UNIVERSIDAD NACIONAL DE INGENIERÍA

FACULTAD DE INGENIERIA MECÁNICA

DISEÑO DE LA RED DE TUBERÍAS PARA COGENERACIÓN EN UN TURBO GENERADOR DE 23 MW PARA UNA AGROINDUSTRIA

INFORME DE SUFICIENCIA

PARA OPTAR EL TÍTULO PROFESIONAL DE:
INGENIERO MECÁNICO

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PROMOCIÓN **2007-I**

LIMA-PERU

2012

DEDICATORIA:

A la Universidad, por abrigar mis sueños.

A mis diferentes jefes por compartir su experiencia y conocimiento.

A mis padres y hermanos por su paciencia y tolerancia.

A mi esposa e hija por el apoyo incondicional.

A mi Dios Jehová a quien debo la vida.

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PRÓLOGO

Antes de la redacción del presente informe me llenaban de dudas como seleccionar un tema que sea práctico y que se pueda desarrollar en la aplicación de nuestra carrera. Si bien es cierto es un tema que se ha tocado en los diferentes materias que se desarrollan en la universidad, es de reciente aplicación en la agroindustria peruana como lo son las Centrales de Cogeneración.

En el **capítulo I**, se da una reseña histórica de la Cogeneración con Turbinas de Vapor y su aplicación en la agroindustria. El aprovechamiento de la energía térmica proveniente de una caldera de vapor CBS, transformándola en otro tipo de energía (energía eléctrica) para luego usarla en el proceso de producción de azúcar y sus derivados, siendo está la aplicación de Cogeneración en este campo.

En el **capítulo II**, se realiza la descripción de los conceptos básicos de ingeniería utilizados en el desarrollo del presente informe para el cálculo y dimensionamiento de las líneas de vapor de alta y baja presión. Además se presenta una descripción de los equipos que forman parte de la Central de Cogeneración Térmica implementada.

La información utilizada se encuentra en las normas y estándares internacionales como son el código ASME B31, cuya aplicación particular para nuestro caso es el código ASME B31.1 edición 2002.

En el **capítulo III**, se muestra la metodología desarrollada para el cálculo de las tuberías que forman parte de las líneas de vapor de alta y baja presión utilizadas en el presente informe. El primer paso es realizar un pre-dimensionamiento basado en el código ASME B31.1 basado en los esfuerzos admisibles para los materiales seleccionados. Después del pre-dimensionamiento se realizó el ruteo de las líneas que van desde la caldera bagacera CBS hasta la turbina de vapor (vapor vivo), desde la turbina de vapor se traza el ruteo de la línea de vapor de extracción que recorre las instalaciones de la planta hasta llegar a un manifold de distribución.

Después de realizado el trazo y con los valores obtenidos en el pre-dimensionamiento se realiza el análisis de esfuerzos y flexibilidad con el software AutoPIPE V8i.

Además de obtener la verificación de los esfuerzos desarrollados en la tubería se puede obtener las cargas que se transmiten a los soportes definiendo con estos la parte final de nuestra de red de tuberías de vapor.

En el **capítulo IV**, se presentan los costos de suministro, fabricación y montaje de la central de cogeneración térmica, incluyendo la red de tuberías de vapor analizado.

CAPÍTULO I

INTRODUCCIÓN

1.1. Antecedentes

Agroindustrial Paramonga es una empresa dedicada al cultivo y producción de caña de azúcar, así como la fabricación de azúcar y sus derivados. Esta empresa desarrolló la implementación de una caldera bagacera CBS.

En el año 2007 se pone en marcha esta caldera logrando una producción de 122,000 toneladas, valor máximo de producción hasta la fecha.

Dentro de sus planes de desarrollo empresarial, contempla la mejora de su rendimiento a través del aprovechamiento energético eficiente implementando una central de cogeneración para entregar, al Sistema Eléctrico Interconectado Nacional (SEIN), sus excedentes de energía eléctrica la que será comercializada en este mercado, después de satisfacer sus necesidades propias de sus procesos productivos (el calor útil que lleva el vapor de sus calderas y la energía eléctrica) para accionar todos sus equipos.

El Turbo Generador es suministrado por SIEMENS así como las tuberías menores, como son las tuberías de lubricación, de vapor de sellado, etc. Las tuberías de vapor vivo, vapor de extracción y el sistema de Enfriamiento deben ser suministrado por la empresa, para lo cual contrata los servicios de una empresa de consultaría para desarrollar el estudio a nivel de ingeniería para estas tuberías.

1.2. Objetivo

El presente informe tiene por objetivo diseñar de la red de tuberías de alta y baja presión para cogeneración en un turbogenerador de 23 MW.

1.3. Alcance

En el presente informe se mostrara los pasos seguidos para el diseño de tuberías de vapor de alta y baja presión, desde su pre-dimensionamiento en base a las normas y/o estándares aplicables, hasta su comprobación mediante un software de análisis de esfuerzos y flexibilidad (AutoPIPE V8i).

1.4. Justificación

Debido al crecimiento que se ha venido dando en la industria azucarera se han ido desarrollando nuevas tecnologías para mejorar sus procesos de producción. Una de estas tecnologías que se han desarrollado son las Centrales de Cogeneración Térmica, que para el caso del presente informe incluyó el mejoramiento de sus procesos de producción y el aprovechamiento energético del vapor de agua generado.

1.5. Cogeneración con Turbinas de Vapor

1.5.1. Breve reseña histórica

Desde sus inicios Agroindustrial Paramonga estaba considerada como LA LLAVE GEOGRÁFICA DEL IMPERIO COSTEÑO ya que tenía una ubicación estratégica con territorios ambicionados por los Incas.

La denominación Paramonga deriva de las voces Mochica PARAG que quiere decir "Vasallos" y MUNGA que quiere decir "Por Aquí".

Los españoles en un primer momento la denominaron PARMONGUILA, según escritos que datan de 1959, firmados por FRAY LOPE DE LA FUENTE y el noble GREGORIO DE LA PEÑA, hallados en el MIRADOR DE LA BARRANCA, de esta provincia.

Durante la conquista española nace el fundo rústico de las familias Asín y Canaval, tiempo en que introducen elementos novedosos para la época hasta convertirla en la Hacienda Sociedad Agrícola Paramonga.

Posteriormente la transnacional Grace & Co. adquiere la propiedad, introduce nueva tecnología y diversifica la producción hasta convertirla en el primer Complejo Agroindustrial Químico Papelero de la región.

Paramonga sufrió la expropiación por el Gobierno Militar del General Juan Velazco Alvarado, que dividió el complejo en 2 empresas, la Sociedad Paramonga Ltda., empresa estatal para la producción de papel y productos químicos, y la Cooperativa Agraria Azucarera Paramonga Ltda. N° 37, cedida en propiedad a sus trabajadores.

Luego de 20 años de Cooperativismo, durante los cuales se redujo la productividad y se acumularon grandes pérdidas, a principio de los 90 se dieron normas para reflotar las empresas azucareras que estaban colapsadas, convirtiéndolas en Sociedades Anónimas.

En el año 1996 la sociedad Río Pativilca compra la mayoría de las acciones y toma el control de la misma.

En 1997 el grupo Wong adquiere la empresa e introduce un estilo gerencial moderno, con una filosofía de trabajo en equipo y mejora continua, consiguiendo resultados productivos nunca antes registrados en Paramonga. En la actualidad posee la certificación ISO 9001:2000 y se encamina para consolidar su liderazgo en el mercado nacional para hacer de ella una empresa de competencia mundial.

CRONOLOGIA

S. XVII: Fundo rústico (hacienda) - Familia Asín

1821: Sociedad Agrícola Paramonga - Familia Canaval.

1837: Se inicia la producción de azúcar de caña.

1927: Se conforma el Complejo Agro Industrial Químico Papelero - Grace & Co.

1969: Se crea la Cooperativa Agraria Azucarera Paramonga Ltda. Nº 37

1976: Paramonga Primer Distrito Agro Industrial del Perú DS Nº 776 /23 Nov. – Alcalde Ing. Víctor Guerrero Fooks.

1837: Se inicia la producción de azúcar de caña.

1927: Se conforma el Complejo Agro Industrial Químico Papelero - Grace & Co.

1969: Se crea la Cooperativa Agraria Azucarera Paramonga Ltda. Nº 37

1976: Paramonga Primer Distrito Agro Industrial del Perú DS Nº 776 /23 Nov. – Alcalde Ing. Víctor Guerrero Fooks.

1994: Se vuelve a privatizar la empresa, creándose Agro Industrial Paramonga S.A.

1996: Río Pativilca adquiere el 72.3% de las acciones.

1998: Paramonga logró el mayor récord de producción de toda su Historia.

1999: Agro Industrial Paramonga S.A.A.- el Grupo Wong, adquiere el 94% de las acciones.

2000: Inicio del cambio de la cultura corporativa y los sistemas de trabajo. Estilo gerencial moderno, con una filosofía de: "creatividad, actitud para el cambio, trabajo en equipo y mejora contínua". Resultados productivos nunca antes registrados en Paramonga.

2001: Debido al éxito de los cambios realizados en el 2,000 y con la base formada, se decidió la implementación de un sistema de calidad basado en la norma ISO9001:2000

2002: Culmina la implementación de un Sistema de Gestión de Calidad al obtener la Certificación ISO 9001:2000 (SGS).

Habilitación Sanitaria aplicando el Plan HACCP (DIGESA-RD Nº 0837/2002/DIGESA/SA).

2005: Inicio de importantes proyectos de inversión, entre ellos la Caldera Bagacera, con el cual nuestra empresa ingresa al tema de responsabilidad social y ambiental.

2006: Re- Certificación ISO 9001: 2000. Consolidación de liderazgo en el mercado nacional.

2007: Se logra nuevo récord de producción alcanzando las 122,000 toneladas, se mejora el cuidado del medio ambiente con la puesta en operación del Caldero Bagacero CBS.

1.6. Bases y Criterios considerados

Para el diseño de las tuberías de vapor de alta y baja presión se ha utilizado las siguientes normas y estándares:

ASME B31.1: este código muestra los requerimientos mínimos para el diseño, *materiales*, *fabricación*, pruebas, *inspección*, operación y *mantenimiento* para sistema de tuberías típicas utilizadas en estaciones de generación de energía eléctrica, plantas industriales, sistemas de enfriamiento y plantas térmicas.

También cubre los requerimientos para tuberías de calderas de potencia y alta temperatura, calderas de agua de alta presión en el que se genera vapor de agua a una presión de más de 15 psig.

Las aplicaciones generales de este código son sistemas de tuberías de vapor, agua, aceite, gas y aire de servicio entre otras.

CAPÍTULO II

CONSIDERACIONES BÁSICAS DE INGENIERÍA

2.1. Introducción

En este capítulo se plantean los modelos, teorías y conceptos pertinentes utilizados en el diseño de la red de tuberías, de tal manera que fundamenten el análisis y la interpretación de los resultados (estudios análogos, revisión de literatura que fundamenta el diagnostico realizado, fundamentación teórica del proyecto)

2.2 Conceptos Generales

Cogeneración: Producción de más de una forma útil de energía (como calor y energía eléctrica) de la misma fuente de energía. Las plantas de Cogeneración producen energía eléctrica cumpliendo con los requisitos de calor de sus procesos industriales. De esta manera mas de la energía transferido al líquido de la caldera se utiliza para un proceso útil.

Ciclo Rankine: Ciclo Termodinámico de 04 etapas usado para máquina de vapor.

Sobrecalentamiento: Calentamiento del agua hasta que llegue a un punto de mayor temperatura que la temperatura de saturación.

Caldera Bagacera: Caldera donde se genera vapor de agua y cuyo combustible es el bagazo de la caña de azúcar, empleado comúnmente en las plantas agroindustriales.

Live Steam (Vapor Vivo): Vapor Sobresaturado.

Extraction Steam (Vapor de Extracción): Vapor Saturado.

Anchor (Anclaje): Restricción rígida de fijación complete que no permite el desplazamiento, traslación ni rotación de la tubería.

Backing Ring (Anillo de Refuerzo): Refuerzo en la forma de un anillo utilizado en la soldadura de de tuberías.

Expansion joint (junta de expansión): Componente de tubería flexible que absorbe el movimiento térmico y/o terminal.

Maximun Allowable Stress (Esfuerzo máximo admisible): Es el valor de esfuerzo máximo que se usa en las fórmulas de diseño para un determinado material y temperatura de diseño.

2.3 Análisis Crítico

2.3.1. Situación actual

Después de la crisis del 80 el Perú se convirtió en un país deficitario en cuanto a su producción azucarera, convirtiéndose en un importante importador. Como consecuencia de la crisis del sector azucarero, el Perú llegó a importar en el año 1998 el 52% del consumo interno.

Sin embargo, con el inicio del proceso de privatización del sector azucarero a partir del año 1996, se han concretado a la fecha una inversión de 320 millones de dólares orientados a la mejora tecnológica, gestión y administración; permitiendo que el Perú pase de ser un importador de azúcar, a auto abastecerse e inclusive capaz de generar excedentes exportables.

Como parte de este crecimiento que se viene dando, la industria azucarera peruana se proyecta a consolidar un negocio sucro alcoholero, sobre la base de una fuerte alianza con los productores de caña de azúcar y con el propósito de desarrollar la producción de etanol carburante y cogenerar energía para la propia industria y las poblaciones de los valles azucareros.

El caso de nuestro estudio es el de una Agroindustrial que ha implementado una Central Térmica de Cogeneración para entregar, al Sistema Eléctrico Interconectado Nacional (SEIN), sus excedentes de energía eléctrica que serán comercializados en el mercado eléctrico nacional, después de utilizar energía para sus procesos productivos del azúcar, el calor útil que lleva el vapor de sus calderas y la energía eléctrica para accionar todos sus equipos. Ver plano N° ISTP-IM-DRTP-DWG-08 (plano de disposición general).

2.3.2 Evaluación General del Sistema

El proceso actual de producción de azúcar viene utilizando equipos como evaporadores, lavadores de gases, secadores, centrifugas, calentadores de jugo, bombas de agua, desaereadores, etc. que son utilizados en los diferentes etapas de la producción de azúcar.

Después del uso de la caña de azúcar el bagazo es almacenado en un depósito contiguo a la nueva Caldera Bagacera CBS donde es utilizado para el proceso de combustión.

La planta viene funcionando con 5 turbinas pequeñas, las cuales procesan el vapor de agua proveniente de la Caldera Bagacera para luego utilizarlo en los diferentes procesos de producción de azúcar y sus derivados.

En este proceso se viene desperdiciando la energía térmica proveniente del vapor de agua y además se viene consumiendo energía eléctrica de la red por lo que los procesos productivos se vuelven más caros.

Para un mejor aprovechamiento de la energía térmica se ha implementado una Central de Cogeneración con sus diferentes sistemas.

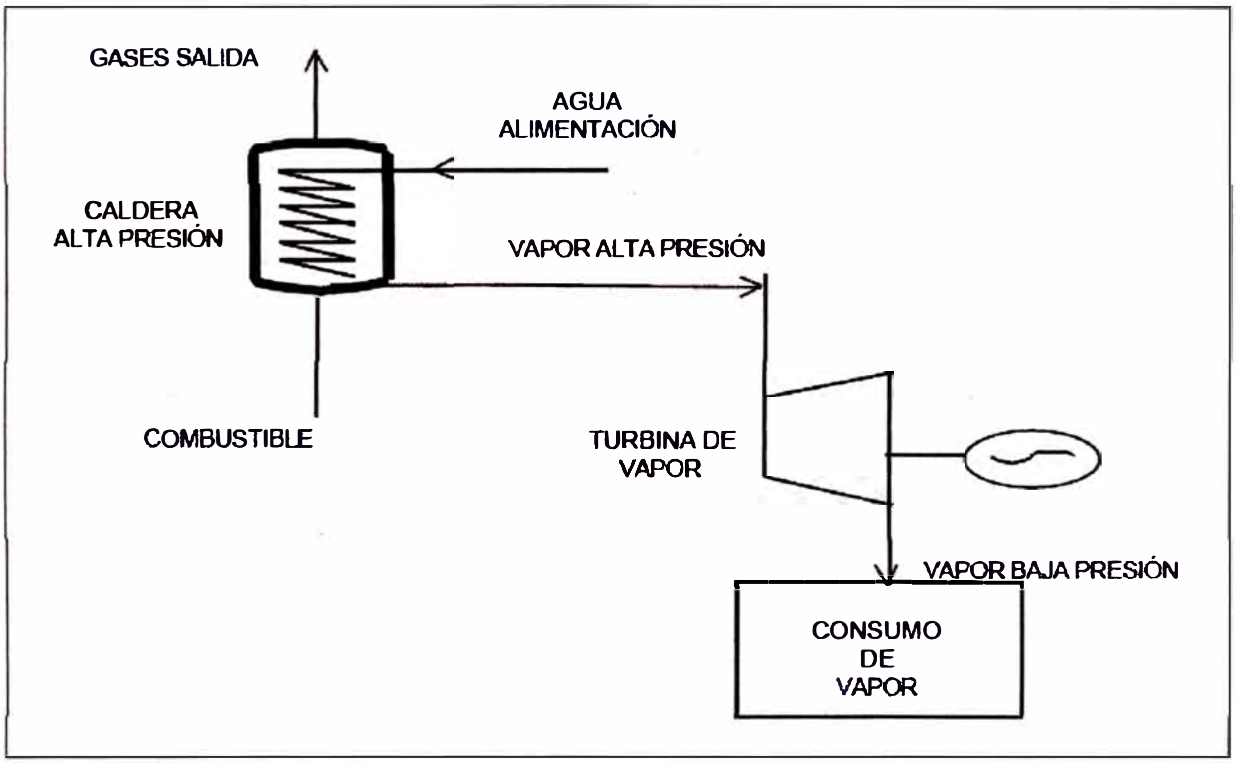
2.4. Descripción General del Equipamiento

Para la implementación de la central de Cogeneración se realizaron obras civiles y electromecánicas relacionadas principalmente con el turbogenerador SIEMENS y sus componentes auxiliares, además del sistema de distribución de vapor y circuito de agua de refrigeración para el sistema de condensación.

El vapor proviene de una caldera acuotubular existente (caldera bagacera CBS), que produce 120 t/h de vapor sobrecalentado a 600 psi(g) y 750 °F. El Vapor Vivo (LIVE STEAM) que se entrega al Turbo Generador sirve para generar energía eléctrica, en condiciones normales la tubería de vapor vivo transporta vapor a 42.38 bar (abs) y una temperatura de 399 °C.

El Vapor de Extracción (EXTRACTION STEAM) proveniente de la turbina a una temperatura de 126 °C y 2.39 bar (abs) de presión, se enfila directamente hacia la nave de molinos, aprovechando las torres de sustentación de una faja transportadora existente. Esta tubería voltea en forma perpendicular a la nave de molinos apoyándose en una estructura soporte. En esta parte la nave no cuenta con cobertura de techo, por el que además se implementó un doble tijeral que sirve para el soporte de la tubería con la misma geometría de las existentes, para en un futuro pueda recibir la cobertura correspondiente. Voltea a 90° sobre las columnas entre la nave de molinos y la nave adyacente y cerca del eje de estas. Vuelve a voltear a 90° sobre una fila de columnas existentes por la zona de los tanques, hasta la altura del manifold de los evaporadores.

Se a incluido además, una estación reductora de vapor ubicada frente al cuarto de control del caldero; está válvula funcionará cuando en un momento determinado la turbina deje de entregar vapor. Está estación reductora de vapor reducirá la presión de entrada de 42.38 bar(g) a 2.39 bar(g), y a la vez saturara el vapor para poder entregarla al sistema a las mismas condiciones actuales (El cálculo y/o selección de esta estación reductora no se desarrollara en el presente informe).

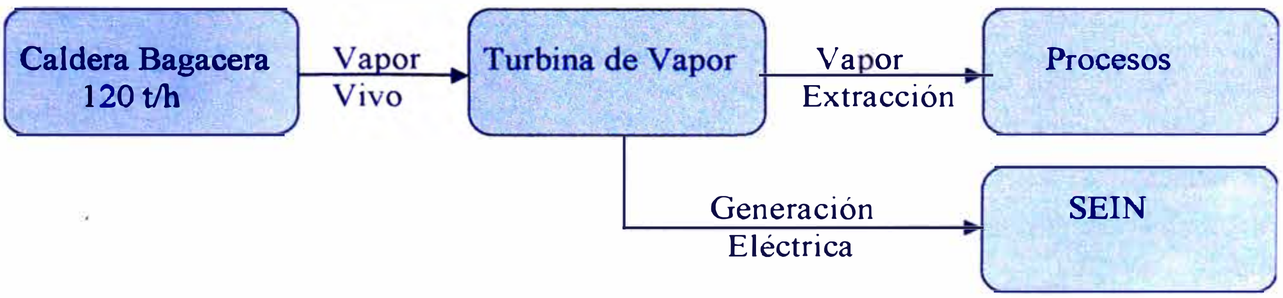


Fuente: Elaboración Propia a partir del libro de termodinámica, Yunus Cengel.

Figura 2.1: Esquema de Principio

Esquema Conceptual Implementado

Sistema de Vapor.



Fuente: Elaboración Propia.

Figura 2.2: Esquema conceptual Cogeneración

Características Técnicas.

Casa de Máquinas:

Constituida por columnas, vigas y losas macizas de concreto armado y un techo de acero estructural apoyado sobre la estructura de concreto.

La cimentación está constituida por zapatas y vigas de concreto armado. La losa de piso es de concreto armado y permitirá el tránsito pesado de equipos. Las losas de los niveles superiores han sido diseñadas considerando las cargas de los tableros y cargas usuales para este tipo de aplicaciones.

El puente grúa tiene una capacidad de 50t, prevista para labores de montaje y mantenimiento, el cual estará apoyado sobre vigas de concreto armado.

La tabiquería es de ladrillo pandereta y se encuentra separada de la estructura *mediante vigas* soleras y columnetas.

Las coberturas laterales y del techo son de plancha metálica tipo TR-4.

Se ha dispuesto espacio apropiado para la circulación de vehículos durante el montaje, mantenimiento, maniobras, etc. y un pase en el sentido longitudinal de la turbina hacia uno de los costados.

Turbo Generador:

La estructura de soporte de la Turbina y del Generador está compuesta por columnas y losas de concreto armado. La estructura esta cimentada sobre una zapata combinada unidas por vigas de cimentación y sirve de soporte a los equipos y demás elementos del sistema.

La estructura soporte del Tank Oil estará compuesta por columnas, vigas y losas de concreto armado. La cimentación de la estructura está conectada con la cimentación del soporte del Generador y la turbina.

Los equipos suministrados por SIEMENS son los siguientes:

- Turbina y paneles de control.
- Unidad Hidráulica
- Reductor
- Generador y paneles de control
- Condensador

La instalación del turbo generador se ejecutará con recursos locales y con la supervisión de la empresa proveedora de los equipos.

Sistema de Tuberías:

Para la conducción del vapor de alta (vapor vivo), se utiliza tuberías de material ASTM A106 de diámetro 12" sch. 80. Estas llevarán aislamiento térmico en colchoneta de Lana Mineral de 3" de espesor en 100 kg/m^3 de densidad, con un acabado metálico en plancha de aluminio liso de 0,6 mm de espesor debidamente rolada, pestañada y sujetadas con tornillos autorroscantes zincados. Los soportes para esta han sido diseñados considerando sus desplazamientos, de acuerdo al grado de libertad correspondiente. Se ha utilizado la estructura existente para los apoyos.

Para el vapor a baja presión se utiliza tuberías de material ASTM A36, principalmente de diámetro 36" sch. 10. Estas llevarán aislamiento térmico en colchoneta de Lana Mineral de 3" de espesor en 100 kg/m^3 de densidad, con un acabado metálico en plancha de aluminio liso de 0,6 mm de espesor debidamente rolada, pestañada y sujetadas con tornillos autorroscantes zincados. Los soportes se han diseñado teniendo en cuenta los grados de libertad de la tubería. Está estará apoyada sobre estructuras diseñadas teniendo en cuenta las cargas actuantes.

La estación reductora de presión está compuesta por válvulas motorizadas que entraran en funcionamiento cuando la turbina salga de operación y se requiera vapor a baja presión para el proceso. El vapor proveniente de la línea de vapor de alta presión a 42.38 bar(g) y 399 °C pasará por válvulas reductoras de presión y de inyección de agua para entregar vapor saturado a 2.39 bar(g) y 126 °C a la línea de baja presión. Se instalará un panel de control para las válvulas de vapor, en alta y baja presión, las cuales serán motorizadas.

Para el sistema de agua de refrigeración, se emplearán tuberías de material ASTM A36 de diámetro 24" sch. 10. Todos los accesorios que se aplicarán serán seleccionados de acuerdo a las condiciones a emplear en cada uno de los casos. La estructura soporte de las tuberías del sistema de refrigeración está compuesta por columnas metálicas, zapatas y pedestales de concreto armado. La cimentación está basada en zapatas aisladas que trasmiten al terreno los esfuerzo ejercidos por la estructura. En los casos donde se presentan zapatas excéntricas se ha considerado el uso de zapatas conectadas mediante vigas de cimentación.

Torre de Enfriamiento:

La central de cogeneración contará con una torre de enfriamiento de agua, de tiro inducido, de 3 celdas, para el enfriamiento de 3 200 m³/h de agua, bajo las siguientes condiciones:

- Temperatura de entrada de agua caliente, 38.5 ºC
- Temperatura de salida de agua fría, 30 ºC
- Carga térmica total, 27,200,000 kcal/h
- Perdida de agua por evaporación, 1,3 %
- Temperatura de bulbo húmedo, 21 °C

Esta área tendrá una pequeña sala eléctrica donde se ubicarán los Centros de control de motores (MCC), desde la cual se controlarán los 3 ventiladores de la torre de refrigeración, y las 4 bombas de agua,.

Mediante un panel de PLC´s se comandarán automáticamente 6 Válvulas Motorizadas ubicadas en la entrada y salida de cada celda. Estas válvulas entraran en funcionamiento cuando el sistema requiera el enfriamiento y será de manera gradual conforme lo requiera el sistema. También se instalará 1 panel de alumbrado para toda la zona de la torre de refrigeración,

Todas las bombas y ventiladores tendrán sus botoneras para mando local, de acuerdo al tipo de control que se adopte.

La energía en 460 V y 230 V será suministrada desde el Turbo generador.

Sistema Eléctrico:

En la sala ubicada al lado lateral del turbo generador, nivel +8.00:

- 01 Banco de baterías de 180 Ah.
- 01 Cargador de baterías.
- 01 Tablero MCC-DC de corriente directa.
- 01 Tablero MCC–AC de 460 V.
- 01 Tablero de Alumbrado en 230 V.
- 01 Tablero de Distribución de Corriente Continua.
- 01 Tablero de Control de la Turbina.
- 01 Tablero de Control del Generador.
- 01 Tablero de Sincronización de la red.

  01 Celda con disyuntor del Generador.

  01Celda con disyuntor salida a la red.

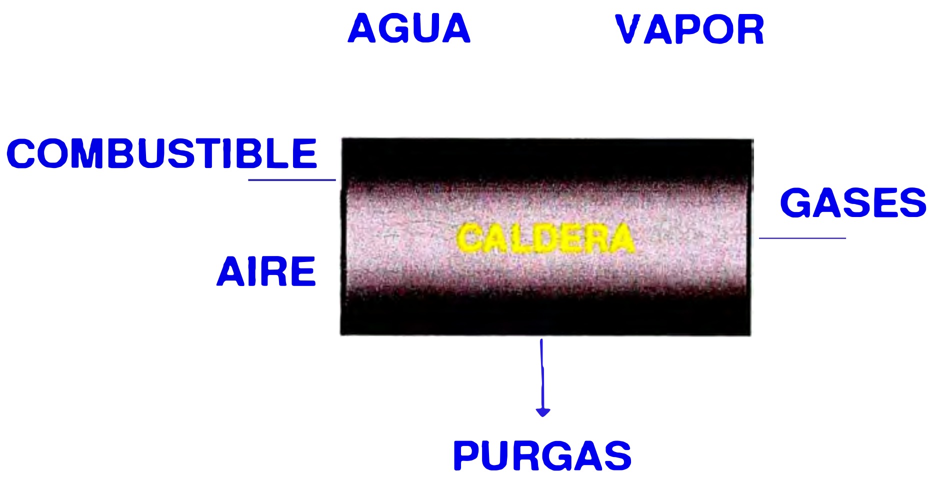
  03 Celdas con disyuntor para salidas, una para alimentar a la Sub estación Principal de Planta, otra para alimentar a la zona de la Piscina y la ultima para alimentar al transformador de 1250 kVA de servicios auxiliares del Turbo Generador.

En el diseño de las canaletas, ductos y buzones de las instalaciones eléctricas y el transformador, los cuales son de concreto armado, se han considerado las cargas actuantes por el terreno, el tránsito sobre el techo y las paredes de las estructuras mencionadas.

La subestación eléctrica contará con 2 transformadores, el primero, es un transformador trifásico 1250 kVA de potencia 13.8/0.480 kV, Dyn5, y el segundo será un transformador trifásico para iluminación de 35 kVA 480/230 V Dyn5 los cuales estarán ubicados en el nivel 0.00.

2.4.1 El sistema de generación de vapor

Los sistemas de generación de vapor o calderas de vapor son aparatos a presión en donde el calor procedente de cualquier fuente de energía se transforma en utilizable, en forma de energía térmica, a través de un medio de transporte en fase líquido o vapor.



Elaboración: Propia.

Figura N° 2.3: Sistema de Generación de Vapor

2.4.2 La turbina de vapor

Las turbinas de Vapor son una de las tecnologías más antiguas y versátiles usadas en la producción e general. La generación de energía usa las turbinas de vapor desde así casi 100 años, cuando reemplazo los alternadores accionados con vapor por dos razones: alta eficiencia y bajo costo. La capacidad de las turbinas de vapor va desde 50 kW hasta 100 MW.

En las turbinas de vapor la generación de electricidad es un subproducto del calor de generación de la caldera. Una turbina de vapor es un contenedor de una fuente de calor independiente y no convierte directamente el combustible en energía eléctrica. La energía se transfiere desde la caldera a la turbina de alta presión a través del vapor que a su vez acciona la turbina y genera energía eléctrica. Las funciones separadas permiten que se pueda usar cualquier tipo de combustible (gas natural, todos los tipos de carbón, madera y subproductos agrícolas).

Para aplicaciones industriales, las turbinas de vapor son generalmente de diseño simple (una sola carcasa) y menos complicado para la confiabilidad y el costo.

2.5. Diseño de las Redes de Tuberías

Para el diseño de las tuberías de vapor se utilizó como referencia el código ASME B31.1 en base al cuál se dimensionó las tuberías.

Con el arreglo de planta se procedió a realizar el recorrido de tuberías y ubicación preliminar de soportes que luego fueron verificados con el software AutoPIPE V8i.

2.6. Código ASME B31.1

El Código ASME B31 para tuberías a presión, está compuesto por varias secciones individuales, siendo cada una un Standard Nacional de USA y son publicadas bajo la dirección del comité B31.

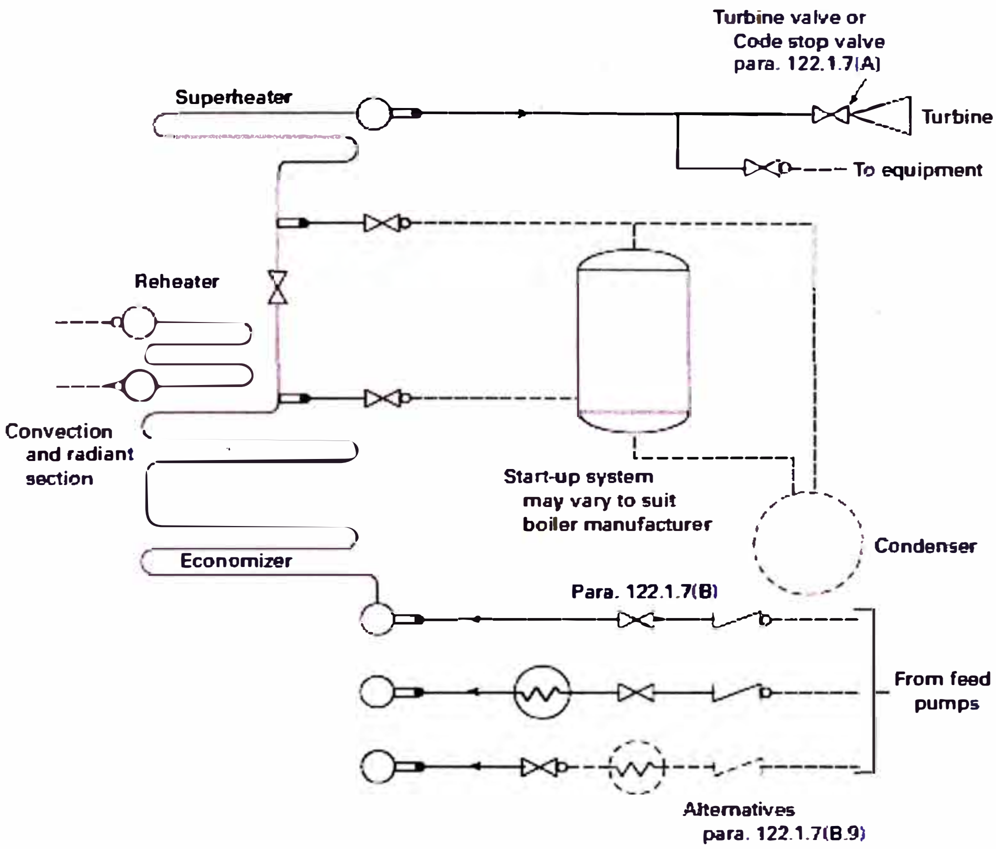
Las reglas de cada sección han sido desarrolladas considerando la necesidad de aplicar requerimientos específicos para los distintos tipos de tuberías.

El código ASME B31.1 considera los requerimientos para el diseño, materiales, fabricación, montaje, pruebas e inspección para sistemas de tuberías de vapor y sistemas de potencia.

Entre los sistemas de tuberías incluidas pero no limitadas solo a ellas se encuentran tuberías que transportan vapor, agua, aceite, gas y aire de servicios.

El código cubre tuberías externas a calderas de calderas de alta presión, alta temperatura y calderas de alta presión de agua que cumplen con lo siguiente: vapor o vapor de agua generado a presiones mayores a 15 psig (100 kPa manométricas); y el agua a alta temperatura se genera a presiones superiores a 160 psig (1103 kPa manométrico) y temperaturas que exceden los 250 °F (120 °C).

El punto desde donde se considera tubería externa a una caldera se muestra en la siguiente ilustración:



Administrative Jurisdiction and Technical Responsibility

——— Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility. Refer to ASME BPVC Section I Preamble.

•——— Boiler External Piping and Joint (BEP) — The ASME BPVC has total administrative jurisdiction (mandatory certification by Code Symbol stamping, ASME Data Forms, and Authorized Inspection) of BEP. The ASME Section Committee B31.1 has been assigned technical responsibility. Refer to ASME BPVC Section I Preamble, fifth, sixth, and seventh paragraphs and ASME B31.1 Scope, para. 100.1.2(A). Applicable ASME B31.1 Editions and Addenda are referenced in ASME BPVC Section I, PG-58.3.

o- - - - Nonboiler External Piping and Joint (NBEP) — The ASME Code Committee for Pressure Piping, B31, has total administrative and technical responsibility.

Fuente: Código ASME B31.1 2010.

FIGURA 2.4: Código de Competencias Límites de tuberías – Generador de Vapor de flujo forzado

El código ASME B31.1 no aplica para:

A) Economizadores, calentadores, recipientes a presión y componentes cubiertos por la Sección del código ASME para calderas y recipientes a presión:

B) Construcción de tuberías de calefacción y distribución de vapor y condensado diseñada para 15 psig o menor, o un sistema de calentamiento de agua diseñado para 30 psig o menor.

La presión interna máxima y temperatura debe incluir consideraciones por variación de cargas ocasionales y transitorias de presión y temperatura.

Para estas variaciones de presión o temperatura, o ambas, se debe exceder los valores de diseño para el análisis de esfuerzos circunferencial sin exceder el esfuerzo máximo admisible por los siguientes valores:

(A) 15% si la duración del evento no es mayor a 8 horas a la vez y no mayor que 800 horas/año: o

(B) 20% si la duración del evento no es mayor a 1hora a la vez y no mayor que 80 horas/año.

2.7. Análisis de Esfuerzos y Flexibilidad

Los esfuerzos admisibles deben estar conforme a la Tabla en el Apéndice A del código ASME B31.1. Está tabla lista los valores de esfuerzos admisibles comúnmente usados para instalaciones de tuberías de vapor y sistemas de potencia.

TABLA 2.1
ACERO AL CARBONO

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimun Tensile, ksi	Specified Minimun Yield, ksi	*E* or *F*
Seamless Pipe and Tube								
A53	A	S	C	1	(2)	48	30	1.00
	B	S	C-Mn	1	(2)	60	35	1.00
A106	A	---	C-Si	1	(2)	48	30	1.00
	B	---	C-Si	1	(2)	60	35	1.00
	C	---	C-Si	1	(2)	70	40	1.00
A179	---	---	C	1	(1) (2) (5)	(47)	26	1.00
A192	---	---	C-Si	1	(2) (5)	(47)	26	1.00
A210	A1	---	C-Si	1	(2)	60	37	1.00
	C	---	C-Mn-Si	1	(2)	70	40	1.00
A333	1	---	C-Mn	1	(2)	55	30	1.00
	6	---	C-Mn-Si	1	(2)	60	35	1.00
A369	FPA	---	C-Si	1	(2)	48	30	1.00
	FPB	---	C-Mn	1	(2)	60	35	1.00
API-5L	A	---	C	1	(1) (2) (14)	48	30	1.00
	B	---	C-Mn	1	(1) (2) (14)	60	35	1.00
Furnace Butt Welded Pipe								
A53	---	F	C	1	(4)	48	30	0.60
API-5L	A25	I & II	C	1	(1) (4) (14)	45	25	0.60
Electric Resistence Welded Pipe and Tube								
A53	A	E	C	1	(2)	48	30	0.85
	B	E	C-Mn	1	(2)	60	35	0.85
A135	A	---	C	1	(1) (2)	48	30	0.85
	B	---	C-Mn	1	(1) (2)	60	35	0.85

TABLA 2.1
ACERO AL CARBONO

Maximun Allowable Stress Values in Tensio, ksi, for Metal Temperature, °F, Not Exceeding												
-20 to 100	200	300	400	500	600	650	-20 to 650	*700*	750	800	Grade	Spec. No.
Seamless Pipe and Tube												
---	---	---	---	---	---	---	12.0	11.7	10.7	9.0	A	A53
---	---	---	---	---	---	---	15.0	14.4	13.0	10.8	B	
---	---	---	---	---	---	---						
---	---	---	---	---	---	---	12.0	11.7	10.7	9.0	A	A106
---	---	---	---	---	---	---	15.0	14.4	13.0	10.8	B	
---	---	---	---	---	---	---	17.5	16.6	14.8	12.0	C	
---	---	---	---	---	---	---	11.8	11.5	10.6	9.2	---	A179
---	---	---	---	---	---	---	11.8	11.5	10.7	9.0	---	A192
---	---	---	---	---	---	---	15.0	14.4	13.0	10.8	A1	A210
---	---	---	---	---	---	---	17.5	16.6	14.8	12.0	C	
---	---	---	---	---	---	---	13.8	---	---	---	1	A333
---	---	---	---	---	---	---	15.0	14.4	---	---	6	
---	---	---	---	---	---	---	12.0	11.7	10.7	9.0	FPA	A369
---	---	---	---	---	---	---	15.0	14.4	13.0	10.8	FPB	
---	---	---	---	---	---	---	12.0	11.7	10.7	9.0	A	API-5L
---	---	---	---	---	---	---	15.0	14.4	13.0	10.8	B	
Furnace Butt Welded Pipe												
---	---	---	---	---	---	---	7.2	7.0	---	---	---	A53
---	---	---	---	---	---	---	---	---	---	---	A25	API-5L
Electric Resistence Welded Pipe and Tube												
---	---	---	---	---	---	---	10.2	9.9	9.1	7.7	A	A53
---	---	---	---	---	---	---	12.8	12.2	11.0	9.2	B	
---	---	---	---	---	---	---	10.2	9.9	9.1	7.7	A	A135
---	---	---	---	---	---	---	12.8	12.2	11.0	9.2	B	

Además se debe considerar los valores de eficiencia de juntas de expansión S, SE o SF, el que sea aplicable.

TABLA 2. 2
EFICIENCIA DE JUNTAS - FACTORES DE SOLDADURA LONGITUDINAL

No.	Type oj Joints		Type of Seam	Examination	Factor *E*
1	Furnace butt weld, continus weld		Straight	As required by listed specification	0.60 [Note (1)]
2	Electric resistance weld		Straight or spiral	As required by listed specification	0.85 [Note (1)]
3	Electric fusion weld				
	(a) Single butt weld (without filler metal)		Straight or spiral	As required by listed specification Additionally 100% radiographed	0.85 [Note (1)] 1.00 [Note (2)]
	(b) Single butt weld (with filler metal)		Straight or spiral	As required by listed specification Additionally 100% radiographed	0.80 [Note (1)] 1.00 [Note (2)]
	(c) Double butt weld (without filler metal)		Straight or spiral	As required by listed specification Additionally 100% radiographed	0.90 [Note (1)] 1.00 [Note (2)]
	(d) Double butt weld (with filler metal)		Straight or spiral	As required by listed specification Additionally 100% radiographed	0.90 [Note (1)] 1.00 [Note (2)]
4	API 5L	Sumerged erc weld (SAW) Gas metal arc weld (GMAW) Combined GMAW, SAW	Straight with one or two seams Spiral	As required by listed specification Additionally 100% radiographed	0.90 [Note (1)] 1.00 [Note (2)]

NOTES:
(1) It is not permitted to increase the longitudinal weld joint efficiebcy factor by additional examination for joint 1 or 2.
(2) Radiography shall be in accordance with the requerimets of para. 136.4.5 or the material specification as applicable.

Limites de Esfuerzos calculadas debido a las cargas sostenidas y la expansión térmica

(A) Esfuerzos por Presión Interna. El cálculo del esfuerzo por presión interna no debe exceder el valor admisible. Esto se cumple cuando el espesor de tubería incluye un refuerzo de acuerdo a los requerimientos del código.

(B) Esfuerzos por Presión Externa. Tubería sujeta a presión externa se considera segura cuando se ha diseñado el espesor de la tubería en base a los requerimientos del código.

CAPÍTULO III

DISEÑO DE LA RED DE TUBERÍAS

3.1. Introducción

En este capítulo se describe la metodología de cálculo para el pre-dimensionamiento de las tuberías de vapor. Con el pre-dimensionamiento de las tuberías y el ruteo de tuberías planteado se procedió a realizar el análisis de esfuerzos y flexibilidad para las dos tuberías de vapor. Además se procedió a realizar el cálculo del aislamiento de las tuberías así como la selección de válvulas y trampas de vapor (este cálculo no es parte del presente informe).

