UNIVERSIDAD NACIONAL DEL CALLAO

FACULTAD DE INGENIERÍA MECÁNICA- ENERGÍA

ESCUELA PROFESIONAL DE INGENIERÍA MECANICA

"DISEÑO DEL PLAN DE ASEGURAMIENTO DE LA CALIDAD DEL PROCESO DE TERMOFUSION DE TUBERIAS DE POLIPROPILENO"

TESIS PARA OPTAR EL TÍTULO PROFESIONAL DE

INGENIERO MECANICO

SHIRLEY INES CONCHA FLORES

Callao, Septiembre, 2014

PERÚ

UNIVERSIDAD NACIONAL DEL CALLAO
FACULTAD DE INGENIERÍA MECÁNICA – ENERGÍA
Jurado Evaluador de Tesis del I ciclo de Tesis

INFORME

El Presidente del Jurado Evaluador del I ciclo de tesis, informa que la sustentación de la tesis titulada: **"DISEÑO DEL PLAN DE ASEGURAMIENTO DE LA CALIDAD DEL PROCESO DE TERMOFUSIÓN DE TUBERÍAS DE POLIPROPILENO"**, presentado por el bachiller **CONCHA FLORES, Shirley Inés**, realizado el día 19 de setiembre del 2014; el mismo que fue aprobado como consta en el acta correspondiente.

Se emite el presente informe para los fines pertinentes.

Bellavista, 29 de setiembre del 2014

Mg. Félix Alfredo Guerrero Roldan
Presidente del Jurado Evaluador
I ciclo de tesis

DEDICATORIA

Dedico este trabajo primero a Dios por haberme dado la fuerza para siempre seguir adelante y a mis padres por el esfuerzo y apoyo incondicional que siempre me brindaron.

AGRADECIMIENTO

Agradezco a Alex De la Cruz, por haberme acompañado durante todo este camino, por la paciencia y el conocimiento brindado.

A Carlos Vera de la empresa IFITSA, quien brindo sus equipos y asesoría para la soldadura de las probetas.

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Gracias al equipo del Taller de Termofusion de SKANSKA, quienes fueron mi inspiración para la realización de esta investigación.

INDICE

INDICE DE TABLAS

INDICE DE FIGURAS

RESUMEN

Esta tesis diseña el plan de aseguramiento de la calidad en el proceso de termofusion para tuberías de polipropileno, el tipo de investigación debido a los ensayos realizados es una Investigación Experimental, considerando un Diseño Descriptivo Simple (Muestra = Probeta; Objeto = FPS).

Esta investigación detalla el procedimiento a seguir para asegurar los requisitos de calidad y medición de resultados para garantizar que las normas internacionales se cumplan. El proceso por el cual se realiza la unión de tuberías de polipropileno es la Termofusion.

Durante el desarrollo de la investigación lo que se busca es realizar el Aseguramiento de la Calidad, el cual es un proceso de ejecución que utiliza los datos tomados durante el Control para la implementación del Plan de Calidad.

Por lo que al diseñar el Plan de Calidad se identifican los requisitos de calidad y se documenta para demostrar el cumplimiento de los estándares internacionales.

En la investigación, se demuestra con ensayos que los resultados obtenidos aplicando el procedimiento del Plan de Calidad, se cumple con lo planteado en la hipótesis, quedando así demostrado que la aplicabilidad de esta investigación nos proporciona orientación y dirección para garantizar que al utilizar las normas apropiadas se obtiene uniones soldadas ACEPTABLES.

Palabras claves: calidad, termoplástico, termofusión, polipropileno.

ABSTRACT

This thesis designs the plan of quality assurance in the process of termofusion polypropylene pipe, the type of research because the tests performed is an Experimental Research, considering Description Design Simple (Sample = Probe; Object = FPS).

This research details the procedure to follow to ensure quality requirements and measuring results to ensure that international standards are met.The process by which the polypropylene pipe joint is made is the Fusing.

During the course of the investigation that is looking to perform Quality Assurance, which is a process running that uses data taken during the control for the implementation of the Quality Plan.

So when designing the Quality Plan quality requirements are identified and documented to demonstrate compliance with international standards.

In research with trials demonstrated that the results obtained using the procedure of Quality Plan are met as stated in the hypothesis. Thus being shown that the applicability of this research provides guidance and direction to ensure that appropriate standards to use welded joints obtained ACCEPTABLE.

Keywords: Quality, thermoplastic, hot melt, polypropylene.

CAPITULO I

PLANTEAMIENTO DE LA INVESTIGACION

1.1. Identificación del problema

Dentro de la industria nacional, los procesos de soldadura por termofusion en tuberías de polipropileno, no tienen un procedimiento estipulado, en lo que se refiere a normas, códigos o estándares internacionales. El diseño de un plan de calidad que describa de manera secuencial las diferentes normas y recomendaciones, para la elaboración de estos procedimientos, hacen posible que las personas dentro de este campo de trabajo y con conocimientos en el área, puedan estar en capacidad de llevar a cabo uniones térmicas de tuberías y accesorios con resultados exitosos.

Por lo que al no estar establecido un diseño del plan de calidad en el proceso de termofusion de tuberías de polipropileno, no se podría asegurar la calidad en la junta soldada por este proceso.

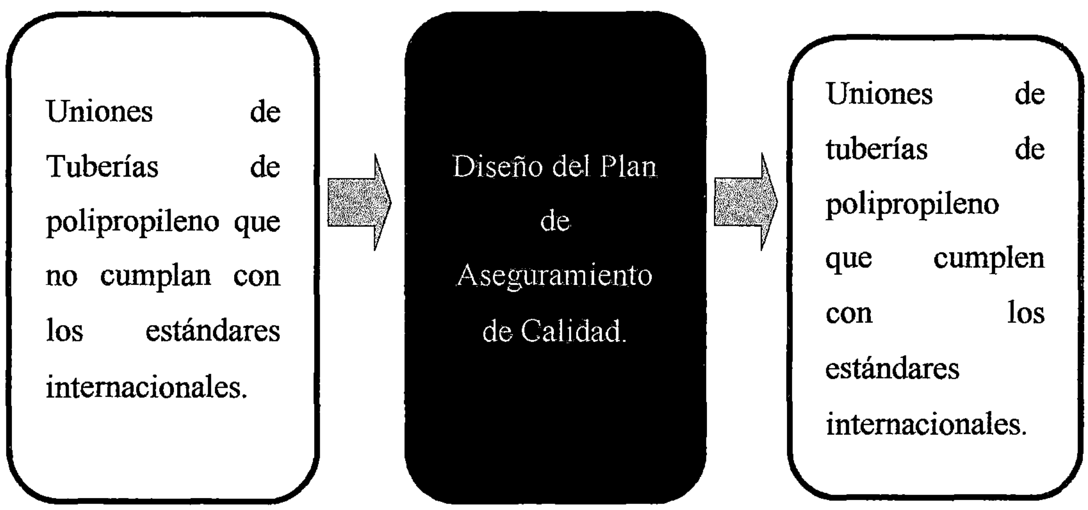
1.2. Formulación del problema

En los diversos procesos que se realizan en el sector minero, refinerías, petroquímicas y otros referentes a la producción con compuestos de fluidos ácidos, alcalinos, etc, que llegan hasta temperaturas de 100°C. Se opta por trabajar con tuberías de polipropileno para el transporte de estos fluidos, de acuerdo a las propiedades químicas, mecánicas y alta resistencia a la corrosión. La unión de estas tuberías se realiza por el proceso de termofusion.

Siguiendo el modelo de la caja negra, se planteó:

FIG. 1.1

CAJA NEGRA



Fuente: Propia

TABLA N°1.1

FORMULACION DEL PROBLEMA

INTERROGANTE	VI	ENLACE	VERBO	VD	DEMILIMITACION
Cómo…?	Diseño de el plan	Para	Asegurar	La calidad en el Proceso de termofusion	Tuberías de polipropileno.

Fuente: Propia

PREGUNTA: ¿Cómo diseñar el plan para asegurar la calidad en el proceso de termofusión de tuberías de polipropileno?

1.3. Objetivos de la investigación

1.3.1. Objetivo General

Diseñar el plan de aseguramiento de la calidad del proceso de termofusión por medio de ensayos y procedimientos de manera sistemática para obtener uniones de tuberías de polipropileno que cumplan con los estándares internacionales.

1.3.2. Objetivos Especifico

- Soldar por el proceso de Termofusion, probetas de tuberías de polipropileno según Código ASME, e inspeccionar la unión por ensayos no destructivos y destructivos de acuerdo a lo establecido en el Código.

- Analizar los resultados de los ensayos para preparar la Especificación de Procedimiento de Fusión (FPS).

1.4. Justificación

El diccionario define calidad como "el grado de excelencia que posee una cosa" o "las características que hacen a algo lo que es", sus elementos y atributos característicos. No coinciden todas las opiniones de los principales expertos. Crosby define calidad como "la conformidad con los requerimientos". Juran resume que es "la aptitud para el uso" y "la calidad es la satisfacción del cliente". La American Society for Quality (ASQ, por sus siglas en inglés) define la calidad como "la totalidad de características de un producto o servicio que sostienen su capacidad para satisfacer determinadas necesidades". [1]

Se entiende por Termofusión; a un método de soldadura utilizado para unir tubos de polymeros y sus conexiones. Las áreas de las partes que se van a unir se calientan a la temperatura de fusión y se unen por aplicación de presión, con acción mecánica o hidráulica, de acuerdo al tamaño de la tubería. Esta técnica produce una integración molecular, garantizando una unión permanente y dejando el tubo monolítico. La Termofusión es la más económica de los sistemas de uniones térmicas. [2]

Para asegurar el control de calidad durante el proceso de termofusión y dar como aceptable estas uniones, me he basado en los procedimientos que existen para el Polietileno, en las normas internacionales. Satisfaciendo así las necesidades productivas y exigencias del cliente.

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[1] MIKELL P. GROOVER. **Fundamentos de la Manufactura Moderna.** México. Mcgraw-Hill/Interamericana Editores, S.A. de C.V. Tercera Edición. 2007.

[2] GRUPO SITSA. **Termofusion**. Disponible en: http://www.termofusion.com.mx/termofusion.html. Consultada el 25 de Junio del 2014.

"No se tiene un procedimiento estipulado, en lo que se refiere a normas, códigos o estándares, sino que se realiza de manera empírica. La elaboración de un procedimiento escrito donde se describa de manera secuencial las diferentes normas y recomendaciones, para la elaboración de estos procedimientos, hacen posible que las personas dentro de este campo de trabajo y con conocimientos en el área, puedan estar en capacidad de llevar a cabo uniones térmicas de tuberías y accesorios con resultados exitosos". [3]

1.5. Importancia

La importancia de este proceso, es que se obtiene una unión permanente y eficaz, además es la más económica de los sistemas de uniones térmicas. La Soldadura por Termofusión es apropiada para la unión de dos tuberías del mismo SDR (Relación de Dimensiones Estándar = relación ø / espesor).

Este proceso de termofusión es un método de soldadura simple y rápida, para unir tubos de polipropileno. Las áreas de las partes que se van a unir se calientan a la temperatura de fusión y se unen por aplicación de presión, con acción mecánica o hidráulica, de acuerdo al tamaño de la tubería y sin usar elementos adicionales de unión.

El Diseño del Plan de Calidad incluye el proceso y actividades que determinan la política de calidad, sus objetivos y responsabilidades para que el proyecto

[3] REVINCA, **Procedimiento de soldadura por termofusion**, 2002, Venezuela.

satisfaga las necesidades para las cuales fue emprendido. El Plan de Calidad se refiere al control de entregables del proyecto.

También su importancia radica en el mínimo impacto ambiental negativo que produce, ya que es temporal, puntual y directo. Se refiere al ruido por el uso de la maquinaría propia. Considerándose de magnitud baja por debajo de los 100 decibeles.

CAPITULO II

MARCO TEORICO

2.1. Antecedentes del estudio.

Las primeras investigaciones que obtuvieron muestras de polipropileno tuvieron que ser mejoradas por diferentes defectos que presentaban, para asi poder ingresar al mercado. Las aplicaciones industriales por sus propiedades lo hace un material resistente a temperaturas altas y sustancias acidas.

John Hyatt, invento un tipo de plástico al que llamo celuloide. El celuloide se fabricaba disolviendo celulosa, un Hidrato de Carbono obtenido de las plantas, en una solución de alcanfor y etanol. El celuloide puede ser ablandado repetidamente y moldeado de nuevo mediante calor, por lo que recibe el calificativo de termoplástico.

En 1907 Leo Baekeland invento la baquetita, el primer plástico calificado como termofijo o termoestable; plásticos que pueden ser fundidos y moldeados mientras están calientes.

En la década de los 30, químicos ingleses descubrieron que el gas etileno polimerizaba bajo la acción del calor y la presión, formando un termoplástico al que llamaron polietileno (PE). Hacia los años 50 aparece el polipropileno (PP). [4]

Las tuberías de Polipropileno, son soldadas mediante el proceso de Termofusion, siendo la Termofusion a Tope el proceso usado en esta Tesis.

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[4] Ingeniería PLastica.com. **Historia del Plástico**. Disponible en: http://www.ingenieriaplastica.com/novedades_ip/instituciones/cipres_historia.html. Consultada el 15 de Mayo del 2014.

Diedrich y Gaube realizaron allá por 1970 estudios experimentales variando los parámetros de soldadura a tope, presión y temperatura, comprobando el comportamiento de la soldadura. El efecto del Índice de Fluidez (MFR) del PE fue investigado por Diedrich y Kempe y publicados en 1980 en las normas DVS 2207-1; DVS 2203-1; DVS 2205-1.

En 1980 en Alemania se puso en marcha un extenso programa con el objetivo de perfeccionar los parámetros de la soldadura a tope con placa calefactora utilizada para unir tuberías de polietileno de espesores superiores a 45 mm.

Varias universidades así como las industrias involucradas, (proveedores materias primas, fabricantes de tuberías y de accesorios, fabricantes de máquinas de soldar), trabajaron en los proyectos de investigación, dando lugar a las normas DVS correspondientes.

Las investigaciones internas de Hoechst AG, Frankfurt, confirmaron que no se producía ningún efecto negativo en el comportamiento a largo plazo de las uniones de PE con placas calefactoras que estaban entre 190 °C y 260 °C de temperatura. La variación de la presión entre 0.15 N/mm² y 0.45 N/mm² también daba buenos resultados. Basándose en estos resultados se estableció una "ventana" para estos dos parámetros de soldadura.[5]

[5] AseTUB. **Soldadura Termica en tuberías de Polietileno**. 2009. España

2.2 Terminología [6]

Polipropileno (PP), n-un polímero preparado por la polimerización de propileno como un único monómero. (Ver plásticos de polipropileno y plástico de propileno) (1978).

Polipropileno de plástico-plástico a base de polímeros hechos con propileno con esencialmente un único monómero. (1975)

Plásticos propileno, n-plásticos a base de polímeros de propileno o copolímeros de propileno con otros monómeros, el propileno que están en mayor cantidad en masa. (ISO) (1982)

Termoplástico, n-un plástico que en repetidas ocasiones se puede ablandar por calentamiento y se endurece por enfriamiento a través de un rango de temperatura característico del plástico, y que en el estado ablandado se puede moldear por flujo en forma de artículos por moldeo o extrusión. (1985)

Termoplástico,-adj capaz de ser ablandadas por calentamiento y endurecido por enfriamiento a través de un rango de temperatura característico del plástico, y que en el estado ablandado se puede moldear por flujo en forma de artículos por moldeo o extrusión.

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[6] ASTM D883. **Standard Terminology Relating to Plastics.** 2000. EEUU

2.3. ¿Qué es Plan de Calidad?

2.3.1. Definición

Según Norma ISO 9001[7], define Plan de Calidad como; "Documento que específica que procedimientos y recursos asociados deben aplicarse, quien debe aplicarlos y cuando deben aplicarse a un proyecto, producto, proceso o contrato especifico".

2.3.2. Descripción de procesos de calidad

De acuerdo al **PMBOK, Capitulo 8 "Proyecto de Gestión de la Calidad"** [8], presenta la siguiente descripción:

Plan de Gestión de la Calidad.- es el proceso de identificación de los requisitos de calidad y/o normas para el proyecto y sus entregables y documentación de como el proyecto demostrara el cumplimiento con los requisitos de calidad.

Realizar Aseguramiento de Calidad.- es el proceso de auditoría de los requisitos de calidad y los resultados de las mediciones de control de calidad para garantizar que las normas de calidad apropiadas y las definiciones operacionales se utilizan.

Control de Calidad.- es el proceso de seguimiento y registrar los resultados de calidad para evaluar el desempeño y recomendar cambios necesarios.

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[7] ISO 9001. **Sistemas de Gestión de la Calidad**. 2008. Suiza
[8] PMBOK. **Gestión de Proyectos**. 2013. EEUU

2.4. Polipropileno [9]

2.4.1. Definición:

El polipropileno (PP) es el polímero termoplástico, parcialmente cristalino, que se obtiene de la polimerización del propileno (o propeno). Pertenece al grupo de las poliolefinas y es utilizado en una amplia variedad de aplicaciones.

Es un termoplástico de excelente resistencia a los agentes químicos, esterilizable al vapor y extraordinarias propiedades de aislaciones eléctricas aun en altas frecuencias.

Su gran resistencia al ataque químico lo sitúa en diversos elementos en construcciones químicas, farmacéuticas, mineras y maquinas en general que no solicite altos esfuerzos de fricción.

El PP tiene un grado de cristalinidad intermedio entre el polietileno de alta y el de baja densidad.

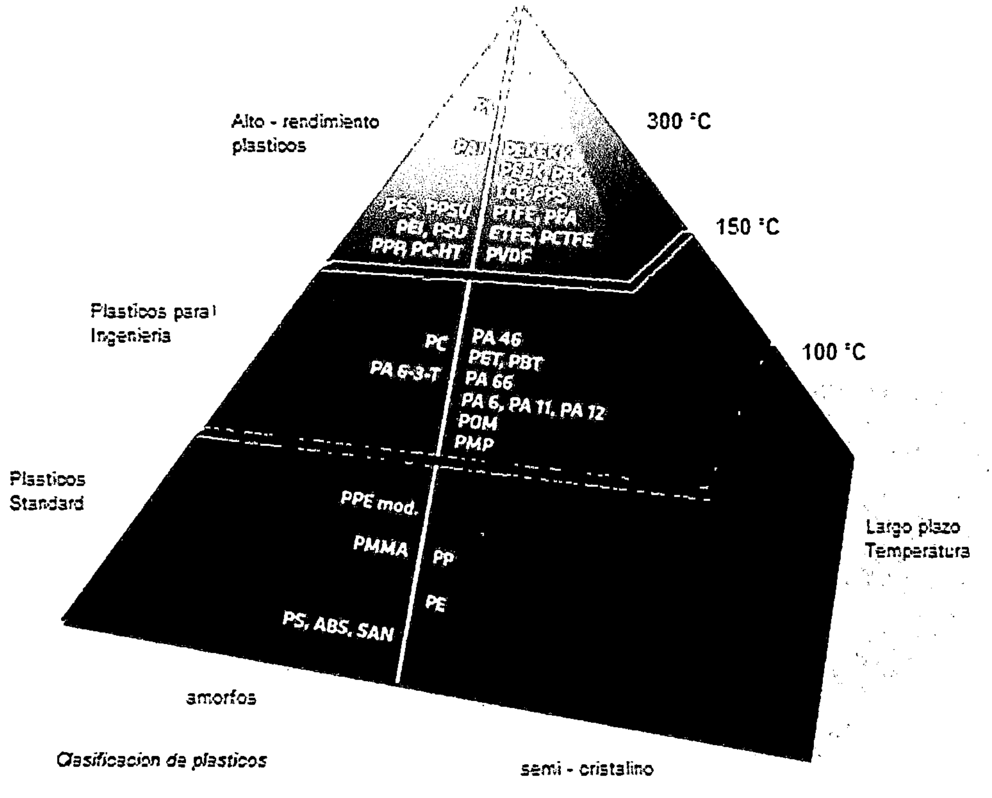
2.4.2. Clasificación de los perfiles plásticos según sus propiedades:

Los perfiles de plásticos, de acuerdo a sus propiedades y comportamiento, tienen un amplia gama de aplicaciones y se clasifican:

[9] Plásticos EFS. **Materiales para Inyección y Extrusión**. Disponible en: http://www.efsplasticos.cl/pag/materiales-para-inyeccion-y-extrusion.php#4. Consultada el 26 de Junio del 2014.

FIGURA 2.1

CLASIFICACION DE PLASTICOS



Fuente: Ensinger [10]

2.4.3. Tipos de Polipropileno:

El Polipropileno puede clasificarse por las materias primas que se utilizan en su elaboración y por su estructura química:

Por Materias Primas:

A. Homopolímero

B. Copolímero Impacto

C. Copolímero Random ·

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[10] Ensinger. **Semi finished Engineering Plastic Products.** June 2013. Alemania

El tipo de Polipropileno a utilizar en la presente tesis es:

A. Polipropileno Homopolimero

- **Definición:**

  Es un polímero termoplástico que contiene sólo monómeros de propileno a lo largo de su cadena polimérica. Su estructura presenta un alto grado de cristalinidad, lo que se traduce en el aporte de rigidez y dureza a la pieza elaborada, pero exhibe pobre resistencia al impacto a bajas temperaturas y su transparencia no es suficiente para algunas aplicaciones.

- **Propiedades:**

  Dentro de las características podemos mencionar:

  - Presenta alta resistencia a la temperatura,
  - Puede esterilizarse por medio de rayos gamma y óxido de etileno,
  - Tiene buena resistencia a los ácidos y bases a temperaturas debajo de 80°C,
  - Tiene pocos solventes orgánicos lo pueden disolver a temperatura ambiente.
  - Posee buenas propiedades dieléctricas,
  - Su resistencia a la tensión es excelente en combinación con la elongación,
  - Su resistencia al impacto es buena a temperatura ambiente, pero a temperaturas debajo de 0°C se vuelve frágil y quebradizo.

TABLA 2.1

PROPIEDADES MECANICAS

	PP homopolimero	PP copolimero	Comentarios
Modulo elástico en tracción (Gpa)	1.1 a 1.6	0.7 a 1.4	
Alargamiento de rotura en tracción (%)	100 a 600	450 a 900	Junto al polietileno, una de las mas altas de todos los termoplásticos.
Carga de rotura en tracción (Mpa)	31 a 42	28 a 38	
Módulo de flexión (Gpa)	1.19 1.75	0.42 a 1.40	
Resistencia al impacto Charpy (KJ/m2)	4 a 20	9 a 40	El PP copolimero posee la mayor resistencia al impacto de todos los termoplásticos.
Dureza shore D	72 a 74	67 a 73	Más duro que el polietileno pero menos que el poliestileno o el PET.

Fuente: Carrocerías Plásticas Ltda [11]

[11] Carrocerías Plásticas Ltda. **http://carroceriasplasticas-ustabuc.blogspot.com/2009/05/propiedades-propiedades-fisicas-la.html**. Consultada en Abril del 2014.

2061

TABLA 2.2

PROPIEDADES TERMICAS

	PP homopolimero	PP copolimero	Comentario
Temperatura de fusión (°C)	160 a 170	130 a 168	Superior a la del polietileno.
Temperatura máxima de uso continuo (°C)	100	100	Superior al polietileno al LDPE y al PVC pero inferior al HDPE al PET y a los "plásticos de ingeniera".
Temperatura de transición vítrea (°C)	-10	-20	

Fuente: Carrocerías Plásticas Ltda [11]

2.4.4. Aplicaciones:

El PP es transformado mediante muchos procesos diferentes. Los más utilizados son:

- Moldeo por inyección de una gran diversidad de piezas, desde juguetes hasta parachoques de automóviles
- Moldeo por soplado de recipientes huecos como por ejemplo botellas o depósitos de combustible
- Termoformado de, por ejemplo, contenedores de alimentos. En particular se utiliza PP para aplicaciones que requieren resistencia a alta temperatura (microondas) o baja temperatura (congelados).

- Producción de fibras, tanto tejidas como no tejidas.
- Extrusión de perfiles, láminas y tubos.
- Producción de película, etc.

2.5. Termofusión

2.5.1. Definición

Soldadura simple y rápida que une dos tubos y sus accesorios. Mediante un calentamiento a temperatura de fusión y se unen por aplicación de presión con acción mecánica (no se usa elemento adicional). Una termofusión siempre se deberá hacer controlando temperatura, tiempo y presión en todo el proceso de termofusión, así como con la utilización de equipos automatizados. [12]

2.5.2. Tipos de soldadura por termofusion [13]

La soldadura por Termofusion se clasifica en:

A. Soldadura por Termofusion de Tope
B. Soldadura por Termofusion a Encaje
C. Soldadura por Termofusion a Solape

[12] CALIDDA. **Instructivo HSE – Union Por Termofusion**. Sistema de Gestión. Código I-GSS-011. 18 de Enero del 2013.
[13] REVINCA, **Procedimiento de soldadura por termofusion**, 2002, Venezuela.

El tipo de soldadura a usar en la presente tesis es:

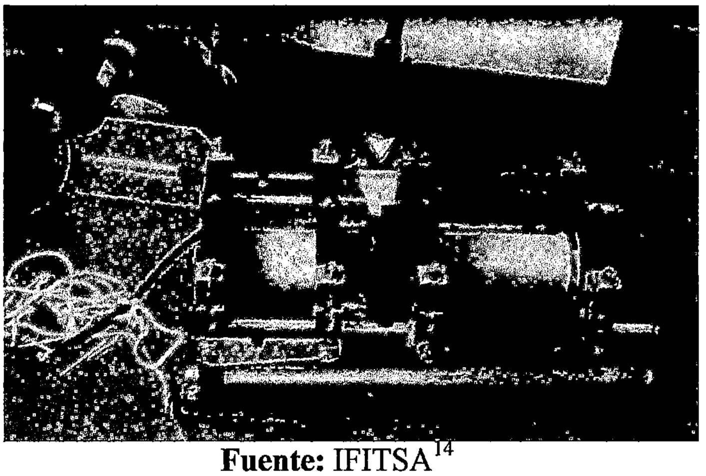
A. Soldadura por Termofusión a Tope.

Es un método de soldadura simple y rápida, para unir tubos de polipropileno y sus accesorios. Las áreas de las partes que se van a unir se calientan a la temperatura de fusión y se unen por aplicación de presión, con acción mecánica o hidráulica, de acuerdo al tamaño de la tubería y sin usar elementos adicionales de unión.

Esta técnica produce una unión permanente y eficaz, además es la más económica de los sistemas de uniones térmicas. La Soldadura a Tope es apropiada para la unión de dos tuberías del mismo SDR (relación ø / espesor) con diámetros desde 32 mm hasta diámetros de 630 mm.

FIGURA N°2.2

SOLDADURA POR TERMOFUSIÓN A TOPE

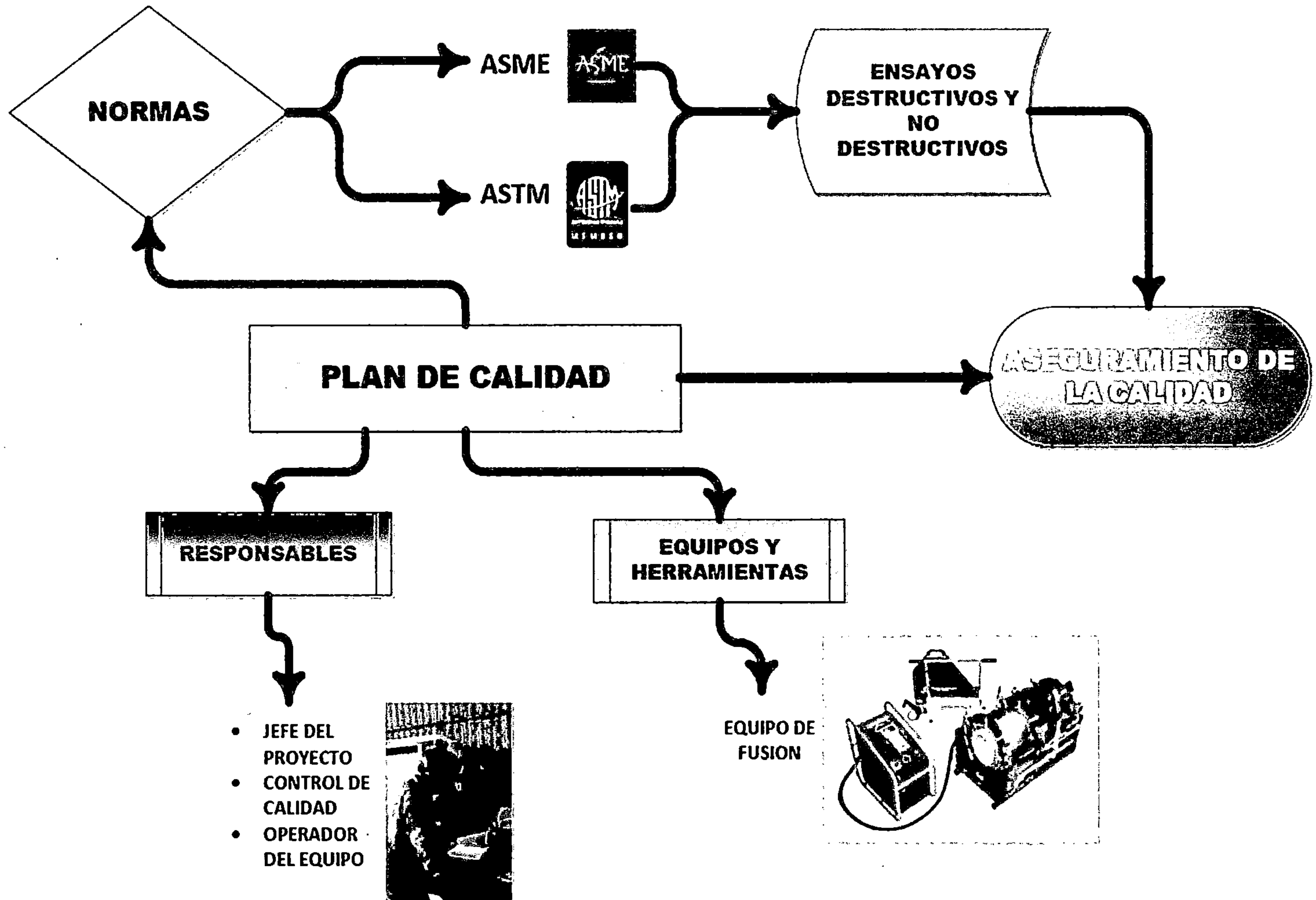


Fuente: IFITSA[14]

[14] IFITSA, Empresa que facilito sus equipos para realizar la fusión.

2.6. Diseño del Plan de Aseguramiento de la Calidad

2.6.1. Diagrama del Plan de Aseguramiento de la calidad



Fuente: Propia

2.7. Plan de Aseguramiento de la Calidad

2.7.1. Responsables

- **Jefe de Proyecto:**
  - Es responsable de gestionar y dar todos los recursos necesarios para la implantación y difusión del Plan de Aseguramiento de Calidad.
  - Es responsable de asegurar el aprovisionamiento de los recursos necesarios para dar cumplimiento al presente Plan de Aseguramiento de Calidad.
- **Control de Calidad**
  - Verificar que se lleven los registros del Plan de Calidad correspondientes en forma adecuada.
  - Verificar que se efectúen los controles respectivos establecidos en el presente Plan de Aseguramiento de Calidad.
  - Verificar que los trabajos se realicen de acuerdo a las especificaciones técnicas del cliente, a los códigos y normas aplicables.
  - Difundir el presente Plan de Aseguramiento de Calidad.
  - Responsable de llevar y registrar los controles estipulados.
- **Supervisor de Seguridad, Salud Ocupacional y Ambiental**
  - Verificar que se hayan colocado todos los equipos de protección colectiva necesario s para dicha labor.

- Verificar el uso correcto del EPP (Equipos de Protección Personal), requerido para cada actividad.
- Verificar la implementación de los controles operacionales de acuerdo con la evaluación de riesgos.
- Garantizar el stock necesario de equipos de protección colectiva con la debida anticipación.
- Verificar la señalización adecuada de la zona.
- Coordinar permanentemente las actividades con supervisión.

