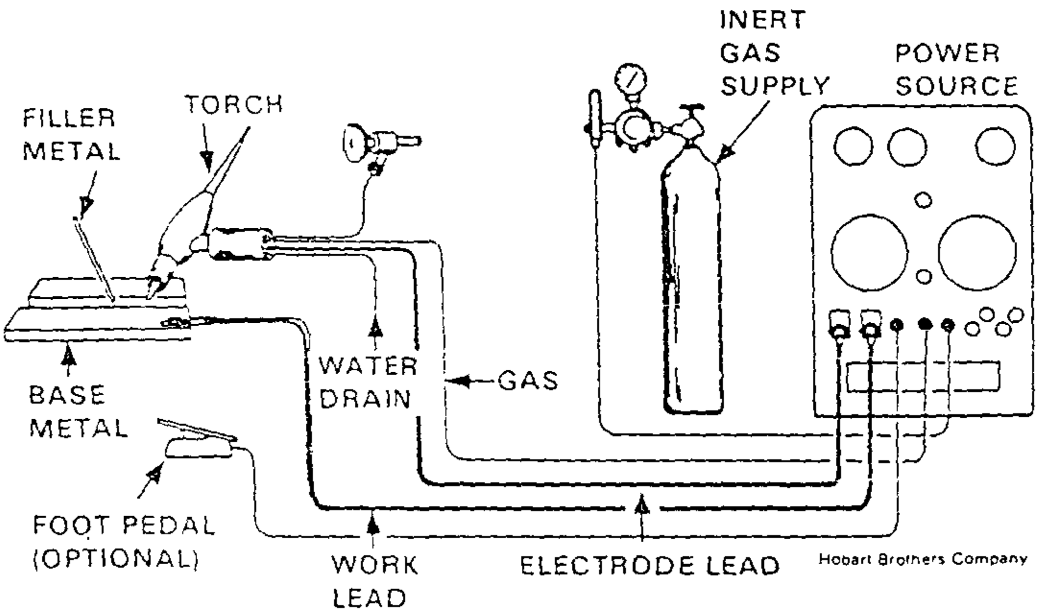
GAS METAL ARC WELDING (GMAW)

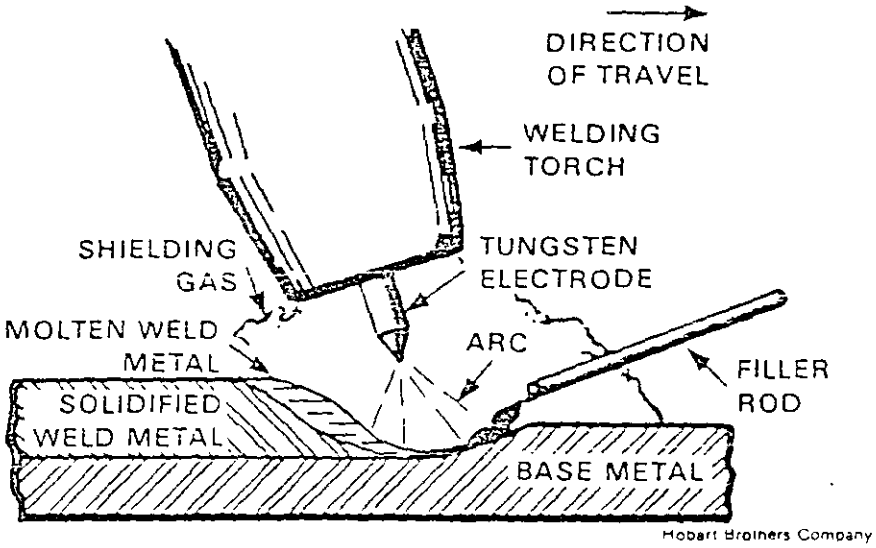




GAS METAL ARC WELDING

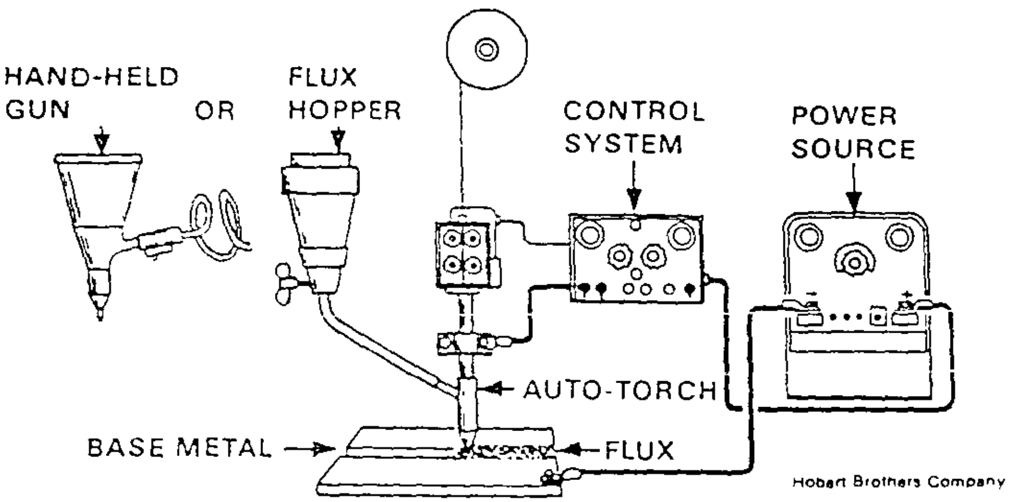
GAS TUNGSTEN ARC WELDING (GTAW)

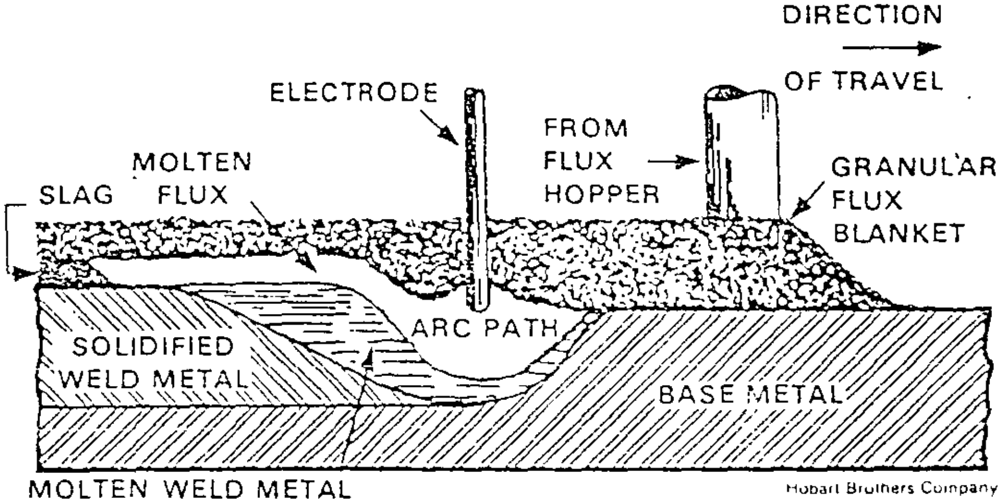




GAS TUNGSTEN ARC WELDING

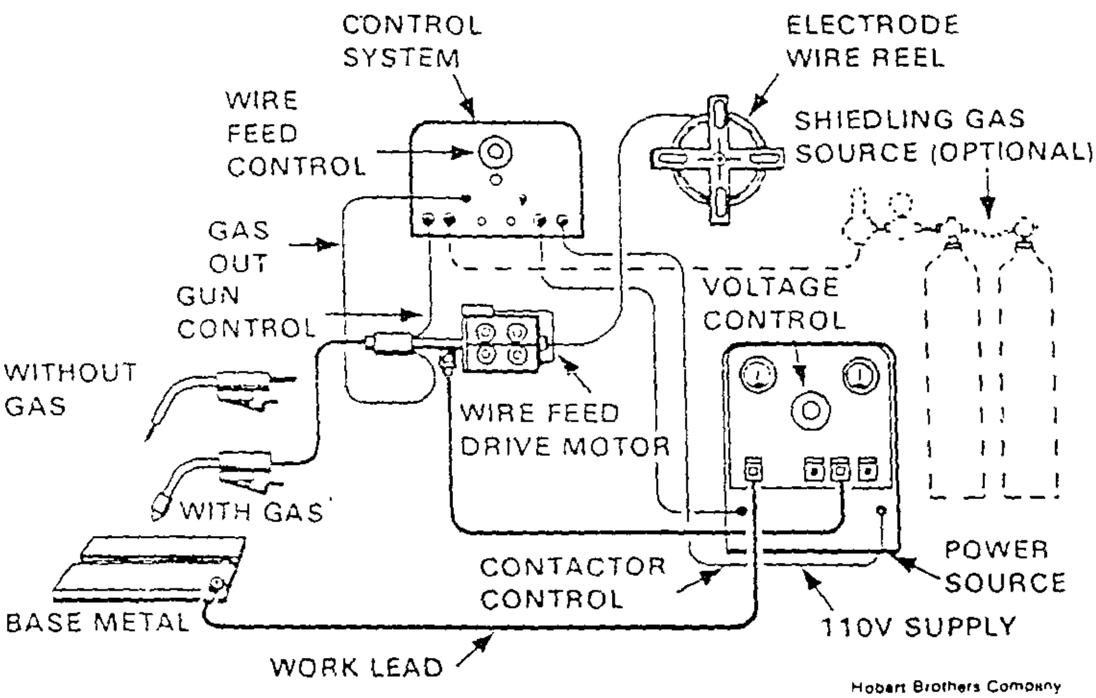
SUBMERGED ARC WELDING (SAW)

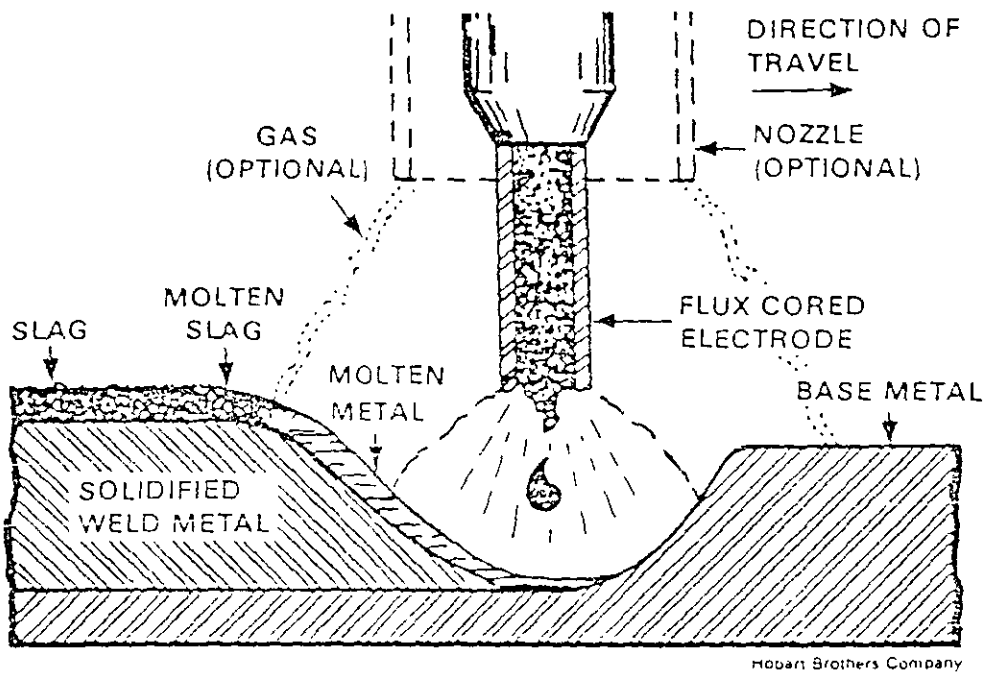




SUBMERGED ARC WELDING

FLUX CORED ARC WELDING (FCAW)

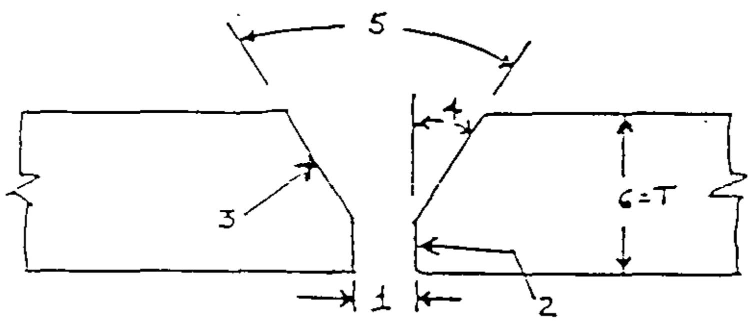




FLUX CORED ARC WELDING

SECTION IX ADDRESSES ONLY THREE TYPES OF WELDS

1. GROOVE WELDS
   a. U GROOVE
   b. J GROOVE
   c. V GROOVE
   d. PARTIAL PENETRATION
   e. ETC.
2. FILLET WELDS
3. STUD WELDS



GROOVE WELD

1.	ROOT OPENING: or GAP	The separation between the member to be joined at root of the joint.
2.	ROOT FACE:	Groove face adjacent to the root of the joint.
3.	GROOVE FACE:	The surface of a member included in the groove.
4.	BEVEL ANGLE:	The angle formed between the prepared surface of a member and a plane perpendicular to the surface of the member.
5.	GROOVE ANGLE:	The total included angle of the groove between parts to be joined by a groove weld.
6.	PLATE THICKNESS:	Thickness welded of test plate or production weldment. Usually indicated by "T".

WELDING PROCESSES (Specifically addressed by Section IX)

OFW	PAW
SMAW	ESW
SAW	EGW
GMAW	EBW
FCAW	Stud welding
GTAW	

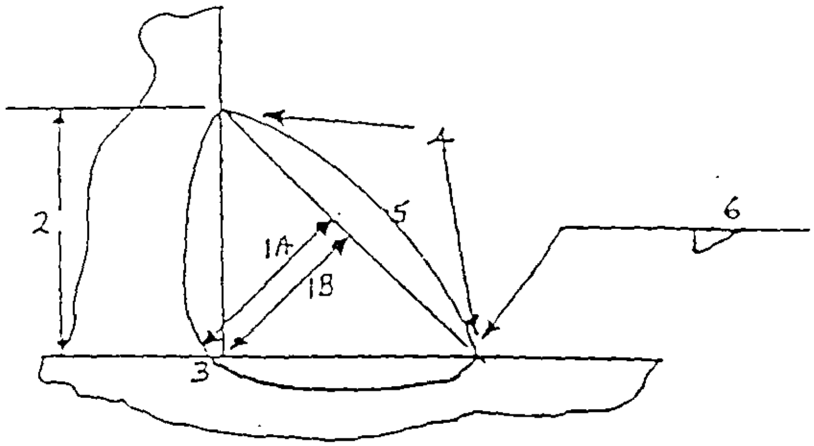
SPECIAL WELDING PROCESSES IN SECTION IX

1. Corrosion-Resistant Weld Metal Overlay

   a. SMAW
   b. SAW
   c. GMAW
   d. GTAW
   e. PAW

2. Hard-Facing Weld Metal Overlay (Wear Resistant)

   a. SMAW
   b. SAW
   c. GMAW
   d. OFW
   e. PAW



FILLET WELD

1A.	THROAT OF A FILLET WELD: (by AWS)	The shortest distance from the root of the fillet weld to its face. Design throat = .707 x leg.
1B.	THEORETICAL THROAT: (by ASME)	The shortest distance from the intersection of the two adjoining members to the fillet weld face.
2.	LEG OF A FILLET WELD:	The distance from the root of the joint to the toe of the fillet weld.
3.	ROOT OF WELD:	Deepest point of useful penetration in a fillet weld.
4.	TOE OF A WELD:	The junction between the face of a weld and the base metal.
5.	FACE OF WELD:	The exposed surface of a weld on the side from which the welding was done.
6.	SIZE OF WELD(S):	Leg length of the fillet. Usually what is on drawings.

PROCEDURE QUALIFICATION RECORD (PQR)

Record of the actual values of the essential variables (and other variables if desired) used when welding a test coupon.

PQR CONTENTS

Verifies mechanical properties of the weld by destructive test

Is intended to provide proof of weldability

Lists actual variables used in making test sample

All essential variables for each process and test result must be listed.

WELDING PROCEDURE QUALIFICATION RECORD (WPS)

- Documents written (& qualified) to provide direction for making production welds to Code requirements (could be more than one piece of paper)
- Intended to provide direction to those individuals responsible for complying with the welding requirements.
- May be used to provide direction to the welder or welding operator.

WPS

Lists acceptable ranges (minimums or maximums) for all parameters

References supporting PQRs

Lists all essential and non-essential (supplementary essential variables if notch toughness applies)

Provide much more detailed description as a true guide for the welder and as a good reference for the foreman and Inspector

WELD DOCUMENTATION GUIDE

WPS	PQR	WPQ
WELDING PROCEDURE SPECIFICATION	PROCEDURE QUALIFICATION RECORD	WELDER PERFORMANCE QUALIFICATION
CONCERNS HOW TO WELD	CONCERNS MECHANICAL PROPERTIES	CONCERNS DEPOSITING SOUND WELD METAL
IS INTENDED TO BE A GUIDE FOR THE WELDER	IS INTENDED TO PROVIDE PROOF OF WELDABILITY	IS INTENDED TO PROVIDE PROOF OF WELDERS ABILITY
LISTS ACCEPTABLE **RANGES** FOR ALL PARAMETERS	LISTS ACTUAL VARIABLES **USED** IN MAKING TEST SAMPLE	LISTS ACTUAL VARIABLES **USED**
HIGHLY RECOMMENDED SUPPORTING PQR OR PQR'S BE LISTED ON THE WPS		LISTS RANGES OF VARIABLES COVERED
	LISTS TEST RESULTS	LISTS TEST RESULTS
	MANDATORY THAT THE WPS FOLLOWED BE LISTED ON THE PQR.	
MUST BE SUPPORTED BY A PQR	QUALIFIES WPS BY WELDING TEST COUPONS, TESTING SPECIMENS AND RECORDING WELD DATA AND TEST RESULTS.	QUALIFIES BY WELDING TEST COUPONS USING THE PARAMETERS OF A WPS, TESTING SPECIMENS AND RECORDING WELD DATA, TEST RESULTS AND RANGES QUALIFIED
MUST PROVIDE DETAILED DESCRIPTION OF VARIABLES NECESSARY TO PRODUCE A SOUND WELD AS A TRUE GUIDE FOR THE WELDER AND AS A GOOD REFERENCE FOR THE FOREMAN AND INSPECTOR		

WPS, PQR, WPQ

This paper has been prepared as a guide to explain what WPS's, PQR's, and WPQ's are and how they should be used.

WPS - Welding Procedure Specification
PQR - Procedure Qualification Record
WPQ - Welder Performance Qualification

Briefly, a WPS lists the variables, both essential and non-essential, and the acceptable ranges of these variables when using the WPS. The WPS is intended to provide direction for the welder. The PQR is intended to provide proof of the weldability of the variables described in the WPS. The WPQ lists what was used in qualifying the welder, the range of parameters he is qualified for and the test results. The WPQ is intended to provide proof of the welder's ability to deposit sound weld metal.

WELDING PROCEDURE SPECIFICATION (WPS)

Each manufacturer or contractor shall list the parameters applicable to welding that he performs in construction of weldments built in accordance with the ASME Code. These parameters shall be listed in a document known as a "Welding Procedure Specification" (WPS).

The WPS shall list in detail the P numbers to be joined, the filler metals to be used, the range of preheat and postweld heat treatment, the thickness range, and all other essential and non-essential variables required in Section IX for each specific process. The WPS is intended to provide the welder with the direction he needs to weld in accordance with the Code and shall be available for reference by the welders and the Authorized Inspector (AI).

All welding variables are listed in Article IV - Welding Data. The variables listed on a WF ay be **essential variables**, those which require requalification when changed, **supplementary essential variables,** those which require requalification when notch toughness requirements are a factor, and non-essential variables, those which require a revision to the WPS but do not require requalification. What may be an essential variable for one process, may be a non-essential variable for another process or may not be a variable at all for a third process.

The WPS specifications and directions should list the amperage range, electrode diameter size, preheat and post weld heat treatment for each base material thickness range. They may also list the type of electrode for various base metals within a P group, and the ranges for voltage, gas flow, wire feed speed, travel speed, slope, polarity, timers, technique, weave-width dwell, torch angle, root gap, tip to work distance, tip to cup distance, cup size, and any additional information that will give the welder direction for making a weld using that WPS. The WPS is intended to provide information for the welder and anything may be contained as long as every essential variable has been qualified.

The proof of the weldability of a WPS is performed in accordance with this Code and the test results are documented on a form called the "Procedure Qualification Record" (PQR). The supporting PQR number shall be available for each WPS and should be recorded on the WPS. You may write several WPS's from the data on a single PQR (e.g., a 1G plate PQR may support WPS's in the 2G, 3F, or 5G on plate or pipe - within all other essential variables). You may also write a single WPS which covers several essential variable changes as long as you h supporting PQR for each essential variable change (e.g., a single WPS may cover a thic s range from 1/16" thru 1-1/4" if you have PQR support for **both** the 1/16" thru 3/16" and 6" thru 1-1/4" thickness ranges).

V-2

PROCEDURE QUALIFICATION RECORD (PQR)

Each manufacturer or contractor shall qualify the WPS by the welding of test coupons and the testing of specimens, as required by this Code, and recording the welding data and test results in a document known as a "Procedure Qualification Record" (PQR). This form shall document the essential variables of the specific welding process or processes (as listed in QW-262 thru QW-281) and the test results. These documents shall be certified by the manufacturer or contractor and shall be available for examination by the Authorized Inspection (AI).

It is required that the essential and non-essential variables of a WPS be followed in welding the test coupons. The WPS identification (including date and revision number) shall be listed on the PQR. The PQR form shall list the actual variables used within the limits of a narrow range, rather than the full range of the variables allowed. A manufacturer may include all additional information he may consider helpful.

The PQR is intended to prove the weldability of a given set of variables. The only variables that are cnsidered essential in procedure qualification are those which affect the physical or mechanical properties. For example: soundly deposited weld metal will yield the same mechanical and physical properties if the test coupon is a plate or a pipe, so plate now qualifies pipe if all other variables remain the same. The properties are also the same if the plate is welded in the flat position or vertical or overhead, so position is no longer a variable in procedure qualification (except where notch-toughness requirements are a factor).

WELDER PERFORMANCE QUALIFICATION (WPQ)

Each manufacturer or contractor shall qualify each welder or welding operator to be used in production to Code requirements. The performance qualification test shall be welded in accordance with one of his qualified Welding Procedure Specifications (WPS). The weld test coupon is tested in accordance with the Code and the results are recorded on a "Record of Welder or Welding Operators Qualification Tests." The welder shall be requalified before welding on production where an essential variables has been changed, e.g., a change to a thickness range or position beyond the welder's qualification.

The Welder Performance Qualification (WPQ) is intended to prove the welder's ability to deposit sound weld metal when welding using a qualified WPS. Position, backing and pipe diameters are essential variables in WPQ.

When welding in production to Code requirements, a welder must follow a qualified WPS, he must be qualified for the essential variables he is using in the WPS and he must weld within the ranges specified on the WPS for each variable.

A welder qualified on a 3/4" thick test coupon is qualified for unlimited thickness, but only to the extent that a qualified WPS is covered. A welder qualified on an F4 electrode is qualified for all lower F numbers, but again only to the extent covered by qualified WPS's.

GUIDE

FOR COMPLETING ASME SECTION IX FORMS

The following "guide" should be used for filling our forms QW-483 (WPS), QW-483 (PQR) and QW-484 (WPQ).

The form QW-482 "WELDING PROCEDURE SPECIFICATION (WPS)" was made up to include the required data for the SMAW, SAW, GMAW, and GTAW processes. It is essential that the requirements of the Code be understood for each process and that all required data be recorded. The form QW-482 is a good guide to follow, but does not list all required data for some processes (i.e., PAW, EBW, etc.) It also lists data not required by all processes (i.e., it lists shielding gas which is not required for SAW).

The data required on a WPS form will be essential variables, supplementary essential variables, and non-essential variables. What may be an essential variable for one process may be a non-essential variable for another process. A complete understanding of the requirements of the Code is essential to filling out a WPS form.

The following form QW-482 has been numbered, with a brief explanation of what is required in each space. The form covers the SAW, SMAW, GTAW, and GMAW processes. This recommended form may be expanded to include other processes or the form may be modified so each process has an individual form. Combination processes or procedures may require an expanded form to cover the required detailed description.

The ranges of each variable must be listed on the WPS. If several diameters of electrodes are used, the range of amps, volts, etc., must be listed for each size. If conditions change over the material thickness range, then the conditions must be listed for each thickness range. This may be listed on a second (or more) sheet(s) of the WPS.

Typical items which are listed on the second (or more) sheet(s) are: process(es), electrode diameters, electrode type(s), filler diameter(s), filler type(s), current voltage(s), polarity, travel speed(s), type of gas, gas flow rate, material thickness range, technique(s), weld progression, tip to work distance, gas shield cup size(s), and other directions for meeting the requirements of the WPS.

A WPS IS:

A document prepared (*and qualified*) to provide direction for making production welds.

FIVE STEPS TO A QUALIFIED WPS

1. Write a sample WPS.
2. Weld a test coupon using the WPS.
3. Prepare test specimens.
4. Evaluate test results.
5. Document results on a PQR and certify.

THINGS FOR A MANUFACTURER TO CONSIDER PRIOR TO WELDING

1. Compatability of weld metal and base material.
2. Metallurgical properties.
3. PWHT or other heat treatment.
4. Design of joints and loadings.
5. Desired mechanical properties.
6. Service requirements.
7. Welder's ability.
8. Equipment available.
9. Location of welds.
10. Ecomony.

MANUFACTURER'S RESPONSIBILITIES FOR RECORDS

- Qualify WPS(s)
- Maintain WPS(s) and PQR(s)
- PQR includes welding data and test results
- All welding test coupons shall be by welders under direct control of manufacturer
- Certify PQR
- Certify that he has qualified each WPS

CONTENTS OF WPS

- Essential variables.
- Non-essential variables.
- Supplementary essential variables. (*When impacts are required*).
- Other information if desired.

PROCEDURE QUALIFICATION RECORD (PQR)

- Modifies or justifies the WPS.
- Support document that documents the results of welding and testing a coupon.

CONTENTS OF PQR

- Essential variables
- Supplementary essential variables. (*When impacts are required*).
- Other information if desired.

NOTE: Only actual information shall be documented. If it wasn't observed it should not be recorded. (i.e. — actual amps, volts, position, etc.)

FIRST: Unqualified WPS

SECOND: The PQR or PQRs

THIRD: The Qualified WPS

NOTE: A manufacturer must have a WPS. This document (or set of documents) shall describe the parameters to be used for welding. A WPS may reference production drawings to cover some variables. If all information required by the WPS is on production drawings, the production drawings may be called the "WPS."

A Code "WPS" may be many pieces of paper or documents. They must be controlled but if all variables are addressed... the Code requirements are met

YOU DON'T REQUALIFY A PROCEDURE, YOU QUALIFY A NEW PROCEDURE QUALIFICATION RECORD.

HOWEVER, A W.P.S. NEED ONLY BE REQUALIFIED WHEN:

- AN ESSENTIAL VARIABLE CHANGES OR,
- THERE IS REASON TO QUESTION TO QUESTION IT'S VALIDITY.

THE W.P.S DESCRIBES

1. THE ESSENTIAL VARIABLES.
2. THE NON-ESSENTIAL VARIABLES.
3. THE SUPPLEMENTARY ESSENTIAL VARIABLES.
4. ANYTHING ELSE USEFUL TO THE WELDER.
5. IT LISTS THE ACCEPTABLE RANGES TO BE FOLLOWED.

QUALIFYING A WPS

WRITE AN UN-QUALIFIED WPS AROUND JOB PARAMETERS. WATCH VARIABLES QW-250, 260.

ESTABLISH TEST COUPON SIZE QW-451, 462, 463.

WELD THE COUPON USING UN-QUALIFIED PARAMETERS QW-210, 250, 260.

MONITOR ALL ESSENTIALS VARIABLES AND RECORD THE ACTUAL VALUES ON THE PQR QW 200.2.

RECOMMEND ALSO RECORDING NON ESSENTIAL VARIABLES

RECORD SUPPLEMENTARY ESSENTIAL VARIABLES IF APPLICABLE

CUT WELD TEST COUPONS INTO SPECIMENS QW-462, 463.

MAKE REQUIRED TESTS PER QW-451

EVALUATE RESULTS TO ARTICLE I ACCEPTANCE STANDARDS QW-150, 160

CERTIFY PQR

COMPARE UNQUALIFIED WPS ESSENTIAL (AND SUPPLEMENTARY ESSENTIAL, IF APPLICABLE) VARIABLES WITH RESULTS OF PQR TO ASSURE COMPLIANCE TO IX.

CERTIFICATE HOLDER APPROVES WPS
(A) ON WPS
OR
(B) ANOTHER QC-TYPE DOCUMENT

USE WPS FOR PRODUCTION

V-9

MECHANICAL TESTS FOR A W.P.S.

1. 2 TENSILE TESTS MINIMUM.
2. 4 BEND TESTS MINIMUM.
   a. SIDE BENDS FOR 3/4" AND GREATER.
   b. FACE & ROOT BENDS FOR LESS THAN 3/ 8".
   c. YOUR OPTION FOR 3/8" TO LESS THAN 3/ 4".
3. THE MATERIALS TESTED MUST BE ONE OF THOSE LISTED ON THE W.P.S.

V-10

QW-450 SPECIMENS

QW-451 Groove-Weld Procedure Qualification Thickness Limits and Test Specimens

QW-451.1
TENSION TESTS AND TRANSVERSE-BEND TESTS

Thickness T of Test Coupon Welded, in	Range of Thickness T of Base Metal Qualified, in [Note (1)]		Thickness t of Deposited Weld Metal Qualified, in [Note (1)]	Type and Number of Tests Required (Tension and Guided-Bend Tests)			
	Min.	Max.	Max.	Tension QW-150	Side Bend QW-160	Face Bend QW-160	Root Bend QW-160
Less than 1/16	T	$2T$	$2t$	2	...	2	2
1/16 to 3/8, incl	1/16	$2T$	$2t$	2	Note (3)	2	2
Over 3/8, but less than 3/4	3/16	$2T$	$2t$	2	Note (3)	2	2
3/4 to less than 1 1/2	3/16	$2T$	$2t$ when $t < 3/4$	2	4	...	...
3/4 to less than 1 1/2	3/16	$2T$	$2T$ when $t \geq 3/4$	2	4	...	...
1 1/2 and over	3/16	8 (2)	$2t$ when $t < 3/4$	2	4	...	...
1 1/2 and over	3/16	8 (2)	8 (2) when $t \geq 3/4$	2	4	...	...

NOTES:
(1) See QW-403 (.2, .3, .6, .9, .10) and QW-407.4 for further limits on range of thicknesses qualified. Also see QW-202.2 for allowable exceptions.
(2) For the welding processes of QW-403.7 only; otherwise per Note (1) or $2T$, or $2t$, whichever is applicable.
(3) Four side bend tests may be substituted for the required face- and root-bend tests, when thickness T is 3/8 in. and over.

3.14

U-11

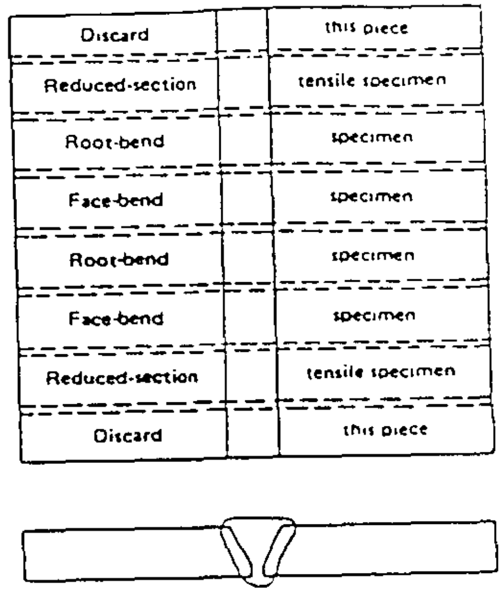
TYPES OF TESTS ARE BASED ON COUPON THICKNESS

- If coupon is over 1" thick, multiple specimens may be cut (*mechanically*)
- Twice as many specimens are required
- Special exception for pipe 3" OD or less

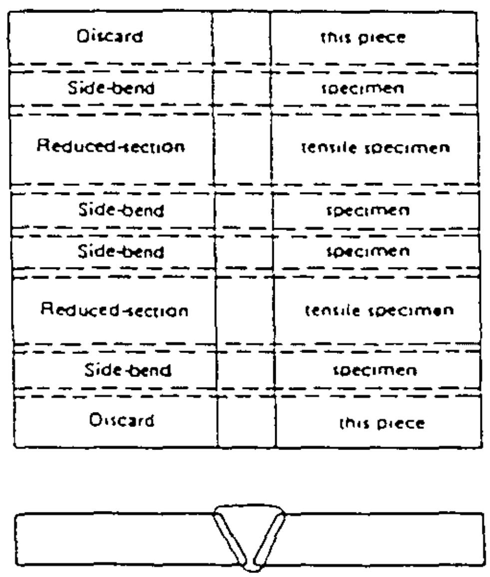
TYPES OF TENSION TESTS

1. REDUCED SECTION --- PLATE
2. REDUCED SECTION --- PIPE
3. TURNED SPECIMEN
4. FULL SECTION --- PIPE

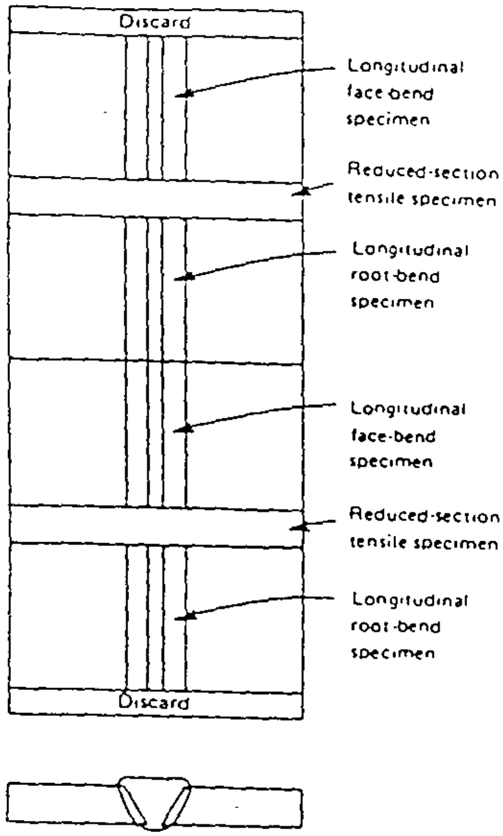
V-12



QW-463.1(a) PLATES — 1/16 TO 3/4 IN.
PROCEDURE QUALIFICATION

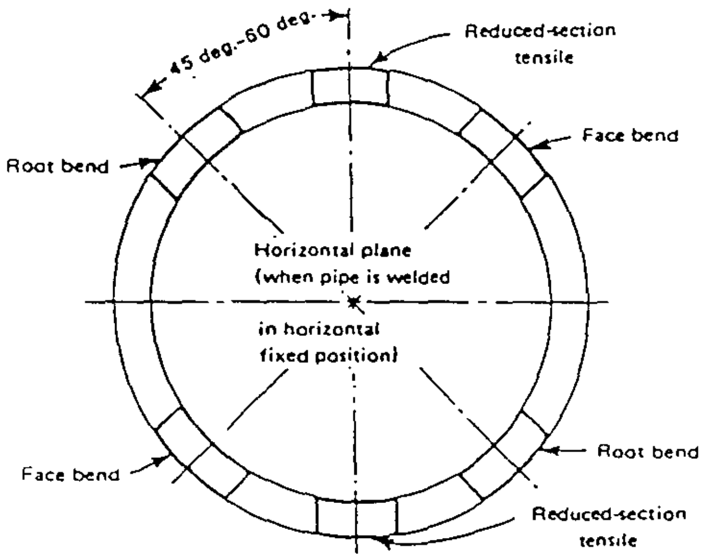


QW-463.1(b) PLATES — OVER 3/4 AND
ALTERNATE 3/8 TO 3/4 IN.
PROCEDURE QUALIFICATION



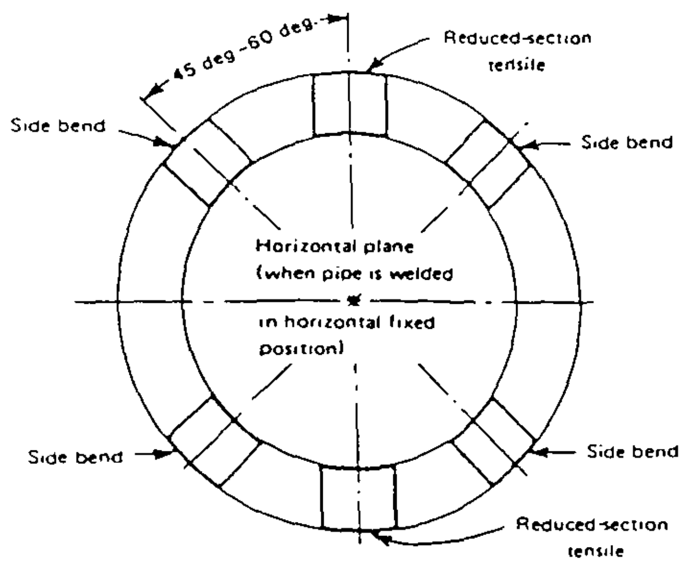
QW-463.1(c) PLATES — LONGITUDINAL
PROCEDURE QUALIFICATION

QW-463 Order of Removal (Cont'd)



Pipes – 1/16 to 3/4 in. Thickness

QW-463.1(d) PROCEDURE QUALIFICATION

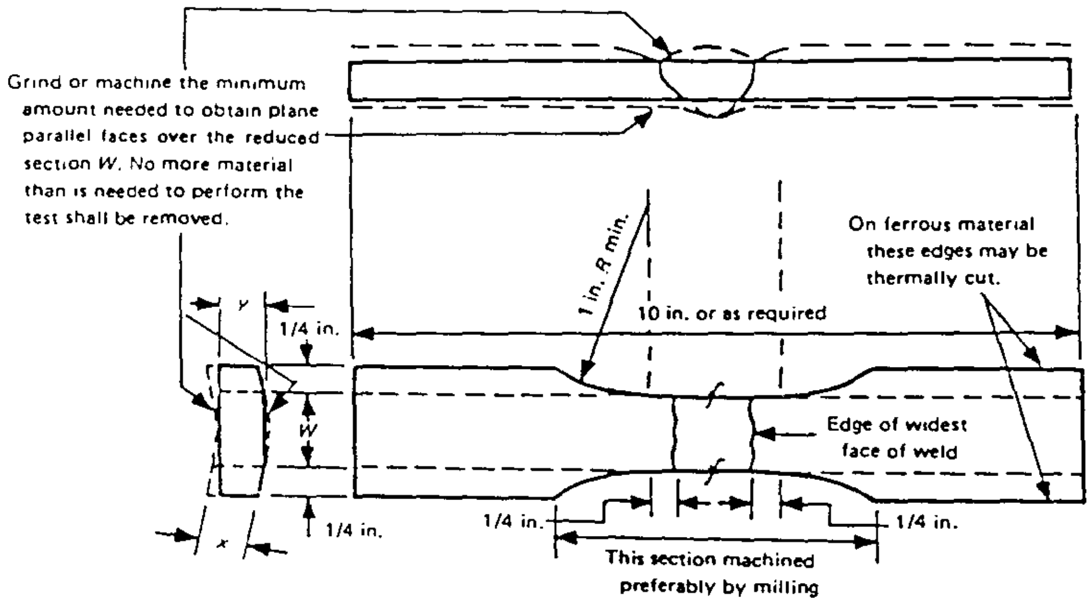


Pipes – Over 3/4 in. Thickness and Alternate From 3/8 in. but Less Than 3/4 in. Thickness

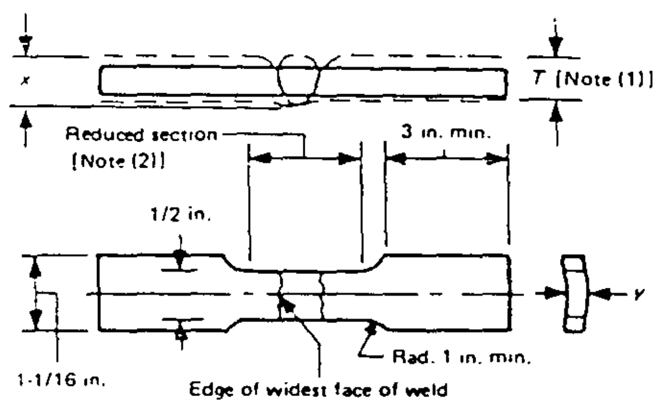
QW-463.1(e) PROCEDURE QUALIFICATION

V-15

QW-462 Test Specimens (Cont'd)



QW-462.1(b) TENSION — REDUCED SECTION — PIPE



NOTES.
(1) The weld reinforcement shall be ground or machined so that the weld thickness does not exceed the base metal thickness T. Machine minimum amount to obtain approximately parallel surfaces.
(2) The reduced section shall not be less than the width of the weld plus $2y$.

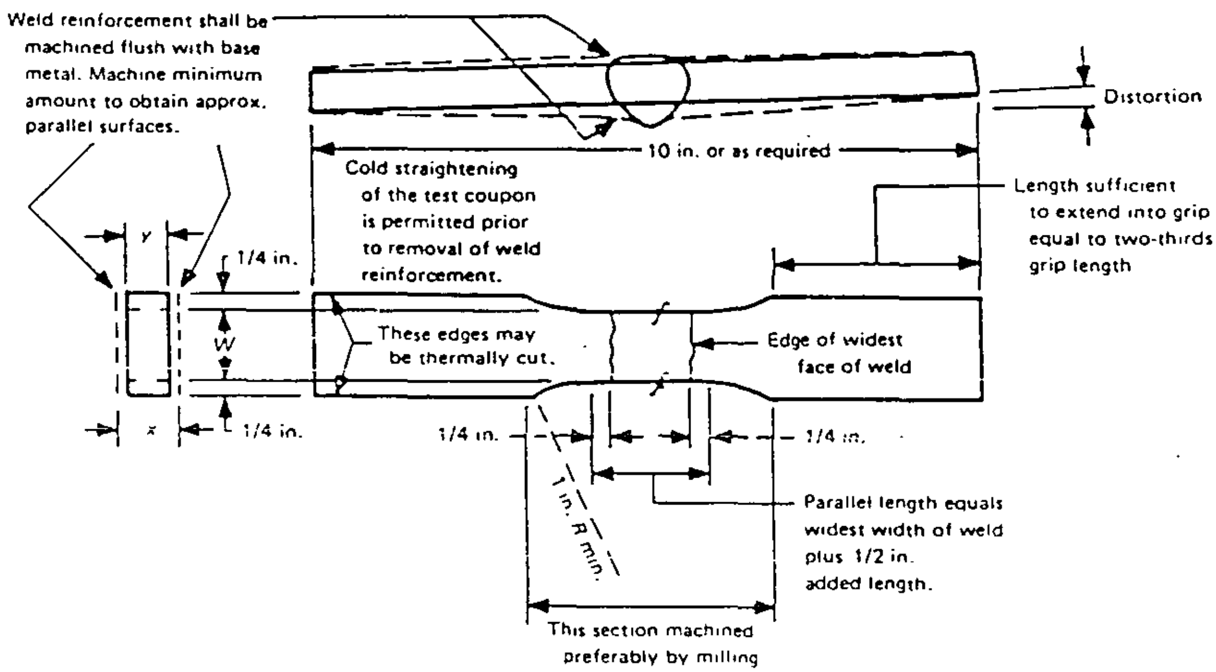
QW-462.1(c) TENSION — REDUCED SECTION ALTERNATE FOR PIPE

V-16

QW-462 Test Specimens

The purpose of the QW-462 figures is to give the manufacturer or contractor guidance in dimensioning test specimens for tests required for procedure and performance qualifications. Unless a minimum, maximum, or tolerance is given in the figures (or as QW-150, QW-160, or QW-180 requires), the dimensions are to be considered approximate. All welding processes and filler material to be qualified must be included in the test specimen.