3.2. Modelo de análisis

3.2.1. Metodología de cálculo

Se procedió a identificar las tuberías de vapor de acuerdo al proceso y/o condiciones de vapor transportado, encontrándose tuberías de vapor vivo y tuberías de vapor de extracción.

Se realizó un pre-dimensionamiento de las líneas de vapor en base a las condiciones de operación (presión, temperatura, etc.) utilizando los materiales existentes y que la norma ASME B31.1 recomienda.

Se procedió a determinar el mínimo espesor permitido para las condiciones de operación definidos en el ítem 3.2.2 Parámetros de diseño.

Con los valores determinados del cálculo anterior se procedió a buscar los espesores estándares de tuberías comerciales.

Verificación de esfuerzos y flexibilidad de las tuberías con el software AutoPIPE V8i (Análisis de Esfuerzos y Flexibilidad), junto con ello se procede a definir los soportes, configuraciones y posiciones.

3.2.2. Parámetros de Diseño

Materiales

Se procedió a seleccionar los siguientes materiales a considerar:

Tuberías Sin Costura para Altas Temperaturas:	ASTM A106
Acero Estructural Tuberías Roladas	ASTM A36
Accesorios	ASTM A105
Pernos de Conexión	ASTM A 325

Condiciones de Operación

Vapor de alta:

Presión (abs) : 42.38 Bar

Temperatura : 399 ºC (750 °F)

Temp máx : 407 ºC (764.60 °F)

G´ : 130 t/h

v´´ : 0.0711 m3/kg

i´´ : 767.6 kCal/kg.

Vapor de baja:

Presión (abs) : 2.39 Bar

Temperatura : 126 ºC (258.8°F)

Temp máx : 150 ºC (302 °F)

G´ : 90 t/h

v´´ : 0.0711 m3/kg

i´´ : 767.6 kCal/kg.

3.2.3. Configuración de la red de tuberías

Para la línea de vapor de alta se tiene el siguiente arreglo:

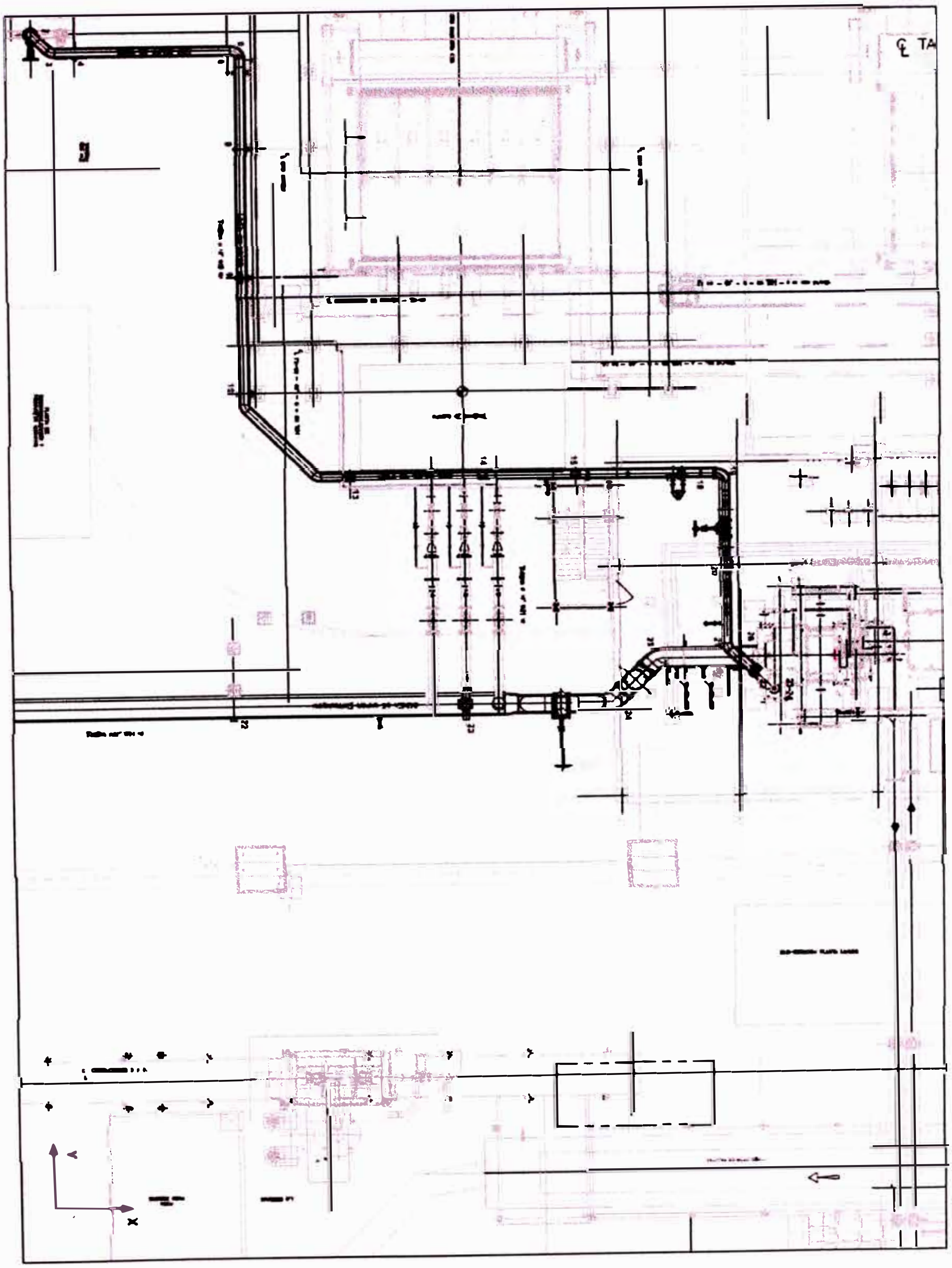


Figura 3.1: Arreglo general de tubería de vapor de alta presión.

Para la línea de vapor de baja se tiene el siguiente recorrido:

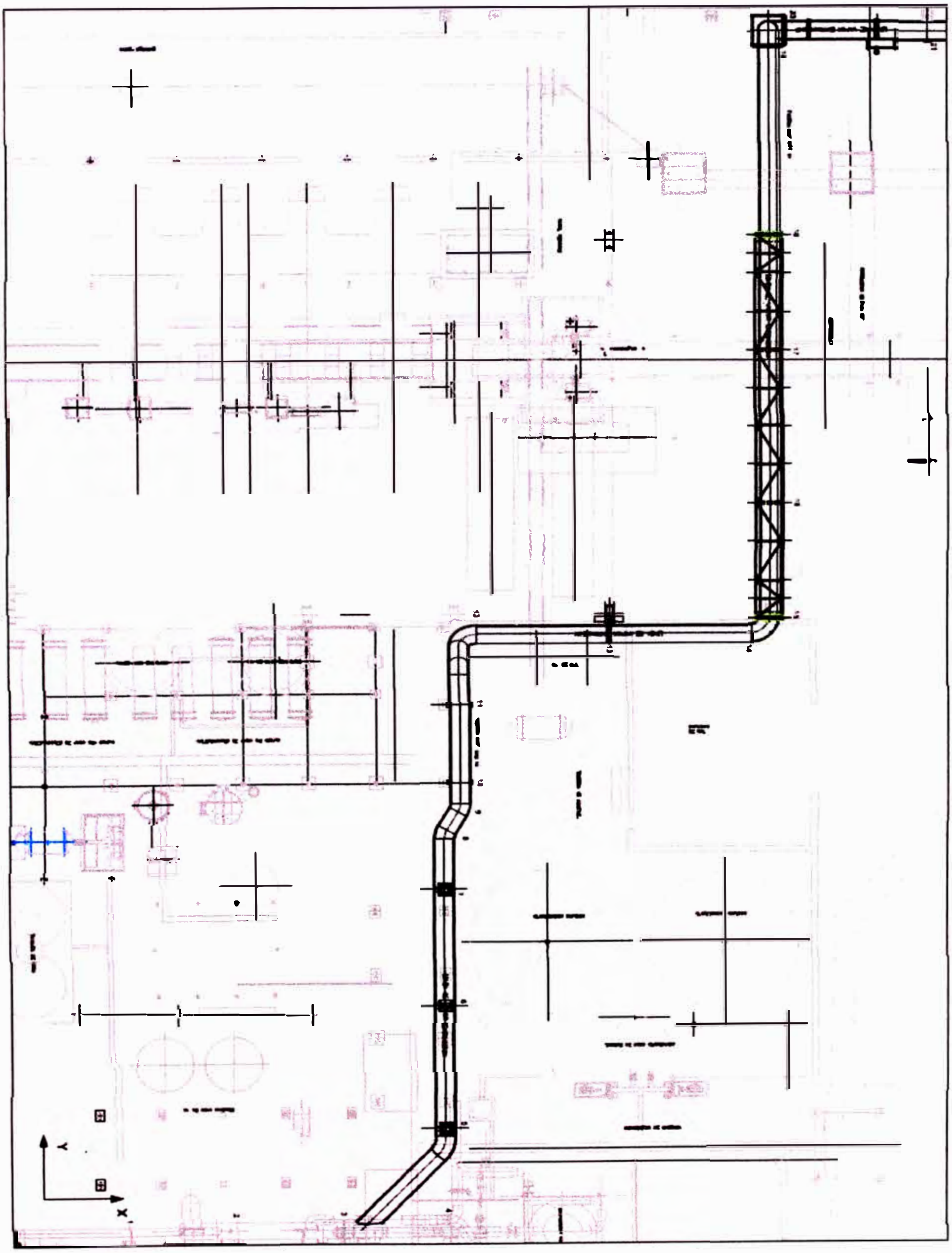


Figura 3.2: Arreglo general de tubería de vapor de baja presión.

3.3. Cálculo de la red de tuberías

3.3.1. Calculo de los espesores de tuberías

Para las consideraciones del cálculo de espesores en los diferentes sistemas de tuberías, se procede a calcular el espesor de pared mínimo de acuerdo al código ASME B31.1 párrafo 104.1.2 para tubería recta.

$$t_m = \frac{PD_0}{2(SE + Py)} + A$$ ....(Ecuación 3.1)

Donde:

t_m = Espesor de pared mínimo requerido en el tubo (pulg.)

P = Presión interna (lb/pulg^2 man).

S = 15000 lb/pulg^2 (para material ASTM A106 B, temperatura de –20 a 50 °F) y 13000 lb/pulg^2 (para material ASTM A106 B, temperatura de 750 °F)

E = Eficiencia de la junta del tubo sin costura.

D = Diámetro de la tubería (pulg).

y = 0.4 (ver tabla 3.1)

A = Espesor Adicional.

TABLA 3.1
VALORES DE *y*

Temperature, °F	900 and Below	950	1000	1050	1100	1150	1200	1250 and Above
Temperature, °C	482 and Below	510	538	566	593	621	649	677 and Above
Ferritic steels	0.4	0.5	0.7	0.7	0.7	0.7	0.7	0.7
Austenitic steel	0.4	0.4	0.4	0.4	0.5	0.7	0.7	0.7
Nickel Alloys UNS N_{06}, N_{08800}, N08810, N08825	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.7

GENERAL NOTES:
(a) The value of may be interpolated between the 50°F (27.8°C) values shown in the Table.
For cast iron and nonferrous materials, *y* equals 0.4
(b) For pipe withh a D_0/t_m ratio less y than, the value of *y* for ferritic and austenitic steels designed for temperatures of 900°F (482°C) and below shall be taken as.

Además se debe verificar que los esfuerzos que se dan por los efectos de la temperatura y presión deben cumplir la siguiente relación (SE <SA):

$$S_A = f(1.25S_c + 0.25S_h)$$ ....(Ecuación 3.2)

Donde:

Sc: Esfuerzo de material base a la temperatura mínima.

Sh: Esfuerzo de material base a la temperatura máxima.

f: Factor de tablas. (ver tabla 3.2)

Se: Esfuerzo de expansión térmica.

TABLA 3.2
Factor de reducción de esfuerzos

Number of Equivalent Full Temperature Cycles N	f
7,000 and less	1.0
7,000 - 14,000	0.9
14,000 - 22,000	0.8
22,000 - 45,000	0.7
45,000 - 100,000	6.0
100,000 and over	0.5

3.3.2. Determinación del espesor mínimo requerido

Vapor de Alta Presión:

Para las condiciones de vapor de alta tenemos:

P = 666.977 lb/pulg² man (47 bar abs)

$S = 13000 lb / pu\lg^2$ *(Para 750 °F)*

$E = 1$ *(Tubería sin costura)*

$D = 12 pu\lg$

Consideramos A= 0,28 pulg (0,18 pulg por corrosión y 0,1 pulg. como factor de seguridad)

Reemplazando en la ecuación 3.1 tenemos:

$$\boxed{t_m = 0.4616 pu\lg = 11.727 mm}$$

El espesor comercial más cercano para una tubería de Ø12" es SCH 80 (17.4 mm).

Vapor de Baja Presión:

SA = 39 500 lb/pulg2.

$$S_E = \frac{iMc}{Z} \leq S_A$$

Donde:

Mc : Momento resultante.

Z : Modulo de la sección de la tubería.

i : Factor de intensificación de esfuerzos.

Para todos los puntos que se analizaron determinamos el esfuerzo "S_E" y seleccionamos el mayor valor para realizar la comparación.

Además tomamos como referencia para la ubicación de soportes la tabla 121.5 del código ASME B31.1

3.3.5. Verificación de esfuerzos con Software AutoPIPE V8i

Con los parámetros obtenidos se procedió a realizar el modelo con el software AutoPIPE V8i obteniéndose los esfuerzos para las combinaciones de cargas descritas anteriormente.

Las cargas consideradas en el modelo son las siguientes:

TABLA 3.4

ESFUERZO ADMISIBLE – VAPOR DE BAJA PRESIÓN

REFERENCIA		ASME B31.1	ASME B31.1	ASME B31.3	ASME B31.3
Parámetros de la tubería	**Unidad**				
Presión interna en tubería recta (Condición), D/6		6.000	6.000	0.000	0.000
ASME B31.3-2008 (304.1.2). t < D/6					
Celula / Presión nominal		10	10	10	10
Tipo de fabricación de la tubería		ERW	ERW	ERW	ERW
Material		ASTM A106 Grade B	ASTM A106 Grade B	ASTM A106 Grade B	ASTM A106 Grade B
Según ASME B31.3-2008 (Tables A-1 and A-1A)					
Diámetro Nominal de la Tubería	in	36	36	36	36
Diámetro Externo de la Tubería, D	in	36	36	36	36
Diámetro Interno de la Tubería, d	in	35.370	35.370	0.312	0.312
Espesor de pared de la Tubería, T	in	0.312	0.312	0.688	0.594
Esfuerzo Permisible Básico	psi	17500	17500	20000	20000
Esfuerzo Permisible en Tensión (B31.3) - S	psi	23275	23275	26000	26000
At design temp: ASME B31.3-2004 (Tables A-1 and A-1A)					
Esfuerzo Permisible en Tensión (B31.3) - S	MPa	160	160	103	103
At design temp:					
Factor de Calidad - (Para ASME B31.3), E		0.85	0.85	0.65	0.85
Tabla A-1B de ASME B31.3					
Coeficiente Y - (Para ASME B31.3), Y		0.40	0.40	0.40	0.40
Tabla 304.1.1 de ASME B31.3					
Otros	**Unidad**				
Tolerancia del Espesor - (Para ASME B31.3), C' Mill=12.5%.T	in	0.039	0.039	0.086	0.074
ASME B31.3-2008 (Apéndice S, Tabla S 301.3.1)					
Tolerancia por Corrosion / Mecánica o Tolerancia genérica, C	in	0.063	0.063	0.063	0.063
ASME B31.3-2008 (Apéndice S, Tabla S 301.3.1)					
Espesor de tubería mínimo requerido, t_m	in	0.3120	0.3120	0.6880	0.5940
Referencia ASME B31.3 304.1.1 tm = t +c + c'					
Espesor de Diseño, t	in	0.2105	0.2105	0.5395	0.4573
Factor de Reducción de Resistencia de la Junta Soldada, W		1.00	1.00	1.00	1.00
ASME B31.3 302.3.5 e)					
Presión de Diseño:					
Presión Máxima, P	psi	232.45	232.45	685.90	580.25
Presión Máxima, P	kPa	1603	1603	4729	4001
Presión Máxima, P	Bar	16.04	16.04	47.33	40.04

Para la tubería de Ø36" SCH 10 seleccionada se puede observar que la presión máxima que puede soportar es de 16.04 bar, siendo este valor mayor a la presión de operación de nuestra tubería de vapor de baja presión cuya máximo valor es de 2.39 bar.

3.3.4. Verificación de esfuerzos

Tomamos como referencia los puntos que presentan mayor Momento, y verificamos que se cumpla la relación: $S_E < S_A$.

Para esta línea tenemos que:

SA = 0.5*(1.25*60000+0.25*16000) = 39 500 lb/pulg^2

TABLA 3.3

ESFUERZO ADMISIBLE – VAPOR DE ALTA PRESIÓN

REFERENCIA		ASME B31.1	ASME B31.1	ASME B31.3	ASME B31.3
Parámetros de la tubería	**Unidad**				
Presión interna en tubería recta (Condición), D/6 ASME B31.3-2008 (304.1.2). t < D/6		2.125	1.792	2.125	1.792
Celula / Presión nominal		80	80	80	80
Tipo de fabricación de la tubería		ERW	ERW	ERW	ERW
Material Según ASME B31.3-2008 (Tables A-1 and A-1A)		ASTM A106 Grade B	ASTM A106 Grade B	ASTM A106 Grade B	ASTM A106 Grade B
Diámetro Nominal de la Tubería	in	12	10	12	10
Diámetro Externo de la Tubería, D	in	12.75	10.75	12.75	10.75
Diámetro Interno de la Tubería, d	in	11.374	9.562	11.374	9.562
Espesor de pared de la Tubería, T	in	0.688	0.594	0.688	0.594
Esfuerzo Permisible Básico	psi	17500	17500	20000	20000
Esfuerzo Permisible en Tensión (B31.3) - S At design temp: ASME B31.3-2004 (Tables A-1 and A-1A)	psi	23275	23275	26600	26600
Esfuerzo Permisible en Tensión (B31.3) - S At design temp:	MPa	160	160	183	183
Factor de Calidad - (Para ASME B31.3), E Tabla A-1B de ASME B31.3		0.85	0.85	0.85	0.85
Coeficiente Y - (Para ASME B31.3), Y Tabla 304.1.1 de ASME B31.3		0.40	0.40	0.40	0.40
Otros	**Unidad**				
Tolerancia del Espesor - (Para ASME B31.3), C' Mill=12.5%.T ASME B31.3-2008 (Apéndice S, Tabla S 301.3.1)	in	0.086	0.074	0.086	0.074
Tolerancia por Corrosion / Mecánica o Tolerancia genérica, C ASME B31.3-2008 (Apéndice S, Tabla S 301.3.1)	in	0.063	0.063	0.063	0.063
Espesor de tubería mínimo requerido, t_m Referencia ASME B31.3 304.1.1 $tm = t + c + c'$	in	0.6880	0.5940	0.6880	0.5940
Espesor de Diseño, t	in	0.5395	0.4573	0.5395	0.4573
Factor de Reducción de Resistencia de la Junta Soldada, W ASME B31.3 302.3.5 e)		1.00	1.00	1.00	1.00
Presión de Diseño:					
Presión Máxima, P	psi	1732.91	1742.28	1980.47	1891.18
Presión Máxima, P	kPa	11948	12013	13655	13729
Presión Máxima, P	Bar	119.57	120.22	136.65	137.39

Para la tubería de Ø12" SCH 80 seleccionada se puede observar que la presión máxima que puede soportar es de 119.57 bar, siendo este valor mayor a la presión de operación de nuestra tubería de vapor de alta presión cuya máximo valor es de 47 bar.

Para la línea de vapor de baja presión tenemos:

Para las condiciones de vapor de alta tenemos:

P = 19.964 lb/pulg² man (2.39 bar abs)

$S = 15000 lb / pu\lg^2$ *(Para 258.8 °F)*

$E = 1$ *(Tubería sin costura)*

$D = 36 pu\lg$

Consideramos A= 0,16 pulg (0,13 pulg por corrosión y 0,03 pulg. como factor de seguridad)

Reemplazando en la ecuación 3.1 tenemos:

$$\boxed{t_m = 0.184 pu\lg = 4.672 mm}$$

El espesor comercial más cercano para una tubería de Ø36" es SCH 10 (7.95 mm).

3.3.3. Determinación de Esfuerzos permisibles

De acuerdo con el código ASME B31.1 podemos obtener los siguientes valores de esfuerzos admisibles, para la línea de vapor de alta presión:

CUADRO N° 3.1

CARGAS

Analyzed Load Case	Description
GR	Gravity
T1	Thermal 1
T2	Thermal 2
E1	Earth 1
E2	Earth 2
E3	Earth 3
E4	Earth 4
W1	Wind 1
P1	Press 1
P2	Press 2

Las combinaciones de carga consideradas de acuerdo al código ASME B31.1 son:

CUADRO N° 3.2

COMBINACION DE CARGAS SEGUN CODIGO

Combination	Category	Combination Method	Allowable Stress kg/cm^2
GR + Max P	Sustain	Sum	Automatic
Max Range	Expansion	Sum	Automatic
Amb to T1	Expansion	Sum	Automatic
Amb to T2	Expansion	Sum	Automatic
Sus. + E1	Occasion	Abs. Sum	Automatic
Sus. + E2	Occasion	Abs. Sum	Automatic
Sus. + E3	Occasion	Abs. Sum	Automatic
Sus. + E4	Occasion	Abs. Sum	Automatic
Sus. + W1	Occasion	Abs. Sum	Automatic
Max P	Hoop	Sum	Automatic

Las combinaciones de carga consideradas que no están sujetas al código ASME B31.1 son:

CUADRO N° 3.3

COMBINACION DE CARGAS

Combination	**Combination Method**
Gravity	Sum
Thermal 1	Sum
Thermal 2	Sum
E1	Sum
E2	Sum
E3	Sum
E4	Sum
Wind 1	Sum
Pressure 1	Sum
Pressure 2	Sum
OPE1	Sum
OPE2	Sum
OPE1+E1	Sum
OPE1+E2	Sum
OPE1+E3	Sum
OPE1+E4	Sum
OPE2+E1	Sum
OPE2+E2	Sum
OPE2+E3	Sum
OPE2+E4	Sum

Para las tuberías de Vapor Vivo se obtuvo los siguientes esfuerzos:

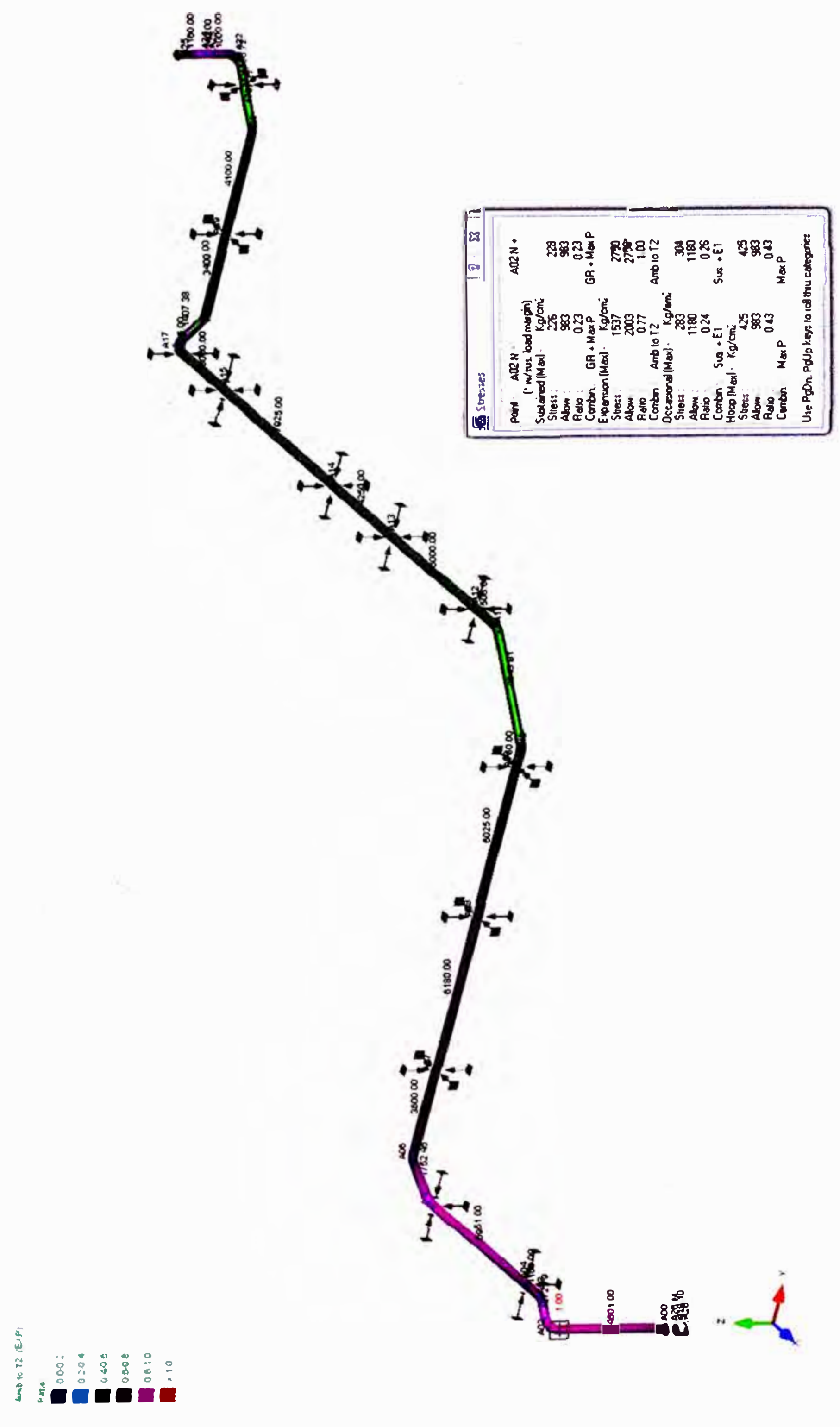


FIGURA N° 3.3: Esfuerzos obtenidos para el código ASME B31.1

El resumen de resultados obtenidos con el software para la tubería de vapor de alta presión seleccionada es:

```
---------------------------------------------------------------------------
VAPOR VIVO
01/11/2012 ANÁLISIS DE ESFUERZOS LÍNEAS DE VAPOR                     BENTLEY
11:20 PM                                      AutoPIPE+9.00 RESULT PAGE   88
---------------------------------------------------------------------------

                         R E S U L T    S U M M A R Y
                         ----------------------------


 Maximum displacements (mm)
 ---------------------------

          Maximum X :     86.023      Point : A11 N      Load Comb.: T1
          Maximum Y :   -137.549      Point : A05 F      Load Comb.: GT1
          Maximum Z :     25.744      Point : A02 N      Load Comb.: T1
          Max. total:    142.578      Point : A05 F      Load Comb.: GT1

 Maximum rotations (deg)
 -----------------------

          Maximum X :     -0.611      Point : A03 N      Load Comb.: T1
          Maximum Y :     -0.633      Point : A03 F      Load Comb.: GT1
          Maximum Z :      1.074      Point : A04        Load Comb.: T1
          Max. total:      1.323      Point : A04        Load Comb.: GT1


 Maximum restraint forces (Kg)
 ------------------------------

          Maximum X :     -12738      Point : A07        Load Comb.: T1
          Maximum Y :      -3762      Point : A14        Load Comb.: T1
          Maximum Z :     -20254      Point : A21        Load Comb.: GT1
          Max. total:      20587      Point : A21        Load Comb.: GT1

 Maximum restraint moments (Kg-cm)
 ----------------------------------

          Maximum X :     677718      Point : A26        Load Comb.: GT1
          Maximum Y :    2210025      Point : A26        Load Comb.: T1
          Maximum Z :     575802      Point : A26        Load Comb.: T1
          Max. total:    2381046      Point : A26        Load Comb.: T1
```

R E S U L T   S U M M A R Y

Maximum pipe forces (Kg)

Maximum X :	-7262	Point : A26	Load Comb.: T1
Maximum Y :	3405	Point : A26	Load Comb.: T1
Maximum Z :	18125	Point : A26	Load Comb.: GT1
Max. total:	19818	Point : A26	Load Comb.: GT1

Maximum pipe moments (Kg-cm)

Maximum X :	1096423	Point : A21	Load Comb.: GT1
Maximum Y :	-2210025	Point : A26	Load Comb.: T1
Maximum Z :	1705293	Point : A05 N	Load Comb.: T1
Max. total:	2381046	Point : A26	Load Comb.: T1

R E S U L T   S U M M A R Y

Maximum sustained stress

Point	: A15
Stress Kg/cm2	: 274
Allowable Kg/cm2	: 983
Ratio	: 0.28
Load combination	: GR + Max P

Maximum displacement stress

Point	: A02 N
Stress Kg/cm2	: 2750
Allowable Kg/cm2	: 2759
Ratio	: 1.00
Load combination	: Amb to T2

Maximum occasional stress

Point	: A19
Stress Kg/cm2	: 620
Allowable Kg/cm2	: 1180
Ratio	: 0.53
Load combination	: Sus. + El

Maximum hoop stress

Point	: A26 M
Stress Kg/cm2	: 425
Allowable Kg/cm2	: 983
Ratio	: 0.43
Load combination	: Max P

R E S U L T   S U M M A R Y

Maximum sustained stress ratio

```
Point              : A15
Stress     Kg/cm2  : 274
Allowable Kg/cm2   : 983
Ratio              : 0.28
Load combination   : GR + Max P
```

Maximum displacement stress ratio

```
Point              : A02 N
Stress     Kg/cm2  : 2750
Allowable Kg/cm2   : 2759
Ratio              : 1.00
Load combination   : Amb to T2
```

Maximum occasional stress ratio

```
Point              : A19
Stress     Kg/cm2  : 620
Allowable Kg/cm2   : 1180
Ratio              : 0.53
Load combination   : Sus. + E1
```

Maximum hoop stress ratio

```
Point              : A26 M
Stress     Kg/cm2  : 425
Allowable Kg/cm2   : 983
Ratio              : 0.43
Load combination   : Max P
```

* * * The system satisfies ASME B31.1 2004 code requirements * * *
* * * for the selected options * * *

Para las tuberías de Vapor de Extracción se obtuvo los siguientes esfuerzoss:

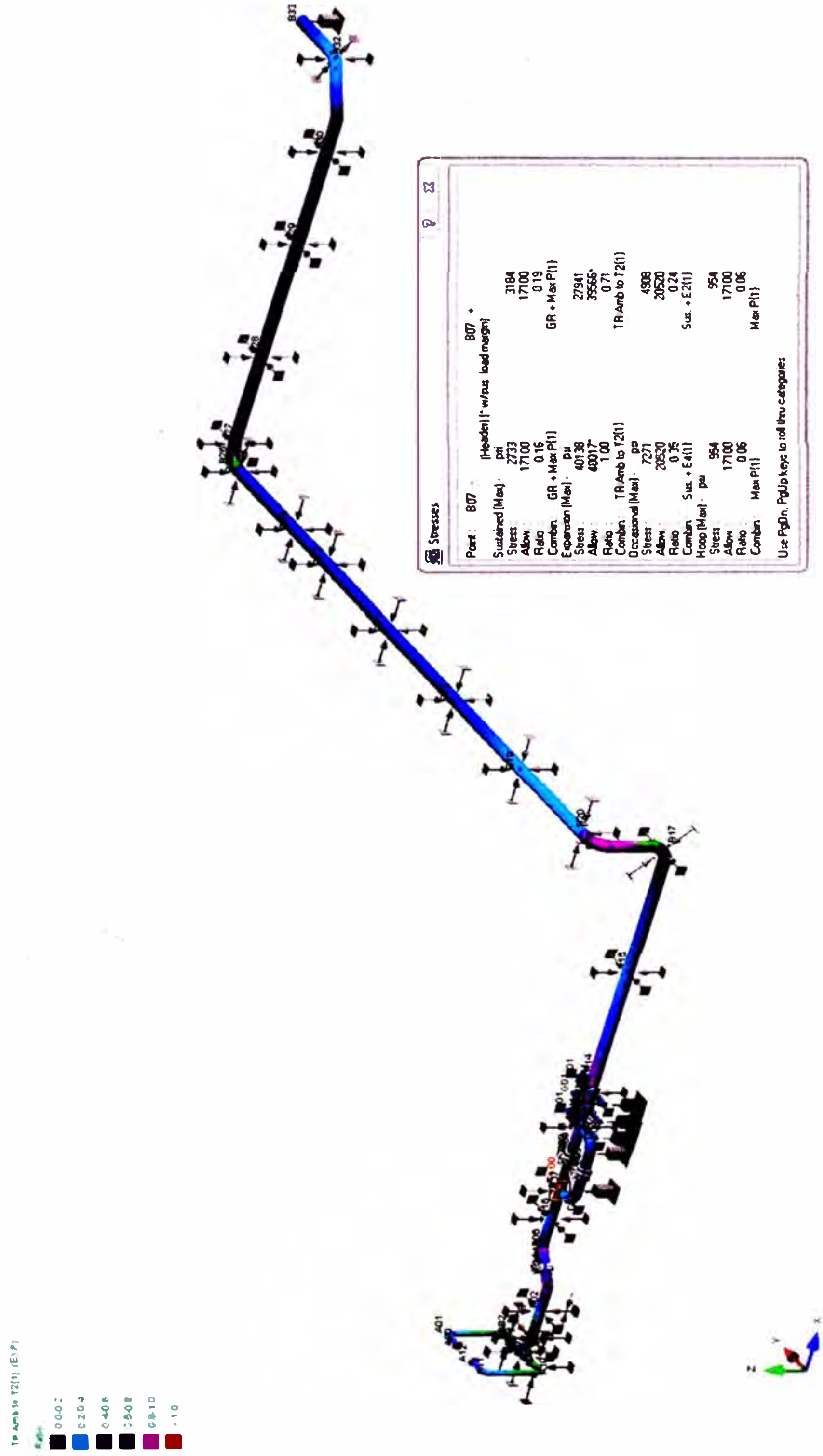


FIGURA N° 3.4: Esfuerzos obtenidos para el código ASME B31.1

El resumen de resultados obtenidos con el software para la tubería de vapor de baja presión seleccionada es:

```
--------------------------------------------------------------------------------
VAPOR EXTRACCION
01/13/2012 ANÁLISIS DE ESFUERZOS LÍNEAS DE VAPOR                        BENTLEY
05:14 PM                              AutoPIPE Plus 9.1.1       RESULT PAGE 290
--------------------------------------------------------------------------------

                          R E S U L T    S U M M A R Y
                          ----------------------------


 Maximum displacements (in)
 --------------------------

          Maximum X :      1.536      Point : B31 F      Load Comb.: GT2P2
          Maximum Y :     -2.895      Point : B18 F      Load Comb.: GT2P2
          Maximum Z :      1.638      Point : B18 F      Load Comb.: GT2P2
          Max. total:      3.327      Point : B18 F      Load Comb.: GT2P2

 Maximum rotations (deg)
 -----------------------

          Maximum X :      0.778      Point : B17 F      Load Comb.: GT2P2
          Maximum Y :     -0.428      Point : B17 M      Load Comb.: GT2P2
          Maximum Z :      0.481      Point : B04        Load Comb.: GT2P2
          Max. total:      0.868      Point : B17 F      Load Comb.: GT2P2


 Maximum restraint forces (lb)
 ------------------------------

          Maximum X :    -699541      Point : A06        Load Comb.: GT2P2
          Maximum Y :      61697      Point : B27        Load Comb.: GT2P2
          Maximum Z :     317729      Point : A06        Load Comb.: GT2P2
          Max. total:     768320      Point : A06        Load Comb.: GT2P2

 Maximum restraint moments (ft-lb)
 ---------------------------------

          Maximum X :     409099      Point : A00        Load Comb.:Thermal 2
          Maximum Y :     -13428      Point : A00        Load Comb.:Thermal 2
          Maximum Z :     -18911      Point : A00        Load Comb.:Thermal 2
          Max. total:     409755      Point : A00        Load Comb.:Thermal 2
```

R E S U L T   S U M M A R Y

Maximum pipe forces (lb)

Maximum X :	770243	Point : B01 F	Load Comb.: GT2P2
Maximum Y :	56580	Point : B25	Load Comb.: GT2P2
Maximum Z :	-255861	Point : B01 F	Load Comb.: GT2P2
Max. total:	770424	Point : B02	Load Comb.: GT2P2

Maximum pipe moments (ft-lb)

Maximum X :	-409099	Point : A00	Load Comb.:Thermal 2
Maximum Y :	-137956	Point : A06	Load Comb.:Thermal 2
Maximum Z :	-164920	Point : B16	Load Comb.: GT2P2
Max. total:	409755	Point : A00	Load Comb.:Thermal 2

R E S U L T   S U M M A R Y

Maximum sustained stress

Point	: B13
Stress psi	: 8028
Allowable psi	: 17100
Ratio	: 0.47
Load combination	: GR + Max P

Maximum displacement stress

Point	: A06
Stress psi	: 40750
Allowable psi	: 41390
Ratio	: 0.98
Load combination	: Max Range

Maximum occasional stress

Point	: B12
Stress psi	: 12994
Allowable psi	: 20520
Ratio	: 0.63
Load combination	: Sus. + E2

Maximum hoop stress

Point	: B11
Stress psi	: 1146
Allowable psi	: 17100
Ratio	: 0.07
Load combination	: Max P

R E S U L T   S U M M A R Y

Maximum sustained stress ratio

Point	: B13
Stress psi	: 8028
Allowable psi	: 17100
Ratio	: 0.47
Load combination	: GR + Max P

Maximum displacement stress ratio

Point	: B07
Stress psi	: 40138
Allowable psi	: 40017
Ratio	: 1.00
Load combination	: Max Range

Maximum occasional stress ratio

Point	: B12
Stress psi	: 12994
Allowable psi	: 20520
Ratio	: 0.63
Load combination	: Sus. + E2

Maximum hoop stress ratio

Point	: B11
Stress psi	: 1146
Allowable psi	: 17100
Ratio	: 0.07
Load combination	: Max P

* * * The system satisfy ASME B31.1 (2007) code requirements * * *
* * * for the selected options * * *

3.4. Cálculo de elementos complementarios

3.4.1. Cálculo del aislamiento térmico

Tuberias de Alta Presión

Realizamos el cálculo de los coeficientes de Convección:

Calculamos h1:

Cálculo Reynolds

$D = 0.3048 \text{ m}$

$\text{Flujo } m = 33.333 \text{ kg/s}$

$u = 2.445 \text{ E} - 05 \text{ kg/m.s}$

$Pr = 0.996$

$u_S = 1.85 \text{ E} - 05 \text{ kg/m.s}$

$\text{Kaire}(20°C) = 0.0263 \text{ W/mK}$

De la siguiente ecuación obtenemos el valor de Reynolds: $Re_D = \frac{4m}{\pi D u}$

Donde: $Re_D = 5695017.62$

Remplazamos los valores obtenidos en la siguiente ecuación:

$$Nu = 0.027 Re_D^{\frac{4}{5}} Pr^{\frac{1}{3}} \left(\frac{u}{u_S}\right)^{0.14}$$

Donde: $Nu = 7116.50$

De la ecuación $Nu_D = \frac{hD}{K}$ obtenemos el valor de h1:

Donde: $h_1 = 614.05456 \; W/m2 - K$

Calculamos h2:

Cálculo Reynolds

$D = 0.3048 \; m$

$\text{Velocidad} = 3.18 \; m/s$

$u = 1.846 \; E - 05 \; kg/m.s$

$Pr = 0.707$

$v = 1.59 \; E - 05 \; m2/s$

$\text{Kaire}(20°C) = 0.0263 \; W/mK$

$Pr_S = 0.996$

De la siguiente ecuación obtenemos el valor de Reynolds: $Re_D = \frac{4m}{\pi D u}$

Donde: $Re_D = 6.10 \; E + 04$

Usando las correlaciones de Zhukauskas tenemos:

$Nu_D = C Re_D^m Pr^n \left(\frac{Pr}{Pr_S}\right)^{1/4}$, Pr < 10, n = 0.37

Constante de Ecuacion para cilindros circular con flujo cruzado

Re	C	m
1-40	0.75	0.4
40-1000	0.51	0.5
1000-200000	0.26	0.6
200000-1000000	0.076	0.7

Donde: $\mathrm{Nu_D} = 156.04126$

De la ecuación $\mathrm{Nu_D} = \frac{hD}{K}$ obtenemos el valor de h2:

Donde: $h_2 = 13.46419\ \mathrm{W/m2-K}$

Por Conductividad tenemos:

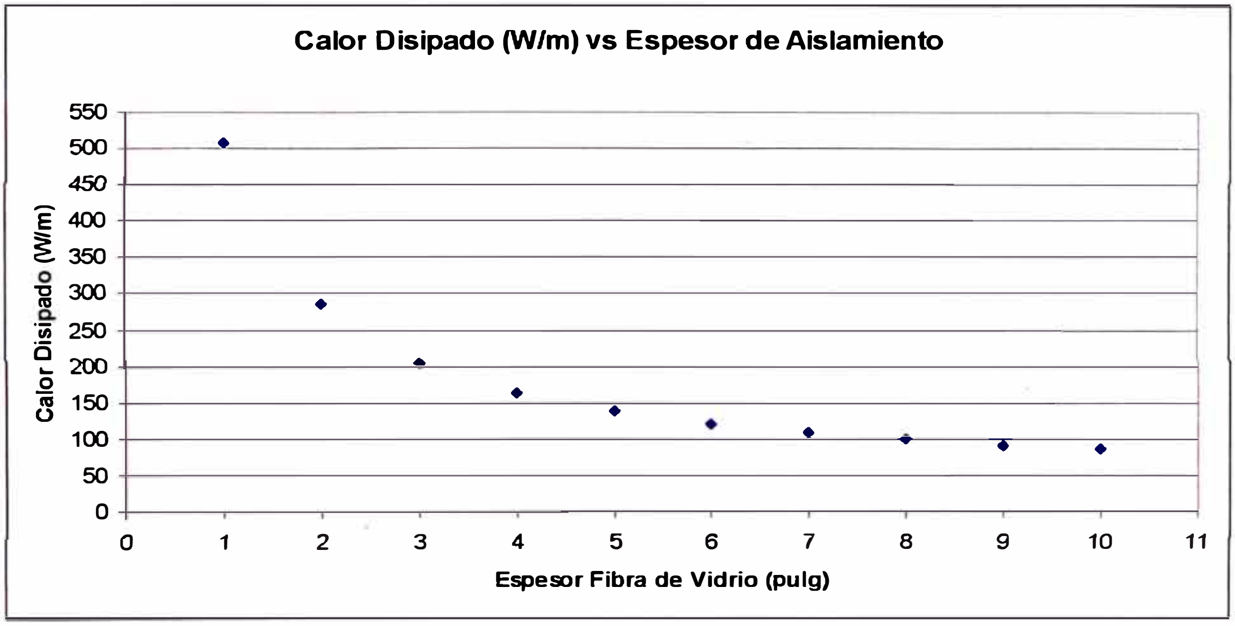
$$q = \frac{T_1 - T_2}{\frac{1}{h_1 2\pi r_1 L} + \frac{Ln(r_2/r_1)}{2\pi K_2 L} + \frac{Ln(r_3/r_2)}{2\pi K_3 L} + \frac{1}{h_2 2\pi r_3 L}}$$

Para la tuberias de 12" SCH 80 tenemos:

T1=	399	°C
T2=	20	°C
r1=	0.14442	mm
r2=	0.1619	mm

K seleccionado	0.035	W / m k	h1=	614.0546	W/ m2 K
			h2=	13.46419	W/ m2 K
K FV(40kg/m3)=	0.035	W / m k	K tubo=	43	W / m k
K rockwool=	0.03	W / m k			
K silicato(300k)=	0.063	W / m k			

Espesor de aislamiento				Resistencias Equivalentes			
e pulg	e (mm)	q_1 (W/m)	q_2 (W/m)	R_1	R_2	R_3	R_4
0	0	5037.77848	5037.77848	0.00179473	0.0004229	0	0.07301395
1	0.0254	5801.3115	520.577359	0.00179473	0.0004229	0.66270775	0.06311243
2	0.0508	6557.84717	291.807521	0.00179473	0.0004229	1.24100799	0.05557573
3	0.0762	7307.48124	209.872544	0.00179473	0.0004229	1.75399328	0.04964703
4	0.1016	8050.30772	167.550068	0.00179473	0.0004229	2.21493148	0.04486132
5	0.127	8786.41892	141.600058	0.00179473	0.0004229	2.63341782	0.04091713
6	0.1524	9515.90549	124.000281	0.00179473	0.0004229	3.01661664	0.03761043
7	0.1778	10238.8565	111.240426	0.00179473	0.0004229	3.37001894	0.03479823
8	0.2032	10955.3593	101.539951	0.00179473	0.0004229	3.69792605	0.03237732
9	0.2286	11665.4998	93.8988244	0.00179473	0.0004229	4.0037703	0.03027134
10	0.254	12369.3624	87.7116931	0.00179473	0.0004229	4.2903344	0.0284226
11	0.2794	13067.03	82.5904198	0.00179473	0.0004229	4.55990567	0.02678667
12	0.3048	13758.5841	78.2745153	0.00179473	0.0004229	4.81438709	0.02532882
13	0.3302	14444.1045	74.5825453	0.00179473	0.0004229	5.05537886	0.02402146



De nuestro cálculo tenemos que para una tubería de Ø 12" SCH 80, con un aislamiento de 3" de espesor tendremos un flujo de 209.87 W/m, con una temperatura de 20°C en la superficie.