▪ **Operador del Equipo de Fusión**[15]

  - Es el responsable de ejecutar y cumplir el presente Plan de Aseguramiento de Calidad, de forma tal que controle los riesgos potenciales evaluados para esta tarea.
  - Reportará al Supervisor de Seguridad o Supervisor de Calidad cualquier condición sub estándar en su equipo o acto sub estándar en el área de trabajo.
  - Deberá realizar el correcto uso de los equipos de protección requeridos para las actividades de soldadura por termofusión.
  - Elaborar el check list de su equipo, así como conocer las capacidades y limitaciones del mismo expuestas en el manual del equipo.
  - Reportar al supervisor de calidad o supervisor de seguridad cualquier desperfecto que pueda presentar su equipo.

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[15] HAUG. **Procedimiento de Preparación, Instalación y montaje de Tuberías HDPE.** 25 de Enero del 2013.

2.7.2. Equipo y herramientas

- **Equipo de Fusión:**

TABLA N° 2.3

GAMA DE ∅ EQUIPOS DE TERMOFUSION

∅ (mm)
40-160
90-250
90-355
200-500
315-630
500-800
710-1200

Fuente: ROTHENBERGER[16]

- ✓ Unidad Hidráulica para el accionamiento manual de la Mesa Alineadora.
- ✓ Taladro Refrentador.
- ✓ Plancha Calefactora Regulable.
- ✓ Mordazas Principales.
- ✓ Mordazas de fijación de diferentes diámetros (mm).
- ✓ Soporte para Plancha Calefactora y Refrentador.
- ✓ Tablero eléctrico 220 V.

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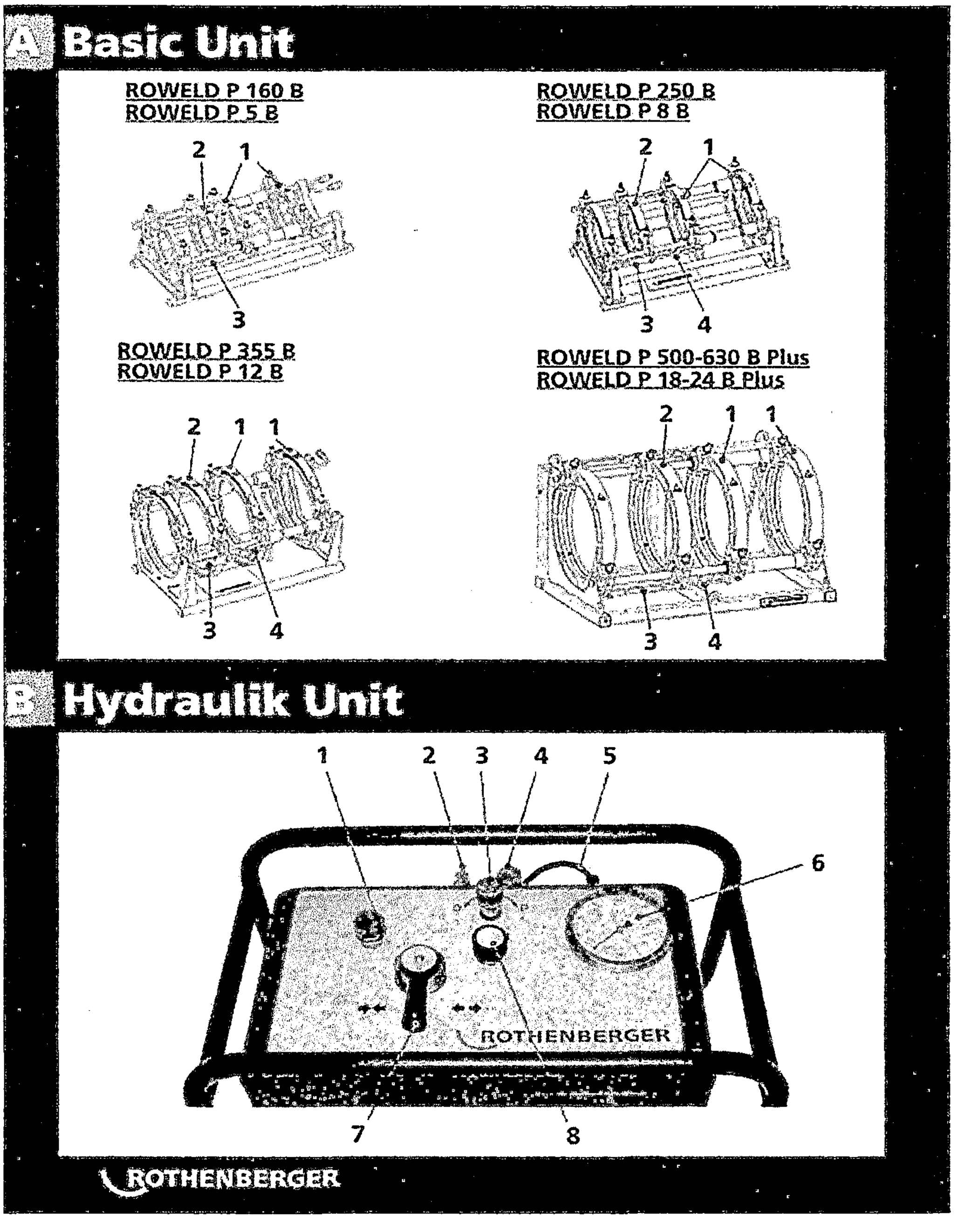
[16] ROTHENBERGER. **http://www.rothenberger.com.br/produtosListaEspanhol.asp**. Consultada en Mayo del 2014.

- **Especificaciones técnicas del equipo de Fusión**[17]

FIGURA N° 2.4

MAQUINA BASE Y GRUPO HIDRAULICO



Fuente: ROTHENBERG[17]

[17] Rothenberger. **INSTRUCTIVO DE USO ROWELD.** Septiembre 2013. Alemania

Maquina base – A

1. Elementos tensores móviles
2. Elemento tensor desplazable
3. Pieza distanciadora con muescas de anclaje
4. Dispositivo de extracción del elemento calefactor

Grupo hidráulico – B

1. Empalme carga aceite y sonda de nivel
2. Conectador acoplamiento rápido
3. Válvula de descarga
4. Manguito acoplamiento rápido
5. Cable de red
6. Manómetro
7. Palanca de mando, hacia la izquierda: cierre, hacia la derecha: apertura
8. Válvula ajuste presión

El grupo hidráulico permite realizar las operaciones marcadas con los símbolos siguientes de la maquina soldadora:

Para juntar las mordazas, mover la palanca de control hacia la izquierda. La velocidad de avance y de formación de presión depende del ángulo de giro.

Para separar las mordazas, mover la palanca de control hacia la derecha. La velocidad de avance depende del ángulo de giro.

Válvula de ajuste de presión para las presiones de fresado, igualación, calentamiento y unión. La presión seleccionada se muestra en el manómetro.

Válvula de descarga, mediante giro a la izquierda puede disminuirse la presión. La velocidad de disminución de presión depende de la cantidad de vueltas. Giro hacia la derecha mantener la presión.

OIL Tubuladura de carga tapa de cierre con aceite – sonda de nivel.

- **Herramientas a usar durante el proceso de termofusion:**

✓ Llaves mixtas

✓ Flexómetro

✓ Sierra circular

✓ Cronometro (reloj)

✓ Arco de sierra

✓ Niveles

✓ Escuadras

✓ Caballetes Regulables.

✓ Tornillo de Banco.

✓ Martillo de Goma

✓ Pirómetro

También se debe tener en consideración los siguientes Materiales que son necesarios para efectuar la soldadura por termo fusión:

✓ Marcadores de pintura

✓ Alcohol metílico para limpieza de tuberías de Polipropileno (bordes)

✓ Toallas de algodón

✓ Tachos para virutas de PP

✓ Malla de seguridad

2.7.3. Normatividad

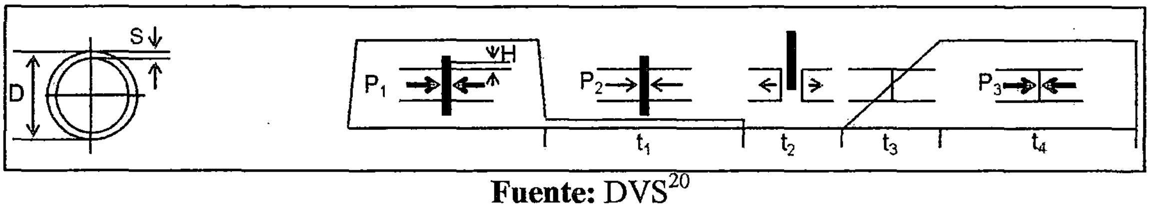
La normatividad vigente aplicada a lo referente a Control de Calidad de Fusión de Plásticos, está referida en el **ASME IX 2013** en **PART QF – ARTICLE XXI**[18].

También en la **ASTM – D2657 – 07**[19], se indica el procedimiento de la fusión a tope (**PROCEDURE - BUTT FUSION**), las consideraciones a tener durante el proceso de soldadura así como las dimensiones del espécimen para la prueba de doblez.

2.7.4. Ciclo de soldadura

FIGURA N° 2.5

CICLO DE SOLDADURA SEGÚN DVS



Fuente: DVS[20]

- **D-DIAMETRO EXTERIOR** (mm)
- **S-ESPESOR DE PARED** (mm)
- **SDR**-Relación: Diámetro /Espesor.
- **T °C**- .-Regular la temperatura de la plancha calefactora:

  Debe ser de 215 ± 5 °C (419 ± 5 ° F).

---

[18] ASME IX 2013, **PART QF – ARTICLE XXI.**
[19] ASTM, **D2657 – 07.**
[20] DVS, **Technical codes on plastics loining technologies**. DVS 2207-1

- **P1-PRESION DE FORMACION** (bar).-Regular la presión que indica el Parámetro recomendado por el fabricante del equipo. Posicione la plancha calefactora en la mesa alineadora y juntar empleando el dispositivo de cerrar (Sistema hidráulico), aplicando la presión correcta.
- **H-DIMENSIÓN DEL CORDÓN INICIAL**.- Debe ser 2 a 2.5 mm toda la circunferencia refrentada.
- **P2-PRESION DE CALENTAMIENTO** (bar).-Bajar presión mínima empleando el dispositivo de abrir (sistema hidráulico).
- **T1- TIEMPO DE CALENTAMIENTO** (S).-Controlar el tiempo de Polifusion empleando Cronometro.
- **T2-TIEMPO DE CALENTAMIENTO MAXIMO** (S).-Tiempo para retira la plancha calefactora; empleando el dispositivo de abrir (sistema hidráulico).
- **T3-TIEMPO PARA ALCANZAR LA PRESION DE SOLDADURA** (seg.).- Tiempo para unir las tuberías; empleando el dispositivo de cerrar (Sistema hidráulico).
- **P3-PRESION DE SOLDADURA**.-Al emplear el dispositivo de cerrar se forma el cordón de soldadura final.
- **H2-DIMENSION DEL CORDÓN FINAL**.- El cordón doble debe enrollarse sobre la superficie adyacente y redondearse en forma uniforme a la vez que mantiene un tamaño consistente alrededor del cordón.

El ancho del cordón debe ser el doble 2 a 2.5 veces a su altura sobre la superficie y la profundidad del canal en forma de V.

- **T4-TIEMPO DE ENFRIAMIENTO**.- controlar en el cronometro, Dejar enfriar manteniendo la presión (P3), Sin aplicar medios refrigerantes.

2.7.5. Procedimiento según ASTM – D2657

A. Llevar las superficies de las placas del calentador a la temperatura adecuada.

B. Limpiar el interior y el exterior de los componentes (tubo o tubería y el accesorio) a unir. Quitar toda la materia extraña de la superficie del componente donde se sujeta en la plantilla de alineación.

C. Alinear cada componente con su mordaza de alineación, y cierre la abrazadera. Compruebe componente de alineación, ajuste según sea necesario, y se colocan frente a frente a los extremos.

C.1. Tenga cuidado al colocar la tubería o conexiones en la mordaza de alineación. Los tubos deberán ser alineados antes de cerrar las abrazaderas; sin embargo, no fuerce el tubo en la alineación empujándolo.

C.2. Llevar los elementos hidráulicos juntos y verifique la alineación de máximos y mínimos, y fuera de redondez. Ajuste según sea necesario.

C.3. Coloque la placa del calentador entre los tubos y arrástrelos contra la placa de calefacción con suficiente fuerza para asegurar el contacto circunferencial completo contra la placa de calefacción. Mantenga los componentes contra la placa de calefacción brevemente, usando fuerza limitada para garantizar que el contacto con la placa se ha hecho. Suelte la fuerza, pero mantenga los componentes contra la placa calentadora hasta que se forme un bordon de tamaño adecuado, la fundición del plástico se desarrolla circunferencialmente alrededor de cada extremo como resultado de la expansión térmica del material. No empuje los componentes de la placa de calefacción cuando se está realizando la fundición del material.

C.4. Mover los componentes fundidos térmicamente lejos de la placa de calefacción, y retire la placa de calefacción. Inspeccionar rápidamente las superficies fundidas. Si la masa fundida es aceptable, inmediatamente se une el bordon con la fuerza suficiente para juntar ambas superficies de fusión alrededor de toda la circunferencia de unión. Cuando ambas superficies del tubo se tocan, deje de mover el componente, pero no suelte la fuerza. Mantenga la fuerza sobre la articulación hasta que la unión se ha enfriado.

C.4.1. No use fuerza excesiva o insuficiente. Si los componentes se juntan con demasiada fuerza, todo el material fundido puede ser empujado fuera de la junta. Si se utiliza demasiada o poca fuerza, sólo la masa fundida se fusionara en la raíz, y como el material fundido en conjuntos enfría y se contrae, se pueden formar huecos o áreas no fusionadas. Si el material ablandado se pega a la placa de calefacción, interrumpa el procedimiento de unión. Limpie la placa de calefacción, volver a colocar los extremos de los componentes, y repetir el proceso desde el principio.

C.4.2. Inspeccionar los componentes rápidamente al terminar, cuando se retira la herramienta de calentamiento. La masa fundida debe ser plana. Una superficie cóncava indica una presión de fusión inaceptable durante el calentamiento. Si se observa una superficie fundida cóncava, no continúe. Permitir que el componente termine de enfriar y volver a empezar desde el inicio.

C.4.3. Para cualquier tamaño de tubería y espesor de pared, la fuerza de unión de fusión real se determina multiplicando la presión interfacial por el área del extremo del tubo. Para determinar un ajuste del calibrador de presión de fusión para máquinas hidráulicas de fusión a tope, la fuerza se divide por el área de los cilindros hidráulicos que mueven el carro de la máquina de fusión. El ajuste de presión manométrica de la máquina de fusión hidráulica, puede ser necesario aumentar la resistencia para superar la fricción interna de la máquina o para proporcionar fuerza adicional para mover los tubos conectados a la máquina de fusión a tope.

C.5. Reposar al menos hasta que se enfríe antes de retirar las abrazaderas u otro dispositivo de alineación. No someta la unión a alta tensión hasta que se haya enfriado a menos de aproximadamente 130 ° F. No aplique presión interna hasta que el material de la junta y sus alrededores han alcanzado la temperatura del medio ambiente.

C.6. Inspeccione visualmente la unión contra pautas de apariencia recomendados. El bordón (cordón) deben ser dimensionados de forma uniforme y todo alrededor de la articulación.

D. Prueba-Evaluar las articulaciones de muestra para comprobar la habilidad y conocimiento del operador de fusión. En algunos casos, las juntas a tope-de fusión pueden ser examinados de forma no destructiva usando equipos de ultrasonidos para detectar huecos u otras discontinuidades. Visualmente, la anchura de los granos de fusión a tope debe ser de 2 a 2-1 / 2 veces la altura del talón por encima de la tubería, y el bordón debe ser redondeado y uniforme del mismo tamaño alrededor de la circunferencia de la tubería. La ranura en V entre los bordones no debe ser más profunda que la mitad de la altura del talón por encima de la superficie de la tubería. Al tope de la fusión de los accesorios moldeados, el cordón del lado apropiado puede mostrar irregularidades en la forma como hendiduras menores, desviaciones y no uniforme por enfriamiento en la pieza moldeada y líneas de soldadura.

En tales casos, la evaluación visual se basa principalmente en el tamaño y la forma del cordón del lado del tubo. Para las pruebas destructivas, las articulaciones en las correas a cortar se encuentran en la Figura 2.6, visualmente examine y pruebe la continuidad del cordón y la fuerza. Los exámenes que se han mostrado útiles para este propósito incluyen el arco interior cara, cara externa curva, alargamiento a la tracción, el par, y el impacto. Los datos cuantificables se pueden obtener mediante el uso de procedimientos de laboratorio y los datos de comparación al contrastar con muestras de control.

2.7.6. Ensayos según ASME IX

Para la calificación de los procedimientos de soldadura por termofusión y calificación de los operadores se realizaran las siguientes pruebas:

A. Ensayo No Destructivo (END)

Se realizará una inspección visual de la unión de muestra.

A.1. Criterio de aceptación:

- ✓ El cordón de soldadura deberá ser continuo y de tamaño constante alrededor de la circunferencia entera del tubo.
- ✓ El cordón deberá estar libre de socavación en los bordes exteriores.

✓ La falta de alineación deberá ser lo más pequeña posible y no deberá exceder el 10% del espesor de la tubería.

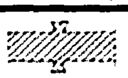
✓ No habrá aberturas, ni vacíos visible entre los cordones del empalme por fusión.

✓ El ancho total del doble cordón de soldadura será aproximadamente ser de 2 a 2 ½ veces la altura del cordón desde la superficie del tubo.

✓ El cordón deberá estar libre de porosidades.

TABLA N° 2.4

CRITERIOS DE ACEPTACION DE LA INSPECCION VISUAL

CORRECTO	
	1.- Bordon redondeado Soldadura correcta
	2.- El bordon es demasiado estrecho y alto Exceso de presion
	3.- El bordon es muy pequeño Pesion insuficiente
	4.- Una hendidura profunda en el centro del bordon Temperatura insuficiente o tiempo de transicion demasiado largo
	5.- Desalineamiento La desviacion maxima permitida es del 10% del espesor de pared
	6.- Diferentes espesores de pared Se recomienda utilizar accesorios electrosoldables
	7.- Los materiales tienen diferentes temperaturas de fusion

Fuente: Soldadura de Plásticos [21]

[21] http://www.soldaduraplasticos.com/control-de-calidad-para-la-soldadura-a-tope/

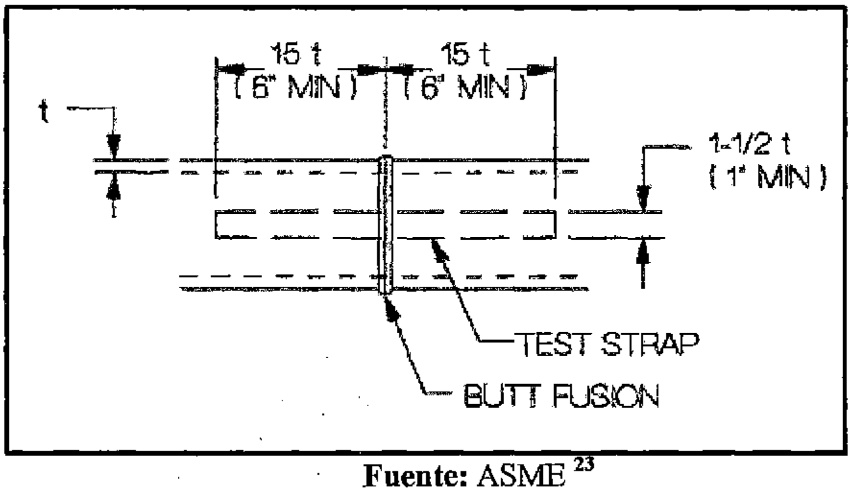
B. Ensayos Destructivos (ED)

Se preparará una probeta de muestra para validar los parámetros.

Evaluar las juntas de las probetas, para verificar la habilidad y el conocimiento del operador de fusión. En algunos casos, la fusión a tope puede examinarse de manera no destructiva usando equipos de ultrasonido para detectar porosidad u otras discontinuidades. Para las pruebas destructivas, cortar tiras de acuerdo a las dimensiones que se indican en la norma **ASME IX – FIGURA QF 463, 464**[22]. Examinar visualmente la continuidad y fuerza de unión. Los exámenes que se han mostrado útiles para este propósito incluyen; cara interna, cara externa; flexión, tracción, elongación, torsor e impacto. Datos cuantificables pueden ser obtenidos por el uso de procedimientos de laboratorio y comparar datos contra muestras de control.

FIGURA N° 2.6

ESPECIMEN ENSAYO DE DOBLEZ



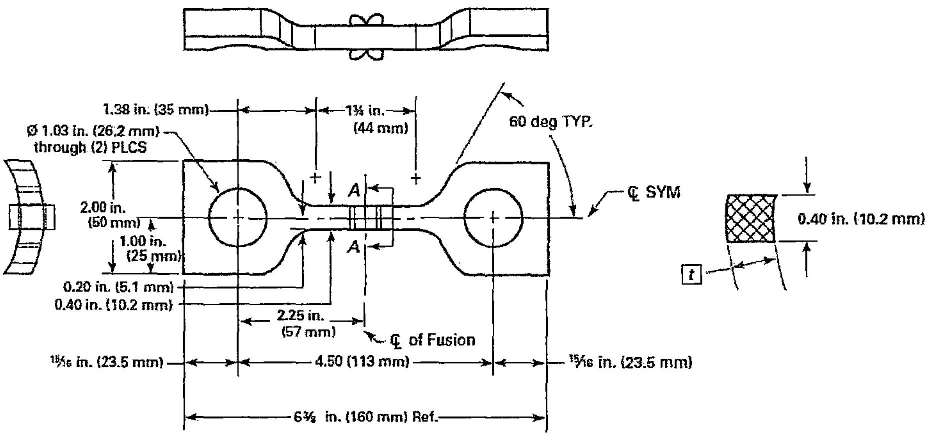
Fuente: ASME [23]

[22] ASTM D2657-07. **Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings.** 24 de Octubre 2012.
[23] ASME IX 2013, **PART QF – ARTICLE XXI.**

FIGURA N° 2.7

ESPECIMEN ENSAYO DE TRACCION

Figure QF-464
HSTIT Specimen Configuration and Dimensions



GENERAL NOTES:
(a) All machined surfaces 125 RMS or better.
(b) 3 place dimensions ±0.005 in. (±0.13 mm).
(c) 2 place dimensions ±0.010 in. (±0.25 mm).
(d) Fractional dimensions ±1/32 in. (±0.80 mm).
(e) All internal radii R 1/2 in. (±0.13 mm).
(f) All external radii R 3/8 in. (10 mm).
(g) Bead remains on after machining.

Fuente: ASME [23]

B.1. Criterio aceptación según ASME:

- ✓ Las pruebas destructivas se deben de realizar diariamente según el ASME IX, entre las cuales están, la prueba de doblez y la prueba de tracción, esta última hasta la rotura de la pared de la tubería de Polipropileno y/o de la unión termo soldada de las tuberías Polipropileno de prueba. La calificación se hará para cada diámetro y para cada espesor de la tubería Polipropileno del proyecto.
- ✓ Las pruebas no destructivas por ultrasonido se realizaran totalmente a todas las uniones de Termo fusión para verificar la continuidad de fase del Polipropileno de las uniones.

- ✓ Las pruebas destructivas serán realizadas con pruebas de doblado y pruebas de tensión a la rotura a partir de una probeta PP cuyo ancho es 1.5 veces el espesor de la pared de la tubería PP; y la longitud 15 veces el espesor de la tubería (longitud a ambos lados de la unión por termo fusión de las tuberías PP) las probetas podrían obtenerse a intervalos de 120° de la circunferencia de la pared de la tubería PP.

CAPITULO III

VARIABLES E HIPOTESIS

3.1. Variables de la investigación

DEPENDIENTES	INDEPENDIENTES
Tuberías de polipropileno que cumplan con estándares internacionales.	Plan de aseguramiento de calidad del proceso de termofusión.

3.2. Operacionalizacion de las variables

VARIABLE	DIMENSIONES	INDICADORES	CATEGORIAS
DEPENDIENTES Uniones de tuberías de polipropileno que cumplan con los estándares internacionales.	- ASTM - ASME IX	Ensayos destructivos y no destructivos normados	ACEPTABLE NO ACEPTABLE
INDEPENDIENTES Diseño del plan de aseguramiento de calidad del proceso de termofusión.	- Procedimientos	Presion Temperatura Tiempo	TABLAS

3.3. Hipótesis

3.3.1. General

Al diseñar el plan de aseguramiento de calidad del proceso de termofusion se obtendrá uniones de tuberías de polipropileno que cumplan con los estándares internacionales.

3.3.2. Específicos

- ✓ Si se preparan probetas de tuberías de polipropileno soldadas por el proceso de termofusión y se realiza Inspección Visual, entonces se realizaran los ensayos destructivos normados.

- ✓ Si los resultados de los ensayos de las probetas de tuberías de polipropileno son aceptables, entonces se prepara la Especificación de Procedimiento de Fusión (FPS).

CAPITULO IV

METODOLOGIA

4.1. Tipo de investigación

Se realizaron experimentos en el Laboratorio de Materiales de la PUCP, bajo el Código ASME, se consideró una probeta a la cual se le realizaron ensayos de tracción y doblez. Al obtener los resultados los cuales se compararon con ensayos similares a tuberías de Polietileno, se pudieron manejar diferentes datos. Por lo que se llega a determinar que la presente Investigación es Experimental.

4.2. Diseño de la investigación

Diseño descriptivo simple:

M: probeta

O: FPS

4.3. Población y Muestra

Población	Muestra	
Tuberías de Polipropileno	Tubería ∅ 1	3”

4.4. Técnicas e instrumentos de recolección de datos

Técnica de observación; se realiza el control de los parámetros a considerar para el posterior análisis, se verifica que se cumpla con lo establecido en las tablas del fabricante del equipo de fusión.

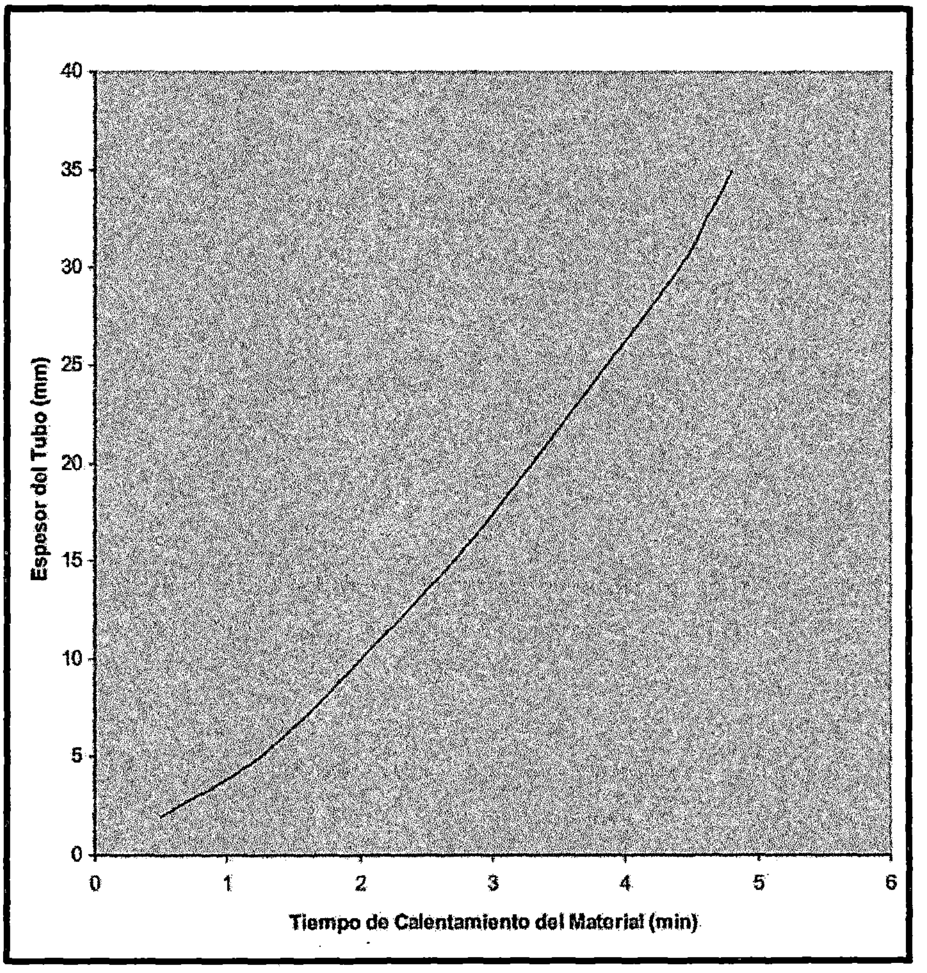
Instrumentos:

- Cronometro
- Pirometro
- Tablas de parámetros del equipo de fusión.
- Procedure Qualification Record PQR.

4.5. Procesamiento estadístico y control de datos

GRAFICO N° 1

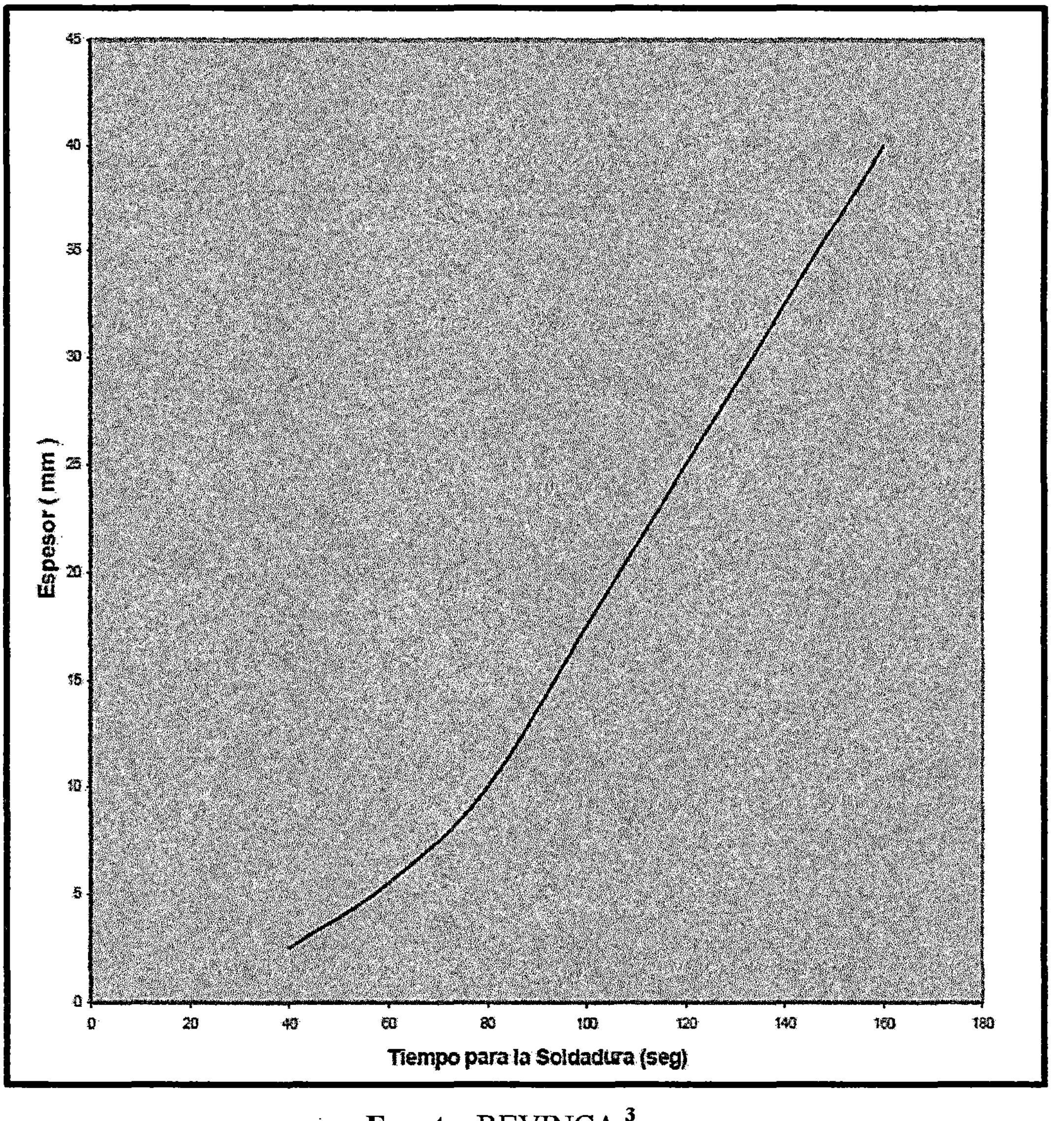
CALENTAMIENTO DEL MATERIAL



Fuente: REVINCA [3]

GRAFICO N° 2

TIEMPO TOTAL DE SOLDADURA



Fuente: REVINCA [3]

CAPITULO V

RESULTADOS

LABORATORIO DE MATERIALES
Departamento de Ingeniería
Sección Ingeniería Mecánica

PONTIFICIA
UNIVERSIDAD CATÓLICA
DEL PERÚ

CON SISTEMA DE ASEGURAMIENTO DE LA CALIDAD SEGÚN NTP ISO/IEC 17025

MAT-AGO-0824-2/2014

ENSAYO DE DOBLADO

MAT-Lab-4.04 Rev.6

INFORME DE LABORATORIO

Número Total de Páginas: 1

SOLICITADO POR : SHIRLEY INES CONCHA FLORES.
DIRECCIÓN : Mz. B Lt. 10 Asociación Cruz de Motupe – Puente Piedra.
REALIZADO POR : Laboratorio de Materiales – Analista 08.
MUESTRA : Tubería de Polipropileno.
FECHA DE EMISIÓN : 2014.08.11.