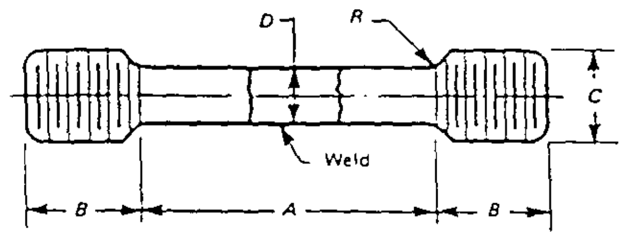
x = coupon thickness including reinforcement
y = specimen thickness
T = coupon thickness excluding reinforcement
W = specimen width, ¾ in.



QW-462.1(a) TENSION — REDUCED SECTION — PLATE

V-17

QW-462 Test Specimens (Cont'd)

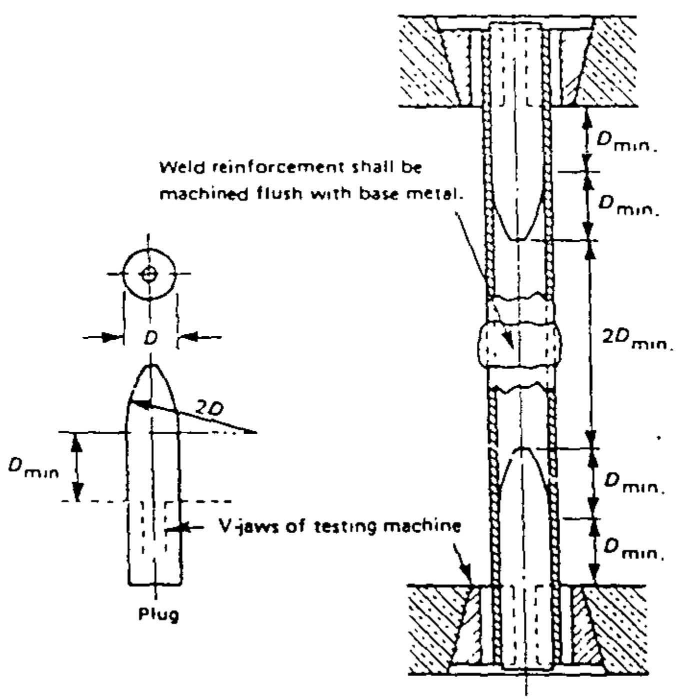


	Standard Dimensions, in.			
	(a) 0.505 Specimen	(b) 0.353 Specimen	(c) 0.252 Specimen	(d) 0.188 specimen
A — Length of reduced section	[Note (1)]	[Note (1)]	[Note (1)]	[Note (1)]
D — Diameter	0.500 ±0.010	0.350 ±0.007	0.250 ±0.005	0.188 ±0.003
R — Radius of fillet	3/8, min.	1/4, min.	3/16, min.	1/8, min
B — Length of end section	1-3/8, approx.	1-1/8, approx	7/8, approx.	1/2, approx.
C — Diameter of end section	3/4	1/2	3/8	1/4

GENERAL NOTES:
(a) Use maximum diameter specimen (a), (b), (c), or (d) that can be cut from the section
(b) Weld should be in center of reduced section.
(c) Where only a single coupon is required the center of the specimen should be midway between the surfaces.
(d) The ends may be of any shape to fit the holders of the testing machine in such a way that the load is applied axially.

NOTE:
(1) Reduced section *A* should not be less than width of weld plus 2*D*.

QW-462.1(d) TENSION — REDUCED SECTION — TURNED SPECIMENS



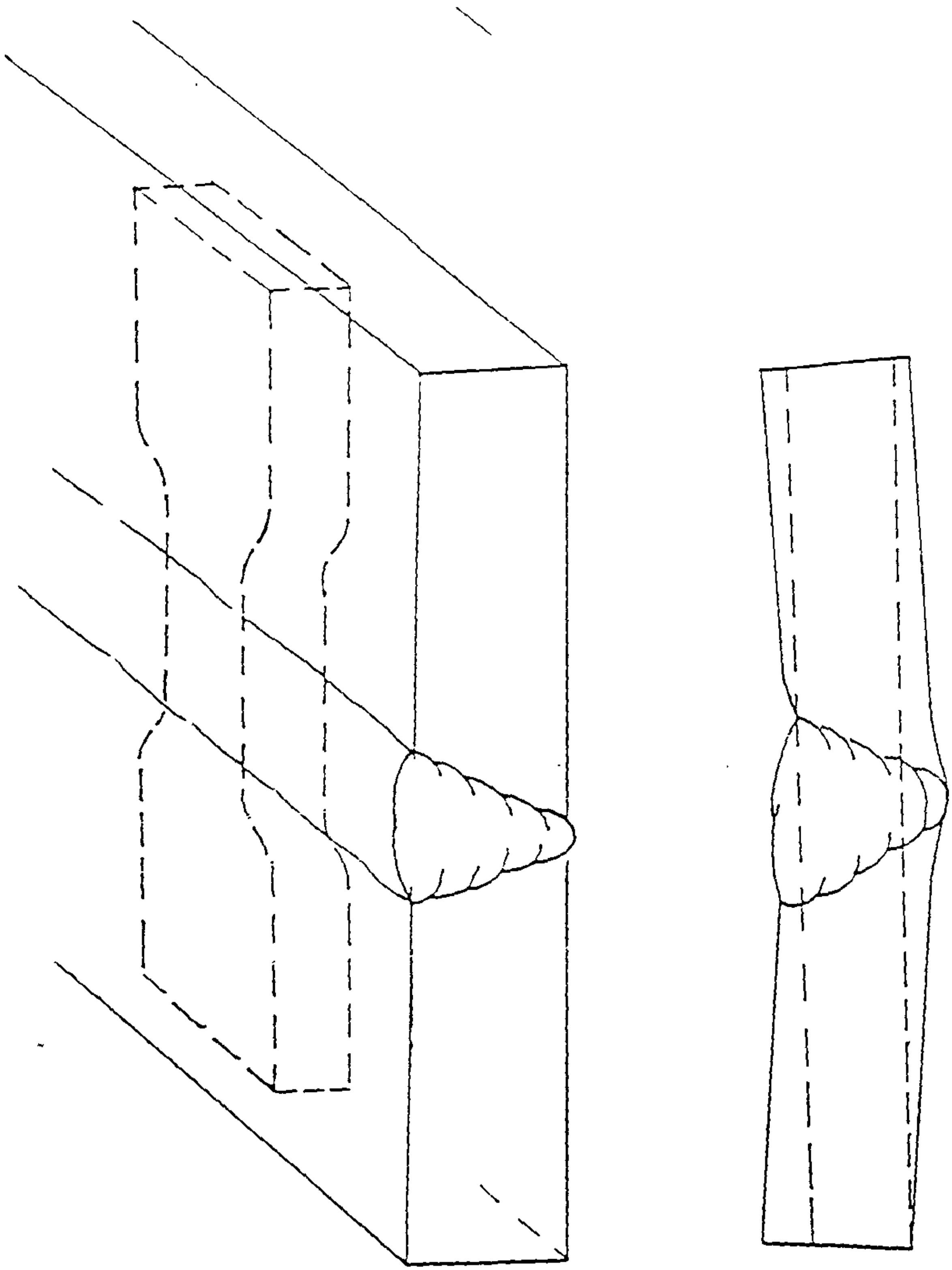
QW-462.1(e) TENSION — FULL SECTION — SMALL DIAMETER PIPE

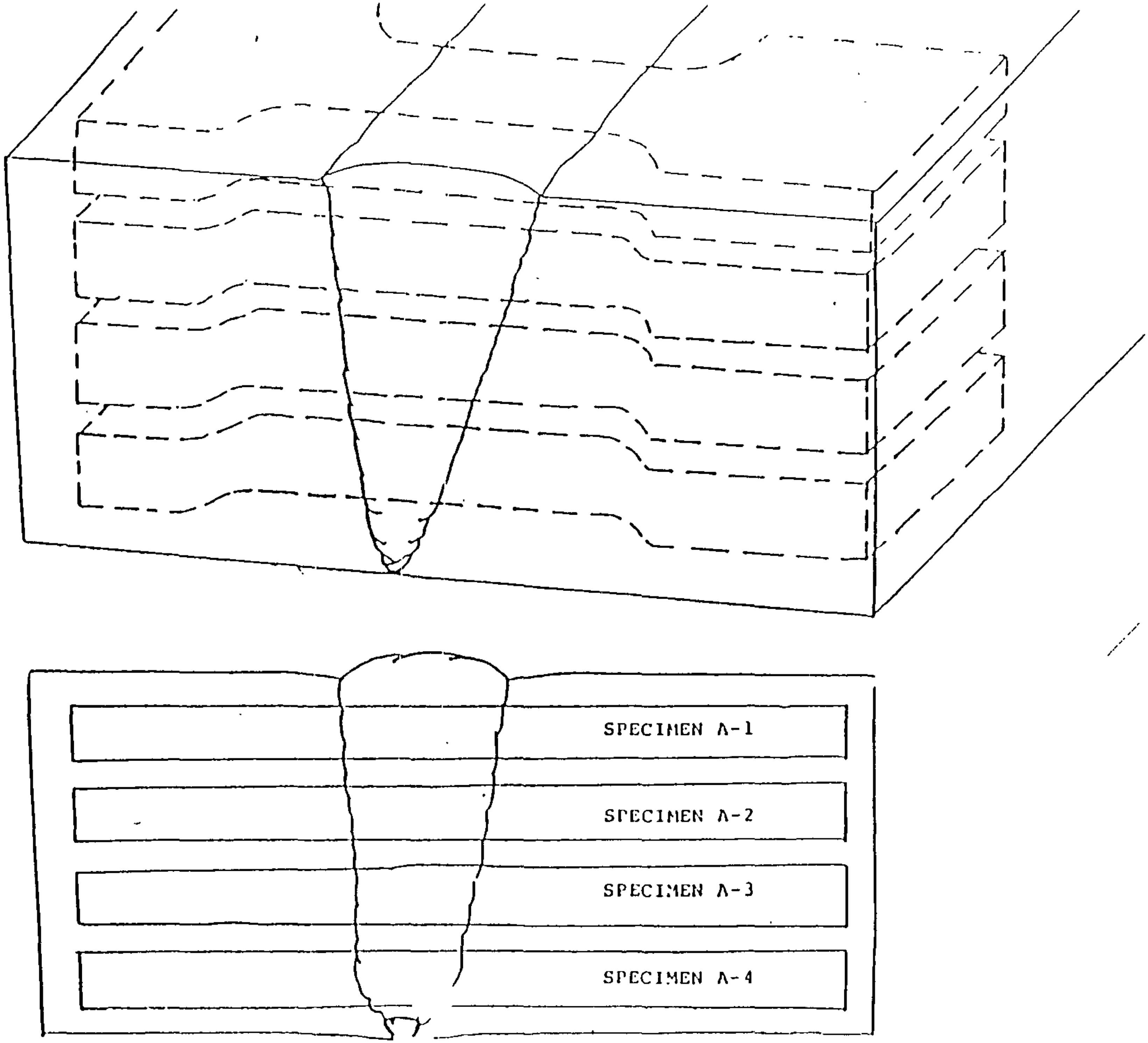
V-19

TENSION TEST ACCEPTANCE CRITERIA

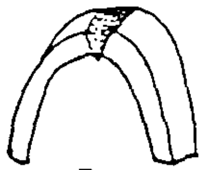
1. MINIMUM STRENGTH OF THE BASE MATERIAL.
2. MINIMUM STRENGTH OF THE WEAKER MATERIAL IF DIFFERENT MATERIALS ARE USED.
3. MINIMUM STRENGTH OF THE WELD METAL IF THE BASE MATERIAL AND THE FILLER MATERIAL HAVE DIFFERENT STRENGTHS AT DESIGN TEMPERATURE.
4. IF THE BREAK OCCURS IN THE BASE MATERIAL, AWAY FROM THE HEAT AFFECTED ZONE, THE CRITERIA MAY BE 5% BELOW THE MINIMUM STRENGTH OF THE BASE MATERIAL.

V-19

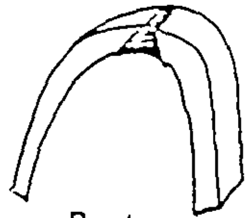



SPECIMEN A-1
SPECIMEN A-2
SPECIMEN A-3
SPECIMEN A-4

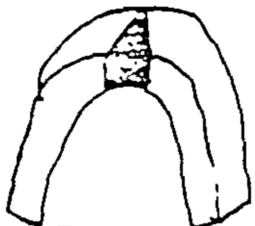
BEND TESTS



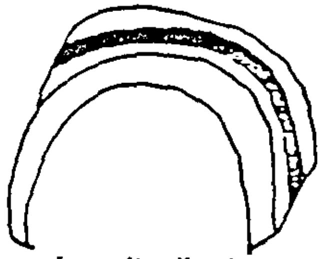
Face
Bend



Root
Bend



Transverse
Side Bend



Longitudinal
Face Bend

GUIDED BEND ACCEPTANCE CRITERIA

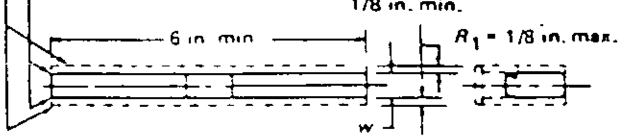
- No open defects in weld or Heat Affected Zone greater than 1/8"
- Cracks at corners may be ignored unless resulting from slag or internal defects

QW-462 Test Specimens (Cont'd)

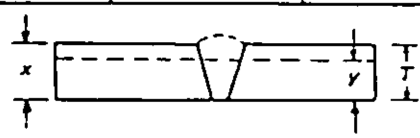
(1a) For procedure qualification of materials other than P-No. 1 in QW-422, if the surfaces of the side bend test specimens are gas cut, removal by machining or grinding of not less than 1/8 in. from the surface shall be required.

(1b) Such removal is not required for P-No. 1 materials, but any resulting roughness shall be dressed by machining or grinding.

(2) For performance qualification of all materials in QW-422, if the surfaces of side bend tests are gas cut, any resulting roughness shall be dressed by machining or grinding.



T, in.	y, in.	w (in.)	
		P-No. 23, F-No. 23, or P-No. 35	All other metals
3/8 to 1-1/2, incl.	T	1/8	3/8
> 1-1/2	[Note (1)]	1/8	3/8



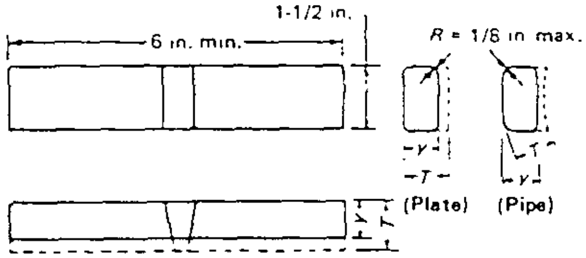
GENERAL NOTE:
Weld reinforcement and backing strip or backing ring, if any, may be removed flush with the surface of the specimen. Thermal c n, machining, or grinding may be employed. Cold straighteni r-mitted prior to removal of the reinforcement.

NOTE:
(1) When specimen thickness T exceeds 1-1/2 in., use one of the following.
(a) Cut specimen into multiple test specimens y of approximately equal dimensions (3/4 in. to 1-1/2 in.).
y = tested specimen thickness when multiple specimens are taken from one coupon
(b) The specimen may be bent at full width. See requirements on jig width in QW-466.1.

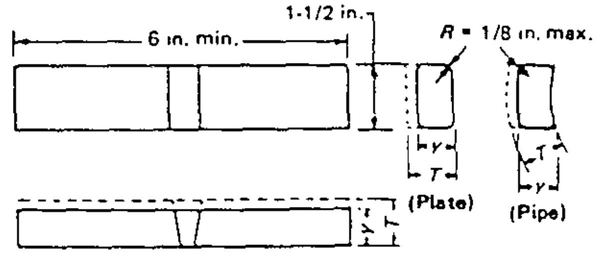
QW-462.2 SIDE BEND

V-23

QW-462 Test Specimens (Cont'd)



Face-bend specimen — Plate and Pipe



Root-bend specimens — Plate and pipe

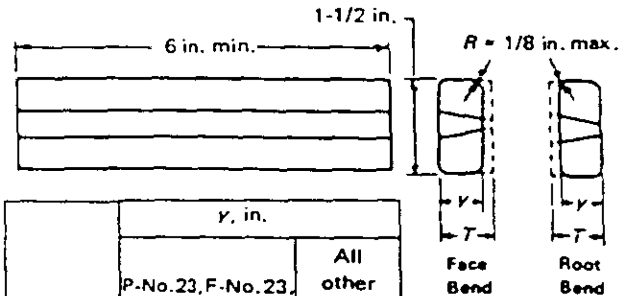
T, in.	Y, in	
	P-No.23, F-No.23, or P-No. 35	All other metals
1/16 < 1/8	T	T
1/8-3/8	1/8	T
>3/8	1/8	3/8

NOTES:

(1) Weld reinforcement and backing strip or backing ring, if any, shall be removed flush with the surface of the specimen. If a recessed ring is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the ring, except that in such cases the thickness of the finished specimen shall be that specified above. Do not flame-cut nonferrous material.

(2) If the pipe being tested is 4 in. nominal diameter or less, the width of the bend specimen may be 3/4 in. for pipe diameters 2 in. to and including 4 in. The bend specimen width may be 3/8 in. for pipe diameters less than 2 in. down to and including 3/8 in. and as an alternative, if the pipe being tested is equal to or less than 1 in. nominal pipe size (1.315 in. O. D.), the width of the bend specimens may be that obtained by cutting the pipe into quarter sections, less an allowance for saw cuts or machine cutting. These specimens cut into quarter sections are not required to have one surface machined flat as shown in QW-462.3(a). Bend specimens taken from tubing of comparable sizes may be handled in a similar manner.

A87 QW-462.3(a) FACE AND ROOT BENDS — TRANSVERSE[1,2]



T, in.	Y, in.	
	P-No.23, F-No.23, or P-No. 35	All other metals
1/16 < 1/8	T	T
1/8-3/8	1/8	T
>3/8	1/8	3/8

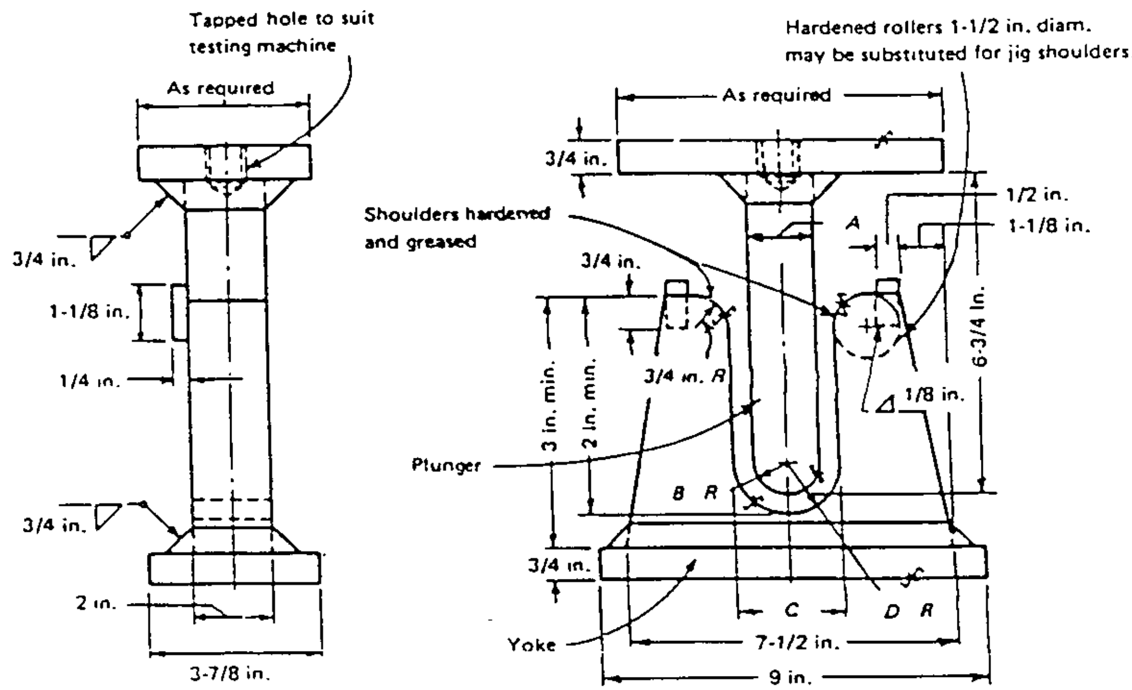
NOTE:

(1) Weld reinforcements and backing strip or backing ring, if any, shall be removed essentially flush with the undisturbed surface of the base material. If a recessed strip is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the strip, except that in such cases the thickness of the finished specimen shall be that specified above.

QW-462.3(b) FACE AND ROOT BENDS — LONGITUDINAL[1]

V-24

QW-466 Test Jigs



Material	Thickness of Specimen, in.	*A*, in.	*B*, in.	*C*, in.	*D*, in.
P-No. 23 to P-No. 2X, P-No 2X with F-No. 23, P-No. 35	1/8	2-1/16	1-1/32	2-3/8	1-3/16
	t = 1/8 or less	16-1/2*t*	8-1/4*t*	18-1/2*t* + 1/16	9-1/4*t* + 1/32
P-No. 11; P-No. 25 to P-No 21 or P-No 22 or P-No. 25	3/8	2-1/2	1-1/4	3-3/8	1-11/16
	t = 3/8 or less	6-2/3*t*	3-1/3*t*	8-2/3*t* + 1/8	4-1/3*t* + 1/16
P-No. 51	3/8	3	1-1/2	3-7/8	1-15/16
	t = 3/8 or less	8*t*	4*t*	10*t* + 1/8	5*t* + 1/16
P-No. 52, P-No. 61, P-No. 62	3/8	3-3/4	1-7/8	4-5/8	2-5/16
	t = 3/8 or less	10*t*	5*t*	12*t* + 1/8	6*t* + 1/16
All others	3/8	1-1/2	3/4	2-3/8	1-3/16
	t = 3/8 or less	4*t*	2*t*	6*t* + 1/8	3*t* + 1/16

GENERAL NOTE: For P-Numbers, see QW-422; for F-Numbers, see QW-432.

QW-466.1 GUIDED-BEND JIG

V-25

GROOVE WELD TEST COUPON QUALIFIES FOR

All fillet weld

(a) Thicknesses
(b) Sizes
(c) Diameters of pipe
(d) Within essential variables

(Note: Exception is P-11A groups 3, 4, 5 and P-11B which requires special qualifications.)

FILLET WELD QUALIFICATIONS (QW-451.3)

- 1 Tee Fillet Test
- 4-5 Macro Etch Tests

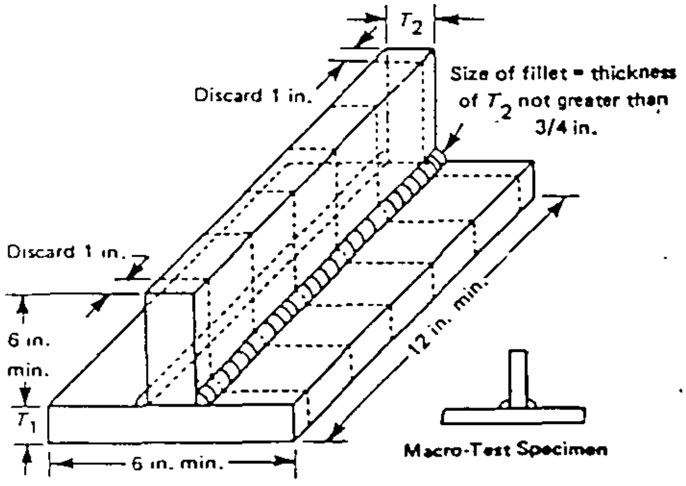
FILLET PROCEDURES

Plate — 5 macro etches
Pipe — 4 macro etches

Acceptance: No visible cracks in weld metal or HAZ, full fusion at the root and leg lengths shall differ by less than 1/8".

V-26

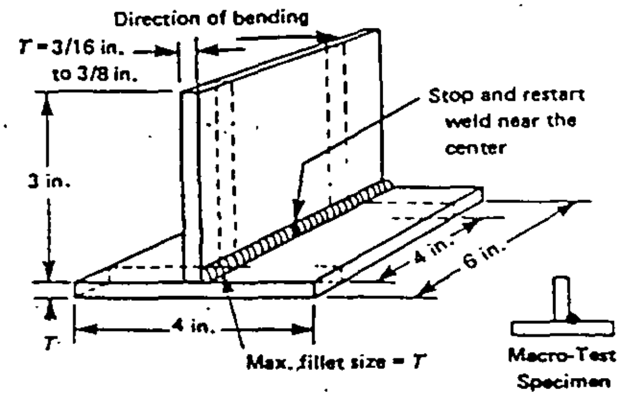
QW-462 Test Specimens (Cont'd)



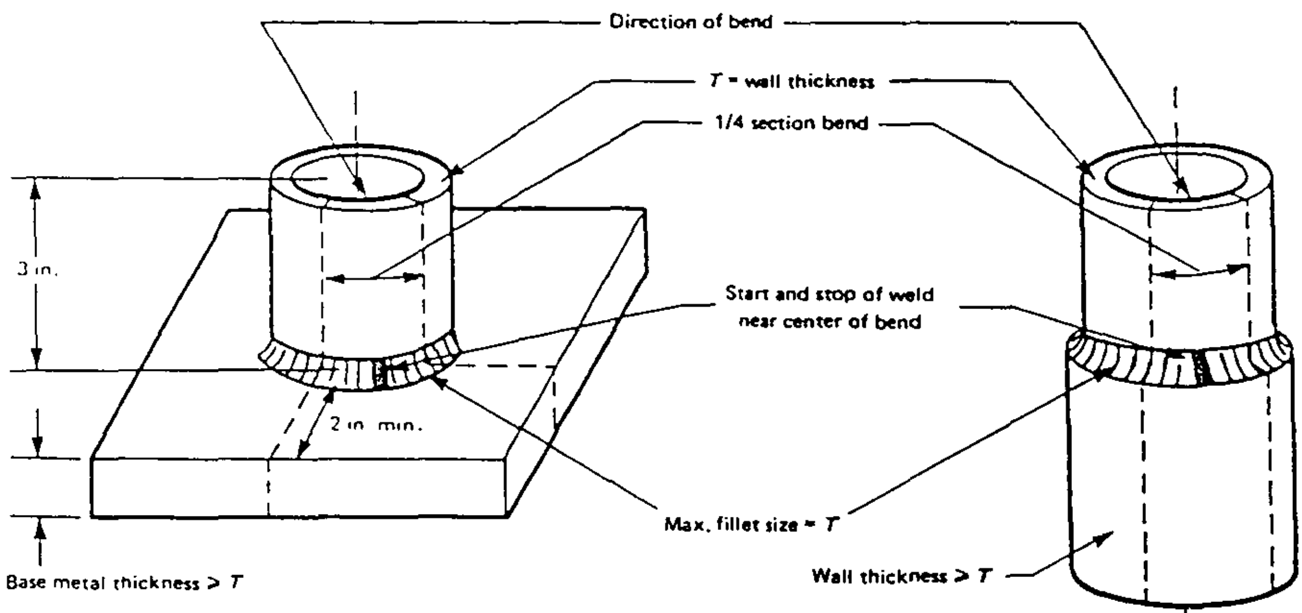
GENERAL NOTE:
Macro test — The fillet shall show fusion at the root of the weld but not necessarily beyond the root. The weld metal and heat affected zone shall be free of cracks.

QW-462.4(a) FILLET WELDS — PROCEDURE

T_1	T_2
1/8 in. and less	T_1
Over 1/8 in.	Equal to or less than T_1 but not less than 1/8 in.



QW-462.4(b) FILLET WELDS — PERFORMANCE



GENERAL NOTE: Either pipe-to-plate or pipe-to-pipe may be used as shown.

A86 QW-462.4(c) FILLET WELDS IN PIPE — PERFORMANCE

V. 27

NEVER USE ARTICLE II
WHEN QUALIFYING WELDERS
OR WELDING OPERATORS

ONLY ARTICLE III APPLIES

WHO IS A WELDER?

One who performs a manual or semi-automatic welding operation.

PURPOSE OF QUALIFYING A WELDER

To determine the welder's ability to deposit sound weld metal.

V-28

WHO IS A WELDING OPERATOR?

One who operates machine or automatic welding equipment.

PURPOSE OF QUALIFYING A WELDING OPERATOR

To determine the operator's mechanical ability to operate the welding equipment.

RESPONSIBILITIES OF MFG. (FOR WELDERS)

- Conduct tests to qualify the welders **to use** one or more of mfg's welding procedures that will be used on Code work.
- Test weld made under supv. and control of Mfg.

WELDER'S PERFORMANCE QUALIFICATION RECORD

A W.P.Q. IS A DOCUMENT FOR RECORDING THE QUALIFICATIONS OF A WELDER OR WELDING OPERATOR.

CONTENTS OF THE WPQ

(a) All applicable variables used by the welder to make a test coupc

(b) Results of the tests

(c) The ranges (*when applicable*) — some variables only have mi or max. values) qualified.

V-30

THE WELDER'S QUALIFICATION IS **LIMITED BY** THE ESSENTIAL VARIABLES OF QW-350.

THE ESSENTIAL VARIABLES OF QW-350 **DO NOT** APPLY TO WELDING OPERATORS.

WELDER RECORDS

- WPQ
- Continuity Log
- I.D. Log

WELDER'S LOG

WELDER A							
SMAW	1/3/85	4/1/85	7/1/85	12/1/85			
GTAW	1/6/85	8/5/85	10/5/85				
SAW	5/8/85	12/1/85	1/1/86				
WELDER B							
GTAW	1/3/85	4/1/85	12/1/85				
GMAW	6/1/85	9/1/85	12/1/85				
WELDER C							
GMAW	6/8/65	12/1/85					
SMAW	9/1/85						

CERTIFICATION OF WELDERS

(a) Not specifically required in IX.

(b) However, recertification and QA/QC program requirements strongly suggest this must be done.

Continued CERTIFICATION OF WELDERS

- Must weld at least every 3 months.
- Must use each process at least every 6 months.
- Need not be on Code work.

Continued CERTIFICATION — EXAMPLE 1

- A welder is qualified on June 15, 1983 to use the SMAW process.
- The welder is qualified on July 30, 1983 to use the GTAW process.

If no welding is performed after July 30, when does this welder's SMAW qualification expire? GTAW?

Continued CERTIFICATION — EXAMPLE 2

SMAW process — June 15, 1983
GTAW process — July 30, 1983
SMAW process — October 15, 1983
SMAW process — November 15, 1983

When does this welder's SMAW qualification expire? GTAW?

V-33

WHAT WOULD BE REQUIRED IF A WELDER'S QUALIFICATIONS EXPIRE?

REQUALIFICATION OF WELDERS

- When time limit expires
- When reason to doubt ability
- When outside limits of qualified ranges

RECERTIFICATION

1. THE WELDER MUST WELD EVERY THREE MONTHS.
2. THE WELDER MUST USE EVERY PROCESS AT LEAST EVERY SIX MONTHS.
3. REQUALIFICATION IS BASED ON ONE COUPON. IF SUCESSFUL, THIS COUPON WILL RE-ESTABLISH THE WELDER'S QUALIFICATIONS FOR ALL THICKNESSES, DIAMETERS ETC. FOR <u>EACH</u> PROCESS.

V.34

PREPARATION OF TEST COUPONS

- Must use a WPS (*qualified or unqualified*)
- Preheat not required
- PWHT not required
- Welders who qualify a WPS may use that WPS in production (*fillet welds are an exception*)
- P-11B WPS groove may not be used to make a P-11B fillet weld but welder may be qualified.
- May be terminated if test appears to be unsatisfactory.

TYPES OF TESTS

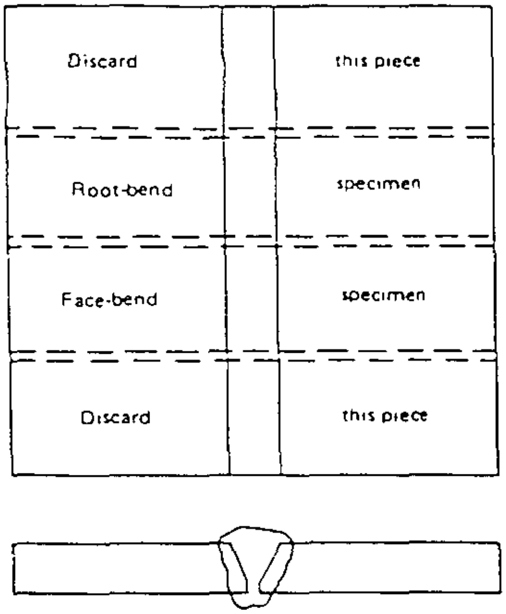
1. Mechanical
   a. Bends
   b. Macro/fracture
2. Radiography
   a. Only permitted by QW-304 or QW-305
   b. 6″ radiograph on plate or entire circumference of pipe

MECHANICAL TESTS FOR WELDERS

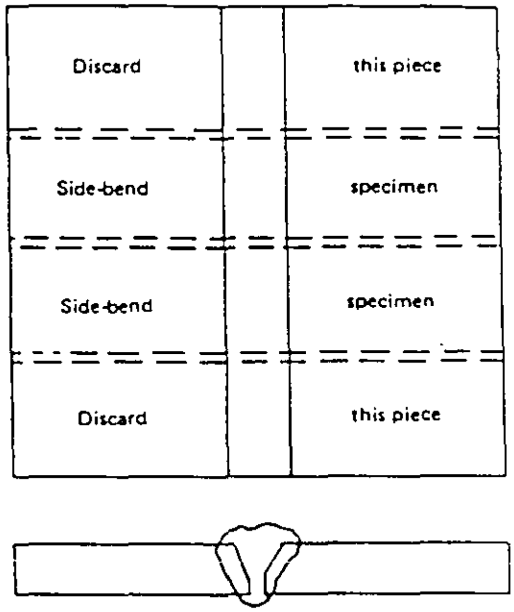
- Plate groove test:
  2 bend tests
- Pipe groove test:
  1G or 2G — 2 bend tests
  5G or 6G — 4 bend tests
- Plate fillet test:
  2 — macro, 1 — fracture
- Pipe fillet test:
  2 — macro, 1 — fracture

V-35

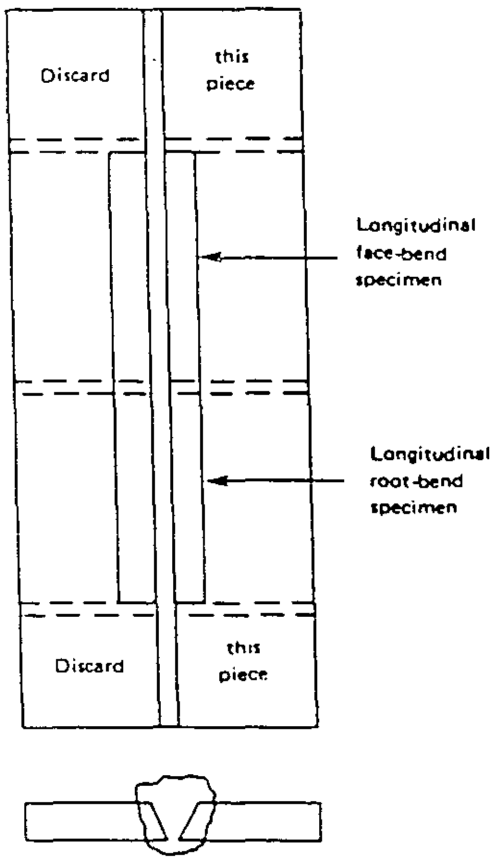
QW-463 Order of Removal (Cont'd)



QW-463.2(a) PLATES — 1/16 TO 3/4 IN.
PERFORMANCE QUALIFICATION



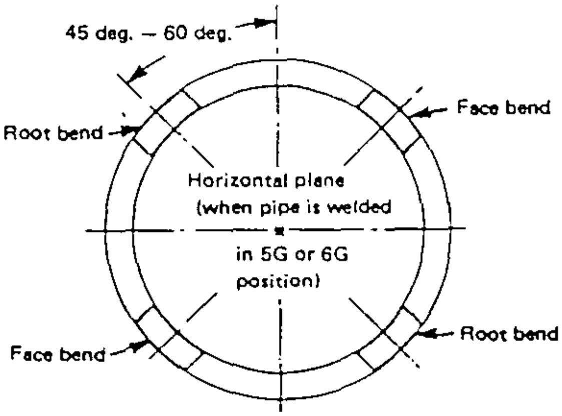
QW-463.2(b) PLATES — OVER 3/4 AND
ALTERNATE 3/8 TO 3/4 IN.
PERFORMANCE QUALIFICATION



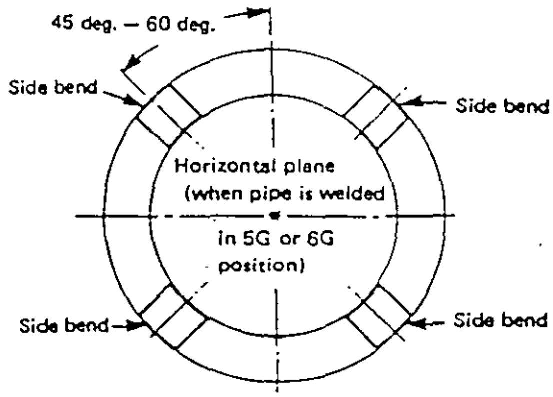
QW-463.2(c) PLATES — LONGITUDINAL PERFORMANCE QUALIFICATION

V-36

QW-463 Order of Removal (Cont'd)



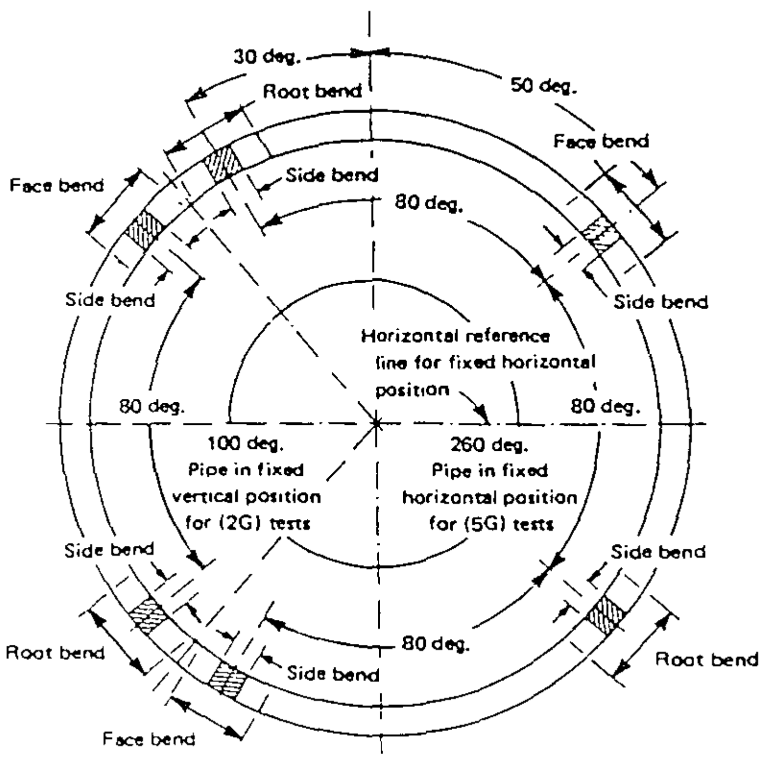
Pipes — 1/16 Up to 3/4 in. Thickness



Pipes — 3/4 in. and Over Thickness and Alternate From 3/8 in. but Less Than 3/4 in. Thickness

A87 QW-463.2(d) PERFORMANCE QUALIFICATION

QW-463.2(e) PERFORMANCE QUALIFICATION A87

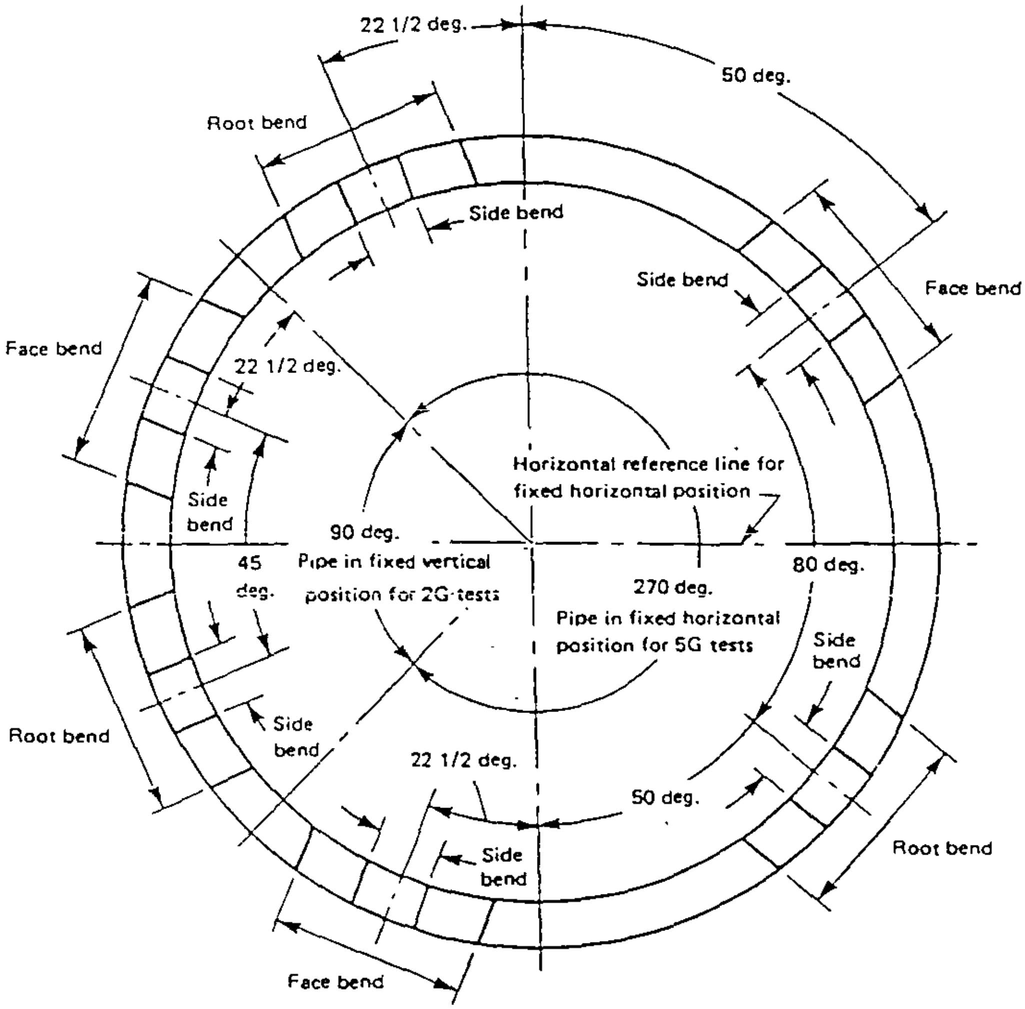


GENERAL NOTE.
When side-bend tests are made in accordance with QW-452.1 and QW-452.3, they shall be removed as shown in QW-463.2(f) in place of the face and root bends.