Entonces para una tubería de Ø 12" SCH 80 con aislamiento de 3" de espesor de fibra de vidrio tendremos un calor disipado de 133.61 W/m2.

TABLA 3.5

ESPESOR DE AISLAMIENTO – FIBRA DE VIDRIO

Temperature (°C)	Diameter nominal (DN) (15)	(25)	(40)	(50)	(80)	(100)	(150)	(200)	(250)	(300)	(400)	(450)	(600)	Flat
	Fiberglass thickness (mm)													
75	25	25	25	25	25	25	25	38	38	38	38	38	38	38
100	25	25	25	25	25	25	25	38	38	38	38	38	38	38
150	25	25	25	25	25	25	25	38	38	38	38	38	38	38
200	25	25	25	25	25	25	25	38	38	38	38	38	38	38
250	25	25	25	25	25	25	38	38	38	38	38	38	38	38
300	25	25	25	38	38	38	38	38	38	38	51	51	51	51
350	38	38	38	38	38	51	51	51	51	51	64	64	64	64
400	38	38	51	51	51	51	64	64	64	64	76	76	76	90
450	38	51	64	64	64	64	76	76	76	89	89	89	89	102

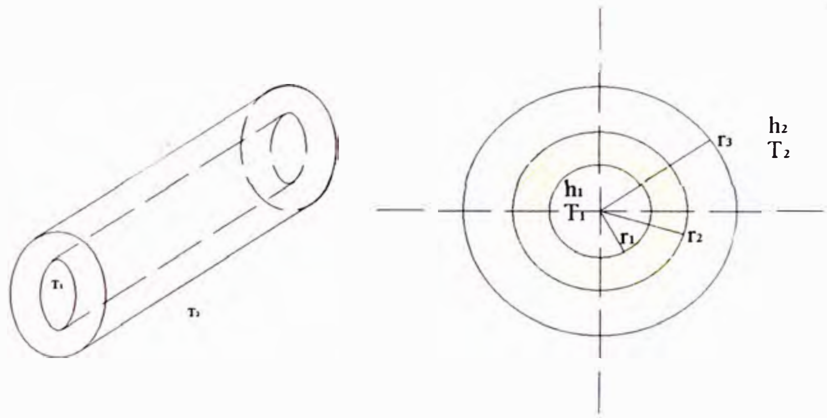
Maximum heat flow = 348.2 W/m2 (highest heat flow of any in the table).

Si usamos la tabla de espesores de aislamiento recomendados ubicada en PIPING HANDBOOK - Mohinder L. Nayyar obtenemos un espesor recomendado de 64 mm (2.5 pulg) para una temperatura de ambiente de 32° C, apropiado para un balance costo beneficio de una tubería con diámetro 12" SCH 80 con un flujo de calor disipado de 348.2 W/m^2, mayor al calculado.

Por lo tanto usaremos 3" de espesor de fibra de vidrio como aislamiento para las tuberías de Ø 12" SCH 80.

Tuberías de Baja Presión

Consideramos el cálculo del espesor del aislamiento de las tuberías usando las correlaciones que están dadas en los libros de texto de transferencia de Calor de Masa (Frank P. Incropera).



Realizamos el cálculo de los coeficientes de Convección:

Calculamos h1:

Cálculo Reynolds

$D = 0.9144\ m$

$Flujo\ m = 22.2222\ kg/s$

$u = 1.34\ E - 05\ kg/m.s$

$Pr = 1.04$

$u_S = 1.85\ E - 05\ kg/m.s$

$Kaire(20°C) = 0.0263\ W/mK$

De la siguiente ecuación obtenemos el valor de Reynolds: $Re_D = \frac{4m}{\pi Du}$

Donde: $Re_D = 2302301.1$

Remplazamos los valores obtenidos en la siguiente ecuación:

$$Nu = 0.027 Re_D^{\frac{4}{5}} Pr^{\frac{1}{3}} \left(\frac{u}{u_S}\right)^{0.14}$$

Donde: $Nu = 3217.18$

De la ecuación $Nu_D = \frac{hD}{K}$ obtenemos el valor de h1:

Donde: $h_1 = 92.532486\ W/m2 - K$

Calculamos h2:

Cálculo Reynolds

$D = 0.9144\ m$

$Velocidad = 3.18\ m/s$

$u = 1.846\ E - 05\ kg/m.s$

$Pr = 0.707$

$v = 1.59\ E - 05\ m2/s$

$Kaire(20°C) = 0.0263\ W/mK$

$Pr_S = 0.996$

De la siguiente ecuación obtenemos el valor de Reynolds: $Re_D = \frac{4m}{\pi Du}$

Donde: $Re_D = 182995.09$

Usando las correlaciones de Zhukauskas tenemos:

$$Nu_D = CRe_D^m Pr^n \left(\frac{Pr}{Pr_S}\right)^{1/4}, \ Pr < 10, \ n = 0.37$$

Constante de Ecuacion para cilindros circular con flujo cruzado:

Re:	C	m
1-40	0.75	0.4
40-1000	0.51	0.5
1000-200000	0.26	0.6
200000-1000000	0.076	0.7

Donde: $Nu_D = 301.65617$

De la ecuación $Nu_D = \frac{hD}{K}$ obtenemos el valor de h2:

Donde: $h_2 = 8.6762438 \ W/m2 - K$

Por Conductividad tenemos:

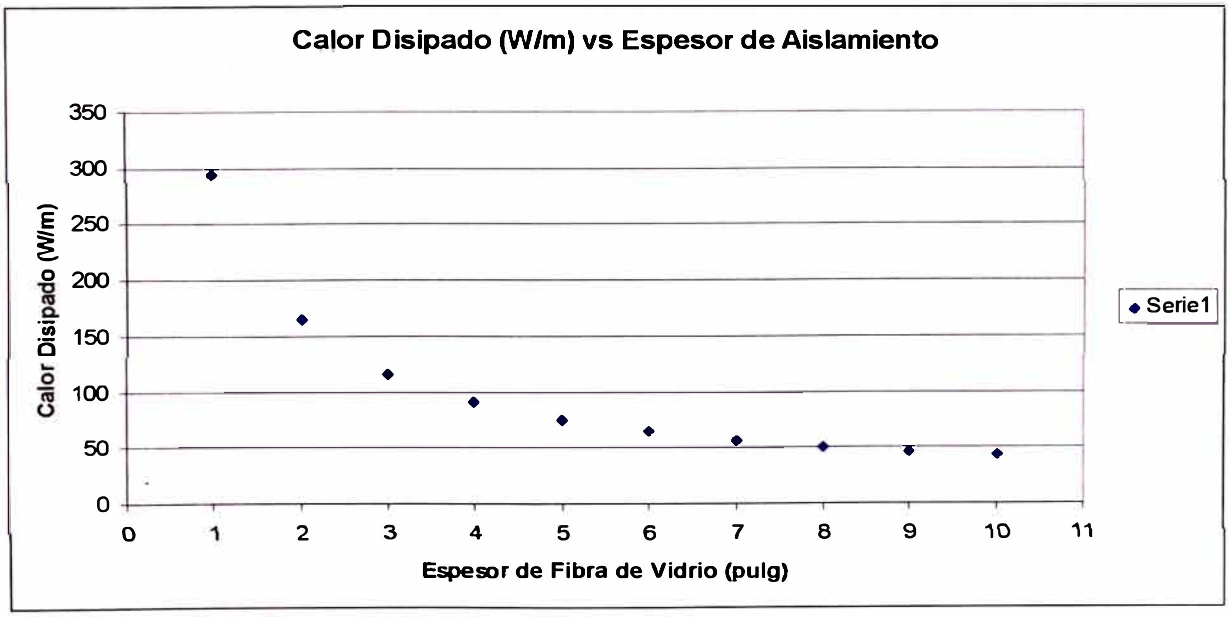
$$q = \frac{T_1 - T_2}{\frac{1}{h_1 2\pi r_1 L} + \frac{Ln(r_2/r_1)}{2\pi K_2 L} + \frac{Ln(r_3/r_2)}{2\pi K_3 L} + \frac{1}{h_2 2\pi r_3 L}}$$

Para la tuberias de 36" SCH 10 tenemos:

T1=	126	°C
T2=	20	°C
r1=	0.37308	mm
r2=	0.381	mm

K seleccionado	0.035	W / m k	h1=	92.53249	W/ m2 K
			h2=	8.676244	W/ m2 K
K FV(40kg/m3)=	0.035	W / m k	K2=K tubo=	43	W / m k
K rockwool=	0.03	W / m k			
K silicato(300k)=	0.063	W / m k			

Espesor de aislamiento				Resistencias Equivalentes			
e pulg	e (mm)	q_1 (W/m)	q_2 (W/m)	R_1	R_2	R_3	R_4
0	0	2006.21138	2006.21138	0.00461038	7.7753E-05	0	0.04814777
1	0.0254	2127.37467	308.758562	0.00461038	7.7753E-05	0.29348365	0.04513854
2	0.0508	2247.12127	171.982824	0.00461038	7.7753E-05	0.56916915	0.04248333
3	0.0762	2365.47589	121.294837	0.00461038	7.7753E-05	0.82909237	0.04012315
4	0.1016	2482.46266	94.8411627	0.00461038	7.7753E-05	1.07495863	0.0380114
5	0.127	2598.10516	78.576161	0.00461038	7.7753E-05	1.30821069	0.03611083
6	0.1524	2712.42642	67.552093	0.00461038	7.7753E-05	1.53007997	0.03439127
7	0.1778	2825.44897	59.579277	0.00461038	7.7753E-05	1.74162594	0.03282803
8	0.2032	2937.19479	53.5392595	0.00461038	7.7753E-05	1.94376669	0.03140072
9	0.2286	3047.68542	48.8010693	0.00461038	7.7753E-05	2.13730306	0.03009236
10	0.254	3156.94187	44.9816873	0.00461038	7.7753E-05	2.32293774	0.02888866
11	0.2794	3264.98471	41.8351185	0.00461038	7.7753E-05	2.50129073	0.02777756
12	0.3048	3371.83405	39.1961291	0.00461038	7.7753E-05	2.67291178	0.02674876
13	0.3302	3477.50955	36.9496045	0.00461038	7.7753E-05	2.83829067	0.02579345



De nuestro cálculo tenemos que para una tubería de Ø 36" SCH 10 tendremos un flujo de calor de 121.29 W/m de calor disipado por longitud de tubería, con una temperatura en la superficie de 20°C aproximadamente para un espesor de 3" de fibra de vidrio.

TABLA 3.6

ESPESOR DE AISLAMIENTO – FIBRA DE VIDRIO (Caliente)

Temperature (°C)	Diameter nominal (DN)													
	(15)	(25)	(40)	(50)	(80)	(100)	(150)	(200)	(250)	(300)	(400)	(450)	(600)	Flat
	Fiberglass thickness (mm)													
75	25	25	25	25	25	25	25	38	38	38	38	38	38	38
100	25	25	25	25	25	25	25	38	38	38	38	38	38	38
150	25	25	25	25	25	25	25	38	38	38	38	38	38	38
200	25	25	25	25	25	25	25	38	38	38	38	38	38	38
250	25	25	25	25	25	25	38	38	38	38	38	38	38	38
300	25	25	25	38	38	38	38	38	38	38	51	51	51	51
350	38	38	38	38	38	51	51	51	51	51	64	64	64	64
400	38	38	51	51	51	51	64	64	64	64	76	76	76	90
450	38	51	64	64	64	64	76	76	76	89	89	89	89	102

Maximum heat flow = 348.2 W/m2 (highest heat flow of any in the table).

Si usamos la tabla de espesores de aislamiento recomendados ubicada en el PIPING HANDBOOK - Mohinder L. Nayyar obtenemos un espesor recomendado de 38 mm (1.5 pulg) para una temperatura de ambiente de 32° C, apropiado para un balance costo beneficio de una tubería con diámetro 36" con un flujo de calor disipado de 348.2 W/m^2, mayor al calculado.

Por lo tanto usaremos 3" de espesor de fibra de vidrio como aislamiento para las tuberías de Ø 36" SCH 10.

3.4.2 Selección de Trampas de vapor

Tuberías de Alta Presión

Para efectos de cálculo se ha considerado los textos de empresas proveedoras de estos equipos tales como SPIRAX SARCO y ARMSTRONG

$$C = \frac{Wx(t_1 - t_2)x0.477}{H}$$

Donde:

C : Cantidad de Condensado en kg

W : Peso total de la tubería en kg (Ver tabla 17-3 para pesos de tuberías)

T1 : Temperatura final de la tubería en °C.

T2 : Temperatura inicial de la tubería en °C.

0.477 : Calor especifico de la tubería de acero en kj / kg.°C

H : Calor Latente del vapor a la temperatura final en kj/kg (Ver tablas de vapor)

Condiciones para el Caso I (cálculo por peso de la tubería) 12" SCH 80:

L: 65 m
W: 131.8 kg /m
t1: 399 °C
t2: 18 °C
H: 544 kJ/kg
Tiempo de enfriamiento 30 min

Cantidad de Condensado:

5724.05 kg/hr

Equivalente : 12592.90 lb/hr

capacidad de Trampa Termodinamica Spirax Sarco TD 52 - 3/4": 3050 Lb/hr

Cantidad de Trampas Recomendadas: 5 Und

Los valores considerados se pueden revisar en las siguientes tablas

TABLA 3.7

PESO DE TUBERIA POR METRO (kg)

Tamaño de Tubo, in	Diametro Exterior, mm	Superficie m^2 / m	Peso de Tuberia, kg/m		
			Cédula 40	**Cédula 80**	**Cédula 160**
1	33.4	0.105	2.51	3.23	4.24
1.25	42.2	0.132	3.38	4.46	5.59
1.5	**48.3**	**0.152**	**4.05**	**5.40**	**7.23**
2	60.3	0.190	5.43	7.47	11.08
2.5	73.0	0.229	8.61	11.40	14.89
3	**88.9**	**0.279**	**11.26**	**15.25**	**21.31**
3.5	101.6	0.319	13.55	18.61	—
4	114.3	0.359	16.05	22.29	33.63
5	**141.3**	**0.444**	**21.75**	**30.92**	**49.04**
6	168.3	0.529	28.23	42.51	67.4
8	219.1	0.688	42.48	64.56	111.1
10	**273.1**	**0.858**	**60.23**	**81.45**	**173**
12	323.9	1.017	79.8	131.8	240
14	355.6	1.117	94	159	283
16	**406.4**	**1.277**	**123**	**204**	**365**
18	457.2	1.436	156	254	460
20	508.0	1.596	183	311	564
24	**609.6**	**1.915**	**254**	**442**	**806**

TABLA 3.8

TABLA DE VAPOR (PROPIEDADES)

Columna 1 *Presion* Manométrica (bar)	Columna 2 *Presion* Absoluta (bar)	Columna 3 *Temperatura* del Vapor (°C)	Columna 4 Calor del Liquido Saturado (kJ/kg)	Columna 5 Calor Latente (kJ/kg)	Columna 6 Calor Total del Vapor (kJ/kg)	Columna 7 Volumen Especifico del Liquido Saturado (m^3/kg)	Columna 8 Volumen Especifico del Vapor Saturado (m^3/kg)
-1.008	0.0061	0.01	0.01	2501.3	2501.4	0.001 000	206.14
-0.99	0.02	17.50	73.48	2460.0	2533.5	0.001 001	67.00
-0.96	0.05	32.88	137.82	2423.7	2561.5	0.001 005	28.19
-0.91	0.10	45.81	191.83	2392.8	2584.7	0.001 010	14.67
-0.76	0.25	64.97	271.93	2346.3	2618.2	0.001 020	6.204
-0.51	0.50	81.33	340.49	2305.4	2645.9	0.001 030	3.240
-0.26	0.75	91.78	384.39	2278.6	2663.0	0.001 037	2.217
-0.01	1.00	99.63	417.46	2258.0	2675.5	0.001 043	1.6940
0.24	1.25	105.99	444.32	2241.0	2685.4	0.001 048	1.3749
0.49	1.50	111.37	467.11	2226.5	2693.6	0.001 053	1.1593
0.74	1.75	116.06	486.99	2213.6	2700.6	0.001 057	1.0036
0.99	2.00	120.23	504.70	2201.9	2706.7	0.001 061	0.8857
1.24	2.25	124.00	520.72	2191.3	2712.1	0.001 064	0.7933
1.49	2.50	127.44	535.37	2181.5	2716.9	0.001 067	0.7187
1.74	2.75	130.60	548.89	2172.4	2721.3	0.001 070	0.6573
1.99	3.00	133.55	561.47	2163.8	2725.3	0.001 073	0.6058
2.24	3.25	136.30	573.25	2155.8	2729.0	0.001 076	0.5620
2.49	3.50	138.88	584.33	2148.1	2732.4	0.001 079	0.5243
2.74	3.75	141.32	594.81	2140.8	2735.6	0.001 081	0.4914
3.0	4.0	143.63	604.74	2133.8	2738.6	0.001 084	0.4625
3.5	4.5	147.93	623.25	2120.7	2743.9	0.001 088	0.4140
4.0	5.0	151.86	640.23	2108.5	2748.7	0.001 093	0.3749
4.5	5.5	155.48	655.93	2097.0	2753.0	0.001 097	0.3427
5.0	6.0	158.85	670.56	2086.3	2756.8	0.001 101	0.3157
6.0	7.0	164.97	697.22	2066.3	2763.5	0.001 108	0.2729
7.0	8.0	170.43	721.11	2048.0	2769.1	0.001 115	0.2404
8.0	9.0	175.38	742.83	2031.1	2773.9	0.001 121	0.2150
9.0	10.0	179.91	762.81	2015.3	2778.1	0.001 127	0.194 44
10.0	11.0	184.09	781.34	2000.4	2781.7	0.001 133	0.177 53
11.0	12.0	187.99	798.65	1986.2	2784.8	0.001 139	0.163 33
12.0	13.0	191.64	814.93	1972.7	2787.6	0.001 144	0.151 25
13.0	14.0	195.07	830.30	1959.7	2790.0	0.001 149	0.140 84
14.0	15.0	198.32	844.89	1947.3	2792.2	0.001 154	0.131 77
16.5	17.5	205.76	878.50	1917.9	2796.4	0.001 166	0.113 49
19.0	20.0	212.42	908.79	1890.7	2799.5	0.001 177	0.099 63
21.5	22.5	218.45	936.49	1865.2	2801.7	0.001 187	0.088 75
24	25	223.99	962.11	1841.0	2803.1	0.001 197	0.079 98
29	30	233.90	1008.42	1795.7	2804.2	0.001 217	0.066 68
34	35	242.60	1049.75	1753.7	2803.4	0.001 235	0.057 070
39	40	250.40	1087.31	1714.1	2801.4	0.001 252	0.049 780
49	50	263.99	1154.23	1640.1	2794.3	0.001 286	0.039 440
59	60	275.64	1213.35	1571.0	2784.3	0.001 319	0.032 440
69	70	285.88	1267.00	1505.1	2772.1	0.001 351	0.027 370
79	80	295.06	1316.64	1441.3	2758.0	0.001 384	0.023 520
89	90	303.40	1363.26	1378.9	2742.1	0.001 418	0.020 480
99	100	311.06	1407.56	1317.1	2724.7	0.001 452	0.018 026
119	120	324.75	1491.3	1193.6	2684.9	0.001 527	0.014 26
139	140	336.75	1571.1	1066.5	2637.6	0.001 611	0.011 485
159	160	347.44	1650.1	930.6	2580.6	0.001 711	0.009 306
179	180	357.06	1732.0	777.1	2509.1	0.001 840	0.007 489
199	200	365.81	1826.3	583.4	2409.7	0.002 036	0.005 834
219.9	220.9	374.14	2099.3	0.0	2099.3	0.003 155	0.003 155

TABLA 3.9

CONDENSACION EN TUBERIAS AISLADAS QUE LLEVAN VAPOR SATURADO SIN MOVER A 21°C (EFICIENCIA TERMICA DEL 75%)

Tamaño de Tubo (in)	Presión, bar(g)								
	1	2	4	8	12	16	32	40	60
	Kilos de Condensado por Hora por Metro								
0.5	0.04	0.05	0.07	0.09	0.10	0.12	0.17	0.19	0.25
0.75	0.05	0.06	0.08	0.11	0.13	0.14	0.21	0.23	0.30
1	0.06	0.08	0.10	0.13	0.15	0.18	0.25	0.29	0.37
1.25	0.08	0.09	0.12	0.16	0.19	0.22	0.31	0.35	0.45
1.5	**0.09**	**0.11**	**0.13**	**0.18**	**0.21**	**0.24**	**0.35**	**0.40**	**0.51**
2	0.11	0.13	0.16	0.22	0.26	0.30	0.43	0.48	0.63
2.5	0.13	0.15	0.19	0.26	0.31	0.35	0.50	0.57	0.75
3	**0.15**	**0.18**	**0.23**	**0.30**	**0.37**	**0.42**	**0.60**	**0.69**	**0.89**
3.5	0.17	0.20	0.26	0.34	0.41	0.47	0.68	0.78	1.01
4	0.19	0.23	0.29	0.38	0.46	0.52	0.76	0.86	1.12
5	**0.23**	**0.27**	**0.35**	**0.46**	**0.56**	**0.64**	**0.92**	**1.05**	**1.36**
6	0.27	0.32	0.41	0.54	0.65	0.75	1.08	1.23	1.60
8	0.34	0.41	0.52	0.69	0.83	0.95	1.38	1.57	2.05
10	**0.41**	**0.50**	**0.63**	**0.84**	**1.02**	**1.16**	**1.69**	**1.93**	**2.51**
12	0.48	0.58	0.74	0.98	1.19	1.36	1.98	2.26	2.95
14	0.52	0.63	0.81	1.07	1.30	1.48	2.16	2.46	3.22
16	**0.59**	**0.72**	**0.91**	**1.21**	**1.47**	**1.68**	**2.44**	**2.79**	**3.65**
18	0.66	0.80	1.02	1.35	1.64	1.87	2.73	3.12	4.08
20	0.72	0.88	1.12	1.49	1.80	2.07	3.01	3.44	4.50
24	**1.04**	**1.25**	**1.59**	**2.10**	**2.52**	**2.88**	**4.14**	**4.72**	**6.12**

Con base en el programa "3Eplus", version 2.11, de la Asociacion de Fabricantes de Aislamiento en Norteamerica (NAIMS), siguiendo el metodo descrito en ASTM C680

L:	65	m
A:	2.26	m2
U:	140	kJ/hr.m2.°C
t1:	399	°C
t2:	18	°C
H:	544	kJ/kg
Tiempo de enfriamiento	30	min

Cantidad de Condensado:

	3600.94	kg/hr
Equivalente :	7922.07	lb/hr

Evidentemente para una tubería delgada se hubiese perdido menos calor al calentarla

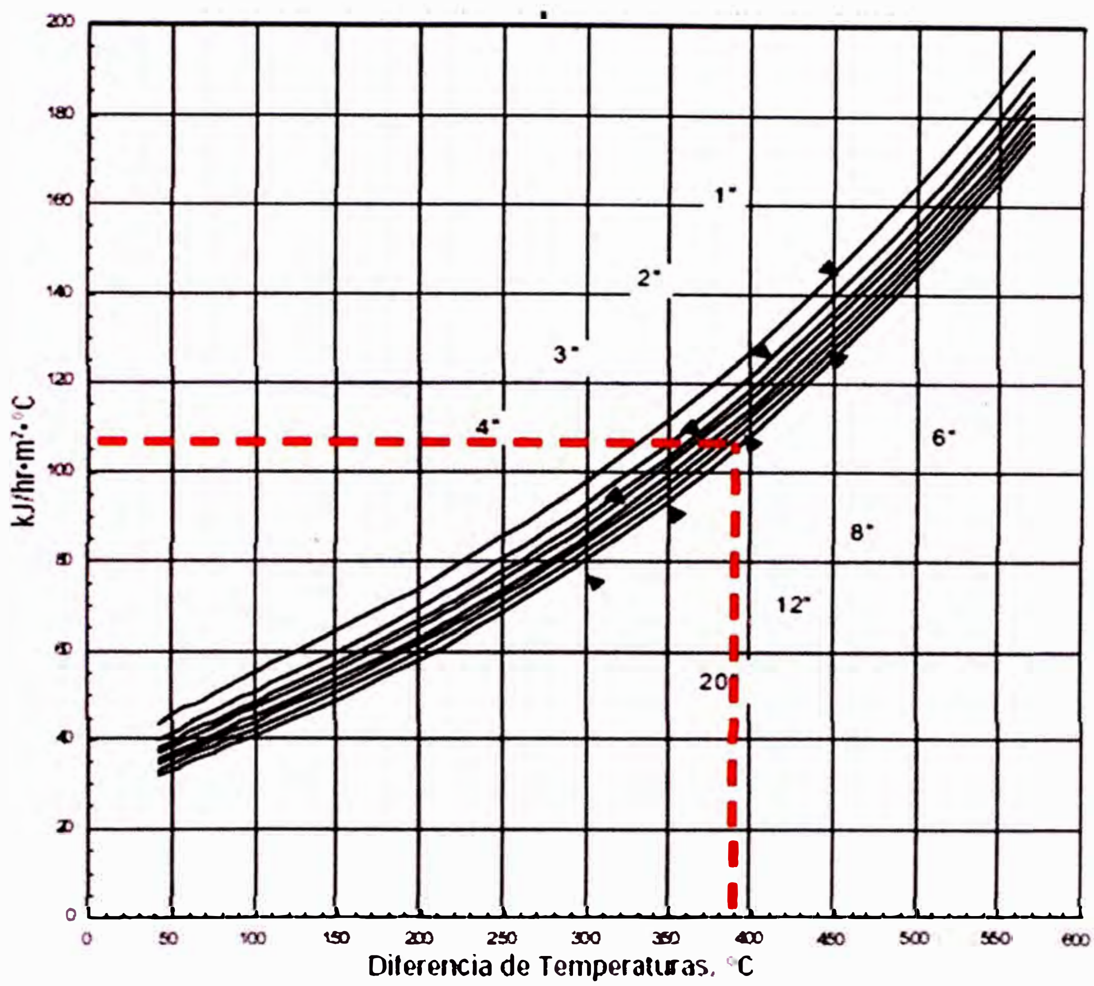


FIGURA N° 3.3: Curvas para Pérdidas de Calor

Tuberías de Baja Presión

Condiciones para el Caso I (cálculo por peso de la tubería) 36" SCH 10:

L: 150 m
W: 213 kg /m
t1: 126 °C
t2: 18 °C
H: 77 kJ/kg
Tiempo de Calentamiento 30 min

Cantidad de Condensado:

42751.59 kg/hr

Equivalente : 94053.50 lb/hr

capacidad de Controlador Automatico Diferencial de Condensado ARMSTRONG - 3/4"
9091 kg/hr

Cantidad de Trampas Recomendadas: 5 Und

Los valores considerados se pueden revisar en las siguientes tablas

TABLA 3.10

PESO DE TUBERIA POR METRO (kg)

Tamaño de Tubo, in	Diametro Exterior, mm	Superficie m^2 / m	Peso de Tuberia, kg/m		
			Cédula 40	Cédula 80	Cédula 160
1	33.4	0.105	2.51	3.23	4.24
1.25	42.2	0.132	3.38	4.46	5.59
1.5	48.3	0.152	4.05	5.40	7.23
2	60.3	0.190	5.43	7.47	11.08
2.5	73.0	0.229	8.61	11.40	14.89
3	88.9	0.279	11.26	15.25	21.31
3.5	101.6	0.319	13.55	18.61	—
4	114.3	0.359	16.05	22.29	33.63
5	141.3	0.444	21.75	30.92	49.04
6	168.3	0.529	28.23	42.51	67.4
8	219.1	0.688	42.48	64.56	111.1
10	273.1	0.858	60.23	81.45	173
12	323.9	1.017	79.8	131.8	240
14	355.6	1.117	94	159	283
16	406.4	1.277	123	204	365
18	457.2	1.436	156	254	460
20	508.0	1.596	183	311	564
24	609.6	1.915	254	442	806

TABLA 3.11

TABLA DE VAPOR (PROPIEDADES)

Columna 1 Presion Manométrica (bar)	Columna 2 Presion Absoluta (bar)	Columna 3 Temperatura del Vapor (°C)	Columna 4 Calor del Liquido Saturado (kJ/kg)	Columna 5 Calor Latente (kJ/kg)	Columna 6 Calor Total del Vapor (kJ/kg)	Columna 7 Volumen Específico del Líquido Saturado (m³/kg)	Columna 8 Volumen Específico del Vapor Saturado (m³/kg)
-1.008	0.0061	0.01	0.01	2501.3	2501.4	0.001 000	206.14
-0.99	0.02	17.50	73.48	2460.0	2533.5	0.001 001	67.00
-0.96	0.05	32.88	137.82	2423.7	2561.5	0.001 005	28.19
-0.91	0.10	45.81	191.83	2392.8	2584.7	0.001 010	14.67
-0.76	0.25	64.97	271.93	2346.3	2618.2	0.001 020	6.204
-0.51	0.50	81.33	340.49	2305.4	2645.9	0.001 030	3.240
-0.26	0.75	91.78	384.39	2278.6	2663.0	0.001 037	2.217
-0.01	1.00	99.63	417.46	2258.0	2675.5	0.001 043	1.6940
0.24	1.25	105.99	444.32	2241.0	2685.4	0.001 048	1.3749
0.49	1.50	111.37	467.11	2226.5	2693.6	0.001 053	1.1593
0.74	1.75	116.06	486.99	2213.6	2700.6	0.001 057	1.0036
0.99	2.00	120.23	504.70	2201.9	2706.7	0.001 061	0.8857
1.24	2.25	124.00	520.72	2191.3	2712.1	0.001 064	0.7933
1.49	2.50	127.44	535.37	2181.5	2716.9	0.001 067	0.7187
1.74	2.75	130.60	548.89	2172.4	2721.3	0.001 070	0.6573
1.99	3.00	133.55	561.47	2163.8	2725.3	0.001 073	0.6058
2.24	3.25	136.30	573.25	2155.8	2729.0	0.001 076	0.5620
2.49	3.50	138.88	584.33	2148.1	2732.4	0.001 079	0.5243
2.74	3.75	141.32	594.81	2140.8	2735.6	0.001 081	0.4914
3.0	4.0	143.63	604.74	2133.8	2738.6	0.001 084	0.4625
3.5	4.5	147.93	623.25	2120.7	2743.9	0.001 088	0.4140
4.0	5.0	151.86	640.23	2108.5	2748.7	0.001 093	0.3749
4.5	5.5	155.48	655.93	2097.0	2753.0	0.001 097	0.3427
5.0	6.0	158.85	670.56	2086.3	2756.8	0.001 101	0.3157
6.0	7.0	164.97	697.22	2066.3	2763.5	0.001 108	0.2729
7.0	8.0	170.43	721.11	2048.0	2769.1	0.001 115	0.2404
8.0	9.0	175.38	742.83	2031.1	2773.9	0.001 121	0.2150
9.0	10.0	179.91	762.81	2015.3	2778.1	0.001 127	0.194 44
10.0	11.0	184.09	781.34	2000.4	2781.7	0.001 133	0.177 53
11.0	12.0	187.99	798.65	1986.2	2784.8	0.001 139	0.163 33
12.0	13.0	191.64	814.93	1972.7	2787.6	0.001 144	0.151 25
13.0	14.0	195.07	830.30	1959.7	2790.0	0.001 149	0.140 84
14.0	15.0	198.32	844.89	1947.3	2792.2	0.001 154	0.131 77
16.5	17.5	205.76	878.50	1917.9	2796.4	0.001 166	0.113 49
19.0	20.0	212.42	908.79	1890.7	2799.5	0.001 177	0.099 63
21.5	22.5	218.45	936.49	1865.2	2801.7	0.001 187	0.088 75
24	25	223.99	962.11	1841.0	2803.1	0.001 197	0.079 98
29	30	233.90	1008.42	1795.7	2804.2	0.001 217	0.066 68
34	35	242.60	1049.75	1753.7	2803.4	0.001 235	0.057 070
39	40	250.40	1087.31	1714.1	2801.4	0.001 252	0.049 780
49	50	263.99	1154.23	1640.1	2794.3	0.001 286	0.039 440
59	60	275.64	1213.35	1571.0	2784.3	0.001 319	0.032 440
69	70	285.88	1267.00	1505.1	2772.1	0.001 351	0.027 370
79	80	295.06	1316.64	1441.3	2758.0	0.001 384	0.023 520
89	90	303.40	1363.26	1378.9	2742.1	0.001 418	0.020 480
99	100	311.06	1407.56	1317.1	2724.7	0.001 452	0.018 026
119	120	324.75	1491.3	1193.6	2684.9	0.001 527	0.014 26
139	140	336.75	1571.1	1066.5	2637.6	0.001 611	0.011 485
159	160	347.44	1650.1	930.6	2580.6	0.001 711	0.009 306
179	180	357.06	1732.0	777.1	2509.1	0.001 840	0.007 489
199	200	365.81	1826.3	583.4	2409.7	0.002 036	0.005 834
219.9	220.9	374.14	2099.3	0.0	2099.3	0.003 155	0.003 155

TABLA 3.12

CONDENSACION EN TUBERIAS AISLADAS QUE LLEVAN VAPOR SATURADO SIN MOVER A 21°C (EFICIENCIA TERMICA DEL 75%)

Tamaño de Tubo (in)	Presión. bar(g)								
	1	2	4	8	12	16	32	40	60
	Kilos de Condensado por Hora por Metro								
0.5	0.04	0.05	0.07	0.09	0.10	0.12	0.17	0.19	0.25
0.75	0.05	0.06	0.08	0.11	0.13	0.14	0.21	0.23	0.30
1	0.06	0.08	0.10	0.13	0.15	0.18	0.25	0.29	0.37
1.25	0.08	0.09	0.12	0.16	0.19	0.22	0.31	0.35	0.45
1.5	**0.09**	**0.11**	**0.13**	**0.18**	**0.21**	**0.24**	**0.35**	**0.40**	**0.51**
2	0.11	0.13	0.16	0.22	0.26	0.30	0.43	0.48	0.63
2.5	0.13	0.15	0.19	0.26	0.31	0.35	0.50	0.57	0.75
3	**0.15**	**0.18**	**0.23**	**0.30**	**0.37**	**0.42**	**0.60**	**0.69**	**0.89**
3.5	0.17	0.20	0.26	0.34	0.41	0.47	0.68	0.78	1.01
4	0.19	0.23	0.29	0.38	0.46	0.52	0.76	0.86	1.12
5	**0.23**	**0.27**	**0.35**	**0.46**	**0.56**	**0.64**	**0.92**	**1.05**	**1.36**
6	0.27	0.32	0.41	0.54	0.65	0.75	1.08	1.23	1.60
8	0.34	0.41	0.52	0.69	0.83	0.95	1.38	1.57	2.05
10	**0.41**	**0.50**	**0.63**	**0.84**	**1.02**	**1.16**	**1.69**	**1.93**	**2.51**
12	0.48	0.58	0.74	0.98	1.19	1.36	1.98	2.26	2.95
14	0.52	0.63	0.81	1.07	1.30	1.48	2.16	2.46	3.22
16	**0.59**	**0.72**	**0.91**	**1.21**	**1.47**	**1.68**	**2.44**	**2.79**	**3.65**
18	0.66	0.80	1.02	1.35	1.64	1.87	2.73	3.12	4.08
20	0.72	0.88	1.12	1.49	1.80	2.07	3.01	3.44	4.50
24	**1.04**	**1.25**	**1.59**	**2.10**	**2.52**	**2.88**	**4.14**	**4.72**	**6.12**

Con base en el programa "3Eplus", versión 2.11, de la Asociación de Fabricantes de Aislamiento en Norteamérica (NAIMS), siguiendo el método descrito en ASTM C680

Condiciones para el Caso II (cálculo por superficie de la tubería):

L:	150 m
A:	6.98 m2
U:	50 kJ/hr.m2.°C
t1:	126 °C
t2:	18 °C
H:	77 kJ/kg
Tiempo de enfriamiento	30 min

Cantidad de Condensado:

36712.99 kg/hr

Equivalente : **80768.57** lb/hr

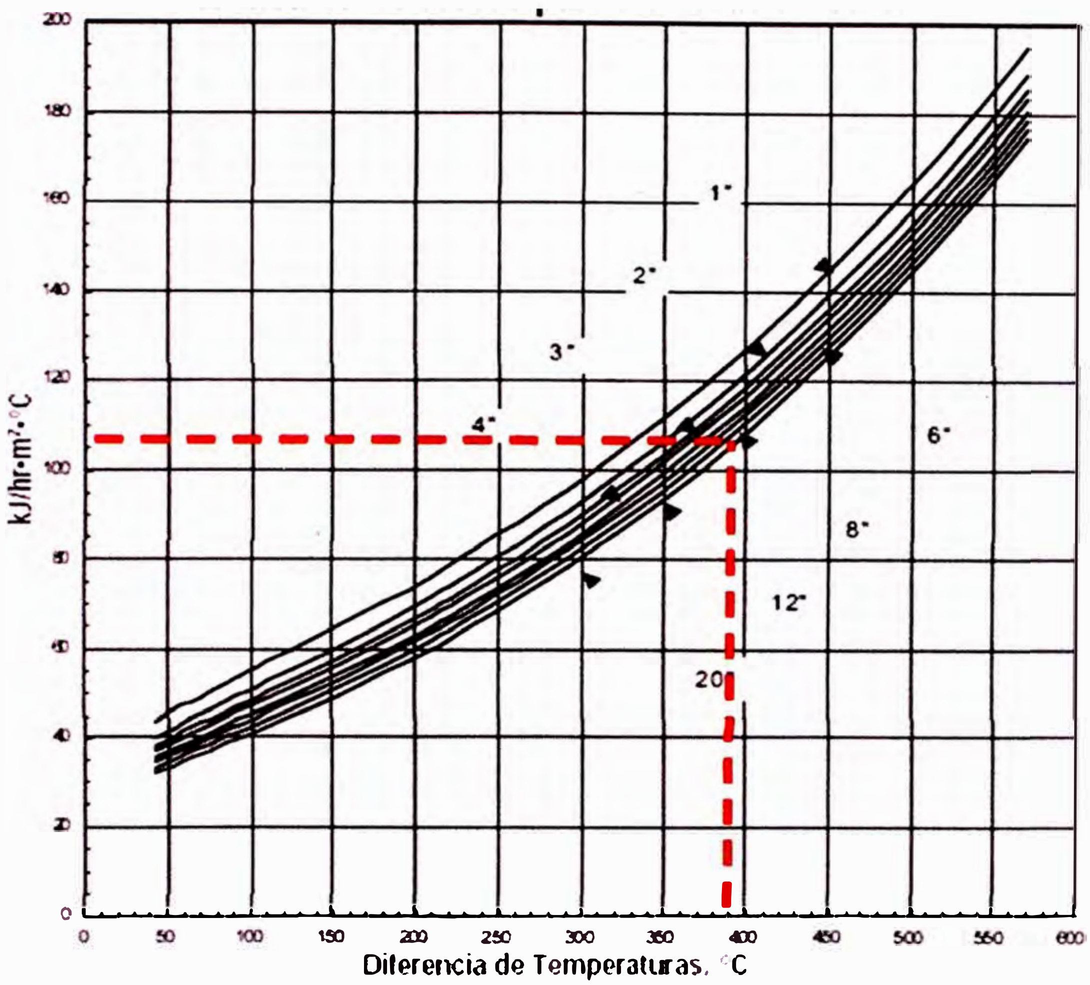


FIGURA N° 3.4: Curvas para Pérdidas de Calor

3.5. Resultados

Se procedió a verificar que los diámetros y tuberías seleccionados fueron los correctos, determinando que:

- Para la tubería de Alta Presión se debe usar una tubería ASTM A106 Gr. B de Ø12" SCH 80, con aislamiento de 3" de fibra de vidrio.
- Para la tubería de Baja Presión se debe usar una tubería ASTM A36 Gr. B de Ø36" SCH 10, con aislamiento de 3" de fibra de vidrio.

CAPÍTULO IV

COSTOS Y PRESUPUESTO

4.1. Introducción

Para la estimación de costos y presupuesto se ha considerado el suministro y montaje mecánico, suministro y montaje eléctrico y las obras civiles. Los costos presentados en el proyecto son del año 2008, por lo que puede variar con los costos actuales, siendo los costos mostrados la estimación de los suministros, construcción y montaje para el desarrollo del proyecto en conjunto.

4.2. Costos - Suministros

A continuación se presenta el resumen del costo de los suministros mecánicos, en donde en los ítems 1.0 y 2.0 están incluidos las líneas de vapor de alta y baja presión.