RESULTADOS:

MUESTRA	ÁNGULO DE DOBLADO	PRESENCIA DE DISCONTINUIDADES	OBSERVACIONES
1	180°	No hay.	CONFORME

Fecha de Ejecución: 2014.08.07.

OBSERVACIONES:

- Condición de la muestra: Visualmente en buen estado.
- La muestra ensayada fue proporcionada por el solicitante.
- Norma de Referencia: ASME IX-13.
- Temperatura ambiente durante el ensayo: 21.7°C.

Según el solicitante:

- Tubería de Ø 90mm x 8.2mm / SDR 11.

PONTIFICIA UNIVERSIDAD CATÓLICA DEL PERÚ
Sección Ingeniería Mecánica

MSc. ANÍBAL ROZAS GALLEGOS CIP. 123020
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LABORATORIO DE MATERIALES
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Sección Ingeniería Mecánica

PONTIFICIA
UNIVERSIDAD CATÓLICA
DEL PERÚ

CON SISTEMA DE ASEGURAMIENTO DE LA CALIDAD SEGÚN NTP ISO/IEC 17025

MAT-AGO-0824-1/2014

ENSAYO DE TRACCIÓN

MAT-Lab-4.04 Rev.6

INFORME DE LABORATORIO

Número Total de Páginas: 2

SOLICITADO POR : SHIRLEY INES CONCHA FLORES.
DIRECCIÓN : Mz. B Lt. 10 Asociación Cruz de Motupe Puente Piedra.
REALIZADO POR : Laboratorio de Materiales - Analista 08.
MUESTRA : Tubería de Polipropileno.
FECHA DE EMISIÓN : 2014.08.11.

RESULTADOS:

MUESTRA		1
SECCIÓN TRANSVERSAL (a x b)	ANCHO (mm)	19.00
	ESPESOR (mm)	8.27
	ÁREA (mm^2)	157.1
CARGAS (kN)	MÁXIMA	5.11
ESFUERZOS (MPa)	MÁXIMA	33

Fecha de ejecución : 2014.08.07.

Incertidumbres (factor de cobertura K=2, para un nivel de confianza de 95%)

- Esfuerzo máximo (MPa) **± 0.2**

OBSERVACIONES:

. Condición de la muestra: Visualmente en buen estado.
. La muestra ensayada fue extraída de la muestra proporcionada por el solicitante.
. Norma de Ensayo: ASME IX-13.
. Temperatura ambiente durante el ensayo: 22.3°C.
. La muestra rompió en la línea de fusión, se aprecia zona con falta de fusión.
Según el Solicitante:
. Tubería de Ø 90mm x 8.2mm / SDR 11.

AA - 44011

PONTIFICIA UNIVERSIDAD CATÓLICA DEL PERÚ
Sección Ingeniería Mecánica

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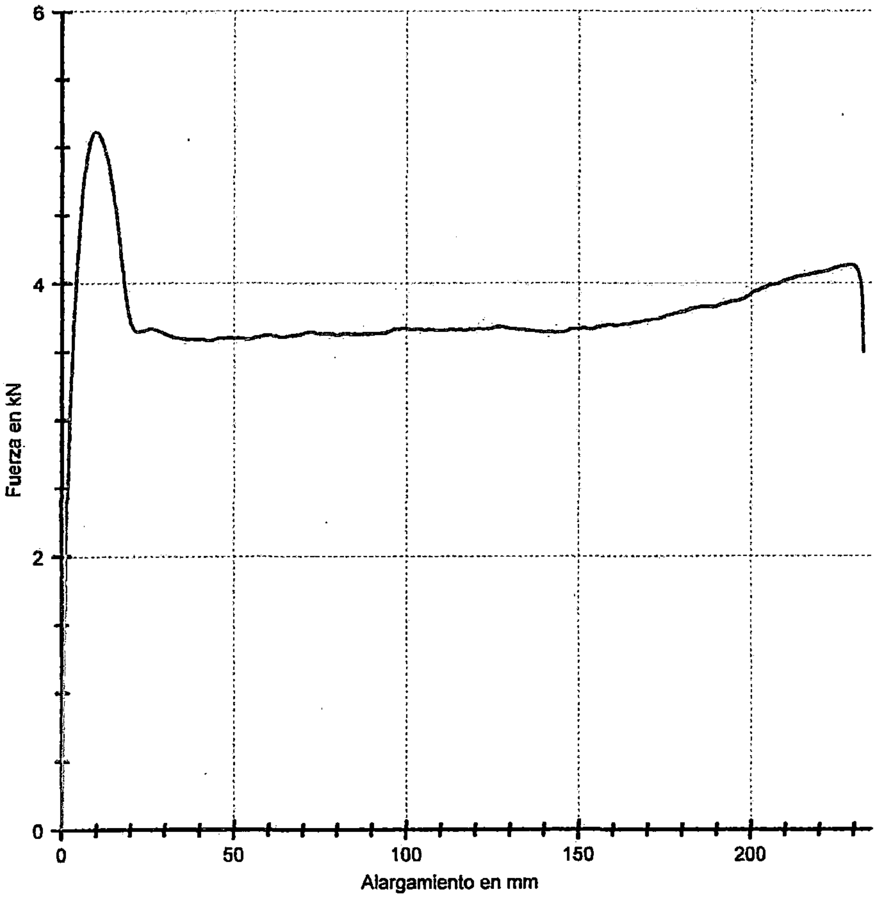
Zwick / Roell 08.08.14

MAT-AGO-0824/2014

CURVA FUERZA - ALARGAMIENTO



AA - 45342

PONTIFICIA UNIVERSIDAD CATÓLICA DEL PERÚ
Sección Ingeniería Mecánica

MSc. ANÍBAL ROZAS GALLEGOS CIP. 123020
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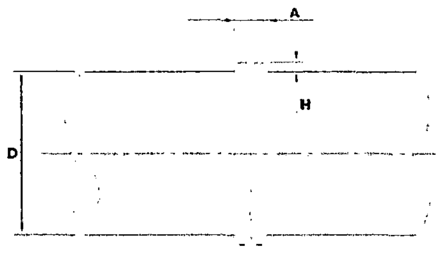
FORM QF-482 Suggested Format for Fusing Procedure Specifications (FPS)
(See QF-201.3, Section IX, ASME Boiler and Pressure Vessel Code)

Company Name *FACULTAD DE INGENIERIA MECANICA DEL CALLAO* By *CONCHA FLORES SHIRLEY INES*
Fusing Procedure Specification No. *FPS-UNAC-001* Date *11/08/2014*
Revision No. *00* Date *11/08/2014*

FPS Qualification [X] By testing [ ] SFPS If qualified by testing, supporting PQR No.(s) *PQR-UNAC-001*
Fusing Process Type *TERMOFUSION*

Joints (QF-402) Details

Joint Type *A TOPE*
Pipe End Preparation *CORTE DE TUBERIA Y REFRENTADO DE CARAS*
Miter Joint Angle *90°*
Pipe Surface Alignment *MORDAZAS*
Sketches, production drawings, weld symbols, or written description should show the general arrangement of the parts to be fused. Where applicable, the details of the joint groove may be specified.



Sketches may be attached to illustrate joint design.

Materials (QF-403)
Specification *POLIPROPILENO* Classification PP - H to Specification *POLIPROPILENO* Classification PP - H
Pipe Size (Diameter) *Hasta 90 mm* Pipe Wall Thickness *Hasta 8.2 mm*
Other *SDR 11*

Position (QF-404)
Pipe Position *HORIZONTAL*
Other *+/- 45°*

Thermal Conditions (QF-405)
Heater Surface Temperature Range *220 +/- 10°C*
Fusing Interfacial Pressure Range *8 bar*
Drag Pressure Range *2 bar* Butt-Fusing Pressure Range *6 bar*
Melt Bead Size Range *1 mm* Heater Plate Removal Time Range *3 seg*
Cool-Down Time at Butt-Fusing Pressure Range *16 min*

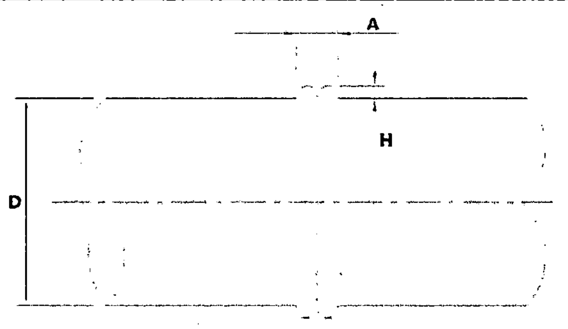
Equipment (QF-406)
Fusing Machine Manufacturer *P160B ROTHEMBERG HIDRAULICA*
Data Acquisition Used [ ] Yes [ ] No Data Acquisition Machine Manufacturer
Hydraulic Hose Length *40 -160 mm*

Technique (QF-407)
Location [X] Fabrication Shop [ ] Field

FORM QF-483 Suggested Format for Fusing Procedure Qualification Records (PQR)
(See QF-201.5(d), Section IX, ASME Boiler and Pressure Vessel Code)

Company Name *FACULTAD DE INGENIERIA MECANICA DEL CALLAO*
Procedure Qualification Record No. *PQR-UNAC-001* Date *07/08/2014*
FPS No. *FPS-UNAC-001*
Fusing Process(es) *TERMOFUSION*

Joints (QF-402)



Pipe Surface Alignment *MORDAZAS*
Pipe End Preparation of Test Coupon

Material (QF-403)
Specification *POLIPROPILENO* Classification PP - H
to Specification *POLIPROPILENO* Classification PP - H
Pipe Size (Diameter) *90 mm*
Pipe Wall Thickness *8.2 mm*
Other *SDR 11*

Equipment (QF-406)
Fusing Machine Manufacturer
P160B ROTHEMBERG HIDRAULICA
Data Acquisition Used ----------
Data Acquisition System Manufacturer --------
Hydraulic Hose Length *40 -160 mm*

Position (QF-404)
Position of Pipe *HORIZONTAL*
Other ---------

Technique (QF-407)
Location [X] Fabrication Shop [ ] Field

Thermal Conditions (QF-405)
Heater Surface Temperature *210 °C*
Fusing Interfacial Pressure *8 bar*
Drag Pressure *2 bar*
Butt-Fusing Pressure *6 bar*
Melt Bead Size *1 mm*
Heater Plate Removal Time *3 seg.*
Cool-Down Time at Butt-Fusing Pressure *16 min*
Tiempo de calentamiento 198 seg.
Other

Other

FORM QF-483 (Back)

PQR No. *PQR-UNAC-001*

Visual Examination (QF-141)

NO PRESENTO NINGUNA DISCONTINUIDAD

Bend Tests (QF-142)

Specimen	**Type**	**Results**
MUESTRA 1	DOBLEZ DE RAIZ	CONFORME
--------	---------------	-----------------------
--------	---------------	-----------------------

High-Speed Tensile Impact Tests (QF-144)

Specimen	**Width/ Diameter**	**Thickness**	**Area**	**Ultimate Load**	**Results**
MUESTRA 1	90mm	8.2mm/SDR11	157.1 mm^2	33 Mpa	CONFORME
--------	------------	------------	---------	---------	---------
--------	------------	------------	---------	---------	---------
--------	------------	------------	---------	---------	---------

Attach additional sheet(s) for high-speed tensile test impact test data for pipe larger than NPS 4 (DN 100).

Fusing Machine Operator's Name CARLOS VERA *Identification No.* 41795826 *Stamp No.* CV-26
Tests Conducted By RONALD PERALTA *Laboratory Test No.* MAT-Lab-4.04

We certify that the statements in this record are correct and that the test joints were prepared, fused, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Organization FACULTAD DE INGENIERIA MECANICA DEL CALLAO
Date 07/08/2014 *Certified By* SHIRLEY CONCHA FLORES

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

FORM QF-484 Suggested Format for Fusing Machine Operator Performance Qualifications (FPQ)
(See QF-301.4, Section IX, ASME Boiler and Pressure Vessel Code)

using Machine Operator's Name *CARLOS VERA* Identification No. *41795826*

Test Description (Information Only)

ype of Test: [X] Original qualification [ ] Requalification

lentification of FPS Followed *FPS-UNAC-001*

ipe Specification *POLIPROPILENO* Classification PP - H to Specification *POLIPROPILENO* Classification PP - H

ipe Size (Diameter) *90 mm* Pipe Wall Thickness *8.2 mm (SDR 11)*

Testing Conditions and Qualification Limits

Fusing Variables (QF-360)	Actual Values	Range Qualified
Pipe Material	POLIPROPILENO	POLIPROPILENO
Pipe Size (Diameter)	90 mm	Hasta 90 mm
Pipe Position	HORIZONTAL	+/- 45°
Fusing Machine Manufacturer	*P160B ROTHEMBERG HIDRAULICA*	*P160B ROTHEMBERG HIDRAULICA*

RESULTS

Visual Examination of Completed Joint [QF-305.2(a)] OK

Examination of Data Acquisition Output [QF-305.2(b)] OK

Bend Tests (QF-302.2)

Specimen No.	Type of Bend	Result	Specimen No.	Type of Bend	Result
MUESTRA 1	*DOBLEZ DE RAIZ*	*OK*	-------	---------------	----------
----------	--------------	----------	-------	---------------	----------

Bend Specimens Evaluated By *RONALD PERALTA* Company *PONTIFICIA UNIVERSIDAD CATOLICA DEL PERU*

Mechanical Tests Conducted By *ANIBAL ROSAS GALLEGOS* Laboratory Test No. *MAT-Lab-4.04*

Fusing Supervised By *CONCHA FLORES SHIRLEY INES*

Data Acquisition Output Examined By *CONCHA FLORES SHIRLEY INES*

We certify that the statements in this record are correct and that the test coupons were prepared, fused, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Organization *FACULTAD INGENIERIA MECANICA DEL CALLAO*

Date *11/08/2014* Certified by *RONALD PERALTA*

CAPITULO VI

DISCUSION DE RESULTADOS

6.1. Contrastación de la Hipótesis con los resultados

RESULTADOS	HIPOTESIS
– Condiciones de la muestra; visualmente en buen estado. – Norma de ensayo ASME IX – 2013 – La muestra no presenta fisura en el material base. – La muestra corresponde a la muestra identificada con: ∅ 90 MM/SDR 11.	Al diseñar un plan de aseguramiento de calidad del proceso de termofusion se obtendrá uniones de tuberías de polipropileno que cumplan con los estándares internacionales.

6.2. Contrastación de los resultados con otros estudios similares

Esta investigación dio resultados que se contrastan con ensayos de otro material, HDPE (Polietileno de alta densidad):

MAT-SET-0902/2012

ENSAYO DE DOBLADO

INFORME DE LABORATORIO

MAT-Lab-4.04

Número Total de Páginas: 3

SOLICITADO POR : SSK MONTAJES E INSTALACIONES S.A.C.
DIRECCIÓN : Calle Amador Merino Reyna 281 Of. 801 - San Isidro.
REALIZADO POR : Laboratorio de Materiales – Analista 09.
MUESTRA : PROBETAS DE HDPE.
FECHA : 2012.09.19.

RESULTADOS:

MUESTRA	ÁNGULO DE DOBLADO	PRESENCIA DE DISCONTINUIDADES	OBSERVACIONES
1	180°	No hay.	CONFORME
2	180°	Fisura de borde (<6mm)	CONFORME

Fecha de Ejecución: 2012.09.19

OBSERVACIONES:

- Condición de la muestra: Visualmente en buen estado.
- Las muestras ensayadas fueron extraídas de las muestras proporcionadas por el solicitante.
- Norma de referencia: ASME Secc. IX 2010
- Las muestras corresponden a la muestra identificada con Ø10" / SDR 11
- Temperatura ambiente durante el ensayo: 21.4°C

PONTIFICIA UNIVERSIDAD CATÓLICA DEL PERÚ
Sección Ingeniería Mecánica

Ing. RAÚL HURTADO ESPEJO CIP. 128758
Jefe del Laboratorio de Materiales

Los resultados presentados son válidos únicamente para las muestras ensayadas.
Prohibida la reproducción total o parcial de este informe sin la autorización escrita del Laboratorio de Materiales.
Los resultados no pueden ser utilizados como una certificación de conformidad con normas de producto o como certificado del sistema de calida de la entidad que lo produce.

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MAT-SET-0902/2012

ENSAYO DE TRACCIÓN

MAT-Lab-4.04 Rev.6

INFORME DE LABORATORIO

Número Total de Páginas: 3

SOLICITADO POR : SSK MONTAJES E INSTALACIONES S.A.C.
DIRECCIÓN : Calle Amador Merino Reyna 281 Of. 801 - San Isidro.
REALIZADO POR : Laboratorio de Materiales - Analista 09.
MUESTRA : PROBETA DE HDPE.
FECHA : 2012.09.19.

RESULTADOS:

MUESTRA		1	2
SECCIÓN TRANSVERSAL (a x b)	ANCHO (mm)	19.43	19.44
	ESPESOR (mm)	26.87	26.09
	ÁREA (mm^2)	522.1	507.2
CARGAS (kN)	MÁXIMA	12.9	12.6
ESFUERZOS (MPa)	MÁXIMA	25	25

Fecha de ejecución : 2012.09.19

Incertidumbres (factor de cobertura K=2, para un nivel de confianza de 95%)

• Esfuerzo máximo (MPa)	± 0.5	± 0.5

OBSERVACIONES:

. Condición de las muestras: Visualmente en buen estado.
. Las muestras ensayadas fueron extraídas de la muestra proporcionadas por el solicitante.
. Norma de ensayo: " ASME IX - 2010.
. Norma de referencia: "Process Piping" ASME B31.3 - 2010
. Temperatura de ambiente durante el ensayo: 21.4°C
. Las muestras rompieron en el material base.
. Las muestras corresponden a la muestra identificada con: ø10" / SDR 11.

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Ing. RAÚL HURTADO ESPEJO CIP. 128758
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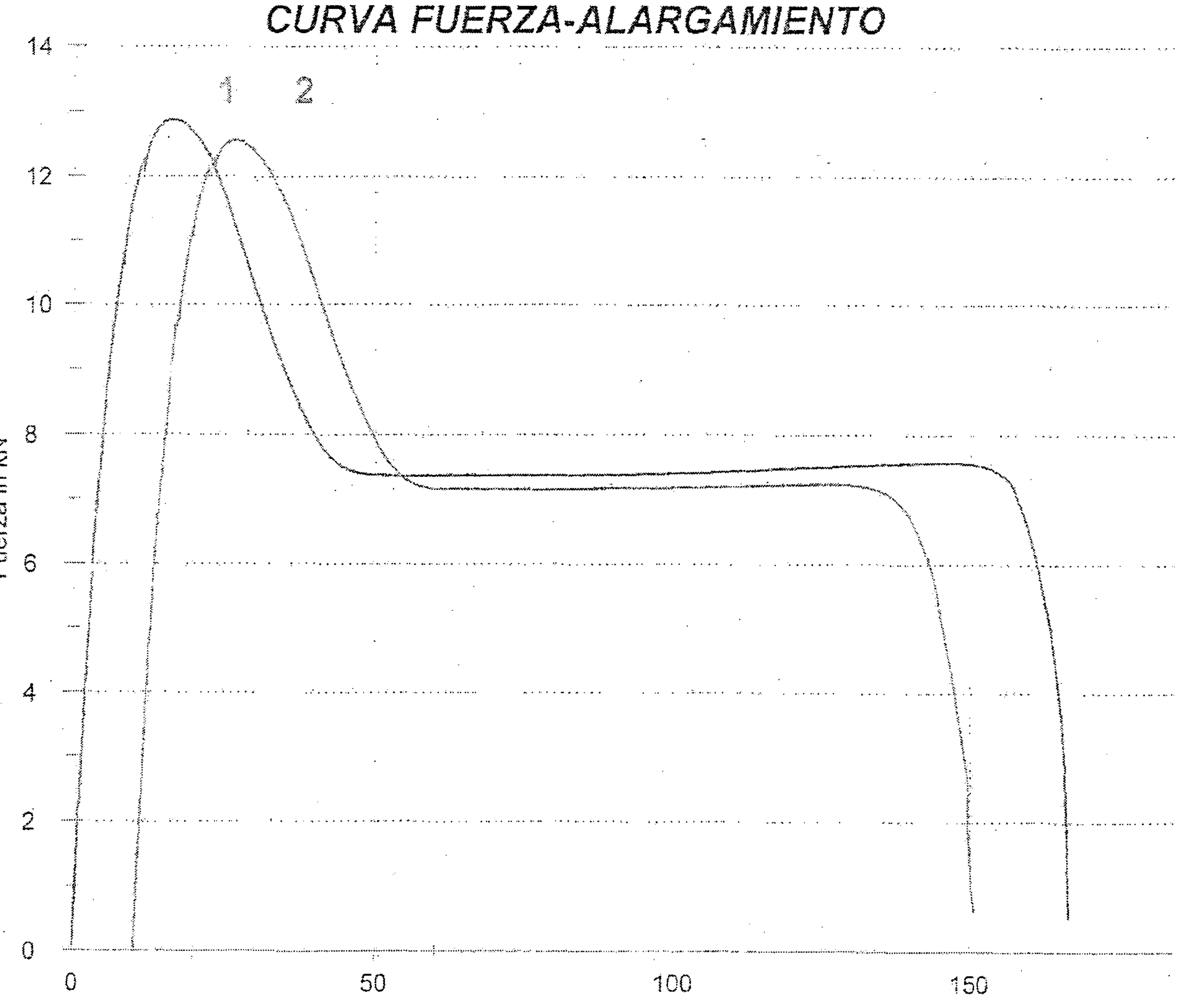
MAT-SET-0902/2012

CURVA FUERZA-ALARGAMIENTO



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SSK	**REGISTRO**	RE-2063-SO-F002
	ACTIVIDAD DE LA CONSTRUCCIÓN	Hoja: 1 de 1
		Revisión: 0
	ESPECIFICACIÓN DE PROCEDIMIENTO DE SOLDADURA (BPS) *(De acuerdo a ASME B31.3)*	Edición: 20/09/12

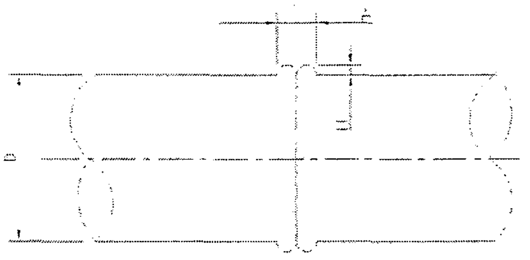
IDENTIFICACION

Registro N°:	*BPS/HDPE/004*		
Nombre de la compañía:	*SSK MONTAJES E INSTALACIONES S.A.C.*	Rev. N°:	*0* Fecha: *03/10/12*
Proceso(s) de soldadura:	*TERMOFUSIÓN*	Autorizado por:	*Sergio Droguett*
		PQR Soporte N°:	*BPQR/HDPE/001*

DISEÑO DE JUNTA

Tipo:	*A tope*
Posición:	*Horizontal*
Preparación:	*Corte de tubería y refrentado de caras*
Limpieza:	*Alcohol metílico y/o thinner*
Alineamiento:	*Mordazas*
Otro:	---

Detalle



H: Altura	A: Ancho (2H ≤ A ≤ 2,5H)	T: Espesor
---	---	*11,03 mm*

METAL BASE

Tipo de material:	*Polietileno de alta densidad (HDPE)*		
Especificación de tipo y grado:	*ASTM D-3035*	A especificación de tipo y grado:	*ASTM D-3035*
Diámetro de tubería:	*4" (Øe 114,5 mm)*	DR de tubería:	*SDR 11*
Rango de espesores:	*5,0 – 54,0 mm*		
Otro:	---		

PARAMETROS DE FUSIÓN

Temperatura superficial de calentador:	*210 ± 10 °C*	Presión de fusión:	*10 bar*
Altura de cordón contra calentador:	*1,5 mm*	Presión de calentamiento:	*1,4 bar*
Tiempo de calentamiento:	*107 s*	Tiempo para alcanzar presión de fusión:	*7 s*
Tiempo de retirar calentador:	*7 s máx.*	Tiempo de enfriamiento:	*14 min*

CONDICIONES AMBIENTALES

Temperatura ambiente:	*5 °C mín.*	Otro:	---
Humedad relativa:	*< 85%*		---

MÁQUINA DE TERMOFUSIÓN

Tipo:	*Maquina hidráulica de fusión a tope*		
Marca:	*Omicron*	Rango de aplicación:	*90 – 315 mm*
Modelo:	*PSO 825*	Otro:	---

NOTAS/ COMENTARIOS/ OBSERVACIONES:

Los parámetros de fusión se obtuvieron del manual de la máquina de termofusión Omicron PSO 825.

APROBACIÓN	Inspector de Soldadura SSK	Control de Calidad SSK	
Nombres y Apellidos	Juan Oré Barrientos	Alexander Gonzales M.	
Fecha	03-10-12	03/10/12	
Firma	[firma]	[firma]	

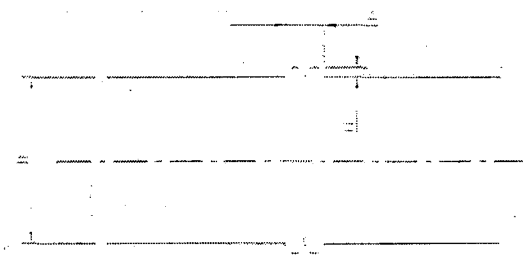
IDENTIFICACIÓN

IDENTIFICACIÓN		Registro Nº:	*BPQR/HDPE/001*
Nombre de la compañía:	*SSK MONTAJES E INSTALACIONES S.A.C.*	Rev. Nº:	*0* Fecha: *21/09/12*
Proceso(s) de soldadura:	*TERMOFUSIÓN*	Autorizado por:	*Sergio Droguett*
		WPS Nº:	*BPS/HDPE/001*

DISEÑO DE JUNTA

Tipo:	*A tope*
Posición:	*Horizontal*
Preparación:	*Corte de tubería y refrentado de caras*
Limpieza:	*Thinner*
Alineamiento:	*Mordazas*
Otro:	---

Detalle



H: Altura	A: Ancho (2H ≤ A ≤ 2,5H)	T: Espesor
5,0 mm	*12,0 mm*	*27,0 mm*

METAL BASE

Elemento No. 1		Elemento No. 2	
Tipo:	[X] Tubería [ ] Accesorio	Tipo:	[X] Tubería [ ] Accesorio
Tipo de material:	*Polietileno de alta densidad (HDPE)*	Tipo de material:	*Polietileno de alta densidad (HDPE)*
	---		---
Especificación de tipo y grado:	*ASTM D-3035*	Especificación de tipo y grado:	*ASTM D-3035*
Diámetro:	*10" (Øe 273,6 mm)*	Diámetro:	*10" (Øe 273,6 mm)*
DR:	*SDR 11*	DR:	*SDR 11*
Espesor:	*27,0 mm*	Espesor:	*27,0 mm*
Otro:	---	Otro:	---

PARAMETROS DE FUSIÓN

Temperatura superficial de calentador:	*220 °C*	Presión de fusión:	*62 bar*
Altura de cordón contra calentador:	*2,5 mm*	Presión de calentamiento:	*8,2 bar*
Tiempo de calentamiento:	*258 s*	Tiempo para alcanzar presión de fusión:	*12 s*
Tiempo de retirar calentador:	*9 s*	Tiempo de enfriamiento:	*31 min*

CONDICIONES AMBIENTALES

Temperatura ambiente:	*15°C*	Otro:	---
Humedad relativa:	*42%*		

MÁQUINA DE TERMOFUSIÓN

Tipo:	*Maquina hidráulica de fusión a tope*		
Marca:	*Omicron*	Rango de aplicación:	*90 – 315 mm*
Modelo:	*PSO 825*	Otro:	---

Registro N°: *BPQR/HDPE/001*

INSPECCIÓN VISUAL

Altura de cordón de soldadura (H): *5,0 mm* — Ancho de cordón de soldadura (A): *12,0 mm*

Apariencia de cordón de soldadura: *Aceptable* — Revisión de registros de adquisición: *Aceptable*

Otro:

ENSAYO DE TRACCIÓN

Informe de Laboratorio N°: MAT-SET-0902/2012

Especímen No.	Ancho (mm)	Espesor (mm)	Area (mm^2)	Carga rotura total (kN)	Resistencia máx. (MPa)	Tipo de falla y ubicación
1	19,43	26,87	522,1	12,9	25	Rotura en material base
2	19,44	26,09	507,2	12,6	25	Rotura en material base

Prueba conducida por: *Raúl Hurtado Espejo* — Fecha: *19/09/2012* — Lugar: *Pontificia Universidad Católica del Perú*

ENSAYO DE DOBLADO

Informe de Laboratorio N°: MAT-SET-0902/2012

Tipo y figura No.	Resultado
1	Aceptable
2	Aceptable

Prueba conducida por: *Raúl Hurtado Espejo* — Fecha: *19/09/2012* — Lugar: *Pontificia Universidad Católica del Perú*

PRUEBA HIDROSTÁTICA

Medio de prueba: --- — Presión de inicio: --- — Presión final: ---

Presión de prueba: --- — Hora de inicio: --- — Hora de fin: ---

Duración de prueba: --- — Resultado: ---

Manómetro:

OTRAS PRUEBAS: ANÁLISIS MACROGRÁFICO

Zona analizada — Sección: --- — Preparación: --- — Ataque químico: --- — Aumentos: ---

Muestras y discontinuidades: ---

Nombre de soldador: *Nilcer Flores López Pierola* — DNI: *10348831* — Estampa No. *B-01*

Prueba conducida por: *Juan Ore Barrientos* — Prueba de laboratorio No. *MAT-SET-0902/2012*

NOTAS/ COMENTARIOS/ OBSERVACIONES:

APROBACIÓN	Inspector de Soldadura SSK	Control de Calidad SSK	
Nombres y Apellidos	Juan Ore Barrientos	Alexander Gonzales M.	
Fecha	03-10-12	03/10/12	
Firma	[firma]	[firma]	

CAPITULO VII

CONCLUSIONES

- Al realizar el proceso de Termofusion según el Plan de Calidad establecido, se demostró que la junta soldada es ACEPTABLE.
- Al realizar la inspección visual se obtuvo un K>0, según ASME es ACEPTABLE.
- Al realizar los ensayos destructivos, preparando las probetas según ASTM, doblez y tracción, se obtuvieron valores dentro de los estándares establecidos en ASME.

  DOBLEZ = espécimen sin fisuras a un Angulo de doblez $\alpha = 160°$

  ESFUERZO MAXIMO = 33MPa (valor dentro de los parámetros establecidos en las propiedades mecánicas del Polipropileno)
- Con los resultados de los ensayos destructivos y no destructivos se procede a realizar el FPS, y se concluye que con los rangos de los parámetros dados en el FPS, se obtendrá buenas juntas de fusión en obra.