QW-463.2(f) PIPE — 10 IN. ASSEMBLY PERFORMANCE QUALIFICATION

V-37

QW-463 Order of Removal (Cont'd)

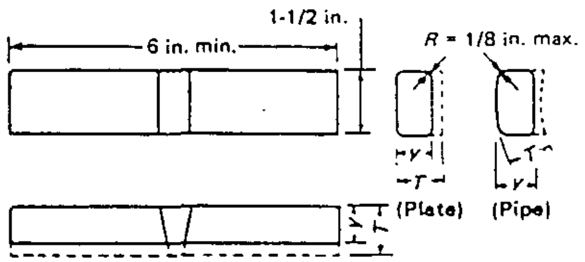


GENERAL NOTE:
When side bend tests are made in accordance with QW-452.1 and QW-452.3, they shall be removed as shown in QW-463.2(g) in place of the face and root bends.

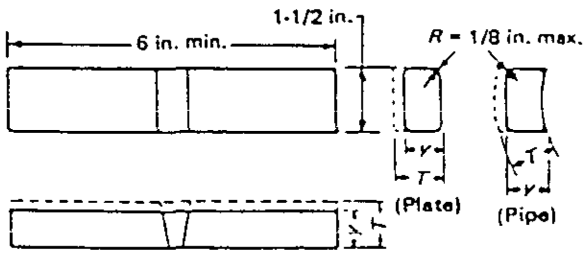
QW-463.2(g) 6 IN. OR 8 IN. ASSEMBLY PERFORMANCE QUALIFICATION

V-38

QW-462 Test Specimens (Cont'd)



Face-bend specimen — Plate and Pipe



Root-bend specimens — Plate and pipe

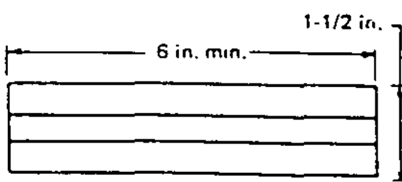
T, in.	*y*, in. P-No.23, F-No.23, or P-No. 35	*y*, in. All other metals
1/16 < 1/8	*T*	*T*
1/8-3/8	1/8	*T*
>3/8	1/8	3/8

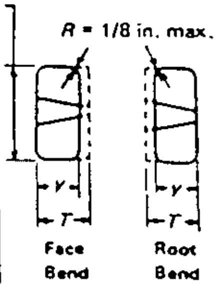
NOTES:

(1) Weld reinforcement and backing strip or backing ring, if any, shall be removed flush with the surface of the specimen. If a recessed ring is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the ring, except that in such cases the thickness of the finished specimen shall be that specified above. Do not flame-cut nonferrous material.

(2) If the pipe being tested is 4 in. nominal diameter or less, the width of the bend specimen may be 3/4 in. for pipe diameters 2 in. to and including 4 in. The bend specimen width may be 3/8 in. for pipe diameters less than 2 in. down to and including 3/8 in. and as an alternative, if the pipe being tested is equal to or less than 1 in. nominal pipe size (1.315 in. O. D.), the width of the bend specimens may be that obtained by cutting the pipe into quarter sections, less an allowance for saw cuts or machine cutting. These specimens cut into quarter sections are not required to have one surface machined flat as shown in QW-462.3(a). Bend specimens taken from tubing of comparable sizes may be handled in a similar manner.

A87 QW-462.3(a) FACE AND ROOT BENDS — TRANSVERSE[1,2]





T, in.	*y*, in. P-No.23, F-No.23, or P-No. 35	*y*, in. All other metals
1/16 < 1/8	*T*	*T*
1/8-3/8	1/8	*T*
>3/8	1/8	3/8

NOTE

(1) Weld reinforcements and backing strip or backing ring, if any, shall be removed essentially flush with the undisturbed surface of the base material. If a recessed strip is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the strip, except that in such cases the thickness of the finished specimen shall be that specified above

QW-462.3(b) FACE AND ROOT BENDS — LONGITUDINAL[1]

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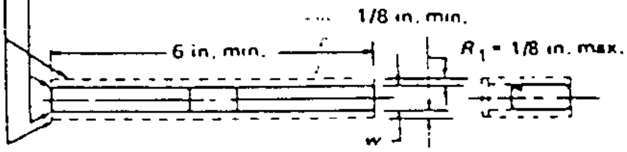
QW-462 Test Specimens (Cont'd)

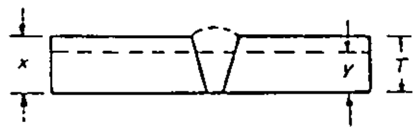
(1a) For procedure qualification of materials other than P-No. 1 in QW-422, if the surfaces of the side bend test specimens are gas cut, removal by machining or grinding of not less than 1/8 in. from the surface shall be required.

(1b) Such removal is not required for P-No. 1 materials, but any resulting roughness shall be dressed by machining or grinding.

(2) For performance qualification of all materials in QW-422, if the surfaces of side bend tests are gas cut, any resulting roughness shall be dressed by machining or grinding.



T, in.	y, in.	w (in.)	
		P-No. 23, F-No. 23, or P-No. 35	All other metals
3/8 to 1-1/2, incl.	T	1/8	3/8
> 1-1/2	[Note (1)]	1/8	3/8



GENERAL NOTE:
Weld reinforcement and backing strip or backing ring, if any, may be removed flush with the surface of the specimen. Thermal cutting, machining, or grinding may be employed. Cold straightening is permitted prior to removal of the reinforcement.

NOTE:
(1) When specimen thickness T exceeds 1-1/2 in., use one of the following.
  (a) Cut specimen into multiple test specimens y of approximately equal dimensions (3/4 in. to 1-1/2 in.).
    y = tested specimen thickness when multiple specimens are taken from one coupon
  (b) The specimen may be bent at full width. See requirements on jig width in QW-466.1.

QW-462.2 SIDE BEND

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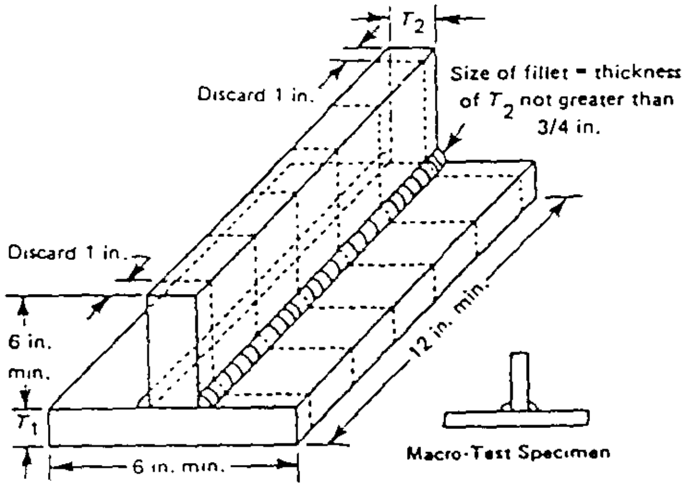
MECHANICAL TESTING
ACCEPTANCE CRITERIA

- Bends — no defect exceeding 1/8" measured on convex surface of the weld after bending.
- Fillet Macro — visually no cracks or lack of fusion. Linear indications @ root less than 1/32" are acceptable.
- Fillet Fracture
  a. no breaks
  b. fracture indicates no incomplete root fusion, no inclusions and porosity greater then 3/8" for plate, or greater than 10% of quarter section thickness on pipe.

MACRO-ETCHING

- Ferrous and nonferrous etching solutions of QW-470
- Written procedure not required
- Personnel need not have any specified qualifications for performing the tests.

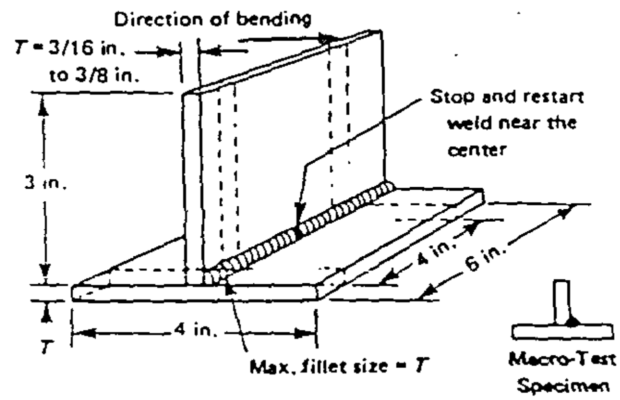
QW-462 Test Specimens (Cont'd)



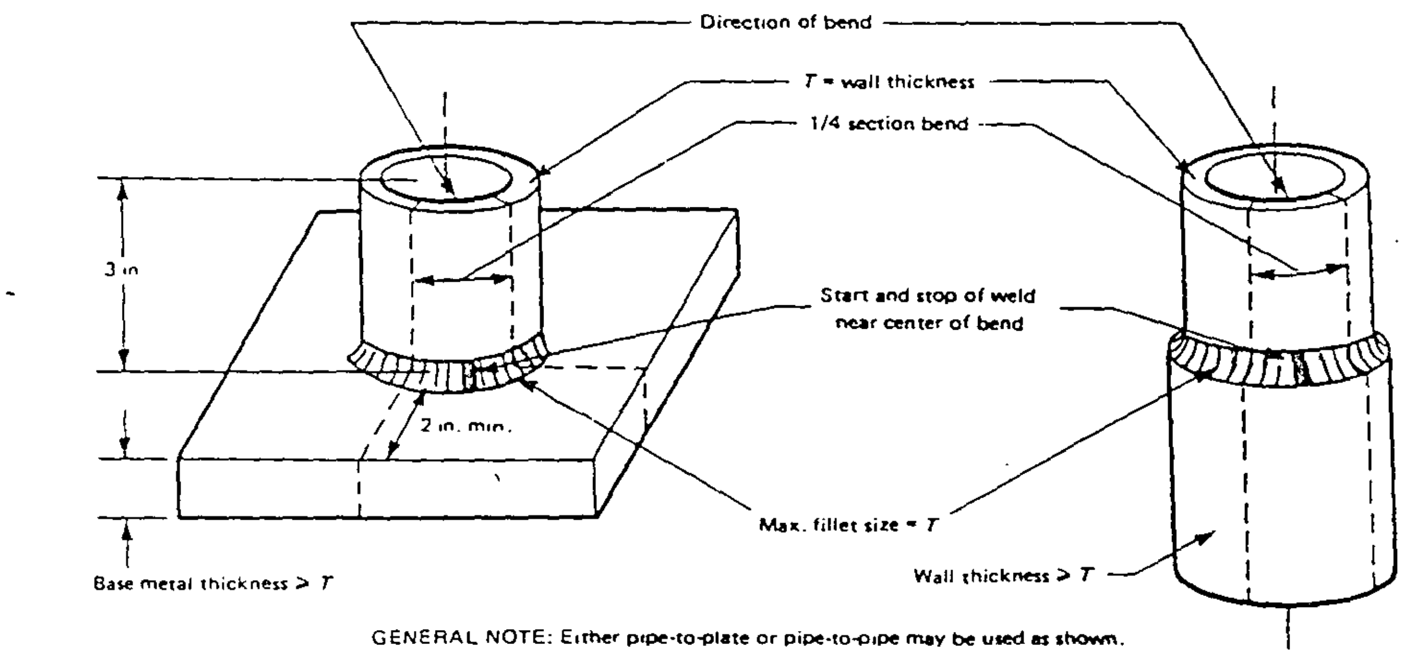
GENERAL NOTE:
Macro test — The fillet shall show fusion at the root of the weld but not necessarily beyond the root. The weld metal and heat affected zone shall be free of cracks.

QW-462.4(a) FILLET WELDS — PROCEDURE

T_1	T_2
1/8 in. and less	T_1
Over 1/8 in.	Equal to or less than T_1 but not less than 1/8 in.



QW-462.4(b) FILLET WELDS — PERFORMANCE



GENERAL NOTE: Either pipe-to-plate or pipe-to-pipe may be used as shown.

A86 QW-462.4(c) FILLET WELDS IN PIPE — PERFORMANCE

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CHOICES FOR TEST COUPON

- Position
- Backing
- Pipe or plate

COMBINATION PROCESSES

- More than one F-number
- More than one process
- More than one welder

RADIOGRAPHIC TESTING FOR WELDERS

- SMAW, SAW, GTAW, PAW, FCAW, and GMAW (not GMAW-S)
- P-1 thru 11, P-3X and P-4X base materials
- GTAW also includes P-2X and P-5X base materials

RADIOGRAPHY FOR WELDS BY A WELDER

- Test Coupon — 6" long RT
- Production Weld — 6" long RT

(Qualification on pipe requires RT of entire circumference of the pipe. Maximum of 4 pipe to accumulate 6" of total weld.)

RADIOGRAPHIC TESTING FOR WELDING OPERATORS

THE REQUIREMENTS FOR RADIOGRAPHING WELDING OPERATORS IS FOUND IN Q.W.- 305. THE REQUIREMENTS ARE THE SAME AS FOR WELDERS. THIS IS A FAIRLY NEW REQUIREMENT AND G.M.A.W. SHORT ARC MUST ALWAYS BE QUALIFIED MECHANICALLY.

RADIOGRAPHY FOR WELDING OPERATORS

— Test Coupon — 6" long RT

— Production Weld — 3' long RT

(Qualification on pipe requires RT of entire circumference of the pipe. Maximum of 4 pipe to accumulate 6" of total weld)

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WELDER RADIOGRAPH ACCEPTANCE CRITERIA COMPARISON

Section IX (QW-191.2)	Section VIII Div. 1 (Full RT-UW-51)
(a) Linear indications: (1) Any crack or zone of incomplete Fusion or Penetration (2) Any elogated Slag inclusion greater than: • 1/8" for t ≤ 3/8" • 1/3 t for t >3/8" to 2¼" incl. • 3/4" for t greater than 2¼" (3) Any group of slag inclusions in-line greater than t in a 12t length (except when distance between inclusions is greater than 6L).	(a) Linear indications: (1) Any crack or zone of incomplete Fusion or Penetration (2) Any elongated Slag inclusion greater than: • 1/4" for t less than 3/4" • 1/3 t for t = 3/4" to 2¼" incl. • 3/4" for t greater than 2¼" (3) Any group of slag inclusions in line greater than t in 12t length (except when distance between inclusions is greater than 6L).
(b) Rounded indications: (1) Max. dimension 20% t or 1/8", whichever is smaller. (2) When T is less than 1/8" max. number of indications is 12 in 6" length. (3) When T is equal to or greater than 1/8" use charts in Appendix I. When max. dia. is less than 1/32" it is irrelevant.	(b) Rounded indications: (1) Max. dimension 25% t or 5/32" whichever is smaller. (Some exceptions) (2) See Appendix 4. When T is less than 1/8" max. number of indications is 12 in 6" length. (3) See Appendix 4. (Some ranges more restrictive, some less restrictive than Section IX.)

t = thickness of deposited weld metal.
T = thickness of base material.
L = length of longest imperfection in a group.

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FAILURE OF TEST
COUPONS FOR WELDING OPERATORS

- Same as welders except for production RT.
- Production RT for immediate retest is 6' long.

FAILURE OF TEST
COUPONS FOR WELDERS

- Immediate RETEST:

  Mechanical — 2 consecutive test coupons

  RT test coupon — 2 consecutive test coupons (not 12" in one test coupon)

  RT production — additional 12" radiograph

- Same method that failed must be used for immediate retests.
- With additional training just start over, no specifics in IX.

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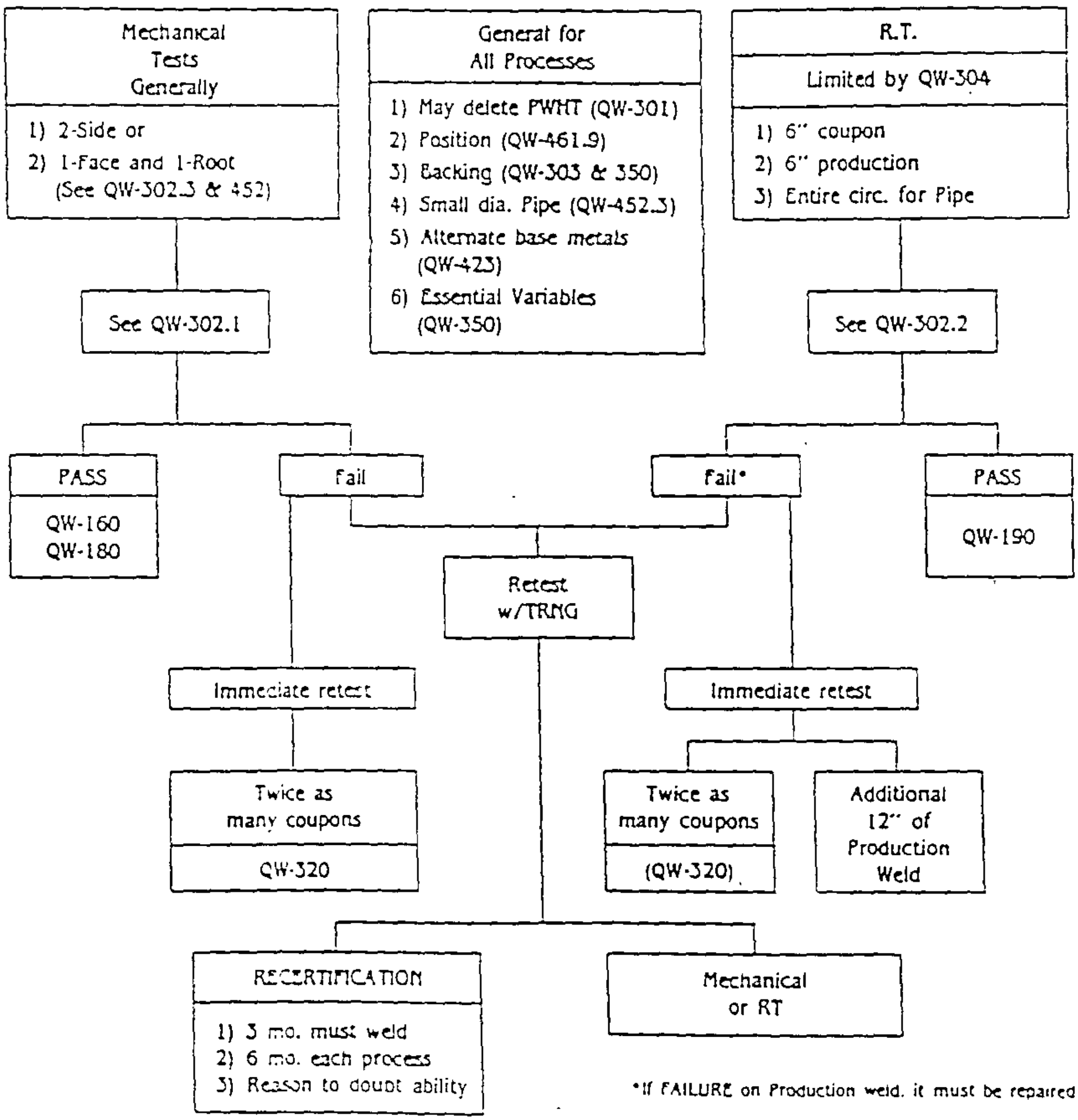
WELDERS **DO NOT** HAVE NON-ESSENTIAL

NOR SUPPLEMENTARY ESSENTIAL VARIABLES

WELDERS **DO NOT NECESSARILY** HAVE TO FOLLOW A WPS WHEN QUALIFYING

- May omit PWHT and preheat
- Base material substitution
- Possible filler metal substitution
- Must, as minimum, follow or record essential variables.

WELDER QUALIFICATION USING A WPS



QW-353 SHIELDED METAL-ARC WELDING (SMAW)
Essential Variables

Paragraph			Brief of Variables
QW-402 Joints	.4	−	Backing
QW-403 Base Metals	.16	φ	Pipe Diameter
	.18	φ	P-Number
QW-404 Filler Metals	.11		F-No. 4X limits
	.15	φ	F-Number limits
	.30	φ	t Weld deposit
QW-405 Positions	.1	+	Position
	.3	φ	↑↓ Vertical welding

QW-354 SEMIAUTOMATIC SUBMERGED-ARC WELDING (SAW)
Essential Variables

Paragraph			Brief of Variables
QW-403 Base Metals	.16	φ	Pipe diameter
	.18	φ	P-Number
QW-404 Filler Metals	.30	φ	t Weld deposit
QW-405 Positions	.1	+	Position

QW-355 SEMIAUTOMATIC GAS METAL-ARC WELDING (GMAW)
[This Includes Flux-Cored Arc Welding (FCAW)]
Essential Variables

Paragraph			Brief of Variables
QW-402 Joints	.4	−	Backing
QW-403 Base Metals	.16	φ	Pipe diameter
	.18	φ	P-Number
QW-404 Filler Metals	.11		F-No. 4X limits
	16		F-No. 2X limits
	28	φ	F-Number
	.30	φ	t Weld metal
	32		t Limit (S. Cir. Arc.)
QW-405 Positions	1	+	Position
	.3	φ	↑↓ Vertical welding
QW-408 Gas	8	−	Gas backing
QW-409 Electrical	2	φ	Transfer mode

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QW-452 Performance Qualification Thickness Limits and Test Specimens

QW-452.1
TRANSVERSE-BEND TESTS

Type of Joint	Thickness of Test Coupon Welded, In. [Note (1)]	Thickness *t* of Deposited Weld Metal Qualified, In. [Note (2)] (See QW-310.1) Max.	Type and Number of Tests Required (Guided-Bend Tests) [Notes (3),(4)] Side Bend QW-462.2(a)	Face Bend [Note (5)] QW-462.3(a)	Root Bend [Note (5)] QW-462.3(a)
Groove	Up to 3/8 incl.	2*t*	Note (6)	1	1
Groove	Over 3/8 but less than 3/4	2*t*	Note (7)	1	1
Groove	3/4 and over	Max. to be welded	2	. . .	. . .

NOTES:

A86 (1) When using one, two, or more welders, the thickness *t* of the deposited weld metal for each welder with each process shall be determined and used individually in the Thickness column.

(2) Two or more pipe test coupons of different thicknesses may be used to determine the deposited weld metal thickness qualified and that thickness may be applied to production welds to the smallest diameter for which the welder is qualified in accordance with QW-452.3

(3) Thickness of test coupon of 3/4 in. or over shall be used for qualifying a combination of three or more welders each of which may use the same or a different welding process.

(4) A total of four specimens is required to qualify for positions 5G and 6G as prescribed in QW-302.3.

(5) Face- and root-bend tests may be used to qualify a combination test of:

(*a*) one welder using two welding processes; or

(*b*) two welders using the same or a different welding process.

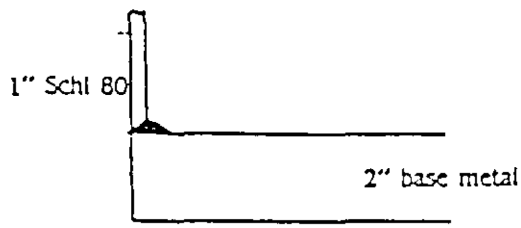
(6) For a 3/8 in. thick coupon, two side-bend tests may be substituted for the required face- and root-bend tests.

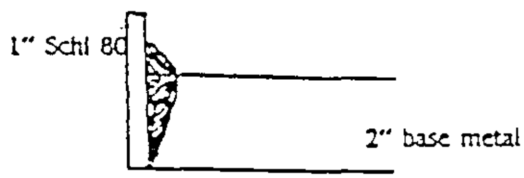
(7) Two side-bend tests may be substituted for the required face- and root-bend tests.

QW-452.3
GROOVE-WELD DIAMETER LIMITS[1,2]

Outside Diameter of Test Coupon, in.	Minimum Outside Diameter Qualified, in.
Less than 1	Size welded
1 to 2⅞	1
2⅞ and over	2⅞

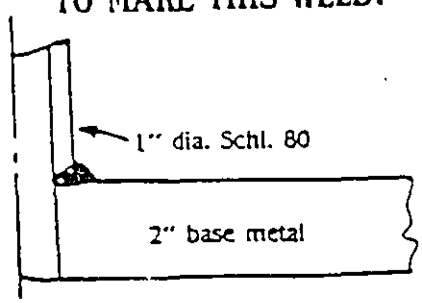
NOTES:
(1) Type and number of tests required shall be in accordance with QW-452.1.
(2) 2⅞ in. O.D. is considered the equivalent of NPS 2½.





Which of the above is small diameter pipe welding under Section IX?

WHAT IS THE LARGEST DIAMETER OF PIPE THE WELDER MAY BE QUALIFIED ON TO MAKE THIS WELD?



QW-423 Alternate Base Materials for Welder Qualification

QW-423.1 Base material used for welder qualification may be substituted for the P-Number material specified in the WPS in accordance with the following.

Base Metal(s) for Welder Qualification	Qualified Production Base Metal(s)
P-No. 1 through P-No. 11 and P-No. 4X	P-No. 1 through P-No. 11 and P-No. 4X
P-No. 21 through P-No. 25	P-No. 21 through P-No. 25
P-No. 52	P-No. 51 and P-No. 52
P-No. 62	P-No. 61 and P-No. 62

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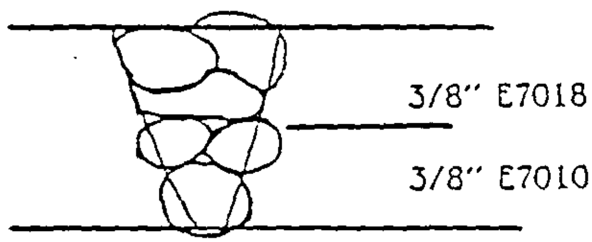
EXAMPLE 1

1. What is welder qualified thickness?
2. What is welder qualified F-Number(s)?
3. How many and what type bends are required?

EXAMPLE 2

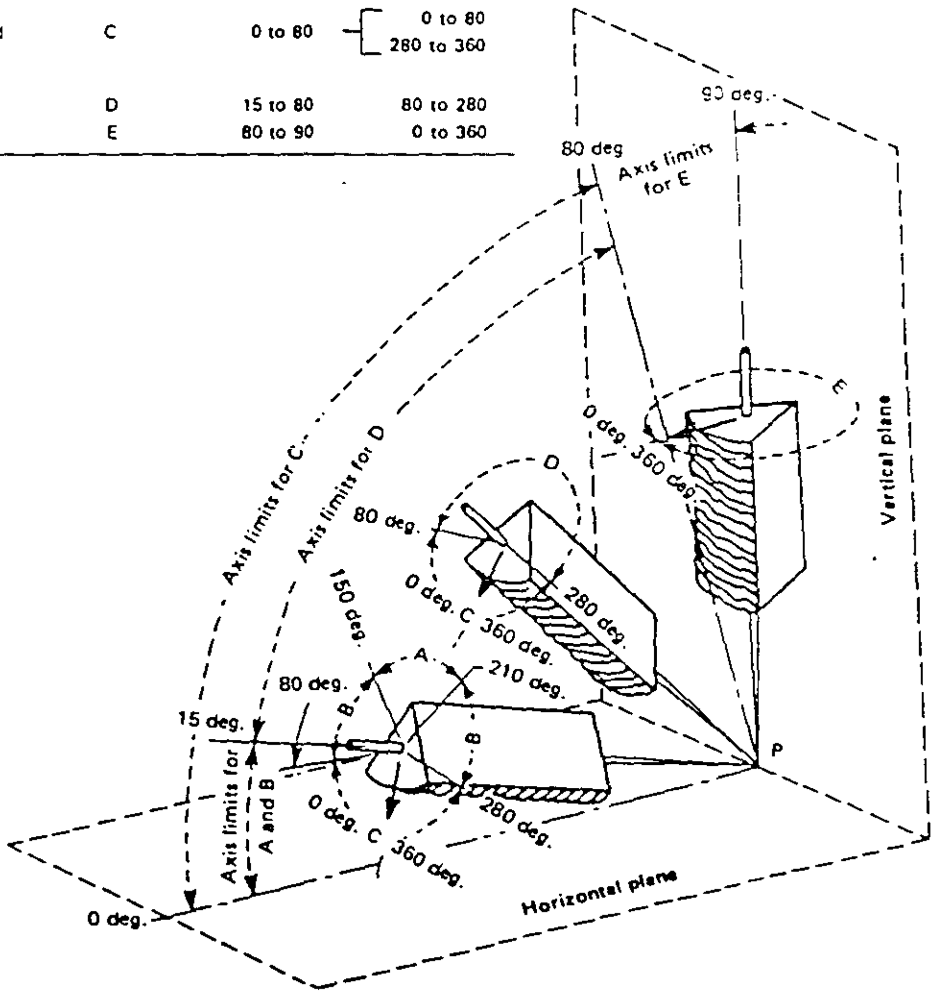


1. What is welder qualified thickness?
2. What is welder qualified F-Number(s)?
3. How many and what type bends are required?

QW-460 GRAPHICS

QW-461 Positions

Tabulation of Positions of Welds			
Position	Diagram Reference	Inclination of Axis, deg.	Rotation of Face, deg.
Flat	A	0 to 15	150 to 210
Horizontal	B	0 to 15	80 to 150 210 to 280
Overhead	C	0 to 80	0 to 80 280 to 360
Vertical	D	15 to 80	80 to 280
	E	80 to 90	0 to 360



GENERAL NOTE:

The horizontal reference plane is taken to lie always below the weld under consideration.

Inclination of axis is measured from the horizontal reference plane toward the vertical.

Angle of rotation of face is measured from a line perpendicular to the axis of the weld and lying in a vertical plane containing this axis. The reference position (0 deg.) of rotation of the face invariably points in the direction opposite to that in which the axis angle increases. The angle of rotation of the face of weld is measured in a clockwise direction from this reference position (0 deg.) when looking at point P.

QW-461.1 POSITIONS OF WELDS — GROOVE WELDS

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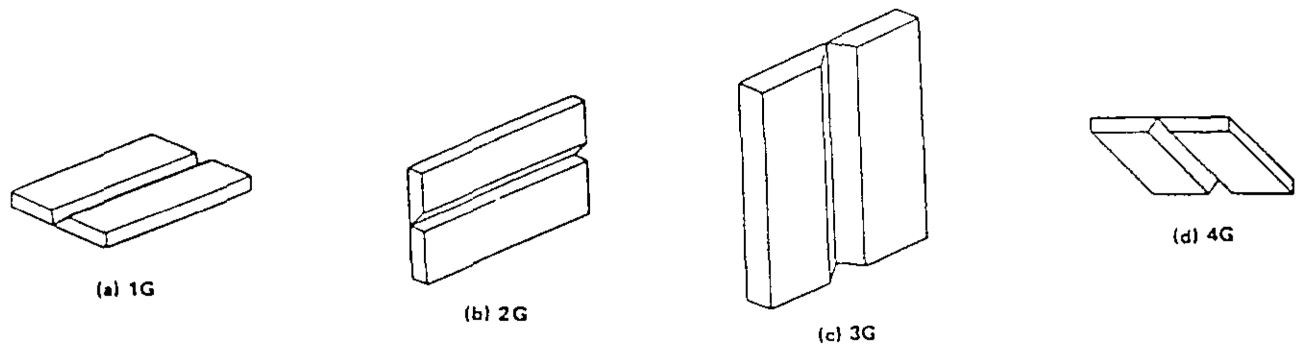
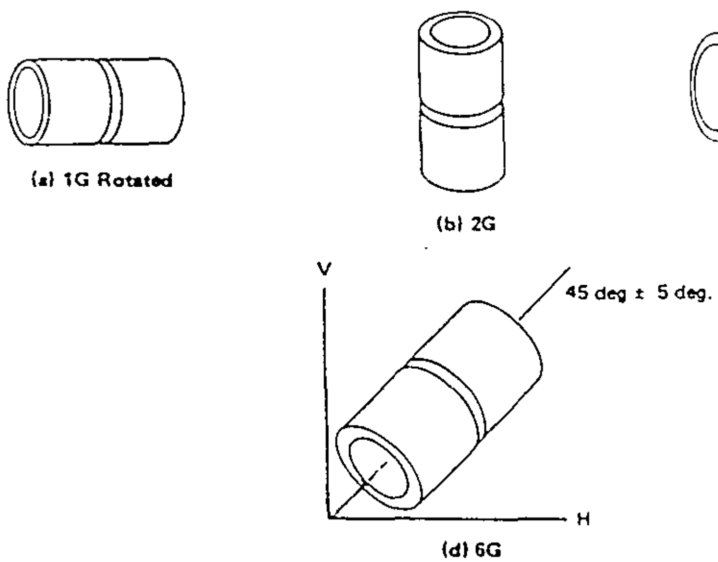
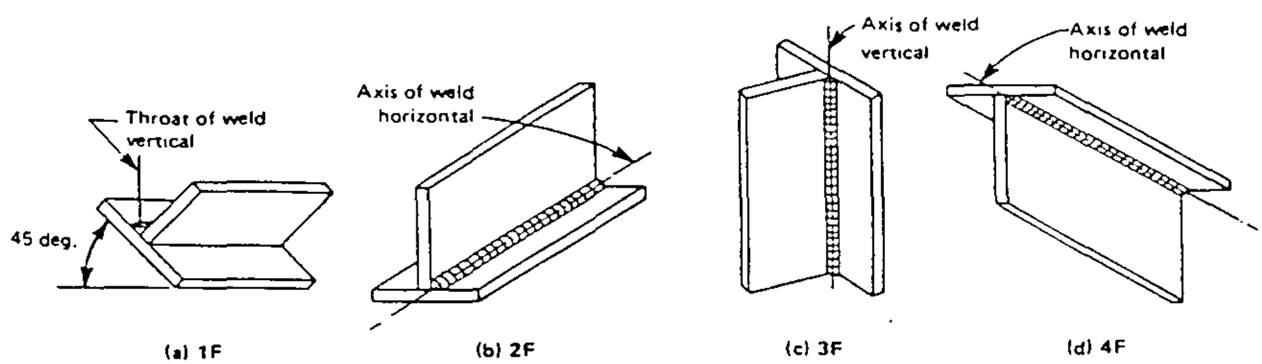
QW-461 Positions (Cont'd)



QW-461.3 GROOVE WELDS IN PLATE — TEST POSITIONS

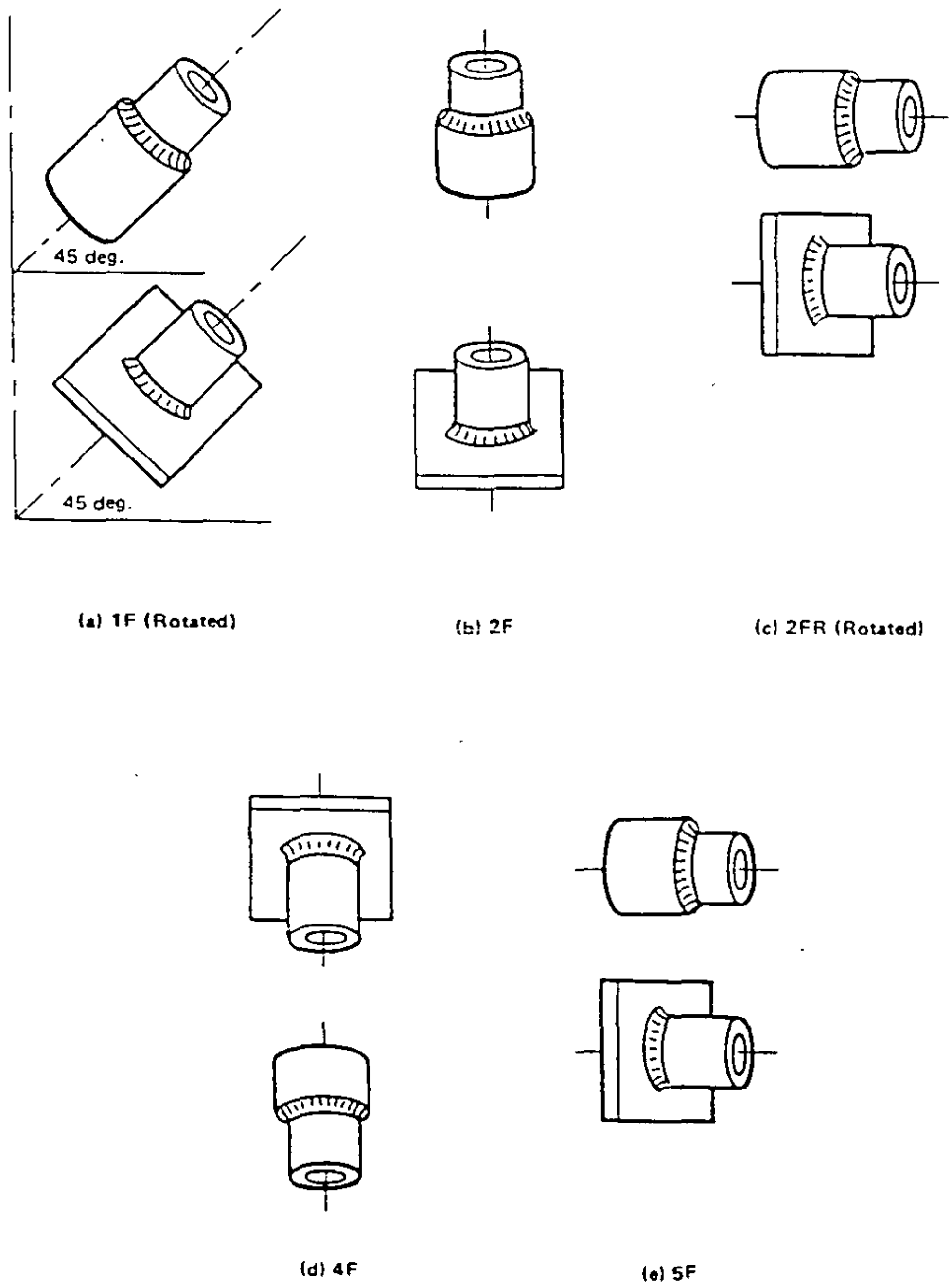


QW-461.4 GROOVE WELDS IN PIPE — TEST POSITIONS



QW-461.5 FILLET WELDS IN PLATE — TEST POSITIONS

QW-461 Positions (Cont'd)



QW-461.6 FILLET WELDS IN PIPE — TEST POSITIONS

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REMEMBER

Even though the welder's range may include many F-Nos., and large thickness ranges, he is limited by the qualified procedures.

Without a qualified WPS the welder maybe qualified to ranges (including min. or max.) that may not be acceptable for Code welding.

LIMITS OF POSITIONS

- Qualification on groove welds qualifies for fillet welds.
- See QW-461.9
- Special orientations not required but permitted (plus or minus 15°)

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QW-461 Positions (Cont'd)

QW-461.9
PERFORMANCE QUALIFICATION — POSITION AND DIAMETER LIMITATIONS
(Within the Other Limitations of QW-303)

Qualification Test		Position and Type Weld Qualified [Note (1)]		
		Groove		Fillet
Weld	Position	Plate and Pipe Over 24 in. O.D.	Pipe ≤ 24 in. O.D.	Plate and Pipe
Plate — Groove	1G	F	F [Note (2)]	F
	2G	F,H	F,H [Note (2)]	F,H
	3G	F,V	F [Note (2)]	F,H,V
	4G	F,O	F [Note (2)]	F,H,O
	3G and 4G	F,V,O	F [Note (2)]	All
	2G, 3G, and 4G	All	F,H [Note (2)]	All
Plate — Fillet	1F	. . .	. . .	F [Note (2)]
	2F	. . .	. . .	F,H [Note (2)]
	3F	. . .	. . .	F,H,V [Note (2)]
	4F	. . .	. . .	F,H,O [Note (2)]
	3F and 4F	. . .	. . .	All [Note (2)]
Pipe — Groove [Note (3)]	1G	F	F	F
	2G	F,H	F,H	F,H
	5G	F,V,O	F,V,O,	All
	6G	All	All	All
	2G and 5G	All	All	All
Pipe — Fillet [Note (3)]	1F	. . .	. . .	F
	2F	. . .	.	F,H
	2FR	. . .	. .	F,H
	4F	. . .	. .	F,H,O
	5F	. . .	. .	All

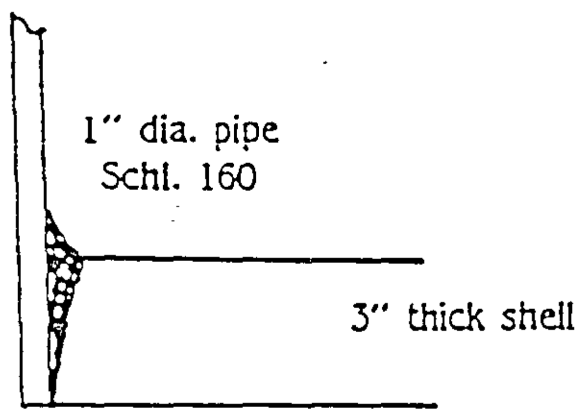
NOTES:
(1) Positions of welding as shown in QW-461.1 and QW-461.2.
F = Flat
H = Horizontal
V = Vertical
O = Overhead
(2) Pipe $2\frac{7}{8}$ in. O.D. and over.
(3) See diameter restrictions in QW-452.3, QW-452.4, and QW-452.6.

V-58

A welder is qualified on the following test coupons. What are his position limits?

1. 6" dia. pipe groove in 6G?

2. Plate groove in 4G position?



May a welder qualified on a plate-groove in the 1G position make this groove weld and fillet weld cap?

W.P.S./P.Q.R./W.P.Q.
FORMS

1. Q.W.-482 AND 483 AND Q.W-484
2. RECOMMENDED FORMS
3. LOCATED IN A NON-MANDATORY APPENDIX
4. SAMPLE IS PRINTED ON THE EXAMPLE IN THE CODE.

MULTIPLE PQR(S) SUPPORTING ONE WPS

- More than one PQR may support a single WPS

- Example: PQR 1 w/PWHT and PQR 2 w/o PWHT support a WPS w/and w/o PWHT

NOTE: Although it may be confusing, it is possible to have only 1 WPS to cover all possible welding circumstances.

ONE PQR MAY SUPPORT SEVERAL WPSs

- For control and clarity to production people manufacturers may limit particular WPS usage.

- Example: A PQR covers all diameter of electrodes for welding.
  WPS 1 covers only 1/16" to 1/8". electrodes.
  WPS 2 covers only 1/8" to 1/4" electrodes.

COMBINATION WELDING PROCESSES AND PROCEDURES

- A change in welding process requiring requalification.

- Several processes may be included in one WPS (they may be qualified separately or in combination).

- Using more than one WPS to complete a weld.

- For WPSs with more than one process, a weld may be made using the same WPS and deleting one or more of the processes within the essential variables.

POWER
BOILERS

CONTENTS

A Detailed Contents Precedes Each Part, the Appendix; and the Forms

PART PG

Figures

Tables

PART PW

Figures

Tables

PART PR
REQUIREMENTS FOR BOILERS FABRICATED BY RIVETING

Manufacturers using riveted construction shall use the 1971 Edition of Section I. Boilers or parts thereof constructed by using riveted construction require the use of the applicable Manufacturers' Data Report Forms as included in the 1971 Edition of Section I.

PART PB

Marking and Reports

Figure

Tables

PART PB
REQUIREMENTS FOR BOILERS FABRICATED BY BRAZING

GENERAL

PB-1 GENERAL

PB-1.1 Scope. The rules in Part PB are applicable to pressure parts of boilers, including piping constructed under the provisions of this Section, that are fabricated by brazing These rules shall be used in conjunction with the general requirements in Part PG and the specific requirements in the applicable Parts of this Section that pertain to the type of boiler under consideration. The rules in Part PB are not applicable to nonpressure bearing attachments to pressure parts that have essentially no load-carrying function (such as extended heat transfer surface, insulation support pins, etc.)

PB-1.1.1 Definition of Brazing. A group of welding processes that produces coalescence of materials by heating them to the brazing temperature in the presence of a filler metal having liquidus above 840°F (450°C) and below the solidus of the base metal The filler metal is distributed between the closely fitted faying surfaces of the joint by capillary action.

PB-1.1.2 Brazing processes that are permitted for use under this Part are classified by method of heating as follows:

(a) torch brazing;
(b) furnace brazing;
(c) induction brazing;
(d) resistance brazing;
(e) dip brazing — salt and flux bath.