TABLA 4.1: RESUMEN DE COSTOS DE SUMINISTRO – MECANICO

ÍTEM	DESCRIPCIÓN	UND	CANT.	P.U.	TOTAL
				US$	US$
1.0	LINEA DE VAPOR DE ALTA PRESIÓN				
1.1	Tuberias y Accesorios				60323.97
1.2	Soporte Metálico				36,237.21
1.3	Equipos				278,694.48
2.0	LINEA DE VAPOR DE BAJA PRESIÓN				
2.1	Tuberias y Accesorios				168,945.84
2.2	Soporte Metálico				42,975.11
2.3	Equipos				154,142.00
3.0	SISTEMA DE REFRIGERACIÓN				
3.1	Torre de Enfriamiento				448,430.40
3.2	Obras Civiles				123,878.22
3.3	Tuberia y Accesorios				105,332.00
3.4	Soporte Metalicos				26,482.50
3.5	Valvulas				113,875.20
3.6	Equipos				220,992.00
4.0	GRUA PUENTE				348,000.00
5.0	TURBO GENERADOR				4,634,064.00
	TOTAL SUMINISTRO MECANICO				6,762,372.92

A continuación se presenta los costos de suministros de las líneas de vapor de alta y baja presión.

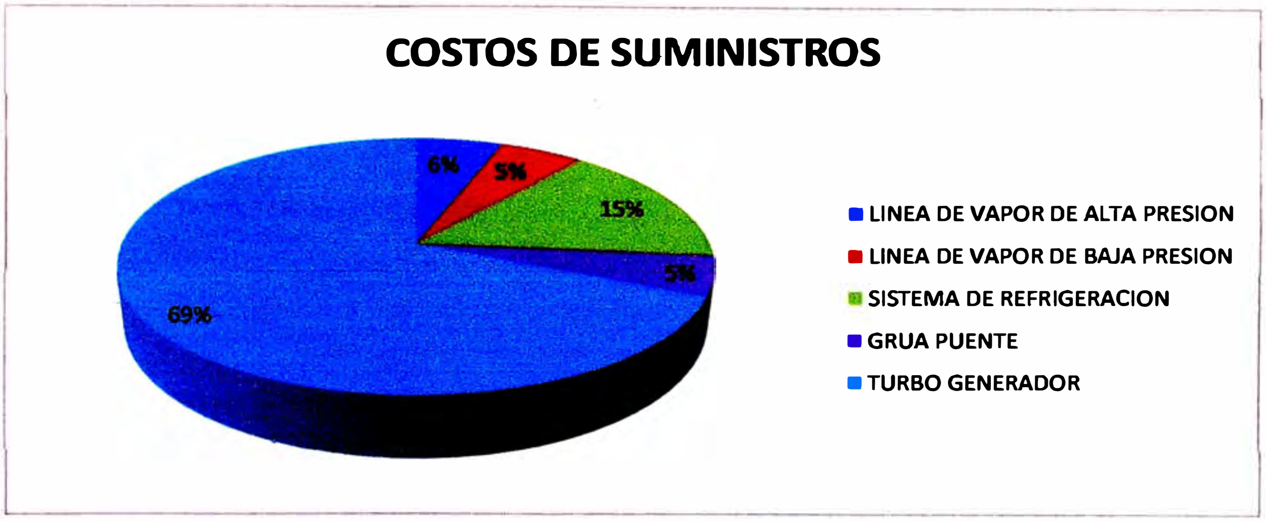
TABLA 4.2: COSTOS DE SUMINISTRO – LINEA DE VAPOR DE ALTA PRESION

ÍTEM	DESCRIPCIÓN	UND	CANT.	P.U. US$	TOTAL US$
1.0	**LINEA DE VAPOR DE ALTA PRESIÓN**				
1.1	**Tuberias y Accesorios**				60323.97
1.1.1	Tuberia Ø12" SCH 80	m	71.00	264.16	18,755.36
1.1.2	Tuberia Ø10" SCH80	m	2.40	192.02	460.85
1.1.3	Codo 45° SCH 80 Ø 12"	pza	7.00	124.85	873.95
1.1.4	Codo 90° SCH 80 Ø 12"	pza	4.00	237.05	949.20
1.1.5	Junta de Expansión Ø 8" PN 47 bar	pza	3.00	9989.00	29,967.00
1.1.6	Trampas de Vapor Termostatica	pza	6.00	325.00	1,950.00
1.1.7	Tuberia Ø 3/4" - trampas de vapor	m	100.00	2.54	254.00
1.1.8	Tuberia Ø 1/2" - Instrumentación	m	18.00	3.38	60.84
1.1.9	Caps	pza	6.00	10.00	60.00
1.1.10	Bridas Ø12" tipo Welding Neck	pza	16.00	255.00	4,080.00
1.1.11	Bridas Ø10" tipo Welding Neck	pza	2.00	215.00	430.00
1.1.12	Reducción Ø 12" a Ø 10"	pza	1.00	81.57	81.57
	Linea de Sellado frontal				
1.1.13	Tuberia Ø 4" SCH 80	m	18.00	44.64	803.52
1.1.14	Codo 90° SCH 80 Ø 4"	pza	5.00	10.25	51.25
	Linea de Sellado posterior				
1.1.15	Tuberia Ø 2 1/2" SCH 80	m	12.00	29.84	358.08
1.1.16	Codo 90° SCH 80 Ø 2 1/2"	pza	5.00	4.50	22.50
	Linea de Agua - Reductora de Presión				
1.1.17	Tuberia Ø 3"	m	45.00	20.32	914.49
1.1.18	Tuberia Ø 1 1/2"	m	16.00	9.74	155.81
1.1.19	Codo 90° Ø 3"	pza	12.00	6.25	74.95
1.1.20	T Ø 3 x 1 1/2"	pza	3.00	7.20	21.60
1.2	**Soporte Metálico**				36,237.21
1.2.1	W8x10	m	2.25	43.60	98.10
1.2.2	W10x22	m	2.10	93.76	196.90
1.2.3	W10x49	m	0.70	213.89	149.72
1.2.4	Soporte tipicos	kg	11.00	168.00	1,848.00
	Plataforma -Sistema Reductor de Presión				
1.2.5	W 6x15	m	86.45	65.486	5,661.22
1.2.6	L 3x1/4	m	88.16	20.385	1,797.14
1.2.7	PL 1/2x200x200	m2	0.64	230.612	147.59
1.2.8	PL 1/2x250x200	m2	0.80	230.612	184.49
1.2.9	PL 1/2x400x200	m2	0.32	230.612	73.80
1.2.10	PL 1x300x300 mm	m2	0.36	456.40	164.31
1.2.11	PL 1/4x100	m	23.24	230.61	5,359.88
1.2.12	TU Ø 1" STD	m	87.85	5.00	439.26
1.2.13	Parrilla metalica	m2	26.62	143.00	3,807.23
	Plataforma				
1.2.14	W 6x15	m	27.50	65.486	1,800.85
1.2.15	L 3x1/4	m	21.00	20.385	428.09
1.2.16	PL 1/2x130x130 mm	m2	0.39	230.612	89.64
1.2.17	PL 1/4x100 mm	m	16.90	230.61	3,897.34
1.2.18	PL 1x300x300 mm	m2	0.36	456.40	164.31
1.2.19	TU Ø 1" STD	m	77.39	5.00	386.95
1.2.20	Parrilla metalica	m2	28.67	143.00	4,100.10
	Soportes Lubricación				
1.2.21	C 8x6.2	m	8.00	16.115	128.92
1.2.22	L 3x1/4	m	14.00	20.385	285.39
	Puertas				
1.2.23	Puerta Corrediza	GLB	1.00	3600.000	3,600.00
1.2.24	Puerta 2690 x 2000 mm	GLB	1.00	468.000	468.00
1.2.25	Puerta 2100 x 1000 mm	GLB	5.00	192.000	960.00
1.3	**Equipos**				278,694.48
	Live Steam				
1.3.1	Válvula Globo Ø 1/2", Clase 600	pza	8.00	33.00	264.00
1.3.2	Válvula Globo Ø 3/4", Clase 600	pza	12.00	39.00	468.00
1.3.3	Válvula Compuerta Ø 12", Clase 600	pza	1.00	6076.00	6,076.00
1.3.4	Válvula Globo Ø 12",Clase 600	pza	1.00	11132.70	11,132.70
	Front Sealing Steam				
1.3.5	Válvula Globo Ø 1/2",Clase 600	pza	3.00	33.00	99.00
1.3.6	Válvula Globo Ø 3/4", Clase 600	pza	5.00	39.00	195.00
1.3.7	*Válvula Compuerta Ø 2 1/2", Clase 600*	pza	1.00	938.11	938.11
1.3.8	Válvula Globo Ø 1", Clase 600	pza	2.00	48.00	96.00
	Rear Sealing Steam				
1.3.9	Válvula Globo Ø 3/4", Clase 600	pza	2.00	39.00	78.00
1.3.10	Válvula Globo Ø 1/2", Clase 600	pza	3.00	33.00	99.00
1.3.11	Válvula Compuerta Ø 4", Clase ANSI 600	pza	1.00	1448.83	1,448.83
1.3.12	Válvula Globo Ø 1", Clase 600	pza	1.00	48.00	48.00
	Reducción de Vapor				
1.3.13	Desuperheater Modelo Convencional	pza	3.00	2780.00	8,340.00
1.3.14	Válvula Reductora de Presión tipo Globo Ø 8"	pza	3.00	36930.00	110,790.00
1.3.15	Válvula Control Reguladora de Temperatura tipo Globo Ø1"	pza	3.00	4625.00	13,875.00
1.3.16	Válvula de seguridad Bridad 6" x 8"	pza	3.00	9310.00	27,930.00
1.3.18	Válvula Compuerta Ø 8", Motorizada	pza	3.00	10816.44	32,449.32
1.3.18	Válvula Compuerta Ø 16", Motorizada	pza	3.00	10816.44	32,449.32
1.3.19	Válvula Check Ø 1 1/2"	pza	3.00	4000.00	12,000.00
	Instrumentos				
1.3.20	Flujometro Ø12" (42.38 bar y 399°C)	pza	1.00	11155.00	11,155.00
1.3.21	Termocupla (42.38bar y 399°C)	pza	1.00	2100.00	2,100.00
1.3.22	Sistema de Camara de condensación	pza	10.00	166.32	1,663.20
1.3.23	*Accesorios*	Glb	1.00	5000.00	5,000.00

TABLA 4.3: COSTOS DE SUMINISTRO – LINEA DE VAPOR DE BAJA PRESION

2.0	**LINEA DE VAPOR DE BAJA PRESIÓN**				
2.1	**Tuberias y Accesorios**				**168,945.84**
2.1.1	Tuberia Ø36" SCH 10	m	135.00	404.18	54,563.85
2.1.2	Tuberla Ø30" SCH10	m	11.24	336.39	3,781.67
2.1.3	*Tuberia Ø18" SCH20*	m	18.73	200.33	3,751.77
2.1.4	Codo 45° SCH 20 Ø 18"	pza	2.00	87.14	174.27
2.1.5	Codo 90° SCH 20 Ø 18"	pza	4.00	154.71	618.85
2.1.6	Reducción Ø 30" a Ø18"	pza	1.00	158.19	158.19
2.1.7	Codo 45° SCH 10 Ø 30"	pza	2.00	317.48	634.95
2.1.8	Codo 45° SCH 10 Ø 36"	pza	3.00	416.80	1,250.40
2.1.9	Codo 90° SCH 10 Ø 36"	pza	4.00	793.60	3,174.40
2.1.10	Junta de Expansión Ø 16" PN 16 bar	pza	3.00	4975.00	14,925.00
2.1.11	Trampas de Vapor Termodinamicas	pza	10.00	132.00	1,320.00
2.1.12	Filtro Y	pza	3.00	28.00	84.00
2.1.13	Tuberia Ø 3/4"	m	100.00	2.54	254.00
2.1.14	Tuberia Ø 1/2"	m	100.00	3.38	338.00
2.1.15	Caps	pza	6.00	10.00	60.00
2.1.16	Bridas Ø18" tipo Welding Neck	pza	4.00	364.04	1,456.18
2.1.17	Bridas Ø30" tipo Welding Neck	pza	2.00	954.96	1,909.91
2.1.18	Bridas Ø36" tipo Welding Neck	pza	20.00	1424.52	28,490.40
2.1.19	Obras Civiles	Glb	1.00	47000.00	47,000.00
2.1.20	Accesorios	Glb	1.00	5000.00	5,000.00
2.2	**Soporte Metálico**				**42,975.11**
2.2.1	W8x10	m	6.00	43.598	261.59
2.2.2	W10x49	m	3.60	213.656	769.16
	Soporte Tipico				
2.2.3	Soporte tipicos	kg	18.00	168.00	3,024.00
	Columna				
2.2.4	W6x15	m	48.00	65.486	3,143.30
2.2.5	W10x49	m	18.00	213.656	3,845.80
2.2.6	W12x26	m	160.80	113.362	18,228.56
2.2.7	L3x1/4	m	90.00	20.385	1,834.65
	Torre- Castillo				
2.2.8	L3x1/4	m	41.55	20.385	846.96
2.2.9	L4x3/8	m	101.61	40.770	4,142.56
2.2.10	W10x49	m	3.82	213.66	816.16
	Tijeral				
2.2.11	W 6 x 15	m	2.40	65.486	157.17
2.2.12	L 3" x 1/4"	m	116.40	20.385	2,372.81
2.2.13	L 4" x 3/8"	m	46.96	40.770	1,914.56
2.2.14	L 2 1/2" x 3/16"	m	24.59	65.792	1,617.83
2.3	**Equipos**				**154,142.00**
	Extraction Steam				
2.3.1	Válvula Globo Ø 3/4", Clase 150	pza	4.00	39	156.00
2.3.2	Válvula Globo Ø 1/2", Clase 150	pza	6.00	33	198.00
2.3.3	Válvula Compuerta Ø 36", Clase 150	pza	1.00	62815	62,815.00
2.3.4	Válvula Globo Ø 36", Clase 150	pza	1.00	62808	62,808.00
	Ejectors Services Steam				
2.3.5	Válvula Globo Ø 4", Clase 300	pza	1.00	1965	1,965.00
	Instrumentos				
2.3.6	Flujometro Ø36" (2.39 bar y 126°C)	pza	1.00	22000	22,000.00
2.3.7	Termocupla (42.38bar y 399°C)	pza	2.00	2100	4,200.00
3.0	**SISTEMA DE REFRIGERACIÓN**				
3.1	**Torre de Enfriamiento**				**448,430.40**
3.2	**Obras Civiles**				**123,878.22**
3.3	**Tuberia y Accesorios**				**105,332.00**
3.4	**Soporte Metalicos**				**26,482.50**
3.5	**Valvulas**				**113,875.20**
3.6	**Equipos**				**220,892.00**
4.0	**GRUA PUENTE**				**348,000.00**
5.0	**TURBO GENERADOR**				**4,634,064.00**
	TOTAL SUMINISTRO MECANICO				**6,782,372.92**

GRAFICO 4.1: COMPARACION DE COSTOS DE SUMINISTRO



De la comparación realizada se puede observar que el mayor costo de suministro para la planta de cogeneración térmica es el Turbo Generador Siemens, representando el 69% del costo de inversión. Las de menor incidencia en el costo de suministros son las líneas de vapor representando en su totalidad el 11% aproximadamente.

4.3. Costos - Montaje

A continuación se presenta el resumen de los costos de montaje mecánico, en donde en los ítems 1.0 y 2.0 están incluidos las líneas de vapor de alta y baja presión.

TABLA 4.4: RESUMEN DE COSTOS DE MONTAJE – MECANICO

ÍTEM	DESCRIPCIÓN	UND	CANT.	P.U. US$	TOTAL US$
1.0	LINEA DE VAPOR DE ALTA PRESIÓN				40,701.34
1.1	Tuberías y Accesorios				8659.71
1.2	Soporte Metálico				8,986.79
1.3	Equipos				15,405.00
1.4	Aislamiento Térmico				7,649.84
2.0	LINEA DE VAPOR DE BAJA PRESIÓN				78,117.65
2.1	Tuberías y Accesorios				28,532.17
2.2	Soporte Metálico				9,104.03
2.3	Equipos				4,699.00
2.4	Aislamiento Térmico				35,782.45
3.0	TURBO GENERADOR				326,736.00
4.0	TORRE DE ENFRIAMIENTO				88,506.00
5.0	GRÚA PUENTE				35,000.00
	TOTAL MONTAJE MECÁNICO				569,060.99

A continuación se presenta los costos de montaje de las líneas de vapor de alta y baja presión.

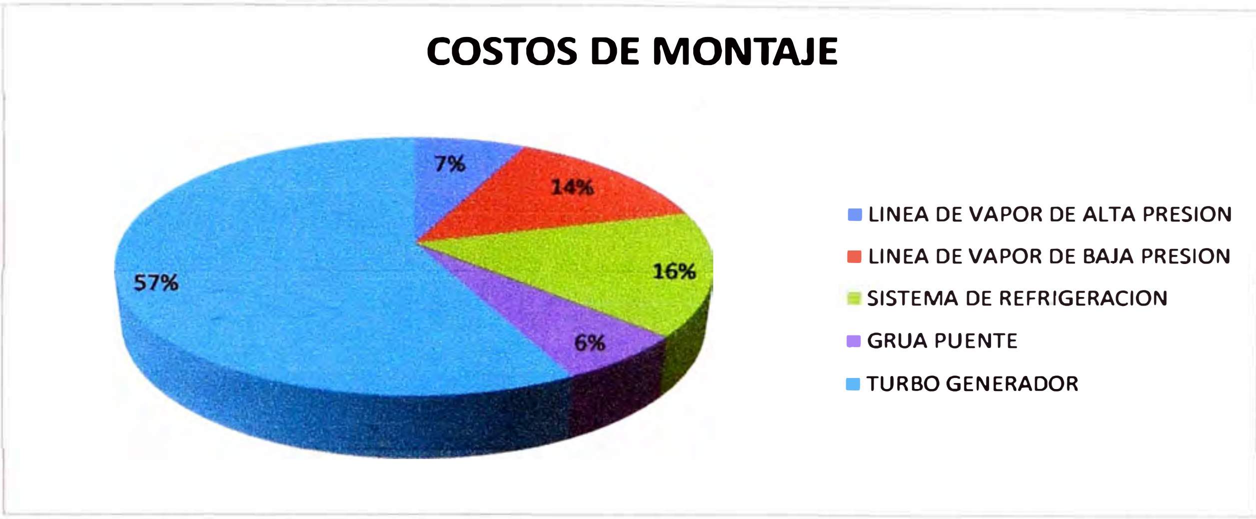
TABLA 4.5: COSTOS DE MONTAJE – LINEA DE VAPOR DE ALTA PRESION

ÍTEM	DESCRIPCIÓN	UND	CANT.	P.U. US$	TOTAL US$
1.0	**LINEA DE VAPOR DE ALTA PRESIÓN**				**40.701.34**
1.1	**Tuberías y Accesorios**				**8659.71**
1.1.1	Tubería Ø12" SCH 80	m	65.82	79.25	5,216.10
1.1.2	Tubería Ø10" SCH80	m	2.40	57.61	138.25
1.1.3	Codo 45° SCH 80 Ø 12"	pza	7.00	29.96	209.75
1.1.4	Codo 90° SCH 80 Ø 12"	pza	4.00	56.89	227.57
1.1.5	Junta de Expansión Ø 8" PN 47 bar	pza	3.00	10.00	30.00
1.1.6	Trampas de Vapor Termostática	pza	6.00	10.00	60.00
1.1.7	Tubería Ø 3/4"	m	100.00	2.40	240.00
1.1.8	Tubería Ø 1/2"	m	100.00	8.00	800.00
1.1.9	Caps	pza	6.00	2.16	12.96
1.1.10	Bridas Ø12" tipo Welding Neck	pza	16.00	61.20	979.20
1.1.11	Bridas Ø10" tipo Welding Neck	pza	2.00	51.60	103.20
1.1.12	Reducción Ø 12" a Ø 10"	pza	1.00	18.55	18.55
	Linea de Sellado frontal				
1.1.13	Tubería Ø 4" SCH 80	m	18.00	13.39	241.06
1.1.14	Codo 90° SCH 80 Ø 4"	pza	5.00	2.46	12.30
	Linea de Sellado posterior				
1.1.15	Tubería Ø 2 1/2" SCH 80	m	12.00	8.95	107.42
1.1.16	Codo 90° SCH 80 Ø 2 1/2"	pza	5.00	1.08	5.40
	Linea de Agua - Reductora de Presión				
1.1.17	Tubería Ø 3"	m	45.00	4.52	203.22
1.1.18	Tubería Ø 1 1/2"	m	16.00	2.18	34.62
1.1.19	Codo 90° Ø 3"	pza	12.00	1.39	16.66
1.1.20	T Ø 3 x 1 1/2"	pza	3.00	1.15	3.46
1.2	**Soporte Metálico**				**8,986.79**
1.2.1	W8x10	m	2.25	8.93	20.09
1.2.2	W10x22	m	2.10	19.20	40.32
1.2.3	W10x49	m	0.70	43.80	30.66
1.2.4	Soporte típicos	kg	11.00	42.00	462.00
	Plataforma -Sistema Reductor de Presión				
1.2.5	W 6x15	m	86.45	13.410	1,159.29
1.2.6	L 3x1/4	m	88.16	4.530	399.36
1.2.7	PL 1/2x200x200	m2	0.64	59.436	38.04
1.2.8	PL 1/2x250x200	m2	0.80	59.436	47.55
1.2.9	PL 1/2x400x200	m2	0.32	59.436	19.02
1.2.10	PL 1x300x300 mm	m2	0.36	117.63	42.35
1.2.11	PL 1/4x100	m	23.24	59.44	1,381.41
1.2.12	TU Ø 1" STD	m	87.85	1.50	131.78
1.2.13	Parrilla metalica	m2	26.62	42.90	1,142.17
	Plataforma				
1.2.14	W 6x15	m	27.50	13.410	368.78
1.2.15	L 3x1/4	m	21.00	4.530	95.13
1.2.16	PL 1/2x130x130 mm	m2	0.39	59.436	23.10
1.2.17	PL 1/4x100 mm	m	16.90	59.44	1,004.47
1.2.18	PL 1x300x300 mm	m2	0.36	117.63	42.35
1.2.19	TU Ø 1" STD	m	77.39	1.50	116.09
1.2.20	Parrilla metalica	m2	28.67	42.90	1,230.03
	Soportes Lubricación				
1.2.21	C 8x6.2	m	8.00	16.115	128.92
1.2.22	L 3x1/4	m	14.00	20.385	285.39
	Puertas				
1.2.23	Puerta Corrediza	GLB	1.00	600.000	600.00
1.2.24	Puerta 2690 x 2000 mm	GLB	1.00	58.500	58.50
1.2.25	Puerta 2100 x 1000 mm	GLB	5.00	24.000	120.00
1.3	**Equipos**				**15,405.00**
	Live Steam				
1.3.1	Válvula Globo Ø 1/2", Clase 600	pza	8.00	18.00	144.00
1.3.2	Válvula Globo Ø 3/4", Clase 600	pza	12.00	24.00	288.00
1.3.3	Válvula Compuerta Ø 12", Clase 600	pza	1.00	781.60	781.60
1.3.4	Válvula Globo Ø 12",Clase 600	pza	1.00	814.40	814.40
	Front Sealing Steam				
1.3.5	Válvula Globo Ø 1/2",Clase 600	pza	3.00	18.00	54.00
1.3.6	Válvula Globo Ø 3/4", Clase 600	pza	5.00	24.00	120.00
1.3.7	Válvula Compuerta Ø 2 1/2", Clase 600	pza	1.00	120.00	120.00
1.3.8	Válvula Globo Ø 1", Clase 600	pza	2.00	27.00	54.00
	Rear Sealing Steam				
1.3.9	Válvula Globo Ø 3/4", Clase 600	pza	2.00	18.00	36.00
1.3.10	Válvula Globo Ø 1/2", Clase ANSI 600	pza	3.00	48.00	144.00
1.3.11	Válvula Compuerta Ø 4", Clase 600	pza	1.00	56.00	56.00
1.3.12	Válvula Globo Ø 1", Clase 600	pza	1.00	72.00	72.00
	Reducción de Vapor				
1.3.13	Desuperheater Modelo Convencional	pza	3.00	200.00	600.00
1.3.14	Válvula Control Vapor tipo Globo Ø 8"	pza	3.00	300.00	900.00
1.3.15	Válvula Control tipo Globo Ø1"	pza	3.00	16.00	48.00
1.3.16	Válvula de seguridad Bridad 6" x 8"	pza	3.00	138.40	415.20
1.3.17	Válvula Compuerta Ø 12", Motorizada	pza	3.00	800.00	2,400.00
1.3.18	Válvula Compuerta Ø 8", Motorizada	pza	3.00	760.00	2,280.00
1.3.19	Válvula Check Ø 1 1/2"	pza	3.00	120.00	360.00
	Instrumentos				
1.3.20	Flujometro Ø4" (42.38 bar y 399°C)	pza	1.00	4462.00	4,462.00
1.3.21	Termocupla (42.38bar y 399°C)	pza	1.00	840.00	840.00
1.3.22	Sistema de Camara de condensación	pza	10.00	41.58	415.80
1.4	**Aislamiento Térmico**				**7,649.84**
1.4.1	Tubería Ø 12" x 3" espesor	m	65.82	65.92	4,339.12
1.4.2	Tubería Ø 10" x 3" espesor	m	2.40	61.09	146.60
1.4.3	Codo Ø 12" x 3" espesor	pza	11.00	65.92	725.12
1.4.4	Reducción Ø 12" x 3" espesor	pza	1.00	65.92	65.92
1.4.5	Válvula Ø 12" x 3" espesor	pza	10.00	145.02	1,450.20
1.4.6	Brida Ø 12" x 3" espesor	pza	14.00	65.92	922.88

TABLA 4.6: COSTOS DE MONTAJE– LINEA DE VAPOR DE BAJA PRESION

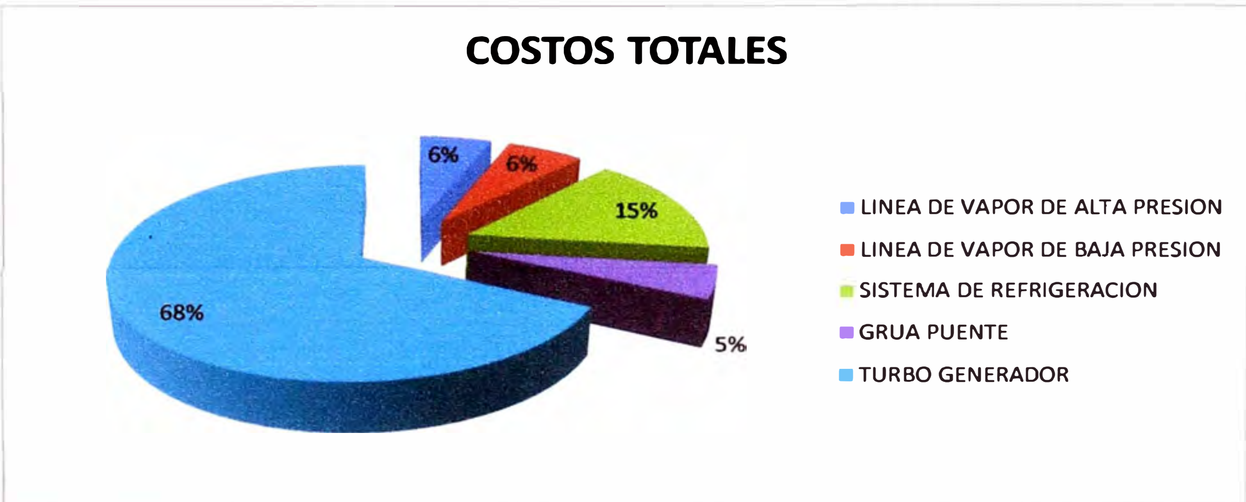
2.0	**LINEA DE VAPOR DE BAJA PRESIÓN**				**78,117.65**
2.1	**Tuberías y Accesorios**				**28,532.17**
2.1.1	Tubería Ø36" SCH 10	m	135.00	106.18	14,333.76
2.1.2	Tubería Ø30" SCH10	m	11.24	88.37	993.43
2.1.3	Tubería Ø18" SCH80	m	18.73	52.63	985.58
2.1.4	Codo 45° SCH 20 Ø 18"	pza	2.00	33.60	67.20
2.1.5	Codo 90° SCH 20 Ø 18"	pza	4.00	59.66	238.63
2.1.6	Reducción Ø 30" a Ø18"	pza	1.00	37.37	37.37
2.1.7	Codo 45° SCH 10 Ø 30"	pza	2.00	83.40	166.80
2.1.8	Codo 45° SCH 10 Ø 36"	pza	3.00	120.00	380.00
2.1.9	Codo 90° SCH 10 Ø 36"	pza	4.00	160.00	640.00
2.1.10	Junta de Expansión Ø 16" PN 16 bar	pza	3.00	995.00	2,985.00
2.1.11	Trampas de Vapor Termodinamicas	pza	10.00	26.40	264.00
2.1.12	*Filtro Y*	pza	3.00	8.40	*25.20*
2.1.13	Tubería Ø 3/4"	m	100.00	0.76	76.20
2.1.14	Tubería Ø 1/2"	m	100.00	1.01	101.40
2.1.15	Caps	pza	6.00	2.00	12.00
2.1.16	Bridas Ø18" tipo Welding Neck	pza	4.00	82.80	331.20
2.1.17	Bridas Ø30"tipo Welding Neck	pza	2.00	217.20	434.40
2.1.18	Bridas Ø36"tipo Welding Neck	pza	20.00	324.00	6,480.00
2.2	**Soporte Metálico**				**9,104.03**
2.2.1	W8x10	m	6.00	8.93	53.57
2.2.2	W10x49	m	3.60	43.75	157.51
	Soporte Típico				
2.2.3	Soporte típicos	kg	18.00	42.00	756.00
	Columna				
2.2.4	W6x15	m	48.00	13.41	643.68
2.2.5	W10x49	m	18.00	43.80	788.40
2.2.6	W12x26	m	160.80	23.21	3,732.81
2.2.7	L3x1/4	m	90.00	4.53	407.70
	Torre- Castillo				
2.2.8	L3x1/4	m	41.55	4.53	188.21
2.2.9	L4x3/8	m	101.61	9.06	920.57
2.2.10	W10x49	m	3.82	43.75	167.31
	Tijeral				
2.2.11	W 6 x 15	m	2.40	13.41	32.18
2.2.12	L 3" x 1/4"	m	116.40	4.53	527.29
2.2.13	L 4" x 3/8"	m	46.96	9.06	425.46
2.2.14	L 2 1/2" x 3/16"	m	24.59	12.34	303.34
2.3	**Equipos**				**4,899.00**
	Extraction Steam				
2.3.1	Válvula Globo Ø 3/4", Clase 150	pza	4.00	24.00	96.00
2.3.2	Válvula Globo Ø 1/2", Clase 150	pza	6.00	18.00	108.00
2.3.3	Válvula Compuerta Ø 36", Clase 150	pza	1.00	750.00	750.00
2.3.4	Válvula Globo Ø 36", Clase 150	pza	1.00	900.00	900.00
	Ejectors Services Steam				
2.3.5	Válvula Globo Ø 4", Clase 300	pza	1.00	70.00	70.00
	Instrumentos				
2.3.6	Flujometro Ø4" (2.39 bar y 126°C)	pza	1.00	75.00	75.00
2.3.7	Termocupla (42.38bar y 399°C)	pza	2.00	1350.00	2,700.00
2.4	**Aislamiento Térmico**				**35,782.45**
2.4.1	Tubería Ø 36" x 3" espesor	m	121.02	144.68	17,509.17
2.4.2	Tubería Ø 30" x 3" espesor	m	11.24	132.33	1,487.39
2.4.3	Tubería Ø 18" x 3" espesor	m	18.73	88.22	1,652.36
2.4.4	Codo Ø 36" x 3" espesor	pza	15.00	217.02	3,255.30
2.4.5	Reducción Ø 36" x 3" espesor	pza	1.00	159.15	159.15
2.4.6	Válvula Ø 36" x 3" espesor	pza	22.00	381.70	7,957.40
2.4.7	Brida Ø 36" x 3" espesor	pza	26.00	144.68	3,761.68
3.0	**TURBO GENERADOR**				**326,736.00**
4.0	**TORRE DE ENFRIAMIENTO**				**88,506.00**
5.0	**GRÚA PUENTE**				**35,000.00**
	TOTAL MONTAJE MECÁNICO				**569,060.99**

GRAFICO 4.2: COMPARACION DE COSTOS DE MONTAJE



Al igual que en el caso de los costos de suministros, el costo de montaje del Turbo Generador es el más alto representando el 57% del total. Las Líneas de vapor representan el 21% del costo aproximadamente. Este último ha tenido un incremento debido a la instalación de válvulas especiales y aislamiento térmico.

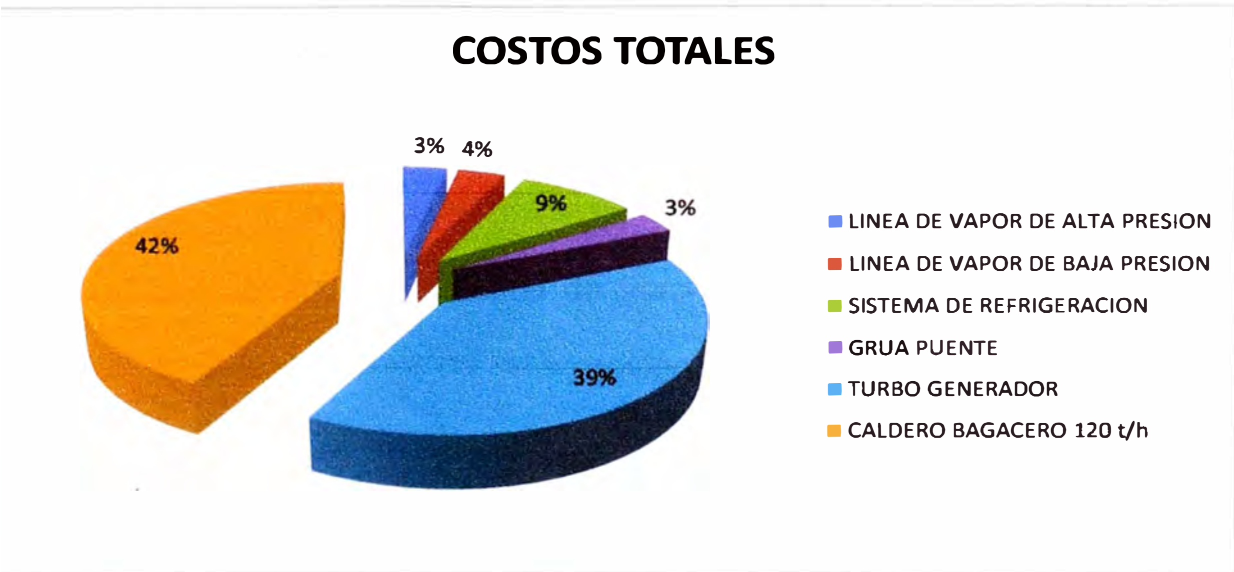
GRAFICO 4.3: COMPARACION DE COSTOS



Al analizar los costoso totales se observa que las líneas de vapor de alta y baja presión representan el 12% del costo total, este valor aunque es relativamente bajo comparado con el costo del turbo generador no deja de ser importante ya que la mala selección de tuberías, válvulas, soportes y/o equipos que forman parte de las líneas de vapor puedn garantizar o no el correcto funcionamiento de la Central de Cogeneración Térmica.

Es por está razón que se debe tener bastante cuidado en el diseño de las redes de tuberías de presión.

De acuerdo a la Ficha Técnica "Proyecto de Caldero Bagacero MDL de Paramonga" el costo de inversión del caldero bagacero de 120 t/h es utilizado por Agroindustrial Paramonga fue de US$ 5´369, 000.00, realizando una comparación del costo total incluido el caldero obtenemos la siguiente gráfica:



Realizando la comparación de costos de implementar una central completa de cogeneración observamos que las tuberías de vapor representan el 7% del costo total de inversión.

CONCLUSIONES

1. Siguiendo las recomendaciones del código ASME B31.1 se ha comprobado mediante cálculos manuales que las tuberías analizadas cumplen los requerimientos del código.
2. Para el presento informe se utilizó como herramienta de análisis de esfuerzos y flexibilidad el software AutoPIPE V8i comprobándose que las tuberías de vapor de alta y baja presión cumplen con el código ASME B31.1.
3. De estos resultados se concluye que la tubería de vapor de alta presión debe ser de material ASTM A106 Gr.B, de Ø12" SCH 80 con aislamiento térmico de fibra de vidrio de 3" de espesor y la tubería de vapor de baja presión debe ser de material ASTM A36 Gr. B de Ø 36" SCH 10.
4. El costo de suministro y montaje por metro lineal de tubería (incluyendo aislamiento, trampas de vapor, válvulas) vapor de alta presión es US$ 920.52 y de vapor de baja presión es US$ 1161.54.

5. Bajo un análisis de costos totales de instalación de la planta de cogeneración, el sistema de tuberías de vapor representa el 7%, considerando que el caldero instalado tiene un costo de inversión de US$ 5´369, 000.00.

RECOMENDACIONES

Se recomienda hacer un análisis de esfuerzos y flexibilidad en todas aquellas tuberías que se consideren de suma importancia para el proceso.

Además se recomienda usar las diferentes normas y/o estándares aplicables para las tuberías principales que tengamos en planta.

Se recomienda realizar un análisis de esfuerzos y flexibilidad, junto con un análisis de hidráulico de las tuberías antes de instalarlas pues de esta manera se pueden ahorrar tiempos de parada por posibles problemas que se presenten durante la puesta en marcha.

BIBLIOGRAFÍA

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Catálogo: SST-300 Industrial Steam Turbines Up to 50 MW – SIEMENS

ASME B31.1-2001, POWER PIPING, ASME CODE FOR PRESSURE PIPING, B31 AN AMERICAN NATIONAL STANDARD.

Technology Characterization: Steam Turbines, Environmental Protection Agency Climate Protection Partnership Division Washington, DC, March 2002.

REAL ACADEMIA ESPAÑOLA, Diccionario de la lengua española, vigésima segunda edición.

Termodinámica, Yunus Cengel.

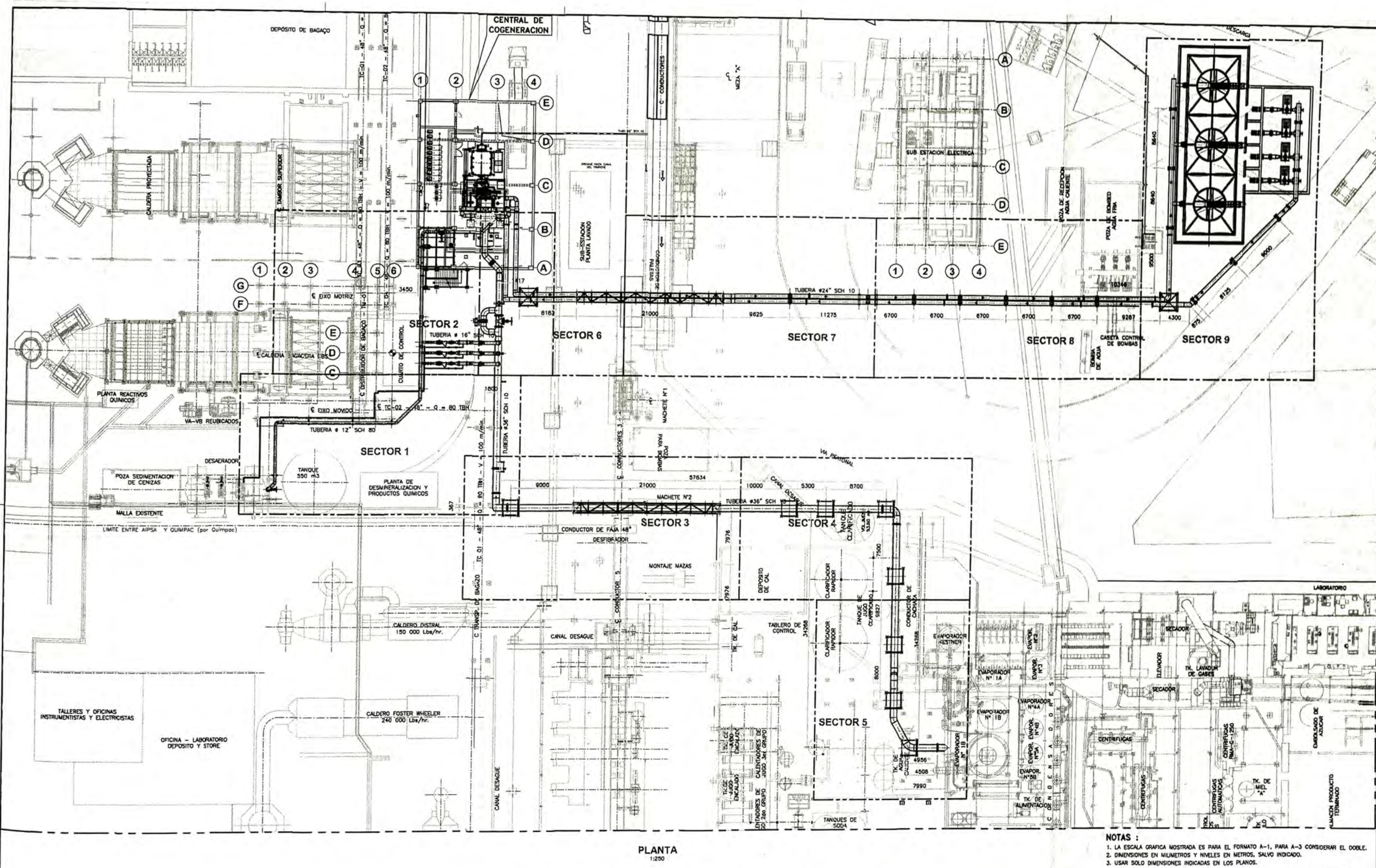
ANEXOS

Anexo 1: Planos de Arreglo General.

Anexo 2: Norma ASME B31.1 2004.

ANEXO 1

Planos de Arreglo General



NOTAS :

1. LA ESCALA GRAFICA MOSTRADA ES PARA EL FORMATO A-1, PARA A-3 CONSIDERAR EL DOBLE.
2. DIMENSIONES EN MILIMETROS Y NIVELES EN METROS, SALVO INDICADO.
3. USAR SOLO DIMENSIONES INDICADAS EN LOS PLANOS.