CAPITULO VIII

RECOMENDACIONES

- ❑ Para realizar el Plan de Calidad se debe cumplir, con los ensayos requeridos en las Normas para el proceso de termofusion.
- ❑ Las probetas deben ser dimensionadas de acuerdo a Normas.
- ❑ Los ensayos No Destructivos, hace referencia a la inspección visual como primer Test para el control de la unión soldada.
- ❑ Los ensayos Destructivos requeridos para realizar el procedimiento son los ensayos de Doblez y Tracción.
- ❑ En la realización del ensayo de doblez, se debe presentar la probeta con un rebaje en la esquinas de los cordones para evitar la concentración de esfuerzos que perjudiquen nuestros resultados.
- ❑ Los resultados de los ensayos son para preparar el Especificación de Procedimiento de Fusión FPS.

CAPITULO IX

REFERENCIAS BIBLIOGRAFICAS

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[12] CALIDDA. **Instructivo HSE – Union Por Termofusion**. Sistema de Gestión. Código I-GSS-011. 18 de Enero del 2013.

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ANEXOS

MATRIZ DE CONSISTENCIA

PROBLEMA	OBJETIVO	HIPOTESIS	METODOLOGIA	POBLACION
Problema General ¿Cómo diseñar un plan para asegurar la calidad en el proceso de termofusión de tuberías de polipropileno?	**Objetivo General** Diseñar un plan de aseguramiento de la calidad del proceso de termofusión por medio de ensayos y procedimientos de manera sistemática para obtener uniones de tuberías de polipropileno que cumplan con los estándares internacionales. **Objetivos Específicos** – Soldar por el proceso de Termofusion, probetas de tuberías de polipropileno según Código ASME, e inspeccionar la unión por ensayos no destructivos y destructivos de acuerdo a lo establecido en el Código. – Analizar los resultados de los ensayos para preparar la Especificación de Procedimiento de Fusión (FPS).	**Hipótesis General** Al diseñar un plan de aseguramiento de calidad del proceso de termofusion se obtendrá uniones de tuberías de polipropileno que cumplan con los estándares internacionales. **Hipótesis Especifica** – Si se preparan probetas de tuberías de polipropileno soldadas por el proceso de termofusión según norma, entonces se realizaran los ensayos destructivos normados. – Si los resultados de los ensayos de las probetas de tuberías de polipropileno son aceptables, entonces se prepara la Especificación de Procedimiento de Fusión (FPS).	**Tipo** Investigación Experimental **Método** Método Descriptivo. **Diseño de la Investigación** Diseño descriptivo simple: M: probeta O: FPS	**Población y Muestra** Tuberías de Polipropileno | Tubería ∅ 1 | 3”

ANEXO 1

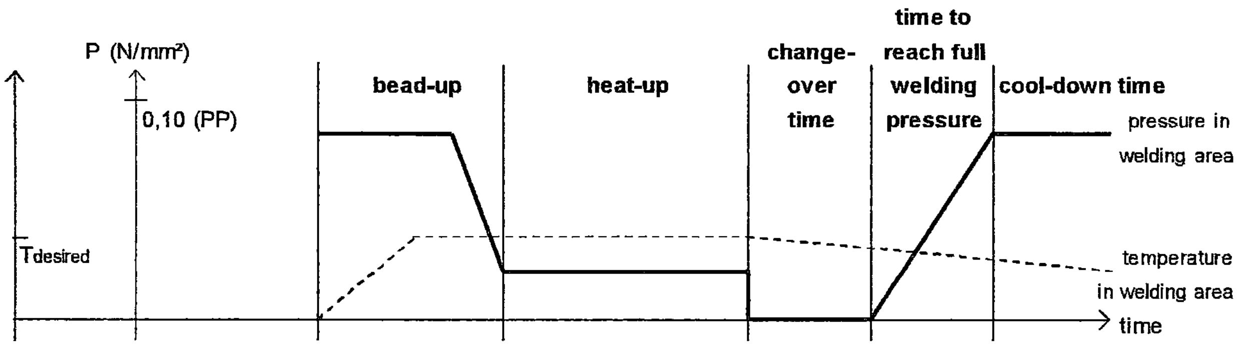
Table for PP

Foundation: 2207, 2208 DIN 16932 German association for welding
Use for: **4400**

1 bar on manometer: **25** N

The standard value for heating element temperature is 210° C +/- 10° C.
The **smaller** the pipe wall the **higher** the temperature.

Additional to the given bead-up force and to the welding force the moving force of the support must be added !



pipe diameter OD [mm]	pipe wall (s) [mm]	SDR	bead-up pressure [bar]	circular bead min. [mm]	heat-up time [s]	max. change-over time [s]	time to reach welding pressure [s]	welding pressure [bar]	cool-down time [min] ❶
50	1,8	33	2	0,5	90	4	5	2	2
	2,0	26	2	0,5	90	4	5	2	2
	2,9	17,6	2	0,5	106	4	5	2	3
	4,6	11	3	0,5	137	5	6	3	6
	6,9	7,4	4	0,5	173	6	7	4	12
	8,3	6	5	1,0	193	6	8	5	14
63	1,8	41	2	0,5	90	4	5	2	2
	2,0	33	2	0,5	90	4	5	2	2
	2,5	26	2	0,5	99	4	5	2	3
	3,6	17,6	3	0,5	119	5	6	3	5
	5,8	11	5	0,5	157	6	7	5	9
	8,6	7,4	6	1,0	197	6	8	6	15
	10,5	6	7	1,0	224	7	10	7	18
75	1,9	41	2	0,5	90	4	5	2	2
	2,3	33	3	0,5	95	4	5	3	2
	2,9	26	3	0,5	106	4	5	3	3
	4,3	17,6	4	0,5	131	5	6	4	6
	6,8	11	6	0,5	172	6	7	6	12
	10,3	7,4	9	1,0	221	7	10	9	17
	12,5	6	10	1,0	251	7	11	10	21
90	2,2	41	3	0,5	94	4	5	3	2
	2,8	33	4	0,5	104	4	5	4	3
	3,5	26	4	0,5	117	5	6	4	4
	5,1	17,6	6	0,5	145	5	6	6	7
	8,2	11	9	1,0	192	6	8	9	14
	12,3	7,4	13	1,0	249	7	11	13	20
	15,0	6	15	1,0	281	8	14	15	24

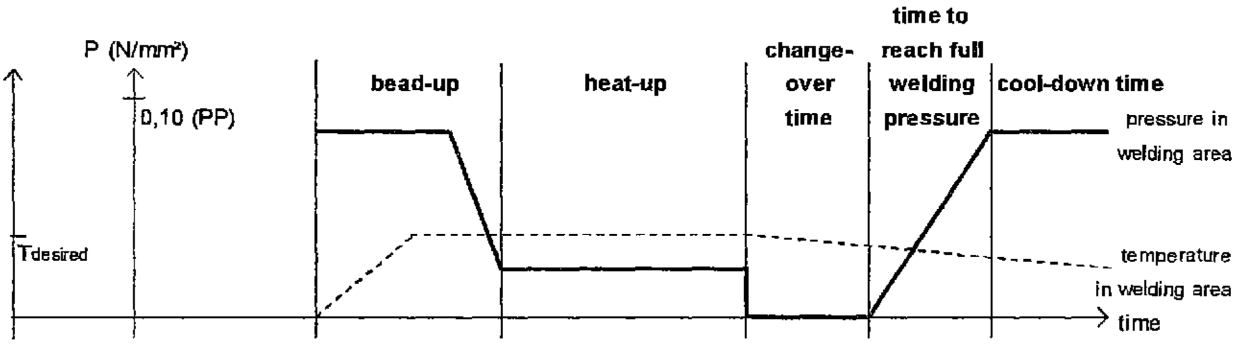
Table for PP

Foundation: 2207, 2208 DIN 16932 German association for welding
Use for: **4400**

1 bar on manometer: **25** N

The standard value for heating element temperature is 210° C +/- 10° C.
The **smaller** the pipe wall the **higher** the temperature.

Additional to the given bead-up force and to the welding force the moving force of the support must be added !



pipe diameter OD [mm]	pipe wall (s) [mm]	SDR	bead-up pressure [bar]	circular bead min. [mm]	heat-up time [s]	max. change-over time [s]	time to reach welding pressure [s]	welding pressure [bar]	cool-down time [min]
110	2,7	41	4	0,5	103	4	5	4	3
	3,4	33	5	0,5	115	5	6	5	4
	4,2	26	6	0,5	130	5	6	6	6
	6,3	17,6	9	0,5	164	6	7	9	10
	10,0	11	13	1,0	217	7	9	13	17
	15,1	7,4	19	1,0	283	8	14	19	24
	18,3	6	22	1,0	322	9	16	22	29
125	3,1	41	5	0,5	110	4	5	5	4
	3,9	33	6	0,5	124	5	6	6	5
	4,8	26	8	0,5	140	5	6	8	7
	7,1	17,6	11	1,0	176	6	7	11	12
	11,4	11	17	1,0	237	7	11	17	19
	17,1	7,4	24	1,0	307	8	15	24	27
	20,8	6	28	1,5	348	10	18	28	33
140	3,5	41	7	0,5	117	5	6	7	4
	4,3	33	8	0,5	131	5	6	8	6
	5,4	26	10	0,5	149	5	6	10	8
	8,0	17,6	14	1,0	189	6	8	14	14
	12,7	11	21	1,0	254	7	12	21	21
	19,2	7,4	30	1,5	332	9	17	30	30
	23,3	6	35	1,5	373	10	20	35	36

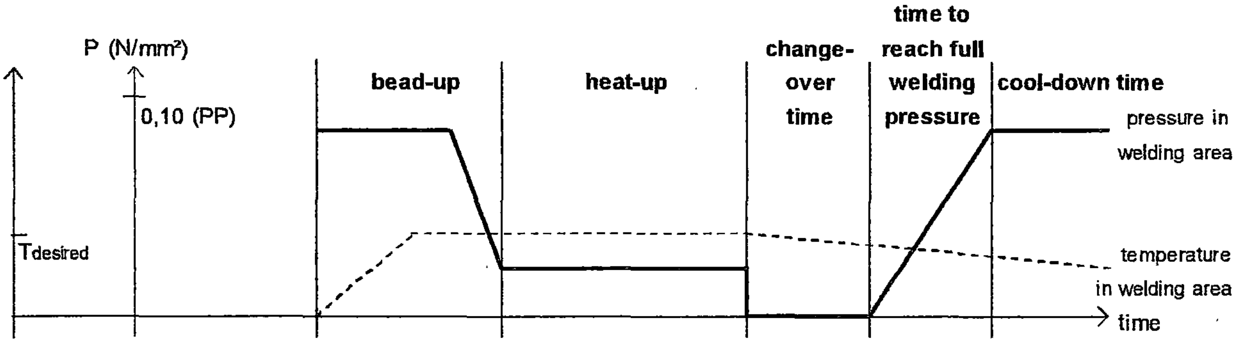
Table for PP

Foundation: 2207, 2208 DIN 16932 German association for welding
Use for: **4400**

1 bar on manometer: **25** N

The standard value for heating element temperature is 210° C +/- 10° C.
The **smaller** the pipe wall the **higher** the temperature.

Additional to the given bead-up force and to the welding force the moving force of the support must be added !



pipe diameter OD [mm]	pipe wall (s) [mm]	SDR	bead-up pressure [bar]	circular bead min. [mm]	heat-up time [s]	max. change-over time [s]	time to reach welding pressure [s]	welding pressure [bar]	cool-down time [min] ❶
160	4,0	41	8	0,5	126	5	6	8	5
	4,9	33	10	0,5	141	5	6	10	7
	6,2	26	12	0,5	162	6	7	12	10
	9,1	17,6	18	1,0	204	6	9	18	15
	14,6	11	27	1,0	277	8	13	27	24
	21,9	7,4	39	1,5	359	10	19	39	34
	26,6	6	45	2,0	405	11	23	45	41

❶ **Remaining under the cool-down time for up to 50% is allowed under the following conditions:**

- prefabrication under workshop conditions
- low additional pressure at unclamping
- no additional pressure during further cooling down
- load onto the workpieces only after being completely cooled down

ANEXO 2

Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings[1]

This standard is issued under the fixed designation D2657; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This practice describes general procedures for making joints with polyolefin pipe and fittings (excluding polyethylene pipe and fittings) by means of heat fusion joining techniques in either a shop or field environment. These procedures are general ones. Specific instructions for heat fusion joining are obtained from product manufacturers. See Practice F2620 for heat fusion joining of polyethylene pipe and fittings.

1.2 The techniques covered are applicable only to joining polyolefin pipe and fittings of related polymer chemistry, for example, polypropylenes to polypropylenes, or polybutylenes to polybutylenes. Material, density, and flow rate shall be taken into consideration in order to develop uniform melt viscosities and formation of a good fusion bond when joining the same material to itself or to other materials of related polymer chemistry.

1.3 Parts that are within the dimensional tolerances given in present ASTM specifications are required to produce sound joints between polyolefin pipe and fittings when using the joining techniques described in this practice.

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

1.5 The text of this practice references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the practice.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See specific safety precautions in 3.1.1, 5.2, 8.2.3.1, Note 8 and Note 9, and A1.1.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F1056 Specification for Socket Fusion Tools for Use in Socket Fusion Joining Polyethylene Pipe or Tubing and Fittings

F2620 Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings

3. Summary of Practice

3.1 Heat-fusion joining uses a combination of heat and force resulting in two melted surfaces flowing together to produce a joint. Fusion bonding occurs when the joint cools below the melt temperature of the material. There is a temperature range within which any particular material is satisfactorily joined. The specific temperature used requires consideration of the properties of the specific material, and the joining environment. With Techniques II or III (3.3.2 or 3.3.3), there is also an appropriate force to be applied which depends upon the material, the fusion equipment being used, and fusion temperature. See Practice F2620 for heat fusion procedure for polyethylene pipe and fittings.

3.1.1 Electrically powered heat fusion tools and equipment are usually not explosion proof. When performing heat fusion in a potentially combustible atmosphere such as in an excavation where gas is present, all electrically powered tools and equipment that will be used in the combustible atmosphere shall be disconnected from the electrical power source and operated manually to prevent explosion and fire. For the heating tool, this requires bringing the heating tool up to or slightly above temperature in a safe area, then disconnecting it from electrical power immediately before use. This procedure is limited to smaller sizes where heating is accomplished before the heating tool drops below acceptable temperature.

[1] This practice is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.20 on Joining.

Current edition approved May 1, 2007. Published May 2007. Originally approved in 1967. Last previous edition approved in 2003 as D2657 – 03. DOI: 10.1520/D2657-07.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2 Adequate joint strength for testing is attained when all of the joint material cools to ambient temperature. The joint shall not be disturbed or moved until it has cooled. See Practice F2620 for heat fusion procedure for polyethylene pipe and fittings.

NOTE 1—Polybutylene undergoes a crystalline transformation for several days after cooling below its melt temperature. Although this phenomenon has an effect on the ultimate physical properties of the material, its effect on testing of joints has not been found to be significant. If there is any question of its effect, a comparison should be made between joints that have been conditioned for different periods of time in order to establish the conditioning-time relationship.

3.3 Three fusion techniques are covered in this practice as follows: See Practice F2620 for heat fusion procedure for polyethylene pipe and fittings.

3.3.1 *Procedure 1, Socket Fusion*—The socket-fusion technique involves simultaneously heating the outside surface of a pipe end and the inside of a fitting socket, which is sized to be smaller than the smallest outside diameter of the pipe. After the proper melt has been generated at each face to be mated, the two components are joined by inserting one component into the other. See Fig. 1. The fusion bond is formed at the interface resulting from the interference fit. The melts from the two components flow together and fuse as the joint cools. Optional alignment devices are used to hold the pipe and socket fitting in Logitudinal alignment during the joining process; especially with pipe sizes 3 in. IPS (89 mm) and larger.

3.3.2 *Procedure 2, Butt Fusion*—The butt-fusion technique in its simplest form consists of heating the squared ends of two pipes, a pipe and a fitting, or two fittings, by holding them against a heated plate, removing the plate when the proper melt is obtained, promptly bringing the ends together, and allowing the joint to cool while maintaining the appropriate applied force. See Fig. 2. An alignment jig shall be used to obtain and maintain suitable alignment of the ends during the fusion operation.

3.3.3 *Procedure 3, Saddle Fusion*—The saddle-fusion technique involves melting the concave surface of the base of a saddle fitting, while simultaneously melting a matching pattern on the surface of the pipe, bringing the two melted surfaces together and allowing the joint to cool while maintaining the appropriate applied force. See Fig. 3.

4. Significance and Use

4.1 The procedures described in Sections 7, 8, and 9, when implemented using suitable equipment and procedures in either a shop or field environment, produce strong pressure-tight joints equal to the strength of the piping material. Some materials are more adaptable to one technique than another. Melt characteristics, average molecular weight and molecular weight distribution are influential factors in establishing suitable fusion parameters; therefore, consider the manufacturer's instructions in the use or development of a specific fusion procedure.

5. Operator Experience

5.1 Skill and knowledge on the part of the operator are required to obtain a good quality joint. This skill and knowledge is obtained by making joints in accordance with proven procedures under the guidance of skilled operators. Evaluate operator proficiency by testing sample joints.

5.2 The party responsible for the joining of polyolefin pipe and fittings shall ensure that detailed procedures developed in conjunction with applicable codes and regulations and the manufacturers of the pipe, fittings, and joining equipment involved, including the safety precautions to be followed, are issued before actual joining operations begin.

6. Apparatus: General Recommendations

6.1 *Heating Tool*—The tool may be heated by gas or electricity. Gas-fired heaters for 2in. IPS and smaller socket and butt fusion joints only, shall have heat sinks of sufficient

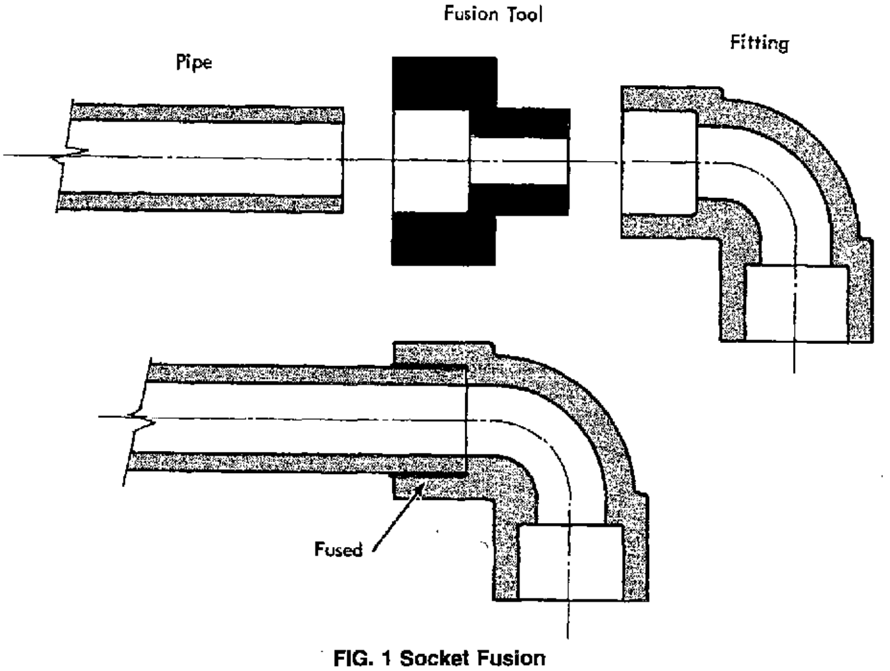


FIG. 1 Socket Fusion

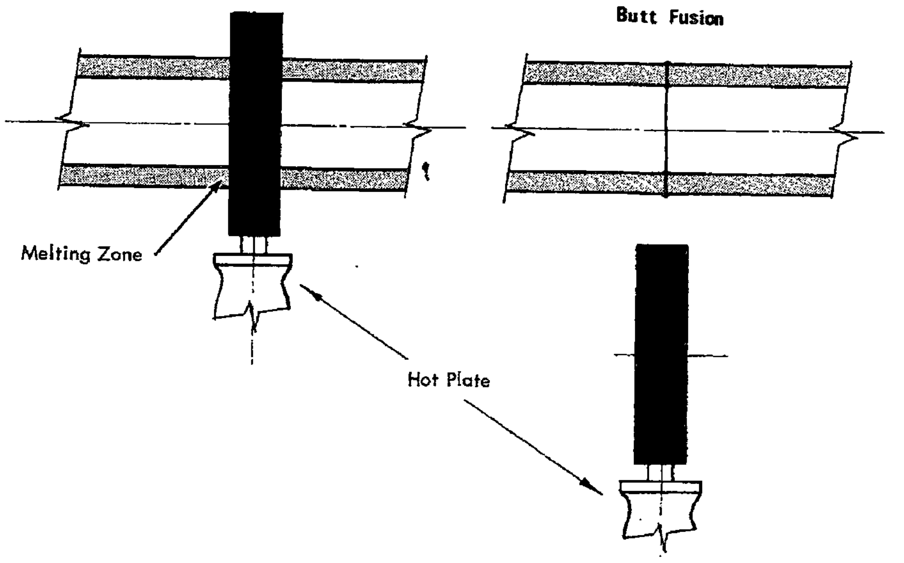


FIG. 2 Typical Butt Fusion Operation

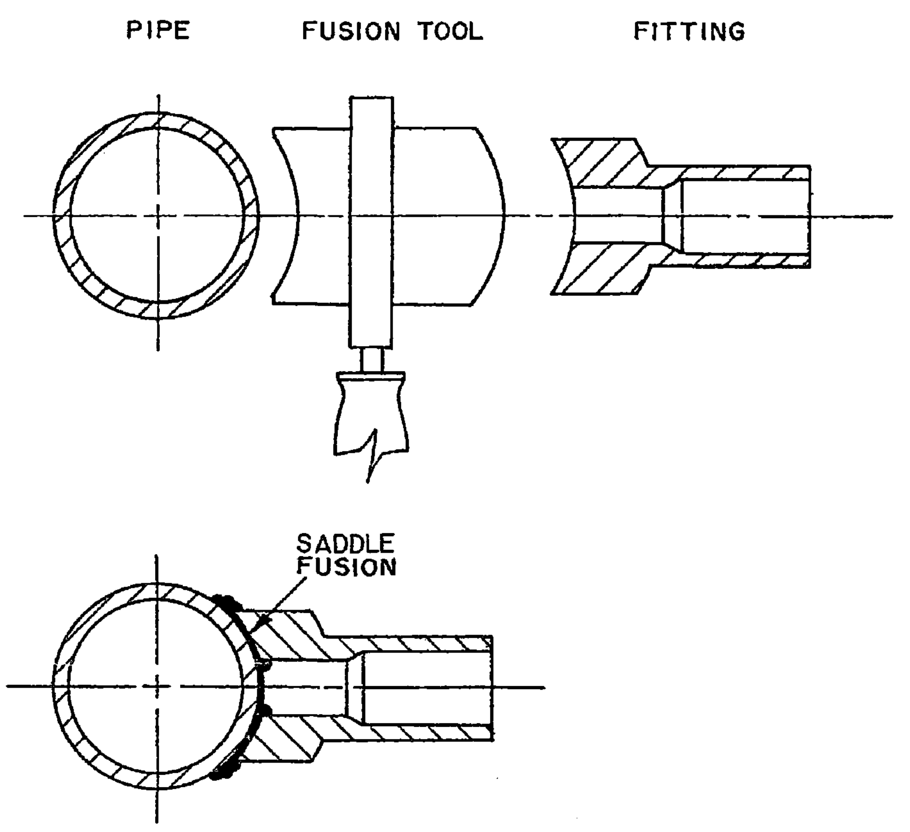


FIG. 3 Saddle Fusion

capacity to prevent excessive draw down of the tool temperature, and are used only in above-freezing conditions. Electric heating plates maintain consistent fusion temperatures when provided with an adequate power source. Electric heating plates for general fusion use shall be controlled thermostatically and most are adjustable for a set point temperature ranging from 300 to 575°F (150 to 300°C). Some tools may have a fixed set point for a particular application.

6.2 *Heating Tool Faces*—Heating tools may be made from materials such as aluminum, stainless steel, copper, or copper alloys. Copper or copper-alloy heating faces are not suitable, unless chromium-plated or clad with another suitable metal, because some polyolefins react with copper. Plastic materials may stick to hot metal heating surfaces. This sticking may be minimized by applying a non-stick coating to the heating surfaces or by fitting a high-temperature, non-stick fabric over the heating surfaces. The heating plate surfaces, coated or uncoated, shall be kept clean and free of contaminants such as dirt, grease and plastic build-up, which may cause excessive sticking and create unsatisfactory joints. Most of these contaminants are removed from the hot tool surfaces using a clean, dry, oil-free lint-free cloth. Do not use synthetic fabrics which may char and stick to the fusion surface. Some pigments, such as carbon black, may stain a heating surface and probably cannot be removed; such stains will not contaminate the joint interface.

6.2.1 After a period of time in service, non-stick coatings or fabrics will deteriorate and become less effective. Deteriorated fabrics should be replaced, and worn, scratched, or gouged non-stick coatings should be re-coated when they lose effectiveness. Heat fusion quality may be adversely affected by deteriorated non-stick surfaces. Spray-on chemicals, such as non-stick lubricants or oils shall not be applied to heating iron surfaces as they will contaminate the joint.

6.3 *Temperature Indicator*—Heating tools shall be equipped with a thermometer or other built-in temperature indicating device. This device indicates the internal temperature of the heating iron which is usually higher than temperature of the fusion surfaces. Use a pyrometer periodically to verify the temperature of the tool surfaces within the pipe or fitting contact area. Select multiple checkpoints to ensure uniform surface temperature.

NOTE 2—A significant temperature variation, that is, cold spots, on the fusion surfaces may indicate a faulty heating iron which may need to be serviced before it can be used.

7. Procedure 1—Socket Fusion

7.1 *Apparatus*—Socket fusion tools manufactured in accordance with Specification F1056 are used for joining polyolefin pipe, tubing, and fittings.

7.1.1 *Heating Tool*—In order to obtain a proper melt, it is necessary for a uniform temperature to be maintained across the heating surface. Therefore, gas-fired tools are generally restricted to use with pipe sizes of 2 in. IPS (63 mm) or less.

7.1.2 *Heating Tool Faces*—Consisting of two parts, a male end for the interior socket surface and a female end for the exterior pipe surface. Both parts shall be made to such tolerances as to cause an interference fit.

7.1.3 *Alignment Jig*—The alignment jig is an optional tool which consists of two sets of devices holding the components in alignment to each other. One set of holding devices is fixed, and the other allows longitudinal movement for making the joint.

7.1.4 *Rounding Clamps*, (cold ring) to maintain roundness of the pipe and control the depth of pipe insertion into the socket during the joining operation.

7.1.5 *Depth Gage*, for proper positioning of the rounding clamp.

7.1.6 *Chamfering Tool*, to bevel the end of the pipe.

NOTE 3—The depth gage and chamfering tool may be combined into a single tool.

7.1.7 *Tubing Cutter*, to obtain a square end cut on the pipe.

7.1.8 *Fitting Puller*, an optional tool to assist in the removal of the fitting from the heating tool and to hold the fitting during assembly.

7.2 *Procedure*:

7.2.1 Attach the proper size heater faces to the heating tool, and heat the tool to the fusion temperature for the material.

7.2.2 Cut the pipe end squarely, and clean the pipe end and fitting, both inside and outside, by wiping with a clean, dry, oil-free, lint-free cloth.

7.2.3 Chamfer the outside edge of the pipe end slightly and fix the rounding clamp about the pipe as determined from the depth gage.

NOTE 4—Chamfering may not be required by some procedures or some fusion tools. Pipe sizes 1 in. (25.4 mm) and smaller are not usually chamfered, regardless of tooling design.

NOTE 5—Some recommend using a 50 to 60-grit emery or garnet cloth to roughen the outside of the pipe and inside of the fitting as a means of minimizing any possible skin interface when making the fusion. Sandpaper is not recommended for this purpose, as it might disintegrate and contaminate the joint interface. If roughening is performed, first clean the surfaces before roughening. Clean dust and particles from the roughened surfaces afterwards by wiping with a clean, dry, oil-free, lint-free cloth.

7.2.4 Bring the preheated tool faces into contact with the outside surface of the end of the pipe and the inside surface of the socket.

7.2.5 Heat the pipe end and the fitting socket for the time required to obtain a proper melt. Proper melt is a function of material, time, tool temperature, and the size of the parts. Pipe and fittings of larger diameters require more time to reach the proper melt consistency than those of smaller diameters. Underheated or overheated materials will not form a good bond.

7.2.6 At the end of the heating time, simultaneously remove the pipe and fitting straight out from the tool, using a snap action. Immediately insert the pipe straight into the socket of the fitting so the rounding clamp is flush against the end of the fitting socket. Hold or block the joint in place until the melts of the mating surfaces have solidified. The exact cooling time depends on the size of the pipe and the material being fused.

7.2.7 Remove the rounding clamp, and inspect the melt pattern at the end of the socket for a complete impression of the rounding clamp in the melt surface. There shall no gaps, voids, or unbonded areas. Clean the heating tool of any residual material using a wood stick or a clean, dry, oil-free, lint-free, non-synthetic cloth. Take care not to damage the heating surfaces. Plastic left on the tool tends to char when reheated, causing a loss of heater efficiency and joint contamination.

7.2.8 Allow for extremes in weather when making field joints. Heating times, operation of alignment jig, dimensional changes, and the like, are affected by extreme conditions.

7.3 *Testing*—Evaluate sample joints in order to verify the skill and knowledge of the fusion operator. Cut joints into straps, (see Fig. 4) and visually examine and test for bond continuity and strength. Bending, peeling, and elongation tests are useful for this purpose.

8. Procedure 2—Butt Fusion

8.1 *Apparatus*:

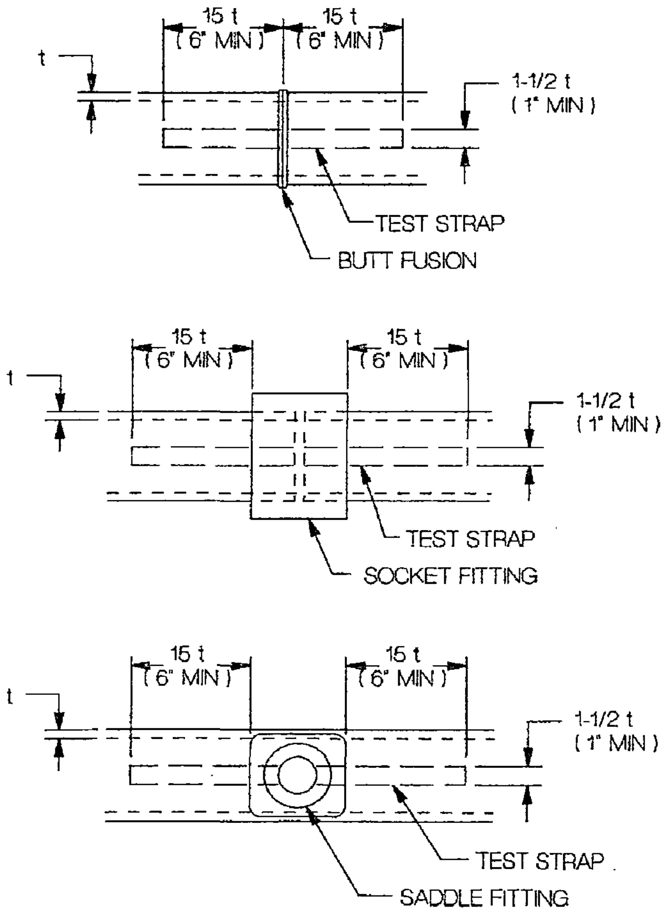


FIG. 4 Bent Strap Test Specimen

8.1.1 *Heating Tool*—The heating tool shall have sufficient area to adequately cover the ends of the size of pipe to be joined.

8.1.2 *Alignment Jig*—The alignment jig is three basic parts: (*1*) a stationary clamping fixture and a movable clamping fixture for holding each of the two parts to be fused in alignment; (*2*) a facer for simultaneously preparing the ends of the parts to be joined (Note 6); and (*3*) appropriate adapters for different pipe sizes. Alignment jigs are manually or hydraulically powered.