PB-1.2 Elevated Temperature. Maximum design temperature is dependent on the brazing filler metal and on the base metals being joined. The maximum design temperatures for some brazing filler metals are shown in Table PB-1.

PB-1.3 Service Restrictions. Brazed components may be used for service up to the temperatures as shown in Table PB-1 provided acceptable qualification tests are performed.

PB-1.4 Responsibility. Each Manufacturer[1] (Certificate of Authorization Holder) is responsible for the brazing done by his organization and shall establish the procedures and conduct the tests required by Section IX, and when necessary those required by this Section to qualify the brazing procedures used in the construction of brazed assemblies and the performance tests of brazers[2] who apply these procedures. Such brazing will ordinarily be done by employees of the Manufacturer who accepts the responsibility for Code construction of the boiler or part being brazed. Alternatively, the Manufacturer may perform Code brazing using the services of individual brazers who are not in his employ provided all the following conditions are met.

PB-1.4.1 All Code construction shall be the responsibility of the Manufacturer

PB-1.4.2 All brazing shall be performed in accordance with Manufacturer's brazing procedure specifications that have been qualified by the Manufacturer in accordance with the requirements of Section IX and when necessary, based on design temperature, with the additional requirements of this Section.

PB-1.4.3 All brazers shall be qualified by the Manufacturer in accordance with the requirements of Section IX.

PB-1.4.4 The Manufacturer's quality control system shall include the following as a minimum.

PB-1.4.4.1 A requirement for complete and exclusive administrative and technical supervision of all brazers by the Manufacturer.

PB-1.4.4.2 Evidence of the Manufacturer's authority to assign and remove brazers at his discretion without involvement of any other organization.

---

[1] Manufacturer includes contractor, Assembler, and installer.
[2] Brazer includes brazing operator.

PART PWT

PART PWT
REQUIREMENTS
FOR WATERTUBE BOILERS

GENERAL

PWT-1 GENERAL

The rules in Part PWT are applicable to watertube boilers and parts thereof and shall be used in conjunction with the general requirements in Part PG as well as with the special requirements in the applicable Parts of this Section that apply to the method of fabrication used. The rules in Part PWT do not apply to external piping.

MATERIALS

PWT-5 GENERAL

PWT-5.1 Materials used in the construction of pressure parts for watertube boilers shall conform to one of the specifications in Section II and shall be limited to those for which allowable stress values are given in Tables 1A and 1B of Section II, Part D, for Section I construction or as otherwise specifically permitted in Part PG and Part PWT.

PWT-5.2 Mud drums of boilers shall be of either wrought steel or cast steel as designated in SA-216.

DESIGN

PWT-8 GENERAL

The rules in the following paragraphs apply specifically to the design of watertube boilers and parts thereof and shall be used in conjunction with the general requirements for design in Part PG as well as with the specific requirements for design in the applicable Parts of this Section that apply to the method of fabrication used.

PWT-9 TUBES AND PIPE

PWT-9.1 Economizer, boiler generator, and superheater tubes shall comply with the specifications as listed in PG-9.

PWT-9.2 Seamless steel pipe not exceeding NPS $1\frac{1}{2}$ (DN 40) complying with SA-53 or SA-106 may be threaded into the tubesheet, drum, or steel fitting of a watertube boiler. Steel fittings, if used, must fully cover the threads.

PWT-9.3 A tube in which a fusible plug is to be installed shall be not less than 0.22 in. (5.6 mm) in thickness at the plug in order to secure four full threads for the plug (See also A-20.)

PWT-10 TUBE WALL THICKNESS

PWT-10.1 The minimum tube wall thickness at the maximum allowable working pressure for carbon or alloy steel tubes or nipples subjected to internal pressure for watertube boilers, economizers, and superheaters shall be determined in accordance with PG-27.2.1.

PWT-10.2 Where the outside diameter of a circular boiler pressure part exceeds 5 in. (127 mm), the minimum thickness shall be determined by the formula in PG-27.2.2.

PWT-10.3 For tubes of the materials listed in its title, Table PWT-10 may be used in lieu of the formula for determining the minimum wall thickness of tubes where expanded into drums or headers, provided the maximum mean wall temperature does not exceed 700°F (371°C)

PWT-11 TUBE CONNECTIONS

Tubes, pipe, and nipples may be attached to shells, heads, headers, and fittings by one of the following methods.

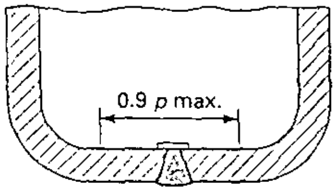


FIG. PWT-12.1 BOX TYPE HEADER JOINT

All other doors, except explosion doors, not used in the firing of the boiler may be provided with bolts or fastenings in lieu of self-locking latching devices.

Explosion doors, if used and if located in the setting walls within 7 ft (2.1 m) of the firing floor or operating platform, shall be provided with substantial deflectors to divert the blast.

01 PWT-15 ACCESS AND FIRING DOORS

The minimum size of an access or fire door opening, in which the minimum furnace dimension is 24 in. (610 mm), shall be not less than 12 in. × 16 in. (305 mm × 406 mm) or equivalent area, 11 in. (280 mm) to be the least dimension in any case. A circular opening shall be not less than 15 in. (381 mm) in diameter.

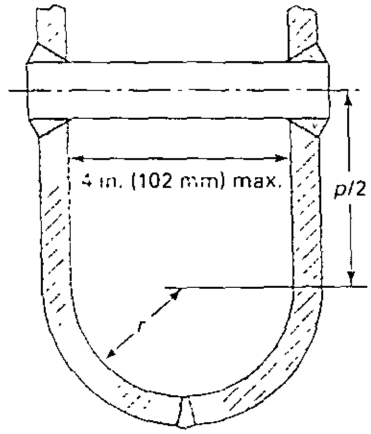


FIG. PWT-12.2 METHOD OF FORMING WATERLEG JOINTS BY WELDING

For furnace dimensions less than 24 in (610 mm), the opening should be $2\frac{3}{4}$ in. × $3\frac{1}{2}$ in. (70 mm × 89 mm) or larger where possible. In cases where the size or shape of the boiler prohibits an opening of that size, two openings with a minimum size of 1 in (25 mm) may be used, preferably oppposite each other, to permit inspection and cleaning of the furnace. If the burner is removable so as to permit inspection and cleaning through the burner opening, a separate access opening need not be provided

PART PFT

PART PFT
REQUIREMENTS
FOR FIRETUBE BOILERS

GENERAL

PFT-1 GENERAL

The rules in Part PFT are applicable to firetube boilers and parts thereof and shall be used in conjunction with the general requirements in Part PG as well as with the specific requirements in the applicable Parts of this Section that apply to the method of fabrication used.

MATERIALS

PFT-5 GENERAL

PFT-5.1 Materials used in the construction of pressure parts for firetube boilers shall conform to one of the specifications given in Section II and shall be limited to those for which allowable stress values are given in Tables 1A and 1B of Section II, Part D, or as otherwise specifically permitted in Part PG and Part PFT

PFT-5.2 Waterleg and doorframe rings of vertical firetube boilers and of locomotive and other type boilers shall be of wrought iron or steel, or cast steel as designated in the SA-216. The ogee or other flanged construction may be used as a substitute in any case.

DESIGN

PFT-8 GENERAL

The rules in the following paragraphs apply specifically to the design of firetube boilers and parts thereof and shall be used in conjunction with the general requirements for design in Part PG as well as with the specific requirements for design in the applicable Parts of this Section that apply to the method of fabrication used.

PFT-9 THICKNESS REQUIREMENTS

PFT-9.1 Shell and Dome. The thickness after forming shall be as determined in accordance with the rules in Part PG but shall not be less than the values shown in the following table

Inside Diameter of Shell or Dome, in. (mm)	Minimum Thickness, in (mm)
36 (914) or under	$\frac{1}{4}$ (6.4)
Over 36 (914) to 54 (1 372)	$\frac{5}{16}$ (8.0)
Over 54 (1 372) to 72 (1 829)	$\frac{3}{8}$ (9.5)
Over 72 (1 829)	$\frac{1}{2}$ (12.7)

PFT-9.2 Tubesheet

PFT-9.2.1 The thickness shall be as determined in accordance with Part PG and Part PFT but shall not be less than the values given in the following table.

Inside Diameter of Shell, in. (mm)	Minimum Thickness, in (mm)
42 (1 067) or under	$\frac{3}{8}$ (9.5)
Over 42 (1 067) to 54 (1 372)	$\frac{7}{16}$ (11.2)
Over 54 (1 372) to 72 (1 829)	$\frac{1}{2}$ (12.7)
Over 72 (1 829)	$\frac{9}{16}$ (14.3)

PFT-9.2.2 When buttwelded to the shell of a firetube boiler, a formed tubesheet with a straight flange longer than $1\frac{1}{2}$ times the tubesheet thickness shall have a straight flange thickness not less than that specified in the table in PFT-9.2.1, but in no case less than 0.75 times the thickness of the shell to which it is attached.

PFT-10 SHELL JOINTS

Longitudinal and circumferential welded joints of a shell or drum shall comply with the rules in Part PW.

PART PFH
OPTIONAL REQUIREMENTS FOR FEEDWATER HEATER (WHEN LOCATED WITHIN SCOPE OF SECTION I RULES)

PFH-1

A feedwater heater is a heat exchanger in which feedwater to be supplied to a boiler is heated by steam or water extracted from the boiler or the prime mover. When such a feedwater heater is located within the limit of Section I piping, as defined by PG-58.3, it falls within the scope of Section I rules. With this arrangement, the feedwater heater may be constructed in compliance with Section VIII, Division 1, subject to the following conditions.

PFH-1.1 The feedwater heater shall conform with Section VIII, Division 1 rules for unfired steam boilers [UW-2(c)].

PFH-1.2 The maximum allowable working pressure of the primary (feedwater) side of the heater shall be not less than the design pressure requirements of ASME B31.1, para. 122.1.3.

PFH-1.3 The design temperature of the tubes shall be not less than the saturated steam temperature corresponding to the maximum allowable working pressure of the shell. If the steam entering the shell side of the feedwater heater is superheated, the design temperature of the tubes in the desuperheating zone shall be not less than the saturation temperature corresponding to maximum allowable shell side working pressure plus 35°F (19°C).

PFH-1.4 The feedwater heater shall be stamped with the ASME Code "U" symbol and be documented with the ASME U-1 Data Form.

PFH-1.5 A nameplate per UG-119 shall be furnished and shall show the additional information "and Part PFH of Section I."

PFH-1.6 The Master Data Report for the completed boiler unit (using Manufacturers' Data Report Form P-2, P-3, P3A, or P-5, as applicable) shall indicate "Feedwater heater constructed to Section VIII, Division 1, as permitted by Part PFH."

than 4, the value of A shall be calculated using the following formula:

$$A = \frac{1.1}{(D_o/t)^2}$$

For values of A greater than 0.10, use a value of 0.10.

Step 2: Using the value of B obtained in Step 1, calculate a value of P_{a1} using the following formula:

$$P_{a1} = \left[\frac{2.167}{D_o/t} - 0.0833\right] B$$

Step 3: Calculate a value of P_{a2} using the following formula:

$$P_{a2} = \frac{2S_B}{D_o/t}\left[1 - \frac{1}{D_o/t}\right]$$

where S_B is the lesser of 2 times themaximum allowable stress values at design metal temperature from Tables 1A and 1B of Section II, Part D; or, 1.8 times the yield strength of the material at Design Metal Temperature from Table Y-1 of Section II, Part D.

Step 4: The smaller of the values of P_{a1} calculated in Step 2, or P_{a2} calculated in Step 3 shall be used for the maximum allowable external pressure P_a. If P_a is smaller than P, select a larger value for t and repeat the design procedure until a value for P_a is obtained that is equal to or greater than P.

PFT-51.1.3 The design pressure or maximum allowable working pressure shall not be less than the maximum expected difference in operating pressure that may exist between the outside and the inside of the furnace or tube at any time.

PFT-51.1.4 When necessary, furnaces shall be provided with stiffeners or other additional means of support to prevent overstress or large distortions under the external loadings listed in PG-22 other than pressure and temperature

PART PMB

PART PMB
REQUIREMENTS FOR MINIATURE BOILERS

GENERAL

PMB-1 GENERAL

The rules in Part PMB are applicable to miniature boilers and parts thereof and shall be used in conjunction with the general requirements in Part PG as well as with the special requirements in the applicable Parts of this Section that apply to the method of fabrication used.

PMB-2 SCOPE

This paragraph contains special rules of construction for miniature boilers only. The classification miniature applies to boilers that do not exceed the following limits:

16 in. (406 mm) inside diameter of shell

20 sq ft (1.9 m^2) heating surface (not applicable to electric boilers)

5 cu ft (0.14 m^3) gross volume,[1] exclusive of casing and insulation

100 psig (690 kPa) maximum allowable working pressure

Where any of the above limits are exceeded, the rules for power boilers shall apply. If the boiler meets the miniature classification, the rules in this paragraph shall supplement the rules for power boilers and take precedence over them when there is conflict.

MATERIALS

PMB-5 GENERAL

PMB-5.1 Materials used in the construction of pressure parts for miniature boilers shall conform to one of the specifications in Section II and shall be limited to those for which allowable stress values are given in Tables 1A and 1B of Section II, Part D, unless specifically permitted in the other applicable Parts of this Section.

PMB-5.2 Steel plates subject to pressure in any part of a miniature boiler shall be of pressure vessel quality. The plates for shells or heads shall be not less than $\frac{1}{4}$ in. (6 mm) in thickness, except that seamless shells shall be not less than $\frac{3}{16}$ in. (4.8 mm) in thickness. Heads used as tubesheets, with tubes rolled in, shall be at least $\frac{5}{16}$ in. (8 mm) in thickness.

PMB-5.3 Steam boiler parts of not over 600 cu in. (9.83 m^3) in volume may be cast from copper alloy complying with requirements of SB-61 or SB-62 of wall thickness not less than $\frac{1}{4}$ in. (6 mm). Such steam boiler parts shall be equipped with at least one brass washout plug of not less than $\frac{1}{2}$ in. (13 mm) and shall be tested to a hydrostatic pressure of 600 psi (4 140 kPa).

PMB-5.4 Heads or parts of miniature boilers, when not exposed to the direct action of the fire, may be made of cast iron or malleable iron provided it complies with a specification permitted in this Section.

PMB-5.5 Due to the small size of parts of miniature boilers, the requirements of Identification, PG-77.1, need not be met, provided the Manufacturer certifies on the Data Report accompanying the boiler that the material is in accordance with the requirements of this Section. Provisions shall be made by the Manufacturer whereby he shall be able to supply complete information regarding the material and details of construction of any boiler built under the provisions of this Code.

DESIGN

PMB-8 GENERAL

The rules in the following paragraphs apply specifically to the design of miniature boilers and parts

[1] This gross volume is intended to include such gas passages as are integral with the assembled pressure parts and a definition is, the volume of a rectangular or cylindrical enclosure into which all the pressure parts of the boiler in their final assembled positions could be fitted. Projecting nozzles or fittings need not be considered in the volume.

PART PEB

PART PEB
REQUIREMENTS FOR ELECTRIC BOILERS

GENERAL

PEB-1 GENERAL

The rules in Part PEB are applicable to electric boilers and parts thereof and shall be used in conjunction with the general requirements in Part PG as well as with the special requirements in the applicable Parts of this Section that apply to the method of fabrication used.

PEB-2 SCOPE

PEB-2.1 This Part contains special rules for construction of electric boilers both of the electrode and immersion resistance element type. This Part does not include electric boilers where the heat is applied to the boiler pressure vessel externally by electric resistance heating elements, induction coils, or other electrical means. These types of electric boilers shall be constructed in accordance with other applicable Parts of this Section.

PEB-2.2 Electric boilers shall be marked with the "S" or "M" symbol (except when the boiler pressure vessel is constructed under the provisions of PEB-3) by the Manufacturer of the boiler pressure vessel. When the trim, fixtures, and fittings such as valves, threaded piping, and appurtenances are connected to the electric boiler by a Manufacturer not authorized to apply the "S" or "M" stamps, the boiler assembler shall apply an "E" stamp to the completed assembly. "E" stamp holders are limited to the use of assembly methods that do not require welding or brazing.

PEB-2.3 An electrode type boiler is defined as an electric boiler in which heat is generated by the passage of an electric current using water as the conductor.

PEB-2.4 An immersion resistance element type boiler is defined as an electric boiler in which heat is generated by the passage of an electric current through a resistance heating element immersed in water.

PEB-3 OPTIONAL REQUIREMENTS FOR THE BOILER PRESSURE VESSEL

The boiler pressure vessel may be constructed in compliance with the ASME Pressure Vessel Code Section VIII, Division 1, rules for unfired steam boilers [UW-2(c)] subject to the following conditions:

PEB-3.1 The Manufacturer who certifies and stamps the completed boiler shall specify to the "U" stamp holder all additional requirements of Part PEB, which are not requirements of Section VIII, Division 1, and shall ensure that these requirements are satisfied.

PEB-3.2 These additional requirements are:

PEB-3.2.1 The materials of construction shall comply with the requirements of PEB-5.1 and PEB-5.3.

PEB-3.2.2 Inspection openings shall comply with the requirements of PEB-10.

PEB-3.3 The boiler pressure vessel shall be stamped with the ASME Code "U" symbol and be documented with the ASME U-1 or U-1A Data Report.

PEB-3.4 The master Data Report P-2A for the Electric Boiler shall indicate "Boiler pressure vessel constructed to Section VIII, Division 1 as permitted by Part PEB."

MATERIALS

PEB-5 GENERAL

PEB-5.1 Materials used in the construction of pressure parts for electric boilers shall conform to one of the specifications in Section II and shall be limited to those permitted by PG-6, PG-7, PG-8, and PG-9 for which allowable stress values are given in Tables 1A and 1B of Section II, Part D, unless specifically permitted in other applicable parts of this Section.

PEB-19 MANUFACTURERS' DATA REPORT FOR ELECTRIC BOILERS

PEB-19.1 This form consists of two parts. Part I is to be completed by the Manufacturer of the boiler pressure vessel who is the holder of the "S" or "M" stamp and his inspection agency. Part II is to be completed by the Manufacturer responsible for the completed electric boiler who shall be authorized to use any of the "S," "M," or "E" stamps.

PEB-19.2 When the boiler pressure vessel is constructed by a "U" stamp holder and certified on a U-1 or U-1A Data Report, Part I shall be completed by the "S," "M," or "E" stamp holder to the extent indicated in Guide A-351.1

PART PVG

FORM P-2 MANUFACTURERS' DATA REPORT FOR ALL TYPES OF BOILERS EXCEPT WATERTUBE AND ELECTRIC

As Required by the Provisions of the ASME Code Rules, Section I

1 Manufactured by ______ 1 ______
(Name and address of Manufacturer)

2. Manufactured for ______ 2 ______
(Name and address of purchaser)

3. Location of Installation ______ 3 ______
(Name and address)

4. Type ___ 4 ___ (HRT, etc.) Boiler No ___ 5 ___ (Mfr's. Serial No) ___ 5 ___ (CRN) ___ 5 ___ (Drawing No.) ___ 5 ___ (Nat'l Board No.) Year Built ___ 6 ___

5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to Section I of the ASME Boiler and Pressure Vessel Code ___ 7 ___ (Year).
Addenda to ___ 8 ___ (Date), and Code Cases ______ (Numbers)

Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors are attached for the following items of this report
______ 9 ______
(Name of part, item number, mfr's name and identifying stamp)
______

6. Shells or drums: ___ 10 ___ (no) ___ 11 ___ (mat'l. spec gr.) ______ [thickness (in)] ______ [dia (ID)] ______ (length, inside) ______ [dia (ID)] ______ (length, inside)

7. Joints: ___ 12 ___ [long (seamless, welded)] ___ 13 ___ [efficiency (as compared to seamless)] ___ 14 ___ [girth (seamless, welded)] ______ (no of shell courses)

8. Heads ______
(Material Specification No · Thickness — Flat Dished, Ellipsoidal — Radius of Dish)

9 Tubesheet ___ 11 ___ (Mat'l Spec., Grade, Thickness) Tube Holes ______ (Dia)

10. Boiler Tubes. No. ______ ___ 11 ___ (Mat'l Spec, Grade) ______ (Straight or Bent)
Dia ______ Length ______ (If various, give max & min) Gauge ______ (or thickness)

11 Furnace No. ___ 15 ___ Size ______ (O.D or W x H) Length, each section ___ 16 ___ Total ___ 16 ___
Type ______ 17 ______
(Plain, Adamson, Ring Reinforced, Corrugated, Combined, or Stayed)
___ 11 ___ (Mat'l. Spec., Grade, Thickness) Seams Type ___ 13 ___ (Seamless, Welded)

12. Staybolts: No ______ Size ___ 18 ___ 11 ___ 18 ___
(Dia, Mat'l Spec Grade, Size Telltale, Net Area)
Pitch ______ (Hor. and Vert) MAWP ___ 20 ___ psi

13 Stays or braces:

Location	Material Spec. No	Type	No and Size	Max Pitch	Fig PFT-32 L/l	Dist. Tubes to Shell	MAWP psi
(a) F H. above tubes	11	21			22	22	22
(b) R H. above tubes							
(c) F.H below tubes							
(d) R H below tubes							
(e) Through stays							
(f) Dome braces							

14. Other Parts. 1. ___ 24 ___ 2 ______ 3 ______
(Brief Description — i e, Dome, Boiler Piping, etc.)
1. ___ 25 ___ 11 ___
2 ______
3 ______
(Mat'l Spec, Grade, Size, Material Thickness, MAWP)

This form (E00068) may be obtained from the ASME Order Dept., 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300

Form P-2 (Back)

15. Openings: (a) Steam ______ 26 ______ (No., Size, and Type) (b) Safety Valve ______ (No., Size, and Type)

(c) Blowoff ______ (No., Size, Type, and Location) (d) Feed ______ (No., Size, Type, and Location)

(e) Manholes: No. ______ Size ______ Location ______

(f) Handholes: No. ______ Size ______ Location ______

16 Fusible Plug (if used) ______ (No., Dia, Location, Mfr's Stamp)

17 Boiler Supports: No ______ Type ______ (Saddles, Legs, Lugs) Attachment ______ (Bolted or Welded)

18 MAWP ______ 27 ______ psi Based On ______ 28 ______ (Code Par. and/or Formula) Heating Surface ______ 29 ______ (Total) sq ft

19 Shop Hydrostatic Test ______ psig 20 Maximum Designed Steaming Capacity ______ lb/hr

21 Remarks ______

______

______

31 CERTIFICATE OF SHOP COMPLIANCE

We certify that the statements made in this data report are correct and that all details of design, material, construction, and workmanship of this boiler conform to Section I of the ASME BOILER AND PRESSURE VESSEL CODE

Our Certificate of Authorization no ______ to use the (S) ______ symbol expires ______ 32 ______

Date ______ Signed ______ (Authorized Representative) Name ______ (Manufacturer)

33 CERTIFICATE OF SHOP INSPECTION

Boiler constructed by ______ at ______

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the state or province of ______ 34 ______ and employed by ______

______ have inspected parts of this boiler referred to as data items ______

______ 35 ______ and have examined Manufacturer's Partial Data Reports for items ______

______ 36 ______ and state that, to the best of my knowledge and belief, the manufacturer has constructed this boiler in accordance with Section I of the ASME BOILER AND PRESSURE VESSEL CODE

By signing this certificate neither the inspector nor his employer makes any warranty, expressed or implied, concerning the boiler described in this Manufacturer's Data Report Furthermore, neither the inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date ______ Signed ______ (Authorized Inspector) Commissions ______ 37 ______ (Nat'l. Board (incl endorsements), State, Province, and No.)

38 CERTIFICATE OF FIELD ASSEMBLY COMPLIANCE

We certify that the field assembly construction of all parts of this boiler conforms with the requirements of SECTION I of the ASME BOILER AND PRESSURE VESSEL CODE

Our Certificate of Authorization no ______ 39 ______ to use the (A) or (S) ______ 39 ______ symbol expires ______ 39 ______.

Date ______ Signed ______ (Authorized Representative) Name ______ (Assembler)

Form P-2 (Back Cont'd)

40 CERTIFICATE OF FIELD ASSEMBLY INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the state or province of ______34______ and employed by ______________________________
have compared statements in this Manufacturer's Data Report with the described boiler and state that the parts referred to as data items ___41___
__________, not included in the certificate of shop inspection, have been inspected by me and that to the best of my knowledge and belief the manufacturer and/or the assembler has constructed and assembled this boiler in accordance with the applicable sections of the ASME BOILER AND PRESSURE VESSEL CODE. The described boiler was inspected and subjected to a hydrostatic test of ______________ psi.

By signing this certificate neither the inspector nor his employer makes any warranty, expressed or implied, concerning the boiler described in this Manufacturer's Data Report. Furthermore, neither the inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection

Date__________ Signed______________________ Commissions__________37__________
(Authorized Inspector) (Nat'l Board (incl endorsements), State, Province, and No.)

A-351 GUIDE FOR COMPLETING MANUFACTURERS' DATA REPORT, FORM P-2 (See PG-112.2.1)

(1) Name and address of Manufacturer, i.e., maker of all components not covered by Partial Data Reports.

(2) Name and address of purchaser and/or owner.

(3) Name and address of location where boiler is to be installed. If not known, so indicate (e.g., "Not known—built for stock").

(4) Show type of boiler documented by this Data Report.

(5) Identification of boiler by applicable numbers. If intended for installation in Canada, indicate the Canadian Design Registration Number and drawing number.

(6) Year in which fabrication was completed in shop.

(7) Date (year) of Section I Edition under which boiler was constructed.

(8) Issue date of most recent Addenda to Section I under which boiler was constructed (e.g., "1990").

(9) To be completed when one or more components comprising the boiler are furnished by others and certified by Partial Data Report(s), Form P-4.

(10) Show quantity and inside dimensions in inches. If more than two shells or drums are used, enter data in Line 14.

(11) Show the complete ASME Material Specification No. and Grade as listed in the appropriate stress allowance table in the Appendix of Section I (e.g., "SA-285-B"). Exception: A specification number for a material not identical to an ASME Specification may be shown *only* if such material meets the criteria in the Foreword of this Section. When material is accepted through a Code Case, the applicable Case number shall be shown.

(12) Indicate type of joint(s).

(13) Show joint efficiency for welded joints.

(14) Same as (12) above.

(15) Show number of furnaces in boiler.

(16) For cylindrical furnaces of the Adamson, ring reinforced, and combined types, show length of each section and total length. For other types, show total length only.

(17) For stayed (firebox) type furnace, also complete Line 12.

(18) If threaded, show diameter at root of thread.

(19) Minimum cross-sectional area after deducting for telltale hole.

(20) Maximum allowable working pressure for the stayed area calculated according to the rules contained in Part PFT.

(21) Type of stay or brace, e.g., diagonal, girder, through, etc.

(22) Deleted.

(23) See applicable paragraphs and figures in Part PFT.

(24) List parts not covered elsewhere on the Data Report. If insufficient space, attach a supplementary sheet (Form P-6).

(25) Tabulate data for parts listed on Line 14.

(26) Show data for main, auxiliary steam outlets, and feedline connections only. Does not apply to small openings for water columns, controls, vents, drains, instrumentation, or to openings for connections internal to the boiler such as risers, downtakes, or downcomers.

(27) Maximum allowable working pressure established in accordance with PG-21.

(28) Show Section I paragraph which applies to the weakest part of the boiler as established by calculation or deformation test.

(29) Boiler heating surface calculated in accordance with PG-70.

(30) Hydrostatic pressure applied in accordance with PG-99 and witnessed by the Authorized Inspector.

(31) To be completed and signed by an authorized representative of the Manufacturer.

(32) Show Manufacturer's ASME Certificate of Authorization number, kind of symbol, and date of expiration of said authorization.

(33) This certificate to be completed by the Authorized Inspection Agency representative who performs the in-shop inspection.

(34) To determine what goes in the space, you should be guided by the following
National Board Stamped Boilers and Pressure Vessels (see Form P-2 Line 4)
After "and/or State or Province" in the certification blocks—

If the Inspector has a valid commission for the state or province where the Manufacturer's shop is located, insert the name of that state or province. If the Manufacturer is located in a non-Code state or province, insert the name of the state or province where the Inspector took his original examination to obtain his National Board Commission, provided he still has a valid commission for that state or province. Otherwise, if no valid commission, show the name of the state or province where he has a valid commission authorizing him to make the shop inspection.

Boilers and Pressure Vessels Not Stamped National Board
Follow the above procedure. However, in this case do not list any National Board Commission number after the Inspector's signature at the bottom of the block.

(35) Indicate in this space the data items covered on Form P-2 on Lines 6 through 20

(36) Indicate by Line numbers those items furnished by other and for which Partial Data Reports (Form P-4) have been examined.

(37) The Inspector's National Board commission number must be shown when the boiler is stamped National Board; otherwise show only his state or province commission number. (See (34) above.)

(38) To be completed when applicable, and signed by an authorized representative of the organization responsible for field assembly of the boiler.

(39) Show assembler's ASME Certificate of Authorization number, kind of symbol, and date of expiration of said authorization.

(40) This certificate to be completed by the Authorized Inspection Agency representative who performs the field assembly inspection.

FORM P-2A MANUFACTURERS' DATA REPORT FOR ALL TYPES OF ELECTRIC BOILERS
As Required by the Provisions of the ASME Code Rules, Section I

PART I — To Be Completed by the Manufacturer of the Boiler Pressure Vessel

1. Manufactured by ______ 1 ______
(Name and address of manufacturer of boiler pressure vessel)

2. Manufactured for ______ 2 ______
(Name and address of purchaser)

3. Location of Installation ______ 3 ______
(Name and address)

4. Type ______ 4 ______ Boiler No. ______ 5 ______ ______ 5 ______
(resistance element, electrode) (Mfr's. Serial No.) (CRN)
______ 5 ______ ______ 5 ______ Year Built ______ 6 ______
(Drawing No.) (Nat'l Brd. No.)

5. The chemical and physical properties of all parts meet the requirements of Material Specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to Section I of the ASME Boiler and Pressure Vessel Code ______ 7 ______ (year), Addenda to ______ 8 ______ (date), and Code Cases ______ (Numbers)

Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors are attached for the following items of this report:
______ 9 ______
______
(Name of part, item number, mfr's name and identifying stamp)

6. Shells or drums. ______ 10 ______ 11 ______
(no.) (mat'l spec. gr.) [thickness (in.)] [dia (ID)] (length, inside) [dia (ID)] (length, inside)

7. Joints ______ 12 ______ 13 ______ 14 ______
[long (seamless, welded)] [efficiency (as compared to seamless)] [girth (seamless, welded)] (no. of shell courses)

8. Heads ______
(Mat'l Spec. No · thickness — flat, dished, ellipsoidal — radius of dish)

9. Other Parts 1 ______ 15 ______ 2. ______ 3 ______
(Brief description — i.e. dome, boiler piping, etc.)
1. ______ 16 ______ 17 ______
2 ______
3. ______
(Mat'l. Spec, Gr, size, material thickness, MAWP)

10. Openings. (a) Steam ______ 18 ______ (b) Safety Valve ______
(No, size, and type) (No., size, and type)
(c) Blowoff ______ (d) Feed ______
(No., size, and type) (No, size, type and location)
(e) Manholes. No ______ Size ______ Location ______
(f) Handholes: No ______ Size ______ Location ______
(g) Elements/Electrodes No ______ Size ______ Location ______

11. Boiler Supports: No. ______ Type ______
(saddles, legs, lugs)
Attachment ______
(bolted or welded)

12. MAWP ______ 19 ______ psi Based on ______ 20 ______
(Code para. and/or formula)

13 Shop Hydrostatic Test ______ 22 ______ psig 14 Maximum Designed Steaming Capacity ______ lb/hr

15 Remarks ______
______
______

23 CERTIFICATE OF COMPLIANCE OF BOILER PRESSURE VESSEL

We certify the statements in Part I of this Data Report to be Correct.
Our Certificate of Authorization No ______ 24 ______ to use the (S) or (M) ______ 24 ______
Symbol expires ______ 24 ______
Date ______ Signed ______ Name ______
(Authorized Representative) (mfr. of boiler pressure vessel)

This form (E00120) may be obtained from the ASME Order Dept., 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300.

(25) CERTIFICATE OF SHOP INSPECTION OF BOILER PRESSURE VESSEL

BOILER PRESSURE VESSEL MADE BY ______________________ at ______________________

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of ______ (26) ______ and employed by ______________________

______________ have inspected parts of this boiler pressure vessel referred to as data items ______ (27) ______

and have examined Manufacturer's Partial Data Reports for items ______ (28) ______

and state that, to the best of my knowledge and belief, the manufacturer has constructed this boiler pressure vessel in accordance with the applicable sections of the ASME BOILER AND PRESSURE VESSEL CODE

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the boiler pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection

Date ______________________

______________________ Commissions ______ (29) ______
(Authorized Inspector) [Nat'l Board (incl endorsements), State, Province, and No]

Part II—To Be Completed by the Manufacturer Responsible for the Completed Boiler

16

Item	Piping (30)				Valves (31)			
	Size	Sch	Spec.	Bolted, Threaded, or Welded	Size	Type	Rating	No
(a) Steam Pipe								
(b) Feed Water					Stop			
Feed Water					Check			
(c) Blowoff								

17 Safety Valves(s) No __________ Size __________ Set Press __________ Total Capacity lb/hr __________

18 Heating Elements Installed. Quantity __________ kW Total __________

19 Electrodes· Quantity __________ kW Total __________

20 Hydrostatic Test of Completed Boiler __________ psig

(32) CERTIFICATE OF COMPLIANCE OF COMPLETED BOILER

We certify that this completed boiler conforms with the requirements of SECTION I of the ASME BOILER AND PRESSURE VESSEL CODE

Our Certificate of Authorization No ______ (24) ______ to use the (S), (M), or (E) ______ (24) ______

Symbol expires ______ (24) ______

Date __________ Signed ______________________ By ______________________
(Authorized Representative) (Assembler)

CERTIFICATE OF SHOP INSPECTION OF COMPLETED BOILER

BOILER MADE BY ______________________ at ______________________

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of ______ (26) ______ and employed by ______________________

of ______________________ and have inspected the completed boiler and have examined Manufacturer's Partial Data Reports for ______ (34) ______

and state that, to the best of my knowledge and belief, the Manufacturer has constructed this boiler in accordance with the applicable sections of the ASME BOILER AND PRESSURE VESSEL CODE

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the boiler described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection

Date ______________________

______________________ Commissions ______ (29) ______
(Authorized Inspector) [Nat'l Board (incl endorsements), State, Province, and No]

A-351.1 GUIDE FOR COMPLETING MANUFACTURERS' DATA REPORT, FORM P-2A (See PG-112.2.1.1)

(1) Name and address of Manufacturer, i.e., maker of all components not covered by Partial Data Reports. When the boiler pressure vessel is constructed by a "U" symbol holder and certified on a U-1 or U-1A Data Report, indicate on line 1 "Boiler pressure vessel constructed to Section VIII, Division 1, as permitted by Part PEB," and attach the U-1 or U-1A Data Report.

(2) Name and address of purchaser and/or owner (to be completed by the Manufacturer of the completed boiler).

(3) Name and address of location where boiler is to be installed. If not known, so indicate (e.g., "Not known—built for stock") (to be completed by the Manufacturer of the completed boiler).

(4) Show type of electric boiler documented by this Data Report.

(5) Identification of boiler by applicable numbers. If intended for installation in Canada, indicate the Canadian Design Registration Number and drawing number.

(5a) The Manufacturer of the boiler pressure vessel shall apply the ASME Code symbol stamp and the National Board Number when required. It is his responsibility to complete Part I of the Data Report, and forward it with the vessel to the company who will apply the trim ("E" symbol holder). The Manufacturer responsible for the trim and completed boiler shall complete Part II of the Data Report and if the boiler is to be stamped "National Board," forward the original Data Report to the National Board for registration.

(6) Year in which fabrication was completed in shop.

(7) Date (year) of Section I Edition under which boiler was constructed.

(8) Issue date of most recent Addenda to Section I under which boiler was constructed (e.g., "1990").

(9) To be completed when one or more components comprising the boiler pressure vessel and furnished by others and certified by Partial Data Report(s), Form P-4.

(10) Show quantity and inside dimensions in inches If more than two shells or drums are used, enter data in Line 9.

(11) Show the complete ASME Material Specification No. and Grade as listed in the appropriate stress allowance table in the Appendix of Section I (e.g., "SA-285-B"). Exception: A specification number for a material not identical to an ASME Specification may be shown *only* if such material meets the criteria in the Foreword of this Section. When material is accepted through a Code Case, the applicable Case number shall be shown.

(12) Indicate type of joint(s).

(13) Show joint efficiency for welded joints.

(14) Same as (12) above.

(15) List parts not covered elsewhere on the data report. If insufficient space, attach a supplementary sheet (Form P-6).

(16) Tabulate data for parts listed on Line 9.

(17) Same as (11) above.

(18) Show data for main and auxiliary steam outlets only. Does not apply to small openings for water column, controls, vents, etc.

(19) Maximum allowable working pressure established in accordance with PG-21 or Section I.

(20) Show Section I paragraph which applies to the weakest part of the boiler pressure vessel as established by calculation or deformation test.

(21) Deleted.

(22) Hydrostatic pressure applied in accordance with PG-99 and witnessed by the Authorized Inspector.

(23) To be completed and signed by an authorized representative of the Manufacturer.

(24) Show Manufacturer's ASME Certificate of Authorization number, kind of symbol, and date of expiration of said authorization.

(25) This certificate to be completed by the Authorized Inspection Agency representative who performs the in-shop inspection.

(26) To determine what goes in the space, you should be guided by the following

National Board Stamped Boilers and Pressure Vessels (see Form P-2A Line 4)
After "and/or State or Province" in the certification blocks—

If the Inspector has a valid commission for the state or province where the Manufacturer's shop is located, insert the name of the state or province. If the Manufacturer is located in a non-Code state or province, insert the name of the state or province where the Inspector took his original examination to obtain his National Board Commission, provided he still has a valid commission for that state or province. Otherwise, if no valid commission, show the name of the state or province where he has a valid commission authorizing him to make the shop inspection.

Boilers and Pressure Vessels Not Stamped National Board
Follow the above procedure. However, in this case do not list any National Board Commission number after the Inspector's signature at the bottom of the block.

(27) Indicate in this space the data items covered on Form P-2 on Lines 6 through 14

(28) Indicate by Line numbers those items furnished by others and for which Partial Data Reports (Form P-4) have been examined

(29) The Inspector's National Board commission number must be shown when the boiler is stamped "National Board"; otherwise show only his state or province commission number (See (26) above)

(30) When piping is supplied with the boiler for steam, blowoff, and feedwater, complete this section. When welded piping is supplied by another stamp holder, leave blank, and provide separate Form P-4A.

(31) Complete this section when valves are furnished with the boiler.

(32) To be completed and signed by an authorized representative of the organization responsible for assembly of the boiler Show ASME Certificate of Authorization number, kind of symbol, and date of said authorization When the boiler pressure vessel is constructed by a "U" symbol holder and certified on a U-1 or U-1A Data Report, the "E" symbol holder shall complete lines 1 through 4 of Part 1

(33) This certificate to be completed by the Authorized Inspection Agency representative who performs the in-shop inspection Leave blank where final shop inspection is not required as permitted by PEB-18.1

(34) Indicate in this space if the welded piping is furnished by others and is covered on Form P-4A.

FORM P-3 MANUFACTURERS' DATA REPORT FOR WATERTUBE BOILERS, SUPERHEATERS, WATERWALLS, AND ECONOMIZERS

As Required by the Provisions of the ASME Code Rules, Section I

MASTER DATA REPORT YES ☐
(Check one) NO ☐

1. Manufactured by ____ 1 ____
(Name and address of manufacturer)
2. Manufactured for ____ 2 ____
(Name and address of purchaser)
3. Location of Installation ____ 3 ____
(Name and address)
4. Unit Identification ____ 4 ____ (Complete boiler, superheater, waterwall, economizer, etc.) ID Nos ____ 5 ____ (Mfr's Serial No.) ____ 5 ____ (CRN) ____ 5 ____ (Drawing No.) ____ 5 ____ (Nat'l. Board No.) ____ 6 ____ (Year Built)
5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to Section I of the ASME Boiler and Pressure Vessel Code ____ 7 ____ (Year),
Addenda to ____ 8 ____ (Date), and Code Cases ____ (Numbers).
Supporting Manufacturer's Data Reports properly identified and signed by Commissioned Inspectors are attached for the following items of this report
____ 9 ____
(Name of part, item number, mfr's name, and identifying stamp)

6(a) Drums

No.	Inside Diameter, in.	Inside Length ft in	Shell Plates: Mat'l. Spec No., Grade	Shell Plates: Thickness, in	Shell Plates: Inside Radius, in	Tubesheets: Thickness in	Tubesheets: Inside Radius, in	Tube Hole Ligament Efficiency, %: Longitudinal	Tube Hole Ligament Efficiency, %: Circumferential
1			10	11		12			
2									
3									

No.	Longitudinal Joints: No. & type*	Longitudinal Joints: Efficiency	Circum. Joints: No. & type	Circum. Joints: Efficiency	Heads: Mat'l. Spec No., Grade	Heads: Thickness, in	Heads: Thickness, in	Heads: Type**	Heads: Radius of Dish	Heads: Manholes No. Size	Hydrostatic Test, psi
1					10	11	12		13		14
2											
3											

*Indicate if (1) Seamless; (2) Fusion welded
**Indicate if (1) Flat, (2) Dished, (3) Ellipsoidal, (4) Hemispherical.

6(b) Boiler Tubes

Diameter	Thickness	Mat'l Spec No., Grade
15	16	10

6(c) Headers No. ____ 17 10 11 or 12 ____
(Box or sinuous or round, Mat'l spec. no., Thickness)

Heads or Ends ____ 18 10 12 ____ (Shape, Mat'l spec no.; Thickness) Hydro Test, psi ____ 14 ____

6(d) Staybolts ____ 10 ____
(Mat'l. spec no., Diameter; Size telltale; Net area)

Pitch ____ (Hor and Vert) in Net Area ____ (Supported by one bolt) in^2 MAWP ____ psi

6(e) Mud Drum ____ 19 20 10 11 or 12 ____ (For sect. header boilers. State Size, Shape, Mat'l. spec. no.; Thickness) Heads or Ends ____ 18 10 12 ____ (Shape, Mat'l. spec no.; Thickness) Hydro Test, psi ____ 14 ____

7(a) Waterwall Headers — 7(b) Waterwall Tubes

No.	Size and Shape	Material Spec. No.	Thickness, in.	Heads or Ends: Shape	Heads or Ends: Thickness, in.	Heads or Ends: Material Spec No	Hydro. Test, psi	Diameter, in	Thickness, in	Material Spec. No
	19 20	10	11 12	18	12	10	14	15	16	10

8(a) Economizer Headers — 8(b) Economizer Tubes

This form (E00069) may be obtained from the ASME Order Dept., 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300

Form P-3 (Back)

9(a) Superheater Headers | Heads or Ends | 9(b) Superheater Tubes

No.	Size and Shape	Material Spec. No.	Thickness, in.	Shape	Thickness, in.	Material Spec. No	Hydro. Test, psi.	Diameter, in	Thickness, in.	Material Spec. No.
	19 20	10	11 12	18	12	10	14	15	16	10

10(a) Other Parts (1) ______ 36 ______ (2) ______________ (3) ______________ 10(b) Tubes for Other Parts

1										
2										
3										

11 Openings (1) Steam ___ 21 ___ 22 ___ 23 ___ (No., size, and type of nozzles or outlets) (2) Safety Valve ___ 22 ___ 23 ___ (No., size, and type of nozzles or outlets)

(3) Blowoff ___ 22 ___ 23 ___ (No., size, and type of nozzles or outlets) (4) Feed ___ 22 ___ 23 ___ (No., size, type, and location of connections)

12		Maximum Allowable Working Pressure	Code Par. and/or Formula on Which MAWP is Based	Shop Hydro Test, psi	Heating Surface, sq ft
a	Boiler				
b	Waterwall				
c	Economizer				
d	Superheater				
e	Other Parts				

Heating surface to be stamped on drum heads

This heating surface not to be used for determining minimum safety valve capacity.