1:250 0 5000 10000 15000 20000 25000 mm

PROYECTISTA:	
Título	DISEÑO DE LA RED DE TUBERÍAS DE PRESIÓN PARA COGENERACION EN UN TURBO GENERADOR DE 23 MW
	INFORME DE SUFICIENCIA PARA OPTAR AL TITULO PROFESIONAL DE INGENIERO MECANICO
DESCRIPCION:	KEY PLAN DISPOSICIÓN GENERAL
PLANO N°	ISTP-IM-DRTP-DWG-01
ESC:	1:250
REV.	0

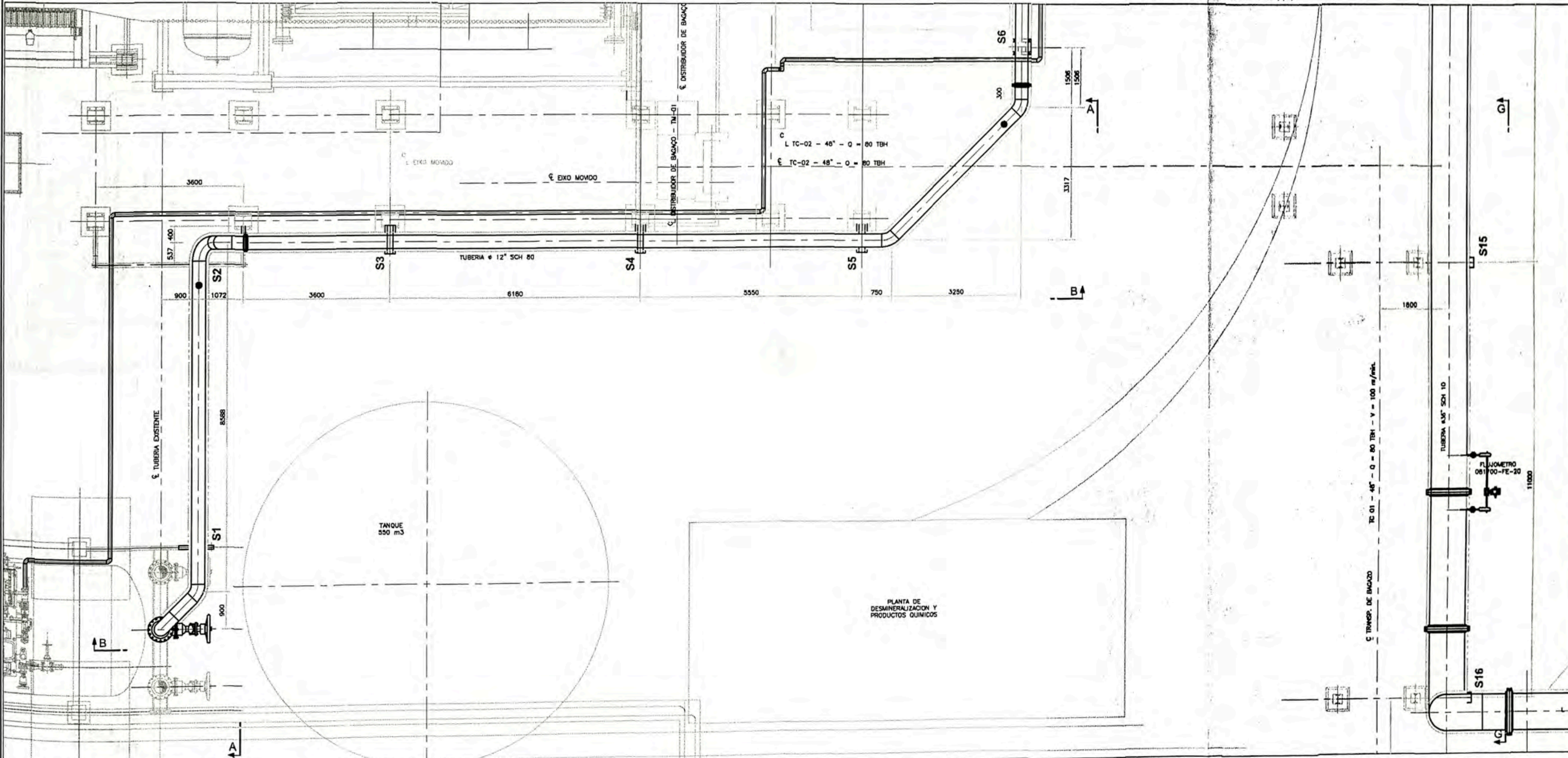
N° REV.	FECHA	REVISIONES	POR	REV.	APR.	CLIENT.
A	13-10-08	EMITIDO PARA SU REVISIÓN	R.T.V.	R.T.V.	R.T.V.	

APROBACION	FECHA	FIRMAS
CLIENTE:		
GTE. ING:		
GTE. PROY.:		

NOMBRES	FECHA	FIRMAS
DISEÑADO POR:		
DIBUJADO POR:		
REVISADO POR:		
APROBADO POR:		
GTE. ING.:		

NOTAS | PLANO N° | PLANOS DE REFERENCIA | COD.PROY. | COD.PROY.CLIENTE. | PLANO CLIENTE N°

CONTINUA EN EL PLANO CSL-081700-4-05 (1/3)



CONTINUA EN EL PLANO CSL-081700-4-26 (1/3)

PLANTA
1:50

NOTAS :
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2. DIMENSIONES EN MILIMETROS Y NIVELES EN METROS, SALVO INDICADO.
3. USAR SOLO DIMENSIONES INDICADAS EN LOS PLANOS.

1:50 0 1000 2000 3000 4000 5000 mm

N° REV.	FECHA	REVISIONES	POR	REV.	APR.	CLIENT.
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A	13-10-08	EMITIDO PARA SU REVISIÓN	R.T.V.	R.T.V	R.T.V.	

NOTAS

PLANO N°	PLANOS DE REFERENCIA

PROYECTISTA:

CLIENTE – APROBACION	FECHA	FIRMAS
CLIENTE:		
GTE. ING.:		
GTE. PROY.:		

PROYECTISTA – NOMBRES	FECHA	FIRMAS
DISEÑADO POR:		
DIBUJADO POR:		
REVISADO POR:		
APROBADO POR:		
GTE. ING.:		

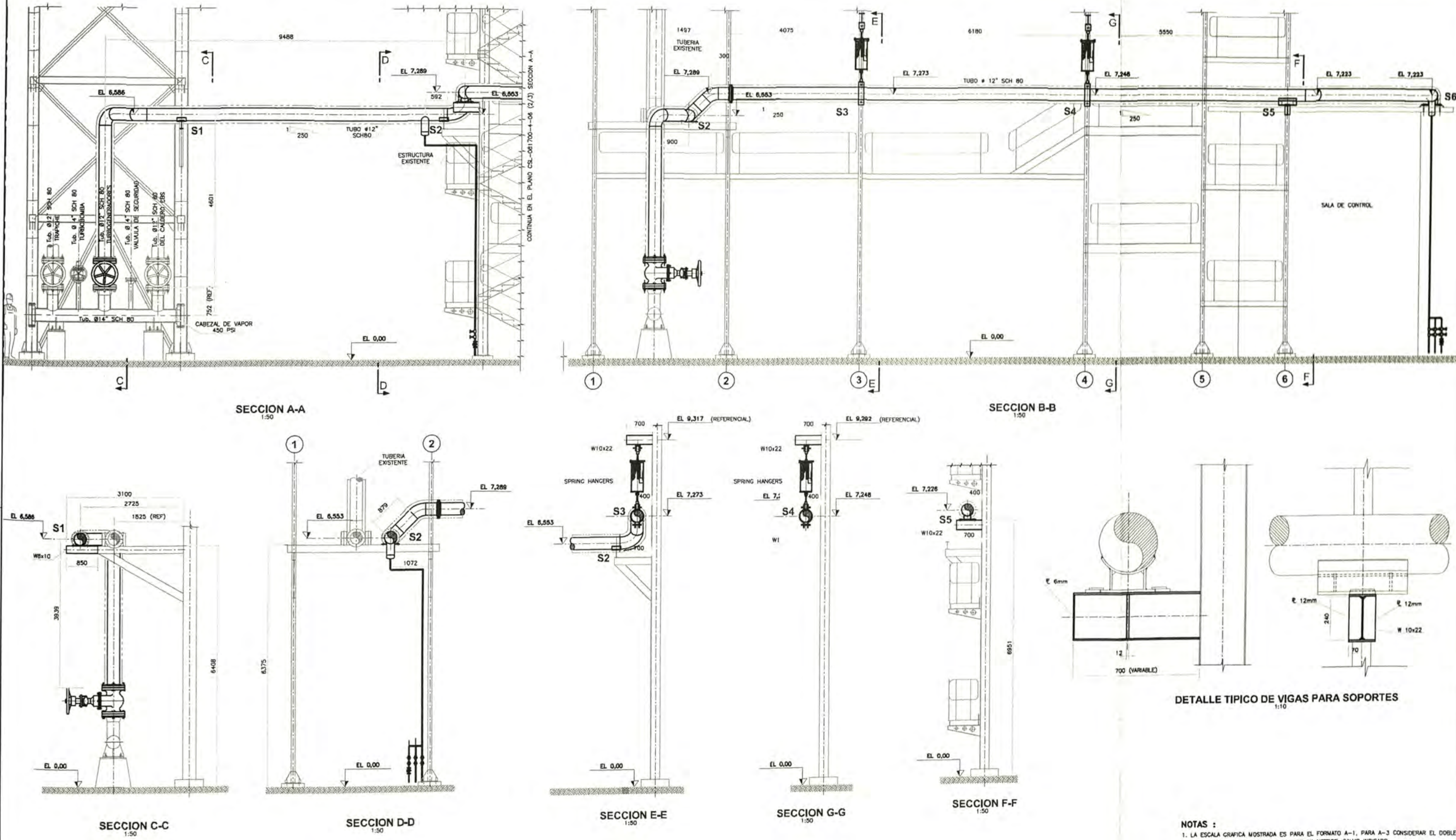
COD.PROY. PLANO N.° ISTP-IM-DRTP-DWG-02 ESC: 1:50

DISEÑO DE LA RED DE TUBERÍAS DE PRESIÓN PARA COGENERACION EN UN TURBO GENERADOR DE 23 MW

INFORME DE SUFICIENCIA PARA OPTAR AL TITULO PROFECIONAL DE INGENIERO MECANICO

DESCRIPCION:
LINEA DE VAPOR VIVO – VAPOR DE EXTRACCIÓN
VISTA DE PLANTA – SECTOR 1

COD.PROY.CLIENTE. PLANO CLIENTE N° REV. 0



NOTAS :

1. LA ESCALA GRAFICA MOSTRADA ES PARA EL FORMATO A-1, PARA A-3 CONSIDERAR EL DOBLE.
2. DIMENSIONES EN MILIMETROS Y NIVELES EN METROS, SALVO INDICADO.
3. USAR SOLO DIMENSIONES INDICADAS EN LOS PLANOS.
4. VER DETALLE DE SOPORTES EN EL PLANO CSL-081700-4-18.

1:50 0 1000 2000 3000 4000 5000 mm
1:10 0 200 400 600 800 1000 mm

DISEÑO DE LA RED DE TUBERÍAS DE PRESIÓN PARA COGENERACION EN UN TURBO GENERADOR DE 23 MW

INFORME DE SUFICIENCIA PARA OPTAR AL TITULO PROFECIONAL DE INGENIERO MECANICO

DESCRIPCION:

LINEA DE VAPOR VIVO
ELEVACIONES Y CORTES – SECTOR 1

N° REV.	FECHA	REVISIONES	POR	REV.	APR.	CLIENT.
0	02-12-11	EMITIDO PARA INFORME DE SUFICIENCIA	R.T.V.	R.T.V.	R.T.V.	
A	13-10-08	EMITIDO PARA SU REVISIÓN	R.T.V.	R.T.V	R.T.V.	

PROYECTISTA:

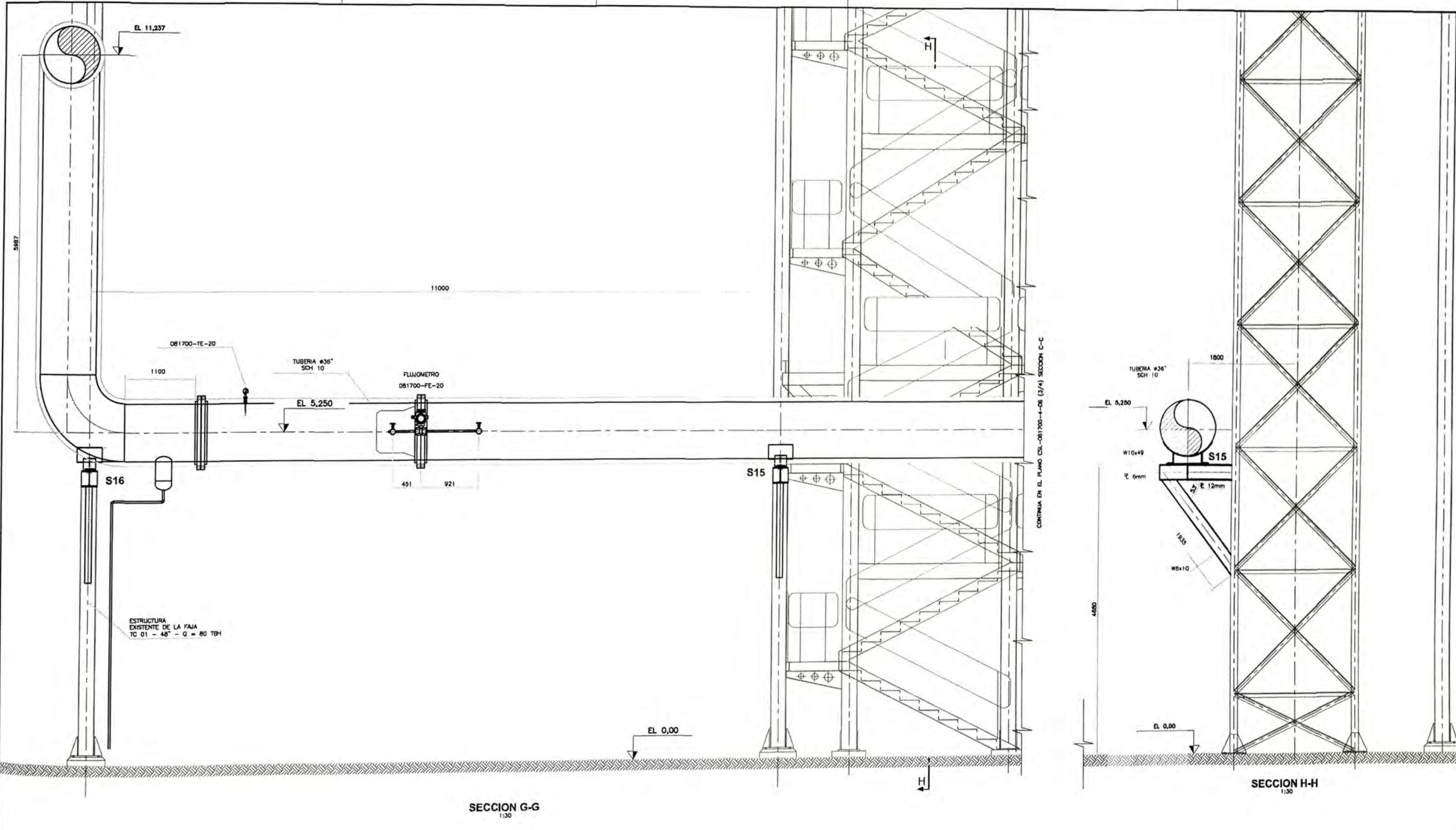
CLIENTE	APROBACION	FECHA	FIRMAS
	CLIENTE:		
	GTE. ING.:		
	GTE. PROT.:		

PROYECTISTA	NOMBRES	FECHA	FIRMAS
	DISEÑADO POR:		
	DIBUJADO POR:		
	REVISADO POR:		
	APROBADO POR:		
	GTE. ING.:		

COD.PROY. PLANO N.° ISTP-IM-DRTP-DWG-03 ESC: 1:50

COD.PROY.CLIENTE. PLANO CLIENTE N° REV. 0

NOTAS | PLANO N° | PLANOS DE REFERENCIA



NOTAS :

1. LA ESCALA GRAFICA MOSTRADA ES PARA EL FORMATO A-1, PARA A-3 CONSIDERAR EL DOBLE.
2. DIMENSIONES EN MILIMETROS Y NIVELES EN METROS, SALVO INDICADO.
3. USAR SOLO DIMENSIONES INDICADAS EN LOS PLANOS.

1:30 0 600 1200 1800 2400 3000 mm

N° REV.	FECHA	REVISIONES	POR	REV.	APR.	CLIENT.
0	02-12-11	EMITIDO PARA INFORME DE SUFICIENCIA	R.T.V.	R.T.V.	R.T.V.	
A	13-10-08	EMITIDO PARA SU REVISIÓN	R.T.V.	R.T.V	R.T.V.	

NOTAS

PLANO N° | PLANOS DE REFERENCIA

PROYECTISTA:

CLIENTE	APROBACION	FECHA	FIRMAS
	CLIENTE:		
	GTE. ING.:		
	GTE. PROY.:		

PROYECTISTA	NOMBRES	FECHA	FIRMAS
	DISEÑADO POR:		
	DIBUJADO POR:		
	REVISADO POR:		
	APROBADO POR:		
	GTE. ING.:		

COD.PROY. PLANO N° ISTP-IM-DRTP-DWG-04 ESC: 1:30

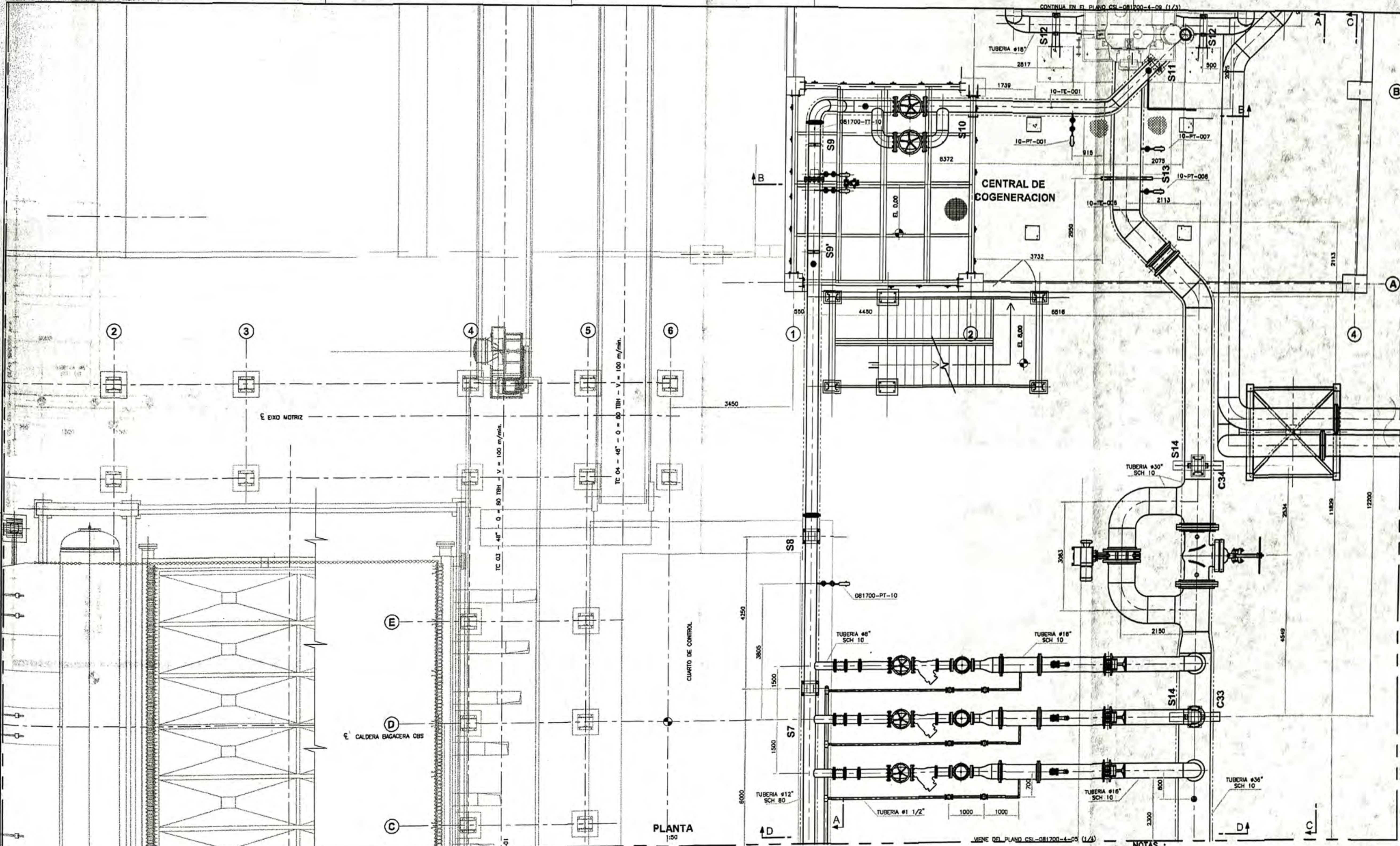
DISEÑO DE LA RED DE TUBERÍAS DE PRESIÓN PARA COGENERACION EN UN TURBO GENERADOR DE 23 MW

INFORME DE SUFICIENCIA PARA OPTAR AL TITULO PROFECIONAL DE INGENIERO MECANICO

DESCRIPCION:

LINEA DE VAPOR DE EXTRACCIÓN
ELEVACIONES Y CORTES – SECTOR 1

COD.PROY.CLIENTE. PLANO CLIENTE N° REV. 0



NOTAS :

1. LA ESCALA GRAFICA MOSTRADA ES PARA EL FORMATO A-1, PARA A-3 CONSIDERAR EL DOBLE.
2. DIMENSIONES EN MILIMETROS Y NIVELES EN METROS, SALVO INDICADO.
3. USAR SOLO DIMENSIONES INDICADAS EN LOS PLANOS.

1:50 0 1000 2000 3000 4000 5000 mm

DISEÑO DE LA RED DE TUBERÍAS DE PRESIÓN PARA COGENERACION EN UN TURBO GENERADOR DE 23 MW

INFORME DE SUFICIENCIA PARA OPTAR AL TITULO PROFESIONAL DE INGENIERO MECANICO

DESCRIPCION:
LINEA DE VAPOR VIVO – VAPOR DE EXTRACCION
VISTA DE PLANTA – SECTOR 2

N° REV.	FECHA	REVISIONES	POR	REV.	APR.	CLIENT.
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A	13-10-08	EMITIDO PARA SU REVISIÓN	R.T.V.	R.T.V.	R.T.V.	

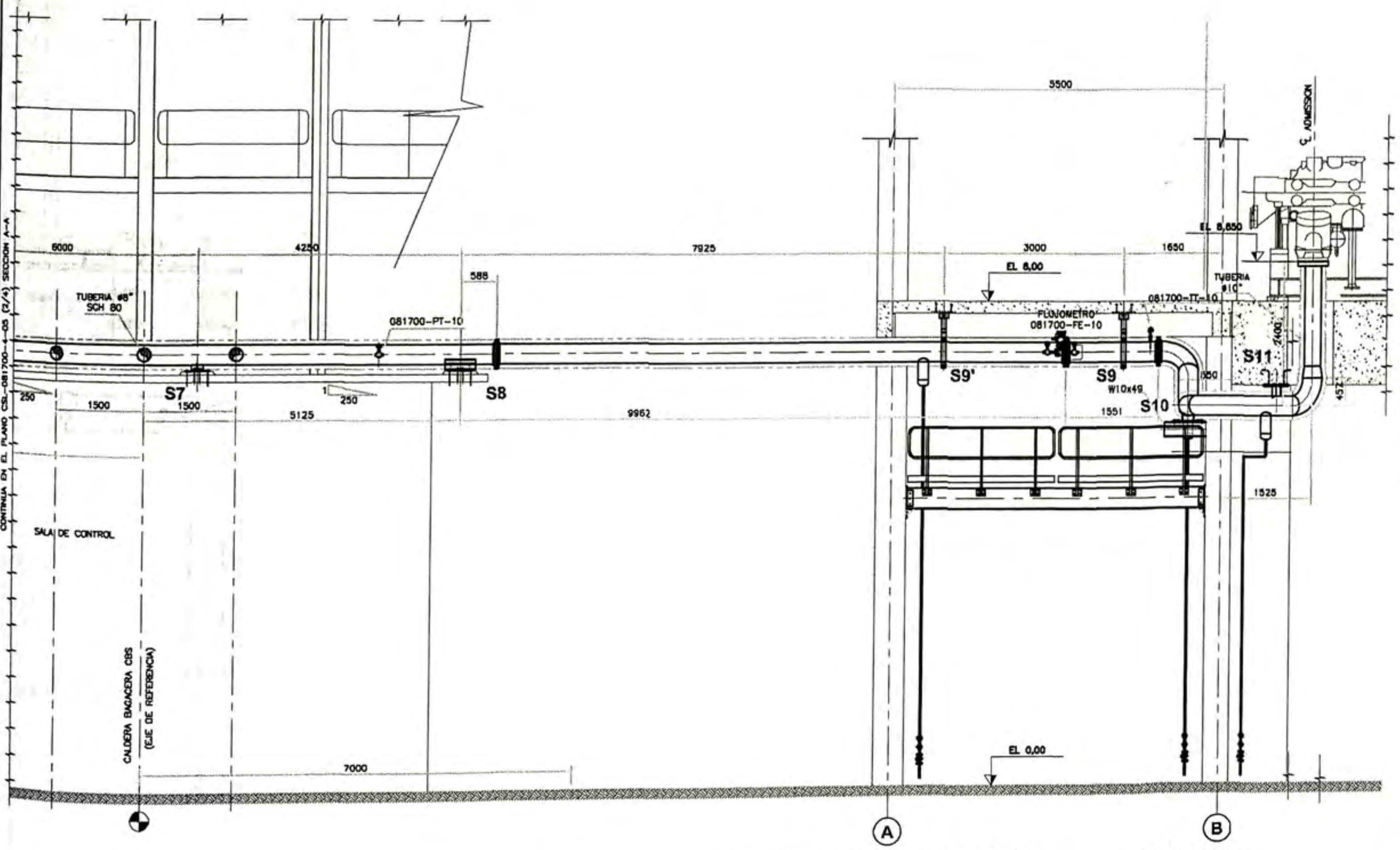
NOTAS | PLANO N° | PLANOS DE REFERENCIA

PROYECTISTA:

CLIENTE	APROBACION	FECHA	FIRMAS
	CLIENTE:		
	GTE. ING.:		
	GTE. PROY.:		

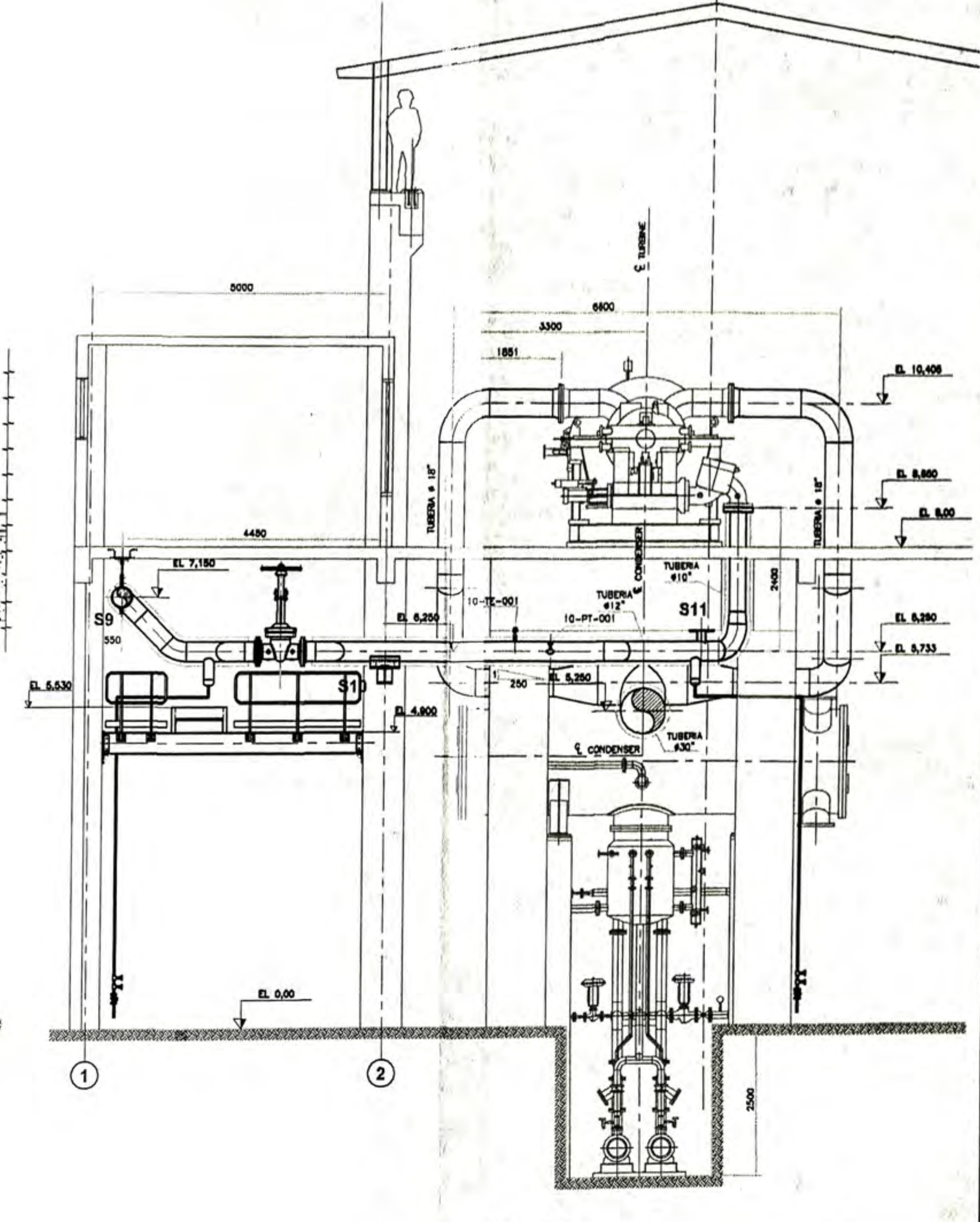
PROYECTISTA	NOMBRES	FECHA	FIRMAS
	DISEÑADO POR:		
	DIBUJADO POR:		
	REVISADO POR:		
	APROBADO POR:		
	GTE. ING.:		

COD.PROY. | PLANO N° ISTP-IM-DRTP-DWG-05 | ESC: 1:50 | COD.PROY.CLIENTE. | PLANO CLIENTE N° | REV. 0



SECCION A-A
1:50

0 02-12-11 EMITIDO PARA INFORME DE SUFICIENCIA R.T.V. R.T.V. R.T.V.



SECCION B-B
1:50

NOTAS :

1. LA ESCALA GRAFICA MOSTRADA ES PARA EL FORMATO A-1, PARA A-3 CONSIDERAR EL DOBLE.
2. DIMENSIONES EN MILIMETROS Y NIVELES EN METROS, SALVO INDICADO.
3. USAR SOLO DIMENSIONES INDICADAS EN LOS PLANOS.
4. VER DETALLE DE SOPORTES EN EL PLANO CSL-081700-4-18.

1:50 0 1000 2000 3000 4000 5000 mm

N° REV.	FECHA	REVISIONES	POR	REV.	APR.	CLIENT.
0	02-12-11	EMITIDO PARA INFORME DE SUFICIENCIA	R.T.V.	R.T.V.	R.T.V.	
A	13-10-08	EMITIDO PARA SU REVISIÓN	R.T.V.	R.T.V	R.T.V.	

PLANO N°	PLANOS DE REFERENCIA

NOTAS

PROYECTISTA:

CLIENTE – APROBACION	FECHA	FIRMAS
CLIENTE:		
GTE. ING.:		
GTE. PROY.:		

PROYECTISTA – NOMBRES	FECHA	FIRMAS
DISEÑADO POR:		
DIBUJADO POR:		
REVISADO POR:		
APROBADO POR:		
GTE. ING.:		

COD.PROY. PLANO N.° ISTP-IM-DRTP-DWG-06 ESC: 1:50

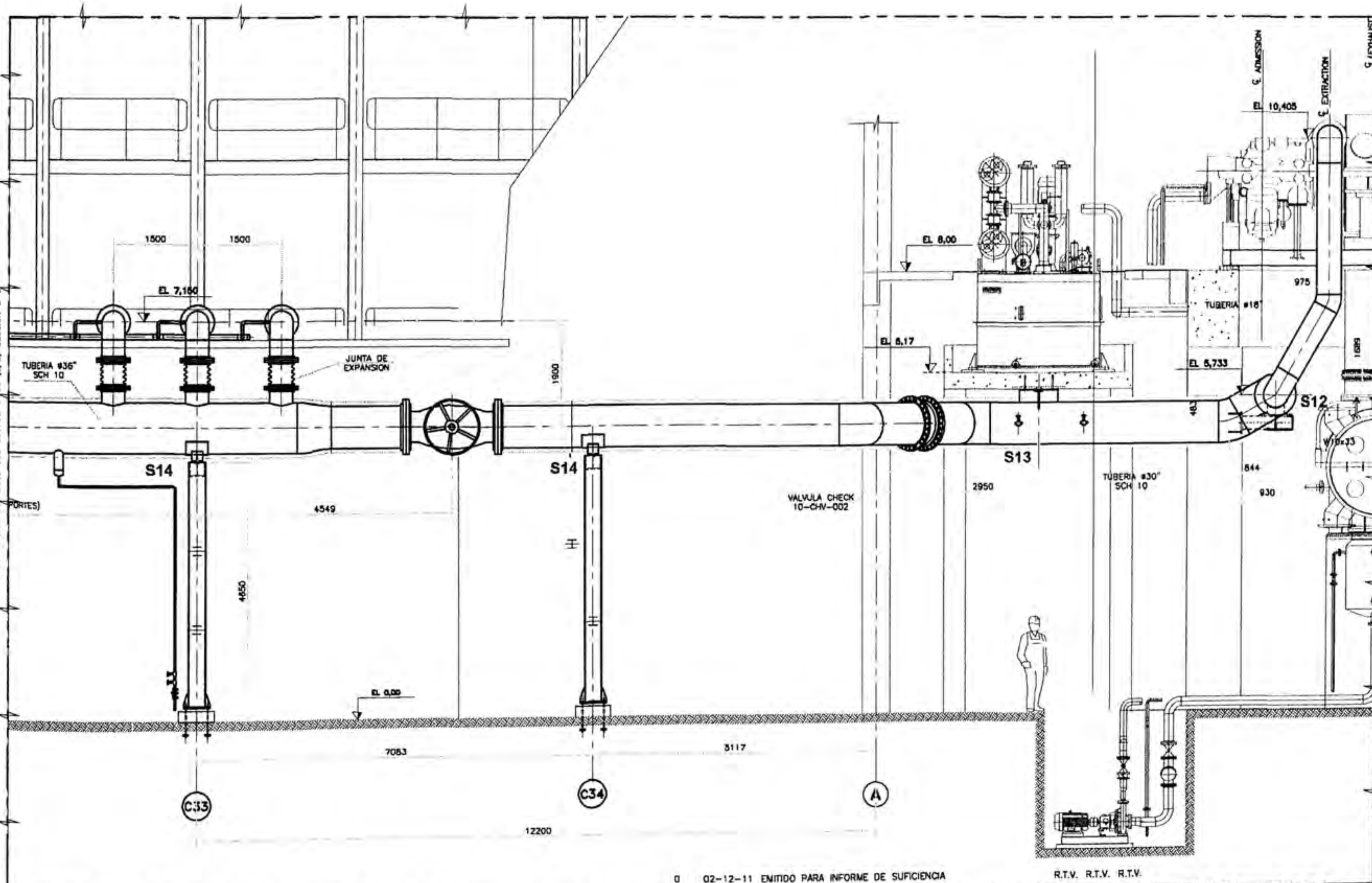
DISEÑO DE LA RED DE TUBERÍAS DE PRESIÓN PARA COGENERACION EN UN TURBO GENERADOR DE 23 MW

INFORME DE SUFICIENCIA PARA OPTAR AL TITULO PROFECIONAL DE INGENIERO MECANICO

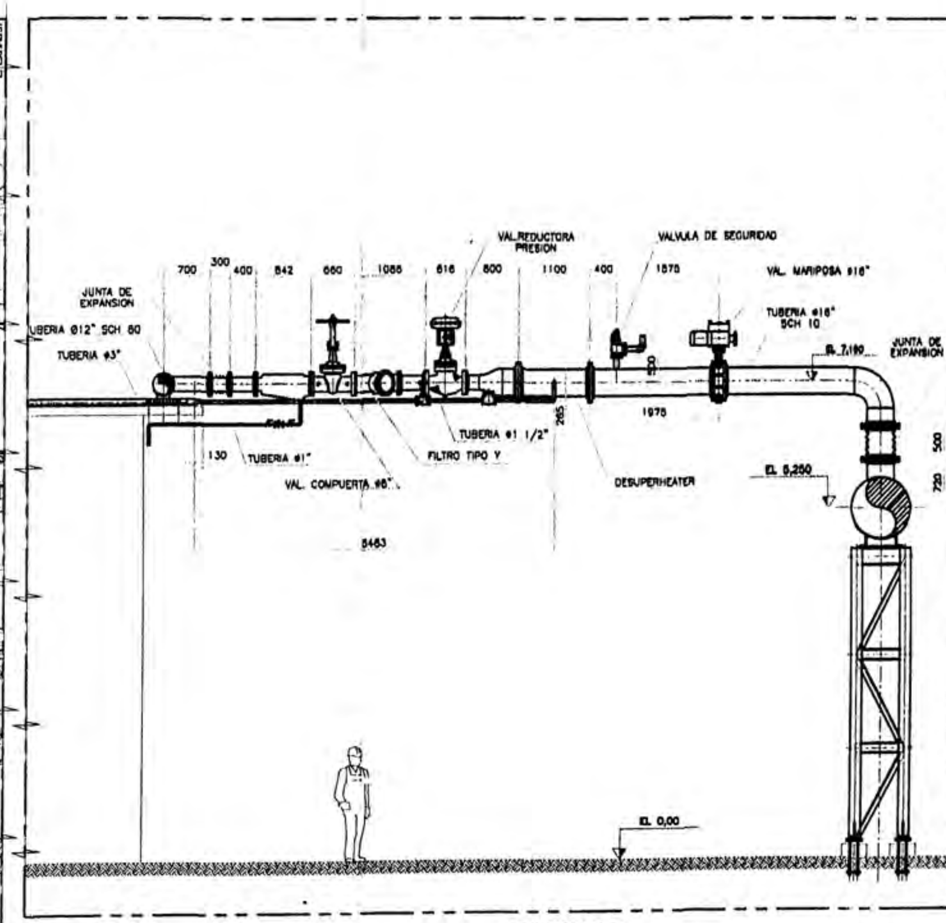
DESCRIPCION:

LINEA DE VAPOR VIVO
ELEVACIONES Y CORTES – SECTOR 2

COD.PROY.CLIENTE. PLANO CLIENTE N° REV. 0



SECCION C-C
1:50



SECCION D-D
1:50

NOTAS :

1. LA ESCALA GRAFICA MOSTRADA ES PARA EL FORMATO A-1, PARA A-3 CONSIDERAR EL DOBLE.
2. DIMENSIONES EN MILIMETROS Y NIVELES EN METROS, SALVO INDICADO.
3. USAR SOLO DIMENSIONES INDICADAS EN LOS PLANOS.

1:50 0 1000 2000 3000 4000 5000 mm

N° REV.	FECHA	REVISIONES	POR	REV.	APR.	CLIENT.
0	02-12-11	EMITIDO PARA INFORME DE SUFICIENCIA	R.T.V.	R.T.V.	R.T.V.	
A	13-10-08	EMITIDO PARA SU REVISIÓN	R.T.V.	R.T.V.	R.T.V.	

NOTAS | PLANO N° | PLANOS DE REFERENCIA

PROYECTISTA:

APROBACION	FECHA	FIRMAS
CLIENTE:		
GTE. ING.:		
GTE. PROY.:		

NOMBRES	FECHA	FIRMAS
DISEÑADO POR:		
DIBUJADO POR:		
REVISADO POR:		
APROBADO POR:		
GTE. ING.:		

COD.PROY. | PLANO N° ISTP-IM-DRTP-DWG-07 | ESC: 1:50

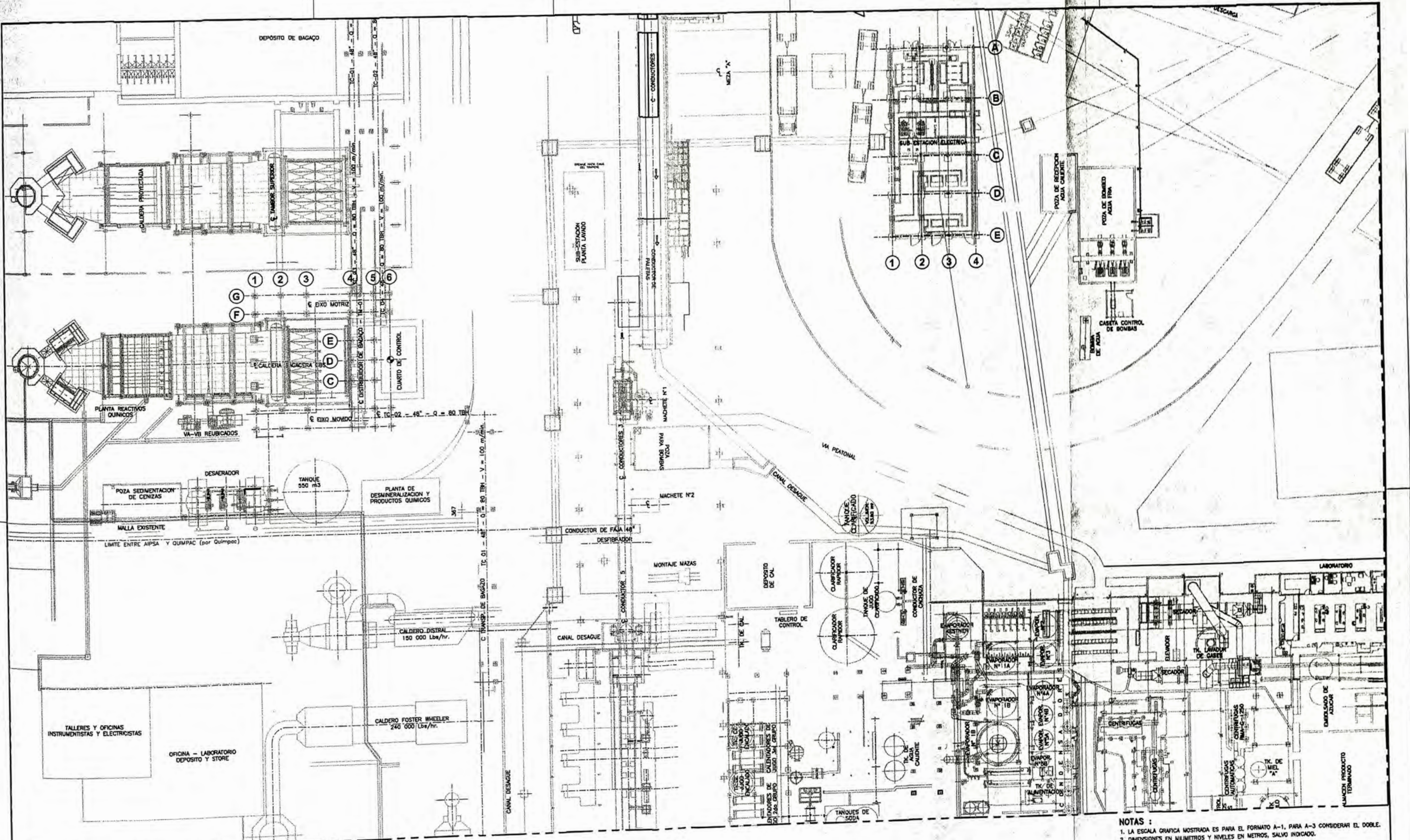
DISEÑO DE LA RED DE TUBERÍAS DE PRESIÓN PARA COGENERACION EN UN TURBO GENERADOR DE 23 MW

INFORME DE SUFICIENCIA PARA OPTAR AL TITULO PROFESIONAL DE INGENIERO MECANICO

DESCRIPCION:

LINEA DE VAPOR DE EXRACCIÓN
ELEVACIONES Y CORTES – SECTOR 2

COD.PROY.CLIENTE. | PLANO CLIENTE N° | REV. 0



PLANTA
1:250

NOTAS :

1. LA ESCALA GRAFICA MOSTRADA ES PARA EL FORMATO A-1, PARA A-3 CONSIDERAR EL DOBLE.
2. DIMENSIONES EN MILIMETROS Y NIVELES EN METROS, SALVO INDICADO.
3. USAR SOLO DIMENSIONES INDICADAS EN LOS PLANOS.