NOTE 6—A facer is a rotating cutting device used to square-off the pipe or fitting ends to obtain properly mating fusion surfaces.

8.2 *Procedure*:

8.2.1 Bring the heater plate surfaces to proper temperature.

8.2.2 Clean the inside and outside of the components (pipe or pipe and fitting) to be joined. Remove all foreign matter from the surface of the component where it will be clamped in the alignment jig.

8.2.3 Align each component with its alignment jig clamp, and close the clamp. Check component to component alignment, adjust as needed, and face off the ends.

8.2.3.1 Take care when placing pipe or fittings in the alignment jig. Pipes shall be aligned before the alignment clamp is closed; however, do not force the pipe into alignment by pushing it against the side of an open alignment jig clamp.

8.2.4 Bring the piping components together and check for high-low alignment, and out-of-roundness. Adjust as required. Re-face after adjustment. The ends of the piping components shall be square to each other around their full circumference.

8.2.5 Place the heater plate between the component ends, and move the component ends against the heater plate with sufficient force to ensure complete circumferential contact against the heater plate. Hold the components against the heater plate briefly, using limited force to ensure that proper contact with the plate has been made. Release the force, but hold the components against the heater plate until an appropriately sized bead of molten plastic develops circumferentially around each component end as a result of the thermal expansion of the material. Do not push the components into the heater plate as the melting progresses.

8.2.6 Move the melted component ends away from the heater plate, and remove the heater plate. Quickly inspect the melted surfaces per 8.2.1. If the melt is acceptable, immediately bring the melted ends together with enough force to roll both component melt beads over to the pipe surface around the entire circumference of the joint. When the bead touches the pipe surface, stop moving the component ends together, but do not release the force. Hold the force on the joint until the joint has cooled.

8.2.6.1 Do not use excessive or insufficient force. If the components are brought together with too much force, all molten material may be pushed out of the joint and cold material brought into contact forming a "cold" joint. If too little force is used, only the melt in the beads may be fused together and, as the molten material in the joint cools and contracts, voids or non-fused areas may be formed. If the softened material sticks to the heater plate, discontinue the joining procedure. Clean the heater plate, re-square the component ends, and repeat the process from the beginning (8.2.2).

8.2.6.2 Inspect the component ends quickly when the heating tool is removed. The melt should be flat. A concave melt surface indicates unacceptable pressure during heating. If a concave melt surface is observed, do not continue. Allow the component ends to cool, and start over from 8.2.1.

8.2.6.3 For any pipe size and wall thickness, the actual fusion joining force is determined by multiplying the interfacial pressure by the area of the pipe end. To determine a fusion pressure gauge setting for hydraulic butt fusion machines, the force is divided by the area of the hydraulic cylinders that move the fusion machine carriage. The hydraulic fusion machine gauge pressure setting may need to be increased to overcome internal machine friction drag or to provide additional force to move pipes attached to the butt fusion machine.

8.2.7 Allow the assembly to stand at least until cool before removing the clamps or other aligning device (Note 7). Do not subject the joint to high stress until it has cooled to less than approximately 130°F. Do not apply internal pressure until the joint and surrounding material have reached ambient air temperature.

NOTE 7—The joint is usually cool enough to remove from the alignment jig if a bare hand can be held against the beads without discomfort (less than approximately 130°F). Further cooling is recommended prior to ditching the pipe.

8.2.8 Visually inspect the joint against recommended appearance guidelines. The beads should be uniformly shaped and sized all around the joint.

8.3 *Testing*—Evaluate sample joints to verify the skill and knowledge of the fusion operator. In some cases, butt-fusion joints can be nondestructively examined using ultrasonic equipment to detect voids or other discontinuities. Visually, the width of butt fusion beads should be 2 to 2-1/2 times the bead height above the pipe, and the beads should be rounded and uniformly sized all around the pipe circumference. The v-groove between the beads should not be deeper than half the bead height above the pipe surface. When butt fusing to molded fittings, the fitting-side bead may display shape irregularities such as minor indentations, deflections and non-uniform bead rollover from molded part cooling and knit lines. In such cases, visual evaluation is based mainly on the size and shape of the pipe-side bead. For destructive tests, cut joints into straps (see Fig. 4), visually examine, and test for bond continuity and strength. Tests that have been found useful for this purpose include inside face bend, outside face bend, tensile elongation, torque, and impact. Quantifiable data may be obtained by the use of laboratory procedures and comparing data against that from control samples.

9. Procedure 3—Saddle Fusion

9.1 *Apparatus*:

9.1.1 *Heating Tool Faces*—The faces are matched sets, by pipe size, of concave and convex blocks which bolt or clamp onto a flat or round core heater.

9.1.2 *Alignment Jigs*—Various types of alignment jigs are available. Alignment jigs provide a means to mount the alignment jig on the pipe, hold the fitting and align it to the pipe, and move the fitting towards and away from the pipe. Alignment jigs are used for saddle fusions for optimum results and are required for certain materials.

NOTE 8—Some materials may be saddle fused using a hand-stab procedure. Consult the manufacturer for a hand-stab procedure.

9.2 *Procedure*:

9.2.1 Bring heater plate and faces to proper temperature.

9.2.2 Clean the mating surfaces of the pipe and the concave surface of the fitting base and roughen the mating surfaces. Emery or garnet cloth of 50 to 60 grit is used to remove the tough outer surface skin. It is essential to remove the surface skin completely without altering the contours of the mating surfaces and to keep the surface clean. Remove dust and particles from the surface after roughing with a clean, dry, oil-free, lint-free cloth.

9.2.3 Install the alignment jig on the pipe. For smaller pipe sizes, install a bolster plate under the pipe to provide additional support.

9.2.4 Install the fitting in the alignment jig. Press the fitting against the pipe to align the fitting base to the pipe, then secure the fitting in the alignment jig.

9.2.5 Place the heater on the pipe and press the fitting against the heater to obtain a melt on both the pipe and the fitting.

NOTE 9—When saddle fittings are fused to pipes that are under pressure, it is important that the surface melt be obtained quickly without too much heat penetration. Otherwise, the pipe may rupture from internal pressure. Consult the manufacturer for specific recommendations for fusing saddle fittings to pipe under pressure.

9.2.6 When a proper melt is achieved, remove the heater, quickly examine the pipe and fitting to ensure proper melt patterns, and immediately place the fitting on the pipe. Hold in place while exerting suitable force for the specified cooling time.

NOTE 10—If a suitable melt pattern has not been achieved, do not reheat; however, continue with the fusion and apply the fitting to the pipe. When the joint has cooled, remove the alignment jig, cut off the top of the fitting to prevent use, and start over at another location.

9.3 Visually inspect the joint against recommended visual inspection guidelines.

9.4 *Testing*—Evaluate sample joints to verify the skill and knowledge of the fusion operator. Cut joints into straps (see Fig. 4), visually examine, and test for bond continuity and strength.

10. Keywords

10.1 butt fusion; fitting; heat fusion; joining; pipe; polybutylene; polyolefin; polypropylene; saddle fusion; socket fusion

ANNEX

(Mandatory Information)

A1. COLD WEATHER PROCEDURES

A1.1 *Cold Weather Handling*—Pipe should be inspected for damage. Polyolefin pipes have reduced impact resistance in sub-freezing conditions. Avoid dropping pipe in sub-freezing conditions. When handling coiled pipe at temperatures below 40°F, it is helpful to uncoil the pipe prior to installation and let it straighten out. Gradually uncoil the pipe and cover it with dirt at intervals to keep it from recoiling. Always use caution when cutting the straps on coils of pipe because the outside end of a coil may spring out when the strapping is removed.

A1.2 *Preparation for Socket, Saddle, and Butt Fusion Joining*:

A1.2.1 *Wind and Precipitation*—The heating tool should be shielded in an insulated container to prevent excessive heat loss. Shield the pipe fusion area and fusion tools from wind, snow, and rain by using a canopy or similar device.

A1.2.2 *Pipe and Fitting Surface Preparation*—The pipe and fitting surfaces to be "joined" or held in clamps should be dry and clean and free of ice, frost, snow, dirt, and other contamination. Regular procedures for preparation of surfaces to be joined, such as facing for butt fusion and roughening for saddle fusion should be emphasized. After preparation, the surfaces should be protected from contamination until joined. Contamination of the area to be fused will likely cause incomplete fusion. Frost and ice on the surfaces of the pipe to be clamped in either a cold ring or alignment jigs may cause slippage during fusion. Inspect coiled pipe to see if it has flattened during storage which could cause incomplete melt pattern or poor fusion. It may be necessary to remove several inches at the pipe ends to eliminate such distortion. Pipe may have a slight toe-in or reduced diameter for several inches at the end of the pipe. The toe-in may need to be removed before butt fusing to a freshly cut pipe end, or to a fitting.

A1.2.3 *Heating*—Work quickly once pipe and fitting have been separated from the heating tool, so that melt heat loss is minimized, but still take time (no more than 3 s) to inspect both melt patterns. Keep the heater dry at all times. Check the temperature of the heating tool regularly with a pyrometer. Keep the heating tool in an insulated container between fusions. Do not increase heating tool temperature above the specified temperature setting. Gas-fired heating tools are used only in above freezing conditions.

A1.3 *Socket Fusion*:

A1.3.1 *Pipe Outside Diameter*—Pipe outside diameter contracts when cold. This results in loose or slipping cold rings. For best results, clamp one cold ring in its normal position adjacent to the depth gage. Place shim material (that is, piece of paper or rag, etc.) around the inside diameter of a second rounding ring and clamp this cold ring directly behind the first cold ring to prevent slippage. The first cold ring allows the pipe adjacent to the heated pipe to expand to its normal diameter during the heating cycle.

A1.3.2 *Fitting Condition*—If possible, store socket fittings at a warm temperature, such as in a truck cab, prior to use. This will make it easier to place the fitting on the heating tool because fittings contract when cold.

A1.3.3 *Heating*—At colder temperatures the pipe and fitting contract, thus the pipe slips more easily into the heating tool. At very cold outdoor temperatures (particularly with 2, 3, and 4 in. IPS pipe), the pipe may barely contact the heating surface. Longer heating cycles are used so that the pipe first expands (from tool heat) to properly contact the heating tool, then develops complete melt. The length of cycle necessary to obtain a complete melt pattern will depend not only on the outdoor (pipe) temperature but wind conditions and operator variation. Avoid cycles in excess of that required to achieve a good melt pattern. To determine the proper cycle time for any particular condition, make a melt pattern on a scrap piece of pipe, using the heating cycle as instructed by the pipe manufacturer. If the pattern is incomplete (be sure rounding rings are being used), try a 3-s longer cycle on a fresh (cold) end of pipe. If the melt pattern is still not completely around the pipe end, add an additional 3 s and repeat the procedure. Completeness of melt pattern is the key. Keep the heater dry at all times. Check the temperature of the heating tool regularly and keep the heating tool in an insulated container between fusions.

A1.4 *Butt Fusion*:

A1.4.1 *Joining* — It will take longer to develop the initial melt bead completely around the pipe ends. Do not increase pressure during heating. When proper melt bead has been obtained, the pipe and heater shall be separated in a rapid, snap-like motion. The melted surfaces shall then be joined immediately in one smooth motion so as to minimize cooling of the melted pipe ends.

A1.5 *Saddle Fusion*:

A1.5.1 *Surface Preparations*—Regular procedures for roughening the surfaces to be fused on the pipe and the fitting should be emphasized. After the surfaces have been prepared, particular care should be taken to protect against contamination.

A1.5.2 *Heating Time*—Make a trial melt pattern on a scrap piece of pipe. A clean, dry piece of wood is used to push the heating tool against the pipe. If the melt pattern is incomplete, add 3 s to the cycle time and make another trial melt pattern on another section of cold pipe. If the pattern is still incomplete, continue 3-s additions on a fresh section of cold pipe until a complete melt pattern is attained. Use this heating cycle for fusions during prevailing conditions. Regardless of the weather or the type of tools used, the important point to remember is that complete and even melt must occur on the fitting and the pipe in order to produce a good fusion joint. This requires pipe preparation to make it clean, straight, round, and well supported.

ANEXO 3

(13)

PART QF
PLASTIC FUSING

ARTICLE XXI
PLASTIC FUSING GENERAL REQUIREMENTS

QF-100 SCOPE

The rules in this Part apply to the preparation and qualification of the fusing procedure specification (FPS), and the performance qualification of fusing machine operators.

QF-101 FUSING PROCEDURE SPECIFICATION (FPS)

A fusing procedure specification (FPS) used by an organization that will have responsible operational control of production fusing shall be an FPS that has been qualified by that organization in accordance with Article XXII, or it shall be a standard fusing procedure specification (SFPS) as defined in QF-201.2.

The FPS or SFPS specify the "variables" (including ranges, if any) under which fusing must be performed. The FPS prepared by the organization and the SFPS shall address the applicable fusing process variables, both essential and nonessential, as provided in Article XXII for production fusing.

QF-102 FUSING PERFORMANCE QUALIFICATION (FPQ)

Fusing machine operator performance qualification is intended to verify the ability of the fusing machine operator to produce a soundly fused joint when following a qualified FPS. The fusing machine operator performance qualification record (FPQ) documents the performance test of the fusing machine operator, and the results of the required mechanical tests.

QF-103 RESPONSIBILITY

QF-103.1 Fusing. Each organization shall conduct the tests required in this Section to qualify the FPS and the performance of the fusing machine operators who apply these procedures. Alternatively, an organization may use an SFPS under the provisions of QF-201.2. The organization shall perform and document the tests required by this Article to qualify the performance of fusing machine operators for fusing operations.

QF-103.2 Records. Each organization shall maintain a record of the results of the mechanical testing performed to satisfy the requirements for FPS and fusing machine operator performance qualifications.

QF-110 FUSED JOINT ORIENTATION

Orientation categories for fused joints are illustrated in Figure QF-461.1.

QF-120 TEST POSITIONS

Fused joints may be made in test coupons oriented in any of the positions shown in Figure QF-461.2.

QF-130 DATA ACQUISITION AND EVALUATION

QF-131 DATA ACQUISITION RECORD REQUIREMENTS

The following fusing variables shall be recorded for each fused test joint:

(a) heater surface temperature immediately before inserting the heater plate

(b) gauge pressure during the initial heat cycle

(c) gauge pressure and elapsed time during the heat-soak cycle

(d) heater removal (dwell) time

(e) gauge pressure and elapsed time during the fusing/cool cycle

(f) drag pressure

(g) joint configuration

(h) pipe diameter and wall thickness

(i) type of HDPE material (specification and classification) and manufacturer

(j) FPS used, operator identification, time, date, and fusing machine identification

QF-132 DATA ACQUISITION RECORD REVIEW

The data acquisition record for each fused test joint shall be compared to the FPS after completion. QF-485 provides a suggested format to document the data acquisition record review. The reviewer shall verify the following:

(a) all data required by QF-131 was recorded

(b) interfacial fusing pressure was within the FPS range

(c) heater surface temperature recorded was within the FPS range

(d) butt-fusing pressure applied during the fusing/cool cycle was correctly calculated to include the drag pressure, fell within the FPS range for the applicable size (e.g., pipe diameter), and agrees with the recorded hydraulic fusing pressure

(e) butt-fusing pressure was reduced to a value less than or equal to the drag pressure at the beginning of the heat soak cycle

(f) fusing machine was opened at the end of the heat soak cycle, the heater was removed, and the ends brought together at the fusing pressure within the time frame specified by the FPS

(g) cooling time at butt-fusing pressure met the minimum time specified by the FPS

If the recorded data is outside the limits of the FPS, the joint is unacceptable.

QF-140 EXAMINATIONS AND TESTS

QF-141 VISUAL EXAMINATION

(a) All fused joints shall receive a visual examination of all accessible surfaces of the fused joint.

(b) *Acceptance Criteria* (see Figure QF-462 for evaluation examples)

(1) There shall be no evidence of cracks or incomplete fusing.

(2) Joints shall exhibit proper fused bead configuration.

(3) Variations in upset bead heights on opposite sides of the cleavage and around the circumference of fused pipe joints are acceptable.

(4) The apex of the cleavage between the upset beads of the fused joint shall remain above the base material surface.

(5) The data record for the FPS or fusing machine operator performance qualification test shall be reviewed and compared to the FPS to verify observance of the specified variables applied when completing the fused test joint.

(6) Fused joints shall not display visible angular misalignment, and outside diameter mismatch shall be less than 10% of the nominal wall thickness.

(c) Visual examination results shall be recorded on the PQR or FPQ.

QF-142 ELEVATED TEMPERATURE SUSTAINED PRESSURE TESTS FOR PIPE

Elevated temperature sustained pressure tests shall be performed in accordance with ASTM D3035-08.

QF-143 BEND TESTS

These tests are designed to impart bending stresses to a butt-fused plastic specimen to evaluate the soundness of the fused joint.

QF-143.1 Reverse-Bend Test (RBT)

(a) Reverse-bend test specimens shall be cut to a minimum width of 1.5 times the test coupon thickness for testing and removed as shown in Figure QF-463(a).

(b) One test specimen shall be bent to place the inside surface of the joint in tension, and the other test specimen shall be bent to place the outside surface of the joint in tension.

(c) The bending process shall ensure the ends of the specimens are brought into contact with one another.

(d) Testing shall be in accordance with ASTM F2620-09, Appendix X4.

(e) Test results shall be recorded on the PQR.

QF-143.2 Guided Side-Bend Test (GSBT)

QF-143.2.1 Significance and Use. This test is designed to impart a bending load on a specimen from a butt fusion joint to evaluate its soundness. It is intended for butt fusion joints of HDPE pipe with a wall thickness greater than 1.0 in. (25 mm).

QF-143.2.2 Test Specimens

(a) Test specimens shall be removed from the fused test coupon with the upset bead remaining on the outside and inside surfaces. A strip having the full thickness of the test coupon and measuring approximately 1 in. (25 mm) wide and 18 in. (450 mm) long shall be removed along the longitudinal axis of the test coupon, with the joint located in the approximate center of the strip. See Figure QF-463(b).

(b) Plane or machine the width down to 0.50 in. ± 03 in. (13 mm ± 0.75 mm) with a smooth finish on both sides. See Figure QF-463(c).

QF-143.2.3 Test Conditions

(a) *Test Temperature.* Conduct the GSBT at a temperature 60°F to 80°F (16°C to 27°C).

(b) *Test speed.* The elapsed time of the test shall be between 30 sec and 60 sec.

QF-143.2.4 Guided Side-Bend Test Procedure

QF-143.2.4.1 Jigs. Test specimens shall be bent in a test jig consisting of a fixed member with two cross bars to support the specimen while force is applied. The hydraulic ram, used to supply the bending force, is also attached to the jig and has a ram attached to the end of the cylinder. See Figure QF-463(d).

QF-143.2.4.2 Bend Procedure. Position the side-bend test specimen with the butt fusion joint in the center of the jig between the support mandrels. Position the ram in the center of the fusion bead on the test specimen. Move the ram slowly until it makes contact with the test specimen and is positioned in line with the fusion bead. Begin to apply the bending force and deflect the side-bend test specimen. The test is complete when the test specimen is bent to an angle of 60 deg ± 10 deg between the inside surfaces of the specimen or until failure occurs. See Figure QF-463(d).

QF-143.3 Acceptance Criteria. The test specimen shall not break or exhibit cracking or fractures on the convex (outer) surface at the fusion interface during this test.

QF-144 HIGH-SPEED TENSILE IMPACT TEST (HSTIT)

This test method is designed to impart tensile impact energy to a butt-fused PE pipe specimen to evaluate its ductility.

QF-144.1 Test Specimens

(a) Test specimens shall be removed from the fused test coupon with the upset bead remaining on the outside diameter and inside diameter surfaces. Specimens for test coupon thicknesses less than or equal to 2 in. (50 mm) shall include the full wall thickness of the fused joint. Specimens for test coupon thicknesses 2 in. (50 mm) and greater may be cut into approximately equal strips between 1 in. (25 mm) and 2.5 in. (64 mm) wide for testing with each segment tested individually such that the full cross section is tested.

(b) Test specimens shall be prepared by machining to achieve the dimensions given in Figure QF-464, with the upset beads remaining intact.

(c) A smooth surface free of visible flaws, scratches, or imperfections shall remain on all faces of the reduced area with no notches, gouges, or undercuts exceeding the dimensional tolerances given in ASTM F2634-07. Marks left by coarse machining operations shall be removed, and the surfaces shall be smoothed with abrasive paper (600 grit or finer) with the sanding strokes applied parallel to the longitudinal axis of the test specimen.

(d) Mark the test specimens in the area outside the hole with the applicable specimen identification using a permanent indelible marker of a contrasting color, or an etching tool.

(e) Condition the test specimens at 73°F ± 4°F (23°C ± 2°C) for not less than 1 hr just prior to conducting the test.

QF-144.2 Test Conditions

(a) Test Temperature. Conduct the high speed impact test at a temperature of 73°F ± 4°F (23°C ± 2°C) unless otherwise specified.

(b) Test Speed. The speed of testing shall be in accordance with Table QF-144.2 with a testing speed tolerance of +0.5 in./sec to −1 in./sec (+13 mm/sec to −25 mm/sec).

Table QF-144.2
Testing Speed Requirements

Wall Thickness	Testing Speed
≤ 1.25 in. (32 mm)	6 in./sec (150 mm/sec)
> 1.25 in. (32 mm)	4 in./sec (100 mm/sec)

QF-144.3 Test Procedure

(a) Set up the machine and set the speed of testing to the rate specified in QF-144.2(b).

(b) Pin each specimen in the clevis tooling of the testing machine, aligning the long axis of the specimen and the tooling with the pulling direction of the test machine.

(c) Testing shall be performed in accordance with ASTM F2634.

(d) Evaluate the test specimen fracture to determine the mode of failure, and note the results in the test record and on the PQR.

QF-144.4 Test Record. The HSTIT shall be documented by preparing a test record that includes the following information:

(a) testing speed applied
(b) testing temperature observed
(c) specimen dimension verification
(d) test machine calibration data
(e) test specimen identification
(f) test date
(g) test operator identification
(h) testing failure mode and acceptance/rejection
(i) test equipment identification

QF-144.5 Acceptance Criteria. Failure mode shall be ductile, with no evidence of brittle failure at the fusion interface. See Figure QF-465, illustrations (a) through (d), for evaluation examples.

ARTICLE XXII
FUSING PROCEDURE QUALIFICATIONS

QF-200 GENERAL

Each organization shall prepare a written FPS as defined in QF-201.1, or assume responsibility for an SFPS as defined in QF-201.2.

QF-201 PROCEDURE QUALIFICATION

QF-201.1 Fusing Procedure Specification (FPS)

(a) Fusing Procedure Specification (FPS). A FPS is a written qualified fusing procedure prepared to provide direction to the fusing machine operator for making production fused joints.

(b) Contents of the FPS. The completed FPS shall address all of the essential and nonessential variables for each fusing process used in the FPS. The essential and nonessential variables for fusing are listed in Table QF-254. The organization may include any other information in the FPS that may be helpful in making a fused joint.

(c) Changes in the documented essential variables require requalification of the FPS.

QF-201.2 Standard Fusing Procedure Specification (SFPS)

(a) Standard Fusing Procedure Specification (SFPS). A fusing procedure specification that contains acceptable polyethylene fusing variables based on standard industry practice and testing as reported in the Plastic Pipe Institute (PPI), Report TR-33-06, or ASTM F2620-09, Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings. A SFPS may be used for production fusing by organizations without further qualification.

(b) Contents of the SFPS. The SFPS shall address all of the essential and nonessential variables listed in QF-220. The organization may include any additional information in the SFPS that may be helpful in making a fused joint.

(c) Changes in the documented parameters of a SFPS beyond the limits specified in QF-220 shall require the qualification of an FPS.

QF-201.3 Format of the FPS or SFPS. The information required to be included in the FPS or SFPS may be in any format, written or tabular, to fit the needs of each organization, provided all essential and nonessential variables outlined in QF-250, or the parameters specified in QF-220 as applicable, are addressed. Form QF-482 has been provided as a guide for preparing the FPS or SFPS.

QF-201.4 Availability of the FPS or SFPS. The FPS or SFPS used for production fusing shall be available for reference and reviewed by the Inspector when fused joints are made.

QF-201.5 Each organization who qualifies a FPS shall prepare a procedure qualification record (PQR) that is defined as follows:

(a) Procedure Qualification Record (PQR). A record of the range of essential variables documented during the fusing of the test coupon(s) and the results of the required visual and mechanical tests performed.

(b) Contents of the PQR. The completed PQR shall document the ranges for all essential variables listed in QF-250 during the fusing of the test coupon(s). Nonessential variables observed during the fusing of the test coupon may be recorded at the organization's option.

The PQR shall be certified by the organization to be a true and accurate record of the variables recorded during the fusing of the test coupon(s) and the required examinations and tests specified in QF-140.

(c) Changes to the PQR. Changes to the PQR are not permitted except for documented editorial corrections or those utilizing addenda. An organization may be permitted to fuse materials other than those used in the FPS qualification, when the alternative materials are assigned to a material grouping in QF-420 whose fusing properties are considered essentially identical. Additional information may be incorporated into a PQR at a later date, provided the information is substantiated as having been associated with the original qualification conditions by lab records or similar documented evidence. All changes to a PQR require recertification (including date) by the organization.

(d) Format of the PQR. The information required to be in the PQR may be in any format, written or tabular, to fit the needs of each organization, provided all essential variables outlined in QF-250 are included. The types and number of tests, and their results shall be reported on the PQR. Form QF-483 has been provided as a guide for preparing the PQR. When required, additional sketches or information may be attached or referenced to record the required variables.

(e) Availability of the PQR. PQRs supporting an FPS to be used in production fusing operations shall be available for review by the inspector.

(f) Multiple FPSs with One PQR/Multiple PQRs with One FPS. Several FPSs may be prepared from the qualification test data recorded on a single PQR. A single FPS may

encompass the range of qualified essential variables represented by multiple PQRs supporting the qualified combination and range of essential variables.

QF-202 TYPE OF TESTS REQUIRED

QF-202.1 Mechanical Tests

QF-202.1.1 High-speed tensile impact test specimens (HSTIT) shall be prepared in accordance with Figure QF-464 and tested in accordance with QF-144.1. The minimum number of specimens required to be tested shall be as follows:

(a) for pipe specimens less than 4 NPS (100 mm): not less than two specimens removed from fused pipe test coupons at intervals of approximately 180 deg apart

(b) for pipe specimens 4 NPS (100 mm) and greater: not less than four specimens removed from fused pipe test coupons at intervals approximately 90 deg apart

(c) other product forms: not less than two specimens removed from fused test coupons

QF-202.1.2 Elevated temperature sustained pressure tests shall be conducted in accordance with QF-142.

QF-202.1.3 If any test specimen required by QF-202.1 fails to meet the applicable acceptance criteria, the test coupon shall be considered unacceptable.

(a) When it can be determined that the cause of failure is not related to incorrectly selected or applied fusing variables, additional test specimens may be removed as close as practicable to the original specimen location to replace the failed test specimens. If sufficient material is not available, another test coupon may be fused utilizing the original fusing parameters.

(b) When it has been determined that the test failure was caused by one or more incorrectly selected or applied essential variable(s), a new test coupon may be fused with appropriate changes to the variable(s) that were determined to be the cause for test failure.

(c) When it is determined that the test failure was caused by one or more fusing conditions other than essential variables, a new set of test coupons may be fused with the appropriate changes to the fusing conditions that were determined to be the cause for test failure. If the new test passes, the fusing conditions that were determined to be the cause for the previous test failure shall be addressed by the organization to ensure that the required properties are achieved in all fused production joints.

QF-202.2 Testing Procedure to Qualify the FPS

QF-202.2.1 Polyethylene Pipe Butt Fusing

(a) For pipe having a wall thickness less than or equal to 2 in. (50 mm), one set of test coupons shall be prepared using any thickness of pipe less than or equal to 2 in. (50 mm) but not less than one-half the thickness of the pipe to be fused in production.

(b) For pipe having wall thickness greater than 2 in. (50 mm), one set of test coupons shall be prepared using pipe of at least 2 in. (50 mm) thickness but not less than one-half the maximum thickness to be fused in production.

(c) Butt-fusing joint coupons shall be prepared in accordance with the FPS using the following combinations of heater temperature ranges and interfacial pressure ranges:

(1) high heater surface temperature and high interfacial pressure, five joints

(2) high heater surface temperature and low interfacial pressure, five joints

(3) low heater surface temperature and high interfacial pressure, five joints

(4) low heater surface temperature and low interfacial pressure, five joints

(d) Each fused joint shall be subject to visual examination per QF-141.

(e) Two fused joints of each combination shall be evaluated using the elevated temperature sustained pressure tests for pipe specified in QF-142.

(f) Three fused joints of each combination described in (c) shall be evaluated using the high speed tensile impact test (HSTIT) specified in QF-144.

QF-203 LIMITS OF QUALIFIED POSITIONS FOR PROCEDURES

Unless otherwise specified by the fusing variables (QF-250), a procedure qualified in any position shown in Figure QF-461.2 qualifies for all positions. A fusing machine operator making and passing the FPS qualification test is qualified only for the position tested (See QF-301.2).

QF-220 STANDARD FUSING PROCEDURE SPECIFICATION (SFPS)

QF-221 SFPS FOR POLYETHYLENE FUSING

QF-221.1 Pipe Butt Fusing of Polyethylene. When the fusing procedure is limited to the following parameters, procedure qualification testing is not required. If the organization deviates from the conditions listed below, procedure qualification testing in accordance with QF-202.2 is required.

(a) The pipe material is limited to PE 2708, PE 3608, and PE 4710.

(b) The axis of the pipe is limited to the horizontal position ±45 deg.

(c) The pipe ends shall be faced to establish clean, parallel mating surfaces that are perpendicular to the pipe centerline on each pipe end, except for mitered joints. When the ends are brought together at the drag pressure, there shall be no visible gap.

(d) For mitered butt fusion joints, the pipe faces shall be at the specific angle to produce the mitered joint. When the ends are brought together at the drag pressure, there shall be no visible gap.

(e) The external surfaces of the pipe are aligned to within 10% of the pipe wall thickness.

(f) The drag pressure shall be measured and recorded. The theoretical fusing pressure shall be calculated so that an interfacial pressure of 60 psi to 90 psi (0.41 MPa to 0.62 MPa) is applied to the pipe ends. The butt-fusing gauge pressure set on the fusing machine shall be the theoretical fusing pressure plus drag pressure.

(g) The heater surface temperature shall be 400°F to 450°F (200°C to 230°C).

(h) The initial heating shall begin by inserting the heater into the gap between the pipe ends and applying the butt-fusing pressure until an indication of melt is observed around the circumference of the pipe. When observed, the pressure shall be reduced to drag pressure and the fixture shall be locked in position so that no outside force is applied to the joint during the heat soak cycle.

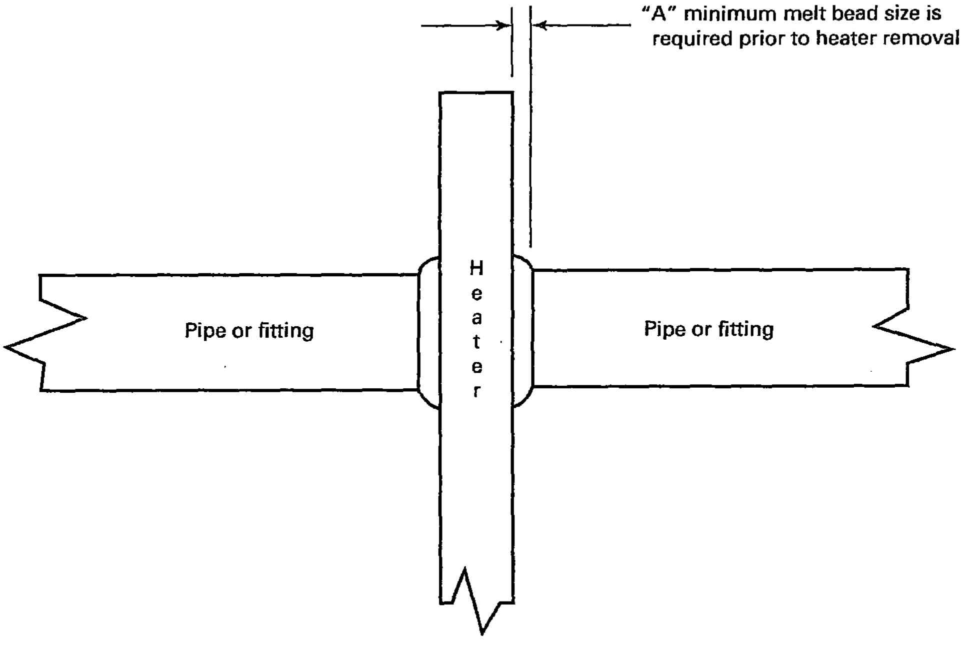
(i) The ends shall be held in place until the minimum bead size is formed between the heater faces and the pipe ends, as shown in Figure QF-221.1. For 14 NPS (350 mm) and larger pipe sizes, the minimum heat soak time of 4.5 min per inch (25 mm) of pipe wall thickness shall be obtained.