13 Field Hydro. Test, psi

14 Maximum Designed Steaming Capacity ________ lb/hr

15 Remarks ____

24 CERTIFICATE OF SHOP COMPLIANCE

We certify that the statements made in this data report are correct and that all details of design, material, construction, and workmanship of this boiler conform to Section I of the ASME BOILER AND PRESSURE VESSEL CODE.

Our Certificate of Authorization No ____ 25 ____ to use the (S) ____ 25 ____ Symbol expires ________ 25 ________.

Date ____________ Signed ______________________ Name ______________________

(Authorized Representative) (Manufacturer)

26 CERTIFICATE OF SHOP INSPECTION

BOILER MADE BY ______________________ at ______________________.

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the state or province of ____ 27 ____ and employed by ______________________ have inspected parts of this boiler referred to as data items ______________________ 28 ______ and have examined Supporting Manufacturer's Data Reports for items ________ 29 ________ and state that, to the best of my knowledge and belief, the Manufacturer has constructed this boiler in accordance with Section I of the ASME BOILER AND PRESSURE VESSEL CODE.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the boiler described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date __________ Signed ______________________ Commissions ________ 30 ________

(Authorized Inspector) [Nat'l. Board (incl. endorsements), State, Province, and No.]

31 CERTIFICATE OF FIELD ASSEMBLY COMPLIANCE

We certify that the field assembly of all parts of this boiler conforms with the requirements of SECTION I of the ASME BOILER AND PRESSURE VESSEL CODE.

Our Certificate of Authorization No ____ 32 ____ to use the (A) or (S) ____ 32 ____ Symbol expires ________ 32 ________.

Date ____________ Signed ______________________ Name ______________________

(Authorized Representative) (Assembler)

Form P-3 (Back Cont'd)

33 CERTIFICATE OF FIELD ASSEMBLY INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the state or province of ______ 27 ______ and employed by ______________________ ______ have compared statements in this Manufacturer's Data Report with the described boiler and state that the parts referred to as data items ______ 34 ______, not included in the Certificate of Shop Inspection, have been inspected by me and that to the best of my knowledge and belief the Manufacturer and/or the assembler has constructed and assembled this boiler in accordance with the applicable sections of the ASME BOILER AND PRESSURE VESSEL CODE. The described boiler was inspected and subjected to a hydrostatic test of ______________ psi. By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the boiler described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date__________ Signed______________________ (Authorized Inspector) Commissions______ 30 ______ (Nat'l. Board (incl endorsements), State, Province, and No.)

A-352 GUIDE FOR COMPLETING MANUFACTURERS' DATA REPORT, FORM P-3 (See PG-112.2.2)

(1) Name and address of Manufacturer, i.e., maker of all components not covered by Supporting Data Reports

(2) Name and address of purchaser and/or owner

(3) Name and address of location where boiler is to be installed. If not known, so indicate (e.g., "Not known—built for stock")

(4) Name the unit documented by this Data Report. Note that this report may cover a complete boiler unit or separate component items (e.g., superheaters and economizers) fabricated by a manufacturer other than the Manufacturer of the boiler unit.

(5) Identification of boiler by applicable numbers. If intended for installation in Canada, indicate the Canadian Design Registration Number and drawing number.

(6) Year in which fabrication was completed in shop.

(7) Date (year) of Section I Edition under which boiler was constructed

(8) Issue date of Addenda to Section I under which boiler was constructed (e.g., "1990")

(9) To be completed when one or more components comprising the boiler are furnished by others, and supported by Data Reports such as Forms P-3, P-4, and P-4a, as appropriate

(10) Show the complete ASME Material Specification No. and Grade as listed in the appropriate stress allowance table in the Appendix of Section I (e.g., "SA-285-B"). Exception: A specification number for a material not identical to an ASME Specification may be shown *only* if such material meets the criteria in the Foreword of this Section. When material is accepted through a Code Case, the applicable Case number shall be shown.

(11) Nominal thickness of the plate.

(12) Minimum thickness after forming.

(13) Radius on concave side of dish

(14) Shop hydrostatic test, if any, applied to individual part prior to test applied to the assembled boiler (see Lines 12 and 13).

(15) Outside diameter

(16) Minimum thickness of tubes.

(17) This space for headers not covered on Lines 7(a) through 10(a). It is intended primarily for sectional headers on straight tube watertube boilers.

(18) Indicate shape as flat, dished, ellipsoidal, or hemispherical.

(19) Use inside dimensions for size.

(20) Indicate shape as square, round, etc.

(21) Show data for main, auxiliary steam outlets, and feedline connections only. Does not apply to small openings for water columns, controls, vents, drains, instrumentation, or to openings for connections internal to the boiler such as risers, downtakes, or downcomers.

(22) Size is nominal pipe size.

(23) Describe type as flanged, welding neck, etc.

(24) To be completed and signed by an authorized representative of the Manufacturer.

(25) Show Manufacturer's ASME Certificate of Authorization number, kind of symbol, and date of expiration of said authorization.

(26) This certificate to be completed by the Authorized Inspection Agency representative who performs the in-shop inspection.

(27) To determine what goes in the space, you should be guided by the following:

National Board Stamped Boilers and Pressure Vessels (see Form P-3 Line 4)
After "and/or State or Province" in the certification blocks—

If the Inspector has a valid commission for the state or province where the Manufacturer's shop is located, insert the name of that state or province. If the Manufacturer is located in a non-Code state or province, insert the name of the state or province where the Inspector took his original examination to obtain his National Board Commission, provided he still has a valid commission for that state or province. Otherwise, if no valid commission, show the name of the state or province where he has a valid commission authorizing him to make the shop inspection

Boilers and Pressure Vessels Not Stamped National Board
Follow the above procedure. However, in this case do not list any National Board Commission number after the Inspector's signature at the bottom of the block.

(28) Indicate the Data Items covered on Form P-3 on Lines 6 through 14.

(29) Indicate by Line numbers those items furnished by others for which Supporting Data Reports have been examined.

(30) The Inspector's National Board commission number must be shown when the boiler is stamped National Board; otherwise show only his state or province commission number. (See (27) above.)

(31) To be completed, when applicable, and signed by an authorized representative of the organization responsible for field assembly of the boiler.

(32) Show ASME Certificate of Authorization number, kind of symbol, and date of expiration of said authorization.

(33) This certificate to be completed by the Authorized Inspection Agency representative who performs the field assembly inspection.

(34) Indicate those items on Line 6 through 14 of Form P-3 inspected in the field that were not inspected in the shop.

(35) List parts not covered elsewhere on the Data Report. If insufficient space, attach a supplementary sheet (Form P-6).

CA 188

FACULTAD DE INGENIERÍA UNAM
DIVISIÓN DE EDUCACIÓN CONTINUA

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CURSOS ABIERTOS

DIPLOMADO EN INGENIERÍA DE CALDERAS Y RECIPIENTES A PRESIÓN

MÓDULO IV : MATERIALES, SOLDADURA Y CALDERAS DE POTENCIA

TEMA:

CUDADO DE CALDERAS E INSTALCIONES TÍPICAS

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DIPLOMADO EN INGENIERÍA DE CALDERAS Y RECIPIENTES SUJETOS A PRESIÓN

MODULO
MATERIALES, SOLDADURA Y CALDERAS DE POTENCIA

TEMA 2: CUIDADO DE CALDERAS.

Contenido:

a) Procedimiento para la puesta en marcha de calderas.
b) Precauciones durante el proceso de arranque.
c) Indicadores importantes en la operación de calderas.
d) Recomendaciones para el cuidado de las calderas.

Antes de iniciar el desarrollo del tema, les quiero mostrar a través de diapositivas, lo que le sucede a las calderas al no tener cuidado en su operación y/o mantenimiento.

Vamos a dar inicio a nuestro tema, considerando que tenemos instalada una caldera nueva tipo tubos de fuego y que ya fue probada en fábrica. Además que tiene su equipo auxiliar completo y que durante su montaje e instalación, se cumplió con los siguientes requisitos:

Requisitos legales. Actualmente se tiene la norma oficial mexicana NOM-122-STPS-1996. Relativa a las condiciones de seguridad e higiene para el funcionamiento de los recipientes sujetos a presión y generadores de vapor ó calderas que operen en los centros de trabajo.

Puntos a considerar:
1.- Tener por escrito un manual de seguridad e higiene para la operación y mantenimiento de la caldera, sus accesorios y dispositivos.
2.- La caldera debe ser instalada en lugares en donde los riesgos sean mínimos.

3.- La caldera se encuentre en piso firme y nivelado capaz de soportar el peso muerto de la misma.
4.- El equipo debe de estar libre de impactos, con suficiente ventilación. Para una ventilación adecuada, el cuarto de calderas deberá estar provisto de áreas de escape de aire caliente en la parte superior del cuarto de calderas, y de áreas para la admisión de aire fresco, necesario para ventilación del mismo y para la combustión.
5.- Debe contar con iluminación general y complementaria:

En caldera	60 Luxes como mínimo.
En quemador	100 Luxes como mínimo.
En cabezal de vapor	60 Luxes como mínimo.
Área de manómetros	100 Luxes como mínimo.

6.- Espacio mínimo de 1.5 m entre el techo y la parte más alta de la caldera.
7.- Espacio mínimo de 1.0 m alrededor de la caldera.

Requisitos técnicos del equipo.
1.- Tener espacio suficiente ya sea por la parte delantera o trasera, para poder cambiar los tubos flux.
2.- Es necesario que el cuarto de calderas cuente con un sistema de drenaje, con registros en: centro de la caldera, en la zona del equipo suavizador y en las trincheras en caso de que existan.
3.- Para la descarga de las purgas, se recomienda un tanque separador centrífugo o una fosa de purgas.
4.- Dentro del tablero de la caldera tener una copia del diagrama eléctrico de la misma.

REVISIÓN DE LA INSTALACIÓN

La Instalación comprende:

1.- Sistema de alimentación de agua.

1.1.- Toma de agua a una presión de 2 a 3 Kg/cm^2 (ver manómetro)
1.2.- Equipo suavizador de agua (simple o doble)
1.3.- Tanque de condensados con sus accesorios y altura adecuada, para producir así una carga positiva en la succión de la bomba y evitar la evaporación del agua al funcionar ésta. Se sugieren las siguientes alturas del tanque de condensados con respecto a la línea de centros de la bomba, cuando la temperatura del agua exceda a 82°C (180°F).

Temperatura en °C	Altura en m.
82 a 93	1.80 o más
93 a 96	2.40 o más
96 a 100	3.90 o más

1.4.- Bomba de alimentación de agua. La conexión entre el tanque de condensados y la bomba, deberá ser de por lo menos el mismo diámetro de succión de la bomba, teniendo un filtro lo mas cercano a ésta y una válvula tipo compuerta.

1.5.- Tubería de alimentación de agua desde la bomba hasta la toma de la caldera conservando el mismo diámetro de descarga de la bomba; Además debe contar con una válvula tipo globo lo mas cercano a la caldera y junto a ésta una o dos válvulas de retención.

2.- Sistema de alimentación de combustible.

2.1.- Utilizando combustóleo.

2.1.1.- Tanque(s) de almacenamiento general. Su instalación se rige por la norma oficial mexicana NOM-005-STPS-1993

2.1.2.- Bomba de trasiego. Tubería aislada con la tubería que conduce el vapor para el precalentador del tanque de combustóleo.

2.1.3.- Tanque de día.

2.1.4.- Bomba de alimentación de combustible al quemador de la caldera, incluye filtro en la succión y válvulas de control manual.

2.1.5.- Precalentador de vapor y eléctrico (pueden estar separados o en una sola pieza), con accesorios y controles para el control automático del vapor y de la temperatura la cual se eleva a 93°C, esta temperatura puede variar dependiendo del tipo de quemador.

2.1.6.- Línea de atomización, dependiendo del fabricante de la caldera, ésta puede ser con aire o vapor.

2.1.7.- Se utiliza piloto de gas L.P. o natural.

2.2.- Utilizando gas natural. (Las instalaciones de gas natural se rigen por la norma oficial mexicana NOM-SECRE-002-1997).

2.2.1.- En la caseta que esta dentro de las instalaciones de la empresa se regula el gasto y la presión requerida; Se conduce hasta el cuarto de calderas.

2.2.2.- Dentro del cuarto de calderas, se tiene: Una válvula de corte manual, un manómetro de rango adecuado y un regulador que nos baja la presión del gas a la requerida por el quemador.
2.2.3.- Después del regulador esta el tren principal de gas y el quemador.
2.2.4.- Se utiliza piloto de gas natural.

2.3.- Utilizando gas L.P. (Las instalaciones de gas L.P. se rigen por el proyecto de norma oficial mexicana NOM-004-SEDG-1998, D.O. del 20 de enero de 1999.
2.3.1.- Tanque(s) de almacenamiento.
2.3.2.- Vaporizador(es) con su tanque trampa. (Si son necesarios)
2.3.3.- Banco de regulación. Se baja la presión del gas L.P. normalmente a 1.5 Kg/cm^2.
2.3.4.- Se conduce el gas L.P. a la presión mencionada hasta dentro del cuarto de calderas.
2.3.5.- Dentro del cuarto de calderas se tiene un segundo regulador llamado de 2a. Etapa que baja la presión del gas L.P. a la requerida por el quemador de la caldera.
2.3.6.- Antes del regulador mencionado, se encuentra instalada una válvula de corte manual, un filtro y un manómetro de rango adecuado.
2.3.7.- Después del regulador de 2a. Etapa, se encuentra el tren principal de gas L.P. y el quemador de la caldera.
2.3.8.- Se utiliza piloto de gas L.P.

2.4.- Utilizando diesel o gasóleo.
2.4.1.- Tanque(s) de almacenamiento general. Su instalación se rige por la norma oficial mexicana NOM-005-STPS-1993.
2.4.2.- Bomba de alimentación de combustible al quemador. Entre la bomba y el tanque va instalada una válvula de corte manual y un filtro; A la descarga de la bomba va un manómetro de rango adecuado y dependiendo del tamaño y tipo de quemador va una válvula de alivio con línea de retorno de combustible.
2.4.3.- Dependiendo del fabricante y del tamaño del quemador; Se puede atomizar mecánicamente, con aire o vapor.
2.4.4.- Dependiendo del tamaño del quemador puede llevar piloto de gas L.P. o de diesel.

3.- Sistema de salida de gases.

3.1.- Termómetro de 100 a 500°C con carátula del diámetro adecuado.
3.2.- Chimenea del mismo diámetro al de la caldera y altura adecuada.
3.3.- Puertos de muestreo de acuerdo al instructivo CCAT-FF-001 de la SEDESOL.
3.4.- Plataforma (si es necesario).

4.- Sistema de purgas.

4.1.- La(s) purga(s) de fondo deben contar con una válvula de cierre lento tipo " Y " , y una válvula de cierre rápido seleccionadas a la presión adecuada. Instaladas en el orden descrito a partir de la salida de la caldera.
4.2.- En la purga de la columna de nivel, va una válvula tipo globo seleccionada a la presión adecuada.
4.3.- Las descargas de la purga del cristal de nivel y la purga del tren de controles, se pueden unir y conectarse en la tubería de descarga de la columna de nivel.
4.4.- La descarga de la purga de la columna de nivel, se puede unir a la descarga de la(s) purga(s) de fondo.
4.5.- La descarga de la(s) purga(s) de fondo, va a una fosa o a un tanque separador centrifugo.

5.- Sistema de energía eléctrica.

5.1.- Para el correcto funcionamiento del equipo eléctrico, es conveniente que el voltaje se mantenga lo más constante posible. Esto es de vital importancia para el circuito de control, el cual no admite variaciones en + o - 10% de los 110 volts nominales.
5.2.- Para el correcto funcionamiento y protección del control programador, se utiliza un transformador tipo seco de ½ KVA de 220 o 440 V a 110 V.
5.3.- Todos los motores deben estar protegidos con arrancadores magnéticos.

6.- Sistema de vapor

6.1.- Inmediatamente después de la salida de vapor de la caldera, va una válvula tipo globo seleccionada para la presión adecuada. Toda tubería de vapor deberá estar debidamente aislada y dependiendo de su longitud tendrá juntas de expansión.

6.2.- En sistemas intercomunicados de vapor con igual presión de trabajo, se deben instalar válvulas de retención a la salida de cada caldera y cuando haya diferentes presiones instalarlas en las calderas de baja presión.

6.3.- Si se utiliza cabezal de vapor, deberá de contar con: Válvula de seguridad, manómetro de rango adecuado, trampa de vapor con descarga al tanque de condensados. Además estará aislado.

6.4.- La descarga de la(s) válvula(s) de seguridad serán independientes y deben soportarse en una forma tal que evite cualquier esfuerzo sobre la(s) válvula(s).

Antes de iniciar el proceso de arranque se recomienda, destapar la caldera por ambos lados y realizar una prueba hidrostática a la presión de diseño, además revisar los refractarios para verificar que no sufrieron ningun daño durante el transporte y montaje de la misma.

A continuación, veremos como se realiza una prueba hidrostática de acuerdo a la sección No. I del código ASME.

PROCEDIMIENTO PARA LA PUESTA EN MARCHA DE CALDERAS Y PRECAUCIONES DURANTE EL PROCESO DE ARRANQUE

1) Realizar una inspección ocular a todo el exterior de la caldera, para verificar que no haya sufrido algún daño en su cuerpo o en alguno de sus controles y accesorios, durante el transporte y montaje.

2) Revisar que haya energía eléctrica en el tablero de control de la caldera y en el arrancador de la bomba de agua (voltaje adecuado).

3) Revisar que el acoplamiento entre el motor y la bomba de agua se encuentre debidamente alineado.

4) Revisar el sentido de la rotación del ventilador, bomba de agua y en su caso de la bomba de combustible que sea el adecuado.

5) Revisar que el tanque de condensados tenga agua y que este al nivel adecuado.

6) Revisar que todas las válvulas de alimentación de agua estén abiertas, retirar el manómetro en la descarga de la bomba para verificar que circula el agua y eliminar el aire que había en la tubería tanto de succión como de descarga. Cuando salga agua sin burbujas colocar de nuevo el manómetro.

7) Revisar que la presión de agua a la entrada del equipo suavizador sea la adecuada (2 a 3 Kg/cm^2).

8) Abrir la válvula de venteo de la caldera.

9) Revisar que las válvulas de purga de fondo, purga de columna de nivel, purga del cristal de nivel, purga del tren de controles, salida principal de vapor y purga de superficie (si cuenta con ella), estén cerradas.

10) Retirar la tapa del control principal de nivel, revisar que no este obstruido el flotador y que las cápsulas de mercurio estén en buen estado y en su lugar.

11) Verificar que los grifos de prueba del control principal de nivel estén cerrados.

12) Verificar que las válvulas del cristal de nivel estén abiertas.

13) Revisar que el control de presión límite y el control de presión modulante estén ajustados a la presión que va trabajar la caldera, así como su diferencial.

14) Revisar en la placa de la(s) válvula(s) de seguridad la presión a la cual esta calibrada. Ésta debe ser mayor a la presión de trabajo pero no mas que la presión de diseño.

15) Revisar el electrodo de ignición que no se haya dañado durante el transporte y montaje de la caldera.

16) Verificar que el voltaje que está recibiendo el motor modutrol sea el adecuado (24 V).

17) Arrancar la bomba de alimentación de agua colocando el selector de tres posiciones, en automático, verificando el amperaje del motor.

18) Verificar que la bomba esta inyectando agua dentro de la caldera, sintiendo el paso en la tubería de descarga de la misma. También se puede verificar tocando la descarga de la válvula de venteo o escuchar el ruido que produce el aire al salir de la caldera.

19) Revisar la tubería y conexiones del agua de alimentación para corregir posibles fugas.

20) Observar en la mirilla de cristal, el nivel del agua dentro de la caldera y marcar el nivel cuando se pare la bomba automáticamente. Este nivel normalmente es de 63 mm medido a partir de su base.

21) Purgar la caldera por el fondo, marcar en la mirilla de cristal, el nivel donde arranca la bomba automáticamente. Aproximadamente es de 44 mm medido a partir de su base.

22) Colocar el selector de la bomba de agua en la posición de apagado y seguir purgando la caldera por el fondo, marcar en la mirilla de cristal, el nivel de corte del quemador (actúa una alarma auditiva). Aproximadamente es de 38mm medido a partir de su base.

23) Verificar que el control de baja presión de aire para la combustión este ajustado a la presión requerida y que funcione correctamente.

24) De acuerdo al tipo de combustible, revisar que no estén bloqueados los controles eléctricos de seguridad con que cuenta la caldera.

A.- Utilizando gas natural o L.P.
- Control por baja presión de gas.
- Control por alta presión de gas.

B.- Utilizando combustóleo.
- Microswitch de arranque.

- Control por baja presión de aire para atomización.
- Control por baja presión de combustible.
- Control por baja temperatura de combustible.
- Control por alta temperatura de combustible.

C.- Utilizando diesel o gasóleo.

- Microswitch de arranque.
- Control por baja presión de aire para atomización.
- Control por baja presión de combustible.

25) Abrir todas las válvulas manuales de alimentación de combustible desde el tanque de almacenamiento hasta el quemador de la caldera.

26) Si se utiliza retorno de combustible, también abrir todas las válvulas.

27) Abrir la válvula manual que alimenta el gas al piloto, verificar la presión la cual debe ser de 5 a 10 pulgadas columna de agua.

28) Cuando se utiliza combustóleo, en algunas calderas el arranque en frío se hace con diesel y se atomiza con aire; Ya que se tiene vapor a 3 Kg/cm^2, se abren todas las válvulas manuales que controlan el paso de vapor a: tanque de almacenamiento general y tanque de día, al llegar a las temperaturas recomendadas (30° C en el tanque de almacenamiento general y 60° C en el tanque de día), se arranca la bomba de trasiego para circular el combustóleo entre el tanque general y el de día.
Se apaga la caldera y se abren las válvulas del combustóleo que hay entre el tanque de día y el quemador, se cierran las válvulas del diesel.
Se arranca la bomba de alimentación de combustible para circular el combustóleo entre el tanque de día y el quemador, se abre la válvula que controla el paso del vapor al precalentador y se enciende el precalentador eléctrico para elevar la temperatura del combustóleo a 93° C y pueda funcionar el quemador. Algunas calderas atomizan con vapor en este momento se hace el cambio.

29) En las calderas que utilizan combustibles líquidos y que tienen línea de retorno, se puede poner a funcionar la bomba de combustible para revisar y ajustar las presiones requeridas por el quemador de la caldera.

Presión de combustible líquido recomendada en operación de alta alimentación, utilizando atomización con aire o vapor:
Presión de abastecimiento: 5.0 Kg/cm^2
Presión de entrada al quemador: 2.5 a 3.5 Kg/cm^2
Presión de retorno: Aprox. 1.0 Kg/cm^2 de diferencia con respecto a la presión de entrada.
Presión de atomización con aire:
Sin flujo de combustible la presión mínima es de 0.5 Kg/cm^2
Con combustible en fuego bajo sube a 0.80 Kg/cm^2
Con combustible en fuego alto no debe sobrepasar los 2.0 Kg/cm^2
Presión de atomización con vapor: Dentro del rango de 0.8 a 1.4 Kg/cm^2
La presión de combustible líquido utilizando atomización mecánica es de 7 Kg/cm^2.

30) La presión de combustible en calderas que utilizan gas L.P. o natural, es baja y depende del tamaño del quemador y del lugar donde este instalado. Se mide en pulgadas columna de agua, en onzas/ $pulg^2$ o en $gr./cm^2$

31) Todos los valores de presión y temperatura mencionados en los puntos anteriores se dan como referencia para poder arrancar la caldera. Los valores reales nos lo dará el análisis de gases que se hace a la caldera en operación para dejarla dentro de norma.

32) Hasta este punto se tiene la caldera lista para iniciar el proceso de arranque.

33) Encender la caldera iniciando el ciclo del control de flama modulante, el cual tiene la siguiente secuencia:

- Se energiza el motor del ventilador y el motor modutrol iniciando un tiempo de prepurga que tiene una duración de 70 segundos, en este lapso la compuerta del aire pasa de fuego bajo a fuego alto y viceversa.
- A los 70 segundos se energiza el transformador de ignición y la válvula solenoide del piloto de gas, estableciéndose el encendido del piloto.
- La fotocelda registra la señal de la flama del piloto. Periodo no mayor a 10 segundos.

- Se energiza la válvula principal de combustible, encendiendo la caldera.
- Después de un período de 15 segundos para verificar la presencia de la flama principal, se apaga el piloto.
- A los 105 segundos se tiene el fin del ciclo de encendido, el programador se para. El quemador modula hasta que la carga de demanda es satisfecha, regresando a fuego bajo.
- Para el quemador. Hay un periodo de pospurga cortándose la corriente al motor del ventilador a los 120 segundos.
- El sistema queda listo para iniciar otro ciclo.

34) Ya que se tiene la caldera encendida se mantiene en fuego bajo y se le da un calentamiento inicial lento de la siguiente manera:
Trabaje la caldera por 10 minutos y apagela por 5 minutos, repita lo anterior tres veces más. Después déjela trabajando en fuego bajo hasta que llegue a una presión de vapor de 3.0 Kg/cm^2, Durante este periodo se recomienda apretar nuevamente los registros pas-mano, el registro pasa-hombre y las tapas de la caldera. Posteriormente se puede pasar a automático, verificando que se apague la caldera a la presión a la cual está ajustado el control de presión límite.

35) Se recuerda que cuando empiece a salir vapor por la válvula de venteo, ésta se cierra.

36) Antes de que una caldera nueva sea puesta en servicio, debe limpiarse cuidadosamente a fin de eliminar la grasa y otras materias orgánicas, óxidos, escamas de laminación, fundentes de soldadura y cualquier otro material inherente à la fabricación y al montaje.
El objetivo a lograr durante la limpieza de una caldera nueva es producir una superficie metálica limpia en todas las partes de la misma que están en contacto con el agua y el vapor durante la operación.
Se recomienda que ésta limpieza química la realice la compañía que esta a cargo del tratamiento del agua.

37) Después que se realizo el lavado químico, se arranca la caldera hasta que pare por presión. Abra lentamente la válvula principal de salida de vapor y verifique que la caldera encienda a la presión que esta ajustado el diferencial del control de presión límite.

38) Verifique que actúan las protecciones de seguridad de la caldera, las cuales son:

-Paro por alta presión de vapor.- Esta prueba se realizó en el punto No. 34

-Paro por bajo nivel de agua.- Estando la caldera en operación, apagar la bomba de agua y purgar la caldera por el fondo. Viendo la mirilla de cristal revisar que el quemador se apague en el nivel que tenemos marcado por corte de bajo nivel.

- Paro por falla de flama.- Teniendo en operación la caldera, retirar la fotocelda del quemador y taparla, dependiendo del control de flama y del tipo de detección, la caldera debe apagarse en un tiempo corto (seg.).

39) Por ultimo, verificar o en su caso ajustar que la caldera este bien carburada desde fuego bajo hasta fuego alto, tomando lecturas de los gases con equipo autorizado por SEMARNAP. La norma oficial mexicana que rige es la NOM-085-ECOL-1994 en su tabla No. 5

40) Caldera lista para su operación normal.

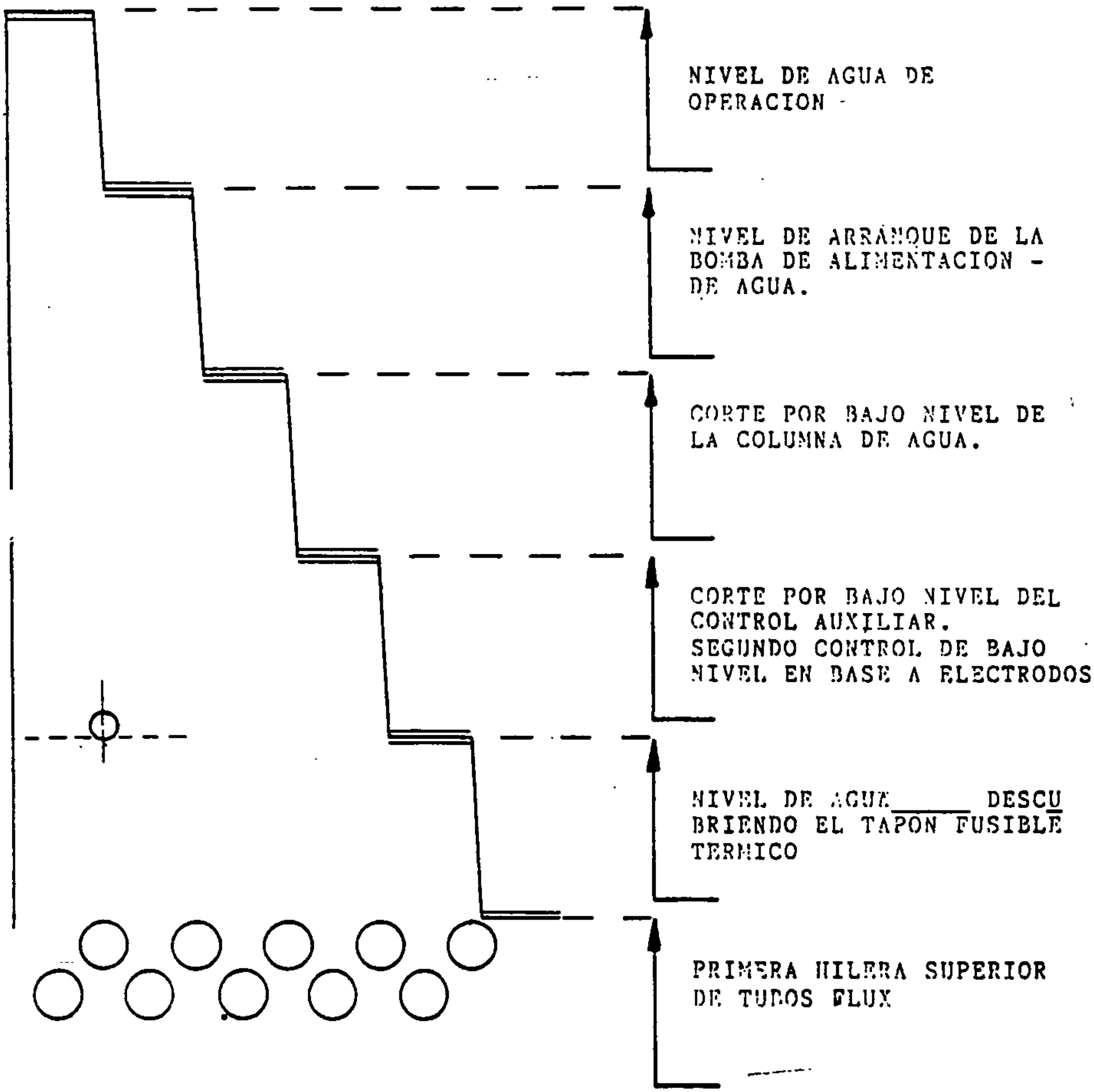
INDICADORES IMPORTANTES EN LA OPERACIÓN DE CALDERAS

I.- CONTROL DE NIVEL.

Se puede decir que éste es uno de los controles más importantes de las calderas, el tipo de control más usual es el de cápsulas de mercurio líquido.

En la parte superior trae una cabeza donde van alojadas dos cápsulas de mercurio, una es de dos hilos la cual controla la bomba que alimenta el agua a la caldera; La otra cápsula es de tres hilos, es la que manda cortar el quemador y activa una alarma sonora al mismo tiempo cuando ocurre un bajo nivel dentro de la caldera.

Como la falla de éste control es la causa más frecuente de siniestros hoy en día, algunos fabricantes de calderas, además del control principal de nivel le instalan un segundo control del tipo de varillas; Y hasta un tercer control: el tapón fusible (en si éste es un indicador).


NIVEL DE AGUA DE OPERACION -
NIVEL DE ARRANQUE DE LA BOMBA DE ALIMENTACION - DE AGUA.
CORTE POR BAJO NIVEL DE LA COLUMNA DE AGUA.
CORTE POR BAJO NIVEL DEL CONTROL AUXILIAR.
SEGUNDO CONTROL DE BAJO NIVEL EN BASE A ELECTRODOS
NIVEL DE AGUA _____ DESCU BRIENDO EL TAPON FUSIBLE TERMICO
PRIMERA HILERA SUPERIOR DE TUBOS FLUX

La práctica ha demostrado que estos intentos de doble protección no son la solución. Si no se purga correctamente la columna de nivel y al lavarse interiormente la unidad, no se hace con esmero ni se inspeccionan cuidadosamente las condiciones reales de funcionamiento de sus partes, por mas controles que se instalen va a ocurrir la falla.

2.- MANÓMETRO PRINCIPAL DE VAPOR.

La caldera debe tener un manómetro graduado en Kg/cm^2, Kpa o bar, éste manómetro se calibrará periódicamente, está instalado en la zona de vapor y forma parte de lo que se llama tren de controles. Cuidar que la presión de trabajo se ubique dentro del tercio medio de la carátula y que ésta sea del tamaño adecuado al tamaño de la caldera, para poder leer desde el frente de la caldera la presión del vapor sin ningún problema.

Para especificar un manómetro se requiere:

- Rango de la presión
- Diámetro de carátula
- Posición de la conexión
- Diámetro de la conexión
- Tipo de fluido que va a manejar

3.- CONTROL DE FLAMA

En la actualidad, el tipo de control y de detección de flama se rige por la norma oficial mexicana NOM-027-SEDG-1996.

Los fabricantes de calderas deben de cumplir con esta norma. Toda la norma se resume a dos tablas:

Tabla 1.- Clases de controles de seguridad de flama según el ciclo de trabajo.

Tabla 2.- Sistemas de detección de flama.

Esta norma tiene algunas fallas, como son:

Acepta calderas que trabajen solo con una flama hasta capacidades de 70 c.c.

Acepta calderas que utilicen varilla detectora como medio de detección hasta capacidades de 473 c.c.

A continuación se presenta una tabla de controles de flama de la marca Honeywell (más común en calderas), donde se indica dentro de que clase entran de acuerdo a la norma y de acuerdo a la practica, hasta que capacidad de caldera se recomiendan.

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SISTEMA DE DETECCION DE FLAMA

SISTEMA	TIPO	COMBUSTIBLE	CAPACIDAD MAXIMA Ms/hr (Kcal/hr) (C.C.)	MAR
AL	FOTORESISTENCIA DE SULFURO DE CADMIO	DIESEL	1675 (400,000) (47.34)	HON
BL	TUBO ELECTRONICO AL VACIO (FOTODIODO)	DIESEL	8375 (2'000,000) (236.70)	HON
BG	VARILLA DETECTORA DE IONIZACION DE FLAMA	GAS	16750 (4'000,000) (473.37)	HON
CDN	FOTORESISTENCIA DE SULFURO DE PLOMO SIN AUTOVERIFICACION DINAMICA	DIESEL/GAS/COMBUSTOLEO	16750 (4'000,000) (473.37)	HON
DDN	FOTOTUBO SENSIBLE A RADIACION ULTRAVIOLETA SIN AUTOVERIFICACION DINAMICA	DIESEL/GAS/COMBUSTOLEO	16750 (4'000,000) (473.37)	HON
CDD	FOTORESISTENCIA DE SULFURO DE PLOMO CON AUTOVERIFICACION DINAMICA	DIESEL/GAS/COMBUSTOLEO	SIN LIMITE	HON
DDD	FOTOTUBO SENSIBLE A RADIACION ULTRAVIOLETA CON AUTOVERIFICACION DINAMICA	DIESEL/GAS/COMBUSTOLEO	SIN LIMITE	HON

NOTA: A PARTIR DE INSTALACIONES CUYA CAPACIDAD DE LIBERACION DE CALOR SOBREPASE LOS 157 (37,500 Kcal/hr) (4.44 C.C.) , INDEPENDIENTEMENTE DEL TIPO DE COMBUSTIBLE QUE UTILICEN; SE DEBERA DE UTILIZAR CONTROL DE SEGURIDAD CONTRA FALLA DE FLAMA CON DETECCIÓN DE FLAMA POR MEDIOS ELECTRONICOS (NO TERMICO)

CONTROLES DE FLAMA MARCA HONEYWELL MÁS COMUNES PARA CALDERAS

Modelo	Servicio	Respuesta a falla de flama	Base	Fotocelda	Amplificador	Pre-purga Seg.	Post-purga Seg.	Combustible	Recomendado para caldera c.c.
RA890F1346 (Clase 2 B) 12 c.c.	Una o dos flamas	3.0 segundos	Q270A1024	C7013A1003 Rectificación	Integrado			Diesel	Hasta 40
				Varilla Detectora				Gas	Hasta 20
9 c.c. RA890G1260 (Clase 2 A)	Una o dos flamas	3.0 segundos	Q270A1024	C7027A1023 (Ultravioleta)	Integrado			Gas	Hasta 40
R4795A1016 (Clase 8 B) (71 c.c.)	Una o dos flamas	0.8 segundos	Q270A1024	C7013A1003 Rectificación	R7289A1012 (Color verde)	7,10,30,60 o 90		Diesel	Hasta 60
				C7027A1023 (Ultravioleta)	R7290A1019 (Color violeta)			Gas	
R4140L1147 (Clase 14 A)	Modulante (Levas)	2 a 4 segundos	Q520A1089	C7015A1076 (Infrarroja)	R7248A1004 (Color rojo)	60	15	Liquido	80 cc en adelante
R4140G1171 (Clase 14 A)	Modulante (Levas)	2 a 4 segundos	Q521A1089	C7027A1023 (Ultravioleta)	R7249A1003 (Color violeta)	70	25	Gas	
* CB-20 (R4140G1023) (Clase 14 A)	Modulante (Levas)	2 a 4 segundos	Q520A1170	C7015A1118 (Infrarroja)	R7248A1046 (Color rojo)	72	16	Todos	
BC7000L1000 (Clase 14 A) (1)	Modulante (Electrónico)	2 a 4 segundos	Q520A1089	De acuerdo a el modulo programado puede utilizar detección infrarroja o ultravioleta.				Todos	
* CB-70 (BC7000L1018) (Clase 14 A) (1)	Modulante (Electrónico)	2 a 4 segundos	Q520A1170	De acuerdo a el modulo programado puede utilizar detección infrarroja o ultravioleta.				Todos	

* Modelo exclusivo calderas marca Cleaver Brooks.
(1) Autoverificación Dinámica.

GZA

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SISTEMAS DE DETECCIÓN DE FLAMA

SISTEMA	TIPO	MARCA Y MODELO	CAPACIDAD MÁXIMA Mj/hr (Kcal/hr) (c.c.)	COMBUSTIBLE
AL	FOTORESISTENCIA DE SULFURO DE CADMIO	HONEYWELL C554A CONTROL DE FLAMAS IC515	1675 (400,000) (47.34)	DIESEL
BL	TUBO ELECTRÓNICO AL VACIÓ (FOTODIODO) (RECTIFICACIÓN)	HONEYWELL C7013A CONTROL DE FLAMAS 922	8375 (2'000,000) (236.70)	DIESEL
BG	VARILLA DETECTORA DE IONIZACIÓN DE FLAMA (RECTIFICACIÓN)	HONEYWELL C7008A CONTROL DE FLAMAS C7008A	16750 (4'000,000) (473.37)	GAS
CDN	FOTORESISTENCIA DE SULFURO DE PLOMO SIN AUTOVERIFICACIÓN DINÁMICA	HONEYWELL C7015A CON AMPLIFICADOR R7248A	16750 (4'000,000) (473.37)	DIESEL/GAS/COMBUSTOLEO
DDN	FOTOTUBO SENSIBLE A RADIACIÓN ULTRAVIOLETA SIN AUTOVERIFICACIÓN DINÁMICA	HONEYWELL C7027A CON AMPLIFICADOR R7249A CONTROL DE FLAMAS IC2200	16750 (4'000,000) (473.37)	DIESEL/GAS/COMBUSTOLEO
CDD	FOTORESISTENCIA DE SULFURO DE PLOMO CON AUTOVERIFICACIÓN DINÁMICA	HONEYWELL C7015A CON AMPLIFICADOR R7248B	SIN LIMITE	DIESEL/GAS/COMBUSTOLEO
DDD	FOTOTUBO SENSIBLE A RADIACIÓN ULTRAVIOLETA CON AUTOVERIFICACIÓN DINÁMICA	HONEYWELL C7076A CON AMPLIFICADOR R7476A	SIN LIMITE	DIESEL/GAS/COMBUSTOLEO

Nota: a partir de instalaciones cuya capacidad de liberación de calor sobrepase los 157 Mj/hr (37,500 kcal/hr) (4.44 c.c.), independientemente del tipo de combustible que utilicen; se deberá de utilizar control de seguridad contra falla de flama con detección de flama por medios electrónicos (no térmico)

GZA

NOMENCLATURA DE TABLA No. 1

I.I.=	Ignición intermitente hasta 8.9 c.c. se mantiene energizado todo el tiempo no lleva piloto y solo se utiliza para combustible diesel.
I.T.=	Ignición interrumpida.
P.C.=	Piloto continuo.
P.I.=	Piloto intermitente.
PT=	Piloto interrumpido.
PP=	Piloto probado.
TVA=	Tiempo de verificación en arranque.
TPEF=	Tiempo para establecimiento de flama.
TDPF=	Tiempo para detección de presencia de flama.
TDFF=	Tiempo para detección de falla de flama.
TBS=	Tiempo para bloqueo de seguridad.
TP=	Tiempo de purga.
TPA=	Tiempo de purga en alta.
TPB=	Tiempo de purga en baja.
TCE=	Tiempo para calefacción de electrodos.
TRI=	Tiempo restringido de ignición con bloqueo de señal de flama al circuito sensor.
TPPE=	Tiempo para prueba de piloto encendido.
TAPE=	Tiempo para apagado de piloto encendedor de quemador principal.
TPP=	Tiempo de pospurga.
TACHD=	Tiempo de autoverificación dinámica.