1:250 0 5000 10000 15000 20000 25000 mm

DISEÑO DE LA RED DE TUBERÍAS DE PRESIÓN PARA COGENERACION EN UN TURBO GENERADOR DE 23 MW

INFORME DE SUFICIENCIA PARA OPTAR AL TITULO PROFESIONAL DE INGENIERO MECANICO

DESCRIPCION: ARREGLO GENERAL VISTA GENERAL

PROYECTISTA:				
APROBACION	FECHA	FIRMAS	NOMBRES	FECHA	FIRMAS
CLIENTE:			DISEÑADO POR:		
GTE. ING.:			DIBUJADO POR:		
GTE. PROY.:			REVISADO POR:		
			APROBADO POR:		
			GTE. ING.:		

COD.PROY. | PLANO N° ISTP-IM-DRTP-DWG-08 | ESC: 1:250 | COD.PROY.CLIENTE. | PLANO CLIENTE N° | REV. 0

N° REV.	FECHA	REVISIONES	POR	REV.	APR.	CLIENT.
A	13-10-08	EMITIDO PARA SU REVISIÓN	R.T.V.	R.T.V.	R.T.V.	

PLANO N° | PLANOS DE REFERENCIA

NOTAS

ANEXO 2

Norma ASME B31.1 2004.

CHAPTER II
DESIGN

PART 1
CONDITIONS AND CRITERIA

101 DESIGN CONDITIONS

101.1 General

These design conditions define the pressures, temperatures and various forces applicable to the design of power piping systems. Power piping systems shall be designed for the most severe condition of coincident pressure, temperature and loading, except as herein stated. The most severe condition shall be that which results in the greatest required pipe wall thickness and the highest flange rating.

101.2 Pressure

All pressures referred to in this Code are expressed in pounds per square inch and kilopascals above atmospheric pressure, i.e., psig [kPa (gage)], unless otherwise stated.

101.2.2 Internal Design Pressure. The internal design pressure shall be not less than the maximum sustained operating pressure (MSOP) within the piping system including the effects of static head.

101.2.4 External Design Pressure. Piping subject to external pressure shall be designed for the maximum differential pressure anticipated during operating, shutdown, or test conditions.

101.3 Temperature

101.3.1 All temperatures referred to in this Code, unless otherwise stated, are the average metal temperatures of the respective materials expressed in degrees Fahrenheit, i.e., °F (Celsius, i.e., °C).

101.3.2 Design Temperature

(A) The piping shall be designed for a metal temperature representing the maximum sustained condition expected. The design temperature shall be assumed to be the same as the fluid temperature unless calculations or tests support the use of other data, in which case the design temperature shall not be less than the average of the fluid temperature and the outside wall temperature.

(B) Where a fluid passes through heat exchangers in series, the design temperature of the piping in each section of the system shall conform to the most severe temperature condition expected to be produced by the heat exchangers in that section of the system.

(C) For steam, feedwater, and hot water piping leading from fired equipment (such as boiler, reheater, superheater, economizer, etc.), the design temperature shall be based on the expected continuous operating condition plus the equipment manufacturers guaranteed maximum temperature tolerance. For operation at temperatures in excess of this condition, the limitations described in para. 102.2.4 shall apply.

(D) Accelerated creep damage, leading to excessive creep strains and potential pipe rupture, caused by extended operation above the design temperature shall be considered in selecting the design temperature for piping to be operated above 800°F.

101.4 Ambient Influences

101.4.1 Cooling Effects on Pressure. Where the cooling of a fluid may reduce the pressure in the piping to below atmospheric, the piping shall be designed to withstand the external pressure or provision shall be made to break the vaccum.

101.4.2 Fluid Expansion Effects. Where the expansion of a fluid may increase the pressure, the piping system shall be designed to withstand the increased pressure or provision shall be made to relieve the excess pressure.

101.5 Dynamic Effects

101.5.1 Impact. Impact forces caused by all external and internal conditions shall be considered in the piping design. One form of internal impact force is due to the propagation of pressure waves produced by sudden changes in fluid momentum. This phenomena is often called water or steam "hammer." It may be caused by the rapid opening or closing of a valve in the system.

The designer should be aware that this is only one example of this phenomena and that other causes of impact loading exist.

101.5.2 Wind. Exposed piping shall be designed to withstand wind loadings, using meteorological data to determine wind forces. Where state or municipal ordinances covering the design of building structures are in effect and specify wind loadings, these values shall be considered the minimum design values.

101.5.3 Earthquake. The effect of earthquakes, where applicable, shall be considered in the design of piping, piping supports, and restraints, using data for the site as a guide in assessing the forces involved. However, earthquakes need not be considered as acting concurrently with wind.

101.5.4 Vibration. Piping shall be arranged and supported with consideration of vibration (see paras. 120.1(c) and 121.7.5).

101.6 Weight Effects

The following weight effects combined with loads and forces from other causes shall be taken into account in the design of piping. Piping shall be carried on adjustable hangers or properly leveled rigid hangers or supports, and suitable springs, sway bracing, vibration dampeners, etc., shall be provided where necessary.

101.6.1 Live Load. The live load consists of the weight of the fluid transported. Snow and ice loads shall be considered in localities where such conditions exist.

101.6.2 Dead Load. The dead load consists of the weight of the piping components, insulation, protective lining and coating, and other superimposed permanent loads.

101.6.3 Test or Cleaning Fluid Load. The test or cleaning fluid load consists of the weight of the test or cleaning fluid.

101.7 Thermal Expansion and Contraction Loads

101.7.1 General. The design of piping systems shall take account of the forces and moments resulting from thermal expansion and contraction, and from the effects of expansion joints.

Thermal expansion and contraction shall be provided for preferably by pipe bends, elbows, offsets or changes in direction of the pipeline.

Hangers and supports shall permit expansion and contraction of the piping between anchors.

101.7.2 Expansion, Swivel, or Ball Joints, and Flexible Metal Hose Assemblies. Joints of the corrugated bellows, slip, sleeve, ball, or swivel types and flexible metal hose assemblies may be used if their materials conform to this Code, their structural and working parts are of ample proportions, and their design prevents the complete disengagement of working parts while in service. However, flexible metal hose assemblies, and expansion joints of the corrugated bellows, slip, or sleeve type shall not be used in any piping system connecting the boiler and the first stop valve in that system.

102 DESIGN CRITERIA

102.1 General

These criteria cover pressure-temperature ratings for standard and specially designed components, allowable stresses, stress limits, and various allowances to be used in the design of piping and piping components.

102.2 Pressure-Temperature Ratings for Piping Components

102.2.1 Components Having Specific Ratings. Pressure-temperature ratings for certain piping components have been established and are contained in some of the standards listed in Table 126.1.

Where piping components have established pressure-temperature ratings which do not extend to the upper material temperature limits permitted by this Code, the pressure-temperature ratings between those established and the upper material temperature limit may be determined in accordance with the rules of this Code, but such extensions are subject to restrictions, if any, imposed by the standards.

Standard components may not be used at conditions of pressure and temperature which exceed the limits imposed by this Code.

102.2.2 Components Not Having Specific Ratings. Some of the Standards listed in Table 126.1, such as those for buttwelding fittings, specify that components shall be furnished in nominal thicknesses. Unless limited elsewhere in this Code, such components shall be rated for the same allowable pressures as seamless pipe of the same nominal thickness, as determined in paras. 103 and 104 for material having the same allowable stress.

Piping components, such as pipe, for which allowable stresses have been developed in accordance with para. 102.3, but which do not have established pressure ratings, shall be rated by rules for pressure design in para. 104, modified as applicable by other provisions of this Code.

Should it be desired to use methods of manufacture or design of components not covered by this Code or not listed in referenced standards, it is intended that the manufacturer shall comply with the requirements of paras. 103 and 104 and other applicable requirements of this Code for design conditions involved. Where components other than those discussed above, such as pipe or fittings not assigned pressure-temperature ratings in an American National Standard, are used, the manufacturer's recommended pressure-temperature rating shall not be exceeded.

102.2.3 Ratings: Normal Operating Condition. A piping system shall be considered safe for operation if the maximum sustained operating pressure and temperature which may act on any part or component of the system does not exceed the maximum pressure and temperature allowed by this Code for that particular part or component. The design pressure and temperature shall not exceed the pressure-temperature rating for the particular component and material as defined in the applicable specification or standard listed in Table 126.1.

102.2.4 Ratings: Allowance for Variation From Normal Operation. The maximum internal pressure and temperature allowed shall include considerations for occasional loads and transients of pressure and temperature.

It is recognized that variations in pressure and temperature inevitably occur, and therefore the piping system, except as limited by component standards referred to in para. 102.2.1 or by manufacturers of components referred to in para. 102.2.2, shall be considered safe for occasional short operating periods at higher than design pressure or temperature. For such variations, either pressure or temperature, or both, may exceed the design values if the computed circumferential pressure stress does not exceed the maximum allowable stress from Appendix A for the coincident temperature by:

(A) 15% if the event duration occurs for no more than 8 hr at any one time and no more than 800 hr/year; or

(B) 20% if the event duration occurs for no more than 1 hr at any one time and no more than 80 hr/year.

102.2.5 Ratings at Transitions. Where piping systems operating at different design conditions are connected, a division valve shall be provided having a pressure-temperature rating equal to or exceeding the more severe conditions. See para. 122 for design requirements pertaining to specific piping systems.

102.3 Allowable Stress Values and Other Stress Limits for Piping Components

102.3.1 Allowable Stress Values

(A) Allowable stress values to be used for the design of power piping systems are given in the Tables in Appendix A, also referred to in this Code Section as the Allowable Stress Tables. These Tables list allowable stress values for commonly used materials at temperatures appropriate to power piping installations. In every case the temperature is understood to be the metal temperature. Where applicable, weld joint efficiency factors and casting quality factors are included in the tabulated values. Thus, the tabulated values are values of S, SE, or SF, as applicable.

(B) Allowable stress values in shear shall not exceed 80% of the values determined in accordance with the rules of para. 102.3.1(A). Allowable stress values in bearing shall not exceed 160% of the determined values.

(C) The basis for establishing the allowable stress values in this Code Section are the same as those in the ASME Boiler and Pressure Vessel Code, Section II, Part D, Appendix 1; except that allowable stresses for cast iron and ductile iron are in accordance with Section VIII, Division 1, Appendix P for Tables UCI-23 and UCD-23, respectively.

102.3.2 Limits of Calculated Stresses Due to Sustained Loads and Thermal Expansion

(A) Internal Pressure Stress. The calculated stress due to internal pressure shall not exceed the allowable stress values given in the Allowable Stress Tables in Appendix A. This criterion is satisfied when the wall thickness of the piping component, including any reinforcement, meets the requirements of para. 104.1 through 104.7, excluding para. 104.1.3 but including the consideration of allowances permitted by paras. 102.2.4, 102.3.3(B), and 102.4.

(B) External Pressure Stress. Piping subject to external pressure shall be considered safe when the wall thickness and means of stiffening meet the requirements of para. 104.1.3.

TABLE 102.3.2(C)
STRESS RANGE REDUCTION FACTORS

Number of Equivalent Full Temperature Cycles N	f
7,000 and less	1.0
7,000–14,000	0.9
14,000–22,000	0.8
22,000–45,000	0.7
45,000–100,000	0.6
100,000 and over	0.5

(C) Allowable Stress Range for Expansion Stresses. Except as permitted in para. 102.3.2(D), the thermal expansion stress range S_E (see paras. 104.8.3 and 119.6.4) shall not exceed the allowable stress range S_A given by the following formula:

$$S_A = f(1.25S_c + 0.25S_h) \quad (1)$$

where

S_c = basic material allowable stress at minimum (cold) temperature from the Allowable Stress Tables

S_h = basic material allowable stress at maximum (hot) temperature from the Allowable Stress Tables

f = stress range reduction factor for cyclic conditions for total number N of full temperature cycles over total number of years during which system is expected to be in operation, from Table 102.3.2(C)

In determining the basic material allowable stresses, S_c and S_h, joint efficiencies need not be applied. The values of allowable stress in the Allowable Stress Tables for welded pipe may be divided by the weld joint factors listed in para. 102.4.3.

Stress reduction factors apply essentially to noncorrosive service and to corrosion resistant materials where employed to minimize the reduction in cyclic life caused by corrosive action.

If the range of temperature change varies, equivalent full temperature cycles may be computed as follows:

$$N = N_E + r_1^5N_1 + r_2^5N_2 + ... + r_n^5N_n \quad (2)$$

where

N_E = number of cycles at full temperature change ΔT_E for which expansion stress S_E has been calculated

$N_1, N_2, \ldots, N_n$ = number of cycles at lesser temperature changes $\Delta T_1, \Delta T_2, \ldots, \Delta T_n$

$r_1, r_2, \ldots, r_n$ = ratio of lesser temperature cycles to that for any which the expansion stress S_E has been calculated
= $\Delta T_1/\Delta T_E, \Delta T_2/\Delta T_E, \ldots, \Delta T_n/\Delta T_E$

(D) Longitudinal Stresses. The sum of the longitudinal stresses S_L due to pressure, weight, and other sustained loads shall not exceed the allowable stress in the hot condition S_h. Where the sum of these stresses is less than S_h, the difference may be used as an additional thermal expansion allowance, which is the second term on the right side of Eq. (13) of para. 104.8.3.

The longitudinal pressure stress S_{lp} shall be determined by either of the following equations:

$$S_{lp} = \frac{PD_o}{4t_n}$$

or

$$S_{lp} = \frac{Pd_n^2}{D_n^2 - d_n^2}$$

102.3.3 Limits of Calculated Stresses due to Occasional Loads

(A) During Operation. The sum of the longitudinal stresses produced by internal pressure, live and dead loads and those produced by occasional loads, such as the temporary supporting of extra weight, may exceed the allowable stress values given in the Allowable Stress Tables by the amounts and durations of time given in para. 104.8.2.

(B) During Test. During pressure tests performed in accordance with para. 137, the circumferential (hoop) stress shall not exceed 90% of the yield strength (0. 2% offset) at test temperature. In addition, the sum of longitudinal stresses due to test pressure and live and dead loads at the time of test, excluding occasional loads, shall not exceed 90% of the yield strength at test temperature.

102.4 Allowances

102.4.1 Corrosion or Erosion. When corrosion or erosion is expected, an increase in wall thickness of the piping shall be provided over that required by other design requirements. This allowance in the judgment of the designer shall be consistent with the expected life of the piping.

102.4.2 Threading and Grooving. The calculated minimum thickness of piping (or tubing) which is to be threaded shall be increased by an allowance equal to thread depth; dimension *h* of ASME B1.20.1 or equivalent shall apply. For machined surfaces or grooves, where the tolerance is not specified, the tolerance shall be assumed to be $\frac{1}{64}$ in. (0.40 mm) in addition to the specified depth of cut. The requirements of para. 104.1.2(C) shall also apply.

102.4.3 Weld Joint Efficiency Factors. The use of joint efficiency factors for welded pipe is required by this Code. The factors in Table 102.4.3 are based on full penetration welds. These factors are included in the allowable stress values given in Appendix A. The factors in Table 102.4.3 apply to both straight seam and spiral seam welded pipe.

102.4.4 Mechanical Strength. Where necessary for mechanical strength to prevent damage, collapse, excessive sag, or buckling of pipe due to superimposed loads from supports or other causes, the wall thickness of the pipe should be increased; or, if this is impractical or would cause excessive local stresses, the superimposed loads or other causes shall be reduced or eliminated by other design methods. The requirements of para. 104.1.2(C) shall also apply.

102.4.5 Bending. The minimum wall thickness at any point in a completed bend shall not be less than required by Formulas (3) or (3A) of para. 104.1.2(A).

(A) Table 102.4.5 is a guide to the designer who must specify wall thickness for ordering pipe. In general it has been the experience that when good shop practices are employed, the minimum thicknesses of straight pipe shown in Table 102.4.5 should be sufficient for bending, and still meet the minimum thickness requirements of para. 104.1.2(A).

(B) The bend thinning allowance in Table 102.4.5 may be provided in all parts of the cross section of the pipe circumference without any detrimental effects being produced.

102.4.6 Casting Quality Factors

(A) General. The use of a casting quality factor is required for all cast components which use the allowable stress values of Appendix A as the design basis. A factor of 0.80 is included in the allowable stress values for all castings given in Appendix A.

This required factor does not apply to component standards listed in Table 126.1, if such standards define allowable pressure-temperature ratings or provide the allowable stresses to be used as the design basis for the component.

(B) For steel materials, a casting quality factor not exceeding 1.0 may be applied when the following requirements are met.

(B.1) All steel castings having a nominal body thickness of $4\frac{1}{2}$ in. (114 mm) or less (other than pipe flanges, flanged valves and fittings, and butt welding end valves, all complying with ASME B16.5 or B16.34) shall be inspected as follows.

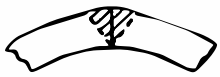
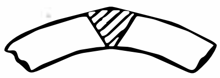
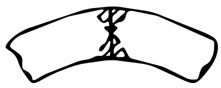
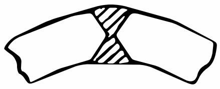
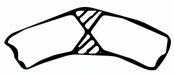
(B.1.1) All critical areas, including the junctions of all gates, risers, and abrupt changes in section or direction and area of weld end preparation shall be radiographed in accordance with Article 2 of Section V of the ASME Boiler and Pressure Vessel Code, and the radiographs shall conform to the requirements of ASTM E 446 Reference Radiographs for Steel Castings up to 2 in. (50 mm) in Thickness or E 186 Reference Radiographs for Heavy Walled [2 to $4\frac{1}{2}$ in. (50 to 114 mm)] Steel Castings, depending upon the section thickness. The maximum acceptable severity level for a 1.0 quality factor shall be as listed in Table 102.4.6(B.1.1).

(B.1.2) All surfaces of each casting, including machined gasket seating surfaces, shall be examined by the magnetic particle or dye penetrant method after heat treatment. The examination techniques shall be in accordance with Article 6 or 7, as applicable, and Article 9 of Section V of the ASME Boiler and Pressure Vessel Code. Magnetic particle or dye penetrant indications exceeding degree 1 of Type I, degree 2 of Type II, and degree 3 of Type III, and exceeding degree 1 of Types IV and V of ASTM E 125, Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings, are not acceptable and shall be removed.

(B.1.3) Where more than one casting of a particular design is produced, each of the first five castings shall be inspected as above. Where more than five castings are being produced, the examination shall be performed on the first five plus one additional casting to represent each five additional castings. If this additional casting proves to be unacceptable, each of the remaining castings in the group shall be inspected.

(B.1.4) Any discontinuities in excess of the maximum permitted in (B.1.1) and (B.1.2) above shall be removed, and the casting may be repaired by welding after the base metal has been inspected to assure complete removal of discontinuities. [Refer to para. 127.4.11(A).] The completed repair shall be subject to

TABLE 102.4.3
LONGITUDINAL WELD JOINT EFFICIENCY FACTORS

No.	Type of Joint	Type of Seam	Examination	Factor E
1	Furnace butt weld, continuous weld 	Straight	As required by listed specification	0.60 [Note (1)]
2	Electric resistance weld 	Straight or spiral	As required by listed specification	0.85 [Note (1)]
3	Electric fusion weld			
	(a) Single butt weld (without filler metal) 	Straight or spiral	As required by listed specification Additionally 100% radiographed	0.85 1.00 [Note (2)]
	(b) Single butt weld (with filler metal) 	Straight or spiral	As required by listed specification Additionally 100% radiographed	0.80 1.00 [Note (2)]
	(c) Double butt weld (without filler metal) 	Straight or spiral	As required by listed specification Additionally 100% radiographed	0.90 1.00 [Note (2)]
	(d) Double butt weld (with filler metal) 	Straight or spiral	As required by listed specification Additionally 100% radiographed	0.90 1.00 [Note (2)]
4	API 5L — Submerged arc weld (SAW) Gas metal arc weld (GMAW) Combined GMAW, SAW 	Straight with one or two seams Spiral	As required by specification Additionally 100% radiographed	0.90 1.00 [Note (2)]

NOTES:
(1) It is not permitted to increase the longitudinal weld joint efficiency factor by additional examination for joint 1 or 2.
(2) Radiography shall be in accordance with the requirements of para. 136.4.5 or the material specification as applicable.

reinspection by the same method as was used in the original inspection and shall be reinspected after any required postweld heat treatment.

(B.2) All steel castings having a nominal body thickness greater than $4\frac{1}{2}$ in. (114 mm) (other than pipe flanges, flanged valves and fittings, and butt welding end valves, all complying with ASME B16.5 or B16.34) shall be inspected as follows.

(B.2.1) All surfaces of each casting including machined gasket seating surfaces, shall be examined by the magnetic particle or dye penetrant method after heat treatment. The examination techniques shall be in accordance with Article 6 or 7, as applicable, and with Article 9 of Section V of the ASME Boiler and Pressure Vessel Code. Magnetic particle or dye penetrant indications exceeding degree 1 of Type I, degree 2 of Type II, and degree 3 of Type III and exceeding degree 1 of Types IV and V of ASTM E 125, Standard Reference

TABLE 102.4.5

Radius of Bends	Min. Thickness Recommended Prior to Bending
6 pipe diameters or greater	$1.06 t_m$
5 pipe diameters	$1.08 t_m$
4 pipe diameters	$1.14 t_m$
3 pipe diameters	$1.25 t_m$

GENERAL NOTES:

(a) Interpolation is permissible for bending to intermediate radii.

(b) t_m is determined by Formula (3) or (3A) of para. 104.1.2(A).

(c) Pipe diameter is the nominal diameter as tabulated in ASME B36.10M, Tables 2 and 4, and ASME B36.19M, Table 1. For piping with a diameter not listed in these Tables, and also for tubing, the nominal diameter corresponds with the outside diameter.

Photographs for Magnetic Particle Indications on Ferrous Castings, shall be removed.

(B.2.2) All parts of castings shall be subjected to complete radiographic inspection in accordance with Article 2 of Section V of the ASME Boiler and Pressure Vessel Code, and the radiographs shall conform to the requirements of ASTM E 280, Reference Radiographs for Heavy Walled [4½ to 12 in. (114 to 305 mm)] Steel Castings.

The maximum acceptable severity level for a 1.0 quality factor shall be as listed in Table 102.4.6 (B.2.2).

(B.2.3) Any discontinuities in excess of the maximum permitted in (B.2.1) and (B.2.2) above shall be removed and may be repaired by welding after the base metal has been magnetic particle or dye penetrant inspected to assure complete removal of discontinuities. [Refer to para. 127.4.11(A).]

(B.2.4) All weld repairs of depth exceeding 1 in. (25 mm) or 20% of the section thickness, whichever is the lesser, shall be inspected by radiography in accordance with (B.2.2) above and by magnetic particle or dye penetrant inspection of the finished weld surface. All weld repairs of depth less than 20% of the section thickness, or 1 in. (25 mm), whichever is the lesser, and all weld repairs of section which cannot be effectively radiographed shall be examined by magnetic particle or dye penetrant inspection of the first layer, of each ¼ in. (6 mm) thickness of deposited weld metal, and of the finished weld surface. Magnetic particle or dye penetrant testing of the finished weld surface shall be done after postweld heat treatment.

(C) For cast iron and nonferrous materials, no increase of the casting quality factor is allowed except when special methods of examination, prescribed by the material specification, are followed. If such increase is specifically permitted by the material specification, a factor not exceeding 1.0 may be applied.

PART 2
PRESSURE DESIGN OF PIPING COMPONENTS

103 CRITERIA FOR PRESSURE DESIGN OF PIPING COMPONENTS

The design of piping components shall consider the effects of pressure and temperature, in accordance with paras. 104.1 through 104.7, including the consideration of allowances permitted by paras. 102.2.4 and 102.4. In addition, the mechanical strength of the piping system shall be determined adequate in accordance with para. 104.8 under other applicable loadings, including but not limited to those loadings defined in para. 101.

104 PRESSURE DESIGN OF COMPONENTS

104.1 Straight Pipe

104.1.2 Straight Pipe Under Internal Pressure

(A) Minimum Wall Thickness. The minimum thickness of pipe wall required for design pressures and for temperatures not exceeding those for the various materials listed in the Allowable Stress Tables, including allowances for mechanical strength, shall not be less than that determined by Formula (3) or (3A), as follows:

$$t_m = \frac{PD_o}{2(SE + Py)} + A \qquad (3)^1$$

$$t_m = \frac{Pd + 2SEA + 2yPA}{2(SE + Py - P)} \qquad (3A)^1$$

Design pressure shall not exceed

$$P = \frac{2SE(t_m - A)}{D_o - 2y(t_m - A)} \qquad (4)^1$$

$$P = \frac{2SE(t_m - A)}{d - 2y(t_m - A) + 2t_m} \qquad (4A)^1$$

[1] *SF* shall be used in place of *SE* where casting quality factors are intended. See definition of *SE*. Units of *P* and *SE* must be identical. Appendix A values must be converted to kPa when the design pressure is in kPa.

TABLE 102.4.6(B.1.1)

Discontinuity Category Designation	Severity Level ≤1 in. (25 mm) Thick	Severity Level >1 in. (25 mm) Thick
For E 446 [Castings up to 2 in. (50 mm) Thickness]		
A	1	2
B	2	3
C Types 1, 2, 3, and 4	1	3
D, E, F, and G	None acceptable	None acceptable

Discontinuity Category Designation	Severity Level
For E 186 [Castings 2 to $4\frac{1}{2}$ in. (50 to 114 mm) Thickness]	
A, B, and Types 1 and 2 of C	2
Type 3 of C	3
D, E, and F	None acceptable

TABLE 102.4.6(B.2.2)

Discontinuity Category Designation	Severity Level
A, B, and Types 1,2, and 3 of C	2
D, E, and F	None acceptable

where the nomenclature used above are:

(A.1) t_m = minimum required wall thickness, in. (mm)

(A.1.1) If pipe is ordered by its nominal wall thickness, the manufacturing tolerance on wall thickness must be taken into account. After the minimum pipe wall thickness t_m is determined by Formula (3) or (3A), this minimum thickness shall be increased by an amount sufficient to provide the manufacturing tolerance allowed in the applicable pipe specification or required by the process. The next heavier commercial wall thickness shall then be selected from thickness schedules such as contained in ASME B36.10M or from manufacturers' schedules for other than standard thickness.

(A.1.2) To compensate for thinning in bends, refer to para. 102.4.5.

(A.1.3) For cast piping components, refer to para. 102.4.6.

(A.1.4) Where ends are subject to forming or machining for jointing, the wall thickness of the pipe, tube, or component after such forming or machining shall not be less than t_m minus the amount provided for removal by para. 104.1.2 (A.6.1).

(A.2) P = internal design pressure, psig [kPa (gage)]

NOTE: When computing the design pressure for a pipe of a definite minimum wall thickness by Formula (4) or (4A), the value of P obtained by these Formulas may be rounded out to the next higher unit of 10. For cast iron pipe, see para. 104.1.2(B).

(A.3) D_o = outside diameter of pipe, in. (mm). For design calculations, the outside diameter of pipe as given in tables of standards and specifications shall be used in obtaining the value of t_m. When calculating the allowable working pressure of pipe on hand or in stock, the actual measured outside diameter and actual measured minimum wall thickness at the thinner end of the pipe may be used to calculate this pressure.

(A.4) d = inside diameter of pipe, in. (mm). For design calculations, the inside diameter of pipe is the maximum possible value allowable under the purchase specification. When calculating the allowable working pressure of pipe on hand or in stock, the actual measured inside diameter and actual measured minimum wall thickness at the thinner end of the pipe may be used to calculate this pressure.

TABLE 104.1.2(A)
VALUES OF y

Temperature, °F	900 and Below	950	1000	1050	1100	1150	1200	1250 and Above
Temperature, °C	482 and Below	510	538	566	593	621	649	677 and Above
Ferritic steels	0.4	0.5	0.7	0.7	0.7	0.7	0.7	0.7
Austenitic steels	0.4	0.4	0.4	0.4	0.5	0.7	0.7	0.7
Nickel Alloys UNS Nos. N08800, N08810, N08825	0.4	0.4	0.4	0.4	04	0.4	0.5	0.7

GENERAL NOTES:

(a) The value of y may be interpolated between the 50°F (27.8°C) values shown in the Table. For cast iron and nonferrous materials, y equals 0.4.

(b) For pipe with a D_o/t_m ratio less than 6, the value of y for ferritic and austenitic steels designed for temperatures of 900°F (480°C) and below shall be taken as:

$$y = \frac{d}{d + D_o} \tag{5}$$

(A.5) SE or *SF* = maximum allowable stress in material due to internal pressure and joint efficiency (or casting quality factor) at the design temperature, psi (kPa). The value of *SE* or *SF* shall not exceed that given in Appendix A, for the respective material and design temperature. These values include the weld joint efficiency *E*, or the casting factor *F*.

(A.6) A = additional thickness, in. (mm):

(A.6.1) to compensate for material removed in threading, grooving, etc., required to make a mechanical joint, refer to para. 102.4.2;

(A.6.2) to provide for mechanical strength of the pipe, refer to para. 102.4.4 (not intended to provide for extreme conditions of misapplied external loads or for mechanical abuse);

(A.6.3) to provide for corrosion and/or erosion, refer to para. 102.4.1;

(A.6.4) for cast iron pipe the following values of *A* shall apply:

Centrifugally cast . . . . 0.14 in. (3.56 mm)
Statically cast . . . . 0.18 in. (4.57 mm)

(A.7) y = coefficient having values as given in Table 104.1.2(A)

(B) The thickness of gray and ductile iron pipe and fittings conveying liquids may be determined from ANSI/AWWA C110/A21.10, ANSI/AWWA C115/A21.15, ANSI/AWWA C150/A21.50, ANSI/AWWA C151/A21.51, or Federal Specification WW-P-421, using the class of pipe for the pressure next higher than the desired internal design pressure in psi (kPa). These thickness include allowances for foundry tolerances and water hammer. Where the thickness of ductile iron pipe for liquid service is calculated, the methods of ANSI/AWWA C115/A21.15, or ANSI/AWWA C150/A21.50 may be used.

Where cast gray and ductile iron pipe is used for steam service, the thickness shall be calculated in accordance with Formula (3) or (3A) using the allowable stress value from the Allowable Stress Tables.

(C) While the thickness determined from Formula (3) or (3A) are theoretically ample for both bursting pressure and material removed in threading, the following minimum requirements are mandatory to furnish added mechanical strength.

(C.1) Where steel pipe is threaded and used for steam service at pressure above 250 psi (1750 kPa) or for water service above 100 psi (700 kPa) with water temperature above 220°F (105°C), the pipe shall be seamless having the minimum ultimate tensile strength of 48,000 psi (330 MPa) and a weight at least equal to Schedule 80 of ASME B36.10M. 01

(C.2) Where threaded brass or copper pipe is used for the services described in (C.1) above, it shall comply with pressure and temperature classifications permitted for these materials by other paragraphs of this Code and shall have a wall thickness at least equal to that specified above for steel pipe of corresponding size.

(C.3) Plain end nonferrous pipe or tube shall have minimum wall thicknesses as follows.

For nominal sizes smaller than NPS $^3/_4$, the thickness shall not be less than that specified for Type K of ASTM B 88.

For nominal sizes NPS $^3/_4$ and larger, the wall thickness shall not be less than 0.049 in. (1.25 mm). The wall thickness shall be further increased, as required, in accordance with para. 102.4.

104.1.3 Straight Pipe Under External Pressure. For determining wall thickness and stiffening requirements for straight pipe under external pressure, the procedures outlined in UG-28, UG-29, and UG-30 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code shall be followed.

104.2 Curved Segments of Pipe

104.2.1 Pipe Bends. Pipe bends shall be subject to the following limitations.

(A) The minimum wall thickness shall meet the requirements of para. 102.4.5 and the fabrication requirements of para. 129.

(B) For ferrous material, when the radius of a bend is 5 nominal pipe diameters or greater, and the nominal wall thickness of the pipe is schedule 40 or thicker, the difference between maximum and minimum diameters shall not exceed 8% of average measured outside diameter of the pipe before bending.

(C) Greater flattening may be permitted or less flattening may be required by the design, depending upon the service, the material, and the stress level involved.

104.2.2 Elbows. Elbows manufactured in accordance with the standards listed in Table 126.1 are suitable for use at the pressure-temperature ratings specified by such standards, subject to the requirements of para. 106.

104.3 Intersections

104.3.1 Branch Connections

(A) This paragraph gives rules governing the design of branch connections to sustain internal and external pressure in cases where the axes of the branch and the run intersect, and the angle between the axes of the branch and of the run is between 45 deg and 90 deg, inclusive.

Branch connections in which the smaller angle between the axes of the branch and the run is less than 45 deg or branch connections where the axes of the branch and the run do not intersect impose special design and fabrication problems. The rules given herein may be used as a guide, but sufficient additional strength must be provided to assure safe service. Such branch connections shall be designed to meet the requirement of para. 104.7.

(B) Branch connections in piping may be made from materials listed in Appendix A by the use of the following:

(B.1) fittings, such as tees, laterals, and crosses made in accordance with the applicable standards listed in Table 126.1 where the attachment of the branch pipe to the fitting is by butt welding, socket welding, brazing, soldering, threading, or by a flanged connection;

(B.2) weld outlet fittings, such as cast or forged nozzles, couplings and adaptors, or similar items where the attachment of the branch pipe to the fitting is by butt welding, socket welding, threading, or by a flanged connection. Such weld outlet fittings are attached to the run by welding similar to that shown in Fig. 127.4.8(E). Couplings are restricted to a maximum of NPS 3.

(B.3) extruded outlets at right angles to the run pipe, in accordance with (G) below, where the attachment of the branch pipe is by butt welding;

(B.4) piping directly attached to the run pipe by welding in accordance with para. 127.4.8 or by socket welding or threading as stipulated below:

(B.4.1) socket welded right angle branch connections may be made by attaching the branch pipe directly to the run pipe provided:

(B.4.1.1) the nominal size of the branch does not exceed NPS 2 or one-fourth of the nominal size of the run, whichever is smaller;

(B.4.1.2) the depth of the socket measured at its minimum depth in the run pipe is at least equal to that shown in ASME B16.11. If the run pipe wall does not have sufficient thickness to provide the proper depth of socket, an alternate type of construction shall be used.

(B.4.1.3) the clearance between the bottom of the socket and the end of the inserted branch pipe is in accordance with Fig. 127.4.4(C);

(B.4.1.4) the size of the fillet weld is not less than 1.09 times the nominal wall thickness of the branch pipe.

(B.4.2) threaded right angle branch connections may be made by attaching the branch pipe directly to the run provided:

(B.4.2.1) the nominal size of the branch does not exceed NPS 2 or one-fourth of the nominal size of the run whichever is smaller;

(B.4.2.2) the minimum thread engagement is: 6 full threads for NPS $^1/_2$ and NPS $^3/_4$ branches; 7 for NPS 1, NPS $1^1/_4$, and NPS $1^1/_2$ branches; and 8 for NPS 2

branches. If the run pipe wall does not have sufficient thickness to provide the proper depth for thread engagement, an alternative type of construction shall be used.

(C) Branch Connections Not Requiring Reinforcement. A pipe having a branch connection is weakened by the opening that must be made in it. Unless the wall thickness of the branch and/or run pipe is sufficiently in excess of that required to sustain the pressure, it is necessary to provide additional material in order to meet the reinforcement requirements of (D) and (E) below. However, there are certain branch connections for which supporting calculations are not required. These are as follows:

(C.1) branch connections made by the use of a fitting (tee, lateral, cross, or branch weld-on fitting), manufactured in accordance with a standard listed in Table 126.1, and used within the limits of pressure-temperature ratings specified in that standard;

(C.2) branch connections made by welding a coupling or half coupling directly to the run pipe in accordance with Fig. 127.4.8(E) provided the nominal diameter of the branch does not exceed NPS 2 or one-fourth the nominal diameter of the run, whichever is less. The minimum wall thickness of the coupling anywhere in the reinforcement zone (if threads are in the zone, wall thickness is measured from the root of the thread to the minimum O.D.) shall not be less than that of the unthreaded branch pipe. In no case shall the thickness of the coupling be less than extra heavy or Class 3000 rating.

Small branch connections NPS 2 or smaller as shown in Fig. 127.4.8(F) may be used provided t_w is not less than the thickness of schedule 160 pipe of the branch size.

(C.3) integrally reinforced fittings welded directly to the run pipe when the reinforcements provided by the fitting and the deposited weld metal meets the requirements of (D) below.

(C.4) integrally reinforced extruded outlets in the run pipe. The reinforcement requirements shall be in accordance with (G) below.

(D) Branch Connections Subject to Internal Pressure Requiring Reinforcement

(D.1) Reinforcement is required when it is not provided inherently in the components of the branch connection. This paragraph gives rules covering the design of branch connections to sustain internal pressure in cases where the angle between the axes of the branch and of the run is between 45 deg and 90 deg Subparagraph (E) below gives rules governing the design of connections to sustain external pressure.

(D.2) Figure 104.3.1(D) illustrates the notations used in the pressure-temperature design conditions of branch connections but does not illustrate the allowances for mill tolerance or any other wall thickness allowance. The designer shall make proper allowances for the effects of corrosion or erosion, threading and grooving, and mechanical strength as specified in paras. 102.4.1, 102.4.2, and 102.4.4 in order that the required minimum reinforcement is assured over the design life of the piping system. These notations are as follows:

α = angle between axes of branch and run, deg

b = subscript referring to branch

D_o = outside diameter of pipe, in. (mm)

d_1 = inside center line longitudinal dimension of the finished branch opening in the run of the pipe, in. (mm)
= $[D_{ob} - 2(T_b - A)]/\sin\alpha$

d_2 = "half width" of reinforcing zone, in. (mm)
= the greater of d_1 or $(T_b - A) + (T_h - A) + d_1/2$ but in no case more than D_{oh}, in. (mm)

h = subscript referring to run or header

L_4 = altitude of reinforcement zone outside of run, in. (mm)
= $2.5(T_b - A) + t_r$ or $2.5(T_h - A)$, whichever is smaller

t_r = thickness of attached reinforcing pad, in Example B, in. (mm); or height of the largest 60 deg right triangle supported by the run and branch outside diameter projected surfaces and lying completely within the area of integral reinforcement, in Example C, in. (mm)

T_b, T_h = actual (by measurement), or minimum wall thickness of the branch or header pipe, in. (mm), permissible under purchase specification

t_{mb}, t_{mh} = required minimum wall thickness, in. (mm), of the branch or header pipe as determined by use of Formula (3) or (3A) in para. 104.1.2(A)

(D.2.1) If the run pipe contains a longitudinal seam which is not intersected by the branch, the stress value of seamless pipe of comparable grade may be used to determine the value of t_{mh} for the purpose of reinforcement calculations only. If the branch intersects a longitudinal weld in the run, or if the branch contains a weld, the weld joint efficiency for either or both shall enter the calculations. If the branch and run both contain longitudinal welds, care shall be taken to ensure that the two welds do not intersect each other.

required reinforcement = $(t_{mh})(d_1)(2 - \sin\alpha) = A_7$

reinforcement areas = A_1, A_2, A_3, A_4, and A_5

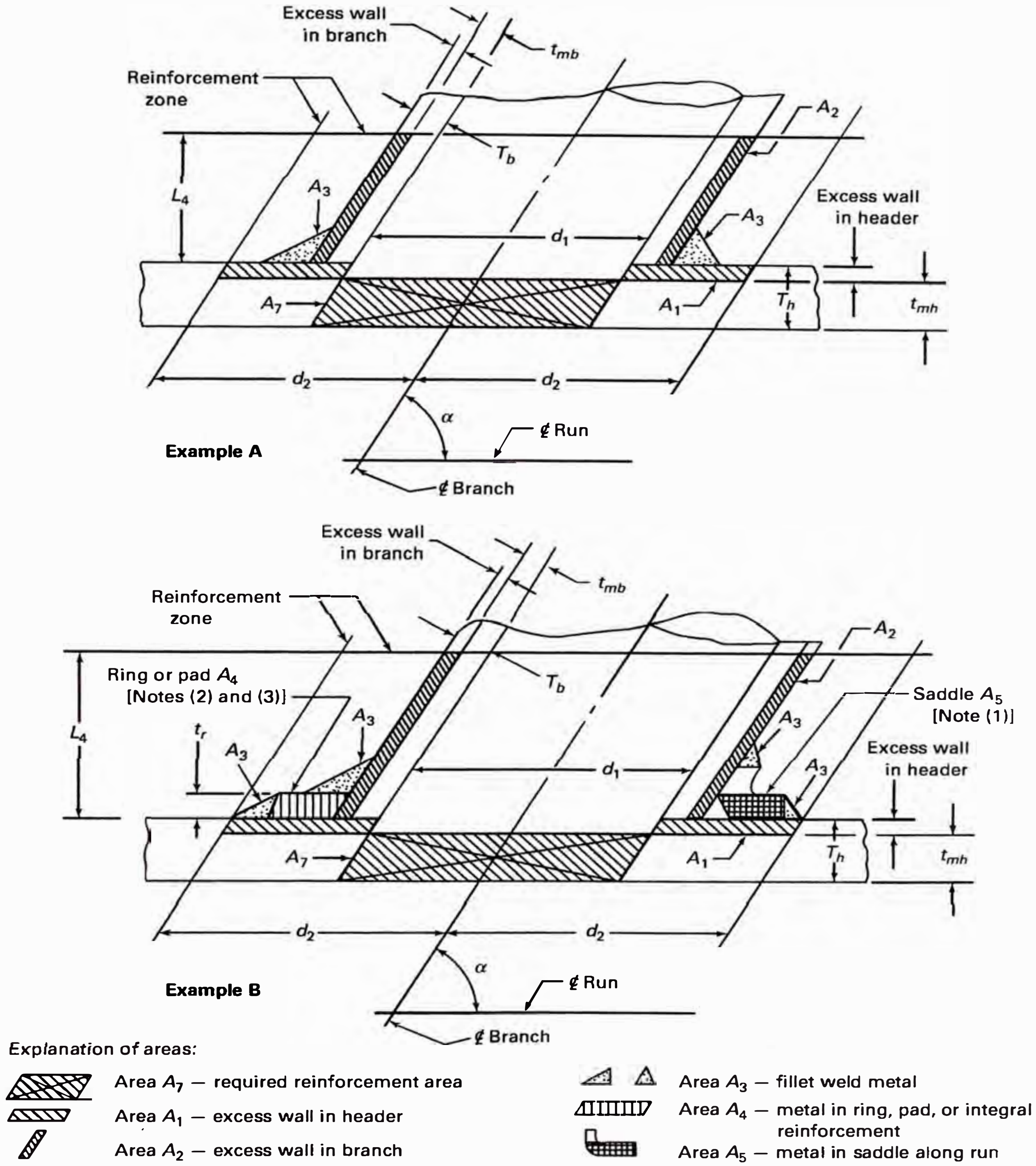
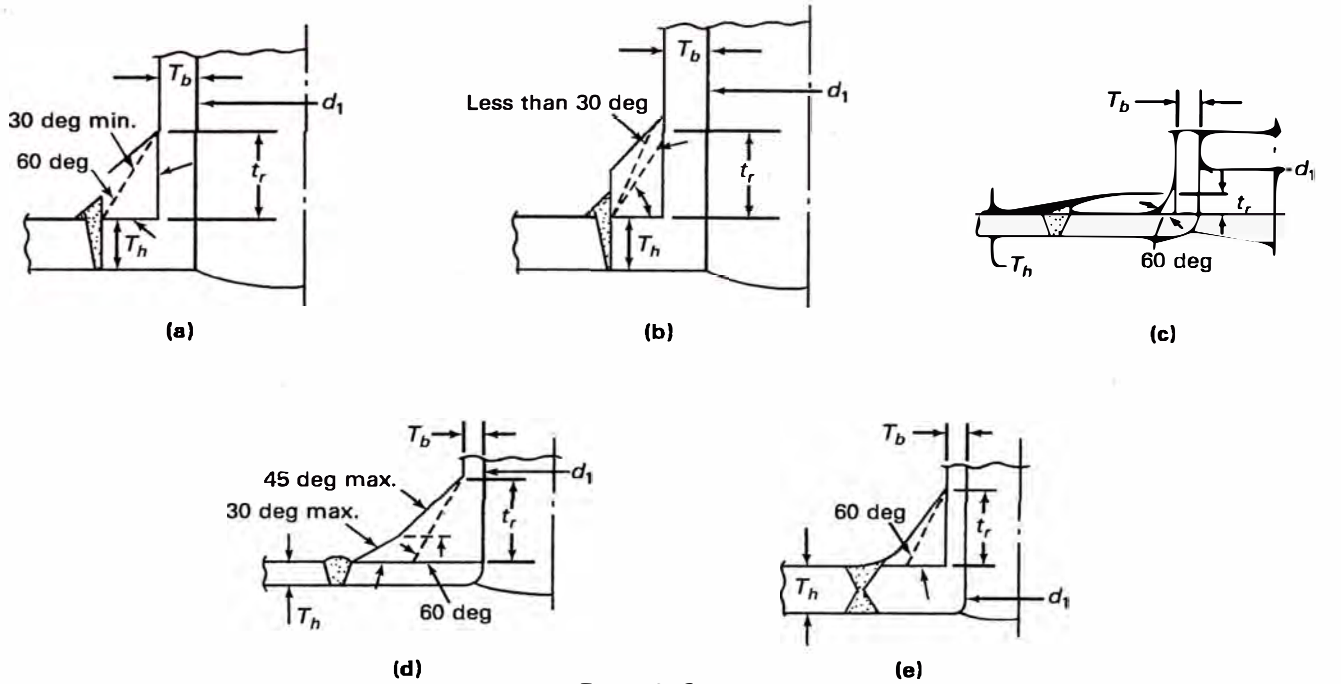


FIG. 104.3.1(D) REINFORCEMENT OF BRANCH CONNECTIONS



Example C

NOTES:

(1) Reinforcing saddles are limited to use on 90 deg branches.