(j) After the proper bead size is formed, the machine shall be opened and the heater removed. The pipe end surfaces shall be smooth, flat, and free of contamination. The pipe ends shall be brought together and the butt-fusing pressure reapplied.

(k) The maximum time from separating the pipe ends from the heater until the pipe ends are pushed together shall not exceed the time given in Table QF-221.2.

(l) The butt-fusing pressure shall be maintained until the joint has cooled, after which the pipe may be removed from the joining machine. The minimum cool time at the butt-fusing pressure shall be 11 min per inch (26 sec per millimeter) of pipe wall thickness of the thicker member.

Figure QF-221.1
Required Minimum Melt Bead Size



Pipe (O.D.), in. (mm)	"A" Minimum Melt Bead Size, in. (mm)
< 2.37 (60)	1/32 (1)
≥ 2.37 (60) to ≤ 3.5 (89)	1/16 (1.5)
> 3.5 (89) to ≤ 8.63 (219)	3/16 (5)
> 8.63 (219) to ≤ 12.75 (324)	1/4 (6)
> 12.75 (324) to ≤ 24 (610)	3/8 (10)
> 24 (610) to ≤ 36 (900)	7/16 (11)
> 36 (900) to ≤ 65 (1625)	9/16 (14)

Table QF-221.2
Maximum Heater Plate Removal Time for Pipe-to-Pipe Fusing

Pipe Wall Thickness, in. (mm)	Maximum Heater Plate Removal Time, sec
Field Applications	
0.17 to 0.36 (4 to 9)	8
> 0.36 to 0.55 (> 9 to 14)	10
> 0.55 to 1.18 (> 14 to 30)	15
> 1.18 to 2.5 (> 30 to 64)	20
> 2.5 to 4.5 (> 64 to 114)	25
> 4.5 (> 114)	30
Fabrication Shop	
1.18 to 2.5 (30 to 64)	40
> 2.5 to 4.5 (> 64 to 114)	50
> 4.5 (> 114)	60

QF-250 FUSING VARIABLES

QF-251 TYPES OF VARIABLES FOR FUSING PROCEDURE SPECIFICATIONS (FPS)

These variables (listed for each fusing process starting in Table QF-254) are categorized as essential or nonessential variables. The "Brief of Variables" listed in the tables are for reference only. See the complete variable description in Article XXIV, QF-400.

QF-252 ESSENTIAL VARIABLES

Essential variables are those that will affect the mechanical properties of the fused joint, if changed, and require requalification of the FPS when any change exceeds the specified limits of the values recorded in the FPS for that variable.

QF-253 NONESSENTIAL VARIABLES

Nonessential variables are those that will not affect the mechanical properties of the fused joint, if changed, and do not require requalification of the FPS when changed.

Table QF-254
Fusing Variables Procedure Specification
Polyethylene Pipe Butt Fusing

Paragraph		Brief of Variables	Essential	Nonessential
QF-402 Joints	.1	ϕ Joint type	X	
	.2	ϕ Pipe surface alignment	X	
QF-403 Material	.1	ϕ PE	X	
	.3	ϕ Wall thickness	X	
	.4	ϕ Cross-sectional area		X
QF-404 Position	.1	ϕ Position	X	
QF-405 Thermal Conditions	.1	ϕ Heater surface temperature	X	
	.2	ϕ Interfacial pressure	X	
	.3	Decrease in melt bead width	X	
	.4	Increase in heater removal time	X	
	.5	Decrease in cool-down time	X	
QF-406 Equipment	.1	ϕ Fusing machine manufacturer		X
QF-407 Technique	.1	ϕ Shop to field, or vice versa		X

GENERAL NOTE: Table QF-254 is applicable to fusing procedure specifications (FPSs) only.

ARTICLE XXIII
PLASTIC FUSING PERFORMANCE QUALIFICATIONS

QF-300 GENERAL

This Article lists the essential variables that apply to fusing machine operator performance qualifications. The fusing machine operator qualification is limited by the essential variables given for the fusing process. These variables are listed in Table QF-362.

QF-301 TESTS

QF-301.1 Intent of Tests. The fusing machine operator performance qualification tests are intended to determine the ability of fusing machine operators to make sound fused joints when following a qualified FPS or SFPS.

QF-301.2 Qualification Tests. Each organization shall qualify each fusing machine operator for the fusing process(es) to be used in production. The performance qualification tests shall be completed using a qualified FPS. A fusing machine operator qualified for fusing in accordance with one qualified FPS or SFPS is also qualified for fusing in accordance with other qualified FPSs or SFPSs within the limits of the fusing operator essential performance variables given in Table QF-362. Visual and mechanical examination requirements are described in QF-302. Retests and renewal of qualification are given in QF-320.

The fusing machine operator responsible for fusing FPS qualification test coupons successfully qualifying the FPS is also qualified as a fusing machine operator within the limits of the essential performance qualification variables given in Table QF-362.

QF-301.3 Identification of Fusing Machine Operators. Each qualified fusing machine operator shall be assigned an identifying number, letter, or symbol by the organization, which shall be used to identify production fused joints completed by the fusing machine operator.

QF-301.4 Record of Tests. The record of fusing machine operator performance qualification (FPQ) tests shall include the qualified ranges of essential performance variables, the type of tests performed, and test results for each fusing machine operator. Suggested forms for these records are given in Form QF-484.

QF-302 TYPE OF TEST REQUIRED

QF-302.1 Visual Examination. For pipe coupons, all surfaces shall be examined visually per QF-141 before cutting specimens. Pipe test coupons shall be visually examined per QF-141 over the entire circumference.

QF-302.2 Mechanical Tests. For pipe coupons, two bend test specimens shall be removed from the fused test joint at intervals of approximately 180 deg. Each specimen shall be tested by one of the following methods:

(a) Reverse-Bend Test. The specimens shall be removed as shown in Figure QF-463, illustration (a), and tested in accordance with QF-143.1.

(b) Guided Side-Bend Test. Each specimen shall be removed as shown in Figure QF-463, illustration (b), and prepared and tested in accordance with QF-143.2.

QF-303 LIMITS OF QUALIFIED POSITIONS AND DIAMETERS (SEE QF-461)

QF-303.1 Pipe Positions. Fusing machine operators who pass the required tests for fusing in the test positions shown in Figures QF-461.1 and QF-461.2 shall be qualified for fusing within the following limits:

(a) The 5G test position qualifies for the horizontal position ±45 deg.

(b) Test positions other than 5G qualify for the orientation tested ±20 deg.

QF-303.2 Pipe Diameters. Pipe sizes within the ranges listed in Table QF-452.3 shall be used for test coupons to qualify within the ranges listed in Table QF-452.3.

QF-305 FUSING MACHINE OPERATORS

Each fusing machine operator shall have passed the mechanical and visual examinations prescribed in QF-301 and QF-302.

QF-305.1 Testing. Qualification testing shall be performed on test coupons in accordance with QF-311 and the following requirements:

(a) The data required by QF-130 shall be recorded for each fusing machine operator.

(b) The supervisor conducting the test shall observe the making of the fused joint and verify that the FPS or SFPS was followed.

QF-305.2 Examination. Test coupons fused in accordance with QF-305.1 shall be evaluated as follows:

(a) The completed joint shall be visually examined in accordance with QF-302.1.

(b) After the joint is complete, the data required by QF-130 shall be reviewed for compliance with the requirements of the FPS or SFPS used for the qualification test.

(c) Bend test specimens shall be removed and tested and in accordance with QF-302.2.

QF-310 QUALIFICATION TEST COUPONS

QF-311 TEST COUPONS

The test coupons shall consist of fusing one pipe joint assembly in at least one of the positions shown in Figure QF-461.2.

QF-320 RETESTS AND RENEWAL OF QUALIFICATION

QF-321 RETESTS

A fusing machine operator who fails one or more of the tests prescribed in QF-302, as applicable, may be retested under the following conditions.

QF-321.1 Immediate Retest Using Visual Examination. When the qualification coupon has failed the visual examination of QF-302.1, retests shall be accepted by visual examination before conducting the mechanical testing.

When an immediate retest is made, the fusing machine operator shall make two consecutive test coupons. If both additional coupons pass the visual examination requirements, the examiner shall select one of the acceptable test coupons for specimen removal to facilitate conducting the required mechanical testing.

QF-321.2 Immediate Retest Using Mechanical Testing. When the qualification coupon has failed the mechanical testing of QF-302.2, and an immediate retest is conducted, the fusing machine operator shall make two consecutive test coupons. If both additional coupons pass the mechanical test requirements, the fusing machine operator is qualified.

QF-321.3 Further Training. When the fusing machine operator has undergone additional training or completed additional fusing practice joints, a new test shall be made for each fusion test joint that failed to meet the requirements.

QF-322 EXPIRATION AND RENEWAL OF QUALIFICATION

QF-322.1 Expiration of Qualification. The performance qualification of a fusing machine operator shall be affected when one of the following conditions occurs:

(a) When a fusing machine operator has not completed a fused joint using a qualified FPS or SFPS for a time period of 6 months or more, their qualification shall expire.

(b) When there is a specific reason to question the ability of the fusing machine operator to make fused joints meeting the requirements of this Section, the qualifications of the fusing machine operator shall be revoked.

QF-322.2 Renewal of Qualification

(a) Performance qualifications that have expired under the provisions of QF-322.1(a) may be renewed by having the fusing machine operator fuse a single test coupon and subjecting the test coupon to the testing required by QF-302. A successful test shall renew all of the fusing machine operator's previous qualifications.

(b) Fusing machine operators whose qualifications have been revoked under the provisions of QF-322.1(b) may be requalified by fusing a test coupon representative of the planned production work. The fused test coupon shall be tested as required by QF-302. A successful test shall restore the fusing machine operator's qualification within the qualified range of essential performance variables listed in Table QF-362.

QF-360 ESSENTIAL VARIABLES FOR PERFORMANCE QUALIFICATION OF FUSING MACHINE OPERATORS

QF-361 GENERAL

A fusing machine operator shall be requalified whenever a change is made in one or more of the essential variables listed in Table QF-362.

Table QF-362
Essential Variables Applicable to Fusing Machine Operators

Paragraph		Brief of Variables
QF-403 Material	.1	ϕ Pipe material
	.2	ϕ Pipe diameter
QF-404 Position	.1	+ Position
QF-406 Equipment	.1	ϕ Equipment manufacturer

ARTICLE XXIV
PLASTIC FUSING DATA

QF-400 VARIABLES

QF-401 GENERAL

Each fusing variable described in this Article is applicable for procedure qualification when referenced in QF-250 for each specific fusing process. Essential variables for performance qualification are referenced in QF-360 for each specific fusing process. A change from one fusing process to another fusing process requires requalification (e.g., a change from butt-fusing to electro-fusing).

QF-401.1 Essential Variable (Procedure). A fusing condition that, if changed, will affect the mechanical properties of the joint (e.g., a change in pipe wall thickness).

QF-401.2 Essential Variable (Performance). A fusing condition that, if changed, will affect the ability of a fusing machine operator to make a sound fused joint [e.g., a change in pipe size (diameter) or pipe position].

QF-401.3 Nonessential Variable (Procedure). A fusing condition that, if changed, will *not* affect the mechanical properties of a fused joint [e.g., a change in pipe size (diameter)].

QF-401.4 Fusing Data. The fusing data includes the fusing variables grouped as joints, pipe material, position, thermal conditions, equipment, and technique.

QF-402 JOINTS

QF-402.1 A change in the type of joint from that qualified, except that a square butt joint qualifies a mitered joint.

QF-402.2 A change in the pipe O.D. surface misalignment of more than 10% of the wall thickness of the thinner member to be fused.

QF-403 MATERIAL

QF-403.1 A change to any pipe material other than those listed in Table QF-422.

QF-403.2 A change in the pipe diameter beyond the range qualified in Table QF-452.3.

QF-403.3 A change in the pipe wall thickness beyond the range qualified. See QF-202.2.1.

QF-403.4 A change in the cross-sectional area to be fused beyond the range specified.

QF-404 POSITION

QF-404.1 The addition of other fusing positions beyond that qualified. See QF-303.1.

QF-405 THERMAL CONDITIONS

QF-405.1 A change in the heater surface temperature to a value beyond the range qualified.

QF-405.2 A change in the interfacial pressure to a value beyond the range qualified.

QF-405.3 A decrease in melt bead size from that qualified.

QF-405.4 An increase in heater plate removal time from that qualified.

QF-405.5 A decrease in the cool time at butt-fusing pressure from that qualified.

QF-406 EQUIPMENT

QF-406.1 A change in the fusing machine manufacturer.

QF-407 TECHNIQUE

QF-407.1 A change in fabrication location from the fabrication shop to field applications or vice versa.

QF-420 MATERIAL GROUPINGS

High-density polyethylene pipe listed in Table QF-422 may be fused in accordance with Section IX.

Table QF-422
Material Grouping

Specification	Classification	Product Form
D3035	PE 2708	Pipe
	PE 3608	
F714	PE 4710	
D3261	PE 2708	Fittings
	PE 3608	
	PE 4710	

QF-450 PIPE FUSING LIMITS

Table QF-452.3
Pipe Fusing Diameter Limits

Size of Test Coupon — IPS [in. (mm)]	Size Qualified — IPS [in. (mm)]	
	Minimum	Maximum
Less than 6 [6.625 (168)]	None	Size tested
6 to less than 8 [6.625 (168) to less than 8.625 (219)]	None	Less than 8 [less than 8.625 (219)]
8 to 20 [8.625 (219) to 20 (508)]	8 [8.625 (219)]	20 [20 (508)]
Greater than 20 [greater than 20 (508)]	Greater than 20 [greater than 20 (508)]	Unlimited

QF-460 GRAPHICS

QF-461 POSITIONS

Figure QF-461.1
Fusing Positions

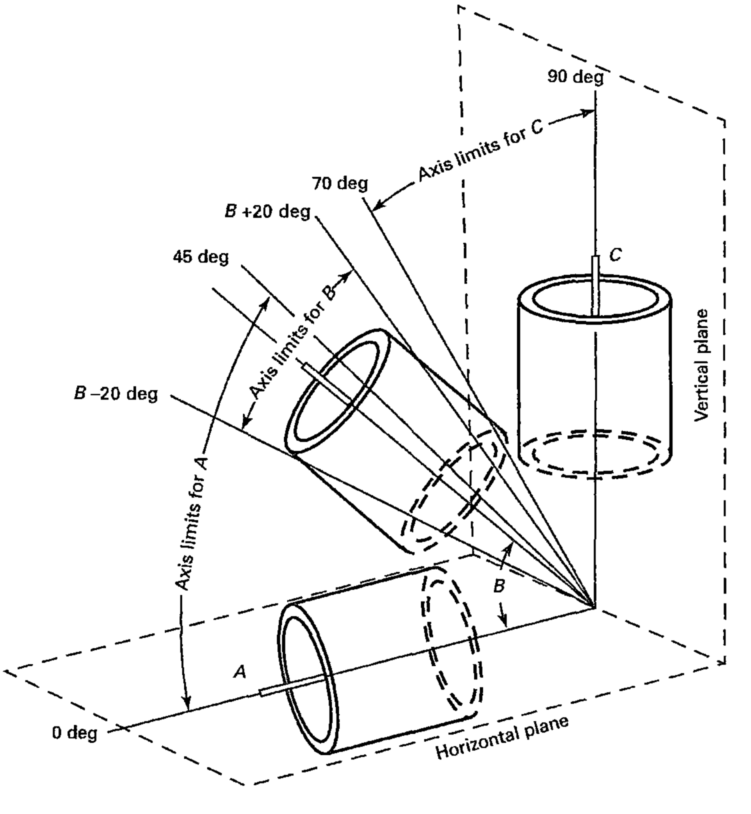


Figure QF-461.1
Fusing Positions (Cont'd)

Table continued

Tabulation of Positions in Joints		
Position	Diagram Reference	Inclination of Axis, deg
Horizontal	A	0 ± 45
Intermediate	B	B ± 20
Vertical	C	90 ± 20

GENERAL NOTE: Inclination of the axis is measured from the horizontal reference plane toward the vertical.

Figure QF-461.2
Fusing Test Positions

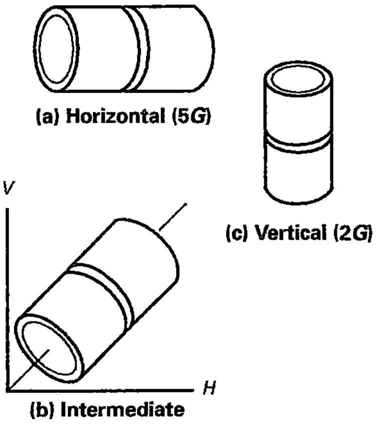
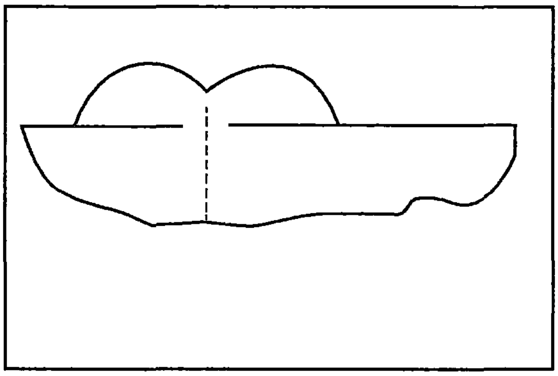
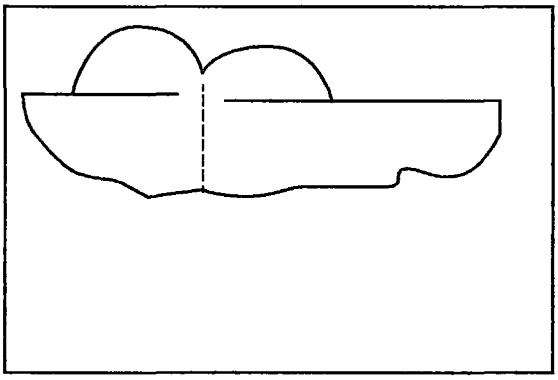


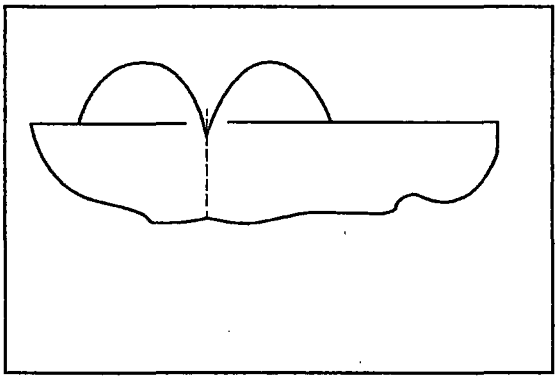
Figure QF-462
Cross Section of Upset Beads for Butt-Fused PE Pipe



(a) Visually Acceptable — Uniform Bead Around Pipe

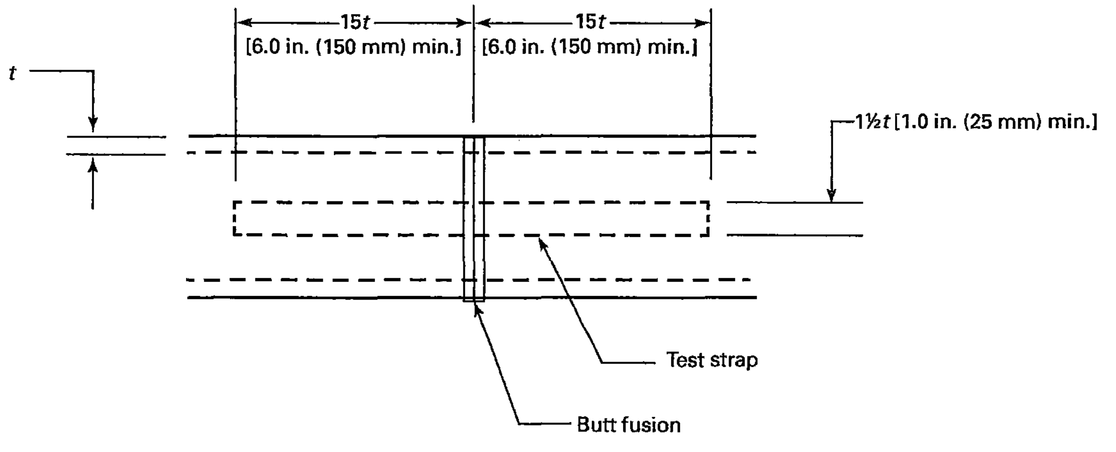


(b) Visually Acceptable — Non-Uniform Bead Around Pipe, But Localized Diameter Mismatch Less Than 10% of the Nominal Wall Thickness

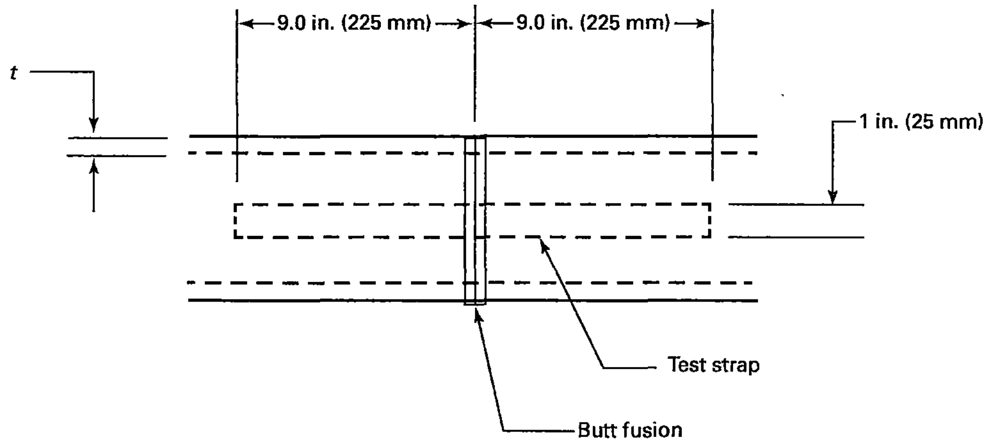


(c) Visually Unacceptable — V-Groove Too Deep at Pipe Tangent for Both Uniform and Non-Uniform Beads

Figure QF-463
Bend Test Specimen Removal, Configuration, and Testing

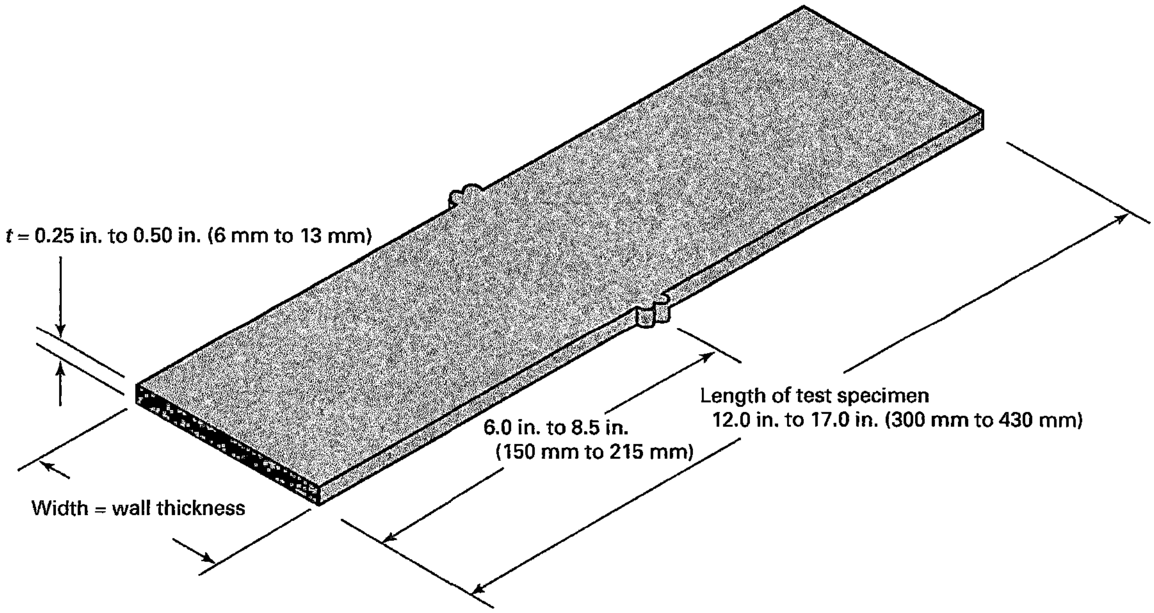


(a) Reverse-Bend Test Specimen Removal [for $t_{max} \leq 1$ in. (25 mm)]

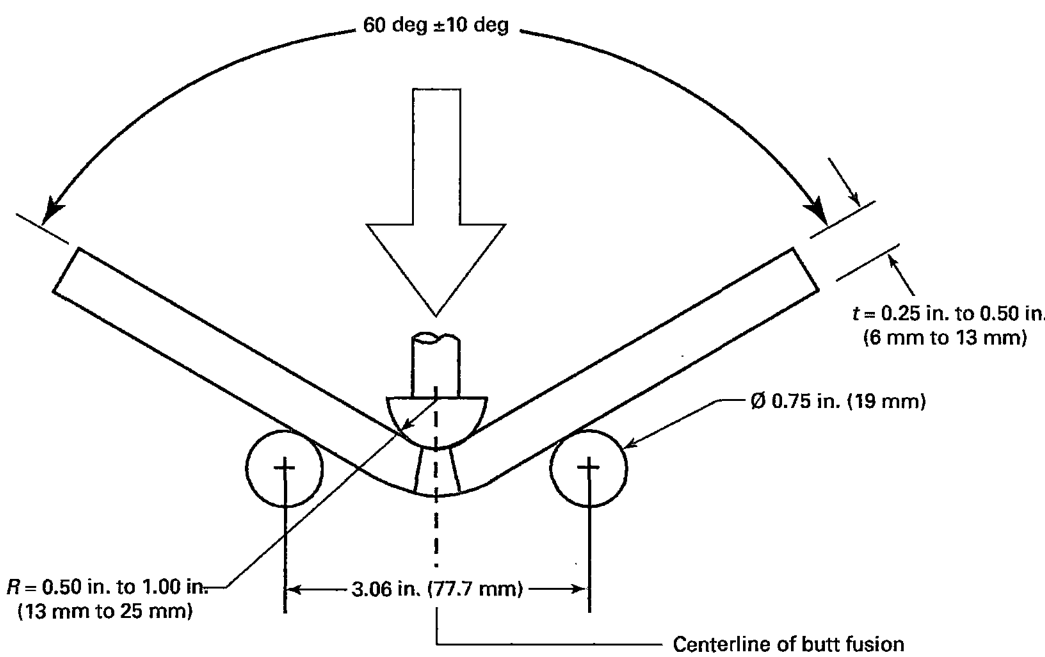


(b) Guided Side-Bend Test Specimen Removal [for $t_{max} > 1$ in. (25 mm)]

Figure QF-463
Bend Test Specimen Removal, Configuration, and Testing (Cont'd)

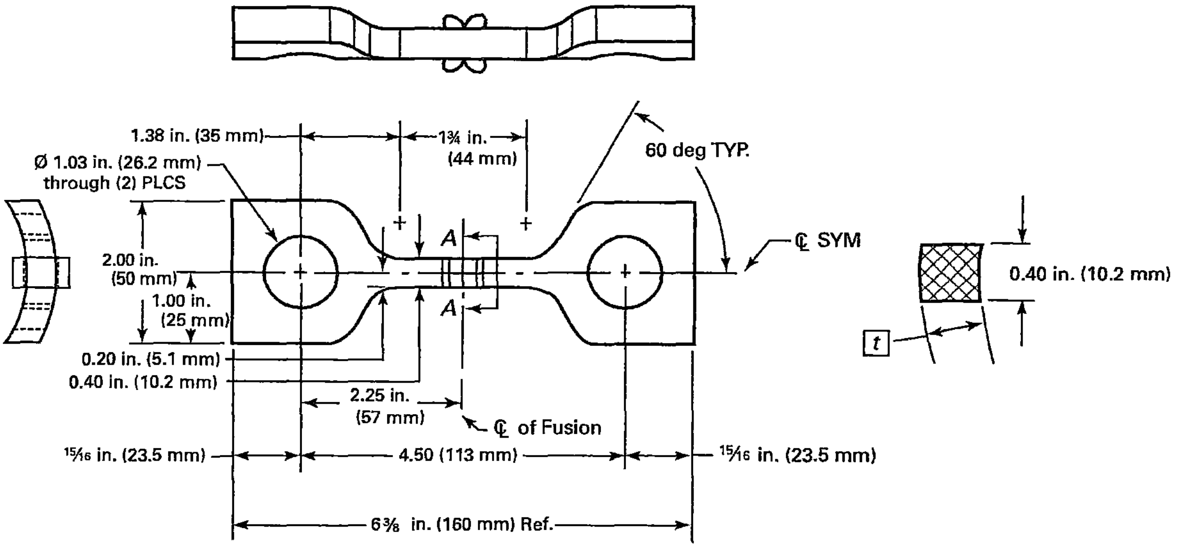


(c) Guided Side-Bend Test Specimen



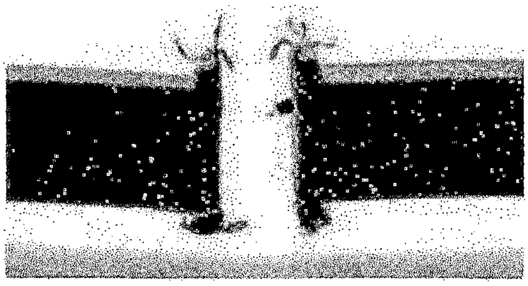
(d) Guided Side-Bend Test Machine Dimensions

Figure QF-464
HSTIT Specimen Configuration and Dimensions

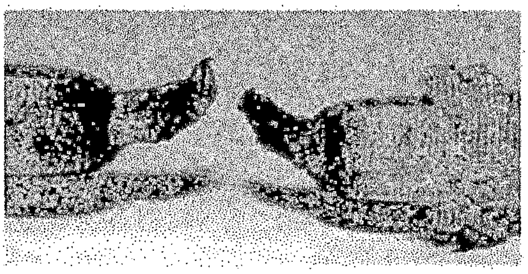


GENERAL NOTES:
(a) All machined surfaces 125 RMS or better.
(b) 3 place dimensions ±0.005 in. (±0.13 mm).
(c) 2 place dimensions ±0.010 in. (±0.25 mm).
(d) Fractional dimensions ±$^1/_{32}$ in. (±0.80 mm).
(e) All internal radii R$^1/_2$ in. (±0.13 mm).
(f) All external radii R$^3/_8$ in. (10 mm).
(g) Bead remains on after machining.