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TABLA I.- CLASES DE CONTROLES DE SEGURIDAD DE FLAMA SEGUN EL CICLO DE TRABAJO

A	B	C	D	E	F	G	H	I	J	K	L	M	N	P	Q	R	S	T	U	V
CLASE	REIGNICION	RECICLO	*TVA MAX.	TPEF MAX.	TDPF MAX.	TDFF MAX.	TBS MAX.	TP MIN.	TPA MIN.	TPB MIN.	TCE MIN.	TRI MAX.	TPPE MIN.	TAPE MAX.	TPP MIN.	CONT. DE PASO DE COMBUST.	IGNICION	PILOTO	CAPACIDAD MAX. MJ/h (Kcal/h)	Limitaciones
1	NO	NO	3	30	30	30	30	NO	NO	NO	NO	- NO	NO	NO	NO	NO REQUIERE	IT	NO HAY	315 (75 000)	SOLO DIESEL
2A	SI	NO	3	15	3	1	15	NO	NO	NO	NO	NO	NO	NO	NO	NO REQUIERE	IT.	P C o P I	315 (75 000)	SOLO GAS
2B	SI	NO	3	15	3	3	15	NO	NO	NO	NO	NO	NO	NO	NO	NO REQUIERE	IT	P I o F.B	420 (100 000)	SOLO DIESEL
3	NO	NO	3	15	3	3	15	NO	NO	NO	NO	NO	NO	NO	NO	NO REQUIERE	IT.	P I o F B	830 (150 000)	NO HAY
4A	NO	NO	3	15	3	3	15	15	NO	NO	NO	NO	NO	NO	NO	NO REQUIERE	IT.	P I o F.B	1 045 (250 000)	NO HAY
4B	NO	SI	3	15	3	3	15	15	NO	NO	NO	NO	NO	NO	NO	NO REQUIERE	IT.	P I o F B	1 045 (250 000)	NO HAY
5A	NO	NO	3	5	5	3	15	15	NO	NO	NO	5	NO	NO	NO	NO REQUIERE	IT.	P I o F B	1 675 (400 000)	NO HAY
5B	NO	SI	3	5	5	3	15	15	NO	NO	NO	5	NO	NO	NO	NO REQUIERE	IT.	P I o F B	1 675 (400 000)	NO HAY
6A	NO	NO	3	10	3	3	15	30	NO	NO	NO	NO	NO	NO	NO	NO REQUIERE	IT.	P I o F.B	1 255 (300 000)	NO HAY
6B	NO	SI	3	10	3	3	15	30	NO	NO	NO	NO	NO	NO	NO	NO REQUIERE	IT	P I o F B	1 255 (300 000)	NO HAY
7	NO	NO	3	5	5	3	15	1	NO	NO	NO	5	5	NO	NO	NO REQUIERE	IT	P P o F B	2 510 (600 000)	NOTA No 13
8A	NO	NO	3	5	5	3	15	30	NO	NO	NO	5	5	NO	NO	NO REQUIERE	IT.	P P o F B	2 510 (600 000)	NOTA No 13
8B	NO	SI	3	5	5	3	15	30	NO	NO	NO	5	5	NO	NO	NO REQUIERE	IT.	P P o F B	2 510 (600 000)	NOTA No 13
9A	NO	NO	3	10	3	3	15	30	NO	NO	5	NO	5	NO	NO	2 PASOS	IT	P P o F B	2 510 (600 000)	NOTA No 13
9B	NO	SI	3	10	3	3	15	30	NO	NO	5	NO	5	NO	NO	2 PASOS	IT	P P o F B	2 510 (600 000)	NOTA No. 13
10A	NO	NO	3	5	5	3	15	30	NO	NO	5	5	5	NO	NO	2 PASOS	IT.	P P o F B	4 185 (1 000 000)	NOTA No 13
10B	NO	SI	3	5	5	3	15	30	NO	NO	5	5	5	NO	NO	2 PASOS	IT.	P P o F.B	4 185 (1 000 000)	NOTA No 13
11A	NO	NO	3	10	3	3	15	30	NO	NO	5	NO	10	10	NO	2 PASOS	IT.	P T.	3 350 (800 000)	NOTA No. 13
11B	NO	SI	3	10	3	3	15	30	NO	NO	5	NO	10	10	NO	2 PASOS	IT.	P T.	3 350 (800 000)	NOTA No 13
12A	NO	NO	3	5	5	3	15	30	NO	NO	5	5	10	10	NO	2 PASOS	IT	P P y P.T.	4 185 (1 000 000)	NOTA No 13
12B	NO	SI	3	5	5	3	15	30	NO	NO	5	5	10	10	NO	2 PASOS	IT	P P y P.T	4 185 (1 000 000)	NOTA No 13
13A	NO	NO	3	10	3	3	15	45	30	15	X	NO	10	NO	15	MODULANTE	IT.	P I	SIN LIMITE	NOTA No 13
13B	NO	SI	3	10	3	3	15	45	30	15	X	NO	10	NO	15	MODULANTE	IT.	P I	SIN LIMITE	NOTA No 13
14A	NO	NO	3	10	3	3	15	45	30	15	X	NO	10	10	15	MODULANTE	IT	P.T.	SIN LIMITE	NOTA No 13
14B	NO	SI	3	10	3	3	15	45	30	15	X	NO	10	10	15	MODULANTE	IT.	P T.	SIN LIMITE	NOTA No 13
15A	NO	NO	3	5	5	3	15	45	30	15	5	5	10	NO	15	MODULANTE	IT	P P	SIN LIMITE	NOTA No 13
15B	NO	SI	3	5	5	3	15	45	30	15	5	5	10	NO	15	MODULANTE	IT	P P	SIN LIMITE	NOTA No 13
16A	NO	NO	3	5	5	3	15	45	30	15	5	5	10	10	15	MODULANTE	IT.	P P. y P T	SIN LIMITE	NOTA No 13
16B	NO	SI	3	5	5	3	15	45	30	15	5	5	10	10	15	MODULANTE	IT	P P y P T.	SIN LIMITE	NOTA No 13
17	NO	X	3	X	5	3	X	X	X	X	X	X	X	X	X	X	X	X	NOTA No 11	NOTA No 13

EQUIVALENCIA DE CONTROLES DE FLAMA DE ACUERDO A DISTINTOS FABRICANTES

HONEYWELL	FIREYE	CONTROL DE FLAMAS (NACIONAL)
RA890 F	TIPO 29RF5	TAC15RL
RA890 G	MODELO 6015	TAC15RL
R4795 A		TAC5415BNR
R4140 L	TIPO 26RJ8	
R4140 G	MODELO 6018	
* CB-20	* CB - 1	
BC 7000	FLAME-MONITOR	

* Modelos exclusivos para calderas marca Cleaver Brooks.

4.- TERMÓMETRO DE CHIMENEA

Éste es un indicador de importancia en la operación de las calderas, una alta temperatura puede ser por dos causas:

- Que este hollinada la caldera.
- Que exista fuga de gases por alguna de las mamparas.

La causa más frecuente, es la primera; Cuando tenga 80° C por arriba de la temperatura del vapor, indica que la caldera tiene hollín y/o incrustación, se debe proceder a lavado y deshollinado.

Si la presión de trabajo de la caldera es de 7.0 Kg/cm^2, de tablas de vapor, la temperatura que corresponde al vapor para ésta presión es de 169.5° C, entonces tenemos:

169.5 + 80 = 249.5° C

En una caldera de tubos de fuego, la temperatura normal de los gases en la base de la chimenea es de 200 a 225° C.

Por lo anterior, es muy importante que la caldera este siempre bien carburada en toda su gama de modulación.

En base a la capacidad de la caldera y al tipo de combustible que utilice su quemador, es la frecuencia con la cual se analizan los gases producto de la combustión.

El fabricante del quemador indica cual es el % de CO_2 (bióxido de carbono) más idóneo para el funcionamiento eficiente del mismo. En la practica se recomiendan los siguientes valores:

RANGO	Gas L.P. o N.	Diesel o G.	Combustóleo
Excelente	10	12.8	13.8
Bueno	9	11.5	13
Regular	8.5	10	12
Pobre	8 o menos	9 o menos	11.5 o menos

Los resultados de una carburación, deben tener los valores de los siguientes parámetros:

Bióxido de carbono, oxigeno, exceso de aire, monóxido de carbono, temperatura de los gases y eficiencia del quemador.

A continuación tenemos las tablas 5 y 6 de la norma oficial mexicana NOM-085-ECOL-1994.

NOM-085-ECOL-1994 (D.O. 2 - DIC - 1994)

TABLA 5

1o. ENERO DE 1998 EN ADELANTE

CAPACIDAD DEL EQUIPO DE COMBUSTIÓN MJ/h	TIPO DE COMBUSTIBLE EMPLEADO	DENSIDAD DE HUMO	PARTÍCULAS (PST) mg/m^3 (kg/10^6 kcal) (1) (2)			BIÓXIDO DE AZUFRE ppm V (Kg/10^6 kcal) (1) (2)			ÓXIDOS DE NITRÓGENO ppm V (Kg/10^6 kcal) (1)			EXCESO DE AIRE DE COMBUSTIÓN % volumen (5)
		Número de mancha u opacidad	ZMCM	ZC (3)	RP	ZMCM	ZC(3)	RP	ZMCM	ZC(4)	RP	
Hasta 5,250 147 CC.	Combustoleo o gasoleo	3	NA	NA	NA	550 (2.04)	1,100 (4.08)	2,200 (8.16)	NA	NA	NA	50
	Otros líquidos	2	NA	NA	NA	550 (2.04)	1,100 (4.08)	2,200 (8.16)	NA	NA	NA	
	Gaseosos	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	
147 CC. De 5,250 a 43,000 1204 CC.	Líquidos	NA	75 (0.106)	350 (0.497)	450 (0.639)	550 (2.04)	1,100 (4.08)	2,200 (8.16)	190 (0.507)	190 (0.507)	375 (1.0)	40
	Gaseosos	NA	NA	NA	NA	NA	NA	NA	190 (0.486)	190 (0.486)	375 (0.959)	
De 43,000 a 110,000 308 CC.	Líquidos	NA	60 (0.085)	300 (0.426)	400 (0.568)	550 (2.04)	1,100 (4.08)	2,200 (8.16)	110 (0.294)	110 (0.294)	375 (1.0)	30
	Gaseosos	NA	NA	NA	NA	NA	NA	NA	110 (0.281)	110 (0.281)	375 (0.959)	
Mayor de 110,000	Sólidos	NA	60 (0.090)	250 (0.375)	350 (0.525)	550 (2.16)	1,100 (4.31)	2,200 (8.16)	110 (0.309)	110 (0.309)	375 (1.052)	25
	Líquidos	NA	60 (0.085)	250 (0.355)	350 (0.497)	550 (2.04)	1,100 (4.08)	2,200 (8.16)	110 (0.294)	110 (0.294)	375 (1.0)	
	Gaseosos	NA	NA	NA	NA	NA	NA	NA	110 (0.281)	110 (0.281)	375 (0.959)	

TABLA 6
MEDICIÓN Y ANÁLISIS DE GASES DE COMBUSTIÓN

CAPACIDAD DEL EQUIPO DE COMBUSTIÓN MJ/h	PARÁMETRO	FRECUENCIA MÍNIMA DE MEDICIÓN	TIPO DE EVALUACIÓN	TIPO DE COMBUSTIBLE
Hasta 5.250 (147 C.C.)	Densidad de humo	1 vez cada 3 meses	puntual (3 muestras); mancha de hollín	líquido y gas
	CO_2·CO.O_2,N_2	1 vez cada 3 meses	puntual (3 muestras); ver anexo 3	líquido y gas
	SO_2	1 vez cada 3 meses	medición indirecta a través de certificados de calidad de combustibles que emita el proveedor	líquido
De 5.250 (147 C.C.) a 43.000 (1204 C.C.)	Partículas suspendidas totales	una vez por año	isocinético (mínimo durante 60 minutos); 2 muestras definitivas (2)	líquido
	NO_x	una vez por año	continuo (4); quimiluminiscencia o equivalente	líquido y gas
	SO_2	una vez por año	medición indirecta a través de certificados de calidad de combustibles que emita el proveedor	líquido
	CO_2,CO.O_2,N_2	diario	puntual (3 muestras); ver anexo 3 o equivalente	líquido y gas
De 43.000 a 110.000 (1204 a 3080 C.C.)	Partículas suspendidas totales	una vez por año	isocinético (mínimo durante 60 minutos); 2 muestras definitivas	líquido
	NO_x	una vez cada 6 meses	continuo (4); quimiluminiscencia o equivalente	líquido y gas
	SO_2	una vez por año	medición indirecta a través de certificados de calidad de combustibles que emita el proveedor	líquido
	CO_2,CO.O_2,N_2	una vez por turno	puntual (3 muestras); ver anexo 3 o equivalente	líquido y gas
Mayor de 110.000 (3080 C.C.)	Partículas suspendidas totales	1 vez cada 6 meses	isocinético (mínimo durante 60 minutos); 2 muestras definitivas	sólido, líquido
	NO_x	permanente (3)	continuo (4); quimiluminiscencia o equivalente	sólido, líquido y gas
	O_2	permanente	continua; campo magnético o equivalente, con registrador como mínimo o equivalente	líquido y gas
	SO_2	una vez por año	medición indirecta a través de certificados de calidad de combustibles que emita el proveedor	sólido, líquido

NOTAS:
(1) Ver 6.1.1.4
(2) Ver 6.1.1.5
(3) El monitoreo continuo de No_x será permanente en las zonas metropolitanas de las ciudades de México, Guadalajara y Monterrey; con una duración de cuando menos 7 días una vez cada tres meses en las zonas críticas; y con una duración de cuando menos 7 días una vez cada seis meses en el resto del país.
(4) Ver 4.13

ANEXO 3
CONTAMINANTES Y SUS MÉTODOS DE EVALUACIÓN PARA FUENTES FIJAS Y MÉTODOS EQUIVALENTES

<table>
<tr><th>CONTAMINANTE</th><th>MÉTODO DE EVALUACIÓN</th><th colspan="2">MÉTODO EQUIVALENTE</th></tr>
<tr><td>Densidad de humo</td><td>• huella o mancha de hollín
• opacidad</td><td colspan="2">- - - -</td></tr>
<tr><td>Partículas suspendidas totales</td><td>• isocinético</td><td colspan="2">- - - -</td></tr>
<tr><td>Óxidos de nitrógeno</td><td>• quimiluminiscencia</td><td colspan="2">• infrarrojo no dispersivo</td></tr>
<tr><td>Óxidos de carbono</td><td>• infrarrojo no dispersivo
• celdas electroquímicas*
• orsat (O_2,CO_2 y CO)</td><td colspan="2">- - - -</td></tr>
<tr><td>Oxígeno</td><td>• celdas electroquímicas
• paramagnéticos</td><td colspan="2">• orsat (O_2,CO_2 y CO)
• óxidos de zirconio (celdas electroquímicas)</td></tr>
<tr><td rowspan="2">SO_2</td><td rowspan="2">medición indirecta a través de certificados de calidad de combustibles que emita el proveedor</td><td rowspan="2">Capacidad del equipo de combustión MJ/h</td><td>Hasta 5,250:
• vía húmeda (torino)
• infrarrojo no dispersivo
• celdas electroquímicas</td></tr>
<tr><td>Mayores de 5,250:
• vía húmeda
• infrarrojo no dispersivo</td></tr>
</table>

Se calcula el valor dado que no se obtiene por medición directa.

5.- TRATAMIENTO DEL AGUA Y PURGAS.

El descuido del mantenimiento por el lado del agua trae como resultado la formación de incrustaciones, picaduras, corrosión, espuma, arrastre de humedad y crestas de nivel de agua.
Es importante un tratamiento de agua con procedimiento adecuado de purgas para conservar las superficies de calefacción de la caldera libres de incrustación y prolongar la vida útil de la misma.
Se recomienda consultar a empresas expertas en tratamiento de agua.
Ellos analizarán el agua y propondrán el tratamiento adecuado basado en el análisis y cantidad de agua cruda que se usará, también dirán la frecuencia de las purgas para reducir la concentración de sales y lodos dentro de la caldera.
El tratamiento se divide en:
Externo.- A través del equipo suavizador, la dureza a la salida debe ser = 0 ppm.
El operador dentro de sus actividades toma muestra del agua a la salida del equipo suavizador y checa su dureza, si le marca algún valor, es el momento para regenerar la resina.
Interno.- Dosificación de productos químicos, puede ser en el tanque de condensados o directamente a la caldera. La cantidad y frecuencia la determina el experto en tratamiento de agua.

PURGAS DE LA CALDERA.- Normalmente se recomienda purgar la caldera mínimo cada turno (la frecuencia real la determina el experto *en tratamiento de agua*).
Purga de fondo.- Se hace de la siguiente manera:
- Teniendo la caldera con presión (normalmente la presión de trabajo), se sube el nivel del agua a la mitad de la mirilla de cristal con la bomba en posición manual.
- Se coloca la bomba de agua en posición de automático.
- Abrir primero la válvula de cierre rápido.
- después se abre la válvula de cierre lento.
- *Se espera a que baje el nivel hasta que arranque la bomba de agua.*
- Se cierra la válvula de cierre lento.
- Se cierra la válvula de cierre rápido.

Las demás purgas tardan aprox. 5 seg.

6.- CONTROL DE PRESIÓN LÍMITE.
Éste control es muy importante su funcionamiento correcto, en el ajustamos la presión de vapor a al cual va a trabajar la caldera. Tiene dos escalas, la principal es para delimitar la presión de paro del quemador de la caldera, la otra es la diferencial, se indica la presión a la cual enciende de nuevo el quemador.

7.- BITÁCORA.
Éste documento es muy útil ya que en el se lleva el historial de la caldera en cuanto a su operación y mantenimiento, desde que se arranca por primera vez.
En base a ese historial se puede formar un programa de mantenimiento preventivo para la caldera.

PARÁMETROS PARA ANOTAR EN UNA BITÁCORA POR TURNO

1. Fecha.
2. Hora.
3. Presión de vapor.
4. Temperatura de gases productos de la combustión.
5. Temperatura del agua de alimentación.
6. Temperatura de combustible (solo si se utiliza combustóleo):
   - En tanque de almacenamiento general
   - En tanque de día.
   - A la entrada del quemador
7. Presión de atomización con aire o vapor (comb. Líquido)
8. Presión de combustible (líquido):
   - A la salida de la bomba de alimentación
   - A la entrada del quemador
   - De retorno
9. Presión de combustible (gas):
   - En el tanque de almacenamiento (gas L.P.)
   - En alta presión regulada
   - En baja presión
10. Purgas: De fondo, columna de nivel, cristal de nivel, tren de controles y de superficie.

11.Tratamiento interno.
12.Tratamiento externo.
13.Consumo de combustible.
14.Pruebas de paro por: alta presión de vapor, bajo nivel de agua y falla de flama.
15.Mantenimientos rutinarios.
16.Análisis de gases.
17.Observaciones.
18.Nombre y firma del operador.

RECOMENDACIONES PARA EL CUIDADO DE LAS CALDERAS

Las calderas de prestigio indudablemente son construidas de acuerdo con el código ASME o alguna otra norma de fabricación de reconocida competencia. En forma similar, el quemador y controles son de marcas de prestigio. Consiguientemente la caldera que se tiene es digna de confianza en cuanto a la seguridad de su operación.

Sin embargo, la seguridad, confiabilidad y eficiencia de operación, solamente pueden conservarse con un programa básico de mantenimiento.

Se recomienda tener un programa de mantenimiento preventivo de acuerdo al tipo de caldera, combustible utilizado y régimen de trabajo.

A continuación se muestra un programa de mantenimiento preventivo descriptivo, más no limitativo.

MANTENIMIENTO PREVENTIVO

I.- DIARIO

1. Realizar las purgas de la caldera por lo menos cada ocho horas de operación.
2. Checar la dureza del agua después del suavizador para saber cuando hay que regenerar la resina. Después de un tiempo de operación se tendrá medida la frecuencia de ésta actividad.
3. Dosificación del tratamiento interno.
4. Si utiliza combustóleo limpiar la boquilla del quemador y el filtro de combustible.
5. Llenar la bitácora con los parámetros de operación.
6. Realizar una inspección ocular a la instalación completa para descubrir cualquier anomalía.
7. Mantener limpia la caldera, sus accesorios y la casa de máquinas.

II.- CADA OCHO DÍAS

1. Si utiliza diesel o gasóleo limpiar la boquilla del quemador y filtro.
2. Comprobar que no hay fugas de gases ni de aire en las juntas de ambas tapas y mirilla trasera.
3. Comprobar la tensión de la banda al compresor y/o ventilador en su caso.
4. Si utiliza atomización con aire limpiar el filtro del compresor.
5. Limpiar el electrodo de ignición del piloto de gas.
6. Apretar las conexiones del cable de ignición.

7. Si utiliza combustóleo, comprobar que los interruptores termostáticos del calentador del combustible operen a la temperatura a que fueron calibrados al hacer la puesta en marcha.
8. Inspeccionar los prensa estopas de la bomba de alimentación de agua.
9. Comprobar que la trampa del calentador de vapor opera correctamente (si se usa Combustóleo). La descarga va al drenaje.
10. Asegúrese que la fotocelda esté limpia, así como el conductor en donde se encuentra colocada.
11. Comprobar el voltaje y amperaje de los motores.

III.- CADA MES

1. Lavar el filtro que esta en la succión de la bomba de agua.
2. Si utiliza gas L.P. o natural limpiar el filtro de combustible.
3. Comprobar que los niveles de agua son los indicados:

   63 mm de nivel máximo.

   45 mm arranque de la bomba.

   38 mm corte por bajo nivel.
4. Comprobar el corte por bajo nivel de agua.- Bajando el interruptor de la bomba de alimentación, el agua al evaporarse irá disminuyendo el nivel, al llegar a 38 mm la caldera debe apagarse. En el caso de no apagarse, hay que parar inmediatamente la caldera e inspeccionar la cápsula de mercurio de tres hilos (en el control de nivel), así como también asegurarse de un correcto funcionamiento del flotador estando la columna excenta de lodos o acumulaciones.

5. Realizar la prueba por falla de flama.
6. Limpiar la malla del ventilador del sistema de aire.
7. Verificar el funcionamiento del piloto de gas.
8. Revisar el apriete del mecanismo de modulación
9. Checar el apriete de las conexiones del tablero de control.
10. Reengrasar los baleros de la bomba de agua.
11. Tirar ligeramente de la palanca de la(s) válvula(s) de seguridad para que escapen y evitar que se peguen en su asiento, ésta actividad se debe realizar estando la caldera a una presión no menor del 75% de la presión de trabajo.

IV.- CADA TRES MESES

1. Revisar la carburación del quemador de la caldera tomando lectura de los gases producto de la combustión.
2. Revisión del mecanismo y cápsulas de mercurio del control de nivel.
3. Las válvulas solenoide deben ser examinadas. Observe la flama cuando el quemador deba apagar. Si la flama no se apaga súbitamente en el momento preciso, puede significar falla o desgaste de la válvula solenoide. Reemplace la válvula para evitar serios problemas.

V.- CADA SEIS MESES

Estando la caldera fría realizar un servicio de limpieza general, el cual consiste en :

1. Retirar tubo del piloto de gas.
2. Retirar el quemador.
3. Destapar la caldera por ambos lados.
4. Retirar los empaques de ambas tapas y de las mamparas.
5. Limpiar los fluxes por el lado del hollín con un escobillón, que se debe de pasar a todo lo largo de los mismos.
6. Limpiar ambos espejos con un cepillo de alambre.
7. Se inspecciona el refractario del hogar, tapa intermedia y tapa trasera que no tenga grietas o que esté desprendido el material. Si es necesario se le aplica un resane.
8. Ya que está limpia por el lado de los gases se procede a hacer el lavado lado agua. Se tira toda el agua que tenga la caldera.
9. Estando completamente vacía, se retiran los registros de mano y el registro de hombre.
10. Se retira el tapón que esta en la entrada de agua a la caldera y los que tiene el control de nivel en sus cruces superior e inferior; además se retira la cabeza del control de nivel para descubrir el flotador.
11. Se retiran los controles de presión y el manómetro principal de vapor, dejando al descubierto la tubería del tren de controles.
12. A la descarga de la bomba de agua se instala una toma para conectar una manguera y se cierra la llave de alimentación de agua a la caldera.
13. Se arranca la bomba de agua, por la manguera saldrá un chorro de agua con cierta presión, se introduce ésta por cada uno de los registros con objeto de lavar los tubos flux por el lado del agua,

todos los lodos saldrán por los registros inferiores y una vez que el agua sale clara indicará que ha quedado limpia.

14. Con el mismo procedimiento se limpia: el interior del control de nivel, la toma de alimentación de agua, la tubería del tren de controles y las cruces de la columna de nivel.
15. Cambiar el empaque del flotador de la columna de nivel, a los tornillos se les pone una mezcla de grafito con aceite para que no se peguen.
16. Cambio del tapón fusible (si la caldera lo tiene).
17. Colocar los controles de presión y el manómetro principal en el tren de controles.
18. Instalar los tapones macho de las cruces de la columna de nivel y de la entrada de alimentación de agua a la caldera, también se le pone la mezcla de grafito con aceite.
19. Cambio de la mirilla de nivel con sus empaques.
20. Cambio de empaques a los registros de mano y al registro de hombre, si son de asbesto se cubren con grafito.
21. Llenar la caldera con agua y realizar prueba hidrostática a la presión de operación para verificar que no haya fuga en los registros.
22. Tapar la caldera por ambos lados cambiando sus empaquetaduras, a todos los tornillos se les aplica la mezcla de grafito con aceite.
23. Colocar el quemador y conectar el piloto de gas.
24. Se tiene la caldera lista para su arranque y revisión de la carburación.
25. Prueba de la(s) válvula(s) de seguridad automáticamente.

VI.- FALLAS MÁS COMUNES

EL QUEMADOR NO INICIA SU CICLO DE ENCENDIDO

Verifique que haya energía eléctrica en el tablero de control de la caldera.
Verifique que los controles limite se encuentren cerrados. Ejemplo: Control de presión de vapor, control de nivel de agua, relevadores bimetálicos de los arrancadores, control de combustión sin restablecer o averiado, control contra baja presión de aire en el quemador, control de baja presión de gas L.P., control de alta presión de gas L.P., terminales eléctricas principales flojas.

EL QUEMADOR INICIA SU CICLO PERO NO HAY CHISPA

Electrodo con porcelana fisurada o dañada.
Electrodo aterrizado, descalibrado o con carbón en su punta.
Transformador de ignición dañado o con cable de ignición flojo en sus terminales.

EL QUEMADOR INICIA CICLO HAY CHISPA PERO NO PRENDE

Exceso de aire por compuerta muy abierta.
Falta gas L.P. en el piloto
Presión en el piloto de gas insuficiente
Impurezas en la línea de gas L.P. del piloto
Válvula solenoide del piloto de gas L.P. dañada u obstruida
Regulador del piloto de gas L.P. dañado o desajustado
Control de presión modulante no manda cerrar la compuerta del aire en el arranque
Compuerta del aire atorada o mecanismo del damper desajustado

PRENDE EL PILOTO, PERO SE SEPARA LA FLAMA DE LA BOQUILLA

Demasiada presión de gas L.P. en la línea del piloto.
Regulador de presión de gas L.P. del piloto dañado

PILOTO ENCENDIDO, PERO NO PRENDE LA FLAMA PRINCIPAL

Flama del piloto de poca intensidad
Válvula principal de combustible no opera
Filtro de combustible tapado
Falla en el control programador
Detector de flama sucio, defectuoso, obstruido o que no apunte a la flama principal
Falso contacto en el amplificador o que este dañado
Válvula mariposa o moduladora de gas L.P. atorada u obstruida
Control de baja presión de aire dañado
Controles de alta o baja presión de gas L.P. dañados

EL QUEMADOR SOLO TRABAJA EN FLAMA BAJA

Interruptor selector de flama baja dañado
Control de presión modulante dañado
Motor modutrol dañado
Mecanismo de modulación trabado

QUEMADOR SE APAGA SIN RAZÓN APARENTE

Falta combustible o baja presión de gas L.P.
Detector de flama averiado
Cápsula de mercurio en el control de presión límite defectuosa
Mecanismo de modulación trabado
Leva de modulación con tornillos desajustados o sea desajuste en la carburación
Alta presión de gas L.P.
Falta de aire para la combustión, actúa el control del aire, posiblemente rotas las bandas que mueven el ventilador.

MOTOR MODULANTE NO OPERA

Selector de modulación dañado
Mecanismo de modulación atorado o dañado
Transformador de 24 V dañado
Control de presión modulante sucio o dañado

MOTOR MODULANTE NO ABRE O CIERRA DURANTE LA PRE-PURGA

Revisar sujeción de contactos
Potenciómetro invertido o dañado
Cables invertidos entre motor y control modulante

EXPLOSIONES EN EL HOGAR DE LA CALDERA

Impurezas o falta de presión para el piloto de gas L.P.
Presión de combustible inestable
Impurezas en la válvula principal de combustible
Compuerta de aire trabada o motor modulante dañado
Averías en la leva dosificadora de combustible, alterando la relación aire-combustible
Manipulación del control de flama

PRESENCIA DE HUMO BLANCO EN LA CHIMENEA

Falta de combustible o exceso de aire

PRESENCIA DE HUMO NEGRO EN LA CHIMENEA

Exceso de combustible o falta de aire

FALTA DE AGUA DE ALIMENTACIÓN

Impurezas en el tanque de condensados
Filtro de agua tapado
Trampas de vapor averiadas, por lo que regresa vapor vivo al tanque de condensados y eleva demasiado la temperatura del agua, la bomba trabaja pero no inyecta el agua. Si la bomba trabaja por tiempos largos en estas condiciones se dañará. La temperatura normal de operación es de 60° C.
Altura reducida entre el tanque de condensados y la bomba del agua.
Posible obstrucción a la entrada del agua en la caldera
Bomba de agua dañada

ALTA TEMPERATURA DE GASES DE COMBUSTIÓN

Hollinamiento de los tubos flux por mala combustión
Mamparas dañadas

NO SE RECUPERA EL NIVEL DE AGUA EN LA CALDERA

Filtro de agua sucio
Falta de agua en el tanque de condensados
Control de nivel averiado
Bomba de agua averiada
Falta de energía eléctrica
Demanda súbita de vapor sin alimentar agua
Tubería de alimentación de agua incrustada u obstruida.

CALDERA INCRUSTADA

Falla en el tratamiento del agua
Purgas inadecuadas
Falta de purgas

A continuación se presenta un resumen de la norma para calderas NOM-122-STPS-1996.

Resumen de la Norma Oficial Mexicana NOM-122-STPS-1996 Relativa a las condiciones de seguridad e higiene para el funcionamiento de los recipientes sujetos a presión y generadores de vapor o calderas que operen en los centros de trabajo.

1. Objetivo

Esta norma Oficial Mexicana establece los requisitos mínimos de seguridad e higiene con que deben contar los recipientes sujetos a presión y los generadores de vapor o calderas que se instalen en los centros de trabajo, así como las características de las inspecciones que se realicen con el fin de vigilar el cumplimiento de esta Norma.

2. Campo de aplicación.

Esta Norma Oficial Mexicana es de observancia obligatoria en los centros de trabajo donde se utilicen los recipientes sujetos a presión y generadores de vapor o calderas a que la misma se refiere.

5. Obligaciones

5.1. Obligaciones del Patrón.

5.1.1. Tener autorizados por la Secretaría los equipos y conservar su vigencia de autorización de funcionamiento durante la vida útil de los equipos, así como el documento señalado en el numeral 6.1, del anexo II.

5.1.4. Contar con el personal capacitado para la operación y mantenimiento de los equipos.

5.1.5. Elaborar y establecer por escrito un manual de seguridad e higiene para la operación y mantenimiento de los equipos, sus accesorios y dispositivos, conforme al artículo 130 párrafo tercero del Reglamento Federal de Seguridad, Higiene y Medio Ambiente de Trabajo.

El manual debe contener: Medidas de seguridad durante el arranque, operación, paro, y para el mantenimiento de los equipos, dispositivos, accesorios y equipos auxiliares, así como los procedimientos para el control y manejo en situaciones de emergencia y retorno a condiciones normales.

5.1.6. Difundir el manual entre los trabajadores encargados de la operación, mantenimiento y seguridad.

5.1.7. Marcar o pintar en un lugar visible del equipo, el número de control que la Secretaría le asignó y entregó por escrito al momento de su autorización. Queda prohibido alterar, cambiar o desaparecer dicho número.

5.1.8. Aislar, proteger e identificar los equipos y tuberías que se encuentren a temperaturas extremas en las áreas de tránsito de los trabajadores y en las áreas de operación de los equipos, conforme a las Normas Oficiales Mexicanas NOM-028-STPS-1993 y NOM-114-STPS-1993.

5.1.9. Dar aviso a la Dirección o a la Delegación correspondiente cuando se pretenda modificar la instalación o las condiciones de operación de los equipos, de acuerdo al artículo 33 del Reglamento Federal de Seguridad, Higiene y Medio Ambiente de Trabajo.

5.1.10. Conservar el registro por cada equipo o grupos de ellos interconectados, conforme al artículo 37 del Reglamento Federal de Seguridad, Higiene y Medio Ambiente de Trabajo, ver anexo IV.

5.1.11. Solicitar la continuidad de la vigencia de la autorización de funcionamiento de los equipos en los términos del punto 6.2 de esta Norma.

5.1.12. Solicitar al fabricante del equipo el certificado de fabricación, la memoria de cálculo y dibujo indicados en el numeral 6.1 del anexo II.

5.1.13. En caso de que el patrón no cuente con la documentación anterior, para los efectos de la autorización deberá presentar constancia de la memoria de cálculo y dibujo del equipo, elaborados por un ingeniero calificado, con base a los datos técnicos del equipo.

5.2. Obligaciones de los trabajadores.

5.2.1. Participar en los cursos de capacitación y adiestramiento para el manejo de los equipos.

5.2.2. Realizar las anotaciones correspondientes que señala el punto 5.1.9. consignando y reportando las condiciones de operación de los equipos, así como cualquier alteración que pueda causar algún accidente o desperfecto.

5.2.3. Operar los equipos de conformidad con lo establecido en los manuales de procedimiento de seguridad proporcionados por el patrón.

6.1.3. La autorización de funcionamiento a que se refiere el punto 6.1 tendrá una vigencia de 10 años para equipos nuevos y de 5 años para equipos usados.

7. Condiciones de seguridad e higiene.

7.3 La presión de operación de los equipos no deben exceder a la presión de calibración de las válvulas de seguridad señalada en la autorización de los mismos.

7.4. Los equipos deben instalarse libres de impactos y vibraciones, con iluminación y ventilación permanente, adecuadas a los procesos que realicen conforme a las NOM-016-STPS-1993, NOM-024-STPS-1993 y NOM-025-STPS-1993.

7.5. Los pisos y accesos a los equipos deben mantenerse libres de obstáculos y materiales que entorpezcan el libre acceso, de tal manera que sea posible realizar fácilmente maniobras en su cercanía.

7.6. Los accesos a los dispositivos de seguridad y equipos auxiliares deben mantenerse libres en todo momento.

7.7. Los generadores de vapor o calderas deben ser instalados en locales o áreas destinadas específicamente para ellos.

7.8. Los generadores de vapor o calderas deben instalarse de tal manera que cuenten con un espacio mínimo de 1.5 m entre el techo del local y la parte más alta del equipo, a fin de permitir efectuar reparaciones, inspecciones, ajustes y pruebas.

7.9. Los generadores de vapor o calderas deben instalarse entre ellos o entre las divisiones que limitan el local, con un espacio mínimo de un metro a partir del cuerpo de la caldera o del accesorio más sobresaliente, de tal manera que permita al personal efectuar la operación y las reparaciones sin dificultad.

7.10. Los depósitos de combustible para el abastecimiento de los generadores de vapor o calderas deben cumplir las condiciones de seguridad de acuerdo a las NOM-002-STPS-1993, NOM-005-STPS-1993 y NOM-022-STPS-1993.

7.11. El generador de vapor o caldera, independientemente de que opere en forma manual o automática, debe estar vigilado permanentemente durante el tiempo que esté en operación.

8. De los dispositivos de seguridad en los equipos.

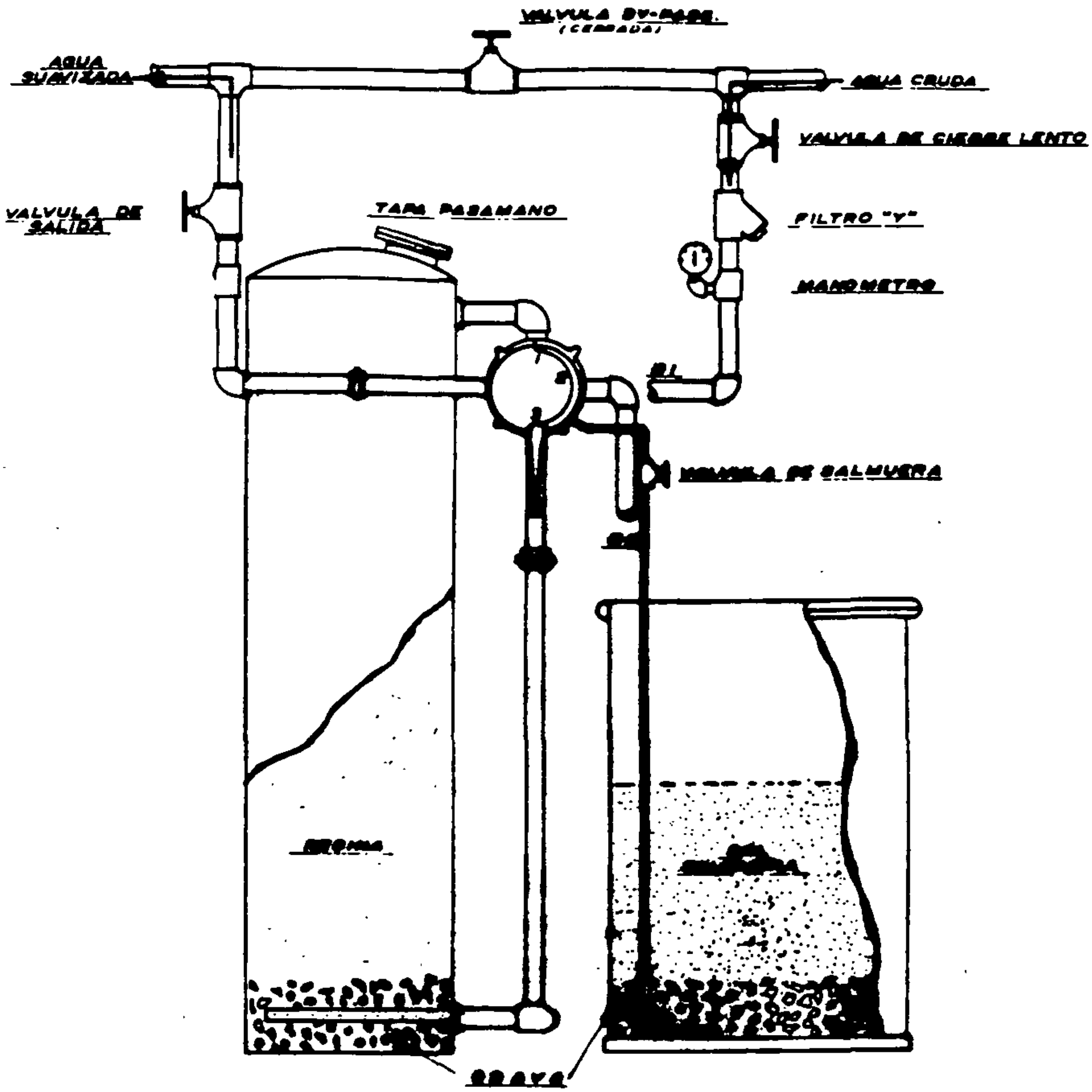
8.1. Los generadores de vapor o calderas deben contar cuando menos con una válvula de seguridad calculada técnicamente para evitar riesgos durante la operación del equipo, cuyas características estén de acuerdo con las condiciones de operación.

8.2. Las válvulas de seguridad de los generadores de vapor o calderas deben instalarse en la parte superior de los mismos y tener la capacidad de descarga acorde al flujo de desfogue teórico.

8.3. La presión de la calibración de las válvulas de seguridad utilizadas en ningún caso debe rebasar la presión de trabajo máxima permisible.

8.4. Los generadores de vapor o calderas deben tener al menos un manómetro graduado en Kg/cm2: kPa O bar, calibrado periódicamente, conectado a la cámara de vapor de tal manera que no esté sujeto a vibraciones y ofrezca una visión clara y libre de obstáculos.

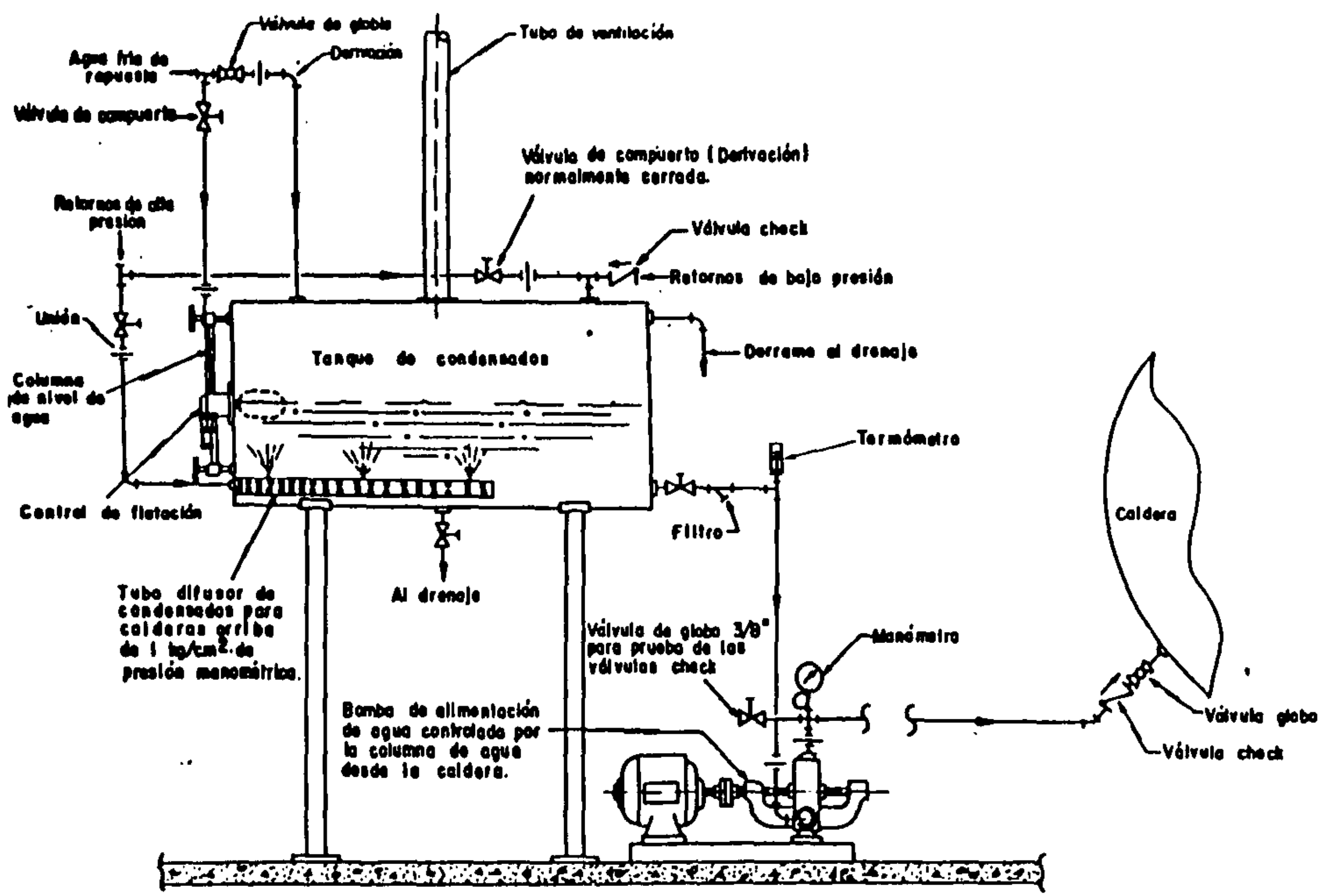
8.5. La presión de operación debe estar ubicada en el tercio medio de la escala de la carátula del manómetro.