(2) When a ring or pad is added as reinforcement (Example B), the value of reinforcing area may be taken in the same manner in which excess header metal is considered, provided the weld completely fuses the branch pipe, header pipe, and ring or pad. *Typical acceptable methods of welding that meet the above requirement are shown in Fig. 127.4.8(D), examples (c)* and (d).

(3) Width to height of rings and pads shall be reasonably proportioned, preferably on a ratio as close to 4:1 as the available horizontal space within the limits of the reinforcing zone along the run and the O.D. of the branch will permit, but in no case may the ratio be less than 1:1.

FIG. 104.3.1(D) REINFORCEMENT OF BRANCH CONNECTIONS (CONT'D)

01 *(D.2.2)* The required reinforcement area in square inches (square millimeters) for branch connections shall be the quantity

$$A_7 = (t_{mh} - A)d_1\ (2 - \sin\alpha)$$

For right angle connections the required reinforcement becomes

$$A_7 = t_{mh}d_1$$

The required reinforcement must be within the limits of the reinforcement zone as defined in (D.2.4) below.

(D.2.3) The reinforcement required by (D.2) shall *be that provided by any combination of areas* A_1, A_2, A_3, A_4, and A_5, as defined below and illustrated in Fig. 104.3.1 (D) where

A_1 = area provided by excess pipe wall in the run
= $(2d_2 - d_1)(T_h - t_{mh})$

A_2 = area, in.^{2} (mm^2), provided by excess pipe wall in the branch for a distance L_4 above the run
= $2L_4\ (T_b - t_{mb})/\sin\alpha$

A_3 = area provided by deposited weld metal beyond the outside diameter of the run and branch, and for fillet weld attachments of rings, pads, and saddles

A_4 = are provided by a reinforcing ring, pad, or integral reinforcement. The value of A_4 may be taken in the same manner in which excess header metal is considered, provided the weld completely fuses the branch pipe, run pipe, and ring or pad, or integral reinforcement. For welding branch connections refer to para. 127.4.8.

A_5 = area provided by a saddle on right angle connections
= (O.D. of saddle − D_{ob})t_r

Portions of the reinforcement area may be composed of materials other than those of the run pipe, but if the allowable stress of these materials is less than that for the run pipe, the corresponding calculated reinforcement area provided by this material shall be reduced in the ratio of the allowable stress being applied to the reinforcement area. No additional credit shall be taken for materials having higher allowable stress values than the run pipe.

(D.2.4) Reinforcement Zone. The reinforcement zone is a parallelogram whose width shall extend a distance d_2 on each side of the center line of the branch pipe, and whose altitude shall start at the inside surface of the run pipe and extend to a distance L_4 from the outside surface of the run pipe.

(D.2.5) Reinforcement of Multiple Openings. It is preferred that multiple branch openings be spaced so that their reinforcement zones do not overlap. If closer spacing is necessary, the following requirement shall be met. The two or more openings shall be reinforced in accordance with (D.2), with a combined reinforcement that has a strength equal to the combined strength of the reinforcement that would be required for the separate openings. No portion of the cross section shall be considered as applying to more than one opening, or be evaluated more than once in a combined area.

When more than two adjacent openings are to be provided with a combined reinforcement, the minimum distance between centers of any two of these openings should preferably be at least $1\frac{1}{2}$ times their average diameter, and the area of reinforcement between them shall be at least equal to 50% of the total required for these two openings.

(D.2.6) Rings, Pads, and Saddles. Reinforcement provided in the form of rings, pads, or saddles shall not be appreciably narrower at the side than at the crotch.

A vent hole shall be provided at the ring, pad, or saddle to provide venting during welding and heat treatment. Refer to para. 127.4.8(E).

Rings, pads, or saddles may be made in more than one piece, provided the joints between pieces have full thickness welds, and each piece is provided with a vent hole.

(D.2.7) Other Designs. The adequacy of designs to which the reinforcement requirements of para. 104.3 cannot be applied shall be proven by burst or proof tests on scale models or on full size structures, or by calculations previously substantiated by successful service of similar design.

(E) Branch Connections Subject to External Pressure Requiring Reinforcement. The reinforcement area in square inches (square millimeters) required for branch connections subject to external pressure shall be

$$0.5 t_{mh} d_1 \, (2 - \sin \alpha)$$

Procedures established heretofore for connections subject to internal pressure shall apply for connections subject to external pressure provided that D_{oh}, D_{ob}, and t_r are reduced to compensate for external corrosion, if required by design conditions.

(F) Branch Connections Subject to External Forces and Moments. The requirements of the preceding paragraphs are intended to assure safe performance of a branch connection subjected only to pressure. However, when external forces and moments are applied to a branch connection by thermal expansion and contraction, by dead weight of piping, valves, and fittings, covering and contents, or by earth settlement, the branch connection shall be analyzed considering the stress intensification factors as specified in Appendix D. Use of ribs, gussets, and clamps designed in accordance with para. 104.3.4 is permissible to stiffen the branch connection, but their areas cannot be counted as contributing to the required reinforcement area of the branch connection.

(G) Extruded Outlets Integrally Reinforced

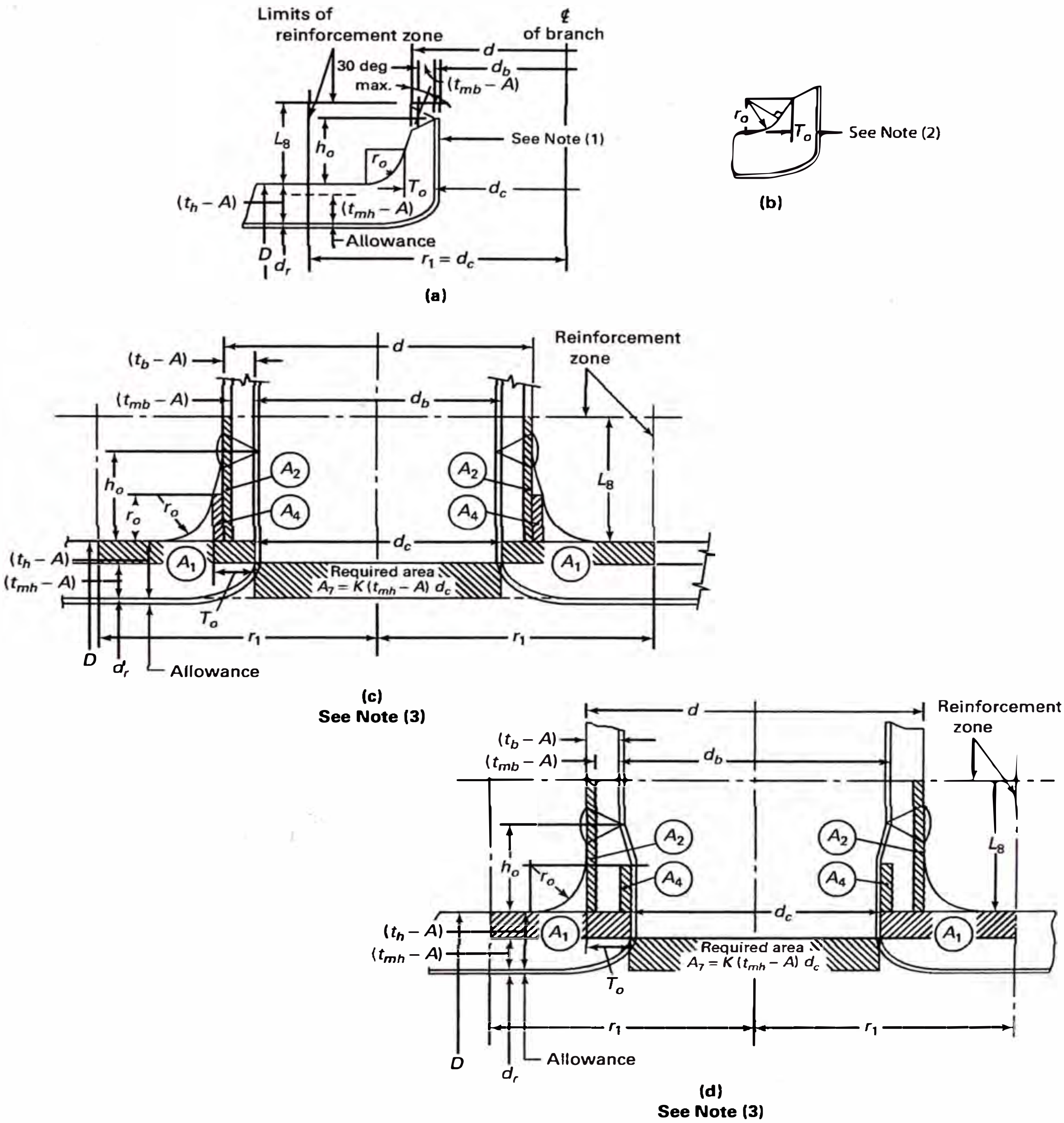
(G.1) The following definitions, modifications, notations, and requirements are specifically applicable to extruded outlets. The designer shall make proper wall thickness allowances in order that the required minimum reinforcement is assured over the design life of the system.

(G.2) Definition. An extruded outlet header is defined as a header in which the extruded lip at the outlet has an altitude above the surface of the run which is equal to or greater than the radius of curvature of the external contoured portion of the outlet; i.e., $h_o \geq r_o$. See nomenclature and Fig. 104.3.1(G).

(G.3) These rules apply only to cases where the axis of the outlet intersects and is perpendicular to the axis of the run. These rules do not apply to any nozzle in which additional nonintegral material is applied in the form of rings, pads, or saddles.

(G.4) The notation used herein is illustrated in Fig. 104.3.1(G). All dimensions are in inches (millimeters).

d = outside diameter of branch pipe
d_b = corroded internal diameter of branch pipe
D = outside diameter of run



NOTES:

(1) Taper bore inside diameter (if required) to match branch pipe 1:3 maximum taper.

(2) Sketch to show method of establishing T_o when the taper encroaches on the crotch radius.

(3) Sketch is drawn for condition where $k = 1.00$.

FIG. 104.3.1(G) REINFORCED EXTRUDED OUTLETS

d_r = corroded internal diameter of run

d_c = corroded internal diameter of extruded outlet measured at the level of the outside surface of the run

h_o = height of the extruded lip. This must be equal to or greater than r_o except as shown in (G.4.2) below.

L_8 = altitude of reinforcement zone
= $0.7\sqrt{dT_o}$

$t_{mb} - A$ = required thickness of branch pipe according to wall thickness Formula (3) or (3A) in para. 104.1.2(A), but not including any thickness for corrosion

$t_b - A$ = actual thickness of branch wall not including corrosion allowance

$t_{mh} - A$ = required thickness of the run according to the Formula (3) or (3A) in para. 104.1.2(A), but not including any allowance for corrosion

$t_h - A$ = actual thickness of run wall, not including the corrosion allowance

T_o = corroded finished thickness of extruded outlet measured at a height equal to r_o above the outside surface of the run

r_1 = half width of reinforcement zone (equal to d_c)

r_o = radius of curvature of external contoured portion of outlet measured in the plane containing the axes of the run and branch. This is subject to the following limitations.

(G.4.1) Minimum Radius. This dimension shall not be less than 0.05d except that on branch diameters larger than NPS 30, it need not exceed 1.50 in. (38 mm).

(G.4.2) Maximum Radius. For outlet pipe sizes 6 in. nominal and larger, this dimension shall not exceed 0.10d + 0.50 in. (0.10d + 12.7 mm). For outlet pipe sizes less than NPS 6, this dimension shall not be greater than 1.25 in. (32 mm).

(G.4.3) When the external contour contains more than one radius, the radius of any arc sector of approximately 45 deg shall meet the requirements of (G.4.1) and (G.4.2) above. When the external contour has a continuously varying radius, the radius of curvature at every point on the contour shall meet the requirements of (G.4.1) and (G.4.2) above.

(G.4.4) Machining other than grinding for weld cleanup shall not be employed in order to meet the above requirements.

(G.5) Required Area. The required area is defined as

$$A_7 = K\,(t_{mh} - A)\,d_c$$

where K shall be taken as follows.

For d/D greater than 0.60,

$$K = 1.00$$

For d/D greater than 0.15 and not exceeding 0.60,

$$K = 0.6 + \tfrac{2}{3}\,d/D$$

For d/D equal to or less than 0.15,

$$K = 0.70$$

The design must meet criteria that the reinforcement area defined in (G.6) below is not less than the required area.

(G.6) Reinforcement Area. The reinforcement area shall be the sum of areas

$$A_1 + A_2 + A_4$$

as defined below.

(G.6.1) Area A_1 is the area lying within the reinforcement zone resulting from any excess thickness available in the run wall.

$$A_1 = d_c(t_h - t_{mh})$$

(G.6.2) Area A_2 is the area lying within the reinforcement zone resulting from any excess thickness available in the branch pipe wall.

$$A_2 = 2L_8\,(t_b - t_{mb})$$

(G.6.3) Area A_4 is the area lying within the reinforcement zone resulting from excess thickness available in the extruded outlet lip.

$$A_4 = 2r_o\,[T_o - (t_b - A)]$$

(G.7) Reinforcement of Multiple Openings. It is pre-

ferred that multiple branch openings be spaced so that their reinforcement zones do not overlap. If closer spacing is necessary, the following requirements shall be met. The two or more openings shall be reinforced in accordance with (G) with a combined reinforcement that has a strength equal to the combined strength of the reinforcement that would be required for separate openings. No portion of the cross section shall be considered as applying to more than one opening, or be evaluated more than once in a combined area.

(G.8) In addition to the above, the manufacturer shall be responsible for establishing and marking on the section containing extruded outlets, the design pressure and temperature. The manufacturer's name or trademarks shall be marked on the section.

104.3.3 Miters. Miter joints, and the terminology related thereto, are described in Appendix D. A widely spaced miter with

$$\theta < 9 \sqrt{\frac{t_n}{r}} \text{ deg}$$

shall be considered to be equivalent to a girth buttwelded joint, and the rules of this paragraph do not apply. Miter joints, and fabricated pipe bends consisting of segments of straight pipe welded together, with θ equal to or greater than this calculated value may be used within the limitations described below.

(A) Pressure shall be limited to 10 psi (70 kPa) under the following conditions:

(A.1) the assembly includes a miter weld with $\theta >$ 22.5 deg, or contains a segment which has a dimension

$$B < 6t_n$$

(A.2) the thickness of each segment of the miter is not less than that determined in accordance with para. 104.1;

(A.3) the contained fluid is nonflammable, nontoxic, and incompressible, except for gaseous vents to atmosphere;

(A.4) the number of full pressure cycles is less than 7000 during the expected lifetime of the piping system; and

(A.5) full penetration welds are used in joining miter segments.

(B) Pressure shall be limited to 100 psi (700 kPa) under the conditions defined in (A.2), (A.3), (A.4), and (A.5) above, in addition to the following:

(B.1) the angle θ does not exceed 22.5 deg; and

(B.2) the assembly does not contain any segment which has a dimension

$$B < 6t_n$$

(C) Miters to be used in other services or at design pressures above 100 psi (700 kPa) shall meet the requirements of para. 104.7.

(C.1) When justification under para. 104.7 is based on comparable service conditions, such conditions must be established as comparable with respect to cyclic as well as static loadings.

(C.2) When justification under para. 104.7 is based on an analysis, that analysis and substantiating tests shall consider the discontinuity stresses which exist at the juncture between segments; both for static (including brittle fracture) and cyclic internal pressure.

(C.3) The wall thickness t_s of a segment of a miter shall not be less than specified in (C.3.1) or (C.3.2) below, depending on the spacing.

(C.3.1) For closely-spaced miter bends (see Appendix D for definition)

$$t_s = t_m \frac{2 - r/R}{2(1 - r/R)}$$

(C.3.2) For widely-spaced miters (see Appendix D for definition)

$$t_s = t_m(1 + 0.64\sqrt{r/t_s} \tan \theta)$$

(the above equation requires an iterative or quadratic solution for t_s).

104.3.4 Attachments. External and internal attachments to piping shall be designed so as not to cause flattening of the pipe, excessive localized bending stresses, or harmful thermal gradients in the pipe wall. It is important that such attachments be designed to minimize stress concentrations in applications where the number of stress cycles, due either to pressure or thermal effect, is relatively large for the expected life of the equipment.

104.4 Closures

104.4.1 General. Closures for power piping systems shall meet the applicable requirements of this Code and shall comply with the requirements described in (A) or (B) below. Closures may be made:

(A) by use of closure fittings, such as threaded or welded plugs, caps, or blind flanges, manufactured in

accordance with standards listed in Table 126.1, and used within the specified pressure-temperature ratings; or

(B) in accordance with the rules contained in the ASME Boiler and Pressure Vessel Code, Section I, Power Boilers, PG-31, or Section VIII, Pressure Vessels, Division 1, UG-34 and UW-13, calculated from

$$t_m = t + A$$

where

t = pressure design thickness, calculated for the given closure shape and direction of loading using appropriate equations and procedures in Section I or Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code

The definition of A and the symbols used in determining t shall have the definitions shown herein, instead of those given in the ASME Boiler and Pressure Vessel Code.

Attachment of a welded flat permanent closure with only a single fillet weld is not permitted.

104.4.2 Openings in Closures. Openings in closures may be made by welding, extruding, or threading. Attachment to the closure shall be in accordance with the limitations provided for such connections in para. 104.3.1 for branch connections. If the size of the opening is greater than one-half of the inside diameter of the closure, the opening shall be designed as a reducer in accordance with para. 104.6.

Other openings in closures shall be reinforced in accordance with the requirements of reinforcement for a branch connection. The total cross-sectional area required for reinforcement in any plane passing through the center of the opening and normal to the surface of the closure shall not be less than the quantity of d_5t, where

d_5 = diameter of the finished opening, in. (mm), and t as defined in (B) above

104.5 Pressure Design of Flanges and Blanks

104.5.1 Flanges — General

(A) Flanges of sizes NPS 24 and smaller, that are manufactured in accordance with ASME B16.1 and B16.5, shall be considered suitable for use at the primary service ratings (allowable pressure at service temperature) except the slip-on flanges to ASME B16.5 shall be limited in application to no higher than Class 300 primary pressure service rating. Refer to para. 127.4.4.

For flanges larger than NPS 24, and manufactured in accordance with the Specifications and Standards listed in Table 126.1, the designer is cautioned about the dimensionally different designs that are available, as well as the limitations of their application.

Flanges not made in accordance with the Specifications and Standards listed in Table 126.1 shall be designed in accordance with Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, except that the requirements for fabrication, assembly, inspection, and testing, and the pressure and temperature limits for materials of this Code for Pressure Piping shall govern. Certain notations used in the ASME Code, namely, P, S_a, S_b, and S_f, shall have the meanings described below instead of those given in the ASME Code. All other notations shall be as defined in the ASME Code.

P = design pressure, psi (kPa) (see paras. 101.2.2 and 101.2.4)

S_a = bolt design stress at atmospheric temperature, psi (kPa)

S_b = bolt design stress at design temperature, psi (kPa)

S_f = allowable stress for flange material or pipe, psi (kPa) (see para. 102.3.1 and Allowable Stress Tables) (stress values converted from MPa to kPa)

For certain specific applications see the limitations of paras. 122.1.1 (F), (G), and (H).

(B) These flange design rules are not applicable to flat face designs employing full face gaskets which extend beyond the bolts.

(C) The bolt design stress in (A) above shall be as established in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, Appendix P for ferrous materials.

(D) Application of bolting materials for flanged joints is covered in para. 108.5.

104.5.2 Blind Flanges

(A) Blind flanges manufactured in accordance with the standards listed in Table 126.1 shall be considered suitable for use at the pressure-temperature rating specified by such Standards.

(B) The required thickness of blind flanges not manufactured in accordance with standards in Table 126.1 shall be calculated from Formula (6).

$$t_m = t + A \tag{6}$$

where

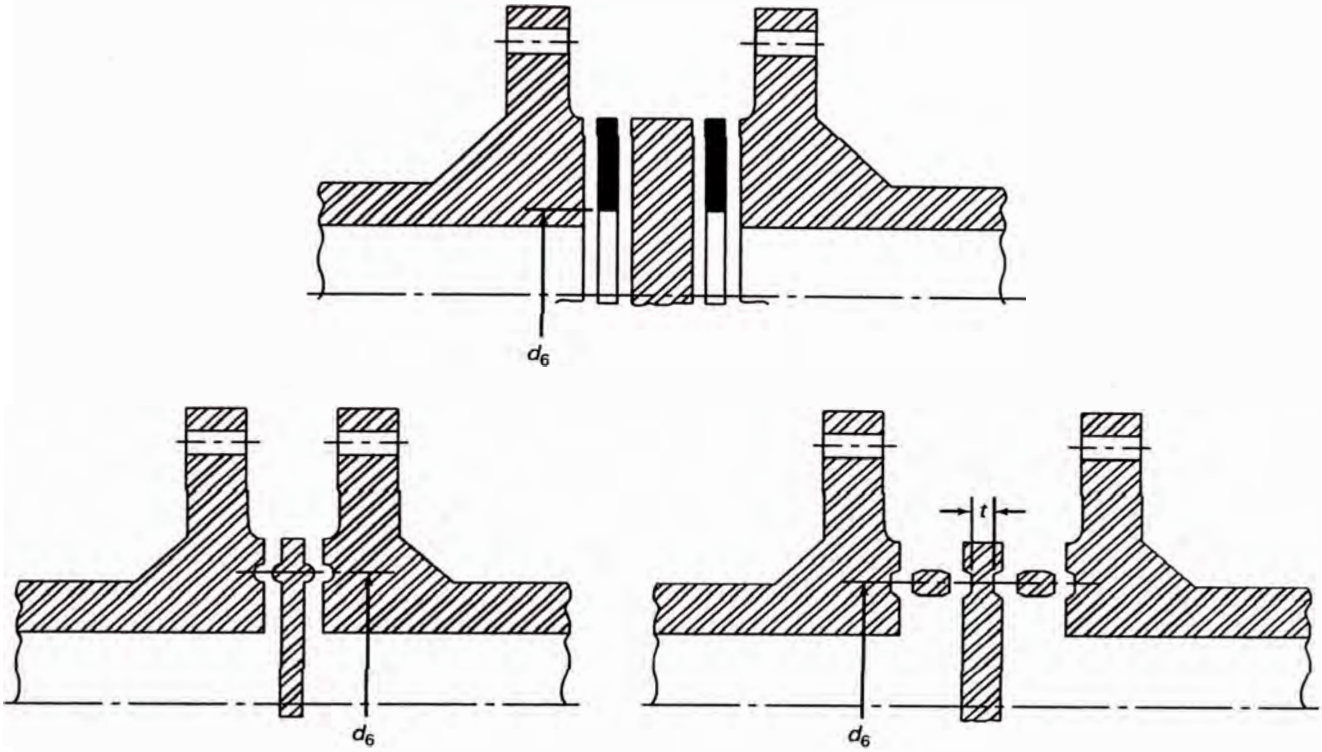


FIG. 104.5.3 TYPES OF PERMANENT BLANKS

t = pressure design thickness as calculated for the given style of blind flange from the appropriate equations for bolted flat cover plates in Section I of the ASME Boiler and Pressure Vessel Code. Certain notations used in these equations, namely, P and SE [see para. 104.1.2(A), footnote 1], shall be considered to have the meanings described in para. 104.1.2(A) instead of those given in the ASME Code. All other notations shall be as defined in the ASME Code.

104.5.3 Blanks

(A) The required thickness of permanent blanks (see Fig. 104.5.3) shall be calculated from the formula

$$t_m = t + A$$

where

t = pressure design thickness as calculated from Formula (7)

$$= d_6\sqrt{\frac{3P}{16SE}} \qquad (7)$$

See para. 104.1.2(A), footnote 1.

d_6 = inside diameter of gasket for raised or flat (plain) face flanges, or the gasket pitch diameter for retained gasketed flanges, in. (mm)

(B) Blanks to be used for test purposes only shall have a minimum thickness not less than the pressure design thickness t specified above except that P shall be not less than the test pressure and SE [see para. 104.1.2(A), footnote 1] may be taken as the specified minimum yield strength of the blank material if the test fluid is incompressible.

(C) Attachment of a welded flat permanent blank with only a single fillet weld is not permitted.

104.6 Reducers

Flanged reducer fittings manufactured in accordance with the Standards listed in Table 126.1 shall be considered suitable for use at the specified pressure-temperature ratings. Where butt welding reducers are made to a nominal pipe thickness, the reducers shall be considered suitable for use with pipe of the same nominal thickness.

104.7 Other Pressure-Containing Components

104.7.1 Pressure-containing components manufactured in accordance with the standards listed in Table 126.1 shall be considered suitable for use under normal operating conditions at or below the specified pressure-temperature ratings. However, the user is cautioned that where certain standards or manufacturers may impose more restrictive allowances for variation from normal operation than those established by this Code, the more restrictive allowances shall apply.

104.7.2 Specially Designed Components. The pressure design of components not covered by the standards listed in Table 126.1 or for which design formulas and procedures are not given in this Code shall be based on calculations consistent with the design criteria of this Code. These calculations shall be substantiated by one or more of the means stated in (A), (B), (C), and (D) below:

(A) extensive, successful service experience under comparable conditions with similarly proportioned components of the same or similar material:

(B) experimental stress analysis, such as described in the ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Appendix 6;

(C) proof test in accordance with either ASME B16.9, MSS SP-97, or the ASME Boiler and Pressure Vessel Code, Section I. A-22; and

(D) detailed stress analysis, such as finite element method, in accordance with the ASME Boiler and Pressure Vessel Code, Division 2, Appendix 4, except that the basic material allowable stress from the Allowable Stress Tables of Appendix A shall be used in place of S_m.

For any of (A) through (D) above, it is permissible to interpolate between sizes, wall thicknesses, and pressure classes and to determine analogies among related materials.

Calculations and documentation showing compliance with this paragraph shall be available for the owner's approval, and, for boiler external piping, they shall be available for the Authorized Inspector's review.

104.8 Analysis of Piping Components

To validate a design under the rules in this paragraph, the complete piping system must be analyzed between anchors for the effects of thermal expansion, weight, other sustained loads, and other occasional loads. Each component in the system must meet the limits in this paragraph. For pipe and fittings, the pressure term in Eqs. (11) and (12) may be replaced with the alternative term for S_{lp} as defined in para. 102.3.2(D). The pressure term in Eqs. (11) and (12) may not apply for bellows and expansion joints. When evaluating stresses in the vicinity of expansion joints, consideration must be given to actual cross-sectional areas that exist at the expansion joint.

104.8.1 Stress due to Sustained Loads. The effects of pressure, weight, and other sustained mechanical loads shall meet the requirements of Eq. (11). 01

English units

$$S_L = \frac{PD_o}{4t_n} + \frac{0.75\ iM_A}{Z} \leq 1.0\ S_h \qquad (11A)$$

Metric units

$$S_L = \frac{PD_o}{4t_n} + \frac{1000\ (0.75i)M_A}{Z} \leq 1.0\ S_h \qquad (11B)$$

where

M_A = resultant moment loading on cross section due to weight and other sustained loads, in-lb (mm-N) (see para. 104.8.4)

Z = section modulus, in.^{3} (mm^3) (see para. 104.8.4)

i = stress intensification factor (see Appendix D). The product 0.75i shall never be taken as less than 1.0.

S_L = sum of the longitudinal stresses due to pressure, weight, and other sustained loads

104.8.2 Stress due to Occasional Loads. The effects of pressure, weight, other sustained loads, and occasional loads including earthquake must meet the requirements of Eq. (12). 01

English units

$$\frac{PD_o}{4t_n} + \frac{0.75iM_A}{Z} + \frac{0.75iM_B}{Z} \leq k\ S_h \qquad (12A)$$

Metric units

$$\frac{PD_o}{4t_n} + \frac{1000(0.75i)M_A}{Z} + \frac{1000(0.75i)M_B}{Z} \le k\,S_h \quad (12B)$$

Terms same as para. 104.8.1 except

k = 1.15 for occasional loads acting for no more than 8 hr at any one time and no more than 800 hr/year [see para. 102.3.3(A)]

k = 1.2 for occasional loads acting for no more than 1 hr at any one time and no more than 80 hr/year [see para. 102.3.3(A)]

M_B = resultant moment loading on cross section due to occasional loads [see para. 102.3.3(A)], such as thrusts from relief/safety valve loads, from pressure and flow transients, and earthquake (see para. 104.8.4). If calculation of moments due to earthquake is required, use only one-half the earthquake moment range. Effects of anchor displacement due to earthquake may be excluded from Eq. (12) if they are included in Eq. (13), in.-lb.

01 **104.8.3 Thermal Expansion Stress Range.** The effects of thermal expansion shall meet the requirements of Eq. (13).

English units

$$S_E = \frac{iM_C}{Z} \le S_A + f\,(S_h - S_L) \quad (13A)$$

Metric units

$$S_E = \frac{1000(iM_C)}{Z} \le S_A + f\,(S_h - S_L) \quad (13B)$$

Terms same as para. 104.8.1 except

M_C = range of resultant moments due to thermal expansion. Also include moments effects of anchor displacement due to earthquake if anchor displacement effects were omitted from Eq. (12) (see para. 104.8.4).

f = stress range reduction factor for cyclic conditions for total number N of full temperature cycles over total number of years during which system is expected to be in operation, from Table 102.3.2(C)

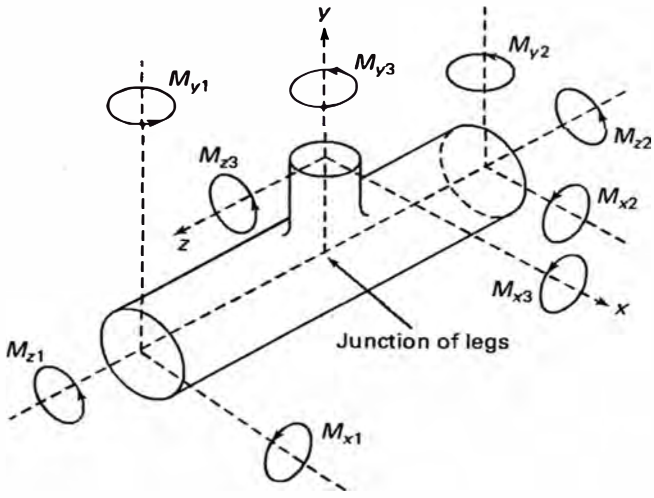


FIG. 104.8.4

104.8.4 Moments and Section Modulus

(A) For purposes of Eqs. (11), (12), and (13), the resultant moments for straight through components, curved pipe, or welding elbows may be calculated as follows:

$$M_j = (M_{xj}^2 + M_{yj}^2 + M_{zj}^2)^{1/2}$$

where

j = A, B, or C as defined in paras. 104.8.1, 104.8.2, and 104.8.3

Z = section modulus of piping, in.^{3} (mm^3)

(B) For full outlet branch connections, calculate the resultant moment of each leg separately in accordance with (A) above. Use Z, section modulus, in Eqs. (11) through (13) as applicable to branch or run pipe. Moments are taken at the junction point of the legs. See Fig. 104.8.4.

(C) For reduced outlets, calculate the resultant moment of each leg separately in accordance with (A) above. Moments are to be taken at the junction point of the legs, unless the designer can demonstrate the validity of a less conservative method. See Fig. 104.8.4. For the *reduced outlet branch*, except for branch connections covered by Fig. D-1:

$$M_A,\ M_B,\ M_C = \sqrt{M_{x3}^2 + M_{y3}^2 + M_{z3}^2}$$

and

Z = $\pi r_b^2 t_e$ (effective section modulus)

r_b = branch mean cross-sectional radius, in. (mm)

t_e = effective branch wall thickness, in. (mm)
= lesser of t_{nh} or it_{nb} in Eq. (13) or lesser of t_{nh} or $0.75it_{nb}$, where $0.75i \geq 1.0$, in Eqs. (11) and (12)

For the *reduced outlet branch connections covered by Fig. D-1:*

$$M_A, M_B, M_C = \sqrt{M_{x3}^2 + M_{y3}^2 + M_{z3}^2}$$

and

$$Z = \pi r'^2_m T_b$$

If L_1 in Fig. D-1 sketches (a), (b), and (c) equals or exceeds $0.5\sqrt{r_i T_b}$, then r'_m can be taken as the radius to the center of T_b when calculating the section modulus and the stress intensification factor. For such a case the transition between branch pipe and nozzle must be evaluated separately from the branch connection.

For the *main run outlets:*

$$M_A, M_B, M_C = \sqrt{M_{x1}^2 + M_{y1}^2 + M_{z1}^2}$$

and

$$M_A, M_B, M_C = \sqrt{M_{x2}^2 + M_{y2}^2 + M_{z2}^2}$$

and

$$Z = \text{section modulus of pipe, in.}^3 \text{ (mm}^3\text{)}$$

PART 3 SELECTION AND LIMITATIONS OF PIPING COMPONENTS

105 PIPE

105.1 General

Pipe conforming to the standards and specifications listed in Appendix A shall be used within the range of temperatures for which allowable stresses are given within the limitations specified herein.

105.2 Metallic Pipe

105.2.1 Ferrous Pipe

(A) Furnace butt welded steel pipe shall not be used for flammable, combustible or toxic fluids.

(B) Cast iron pipe may be used for design pressures within the ratings established by the standards and specifications listed in Tables 126.1 and A-5 and Notes thereto, and the limitations herein and in para. 124.4. Cast iron pipe shall not be used for flammable, combustible, or toxic fluids.

105.2.2 Nonferrous Pipe

(A) Copper and brass pipe for water and steam service may be used for design pressures up to 250 psi (1750 kPa) and for design temperatures to 406°F (208°C).

(B) Copper and brass pipe for air may be used in accordance with the allowable stresses given in the Allowable Stress Tables.

(C) Copper tubing may be used for dead-end instrument service with the limitations stated in para. 122.3.2(D).

(D) Copper, copper alloy, or aluminum alloy pipe or tube may be used under the conditions stated in para. 124.7. Copper, copper alloy, or aluminum pipe or tube shall not be used for flammable, combustible, or toxic fluids except as permitted in paras. 122.7 and 122.8.

105.3 Nonmetallic Pipe 01

(A) Plastic pipe may be used for water and nonflammable liquids where experience or tests have demonstrated that the plastic pipe is suitable for the service conditions, and the pressure and temperature conditions are within the manufacturer's recommendations. Until such time as mandatory rules are established for these materials, pressure shall be limited to 150 psi (1000 kPa) and temperature to 140°F (60°C) for water service. Pressure and temperature limits for other services shall be based on the hazards involved, but in no application shall they exceed 150 psi (1000 kPa) and 140°F (60°C). For nonmandatory rules for nonmetallic piping, see Appendix III of this Code.

(B) Reinforced thermosetting resin pipe may be used, in addition to the services listed in para. 105.3(A), in buried flammable and combustible liquid service subject to the limitations described in para. 122.7.3(F).

(C) Reinforced concrete pipe may be used in accordance with the specifications listed in Table 126.1 for water service up to 150°F (65°C).

(D) A flexible nonmetallic pipe or tube assembly may be used in applications where:

(a) satisfactory service experience exists;

(b) the pressure and temperature conditions are within the manufacturer's recommendations; and

(c) the conditions described in paras. 104.7, 124.7, and 124.8 are met.

(E) Polyethylene pipe may be used, in addition to

the service listed in para. 105.3(A), in buried flammable and combustible liquid and gas service subject to the limitations described in paras. 122.7.2(D) and 122.8.1(B.4).

106 FITTINGS, BENDS, AND INTERSECTIONS

106.1 Fittings

(A) Threaded, flanged, grooved and shouldered socket-welding, buttwelding, compression, and solder-joint fittings made in accordance with the applicable standards in Table 126.1 may be used in power piping systems within the material, size, pressure, and temperature limitations of those standards, and within any further limitations specified in this Code. Material for fittings in flammable, combustible, or toxic fluid systems shall in addition conform to the requirements of paras. 122.7 and 122.8.

(B) Fittings not covered by the Standards listed in Table 126.1 may be used if they conform to para. 104.7.

(C) Cast buttwelding steel fittings not covered by the dimensional standards listed in Table 126.1 may be used up to the manufacturer's pressure and temperature ratings, provided they are radiographed in accordance with the method of ASTM E 142 and meet the acceptance requirements of ASTM E 446, E 186, and E 280 as applicable for the thickness being radiographed.

(D) Fabricated ends for grooved and shouldered type joints are acceptable, provided they are attached by full penetration welds, double fillet welds, or by threading. Fabricated ends attached by single fillet welds are not acceptable.

106.1.1 Bell and Spigot Fittings. Bell and spigot fittings complying with applicable standards listed in Table 126.1 may be used for cold water and drainage service.

106.2 Bends and Intersections

Bends and extruded branch connections may be used when designed in accordance with the provisions of paras. 104.2 and 104.3, respectively. Miters may be used within the limitations of para. 104.3.3.

106.3 Pipe Couplings

(A) Cast iron and malleable iron pipe couplings shall be limited in application as referenced in paras. 124.4 and 124.5, respectively.

(B) Straight thread couplings shall not be used.

106.4 Flexible Metal Hose Assembly

(A) Flexible metal hose assemblies may be used to provide flexibility in a piping system, to isolate or control vibration, or to compensate for misalignment. The design conditions shall be in accordance with para. 101 and within the limitations of the assembly as recommended by the manufacturer. The basis for their application shall include the following service conditions: thermal cycling, bend radius, cycle life, and the possibility of corrosion and erosion. Installation shall be limited to a single-plane bend, free from any torsion effects during service conditions and nonoperating periods. Type of end-connector components shall be consistent with the requirements of this Code.

(B) A flexible metal hose assembly, consisting of one continuous length of seamless or butt welded tube with helical or annular corrugations, is not limited as to application in piping systems which are within the scope of this Code, provided that the conditions described in (A) above are met. For application subject to internal pressure the flexible element shall be contained within one or more separate layers of braided metal permanently attached at both coupling ends by welding or brazing. For application in toxic fluid systems, it is recommended that the designer also review the standards published by the relevant fluid industry for any additional safety and materials requirements that may be necessary.

(C) A flexible metal hose assembly consisting of wound interlocking metal strips may be applied to atmospheric vent systems only and shall not be used in systems which convey high temperature, flammable, toxic, or searching-type fluids. Where applicable, as determined by the designer and within the limitations described in para. 122.6 and those imposed by the manufacturer, this type of hose assembly may be used at pressure relieving devices.

107 VALVES

107.1 General

(A) Valves complying with the standards and specifications listed in Table 126.1 shall be used within the specified pressure-temperature ratings.

(B) Valves not complying with (A) above shall be of a design, or equal to the design, which the manufacturer recommends for the service as stipulated in para. 102.2.2.

(C) Some valves are capable of sealing simultaneously against a pressure differential between an internal cavity of the valve and the adjacent pipe in both directions. Where liquid is entrapped in such a valve and is subsequently heated, a dangerous rise in pressure can result. Where this condition is possible, the Owner shall provide means in design, installation, and/or operation to assure that the pressure in the valve shall not exceed the rated pressure for the attained temperature. A relief device used solely for the over-pressure protection from such entrapped fluid and conforming to (A) or (B) above need not comply with the requirements of para. 107.8. Any penetration of the pressure retaining wall of the valve shall meet the requirements of this Code.