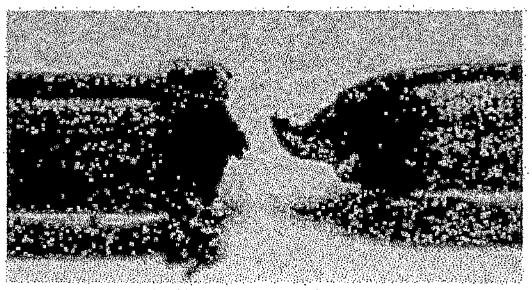
Figure QF-465
HSTIT Specimen Failure Examples



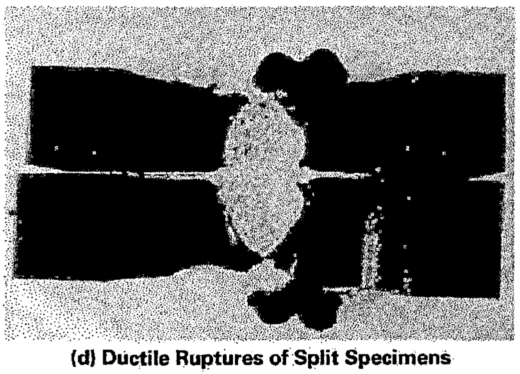
(a) Brittle Rupture



(b) Ductile Rupture Outside Fusion Interface



(c) Ductile Rupture Adjacent to Fusion Interface



(d) Ductile Ruptures of Split Specimens

QF-480 FORMS

FORM QF-482 Suggested Format for Fusing Procedure Specifications (FPS)
(See QF-201.3, Section IX, ASME Boiler and Pressure Vessel Code)

Company Name____________________ By____________________

Fusing Procedure Specification No.____________________ Date ____________________

Revision No.____________________ Date____________________

FPS Qualification ☐ By testing ☐ SFPS If qualified by testing, supporting PQR No.(s) ____________________

Fusing Process Type ____________________

Joints (QF-402) Details

Joint Type ____________________

Pipe End Preparation ____________________

Miter Joint Angle ____________________

Pipe Surface Alignment ____________________

Sketches, production drawings, weld symbols, or written description should show the general arrangement of the parts to be fused. Where applicable, the details of the joint groove may be specified.

Sketches may be attached to illustrate joint design.

Materials (QF-403)

Specification __________ Classification__________ to Specification __________ Classification__________

Pipe Size (Diameter)__________ Pipe Wall Thickness__________

Other____________________

Position (QF-404)

Pipe Position____________________

Other ____________________

Thermal Conditions (QF-405)

Heater Surface Temperature Range____________________

Fusing Interfacial Pressure Range____________________

Drag Pressure Range__________ Butt-Fusing Pressure Range__________

Melt Bead Size Range__________ Heater Plate Removal Time Range __________

Cool-Down Time at Butt-Fusing Pressure Range____________________

Equipment (QF-406)

Fusing Machine Manufacturer____________________

Data Acquisition Used ☐ Yes ☐ No Data Acquisition Machine Manufacturer__________

Hydraulic Hose Length____________________

Technique (QF-407)

Location ☐ Fabrication Shop ☐ Field

____

FORM QF-483 Suggested Format for Fusing Procedure Qualification Records (PQR)
(See QF-201.5(d), Section IX, ASME Boiler and Pressure Vessel Code)

Company Name ______________________________

Procedure Qualification Record No. ______________ Date ______________

FPS No. ______________________________

Fusing Process(es) ______________________________

Joints (QF-402)

Pipe Surface Alignment ______________

Pipe End Preparation of Test Coupon

Material (QF-403)

Specification ______________ Classification ______________

to Specification ______________ Classification ______________

Pipe Size (Diameter) ______________

Pipe Wall Thickness ______________

Other ______________

Equipment (QF-406)

Fusing Machine Manufacturer ______________

____

Data Acquisition Used ☐ Yes ☐ No

Data Acquisition System Manufacturer ______________

Hydraulic Hose Length ______________

Position (QF-404)

Position of Pipe ______________

Other ______________

Technique (QF-407)

Location ☐ Fabrication Shop ☐ Field

____

____

____

____

Thermal Conditions (QF-405)

Heater Surface Temperature ______________

Fusing Interfacial Pressure ______________

Drag Pressure ______________

Butt-Fusing Pressure ______________

Melt Bead Size ______________

Heater Plate Removal Time ______________

Cool-Down Time at Butt-Fusing Pressure ______________

Other ______________

____

Other

____

____

____

____

____

____

FORM QF-483 (Back) PQR No. ________

Visual Examination (QF-141)

____

____

____

____

Elevated Temperature Sustained Pressure Tests (QF-142)

Joint No.	Heater Temperature	Interfacial Pressure	Result	Joint No.	Heater Temperature	Interfacial Pressure	Result

High-Speed Tensile Impact Tests (QF-144)

Joint No.	Spec. No.	Heater Temperature	Interfacial Pressure	Type of Failure	Location of Failure	Joint No.	Spec. No.	Heater Temperature	Interfacial Pressure	Type of Failure	Location of Failure

Attach additional sheet(s) for high-speed tensile test impact test data for pipe larger than NPS 4 (DN 100).

Fusing Machine Operator's Name ________ Identification No. ________ Stamp No. ________

Tests Conducted By ________ Laboratory Test No. ________

We certify that the statements in this record are correct and that the test joints were prepared, fused, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Organization ________

Date ________ Certified By ________

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

FORM QF-484 Suggested Format for Fusing Machine Operator Performance Qualifications (FPQ)
(See QF-301.4, Section IX, ASME Boiler and Pressure Vessel Code)

Fusing Machine Operator's Name ____________________ Identification No. ____________________

Test Description *(Information Only)*

Type of Test: ☐ Original qualification ☐ Requalification

Identification of FPS Followed ____________________

Pipe Specification__________ Classification__________ to Specification__________ Classification__________

Pipe Size (Diameter) __________ Pipe Wall Thickness __________

Testing Conditions and Qualification Limits

Fusing Variables (QF-360)	Actual Values	Range Qualified
Pipe Material		
Pipe Size (Diameter)		
Pipe Position		
Fusing Machine Manufacturer		

RESULTS

Visual Examination of Completed Joint [QF-305.2(a)] ____________________

Examination of Data Acquisition Output [QF-305.2(b)] ____________________

Bend Tests (QF-302.2)

Specimen No.	Type of Bend	Result	Specimen No.	Type of Bend	Result

Bend Specimens Evaluated By ____________________ Company ____________________

Mechanical Tests Conducted By ____________________ Laboratory Test No. ____________________

Fusing Supervised By ____________________

Data Acquisition Output Examined By ____________________

We certify that the statements in this record are correct and that the test coupons were prepared, fused, and tested in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

Organization ____________________

Date ____________________ Certified by ____________________

FORM QF-485 Suggested Format for Plastic Pipe Fusing Data Acquisition Log Review
(See QF-131 Section IX, ASME Boiler and Pressure Vessel Code)

Job Information__________ Job Number__________

Fusing Machine Operator Name__________ Fusing Machine Operator Identification__________

FPS or SFPS Used__________ Date __________ Time __________

Fusing Machine Identification __________ Fusing Machine Manufacturer__________Joint Number__________

Pipe Specification __________Classification __________ to Specification __________ Classification __________

Pipe Size (Diameter)__________ Pipe Wall Thickness__________ Joint Configuration __________

FUSING VARIABLES

Heater Surface Temperature__________ Within Qualification Range ☐ Yes ☐ No

Interfacial Fusing Pressure__________ Within Qualification Range ☐ Yes ☐ No

Drag Pressure__________

Butt-Fusing Pressure: Within Qualification Range ☐ Yes ☐ No

Calculated Value__________ Recorded Hydraulic-Fusing Pressure __________ Acceptable ☐ Yes ☐ No

Butt-Fusing Pressure Drop to Less Than Drag Pressure? ☐Yes ☐ No

Gauge Pressure During Initial Heat Cycle__________ Elapsed Time During Initial Heat Cycle__________

Gauge Pressure During Heat-Soak Cycle__________ Elapsed Time During Heat-Soak Cycle __________

Gauge Pressure During Fusing/Cool Cycle__________

Elapsed Time During Fusing/Cool Cycle__________Within Qualification Range ☐ Yes ☐ No

Melt Bead Size__________ Within Qualification Range ☐ Yes ☐ No

Heater Plate Removal Time__________ Within Qualification Range ☐ Yes ☐ No

Data Logger Probe __________External Probe __________

Data Acquisition System Manufacturer __________

Review of the Recorded Pressure/Time Diagram

Acceptable ☐ Yes ☐ No

Data Acquisition Acceptable ☐ Yes ☐ No

Examiner name__________ Examiner signature__________

Date __________

QF-490 DEFINITIONS

QF-491 GENERAL

Terms relating to fusing used in Section IX are listed in QG-109. Other common terms relating to fusing are defined in ASTM F 412, Standard Terminology Relating to Plastic Piping Systems.

QF-492 DEFINITIONS

Definitions relocated to QG-109.

ANEXO 4

8

PROJECT QUALITY MANAGEMENT

Project Quality Management includes the processes and activities of the performing organization that determine quality policies, objectives, and responsibilities so that the project will satisfy the needs for which it was undertaken. Project Quality Management uses policies and procedures to implement, within the project's context, the organization's quality management system and, as appropriate, it supports continuous process improvement activities as undertaken on behalf of the performing organization. Project Quality Management works to ensure that the project requirements, including product requirements, are met and validated.

Figure 8-1 provides an overview of the Project Quality Management processes, which include:

8.1 Plan Quality Management—The process of identifying quality requirements and/or standards for the project and its deliverables and documenting how the project will demonstrate compliance with quality requirements.

8.2 Perform Quality Assurance—The process of auditing the quality requirements and the results from quality control measurements to ensure that appropriate quality standards and operational definitions are used.

8.3 Control Quality—The process of monitoring and recording results of executing the quality activities to assess performance and recommend necessary changes.

These processes interact with each other and with processes in other Knowledge Areas as described in detail in Section 3 and Annex A1.

Project Quality Management addresses the management of the project and the deliverables of the project. It applies to all projects, regardless of the nature of their deliverables. Quality measures and techniques are specific to the type of deliverables being produced by the project. For example, the project quality management of software deliverables may use different approaches and measures from those used when building a nuclear power plant. In either case, failure to meet the quality requirements can have serious, negative consequences for any or all of the project's stakeholders. For example:

- Meeting customer requirements by overworking the project team may result in decreased profits and increased project risks, employee attrition, errors, or rework.
- Meeting project schedule objectives by rushing planned quality inspections may result in undetected errors, decreased profits, and increased post-implementation risks.

Quality and *grade* are not the same concepts. Quality as a delivered performance or result is "the degree to which a set of inherent characteristics fulfill requirements" (ISO 9000) [10]. Grade as a design intent is a category assigned to deliverables having the same functional use but different technical characteristics. The project manager and the project management team are responsible for managing the tradeoffs associated with delivering the required levels of both quality and grade. While a quality level that fails to meet quality requirements is always a problem, a low grade of quality may not be a problem. For example:

- It may not be a problem if a suitable low-grade software product (one with a limited number of features) is of high quality (no obvious defects, readable manual). In this example, the product would be appropriate for its general purpose of use.
- It may be a problem if a high-grade software product (one with numerous features) is of low quality (many defects, poorly organized user documentation). In essence, its high-grade feature set would prove ineffective and/or inefficient due to its low quality.

The project management team should determine the appropriate levels of accuracy and precision for use in the quality management plan. *Precision* is a measure of exactness. For example, the magnitude for each increment on the measurement's number line is the interval that determines the measurement's precision—the greater the number of increments, the greater the precision. *Accuracy* is an assessment of correctness. For example, if the measured value of an item is very close to the true value of the characteristic being measured, the measurement is more accurate. An illustration of this concept is the comparison of archery targets. Arrows clustered tightly in one area of the target, even if they are not clustered in the bull's-eye, are considered to have high precision. Targets where the arrows are more spread out but equidistant from the bull's-eye are considered to have the same degree of accuracy. Targets where the arrows are both tightly grouped and within the bull's-eye are considered to be both accurate and precise. Precise measurements are not necessarily accurate measurements, and accurate measurements are not necessarily precise measurements.

The basic approach to project quality management as described in this section is intended to be compatible with International Organization for Standardization (ISO) quality standards. Every project should have a quality management plan. Project teams should follow the quality management plan and should have data to demonstrate compliance with the plan.

In the context of achieving ISO compatibility, modern quality management approaches seek to minimize variation and to deliver results that meet defined requirements. These approaches recognize the importance of:

- **Customer satisfaction.** Understanding, evaluating, defining, and managing requirements so that customer expectations are met. This requires a combination of conformance to requirements (to ensure the project produces what it was created to produce) and fitness for use (the product or service needs to satisfy the real needs).
- **Prevention over inspection.** Quality should be planned, designed, and built into—not inspected into the project's management or the project's deliverables. The cost of preventing mistakes is generally much less than the cost of correcting mistakes when they are found by inspection or during usage.
- **Continuous improvement.** The PDCA (plan-do-check-act) cycle is the basis for quality improvement as defined by Shewhart and modified by Deming. In addition, quality improvement initiatives such as Total Quality Management (TQM), Six Sigma, and Lean Six Sigma could improve the quality of the project's management as well as the quality of the project's product. Commonly used process improvement models include Malcolm Baldrige, *Organizational Project Management Maturity Model (OPM3®)*, and Capability Maturity Model Integrated (CMMI®).
- **Management Responsibility.** Success requires the participation of all members of the project team. Nevertheless, management retains, within its responsibility for quality, a related responsibility to provide suitable resources at adequate capacities.
- **Cost of quality (COQ).** Cost of quality refers to the total cost of the conformance work and the nonconformance work that should be done as a compensatory effort because, on the first attempt to perform that work, the potential exists that some portion of the required work effort may be done or has been done incorrectly. The costs for quality work may be incurred throughout the deliverable's life cycle. For example, decisions made by the project team can impact the operational costs associated with using a completed deliverable. Post-project quality costs may be incurred because of product returns, warranty claims, and recall campaigns. Therefore, because of the temporary nature of projects and the potential benefits that may be derived from reducing the post-project cost of quality, sponsoring organizations may choose to invest in product quality improvement. These investments generally are made in the areas of conformance work that act to prevent defects or act to mitigate the costs of defects by inspecting out nonconforming units. Refer to Figure 8-2 and Section 8.1.2.2. Moreover, the issues related to post-project COQ should be the concern of program management and portfolio management such that project, program, and portfolio management offices should apply appropriate reviews, templates, and funding allocations for this purpose.

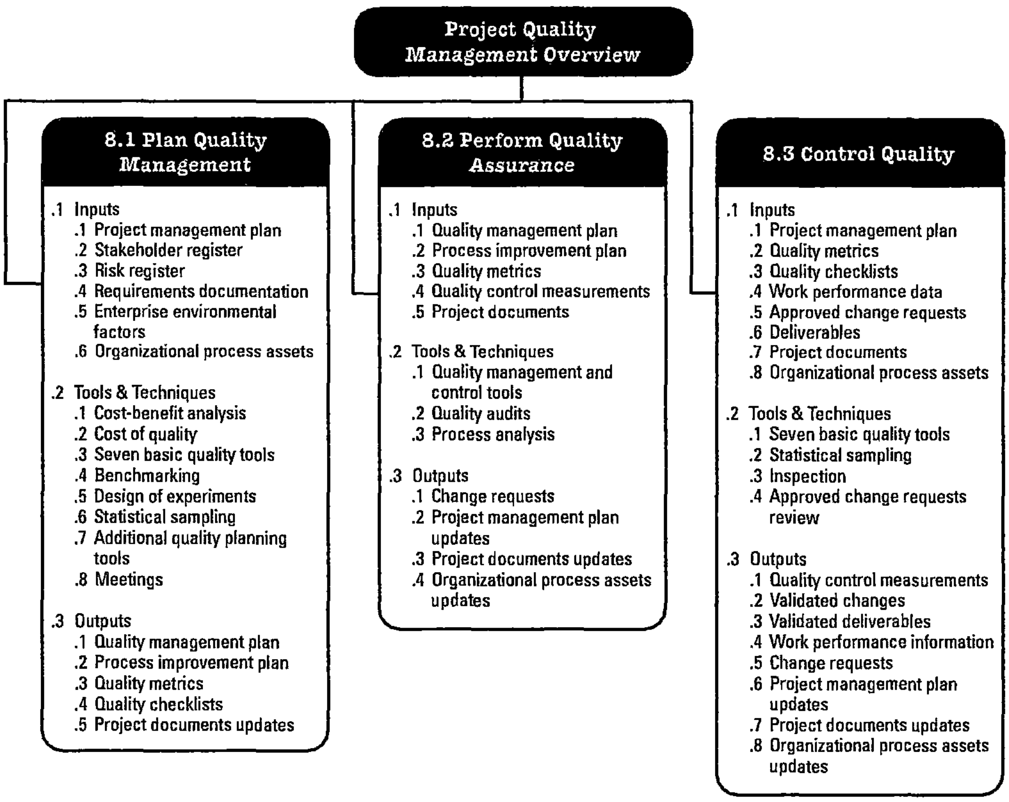


Figure 8-1. Project Quality Management Overview

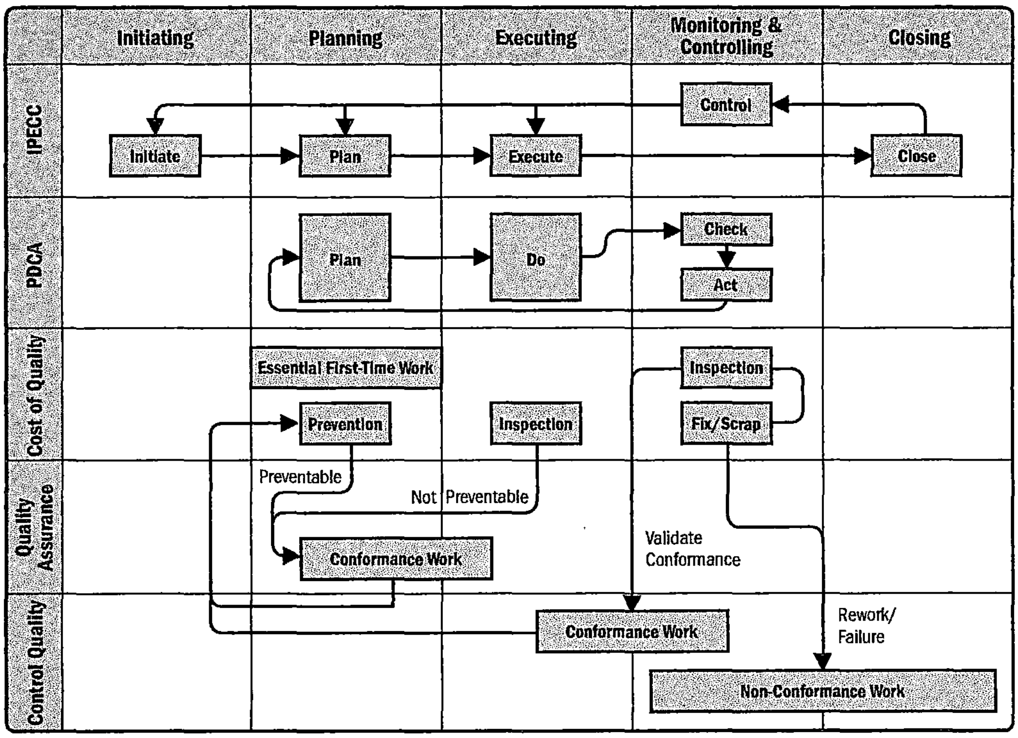


Figure 8-2. Fundamental Relationships of Quality Assurance and Control Quality to the IPECC, PDCA, Cost of Quality Models and Project Management Process Groups

8.1 Plan Quality Management

Plan Quality Management is the process of identifying quality requirements and/or standards for the project and its deliverables, and documenting how the project will demonstrate compliance with relevant quality requirements. The key benefit of this process is that it provides guidance and direction on how quality will be managed and validated throughout the project. The inputs, tools and techniques, and outputs of this process are depicted in Figure 8-3. Figure 8-4 depicts the data flow diagram of the process.

Inputs	Tools & Techniques	Outputs
.1 Project management plan .2 Stakeholder register .3 Risk register .4 Requirements documentation .5 Enterprise environmental factors .6 Organizational process assets	.1 Cost-benefit analysis .2 Cost of quality .3 Seven basic quality tools .4 Benchmarking .5 Design of experiments .6 Statistical sampling .7 Additional quality planning tools .8 Meetings	.1 Quality management plan .2 Process improvement plan .3 Quality metrics .4 Quality checklists .5 Project documents updates

Figure 8-3. Plan Quality Management Inputs, Tools & Techniques, and Outputs

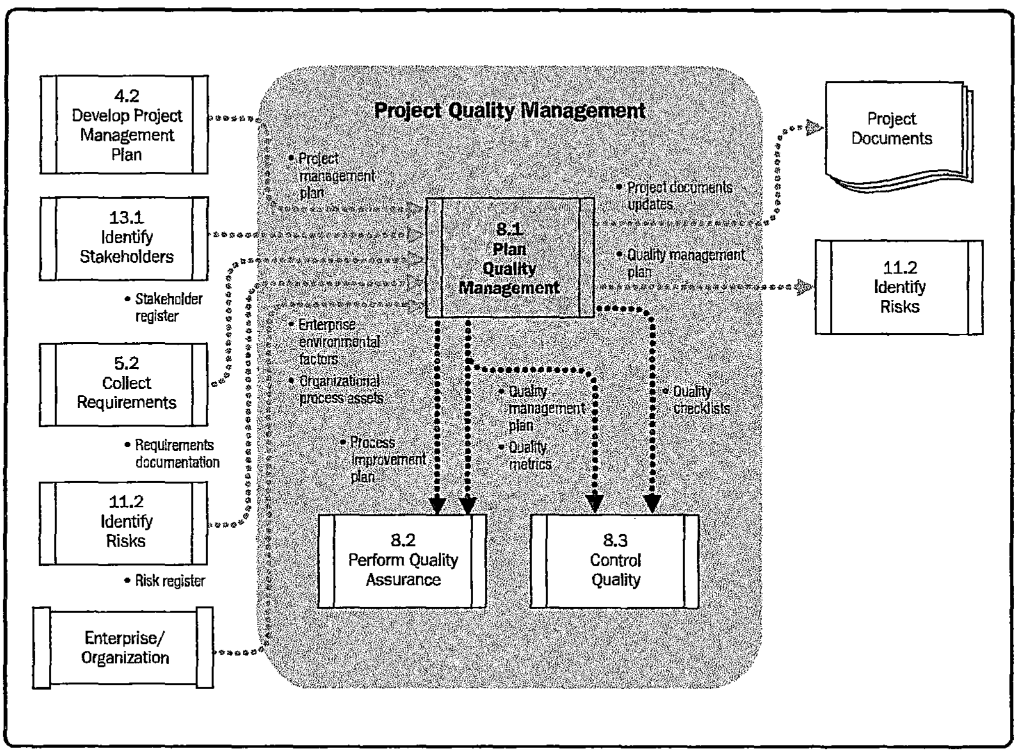


Figure 8-4. Plan Quality Management Data Flow Diagram

Quality planning should be performed in parallel with the other planning processes. For example, proposed changes in the deliverables to meet identified quality standards may require cost or schedule adjustments and a detailed risk analysis of the impact to plans.

The quality planning techniques discussed here are those used most frequently on projects. There are many others that may be useful on certain projects or in some application areas.

8.1.1 Plan Quality Management: Inputs

8.1.1.1 Project Management Plan

Described in Section 4.2.3.1. The project management plan is used to develop the quality management plan. The information used for the development of the quality management plan includes, but is not limited to:

- **Scope baseline.** The scope baseline (Section 5.4.3.1) includes:
  - *Project scope statement.* The project scope statement contains the project description, major project deliverables, and acceptance criteria. The product scope often contains details of technical issues and other concerns that can affect quality planning and that should have been identified as a result of the planning processes in Project Scope Management. The definition of acceptance criteria may significantly increase or decrease quality costs and therefore, project costs. Satisfying all acceptance criteria that the needs of the sponsor and/or customer have been met.
  - *Work breakdown structure (WBS).* The WBS identifies the deliverables and the work packages used to measure project performance.
  - *WBS dictionary.* The WBS dictionary provides detailed information for WBS elements.
- **Schedule baseline.** The schedule baseline documents the accepted schedule performance measures, including start and finish dates (Section 6.6.3.1).
- **Cost baseline.** The cost baseline documents the accepted time interval being used to measure cost performance (Section 7.3.3.1).
- **Other management plans.** These plans contribute to the overall project quality and may highlight actionable areas of concern with regard to the project's quality.

8.1.1.2 Stakeholder Register

Described in Section 13.1.3.1. The stakeholder register aids in identifying those stakeholders possessing a particular interest in, or having an impact on, quality.

8.1.1.3 Risk Register

Described in Section 11.2.3.1. The risk register contains information on threats and opportunities that may impact quality requirements.

8.1.1.4 Requirements Documentation

Described in Section 5.2.3.1. Requirements documentation captures the requirements that the project shall meet pertaining to stakeholder expectations. The components of the requirements documentation include, but are not limited to, project (including product) and quality requirements. The requirements are used by the project team to help plan how quality control will be implemented on the project.

8.1.1.5 Enterprise Environmental Factors

Described in Section 2.1.5. The enterprise environmental factors that influence the Plan Quality Management process include, but are not limited to:

- Governmental agency regulations;
- Rules, standards, and guidelines specific to the application area;
- Working or operating conditions of the project or its deliverables that may affect project quality; and
- Cultural perceptions that may influence expectations about quality.

8.1.1.6 Organizational Process Assets

Described in Section 2.1.4. The organizational process assets that influence the Plan Quality Management process include, but are not limited to:

- Organizational quality policies, procedures, and guidelines. The performing organization's quality policy, as endorsed by senior management, sets the organization's intended direction on implementing its quality management approach;
- Historical databases; and
- Lessons learned from previous phases or projects.

8.1.2 Plan Quality Management: Tools and Techniques

8.1.2.1 Cost-Benefit Analysis

The primary benefits of meeting quality requirements include less rework, higher productivity, lower costs, increased stakeholder satisfaction, and increased profitability. A cost-benefit analysis for each quality activity compares the cost of the quality step to the expected benefit.

8.1.2.2 Cost of Quality (COQ)

Cost of quality includes all costs incurred over the life of the product by investment in preventing nonconformance to requirements, appraising the product or service for conformance to requirements, and failing to meet requirements (rework). Failure costs are often categorized into internal (found by the project) and external (found by the customer). Failure costs are also called cost of poor quality. Figure 8-5 provides some examples to consider in each area.

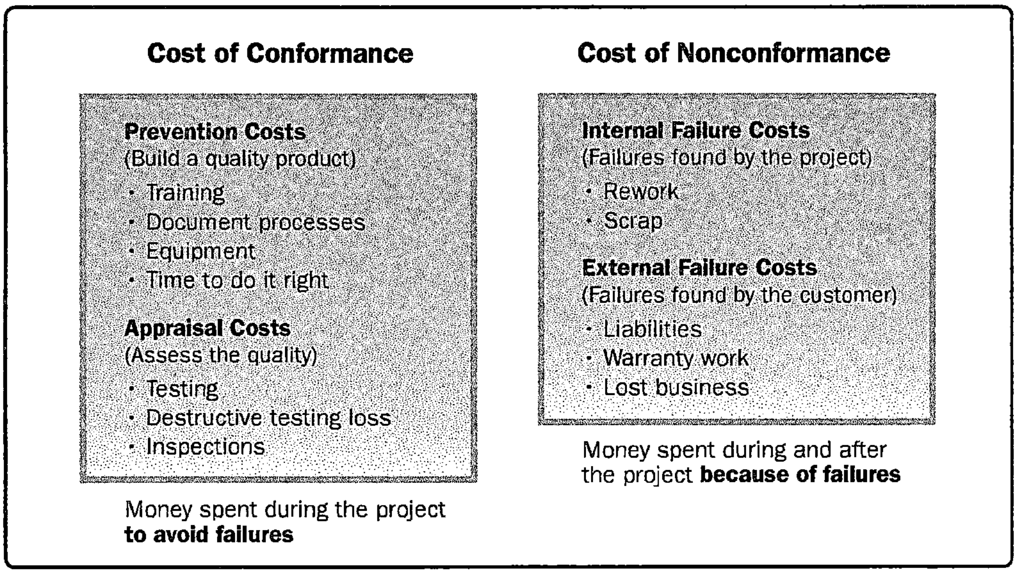


Figure 8-5. Cost of Quality

8.1.2.3 Seven Basic Quality Tools

The seven basic quality tools, also known in the industry as 7QC Tools, are used within the context of the PDCA Cycle to solve quality-related problems. As conceptually illustrated in Figure 8-7, the seven basic quality tools are:

- *Cause-and-effect diagrams,* which are also known as fishbone diagrams or as Ishikawa diagrams. The problem statement placed at the head of the fishbone is used as a starting point to trace the problem's source back to its actionable root cause. The problem statement typically describes the problem as a gap to be closed or as an objective to be achieved. The causes are found by looking at the problem statement and asking "why" until the actionable root cause has been identified or until the reasonable possibilities on each fishbone have been exhausted. Fishbone diagrams often prove useful in linking the undesirable effects seen as special variation to the assignable cause upon which project teams should implement corrective actions to eliminate the special variation detected in a control chart.
- *Flowcharts,* which are also referred to as process maps because they display the sequence of steps and the branching possibilities that exist for a process that transforms one or more inputs into one or more outputs. Flowcharts show the activities, decision points, branching loops, parallel paths, and the overall order of processing by mapping the operational details of procedures that exist within a horizontal value chain of a SIPOC model (Figure 8-6). Flowcharts may prove useful in understanding and estimating the cost of quality in a process. This is obtained by using the workflow branching logic and associated relative frequencies to estimate expected monetary value for the conformance and nonconformance work required to deliver the expected conforming output.

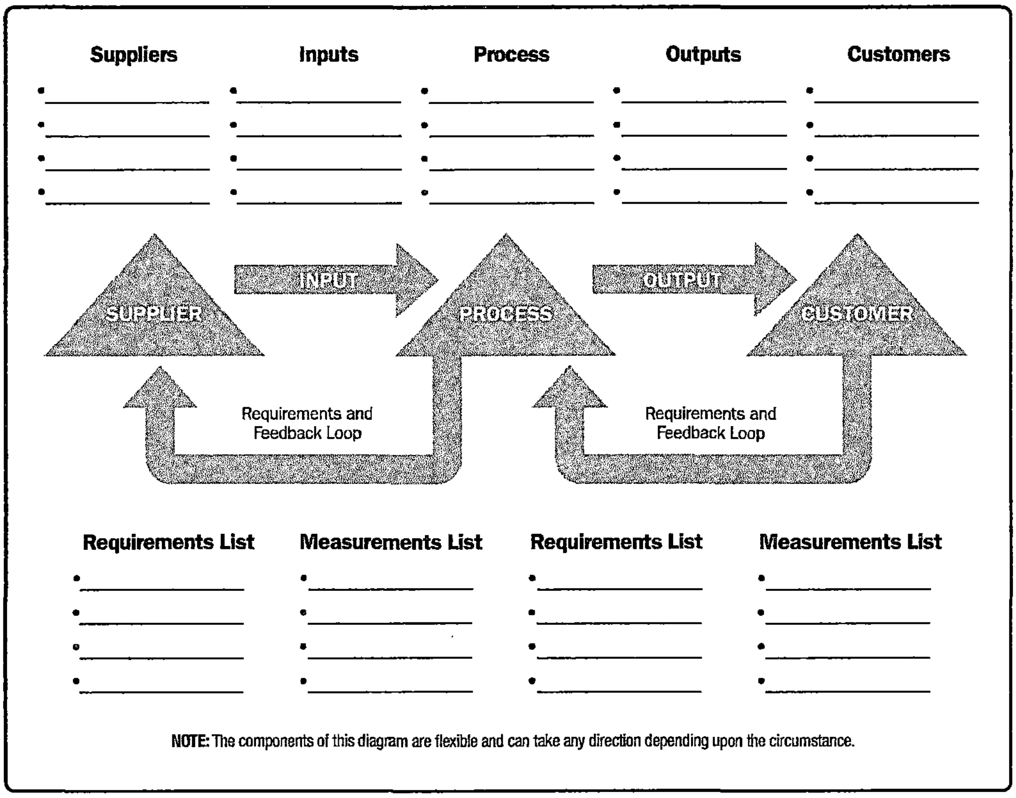


Figure 8-6. The SIPOC Model

- *Checksheets,* which are also known as tally sheets and may be used as a checklist when gathering data. Checksheets are used to organize facts in a manner that will facilitate the effective collection of useful data about a potential quality problem. They are especially useful for gathering attributes data while performing inspections to identify defects. For example, data about the frequencies or consequences of defects collected in checksheets are often displayed using Pareto diagrams.
- *Pareto diagrams,* exist as a special form of vertical bar chart and are used to identify the vital few sources that are responsible for causing most of a problem's effects. The categories shown on the horizontal axis exist as a valid probability distribution that accounts for 100% of the possible observations. The relative frequencies of each specified cause listed on the horizontal axis decrease in magnitude until the default source named "*other*" accounts for any nonspecified causes. Typically, the Pareto diagram will be organized into categories that measure either frequencies or consequences.