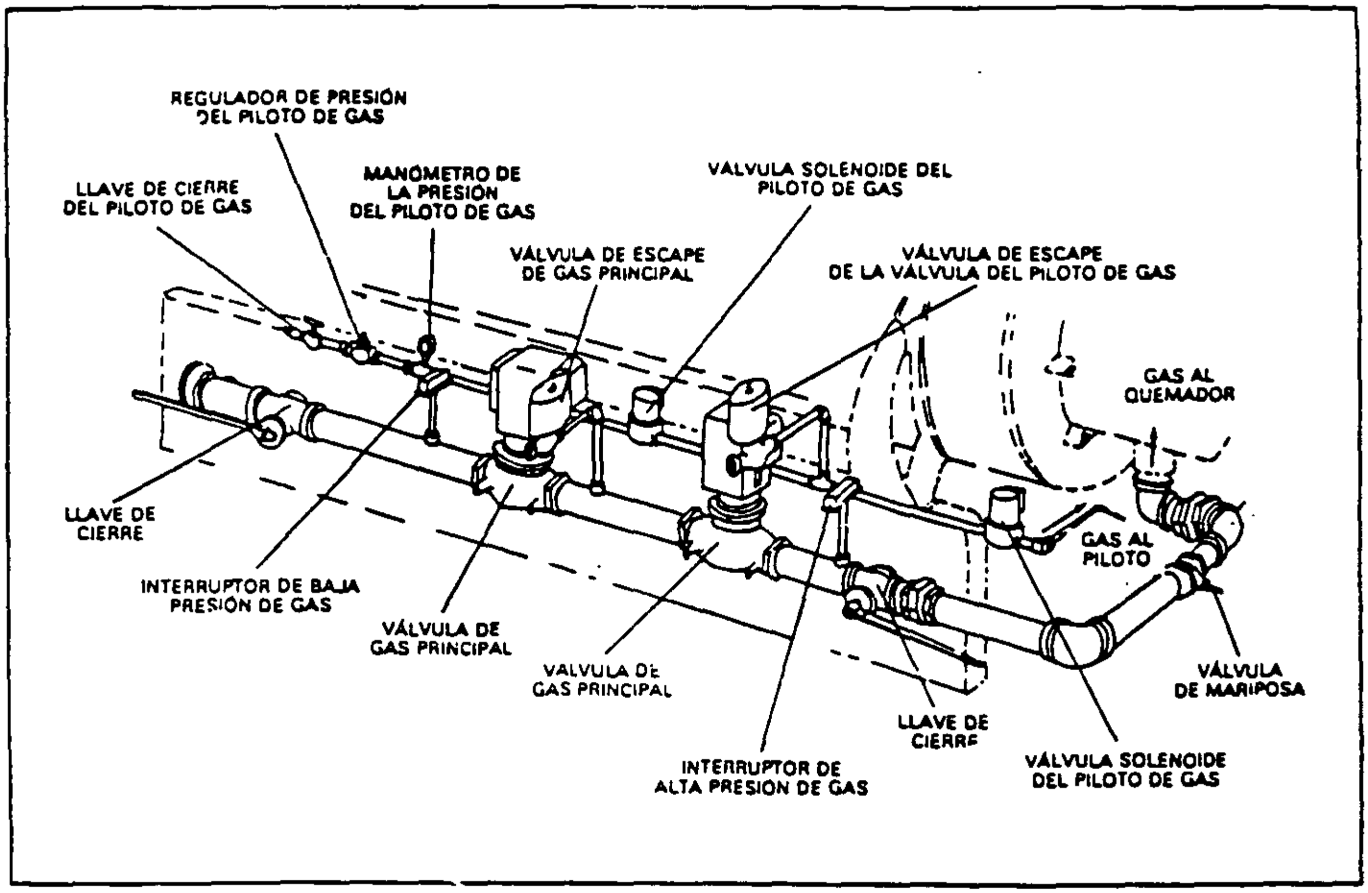


#1 : La entrada de agua dura a la válvula de puertos múltiples es por la parte trasera de la misma.

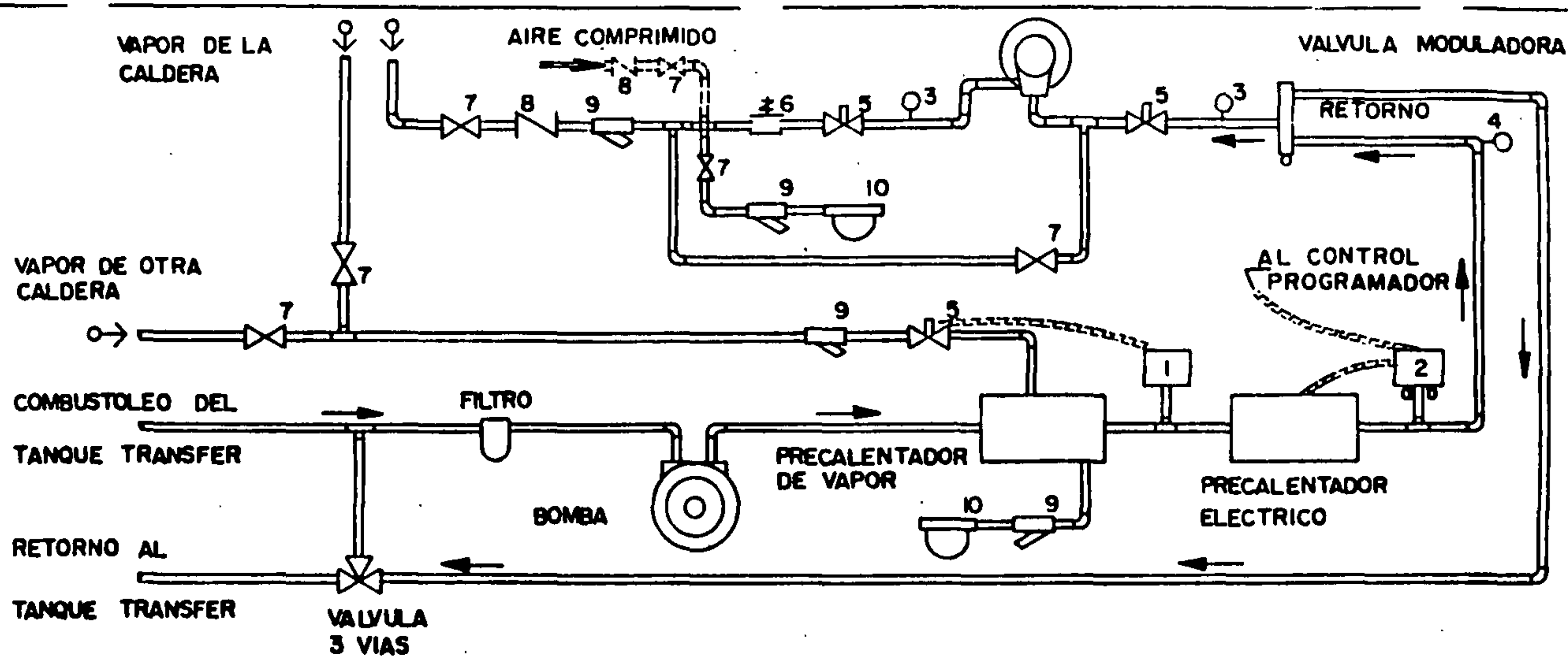
#2: Purga e drenaje.

Típico arreglo del tanque de condensados con tapas planas y bomba de agua de alimentación.





CONJUNTO BÁSICO DEL GAS



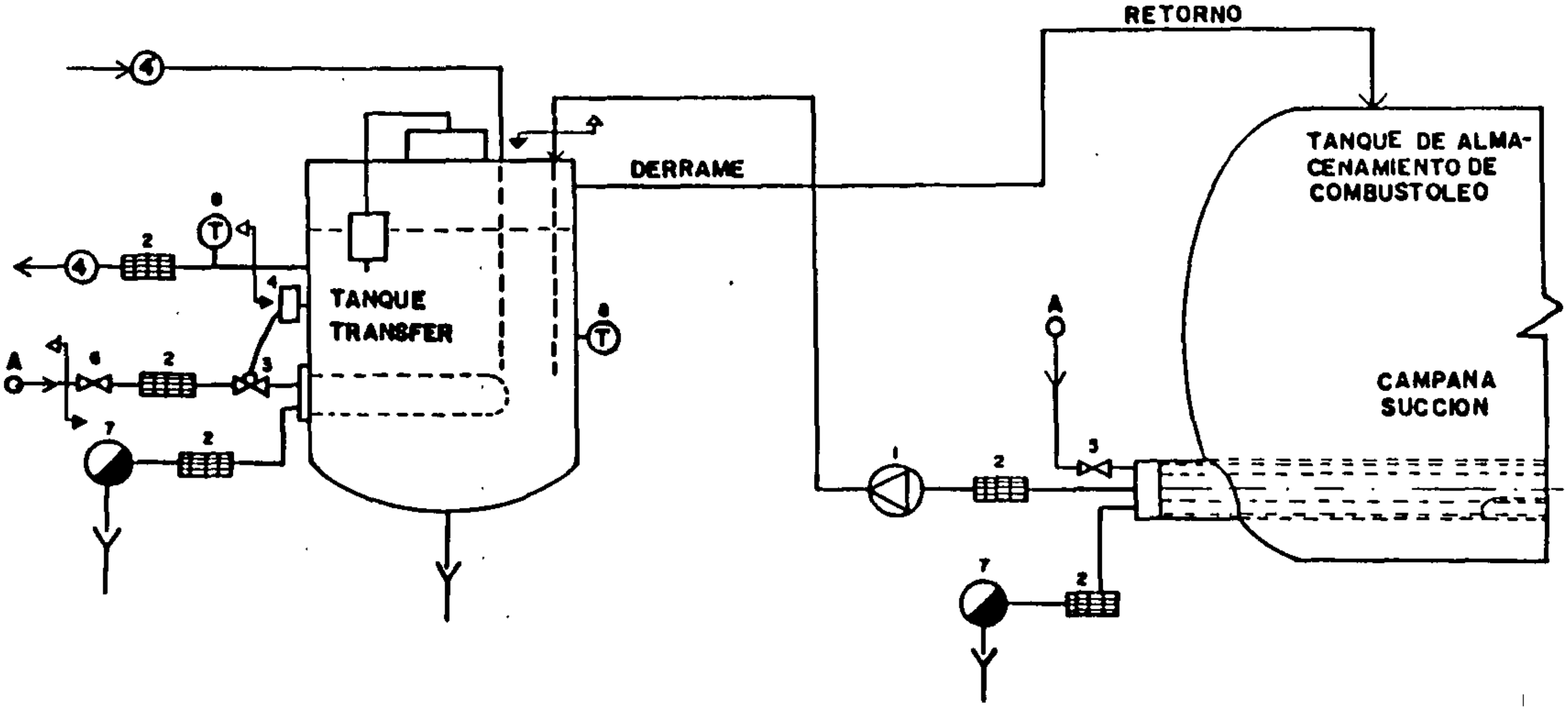
COMBUSTOLEO

AIRE COMPRIMIDO

VAPOR

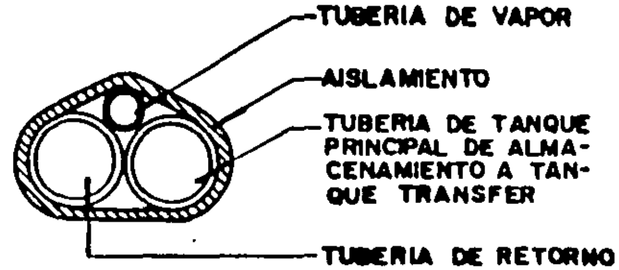
1.- CONTROL DE TEMPERATURA
  a) ACCIONA LA VALVULA SOLENOIDE DE VAPOR.
2.- CONTROL DE TEMPERATURA DUAL
  a) ACCIONA EL PRECALENTADOR ELECTRICO
  b) ACCIONA LA VALVULA SOLENOIDE DE COMBUSTOLEO
3.- INDICADOR DE PRESION
4.- INDICADOR DE TEMPERATURA
5.- VALVULA SOLENOIDE
6.- REGULADORA DE PRESION
7.- VALVULA DE GLOBO MANUAL
8.- VALVULA DE RETENCION
9.- FILTRO VAPOR / AIRE
10.- TRAMPA DE VAPOR

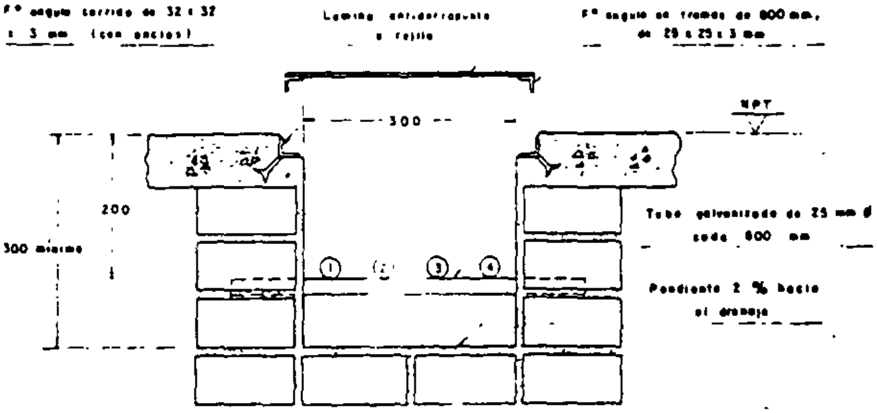
SISTEMA DE ALIMENTACION DE COMBUSTOLEO LIGERO N° 6 -MODULANTE-



- A VAPOR DEL CABEZAL
- 4 ALIMENTACION COMBUSTOLEO
- 4 RETORNO COMBUSTOLEO
- 1 BOMBA TRASIEGO
- 2 FILTRO
- 3 VALVULA SOLENOIDE
- 4 CONTROL DE TEMPERATURA
- 5 VALVULA DE AGUJA
- 6 VALVULA
- 7 TRAMPA
- 8 INDICADOR DE TEMPERATURA

DETALLE DE GUIA DE TUBERIAS EN TRINCHERA

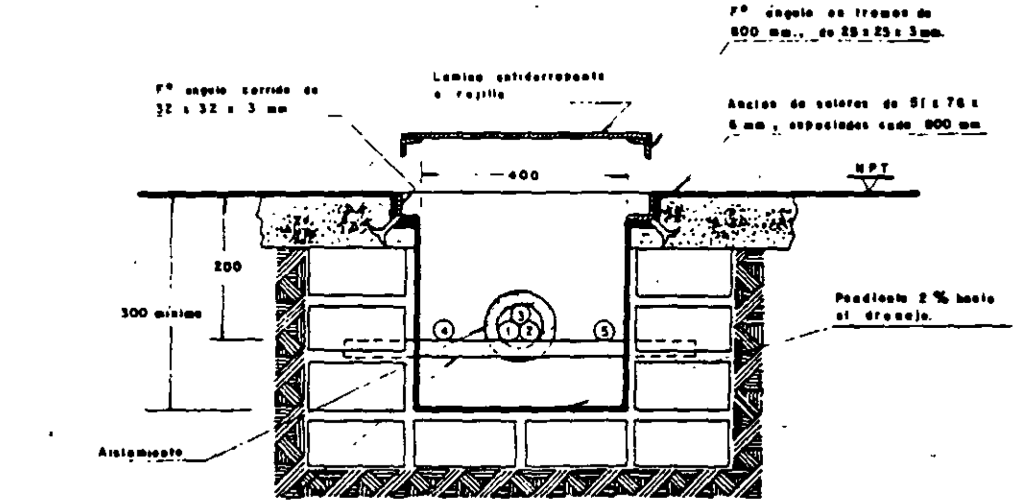




1 - Alimentacion de combustible a la(s) caldera(s)
2 - Retorno de combustible al tanque
3 - Tuberia de purgas de la(s) caldera(s)
4 - Alimentacion de agua a la(s) caldera(s)

DETALLE TRINCHERA

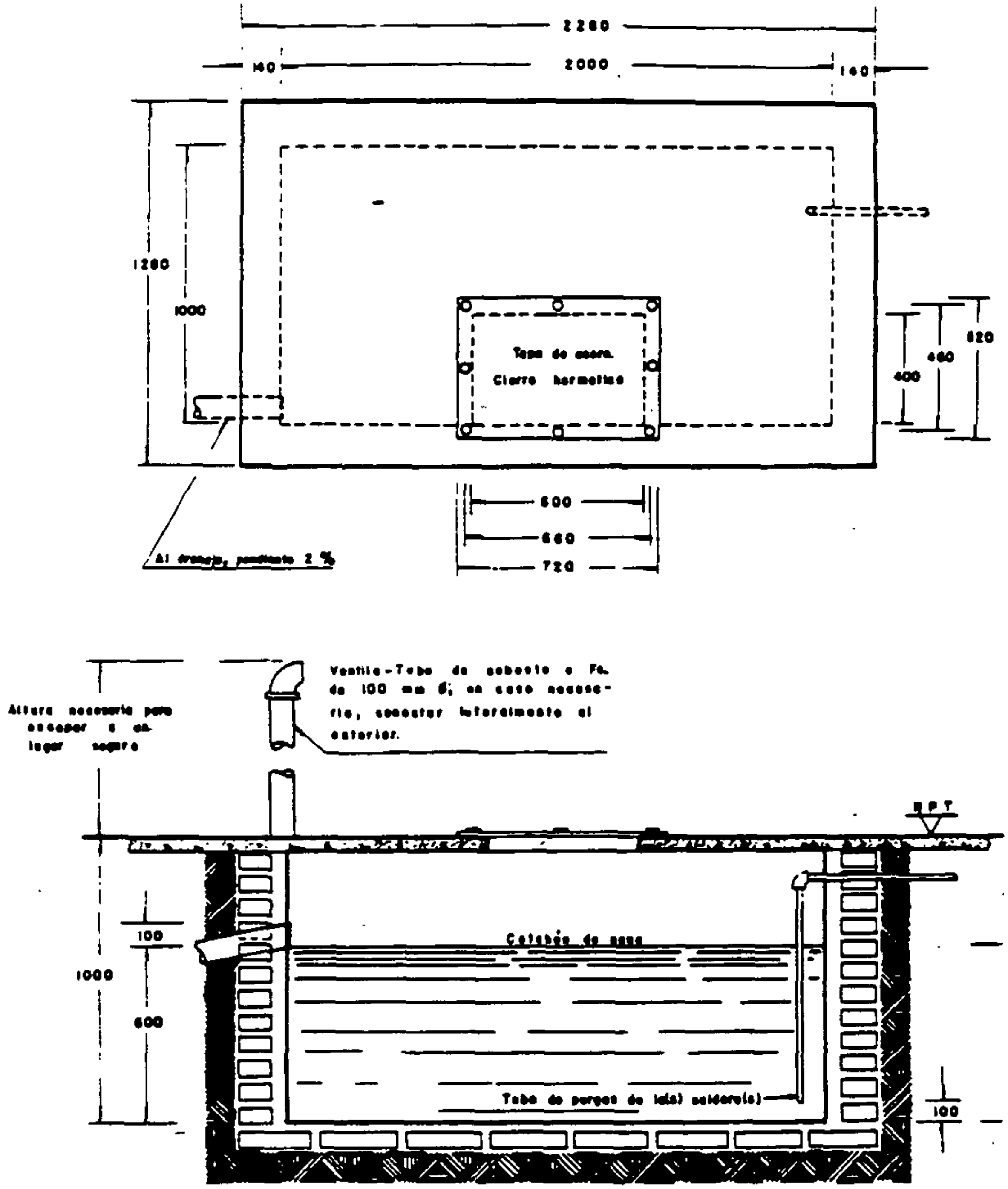
DIESEL



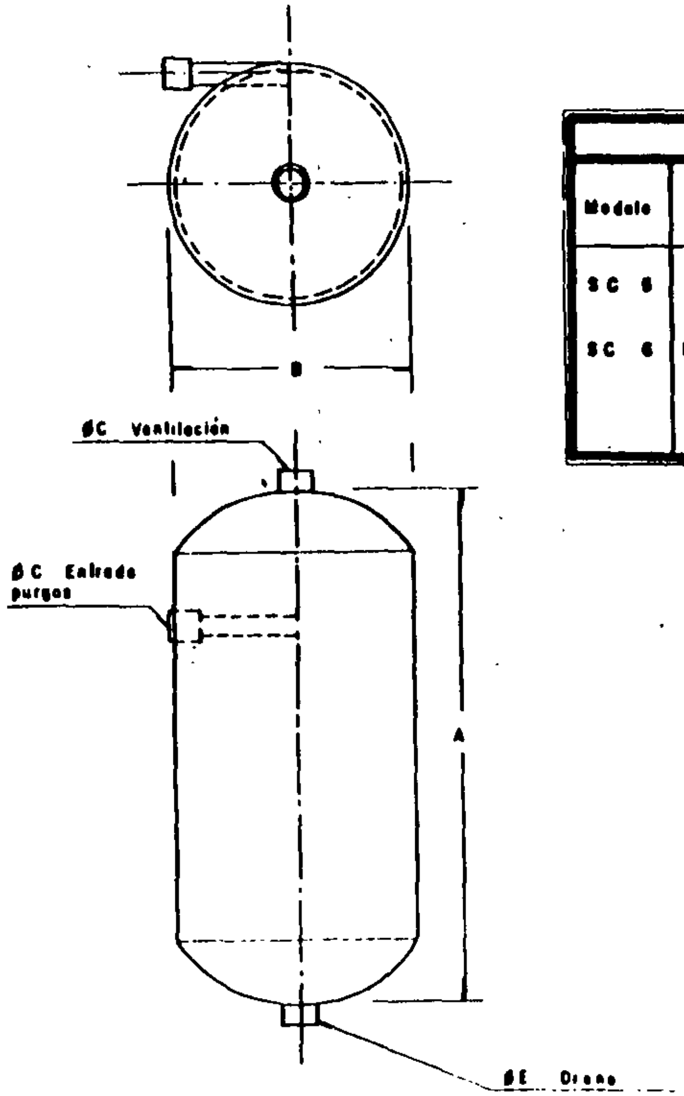
1 – Alimentación de combustible a la(s) caldera(s).
2 – Retorno de combustible al tanque de almacenamiento.
3 – Tubo de vapor al tanque de almacenamiento.
4 – Tuberia de purgas de la(s) caldera(s).
5 – Alimentación de agua a la(s) caldera(s).

DETALLE TRINCHERA

PETROLEO PESADO



FOSA DE PURGAS



DIMENSIONES DEL SEPARADOR CENTRIFUGO									
Modelo	Caballos Caldera	Presión Kg/cm² (lbs/pulg²)	Volumen Lts.	Espesor placa mm (")	A mm	B mm	C mm (")	D mm (")	E mm (")
SC 5	125 a 350	10.5 (150)	75	7.9 (5/16)	864	356	38 (1-1/2)	152 (6)	102 (4)
SC 6	125 a 350	21.0 (300)	141	9.5 (3/8)	1422	356	38 (1-1/2)	152 (6)	152 (6)

SEPARADOR CENTRIFUGO

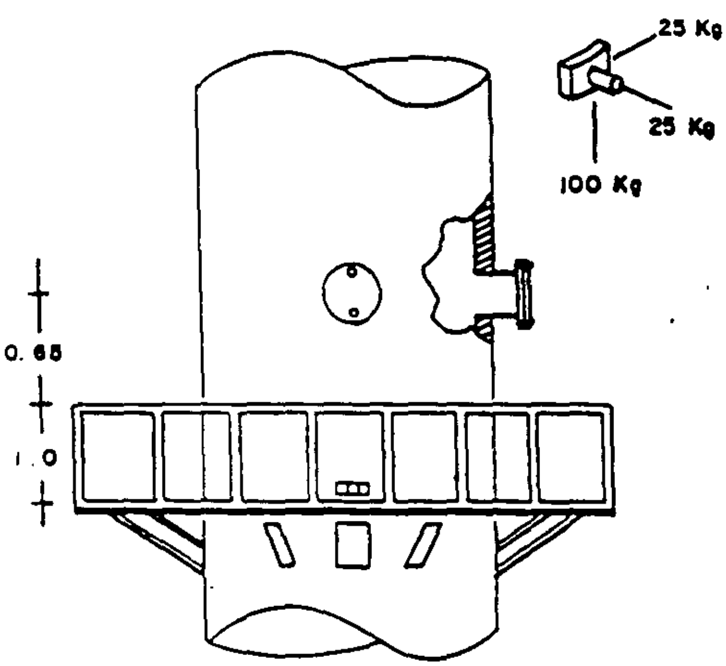


FIG. 4

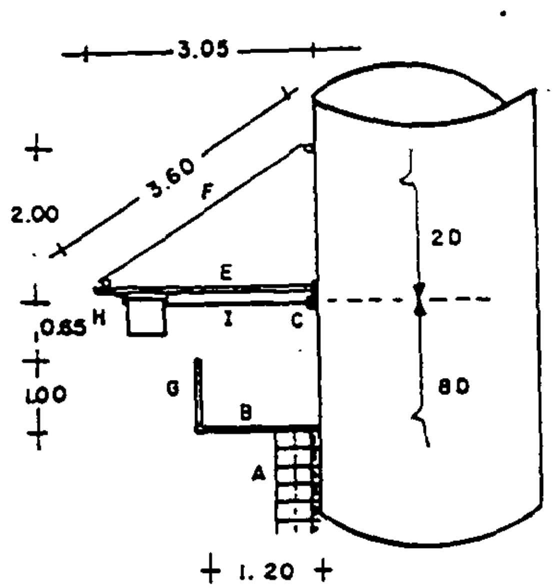


FIG. 5

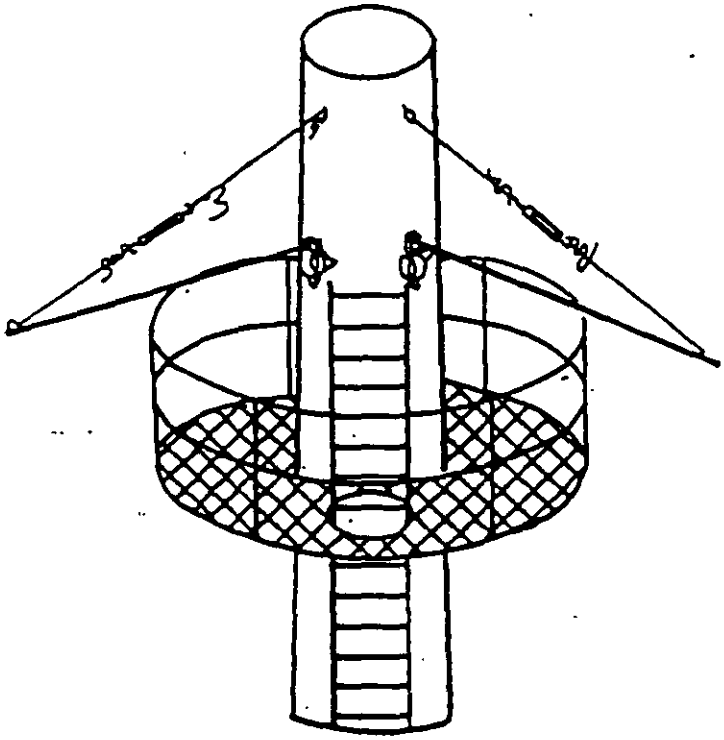
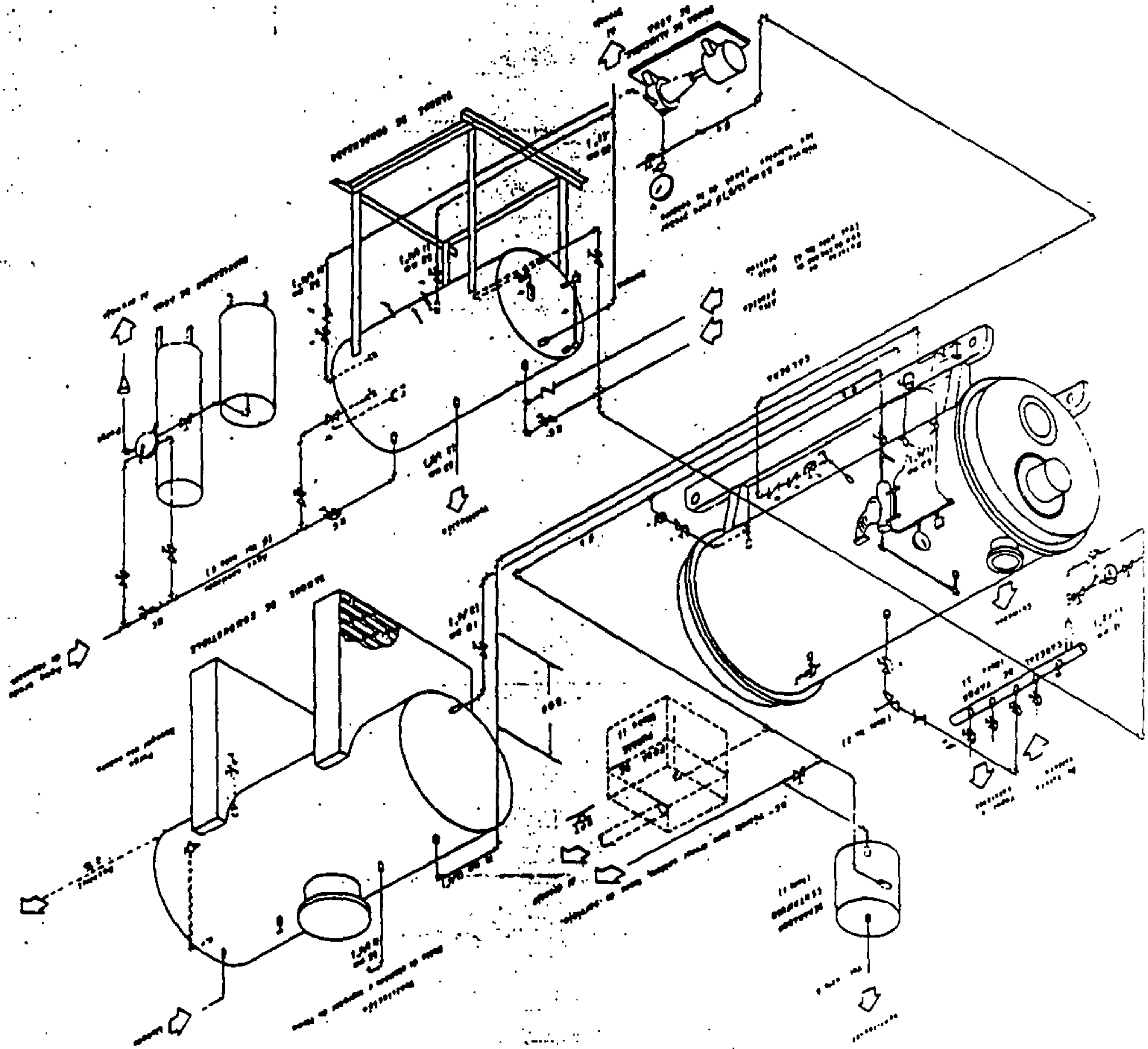


FIG. 6

FIG. 4 · VISTA LATERAL DE PUERTOS Y PLATAFORMA PARA MUESTREO

FIG. 5 : PERFIL DE PUERTOS Y PLATAFORMA PARA MUESTREO

FIG. 6 : INSTALACION COMPLETA DE PUERTOS Y PLATAFORMA DE MUESTREO



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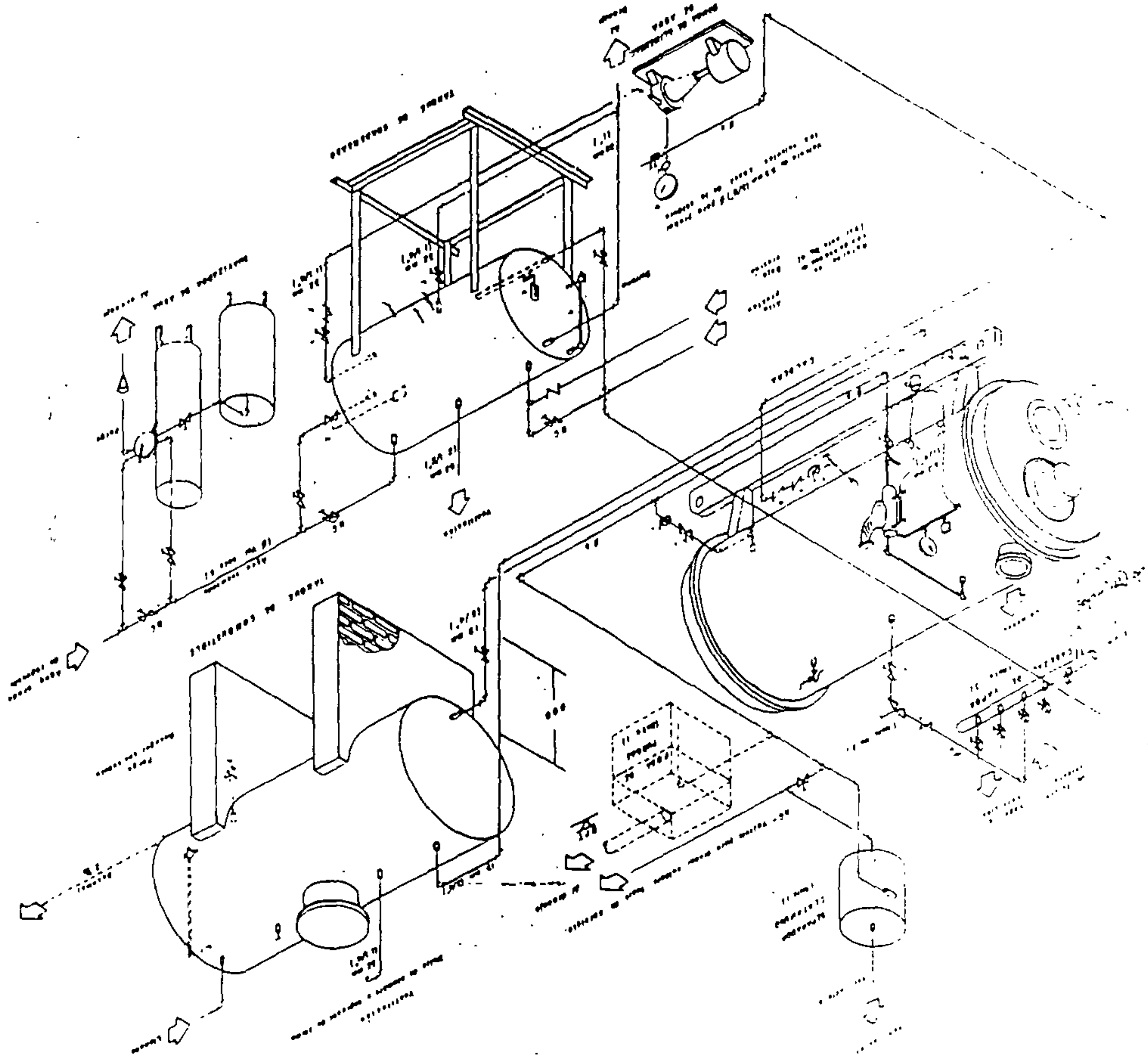

FACULTAD DE INGENIERÍA UNAM
DIVISIÓN DE EDUCACIÓN CONTINUA

"Tres décadas de orgullosa excelencia" 1971 - 2001

CURSOS ABIERTOS

DIPLOMADO EN INGENIERÍA DE CALDERAS Y RECIPIENTES A PRESIÓN

MÓDULO IV : MATERIALES, SOLDADURA Y CALDERAS DE POTENCIA

TEMA:

VERIFICACIÓN DE RECIPIENTES SUJETOS A PRESIÓN EXPEDIENTE DE INTEGRIDAD MECÁNICA

EXPOSITOR: ING. ANTONIO GARCÍA MORENO
SEDE: PALACIO DE MINERÍA
MAYO 2003

VERIFICACION DE RECIPIENTES SUJETOS A PRESION
EXPEDIENTE DE INTEGRIDAD MECANICA

La empresa donde se encuentra instalado el equipo cuenta con un Sistema de Administración de la Seguridad

El Sistema de Administración de la Seguridad está dirigido a los equipos

El Sistema de Administración de la Seguridad contiene elementos aplicables a la integridad mecánica
El Sistema de Administración de la Seguridad dirigido a los equipos demuestra con evidencias que cubre los aspectos siguientes:

Mantenimiento
Reparaciones o modificaciones
Revisiones (inspección)
Operación (procedimientos o instructivos)
Planes de emergencia (procedimientos o guías)
Análisis de riesgos (inspección)
Documentación y registros (control de documentos)
El Sistema de Administración de la Seguridad dirigido a los equipos está instrumentado en forma de procedimientos o instructivos escritos
Los procedimientos o instructivos escritos del Sistema de Administración de la Seguridad dirigido a los equipos están aprobados por los responsables técnicos operativos de los equipos

Los procedimientos o instructivos escritos del Sistema de Administración de la Seguridad dirigido a los equipos están aprobados por el patrón

- Los procedimientos o instructivos escritos del Sistema de Administración de la Seguridad dirigido a los equipos contemplan la generación de evidencias documentales de las actividades
- El patrón presenta anexo al Formato N-020, una descripción resumida del Sistema de Administración de la Seguridad dirigido a los equipos
- La descripción del Sistema de Administración de la Seguridad dirigido a los equipos explica como su implementación provee un grado de confianza aceptable para la operación segura del equipo
- MANTENIMIENTO

Clasificación (mayor ó menor, rutina ó reparaciones, etc.)
Procedimientos aplicables por clasificación
Programas según clasificación
Capacitación ó Calificación del personal implicado en el mantenimiento de acuerdo a la clasificación
Registros de actividades

- REVISION EN SERVICIO

Métodos y procedimientos de inspección
Programas
Calificación mínima del personal operador y evaluador
Criterios de aceptación y rechazo
Registros de actividades

- OPERACIÓN

Procedimientos aplicables
Descripción de actividades en caso de emergencia (instrucciones o planes de contingencia aplicables) que incluyan medios disponibles para mitigar los efectos
Pruebas periódicas (a todo el equipo o a sus partes)
Calibración de los instrumentos de medición
Capacitación ó Calificación del personal de operación
Registros de actividades

- DOCUMENTACION Y REGISTROS

Control de actualizaciones de documentos para las actividades de mantenimiento, operación y revisión
Control de la generación sistemática de registros de las actividades de mantenimiento, operación y revisión
Control de registros (manejo)

El patrón exhibe un expediente de integridad mecánica
El expediente de integridad mecánica es el resultado de la implementación del Sistema de Administración de la Seguridad
El expediente de integridad mecánica contiene los documentos esenciales que permiten conocer el estado de la integridad mecánica y operativa del equipo, incluyendo sus aparatos auxiliares y dispositivos de seguridad

- El expediente de integridad mecánica está actualizado y contiene información de toda la vida operativa del equipo

- El expediente de integridad mecánica contiene los siguientes documentos:

- EQUIPO NUEVO O USADO

Índice
Formato N-020 (copia del presentado a la STPS) con sello
FABRICACION
Dibujo, plano o documento (libro de proyecto, manual, catálogo) del equipo

Los dibujos o planos de los equipos contienen al menos los siguientes aspectos:
Cortes principales del equipo
Detalles relevantes (Ubicación de boquillas, por ejemplo)
Acotaciones básicas (espesores, diámetros, longitudes, entre otras)
Arreglo básico del sistema de soporte
Los dibujos, planos o documentos deben estar avalados por el fabricante o constructor del equipo, o por un responsable técnico designado por el patrón.

- Si existe la necesidad de generar dibujos, planos o documentos nuevos por carecer de los de fabricación, el responsable técnico que los avale debe ser un profesional con experiencia en el área de diseño, mantenimiento o inspección de los equipos.

- La información presentada debe incluir la condición actual del equipo, y las modificaciones efectuadas deben estar avaladas como se indica, ya sea en documentos separados o en una revisión del dibujo, plano o documento. Fotografía o calca de placa de datos del equipo adherida o estampada por el fabricante del equipo

- Certificado de cumplimiento con norma o código de fabricación
- Certificado de pruebas hidrostáticas de fabrica
- La siguiente información está en el certificado de fabricación o en un documento respaldado por un ingeniero mediante su nombre , firma y anexando copia de su cédula profesional
- Presión y temperatura de diseño y de operación
- Presión de trabajo máxima permitida
- Dispositivos de seguridad (presión de calibración, área de desfogue y ubicación)
- Capacidad volumétrica , para recipientes sujetos a presión y recipientes criogénicos)

- Capacidad generativa, para calderas
- Fluidos manejados
- Especificaciones de los materiales de las paredes sujetas a presión (designación y esfuerzo a la tensión)

- Normativa o código de construcción aplicable
- Las especificaciones técnicas tienen el respaldo en cálculos o tablas de la normativa o del código de construcción aplicable, basados en las condiciones de diseño o de servicio del equipo.
- OPERACIÓN

Descripción breve de la operación del equipo
Función del equipo
Riesgos inherentes
Medios de control de riesgos ó la operación

- DISPOSITIVOS DE SEGURIDAD

Identificación de los dispositivos de seguridad que protegen al equipo
Documentación de calibraciones

EQUIPO USADO

- REVISION Y MANTENIMIENTO
  Programa de revisiones
  Resumen cronológico de las revisiones efectuadas de acuerdo al programa
  Registros de revisiones
  Documentos relacionados con la revisión
  Resumen de resultados de revisiones en servicio
  Registro de revisiones en servicio
  Documentación de las revisiones en servicio
  Todos los resultados de las revisiones están avalados por escrito y firmados por el responsable técnico de mantenimiento, operación o inspección según aplica.

- Programa de mantenimiento
- Resumen cronológico del mantenimiento efectuado de acuerdo al programa
- Registros de mantenimiento
- Documentos relacionados con el mantenimiento

- MODIFICACIONES Y ALTERACIONES
  Resumen cronológico de modificaciones y alteraciones efectuadas al equipo
  Registro de modificaciones y alteraciones
  Documentos relacionados con las modificaciones y alteraciones

Resumen cronológico de modificaciones y alteraciones efectuadas al equipo que implicaron soldadura en el cuerpo a presión
Registro de modificaciones y alteraciones que implicaron soldadura en el cuerpo a presión
Documentos relacionados con las modificaciones y alteraciones que implicaron soldadura en el cuerpo a presión

- TRANSITORIOS
  Resumen de transitorios relevantes
  Resultados del análisis efectuado para determinar sus consecuencias

- INFORMACION ADICIONAL
  El patrón agrega la información necesaria para evidenciar el estado del equipo

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DIPLOMADO EN INGENIERÍA DE CALDERAS Y RECIPIENTES A PRESIÓN

MÓDULO IV : MATERIALES, SOLDADURA Y CALDERAS DE POTENCIA

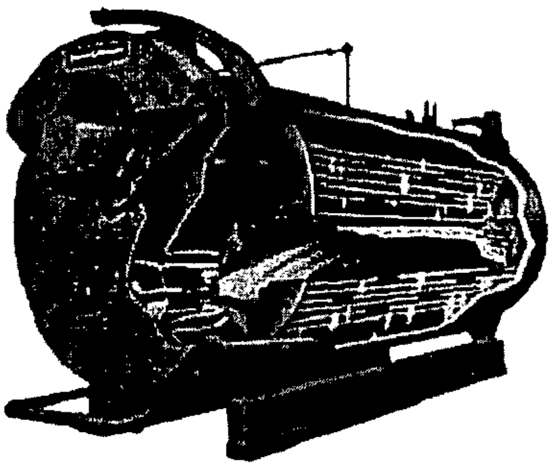
TEMA:

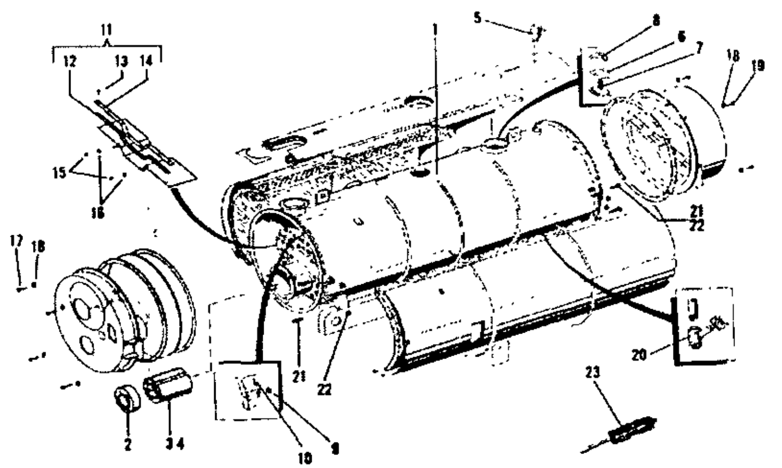
ANEXO DEL EXPEDIENTE DE INTEGRIDAD MECÁNICA

EXPOSITOR: ING. ANTONIO GARCÍA MORENO
SEDE: PALACIO DE MINERÍA
MAYO 2003

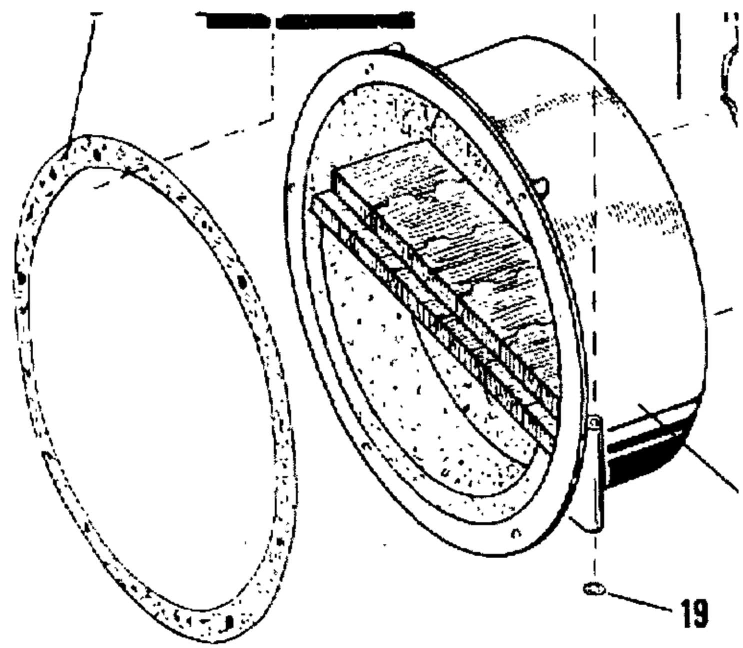
Palacio de Minería, Calle de Tacuba No. 5, Primer piso, Delegación Cuauhtémoc, CP 06000, Col. Centro, México D.F., APDO Postal M-2285 • Tels. 5521 4021 al 24, 5623.2910 y 5623.2971 • Fax. 5510.0573

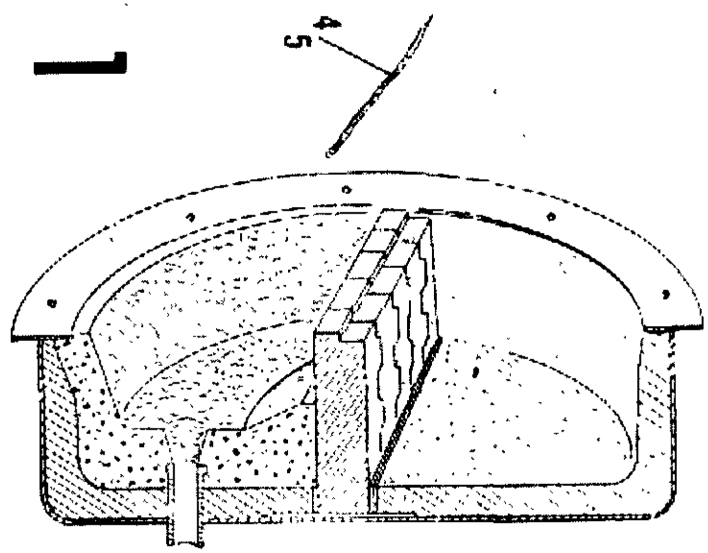
Características de diseño de la caldera



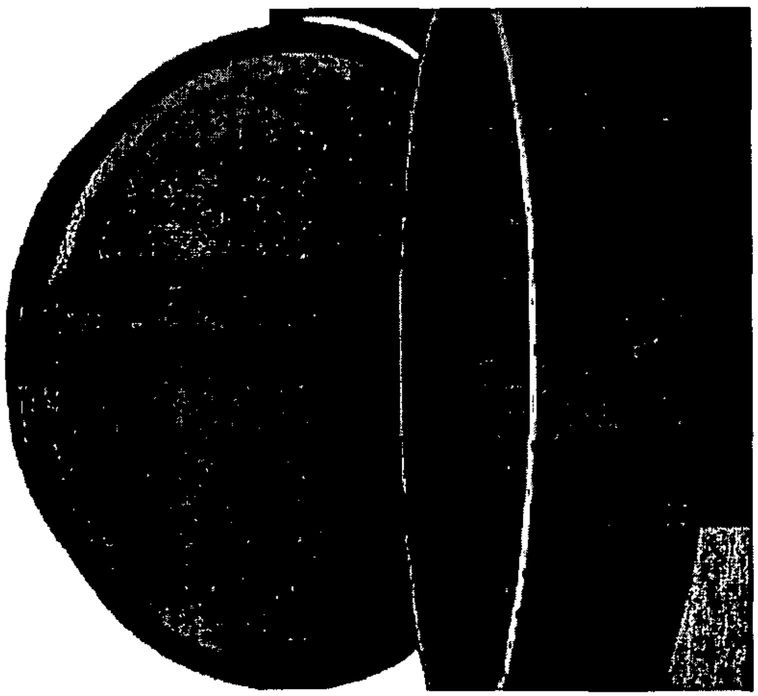


Características de diseño de la caldera

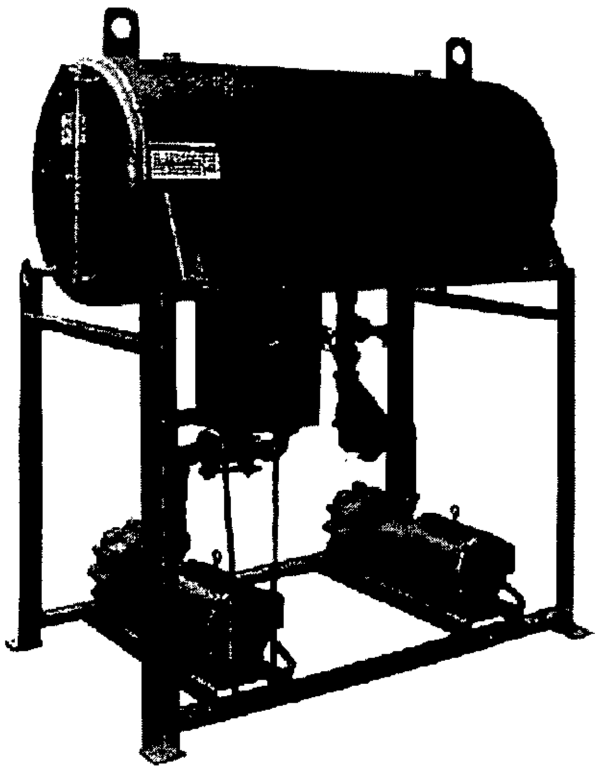


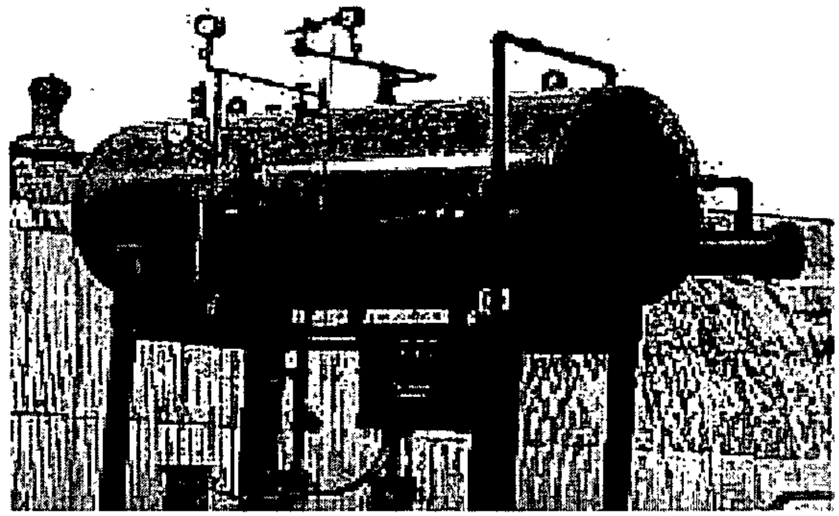


Características de diseño de la caldera

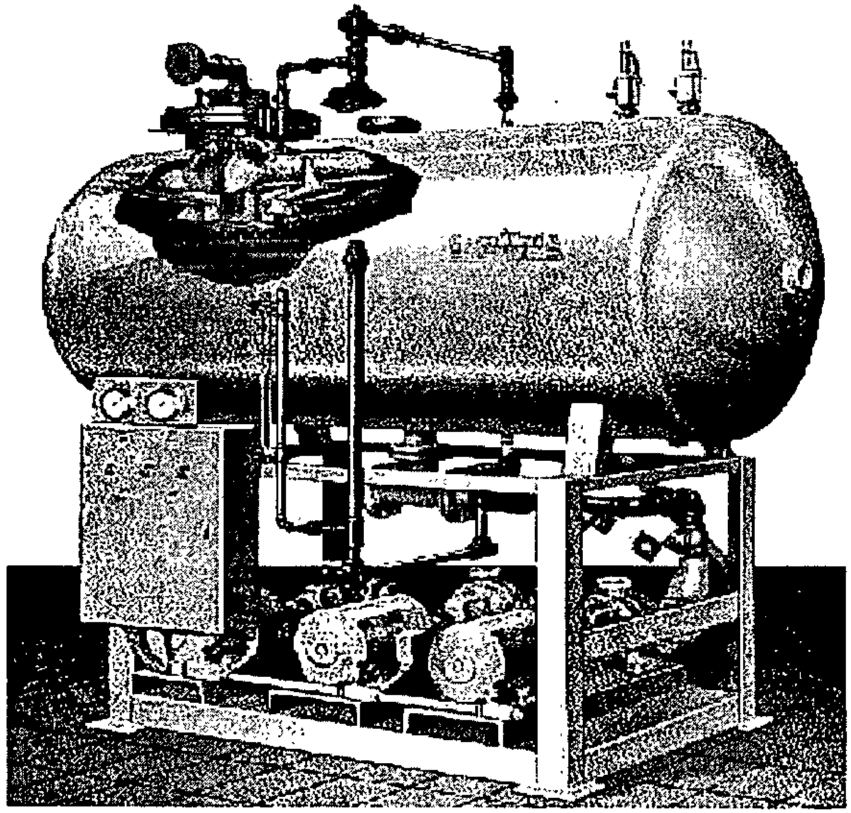


Líneas de alimentación

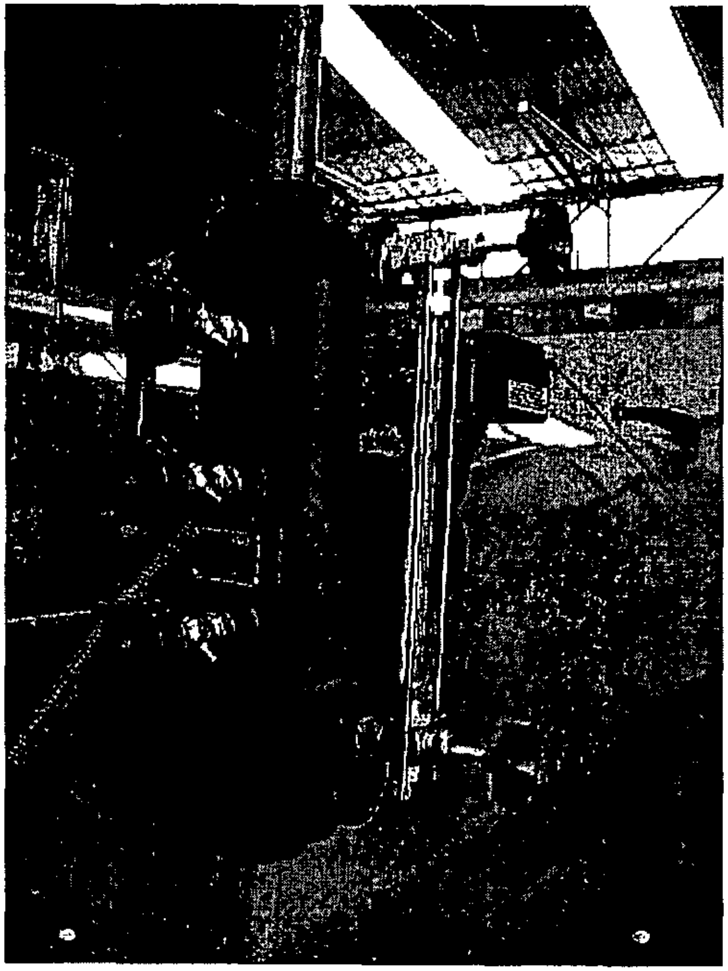


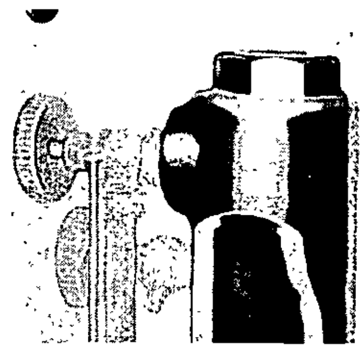


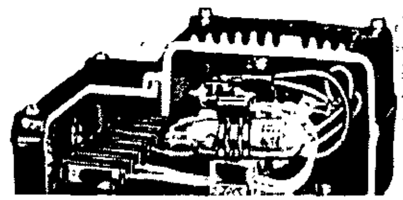
Líneas de alimentación



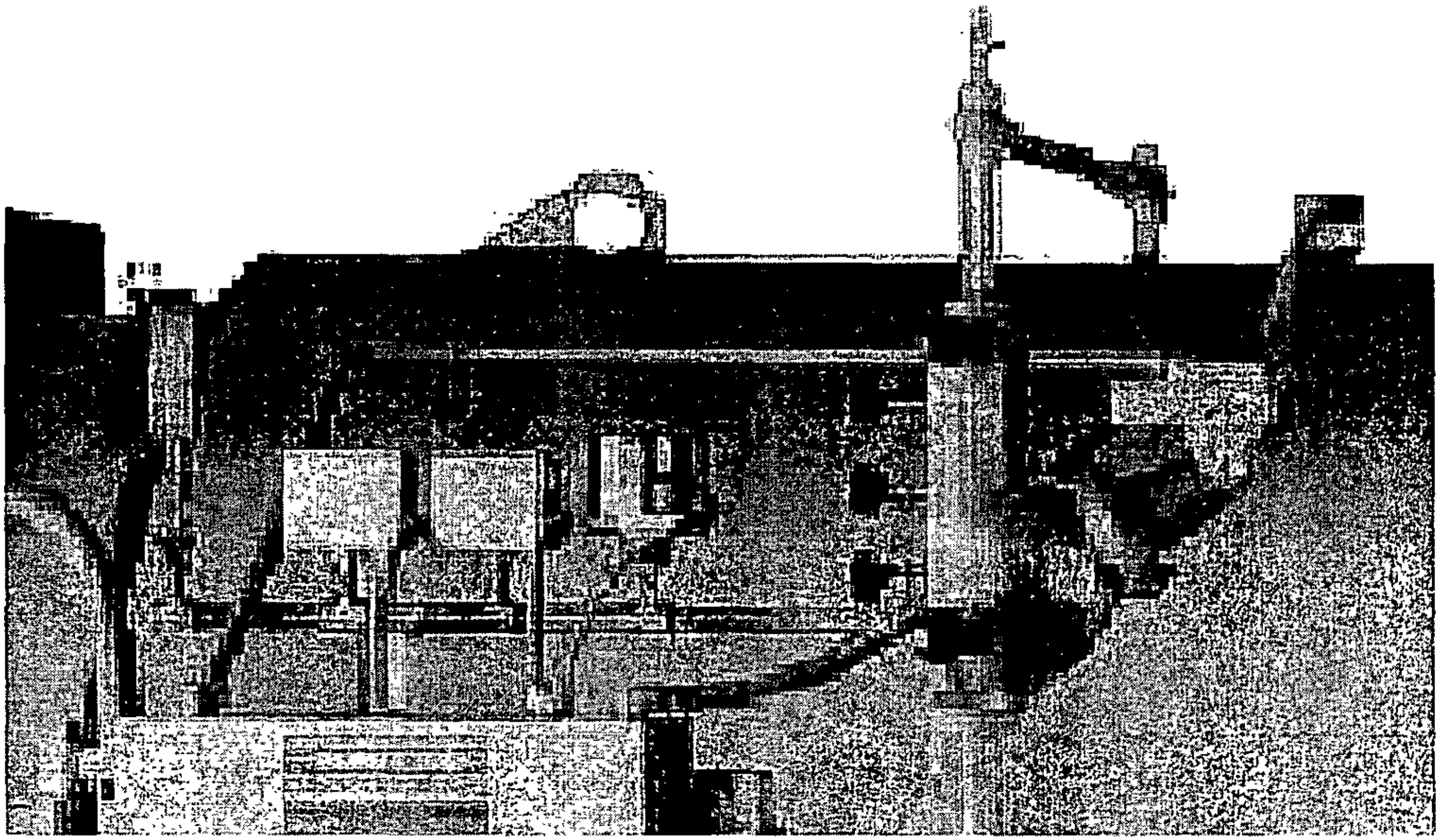
Control de nivel de agua



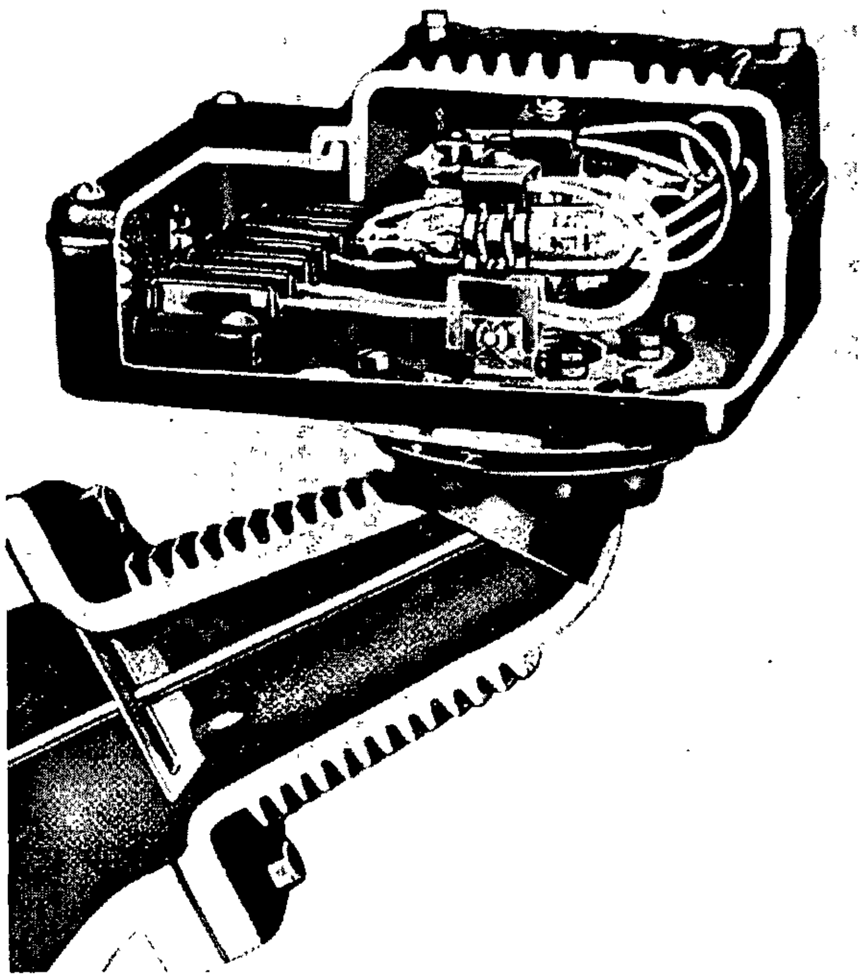




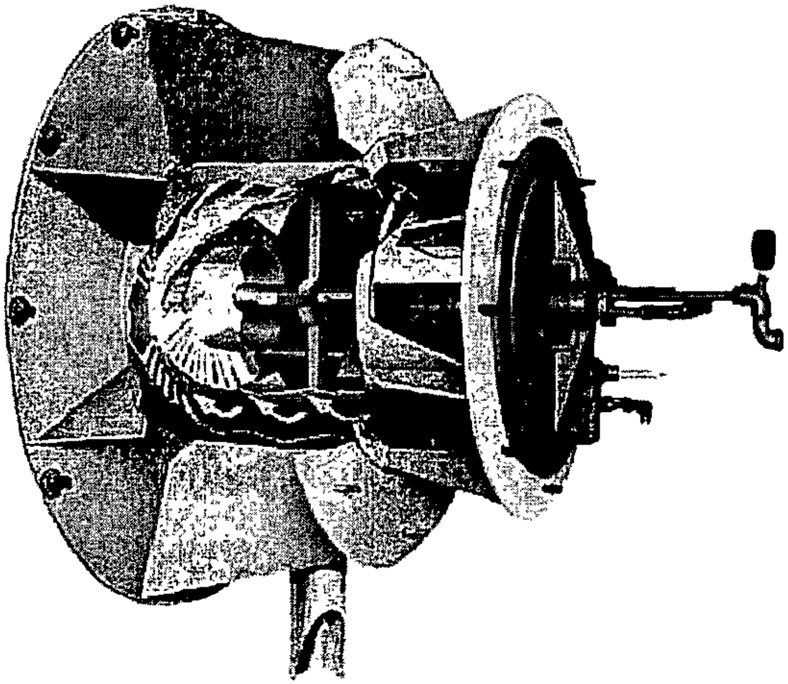
Controles de presión

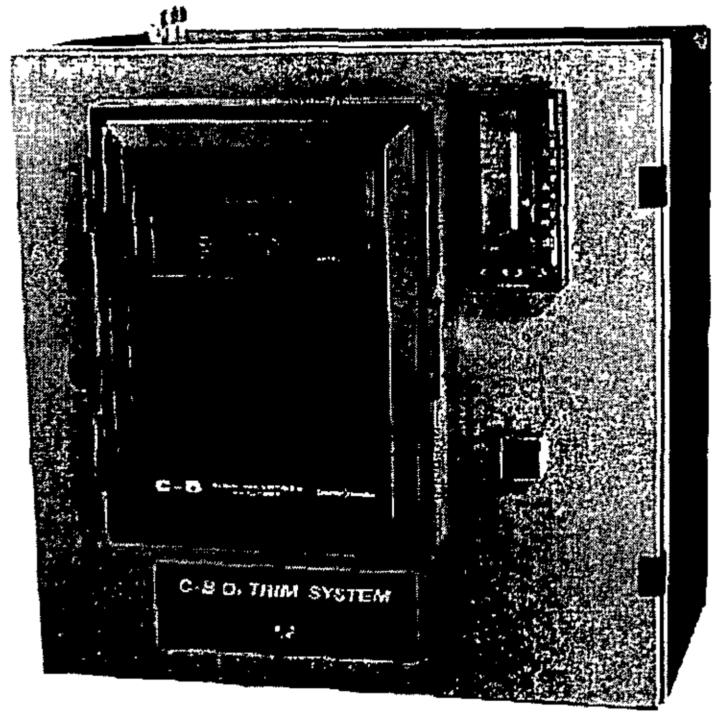


Control de nivel de agua



Control de combustión





LA PAUSA DE SEGURIDAD

1. ¿Sé lo que voy a hacer?
2. ¿Conozco el método y/o procedimiento para este trabajo?
3. ¿Estoy en condiciones emocionales y físicas para este trabajo?
4. ¿Existe algún riesgo que pueda lastimarme?
5. ¿Existen en el área sustancias o equipo ajeno al proceso?
6. ¿Conozco que Equipo de Protección Personal (EPP) debo usar?
7. ¿Mi EPP está completo y en buenas condiciones?
8. ¿Las herramientas y equipo que voy a usar es el más adecuado?
9. ¿Se encuentran en buen estado para este trabajo?
10. ¿Requiero que alguién me ayude?
11. ¿Me entregaron el equipo parado, vacío, limpio, despresurizado?
12. ¿Requiero bloquear, etiquetar, candadear, etc.?
13. ¿Necesito que me asesore mi supervisor durante el trabajo?
14. ¿Necesito que me asesore personal de Seguridad Industrial durante el trabajo?

RECUERDA: Ningún trabajo es tan importante que no puedas tomarte el tiempo para pensar en cómo hacerlo en forma segura.

ROMBO DE SEGURIDAD

Inflamabilidad

0 Mínimo. No arden, son estables

1 Ligero. Arden arriba de 93.3 °C

2 Moderado. Arden arriba de 37.8 °C

3 Alto. Arden arriba de 23 °C

4 Severo. Arden debajo de 23 °C

Salud

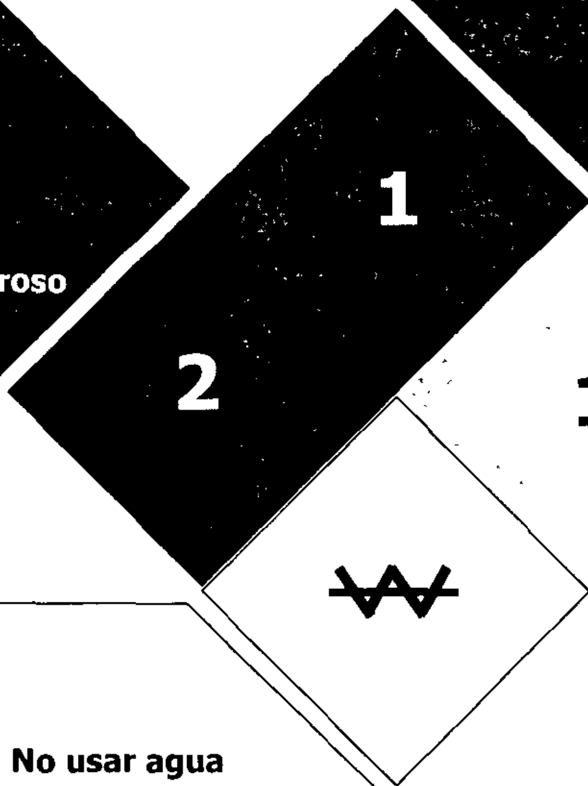
0 Mínimo. Material Normal

1 Ligero. Riesgo leve

2 Moderado. Peligroso

3 Alto. Extremadamente peligroso

4 Severo. Mortal



Especiales

OXI Oxidantes

ACID Acidos

ALC Alcalinos

CORR Corrosivos

No usar agua

Riesgo de radiación

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DIPLOMADO EN INGENIERÍA DE CALDERAS Y RECIPIENTES A PRESIÓN

MÓDULO IV : MATERIALES, SOLDADURA Y CALDERAS DE POTENCIA

TEMA:

CUDADO DE CALDERAS

EXPOSITOR: ING. ANTONIO GARCÍA MORENO
SEDE: PALACIO DE MINERÍA
MAYO 2003

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CUIDADOS DE LA CALDERA

Ing. Antonio García Moreno

INTRODUCCION

La operación segura, confiable y eficiente de su caldera comienza desde la selección de un sistema bien diseñado que satisfaga todas la normas correspondientes:

- Capacidad adecuada para el servicio
- Combustible a utilizar
- Fabricación bajo normas (ASME, NOM, etc)

INTRODUCCION

De la misma forma que cualquier equipo industrial una caldera requiere un programa de mantenimiento planificado a fin de proporcionar una operación adecuada y duradera.

INTRODUCCION

Un manual completo debe incluir:

- Descripción general del equipo y principios de operación
- Información sobre el recipiente a presión
- Requerimientos de calidad del agua
- Instrucciones sobre la limpieza
- Recomendaciones sobre los sistemas de tratamiento de agua

INTRODUCCION

- Información sobre la inspección
- Instrucciones de encendido y operación
- Procedimientos de ajuste
- Diagnóstico de averias
- Detalles de inspección y mantenimiento
- Información para ordenar refacciones

CUIDADOS DE LA PARTE INTERIOR DEL RECIPIENTE A PRESION

Un cuidado adecuado del interior del recipiente de presión le traerá las siguientes ventajas:

- Larga duración de la caldera
- Aumento en el tiempo efectivo de operación
- Mayor eficiencia y por lo tanto menor consumo de combustible

6

TRATAMIENTO DE AGUA

Un programa de tratamiento de agua adecuado y procedimientos de purga correctos son vitales para mantener las superficies de calefacción de su caldera libres de efectos dañinos que puedan reducir su vida útil.

TRATAMIENTO DE AGUA

Un programa de tratamiento de agua bien orientado debe prevenir la formación de incrustaciones, eliminar la corrosión causada por el oxigeno en el agua cruda y disminuir el arrastre de humedad causado por espumeo.

TRATAMIENTO DE AGUA

El personal encargado del tratamiento de aguas deberá recomendar los procedimientos y frecuencia de purgas requeridas a fin de reducir la concentración de sólidos en la caldera.

Se debe de llevar un control estricto de :

- Parámetros de tratamiento.
- Equipo de tratamiento, productos químicos y control de registros.
- Inspecciones al interior del equipo y la instalación.

CORROSION POR OXIGENO

Para verificar la corrosión por oxigeno, drene la unidad y remueva los registros de mano y de hombre para una inspección visual de toda la superficie en contacto con el agua. Inspeccione las superficies interiores del recipiente (especialmente de la zona posterior de la caldera) utilizando una linterna y espejos buscando que no haya evidencias de burbujas, "marcas de viruela", o erosión en la superficie del metal.

FORMACION DE INCRUSTACIONES

Las incrustaciones actúan como aislantes y pueden originar a su ves esfuerzos térmicos en la superficie en contacto con los gases calientes, estos esfuerzos y/o deformaciones pueden caer en problemas críticos de fugas y daños en uniones entre otros.

INCRUSTACIONES

Una incrustación de 1.6mm de espesor aumenta el consumo de combustible en un 15%,una incrustación de 3.2mm requiere 20% más de combustible y una de 6.4mm hasta un 39% más.

RECUERDE . Las verificaciones periódicas se requieren aún con un buen programa de tratamiento de aguas.

INCRUSTACIONES

Durante la inspección visual del interior del recipiente utilice herramienta para obtener muestras de cualquier incrustación que se haya formado, especialmente en la parte posterior de la caldera.

Analice las muestras para determinar su composición. Recuerde que el origen de las incrustaciones generalmente se debe a presencia de sales de calcio, magnesio y/o sílice.

ACUMULACION DE SEDIMENTOS

Muchas veces un tratamiento o condiciones inadecuadas de operación pueden provocar una acumulación excesiva de sedimentos en el fondo de la caldera. Durante la operación estos sedimentos deben ser controlados a base de un programa de purgas. Durante la inspección deben ser retirados con un lavado de agua a alta presión.

ARRASTRES DE HUMEDAD

El vapor húmedo y el condensado pueden ser ocasionados por:

- Altas concentraciones de sólidos por falta de purgas.
- Tratamiento inadecuado de agua de alimentación.
- Línea de vapor "estrangulada" o de dimensión inadecuada.
- Cargas repentinas debidas a aperturas súbitas de válvulas.
- Sobrecarga constante (sobredemanda).
- Líneas de vapor sin trampas.

ARRASTRES DE HUMEDAD

Los efectos principales de los arrastres de humedad son:

- Golpe de ariete en las líneas de vapor.
- Vapor de baja temperatura.
- Sobredemanda ocasionada por la baja cantidad de calor disponible.

EMPAQUES

Siempre que realice una inspección deberá considerar suficientes empaques para registros, estos deben ser cambiados en su totalidad, siempre que se abra algún registro. Es muy importante el sello en el recipiente, la más mínima fuga causará que el metal de la caldera sufra corrosión y dañe los asientos de los registros.

PROCEDIMIENTOS DE CONSERVACION

Cuando una caldera estará fuera de servicio por un periodo de tiempo menor a los 3 meses es conveniente para disminuir la corrosión por oxígeno inundar la caldera:

- Encienda la caldera para que produzca vapor ventilando desde el punto más alto para eliminar la mayor parte de oxígeno retenido.
- Agregue el tratamiento químico adecuado y/o recomendado.

PROCEDIMIENTOS DE CONSERVACI

ÓN

- Asegúrese que no haya posibilidad de que el agua se congele.
- Cierre todas las válvulas (aísle el equipo) y desconecte la energía eléctrica.
- Abra la puerta de la caldera del lado de la chimenea para evitar el flujo de aire natural y húmedo a través de los tubos.

PROCEDIMIENTOS DE CONSERVACIÓN

El método "seco" para mantener una caldera fuera de servicio es:

- Drene la caldera y quite las tapas de todos los registros.
- Coloque encima de los tubos charolas con productos que absorvan humedad.
- Cierre las tapas de los registros.
- Abra la puerta de la caldera del lado de la chimenea para evitar el flujo de aire natural y húmedo a través de los tubos.

CUIDADOS EN EL LADO DE FUEGO

El problema más importante en el hogar y los tubos de la caldera es la acumulación de hollín y otros elementos no combustibles con la consiguiente reducción de transferencia de calor e incremento en el consumo de combustible.

La acumulación de hollín aumenta la temperatura en la chimenea de la caldera lo que indica que hay necesidad de limpieza.

La frecuencia con que se realice esta dependerá de la carga de la caldera, tipo y calidad de combustible y eficiencia de combustión.

Los productos de combustión requieren atención rigurosa. Estos pueden contener óxidos sulfurosos o nitrosos, los cuales absorven humedad, formando ácidos que corroen las superficies de la zona de combustión y desalojo de gases.

HOGAR, TUBOS Y PLACAS

Cheque cuidadosamente el hogar, los tubos y las placas para determinar si hay evidencia de ampollas o “marcas de viruela” que indican corrosión.

La corrosión puede controlarse:

- Manteniendo una temperatura adecuada en el agua de alimentación.
- Ajustando la proporción aire combustible (carburación adecuada).
- Ajustando los controles de operación para que el equipo se mantenga encendido la mayor parte del ciclo.

LIMPIEZA DE TUBOS

La evidencia de una acumulación densa de hollín en breves periodos de tiempo puede significar una proporción inadecuada de aire combustible.

La temperatura de los gases en la chimenea es un indicador importante para programar una limpieza o mantenimiento. Como regla general un aumento de 4° C en la temperatura de la salida de gases equivale a un 1% de perdida de eficiencia.

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EMPAQUES

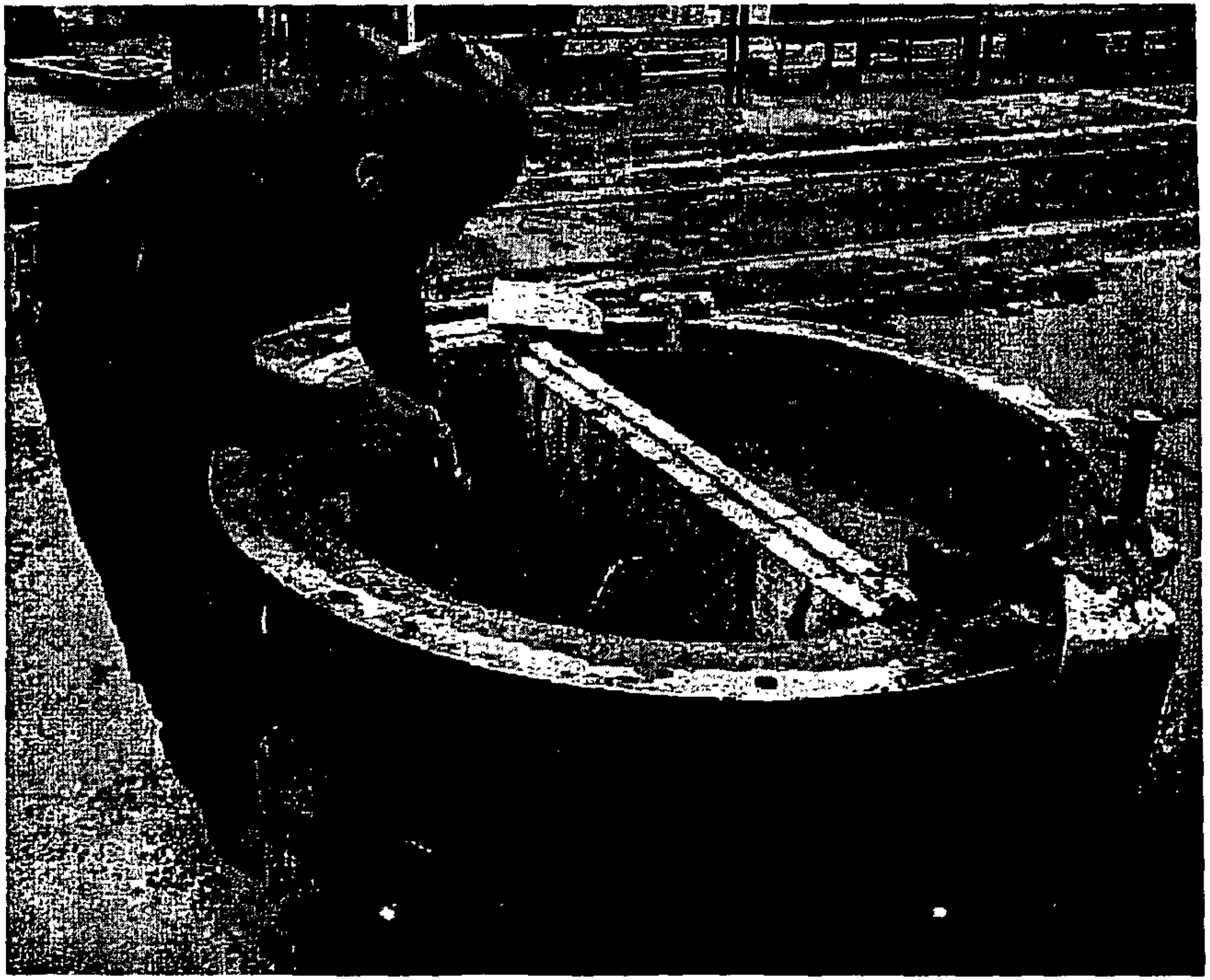
Verifique visualmente los empaques de las puertas para asegurarse que están en buenas condiciones y bien sujetos. Se requiere un sello efectivo en la zona de combustión para evitar pérdida de eficiencia, quema de los empaques y deformación del metal de las puertas. Los empaques deben ser reemplazados siempre que se abran las puertas, recuerde que por disposición internacional está prohibido el uso de empaques de base asbesto.

REFRACTARIO

Cheque el hogar al mismo tiempo que verifica la parte interior del recipiente.

Abra las puertas dela caldera de manera que el refractario quede al “descubierto”. Verifique la presencia de grietas y/o erosión en la superficie del material cuando esta sea significativa será necesario el reemplazo total del material, cuando sea posible por el grado de deterioro menor resane la superficie con un material refractario aplicado con brocha (lechada).

REFRACTARIOS



REFRACTARIOS

El emboquillado del hogar y las mamparas deflectoras en la zona de combustión están regularmente armadas a base de ladrillos, cuando estos presenten daños o quebraduras es conveniente su reemplazo para evitar problemas de combustión.

CUIDADOS DEL QUEMADOR

La mejor forma de determinar si las boquillas o inyectores de combustible necesitan limpieza, ajustes en la presión, ajustes en las conexiones, etc., es manteniendo un registro diario de presiones, temperaturas y cualquier otra información de los indicadores.

En una caldera alimentada con combustible líquido una caída de presión puede indicar un filtro obstruido, una válvula reguladora defectuosa, o una fuga de aire en la línea de succión.

CUIDADOS DEL QUEMADOR

En una caldera alimentada con gas, una caída en la presión puede significar un problema en la línea principal de suministro (línea pública) o funcionamiento defectuoso de reguladores.

Una elevación de temperatura en la chimenea no siempre significa una combustión pobre, o un hogar o la parte interior del recipiente defectuosa, en un arranque las variaciones de temperatura son normales durante el cambio de carga.

Las chimeneas deben estar limpias sin trazas de humo, una chimenea emitiendo humos indica una necesidad de ajuste en el quemador, o problemas de carburación.

Por otro lado debe verificarse visualmente la operación de válvulas manuales y automáticas, sobre todo durante el paro de la unidad. Si la flama no se extingue inmediatamente será indicio de problemas de sello y requerirá seguramente de cambio de válvulas

CUIDADO DE LOS CONTROLES

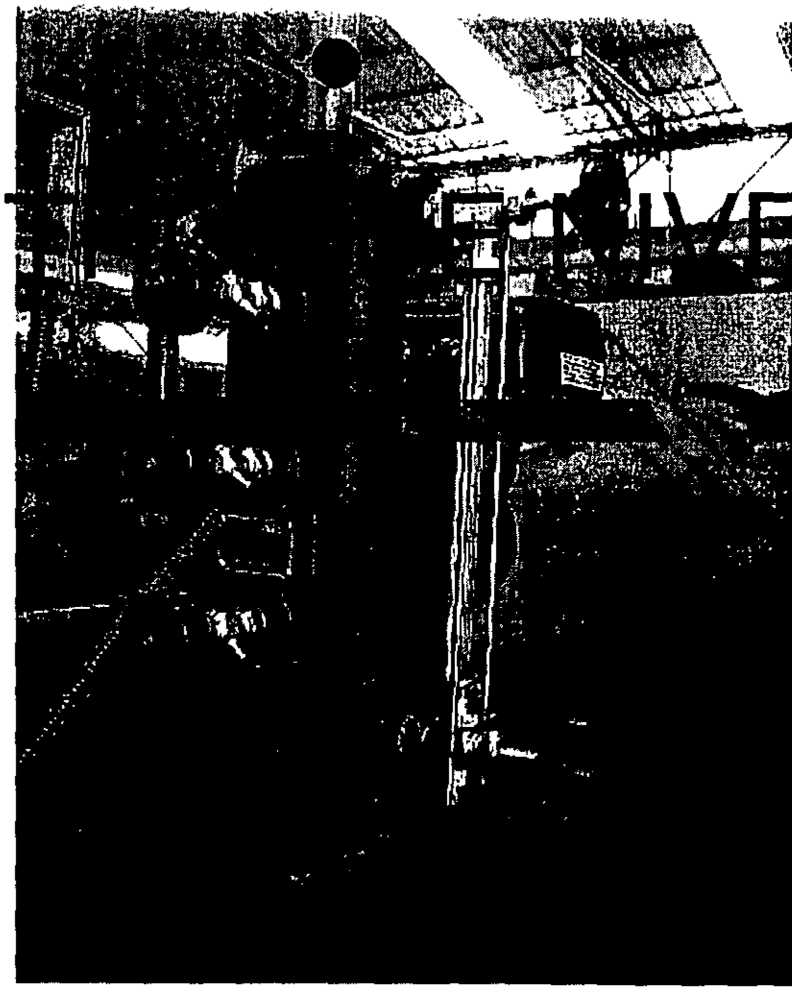
El indicador de nivel y el control de operación de la alimentación de agua deberá estar libre de obstrucciones por lo que es muy importante purgarlos periódicamente.

Una prueba de operación programada evita posibles emergencias.

La revisión de interconexiones y el empleo de crucetas, facilita la inspección y limpieza.

Recuerde que un programa de mantenimiento bien planificado garantiza una operación segura y confiable.

CONTROL DE NIVEL



VERIFICACION DEL RENDIMIENTO

Considere los siguientes parámetros para establecer si está obteniendo un buen rendimiento en su equipo:

- Temperatura de gases.
- Análisis de gases de combustión.
- Frecuencia de purgas.
- Temperatura del cuerpo de la caldera.

MANTENIMIENTO SIMPLIFICADO

Un programa de mantenimiento adecuado beneficia el rendimiento del equipo, su vida útil, evita paros innecesarios y pérdidas económicas.

"Más que mantenerse preocupados por la operación del equipo hay que mantenerse ocupados en procurar su buena operación"

DIARIO

- Verificar, niveles de agua y niveles de combustión.
- Purgar caldera y columnas.
- Registrar las variables de operación, presión y temperatura de agua, presión y temperatura de combustible, temperatura de gases, tratamiento de aguas, presión de operación, etc.
- Efectúe el tratamiento de agua de acuerdo a las recomendaciones.

CADA SEMANA

- Verifique cierre de válvulas de combustible, conexiones en general, luces indicadoras y alarmas, controles límites de operación, controles de seguridad y sus conexiones, fugas, ruidos anormales, vibraciones, y cualquier condición que manifieste una operación fuera de lo establecido.

CADA AÑO

- Programe la inspección y verificación del recipiente a presión.
- Desmonte, limpie, ajuste y/o reemplace los controles de seguridad.
- Desmonte, limpie y verifique la calibración de instrumentos y accesorios.
- Desmonte las válvulas de seguridad y verifique su calibración.