- *Histograms,* are a special form of bar chart and are used to describe the central tendency, dispersion, and shape of a statistical distribution. Unlike the control chart, the histogram does not consider the influence of time on the variation that exists within a distribution.
- *Control charts,* are used to determine whether or not a process is stable or has predictable performance. Upper and lower specification limits are based on requirements of the agreement. They reflect the maximum and minimum values allowed. There may be penalties associated with exceeding the specification limits. Upper and lower control limits are different from specification limits. The control limits are determined using standard statistical calculations and principles to ultimately establish the natural capability for a stable process. The project manager and appropriate stakeholders may use the statistically calculated control limits to identify the points at which corrective action will be taken to prevent unnatural performance. The corrective action typically seeks to maintain the natural stability of a stable and capable process. For repetitive processes, the control limits are generally set at ±3 s around a process mean that has been set at 0 s. A process is considered out of control when: (1) a data point exceeds a control limit; (2) seven consecutive plot points are above the mean; or (3) seven consecutive plot points are below the mean. Control charts can be used to monitor various types of output variables. Although used most frequently to track repetitive activities required for producing manufactured lots, control charts may also be used to monitor cost and schedule variances, volume, and frequency of scope changes, or other management results to help determine if the project management processes are in control.
- *Scatter diagrams,* plot ordered pairs (X, Y) and are sometimes called correlation charts because they seek to explain a change in the dependent variable, Y, in relationship to a change observed in the corresponding independent variable, X. The direction of correlation may be proportional (positive correlation), inverse (negative correlation), or a pattern of correlation may not exist (zero correlation). If correlation can be established, a regression line can be calculated and used to estimate how a change to the independent variable will influence the value of the dependent variable.

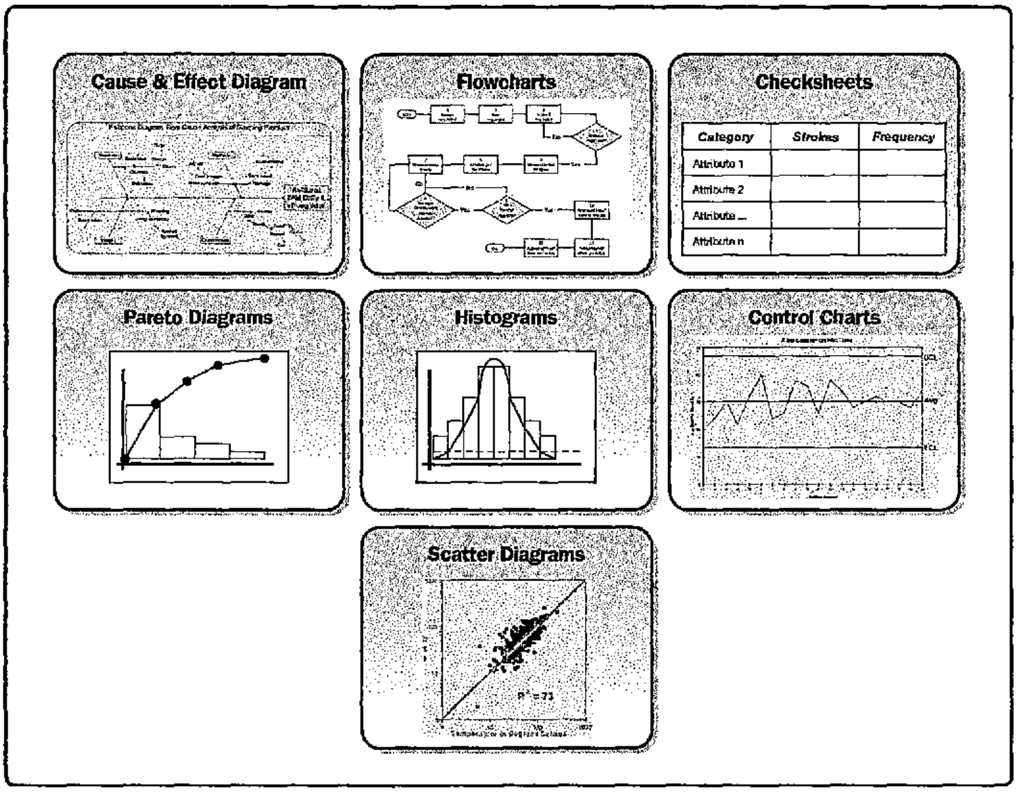


Figure 8-7. Storyboard Illustrating a Conceptual Example of Each of the Seven Basic Quality Tools

8.1.2.4 Benchmarking

Benchmarking involves comparing actual or planned project practices to those of comparable projects to identify best practices, generate ideas for improvement, and provide a basis for measuring performance.

Benchmarked projects may exist within the performing organization or outside of it, or can be within the same application area. Benchmarking allows for analogies from projects in a different application area to be made.

8.1.2.5 Design of Experiments

Design of experiments (DOE) is a statistical method for identifying which factors may influence specific variables of a product or process under development or in production. DOE may be used during the Plan Quality Management process to determine the number and type of tests and their impact on cost of quality.

DOE also plays a role in optimizing products or processes. DOE is used to reduce the sensitivity of product performance to sources of variations caused by environmental or manufacturing differences. One important aspect of this technique is that it provides a statistical framework for systematically changing all of the important factors, rather than changing the factors one at a time. Analysis of the experimental data should provide the optimal conditions for the product or process, highlight the factors that influence the results, and reveal the presence of interactions and synergy among the factors. For example, automotive designers use this technique to determine which combination of suspension and tires will produce the most desirable ride characteristics at a reasonable cost.

8.1.2.6 Statistical Sampling

Statistical sampling involves choosing part of a population of interest for inspection (for example, selecting ten engineering drawings at random from a list of seventy-five). Sample frequency and sizes should be determined during the Plan Quality Management process so the cost of quality will include the number of tests, expected scrap, etc.

There is a substantial body of knowledge on statistical sampling. In some application areas, it may be necessary for the project management team to be familiar with a variety of sampling techniques to assure the sample selected represents the population of interest.

8.1.2.7 Additional Quality Planning Tools

Other quality planning tools are used to define the quality requirements and to plan effective quality management activities. These include, but are not limited to:

- **Brainstorming.** This technique is used to generate ideas (defined in Section 11.2.2.2).
- **Force field analysis.** These are diagrams of the forces for and against change.
- **Nominal group technique.** This technique is used to allow ideas to be brainstormed in small groups and then reviewed by a larger group.
- **Quality management and control tools.** These tools are used to link and sequence the activities identified (defined in Section 8.2.2.1).

8.1.2.8 Meetings

Project teams may hold planning meetings to develop the quality management plan. Attendees at these meetings may include the project manager; the project sponsor; selected project team members; selected stakeholders; anyone with responsibility for Project Quality Management activities namely Plan Quality Management, Perform Quality Assurance, or Control Quality; and others as needed.

8.1.3 Plan Quality Management: Outputs

8.1.3.1 Quality Management Plan

The quality management plan is a component of the project management plan that describes how the organization's quality policies will be implemented. It describes how the project management team plans to meet the quality requirements set for the project.

The quality management plan may be formal or informal, detailed, or broadly framed. The style and detail of the quality management plan are determined by the requirements of the project. The quality management plan should be reviewed early in the project to ensure that decisions are based on accurate information. The benefits of this review can include a sharper focus on the project's value proposition and reductions in costs and in the frequency of schedule overruns that were caused by rework.

8.1.3.2 Process Improvement Plan

The process improvement plan is a subsidiary or component of the project management plan (Section 4.2.3.1). The process improvement plan details the steps for analyzing project management and product development processes to identify activities that enhance their value. Areas to consider include:

- **Process boundaries.** Describe the purpose of the process, the start and end of the process, its inputs and outputs, the process owner, and the stakeholders of the process.
- **Process configuration.** Provides a graphic depiction of processes, with interfaces identified, used to facilitate analysis.
- **Process metrics.** Along with control limits, allows analysis of process efficiency.
- **Targets for improved performance.** Guide the process improvement activities.

8.1.3.3 Quality Metrics

A quality metric specifically describes a project or product attribute and how the control quality process will measure it. A measurement is an actual value. The tolerance defines the allowable variations to the metric. For example, if the quality objective is to stay within the approved budget by ± 10%, the specific quality metric is used to measure the cost of every deliverable and determine the percent variance from the approved budget for that deliverable. Quality metrics are used in the perform quality assurance and control quality processes. Some examples of quality metrics include on-time performance, cost control, defect frequency, failure rate, availability, reliability, and test coverage.

8.1.3.4 Quality Checklists

A checklist is a structured tool, usually component-specific, used to verify that a set of required steps has been performed. Based on the project's requirements and practices, checklists may be simple or complex. Many organizations have standardized checklists available to ensure consistency in frequently performed tasks. In some application areas, checklists are also available from professional associations or commercial service providers. Quality checklists should incorporate the acceptance criteria included in the scope baseline.

8.1.3.5 Project Documents Updates

Project documents that may be updated include, but are not limited to:

- Stakeholder register (Section 13.1.3.1); and
- Responsibility assignment matrix (Section 9.1.2.1); and
- WBS and WBS Dictionary.

8.2 Perform Quality Assurance

Perform Quality Assurance is the process of auditing the quality requirements and the results from quality control measurements to ensure that appropriate quality standards and operational definitions are used. The key benefit of this process is that it facilitates the improvement of quality processes. The inputs, tools and techniques, and outputs of this process are depicted in Figure 8-8. Figure 8-9 depicts the data flow diagram of the process.

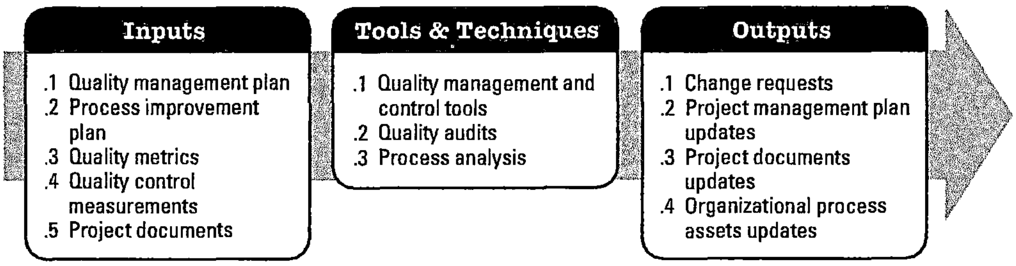


Figure 8-8. Perform Quality Assurance: Inputs, Tools & Techniques, and Outputs

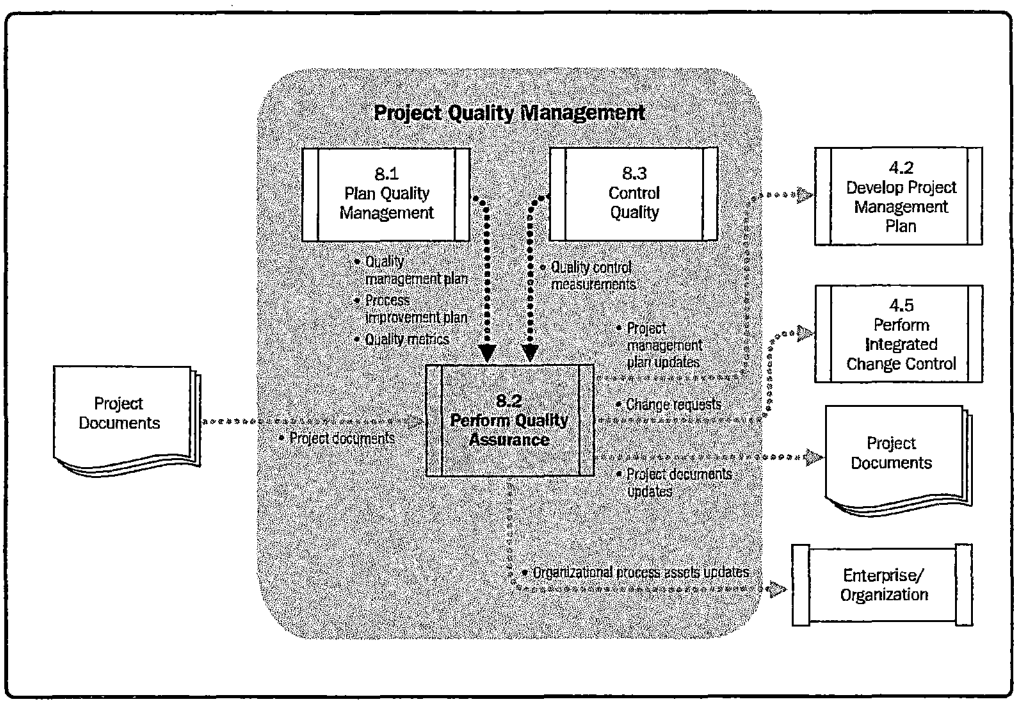


Figure 8-9. Perform Quality Assurance Data Flow Diagram

The quality assurance process implements a set of planned and systematic acts and processes defined within the project's quality management plan. Quality assurance seeks to build confidence that a future output or an unfinished output, also known as work in progress, will be completed in a manner that meets the specified requirements and expectations. Quality assurance contributes to the state of being certain about quality by preventing defects through the planning processes or by inspecting out defects during the work-in-progress stage of implementation. Perform Quality Assurance is an execution process that uses data created during Plan Quality Management (Section 8.1) and Control Quality (Section 8.3) processes.

In project management, the prevention and inspection aspects of quality assurance should have a demonstrable influence on the project. Quality assurance work will fall under the conformance work category in the cost of quality framework.

A quality assurance department, or similar organization, often oversees quality assurance activities. Quality assurance support, regardless of the unit's title, may be provided to the project team, the management of the performing organization, the customer or sponsor, as well as other stakeholders not actively involved in the work of the project.

Perform Quality Assurance also provides an umbrella for continuous process improvement, which is an iterative means for improving the quality of all processes. Continuous process improvement reduces waste and eliminates activities that do not add value. This allows processes to operate at increased levels of efficiency and effectiveness.

8.2.1 Perform Quality Assurance: Inputs

8.2.1.1 Quality Management Plan

Described in Section 8.1.3.1. The quality management plan describes the quality assurance and continuous process improvement approaches for the project.

8.2.1.2 Process Improvement Plan

Described in Section 8.1.3.2. The project's quality assurance activities should be supportive of and consistent with the performing organization's process improvement plans.

8.2.1.3 Quality Metrics

Described in Section 8.1.3.3. The quality metrics provide the attributes that should be measured and the allowable variations.

8.2.1.4 Quality Control Measurements

Described in Section 8.3.3.1. Quality control measurements are the results of control quality activities. They are used to analyze and evaluate the quality of the processes of the project against the standards of the performing organization or the requirements specified. Quality control measurements can also compare the processes used to create the measurements, and validate actual measurements to determine their level of correctness.

8.2.1.5 Project Documents

Project documents may influence quality assurance work and should be monitored within the context of a system for configuration management.

8.2.2 Perform Quality Assurance: Tools and Techniques

8.2.2.1 Quality Management and Control Tools

The Perform Quality Assurance process uses the tools and techniques of the Plan Quality Management and Control Quality processes. In addition, other tools that are available include (see also Figure 8-10):

- **Affinity diagrams.** The affinity diagram is similar to mind-mapping techniques in that they are used to generate ideas that can be linked to form organized patterns of thought about a problem. In project management, the creation of the WBS may be enhanced by using the affinity diagram to give structure to the decomposition of scope.
- **Process decision program charts (PDPC).** Used to understand a goal in relation to the steps for getting to the goal. The PDPC is useful as a method for contingency planning because it aids teams in anticipating intermediate steps that could derail achievement of the goal.
- **Interrelationship digraphs.** An adaptation of relationship diagrams. The interrelationship digraphs provide a process for creative problem solving in moderately complex scenarios that possess intertwined logical relationships for up to 50 relevant items. The interrelationship digraph may be developed from data generated in other tools such as the affinity diagram, the tree diagram, or the fishbone diagram.
- **Tree diagrams.** Also known as systematic diagrams and may be used to represent decomposition hierarchies such as the WBS, RBS (risk breakdown structure), and OBS (organizational breakdown structure). In project management, tree diagrams are useful in visualizing the parent-to-child relationships in any decomposition hierarchy that uses a systematic set of rules that define a nesting relationship. Tree diagrams can be depicted horizontally (such as a risk breakdown structure) or vertically (such as a team hierarchy or OBS). Because tree diagrams permit the creation of nested branches that terminate into a single decision point, they are useful as decision trees for establishing an expected value for a limited number of dependent relationships that have been diagramed systematically.

- **Prioritization matrices.** Identify the key issues and the suitable alternatives to be prioritized as a set of decisions for implementation. Criteria are prioritized and weighted before being applied to all available alternatives to obtain a mathematical score that ranks the options.
- **Activity network diagrams.** Previously known as arrow diagrams. They include both the AOA (Activity on Arrow) and, most commonly used, AON (Activity on Node) formats of a network diagram. Activity network diagrams are used with project scheduling methodologies such as program evaluation and review technique (PERT), critical path method (CPM), and precedence diagramming method (PDM).
- **Matrix diagrams.** A quality management and control tool used to perform data analysis within the organizational structure created in the matrix. The matrix diagram seeks to show the strength of relationships between factors, causes, and objectives that exist between the rows and columns that form the matrix.

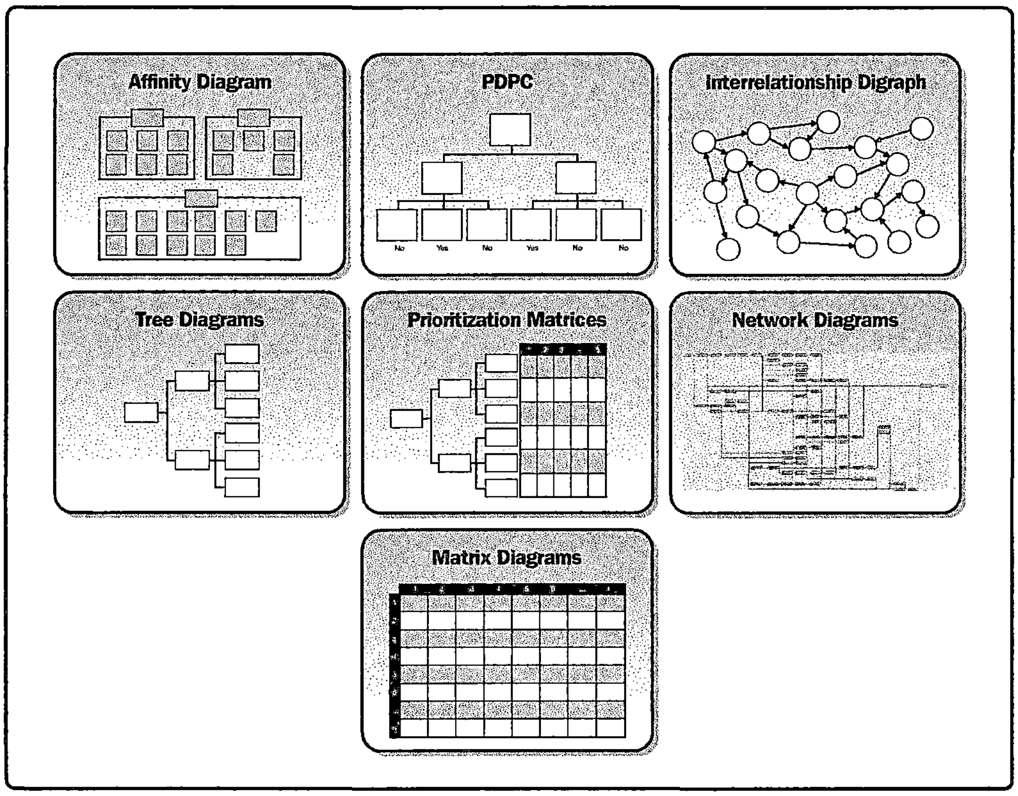


Figure 8-10. Storyboard Illustrating the Seven Quality Management and Control Tools

8.2.2.2 Quality Audits

A quality audit is a structured, independent process to determine if project activities comply with organizational and project policies, processes, and procedures. The objectives of a quality audit may include:

- Identify all good and best practices being implemented;
- Identify all nonconformity, gaps, and shortcomings;
- Share good practices introduced or implemented in similar projects in the organization and/or industry;
- Proactively offer assistance in a positive manner to improve implementation of processes to help the team raise productivity; and
- Highlight contributions of each audit in the lessons learned repository of the organization.

The subsequent effort to correct any deficiencies should result in a reduced cost of quality and an increase in sponsor or customer acceptance of the project's product. Quality audits may be scheduled or random, and may be conducted by internal or external auditors.

Quality audits can confirm the implementation of approved change requests including updates, corrective actions, defect repairs, and preventive actions.

8.2.2.3 Process Analysis

Process analysis follows the steps outlined in the process improvement plan to identify needed improvements. This analysis also examines problems experienced, constraints experienced, and non-value-added activities identified during process operation. Process analysis includes root cause analysis—a specific technique used to identify a problem, discover the underlying causes that lead to it, and develop preventive actions.

8.2.3 Perform Quality Assurance: Outputs

8.2.3.1 Change Requests

Change requests are created and used as input into the Perform Integrated Change Control process (Section 4.5) to allow full consideration of the recommended improvements. Change requests are used to take corrective action, preventive action, or to perform defect repair.

8.2.3.2 Project Management Plan Updates

Elements of the project management plan that may be updated include, but are not limited to:

- Quality management plan (Section 8.1.3.1),
- Scope management plan (Section 5.1.3.1),
- Schedule management plan (Section 6.1.3.1), and
- Cost management plan (7.1.3.1).

8.2.3.3 Project Documents Updates

Project documents that may be updated include, but are not limited to:

- Quality audit reports,
- Training plans, and
- Process documentation.

8.2.3.4 Organizational Process Assets Updates

Elements of the organizational process assets that may be updated include, but are not limited to, the organization's quality standards and the quality management system.

8.3 Control Quality

Control Quality is the process of monitoring and recording results of executing the quality activities to assess performance and recommend necessary changes. The key benefits of this process include: (1) identifying the causes of poor process or product quality and recommending and/or taking action to eliminate them; and (2) validating that project deliverables and work meet the requirements specified by key stakeholders necessary for final acceptance. The inputs, tools and techniques, and outputs of this process are depicted in Figure 8-11. Figure 8-12 depicts the data flow diagram of the process.

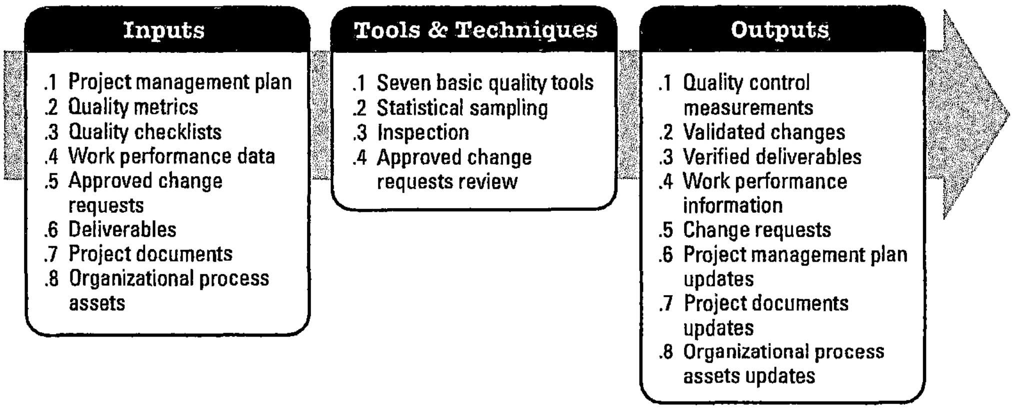


Figure 8-11. Control Quality: Inputs, Tools & Techniques, and Outputs

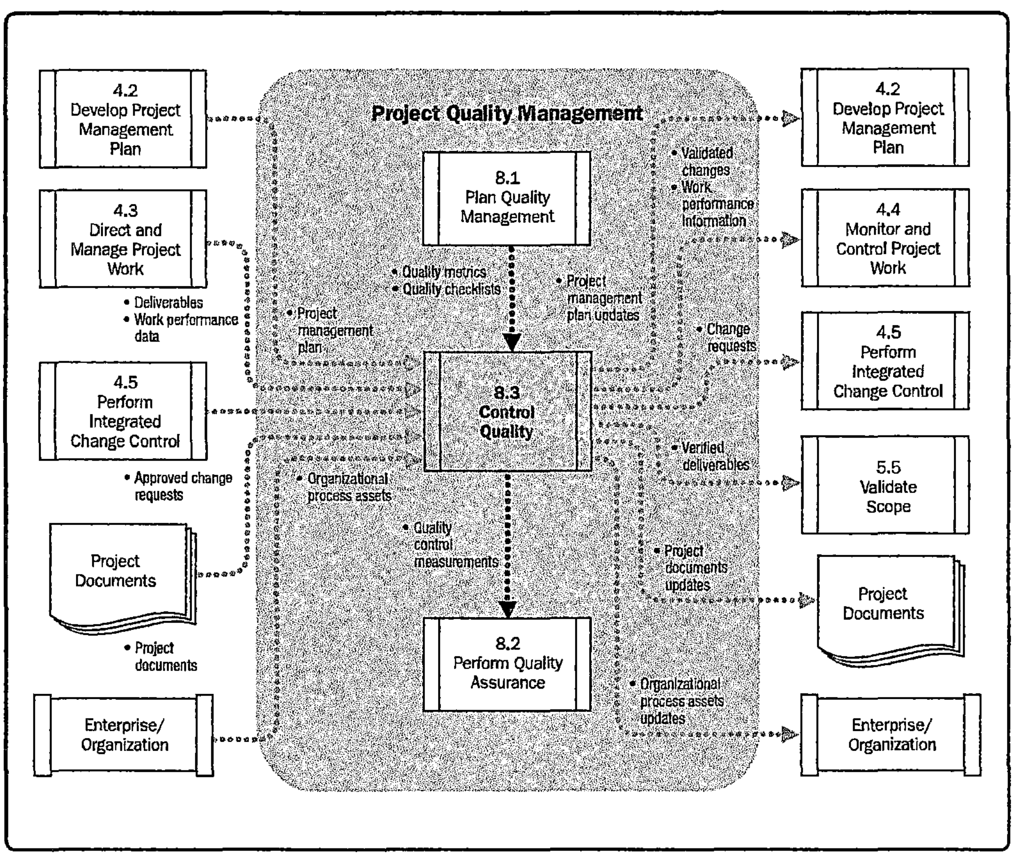


Figure 8-12. Control Quality Data Flow Diagram

The Control Quality process uses a set of operational techniques and tasks to verify that the delivered output will meet the requirements. Quality assurance should be used during the project's planning and executing phases to provide confidence that the stakeholder's requirements will be met and quality control should be used during the project executing and closing phases to formally demonstrate, with reliable data, that the sponsor and/or customer's acceptance criteria have been met.

The project management team may have a working knowledge of statistical control processes to evaluate data contained in the control quality outputs. Among other subjects, the team may find it useful to know the differences between the following pairs of terms:

- *Prevention* (keeping errors out of the process) and *inspection* (keeping errors out of the hands of the customer).
- *Attribute sampling* (the result either conforms or does not conform) and *variables sampling* (the result is rated on a continuous scale that measures the degree of conformity).
- *Tolerances* (specified range of acceptable results) and *control limits* (that identify the boundaries of common variation in a statistically stable process or process performance).

8.3.1 Control Quality: Inputs

8.3.1.1 Project Management Plan

Described in Section 8.1.3.1. The project management plan contains the quality management plan, which is used to control quality. The quality management plan describes how quality control will be performed within the project.

8.3.1.2 Quality Metrics

Described in Section 4.2.3.1. A quality metric describes a project or product attribute and how it will be measured. Some examples of quality metrics include: function points, mean time between failure (MTBF), and mean time to repair (MTTR).

8.3.1.3 Quality Checklists

Described in Section 8.1.3.4. Quality checklists are structured lists that help to verify that the work of the project and its deliverables fulfill a set of requirements.

8.3.1.4 Work Performance Data

Described in Section 4.3.3.2. Work performance data can include:

- Planned vs. actual technical performance,
- Planned vs. actual schedule performance, and
- Planned vs. actual cost performance.

8.3.1.5 Approved Change Requests

As part of the Perform Integrated Change Control process, a change log update indicates that some changes are approved and some are not. Approved change requests may include modifications such as defect repairs, revised work methods, and revised schedule. The timely implementation of approved changes needs to be verified.

8.3.1.6 Deliverables

Described in Section 4.3.3.1. A deliverable is any unique and verifiable product, result, or capability that results in a validated deliverable required by the project.

8.3.1.7 Project Documents

Project documents may include, but are not limited to:

- Agreements,
- Quality audit reports and change logs supported with corrective action plans,
- Training plans and assessments of effectiveness, and
- Process documentation such as those obtained using either the seven basic quality tools or the quality management and control tools shown in Figures 8-7 and 8-10.

8.3.1.8 Organizational Process Assets

Described in Section 2.1.4. The organizational process assets that influence the Control Quality process include, but are not limited to:

- The organization's quality standards and policies,
- Standard work guidelines, and
- Issue and defect reporting procedures and communication policies.

8.3.2 Control Quality: Tools and Techniques

8.3.2.1 Seven Basic Quality Tools

Described in Section 8.1.2.3. The seven basic quality tools are illustrated conceptually in Figure 8-7.

8.3.2.2 Statistical Sampling

Described in Section 8.1.2.6. Samples are selected and tested as defined in the quality management plan.

8.3.2.3 Inspection

An inspection is the examination of a work product to determine if it conforms to documented standards. The results of an inspection generally include measurements and may be conducted at any level. For example, the results of a single activity can be inspected, or the final product of the project can be inspected. Inspections may be called reviews, peer reviews, audits, or walkthroughs. In some application areas, these terms have narrow and specific meanings. Inspections also are used to validate defect repairs.

8.3.2.4 Approved Change Requests Review

All approved change requests should be reviewed to verify that they were implemented as approved.

8.3.3 Control Quality: Outputs

8.3.3.1 Quality Control Measurements

Quality control measurements are the documented results of control quality activities. They should be captured in the format that was specified through the Plan Quality Management process (Section 8.1).

8.3.3.2 Validated Changes

Any changed or repaired items are inspected and will be either accepted or rejected before notification of the decision is provided. Rejected items may require rework.

8.3.3.3 Verified Deliverables

A goal of the Control Quality process is to determine the correctness of deliverables. The results of performing the Control Quality process are verified deliverables. Verified deliverables are an input to Validate Scope (5.5.1.4) for formalized acceptance.

8.3.3.4 Work Performance Information

Work performance information is the performance data collected from various controlling processes, analyzed in context and integrated based on relationships across areas. Examples include information about the project requirements fulfillment such as causes for rejections, rework required, or the need for process adjustments.

8.3.3.5 Change Requests

If the recommended corrective or preventive actions or a defect repair requires a change to the project management plan, a change request (Section 4.4.3.1) should be initiated in accordance with the defined Perform Integrated Change Control (4.5) process.

8.3.3.6 Project Management Plan Updates

Elements of the project management plan that may be updated include, but are not limited to:

- Quality management plan (Section 8.1.3.1), and
- Process improvement plan (Section 8.1.3.2).

8.3.3.7 Project Documents Updates

Project documents that may be updated include, but are not limited to,

- Quality standards;
- Agreements;
- Quality audit reports and change logs supported with corrective action plans;
- Training plans and assessments of effectiveness; and
- Process documentation, such as information obtained using the seven basic quality tools or the quality management and control tools.

8.3.3.8 Organizational Process Assets Updates

Elements of the organizational process assets that may be updated include, but are not limited to:

- **Completed checklists.** When checklists are used, the completed checklists become part of the project documents and organizational process assets (Section 4.1.1.5).
- **Lessons learned documentation.** The causes of variances, the reasoning behind the corrective action chosen, and other types of lessons learned from control quality are documented so they become part of the historical database for both the project and the performing organization.