(D) Only valves designed such that the valve stem is retained from blow-out by an assembly which functions independently of the stem seal retainer shall be used.

(E) Materials used for pressure retention for valves in flammable, combustible, or toxic fluid systems shall in addition conform to the requirements of paras. 122.7 and 122.8.

107.2 Marking

Each valve shall bear the manufacturer's name or trademark and reference symbol to indicate the service conditions for which the manufacturer guarantees the valve. The marking shall be in accordance with ASME B16.5 and B16.34.

107.3 Ends

Valves may be used with flanged, threaded, butt welding, socket welding, or other ends in accordance with applicable standards as specified in para. 107.1(A).

107.4 *Stem Threads*

Stem threads of valves may be internal or external with reference to the valve bonnet. Outside screw and yoke design shall be used for valves NPS 3 and larger for pressures above 600 psi (4150 kPa).

107.5 Bonnet Joints

Bonnet joints may be of flanged, welded, pressure seal, union type, or other design, except that screwed bonnet connections in which the seal depends on a steam tight threaded joint shall not be permitted as source valves in steam service at pressures above 250 psi (1750 kPa).

107.6 Bypasses

Sizes of bypasses shall be in accordance with MSS SP-45 as a minimum standard. Pipe for bypasses shall be at least schedule 80 seamless, and of a material of the same nominal chemical composition and physical properties as that used for the main line. Bypasses may be integral or attached.

107.8 Safety, Safety Relief, and Relief Valves

107.8.1 General. Safety, safety relief, and relief valves shall conform to the requirements specified in this Code for flanges, valves, and fittings for the pressures and temperatures to which they may be subjected.

107.8.2 Safety, Safety Relief, and Relief Valves on Boiler External Piping. Safety, safety relief, and relief valves on boiler external piping shall be in accordance with para. 122.1.7(D.1) of this Code.

107.8.3 Safety, Safety Relief, and Relief Valves on Nonboiler External Piping. Safety, safety relief, and relief valves on nonboiler external piping (except for reheat safety valves) shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, UG-126 through UG-133. Reheat safety valves shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section I, PG-67 through PG-73.

107.8.4 Nonmandatory Appendix. For nonmandatory rules for the design of safety valve installations, see Appendix II of this Code.

108 PIPE FLANGES, BLANKS, FLANGE FACINGS, GASKETS, AND BOLTING

108.1 Flanges

Flanges shall conform to the design requirements of para. 104.5.1 or to the standards listed in Table 126.1. They may be integral or shall be attached to pipe by threading, welding, brazing, or other means within the applicable standards specified in Table 126.1.

108.2 Blanks

Blanks shall conform to the design requirements of para. 104.5.3.

108.3 Flange Facings

Flange facings shall be in accordance with the applicable standards listed in Tables 126.1 and 112. When bolting Class 150 standard steel flanges to flat face cast iron flanges, the steel flange shall be furnished with a flat face. Steel flanges of Class 300 raised face standard may be bolted to Class 250 raised face cast iron.

108.4 Gaskets

Gaskets shall be made of materials which are not injuriously affected by the fluid or by temperature. They shall be in accordance with Table 112.

108.5 U. S. Customary Bolting

108.5.1 General

(A) Bolts, bolt studs, nuts, and washers shall comply with applicable standards and specifications listed in Table 126.1 and Table 112. Bolts and bolt studs shall extend completely through the nuts.

(B) Washers, when used under nuts, shall be of forged or rolled material with steel washers being used under steel nuts and bronze washers under bronze nuts.

(C) Nuts shall be provided in accordance with the requirements of the specification for the bolts and bolt studs.

(D) Alloy steel bolt studs shall be either threaded full length or provided with reduced shanks of a diameter not less than that at the root of the threads. They shall have ASME heavy hexagonal nuts. Headed alloy bolts shall not be used with other than steel or stainless steel flanges.

(E) All alloy steel bolt studs and carbon steel bolts or bolt studs and accompanying nuts shall be threaded in accordance with ASME B1.1 Class 2A for external threads and Class 2B for internal threads. Threads shall be the coarse-thread series except that alloy steel bolting $1\frac{1}{8}$ in. and larger in diameter shall be the 8-pitch-thread series.

(F) Carbon steel headed bolts shall have square, hex, or heavy hex heads (ANSI B18.2.1) and shall be used with hex or heavy hex nuts (ASME B18.2.2). For bolt sizes smaller than $\frac{3}{4}$ in., square or heavy hex heads and heavy hex nuts are recommended. For bolt sizes larger than $1\frac{1}{2}$ in., bolt studs with a hex or heavy hex nut on each end are recommended. For cast iron or bronze flanges using $\frac{3}{4}$ in. and larger carbon steel headed bolts, square nuts may be used.

108.5.2 For the various combinations of flange materials, the selection of bolting materials and related rules concerning flange faces and gaskets shall be in accordance with para. 108 and Table 112.

108.5.3 Bolting requirements for components not covered by para. 108.5.2 shall be in accordance with para. 102.2.2

108.6 Metric Bolting

108.6.1 General. The use of metric bolts, bolt studs, nuts, and washers shall conform to the general requirements of para. 108.5, but the following are allowed. 01

(A) Threads shall be in accordance with ASME B1.13M, M profile, with tolerance Class 6g for external threads and Class 6H for internal threads.

(B) Threads shall be the coarse-thread series for size M68 and smaller, and 6 mm fine-pitch for M70 and larger sizes, except that alloy steel bolting M30 and larger shall be the 3 mm fine-pitch.

(C) Nuts shall be heavy hex in accordance with ASME B18.2.4.6M. Headed bolts shall be either hex or heavy hex in accordance with ASME B18.2.3.5M and B18.2.3.6M, respectively. Heavy hex heads are recommended for headed bolt sizes M18 and smaller.

(D) Bolt studs are recommended in lieu of headed bolts for sizes M39 and larger.

(E) Metric bolting is not approved for boiler external piping applications.

108.6.2 Responsibilities When Specifying or Allowing Metric Bolting 01

(A) The piping designer is responsible for specifying the metric bolt size to be used with each class and size of flange.

(B) The designer shall ensure that the selected metric size will fit within the flange bolt holes, and that adequate space exists for bolt heads, nuts, and the assembly tool.

(C) In those instances where the selected metric bolt size is smaller in root thread area than the corresponding U.S. Customary size, the designer shall ensure that the selected size is capable of the required assembly torque and of producing the required gasket loading to adequately seal at design pressure. Further, the designer shall ensure sufficient contact area exists between the flange metal and both the nut and bolt head to withstand the required bolt loading. If not, larger bolting or a higher flange class shall be selected.

PART 4
SELECTION AND LIMITATIONS OF PIPING JOINTS

110 PIPING JOINTS

The type of piping joint used shall be suitable for the design conditions and shall be selected with consideration of joint tightness, mechanical strength, and the nature of the fluid handled.

111 WELDED JOINTS

111.1 General

Welded joints may be used in any materials allowed by this Code for which it is possible to qualify WPSs, welders, and welding operators in conformance with the rules established in Chapter V.

All welds shall be made in accordance with the applicable requirements of Chapter V.

111.2 Butt Welds

111.2.1 Design of Butt Welds. The design of butt welds shall include the evaluation of any expected joint misalignment [para. 127.3(C)], which may result from specification of joint geometries at variance with the recommendations of this Code.

111.2.2 Backing Rings for Butt Welds. If backing rings are used in services where their presence will result in severe corrosion or erosion, the backing ring shall be removed and the internal surface ground smooth. In such services, where it is impractical to remove the backing ring, consideration shall be given to welding the joint without a backing ring, or with a consumable type insert ring.

111.3 Socket Welds

111.3.1 Restrictions on size of socket welded components are given in paras. 104.3.1(B.4), 122.1.1(H), and 122.8.2(C). Special consideration should be given to further restricting the use of socket welded piping joints where temperature or pressure cycling or severe vibration is expected to occur or where the service may accelerate crevice corrosion.

111.3.2 Dimensions for sockets of socket welding components shall conform to ASME B16.5 for flanges and ASME B16.11 for fittings. Assembly of socket welded joints shall be made in accordance with para. 127.3(E).

111.3.3 A branch connection socket welded directly into the wall of the run pipe shall be in accordance with requirements of para. 104.3.1(B.4).

111.3.4 Drains and bypasses may be attached to a fitting or valve by socket welding, provided the socket depth, bore diameter, and shoulder thickness conform to the requirements of ASME B16.11.

111.4 Fillet Welds

Fillet welds shall have dimensions not less than the minimum dimensions shown in Figs. 127.4.4(B), 127.4.4(C), and 127.4.8(D).

111.5 Seal Welds

Seal welding of connections, including threaded joints, may be used to avoid joint leakage but the welding shall not be considered as contributing any strength to the joint. Also see para. 127.4.5. Seal welded threaded joints are subject to the limitations of para. 114.

112 FLANGED JOINTS

Flanged joints shall conform to paras. 108 and 110 and Table 112.

113 EXPANDED OR ROLLED JOINTS

Expanded or rolled joints may be used where experience or test has demonstrated that the joint is suitable for the design conditions and where adequate provisions are made to prevent separation of the joint.

114 THREADED JOINTS

Threaded joints may be used within the limitations specified in para. 106 and within the other limitations specified herein.

114.1

All threads on piping components shall be taper pipe threads in accordance with the applicable Standards listed in Table 126.1. Threads other than taper pipe threads may be used for piping components where tightness of the joint depends on a seal weld or a seating surface other than the threads, and where experience or test has demonstrated that such threads are suitable.

TABLE 112
PIPING FLANGE BOLTING, FACING, AND GASKET REQUIREMENTS
Refer to Paras. 108, 110, and 112

	Flange A Mating With Flange B				
Item	**Flange A**	**Flange B**	**Bolting**	**Flange Facings**	**Gaskets**
(a)	Class 25 cast iron	Class 25 cast iron	(a)(1) "Low strength" [Notes (1), (2), and (5)]	(a)(1) Flat	(a)(1) Flat ring nonmetallic to ASME B16.21, Table 1
			(a)(2) "Higher strength" or "low strength" [Notes (1) through (5)]	(a)(2) Flat	(a)(2) Full face nonmetallic to ASME B16.21, Table 1
(b)	Class 125 cast iron	Class 125 cast iron, Class 150 steel and stainless steel (excluding MSS SP-51), or Class 150 ductile iron	"Low strength" [Notes (1), (2), and (5)]	Flat	Flat ring; nonmetallic to ASME B16.21, Table 2
(c)	Class 125 cast iron, Class 150 bronze, MSS SP-51 stainless steel, or nonmetallic	Class 125 cast iron, Class 150 bronze, Class 150 steel and stainless steel (including MSS SP-51), Class 150 ductile iron, or nonmetallic	"Higher strength" or "low strength" [Notes (1) through (7)]	Flat	Full face nonmetallic to ASME B16.21, Table 2 [Notes (8), (9)]
(d)	Class 150 steel and stainless steel (excluding MSS SP-51), or Class 150 ductile iron	Class 150 steel and stainless steel (excluding MSS SP-51), or Class 150 ductile iron	(d)(1) "Low strength" [Notes (1), (2), and (5)]	(d)(1) Raised or flat on one or both flanges	(d)(1) Flat ring nonmetallic to ASME B16.5, Annex E, Group Ia, Fig. E3 [Note (11)]
			(d)(2) "Higher strength" [Notes (3), (4), and (5)]	(d)(2) Raised or flat on one or both flanges	(d)(2) Ring style to ASME B16.5, Annex E, Groups Ia and Ib, Fig. E3 [Notes (10) and (11)]
			(d)(3) "Higher strength" or "low strength" [Notes (1) through (5)]	(d)(3) Flat	(d)(3) Full face nonmetallic to ASME B16.5, Annex E, Group Ia material
(e)	Class 150 steel and stainless steel (excluding MSS SP-51)	Class 150 steel and stainless steel (excluding MSS SP-51)	"Higher strength" [Notes (3), (4), and (5)]	Ring joint	Ring joint to ASME B16.20

(continued)

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TABLE 112
PIPING FLANGE BOLTING, FACING, AND GASKET REQUIREMENTS (CONT'D)
Refer to Paras. 108, 110, and 112

Item	Flange A Mating With Flange B: Flange A	Flange A Mating With Flange B: Flange B	Bolting	Flange Facings	Gaskets
(f)	Class 250 cast iron	Class 250 cast iron, Class 300 steel and stainless steel, or Class 300 ductile iron	(f)(1) "Low strength" [Notes (1), (2), and (5)]	(f)(1) Raised or flat on one or both flanges	(f)(1) Flat ring nonmetallic to ASME B16.21, Table 3
			(f)(2) "Higher strength" or "low strength" [Notes (1) through (5)]	(f)(2) Flat	(f)(2) Full face nonmetallic to ASME B16.21 Table 6 (Class 300)
(g)	Class 300 bronze	Class 250 cast iron, Class 300 bronze, Class 300 steel and stainless steel, or Class 300 ductile iron	"Higher strength" or "low strength" [Notes (1) through (7)]	Flat	Full face nonmetallic to ASME B16.21, Table 11 [Note (8)]
(h)	Class 300 ductile iron	Class 300 steel and stainless steel, or Class 300 ductile iron	(h)(1) "Low strength" [Notes (1), (2), and (5)]	(h)(1) Raised or flat on one or both flanges	(h)(1) Flat ring nonmetallic to ASME B16.5, Annex E, Group Ia, Fig. E3 [Note (11)]
			(h)(2) "Higher strength" [Notes (3), (4) and (5)]	(h)(2) Raised or flat on one or both flanges	(h)(2) Ring style to ASME B16.5, Annex E [Notes (10) and (11)]
			(h)(3) "Higher strength" or "low strength" [Notes (1) through (5)]	(h)(3) Flat	(h)(3) Full face nonmetallic to ASME B16.5, Annex E, Group Ia material [Note (11)]

(continued)

TABLE 112
PIPING FLANGE BOLTING, FACING, AND GASKET REQUIREMENTS (CONT'D)
Refer to Paras. 108, 110, and 112

	Flange A Mating With Flange B				
Item	Flange A	Flange B	Bolting	Flange Facings	Gaskets
(i)	Class 300 and higher classes, steel and stainless steel	Class 300 and higher classes, steel and stainless steel	(i)(1) "Low strength" [Notes (1), (2), and (5)]	(i)(1) Raised or flat on one or both flanges; large or small male and female; large or small tongue and groove	(i)(1) Flat ring nonmetallic to ASME B16.5, Para. 6.11 and Annex E, Group Ia material [Note (11)]
			(i)(2) "Higher strength" [Notes (3), (4), and (5)]	(i)(2) Raised or flat on one or both flanges; large or small male and female; large or small tongue and groove	(i)(2) Ring style to ASME B16.5, Para. 6.11 and Annex E [Notes (10) and (11)]
			(i)(3) "Higher strength" [Notes (3), (4), and (5)]	(i)(3) Ring joint	(i)(3) Ring joint to ASME B16.20
(j)	Class 800 cast iron	Class 800 cast iron	"Low strength" [Notes (1), (2), and (5)]	Raised or large male and female	Flat ring nonmetallic to ASME B16.21, Table 4

GENERAL NOTES:

(a) Bolting (including nuts), flange facing, and gasket selection (materials, dimensions, bolt stress, gasket factor, seating stress, etc.) shall be suitable for the flanges, service conditions, and hydrostatic tests. There shall be no overstressing of the gasket or flanges from the expected bolt loading or external bending loads.

(b) Unless otherwise stated, the flange facing described applies to both flanges A and B.

(c) For flanges other than to ASME B16.1, in sizes larger than NPS 24 (NPS 12 in Class 2500), gasket dimensions should be verified against the flanges specified (e.g., MSS SP-44 and API 605).

(d) The effective seating of a full face gasket shall extend to the outside edge of the flange. For flat or raised face flanges, a flat ring or ring style gasket shall be self-centering, extending to the inner edge of the bolt holes or bolts. Where the joint contains a cast iron, bronze, nonmetallic, or MSS SP-51 stainless steel flange, the effective gasket seating shall extend to the outside diameter of the gasket.

(e) Unconfined nonmetallic gaskets shall not be used on flat or raised face flanges if the expected normal operating pressure exceeds 720 psi (4950 kPa) or the temperature exceeds 750°F (400°C). Metal gaskets, spiral wound gaskets of metal with nonmetallic filler, and confined nonmetallic gaskets are not limited as to pressure or temperature provided the gasket materials are suitable for the maximum fluid temperatures.

(continued)

TABLE 112 (CONT'D)

NOTES:

(1) "Low strength" bolting shall conform to ASTM:

A 193, Grade B8A, B8CA, B8MA, or B8TA
A 193, Class 1, Grade B8, B8C, B8M, or B8T

A 307, Grade 8 [Bolting to A 307, Grade B shall not be used at temperatures greater than 400°F (200°C)]

A 320, Class 1, Grade B8, B8C, B8M, or B8T

(2) Nuts for "low strength" bolting shall conform to the grade of ASTM A 194 or A 563 as required by the bolting specification.

(3) "Higher strength" bolting shall conform to ASTM:

A 193, Grade B5, B6, B6X, B7, B7M, or B16
A 193, Class 2, Grade B8, B8C, B8M, or B8T

A 320, Grade L7, L7A, L7B, L7C, or L43
A 320, Class 2, Grade B8, B8C, B8F, B8M, or B8T

A 354, Grade BC or BD

A 437, Grade B4B, B4C, or B4D

A 453, Grade 651 or 660

(4) Nuts for "higher strength" bolting shall conform to the grade of ASTM A 194, A 437, A 453, A 563, or A 564, as required by the bolting specification.

(5) For temperatures below −20°F (−29°C), bolting conforming to the ASTM A 320 classes and grades listed, respectively, in Note (3) "higher strength" and Note (1) "low strength" shall be used. For this bolting to ASTM A 320, Grades L7, L7A, L7B, L7C, and L43, the nuts shall conform to ASTM A 194, Grade 4 or 7 with impact requirements of A 320. For bolting to the other grades of A 320, the nuts shall conform to A 320.

(6) Additionally, for joints containing bronze flanges, nonferrous bolting conforming to the following may be used:

ASTM B 98, UNS C65100, C65500, and C66100; half hard; to 350°F (177°C) maximum

ASTM B 150, UNS C61400, to 500°F (260°C) maximum
ASTM B 150, UNS C63000 and C64200, to 550°F (288°C) maximum

ASTM B 164, UNS N04400 and N04405; hot finish; 550°F (288°C) maximum
ASTM B 164, UNS N04400, cold drawn, cold drawn and stress relieved, or cold drawn and stress equalized; and N04405, cold drawn, to 500°F (260°C) maximum

(7) Where a flanged joint contains dissimilar materials (e.g., bronze flanges with steel bolting) and has a design temperature exceeding 300°F (149°C), the differences in coefficients of expansion shall be considered.

(8) For bronze flanges where "low strength" or nonferrous bolting is used, nonmetallic gaskets having seating stresses greater than 1600 psi shall not be used.

(9) For stainless steel flanges to MSS SP-51 and for nonmetallic flanges, preference shall be given to gasket materials having the lower minimum design seating stress as listed in ASME B16.5, Fig. E1, Group 1a.

(10) For items (d)(2), and (i)(2), where two flat face flanges are used in a joint and the gasket seating width (considering both the gasket and the flanges) is greater than that of an ASME B16.5 flange having a standard raised face, the gasket material shall conform to ASME B16.5, Annex E, Group 1a.

(11) Where asbestos sheet, fiber or filler material for gaskets is specified in ASME B16.5, this limitation shall not apply to ASME B31.1 applications. Any nonmetallic material suitable for the operating conditions may be used in lieu of asbestos provided the requirements of Table 112 are met.

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TABLE 114.2.1

Maximum Nominal Size, in.	Maximum Pressure	
	psi	kPa
3	400	2 750
2	600	4 150
1	1200	8 300
$^3/_4$ and smaller	1500	10 350

GENERAL NOTE: For instrument, control and sampling lines, refer to para. 122.3.6(A.5)

114.2.1 Threaded joints shall not be used where severe erosion, crevice corrosion, shock, or vibration is expected to occur, nor at temperatures over 925°F (495°C). Size limits for steam and hot water service [above 220°F (105°C)] shall be as listed in Table 114.2.1.

114.2.2 Threaded access holes with plugs, which serve as openings for radiographic inspection of welds, are not subject to the limitations of para. 114.2.1 and Table 114.2.1, provided their design and installation meets the requirement of para. 114.1. A representative type of access hole and plug is shown in PFI ES-16.

114.2.3 Threaded connections for insertion type fluid temperature determination, flow measurement, and sampling devices are not subject to the temperature limitation stated in para. 114.2.1 nor the pressure limitations stated in Table 114.2.1 provided that design and installation meet the requirements of paras. 104.3.1 and 114.1. At temperatures greater than 925°F (495°C) or at pressures greater than 1500 psi (10 350 kPa), these threaded connections shall be seal welded in accordance with para. 127.4.5. The design and installation of insertion type fluid temperature determination, flow measurement, and sampling devices shall be adequate to withstand the effects of the fluid characteristics, fluid flow, and vibration.

114.3

Pipe with a wall thickness less than that of standard weight of ASME B36.10M steel pipe shall not be threaded, regardless of service. For additional threading limitations for pipe used in:

(A) steam service over 250 psi (1750 kPa); or

(B) water service over 100 psi (700 kPa) and 220°F (105°C).

See para. 104.1.2(C.1).

115 FLARED, FLARELESS, AND COMPRESSION JOINTS

Flared, flareless, and compression type tubing fittings may be used for tube sizes not exceeding 2 in. (50 mm) O.D. within the limitations of applicable standards and specifications listed in Table 126.1.

In the absence of standards, specifications, or allowable stress values for the material used to manufacture the fitting, the designer shall determine that the type and the material of the fitting selected is adequate and safe for the design conditions in accordance with the following requirements.

(A) The pressure design shall meet the requirements of para. 104.7.

(B) A suitable quantity of the type, size, and material of the fittings to be used shall meet successful performance tests to determine the safety of the joint under simulated service conditions. When vibration, fatigue, cyclic conditions, low temperature, thermal expansion, or hydraulic shock are expected, the applicable conditions shall be incorporated in the test.

115.1

Fittings and their joints shall be compatible with the tubing with which they are to be used and shall conform to the range of wall thicknesses and method of assembly recommended by the manufacturer.

115.2

Fittings shall be used at pressure-temperature ratings not exceeding the recommendations of the manufacturer. Service conditions, such as vibration and thermal cycling, shall be considered in the application.

115.3

See para. 114.1 for requirements of threads on piping components.

115.4

Flareless fittings shall be of a design in which the gripping member or sleeve shall grip or bite into the outer surface of the tube with sufficient strength to hold the tube against pressure, but without appreciably distorting the inside tube diameter. The gripping member shall also form a pressure seal against the fitting body.

When using bite type fittings, a spot check shall be made for adequate depth of bite and condition of tubing by disassembling and reassembling selected joints.

Grip type fittings that are tightened in accordance with manufacturer's instructions need not be disassembled for checking.

116 CAULKED JOINTS

116.1

Caulked or leaded joints of the bell and spigot type which are caulked with lead and packing material may be used for cold water service.

116.2

Caulked joints may be used at pressures permitted for the pipe to which they are applied where provisions are made to prevent disengagement of the joints at bends and dead ends, and to support lateral reactions produced by branch connections or other causes.

117 BRAZED AND SOLDERED JOINTS

117.1

Brazed socket-type joints shall be made with suitable brazing alloys. The minimum socket depth shall be sufficient for the intended service. Brazing alloy shall either be end-fed into the socket or shall be provided in the form of a preinserted ring in a groove in the socket. The brazing alloy shall be sufficient to fill completely the annular clearance between the socket and the pipe or tube. The limitations of paras. 117.3(A) and (D) shall apply.

117.2

Soft soldered socket-type joints made in accordance with applicable standards listed in Table 126.1 may be used within their specified pressure-temperature ratings. The limitations in paras. 117.3 and 122.3.2(E.2.3) for instrument piping shall apply. The allowances of para. 102.2.4 do not apply.

117.3 Limitations

(A) Brazed socket-type joints shall *not* be used on systems containing flammable or toxic fluids in areas where fire hazards are involved.

(B) Soldered socket-type joints shall be limited to systems containing nonflammable and nontoxic fluids.

(C) Soldered socket-type joints shall not be used in piping subject to shock or vibration.

(D) Brazed or soldered joints depending solely upon a fillet, rather than primarily upon brazing or soldering material between the pipe and sockets, are not acceptable.

118 SLEEVE COUPLED AND OTHER PROPRIETARY JOINTS

Coupling type, mechanical gland type, and other proprietary joints may be used where experience or tests have demonstrated that the joint is safe for the operating conditions, and where adequate provision is made to prevent separation of the joint.

PART 5
EXPANSION, FLEXIBILITY, AND SUPPORTING

119 EXPANSION AND FLEXIBILITY

119.1 General

In addition to the design requirements for pressure, weight, and other loadings, power piping systems subject to thermal expansion or contraction or to similar movements imposed by other sources shall be designed in accordance with the requirements for the evaluation and analysis of flexibility and stresses specified herein.

119.2 Stress Range

Stresses caused by thermal expansion, when of sufficient initial magnitude, relax in the hot condition as a result of local yielding or creep. A stress reduction takes place and usually appears as a stress of reversed sign when the component returns to the cold condition. This phenomenon is designated as self-springing of the line and is similar in effect to cold springing. The extent of self-springing depends on the material, the magnitude of the initial expansion and fabrication stress, the hot service temperature and the elapsed time. While the expansion stress in the hot condition tends to diminish with time, the sum of the expansion strains for the hot and cold conditions during any one cycle remains substantially constant. This sum is referred to as the strain range; however, to permit convenient association with allowable stress, stress range is selected as the criterion for the thermal design of piping. The allowable stress range shall be determined in accordance with para. 102.3.2(C).

119.3 Local Overstrain

All the commonly used methods of piping flexibility analysis assume elastic behavior of the entire piping system. This assumption is sufficiently accurate for systems where plastic straining occurs at many points or over relatively wide regions, but fails to reflect the actual strain distribution in unbalanced systems where only a small portion of the piping undergoes plastic strain, or where, in piping operating in the creep range, the strain distribution is very uneven. In these cases, the weaker or higher stressed portions will be subjected to strain concentrations due to elastic follow-up of the stiffer or lower stressed portions. Unbalance can be produced:

(A) by use of small pipe runs in series with larger or stiffer pipe, with the small lines relatively highly stressed;

(B) by local reduction in size or cross section, or local use of a weaker material; or

(C) in a system of uniform size, by use of a line configuration for which the neutral axis or thrust line is situated close to the major portion of the line itself, with only a very small offset portion of the line absorbing most of the expansion strain.

Conditions of this type should preferably be avoided, particularly where materials of relatively low ductility are used; if unavoidable, they may be mitigated by the judicious application of cold spring.

It is recommended that the design of piping systems of austentic steel materials be approached with greater over-all care as to inspection, material selection, fabrication quality, erection, and elimination of local stress raisers.

119.5 Flexibility

Power piping systems shall be designed to have sufficient flexibility to prevent pipe movements from causing failure from overstress of the pipe material or anchors, leakage at joints, or detrimental distortion of connected equipment resulting from excessive thrusts and moments. Flexibility shall be provided by changes of direction in the piping through the use of bends, loops, or offsets; or provisions shall be made to absorb thermal movements by utilizing expansion, swivel, or ball joints, corrugated pipe, or flexible metal hose assemblies.

119.5.1 Expansion, Swivel, or Ball Joints, and Flexible Metal Hose Assemblies. Except as stated in para. 101.7.2, these components may be used where experience or tests have demonstrated that they are suitable for expected conditions of pressure, temperature, service, and cyclic life.

Restraints and supports shall be provided, as required, to limit movements to those directions and magnitudes permitted for specific joint or hose assembly selected.

119.6 Properties

Thermal expansion data and moduli of elasticity shall be determined from Appendix B and Appendix C, Tables C-1 and C-2, which cover more commonly used piping materials. For materials not included in these Tables, reference shall be to authoritative source data such as publications of the National Institute of Standards and Technology.

119.6.1 Thermal Expansion Range. The thermal expansion range shall be determined from Appendix B as the difference between the unit expansion shown for the highest metal temperature and that for the lowest metal temperature resulting from operating or shutdown conditions.

119.6.2 Moduli of Elasticity. The cold and hot moduli of elasticity E_c and E_h shall be as shown in Appendix C, Table C-1 for ferrous materials and Table C-2 for nonferrous materials, based on the temperatures established in para. 119.6.1.

119.6.3 Poisson's Ratio. Poisson's ratio, when required for flexibility calculations, shall be taken as 0.3 at all temperatures for all materials.

119.6.4 Stresses. Calculations for the stresses shall be based on the least cross section area of the component, using nominal dimensions at the location of local strain. Calculations for the thermal expansion stress range S_E shall be based on the modulus of elasticity E_c at room temperature.

119.7 Analysis

119.7.1 Method of Analysis. All piping shall meet the following requirements with respect to thermal expansion and flexibility:

(A) It shall be the designer's responsibility to perform an analysis unless the system meets one of the following criteria.

(A.1) The piping system duplicates a successfully operating installation or replaces a system with a satisfactory service record.

(A.2) The piping system can be adjudged adequate by comparison with previously analyzed systems.

(A.3) The piping system is of uniform size, has not

more than two anchors and no intermediate restraints, is designed for essentially noncyclic service (less than 7000 total cycles), and satisfies the following approximate criterion:

(a) English Units

$$\frac{DY}{(L - U)^2} \leq 0.03$$

(b) SI Units

$$\frac{DY}{(L - U)^2} \leq 208.3$$

where

D = nominal pipe size, in. (mm)

Y = resultant of movements to be absorbed by pipe lines, in. (mm)

L = developed length of line axis, ft (m)

U = anchor distance (length of straight line joining anchors), ft (m)

WARNING: No general proof can be offered that this equation will yield accurate or consistently conservative results. It was developed for ferrous materials and is not applicable to systems used under severe cyclic conditions. It should be used with caution in configurations such as unequal leg U-bends (*L/U* > 2.5), or near straight "saw-tooth" runs, or for large diameter thin-wall pipe, or where extraneous displacements (not in the direction connecting anchor points) constitute a large part of the total displacement. There is no assurance that terminal reactions will be acceptably low, even if a piping system falls within the above limitations.

(B) All systems not meeting the above criteria, or where reasonable doubt exists as to adequate flexibility of the system, shall be analyzed by simplified, approximate, or comprehensive methods of analysis that are appropriate for the specific case.

(C) Approximate or simplified methods may be applied only if they are used for the range of configurations for which their adequate accuracy has been demonstrated.

(D) Acceptable comprehensive methods of analysis include: analytical, model tests, and chart methods which provide an evaluation of the forces, moments and stresses caused by bending and torsion from the simultaneous consideration of terminal and intermediate restraints to thermal expansion of the entire piping system under consideration, and including all external movements transmitted to the piping by its terminal and intermediate attachments. Correction factors shall be applied for the stress intensification of curved pipe and branch connections, as provided by the details of these rules, and may be applied for the increased flexibility of such component parts.

119.7.3 Basic Assumptions and Requirements. In calculating the flexibility of a piping system between anchor points, the system between anchor points shall be treated as a whole. The significance of all parts of the line and of all restraints, such as supports or guides, including intermediate restraints introduced for the purpose of reducing moments and forces on equipment or small branch lines, shall be considered.

Flexibility calculations shall take into account stress intensifying conditions found in components and joints. Credit may be taken when extra flexibility exists in such components. In the absence of more directly applicable data, the flexibility factors and stress-intensification factors shown in Appendix D may be used.[2]

Dimensional properties of pipe and fittings used in flexibility calculations shall be based on nominal dimensions.

The total expansion range as determined from para. 119.6.1 shall be used in all calculations, whether or not the piping is cold sprung. Not only the expansion of the line itself, but also linear and angular movements of the equipment to which it is attached shall be considered.

Where simplifying assumptions are used in calculations or model tests, the likelihood of attendant underestimates of forces, moments, and stresses, including the effects of stress-intensification shall be evaluated.

119.8 Movements

Movements caused by thermal expansion and loadings shall be determined for consideration of obstructions and design of proper supports.

119.9 Cold Spring

The beneficial effect of judicious cold springing in assisting a system to attain its most favorable position sooner is recognized. Inasmuch as the life of a system under cyclic conditions depends on the stress range rather than the stress level at any one time, no credit for cold spring is allowed with regard to stresses. In

[2] The stress-intensification factors in Appendix D have been developed from fatigue tests of representative commercially available, matching product forms and assemblies manufactured from ductile ferrous materials. The allowable stress-range is based on tests of carbon and stainless steels. Caution should be exercised when applying Figs. (1) and (13) for the allowable stress-range for certain nonferrous materials (e.g., copper and aluminum alloys) for other than low cycle applications.

calculating end thrusts and moments acting on equipment, the actual reactions at any one time, rather than their range, are significant. Credit for cold springing is accordingly allowed in the calculation of thrusts and moments, provided an effective method of obtaining the designed cold spring is specified and used.

119.10 Reactions

01 **119.10.1 Computing Hot and Cold Reactions.** In a piping system with no cold spring or an equal percentage of cold springing in all directions, the reactions (forces and moments) of R_h and R_c, in the hot and cold conditions, respectively, shall be obtained from the reaction R derived from the flexibility calculations based on the modulus of elasticity at room temperature E_c, using Eqs. (9) and (10).

$$R_h = \left(1 - \tfrac{2}{3}C\right)\left(\frac{E_h}{E_c} R\right) \qquad (9)$$

$$R_c = -CR, \text{ or}$$

$$= -\left[1 - \frac{(S_h)}{(S_E)} \cdot \frac{(E_c)}{(E_h)}\right] R \qquad (10)$$

whichever is greater, and with the further condition that

$$\frac{(S_h)}{(S_E)} \cdot \frac{(E_c)}{(E_h)} < 1$$

where

C = cold spring factor varying from zero for no cold spring to 1.00 for 100% cold spring

S_E = computed thermal expansion stress range, psi (MPa)

E_c = modulus of elasticity in the cold condition, psi (MPa)

E_h = modulus of elasticity in the hot condition, psi (MPa)

R = maximum reaction for full expansion range based on E_c which assumes the most severe condition (100% cold spring, whether such is used or not), lb and in-lb (N and mm-N)

R_c, R_h = maximum reactions estimated to occur in the cold and hot conditions, respectively, lb and in.-lb (N and mm-N)

If a piping system is designed with different percentages of cold spring in various directions, Eqs. (9) and (10) are not applicable. In this case, the piping system shall be analyzed by a comprehensive method. The calculated hot reactions shall be based on theoretical cold springs in all directions not greater than two-thirds of the cold springs as specified or measured.

119.10.2 Reaction Limits. The reactions computed shall not exceed limits which the attached equipment can sustain. Equipment allowable reaction limits (forces and moments) on piping connections are normally established by the equipment manufacturer.

120 LOADS ON PIPE SUPPORTING ELEMENTS

120.1 General

(A) The broad terms "Supporting Elements" or "Supports" as used herein shall encompass the entire range of the various methods of carrying the weight of pipe lines, insulation, and the fluid carried. It therefore includes "hangers" which are generally considered as those elements which carry the weight from above, with the supporting members being mainly in tension. Likewise, it includes "supports" which on occasion are delineated as those which carry the weight from below, with the supporting members being mainly in compression. In many cases a supporting element may be a combination of both of these.

(B) In addition to the weight effects of piping components, consideration shall be given in the design of pipe supports to other load effects introduced by service pressure, wind, earthquake, etc., as defined in para. 101. Hangers and supporting elements shall be fabricated and assembled to permit the free movement of piping caused by thermal expansion and contraction. The design of elements for supporting or restraining piping systems, or components thereof, shall be based on all the concurrently acting loads transmitted into the supporting elements.

(C) Where the resonance with imposed vibration and/or shock occurs during operation, suitable dampeners, restraints, anchors, etc., shall be added to remove these effects.

120.2 Supports, Anchors, and Guides

120.2.1 Rigid Type Supports

(A) The required strength of all supporting elements shall be based on the loadings as given in para. 120.1, including the weight of the fluid transported or the fluid used for testing, whichever is heavier. The allow-

able stress in supporting equipment shall be as specified in para. 121.2.

(B) Exceptions may be made in the case of supporting elements for large size gas or air piping, exhaust steam, relief or safety valve relief piping, but only under the conditions where the possibility of the line becoming full of water or other liquid is very remote.

120.2.2 Variable and Constant Supports. Load calculations for variable and constant supports, such as springs or counterweights, shall be based on the design operating conditions of the piping. They shall not include the weight of the hydrostatic test fluid. However, the support shall be capable of carrying the total load under test conditions, unless additional support is provided during the test period.

120.2.3 Anchors or Guides. Where anchors or guides are provided to restrain, direct, or absorb piping movements, their design shall take into account the forces and moments at these elements caused by internal pressure and thermal expansion.

120.2.4 Supplementary Steel. Where it is necessary to frame structural members between existing steel members, such supplementary steel shall be designed in accordance with American Institute of Steel Construction specifications, the Uniform Building Code, or similar recognized structural design standards. Increases of allowable stress values for short duration loading, such as outlined in para. 121.2(I), are not permitted.

121 DESIGN OF PIPE SUPPORTING ELEMENTS

121.1 General

Design of standard pipe supporting elements shall be in accordance with the rules of MSS SP-58. Allowable stress values and other design criteria shall be in accordance with this paragraph. Supporting elements shall be capable of carrying the sum of all concurrently acting loads as listed in para. 120. They shall be designed to provide the required supporting effort and allow pipeline movement with thermal changes without causing overstress. The design shall also prevent complete release of the piping load in the event of spring failure or misalignment. All parts of the supporting equipment shall be fabricated and assembled so that they will not be disengaged by movement of the supported piping. The maximum safe loads for bolts, threaded hanger rods, and all other threaded members shall be based on the root area of the threads.

121.2 Allowable Stress Values 01

(A) Allowable stress values tabulated in MSS SP-58 or in Appendix A of this Code Section may be used for the base materials of all parts of pipe supporting elements.

(B) Where allowable stress values for a material specification listed in Table 126.1 are not tabulated in Appendix A or in MSS SP-58, allowable stress values from Section II, Part D, Tables 1A and 1B of the ASME Boiler and Pressure Vessel Code may be used, provided the requirements of para. 102.3.1(B) are met. Where there are no stress values given in Section II, Part D, Tables 1A and 1B, an allowable stress value of 25% of the minimum tensile strength given in the material specification may be used, for temperatures not exceeding 650°F (345°C).

(C) For a steel material of unknown specification, or of a specification not listed in Table 126.1 or MSS SP-58, an allowable stress value of 30% of yield strength (0.2% offset) at room temperature may be used at temperatures not exceeding 650°F (345°C). The yield strength shall be determined through a tensile test of a specimen of the material and shall be the value corresponding to 0.2% permanent strain (offset) of the specimen. The allowable stress values for such materials shall not exceed 9500 psi (65.5 MPa).

(D) The allowable shear stress shall not exceed 80% of the values determined in accordance with the rules of (A), (B), and (C) above.

(E) The allowable compressive stress shall not exceed the value as determined in accordance with the rules of (A), (B), or (C) above. In addition, consideration shall be given to structural stability.

(F) The allowable bearing stress shall not exceed 160% of the value as determined in accordance with the rules of (A), (B), or (C) above.

(G) The allowable base material tensile stress determined from (A), (B), or (C) above shall be reduced 25% for threaded hanger rods.

(H) The allowable stress in welds in support assemblies shall be reduced 25% from those determined in accordance with (A), (B), (C), or (D) above for the weaker of the two metals joined.

(I) Increases in the allowable stress values shall be permitted as follows:

(1) an increase of 20% for short time overloading during operation;

(2) an increase to 80% of the minimum yield strength at room temperature during hydrostatic testing. Where the material allowable stress has been established in accordance with the rules of (C) above, the allowable

stress value during hydrostatic testing shall not exceed 16,000 psi (110.3 MPa).

121.3 Temperature Limitations

Parts of supporting elements which are subjected principally to bending or tension loads and which are subjected to working temperatures for which carbon steel is not recommended shall be made of suitable alloy steel, or shall be protected so that the temperature of the supporting member will be maintained within the appropriate temperature limits of the material.

121.4 Hanger Adjustments

Hangers used for the support of piping, NPS $2^1/_2$ and larger, shall be designed to permit adjustment after erection while supporting the load. Screwed adjustments shall have threaded parts to conform to ASME B1.1. Class 2 fit turnbuckles and adjusting nuts shall have the full length of thread in engagement. Means shall be provided for determining that full thread length is in engagement. All screw and equivalent adjustments shall be provided with suitable locking devices.

121.5 Hanger Spacing

Supports for piping with the longitudinal axis in approximately a horizontal position shall be spaced to prevent excessive sag, bending and shear stresses in the piping, with special consideration given where components, such as flanges and valves, impose concentrated loads. Where calculations are not made, suggested maximum spacing of supports for standard and heavier pipe are given in Table 121.5. Vertical supports shall be spaced to prevent the pipe from being overstressed from the combination of all loading effects.

121.6 Springs

The springs used in variable or constant effort type supports shall be designed and manufactured in accordance with MSS SP-58.

121.7 Fixtures

121.7.1 Anchors and Guides

(A) Anchors, guides, pivots, and restraints shall be designed to secure the desired points of piping in relatively fixed positions. They shall permit the piping to expand and contract freely in directions away from the anchored or guided point and shall be structurally suitable to withstand the thrusts, moments, and other loads imposed.

TABLE 121.5
SUGGESTED PIPE SUPPORT SPACING

Nominal Pipe Size, NPS	Suggested Maximum Span			
	Water Service		Steam, Gas, or Air Service	
	ft	m	ft	m
1	7	2.1	9	2.7
2	10	3.0	13	4.0
3	12	3.7	15	4.6
4	14	4.3	17	5.2
6	17	5.2	21	6.4
8	19	5.8	24	7.3
12	23	7.0	30	9.1
16	27	8.2	35	10.7
20	30	9.1	39	11.9
24	32	9.8	42	12.8

GENERAL NOTES:

(a) Suggested maximum spacing between pipe supports for horizontal straight runs of standard and heavier pipe at maximum operating temperature of 750°F (400°C).

(b) Does not apply where span calculations are made or where there are concentrated loads between supports, such as flanges, valves, specialties, etc.

(c) The spacing is based on a fixed beam support with a bending stress not exceeding 2300 psi (15.86 MPa) and insulated pipe filled with water or the equivalent weight of steel pipe for steam, gas, or air service, and the pitch of the line is such that a sag of 0.1 in. (2.5 mm) between supports is permissible.

(B) Rolling or sliding supports shall permit free movement of the piping, or the piping shall be designed to include the imposed load and frictional resistance of these types of supports, and dimensions shall provide for the expected movement of the supported piping. Materials and lubricants used in sliding supports shall be suitable for the metal temperature at the point of sliding contact.

(C) Where corrugated or slip-type expansion joints, or flexible metal hose assemblies are used, anchors and guides shall be provided where necessary to direct the expansion into the joint or hose assembly. Such anchors shall be designed to withstand the force specified by the manufacturer for the design conditions at which the joint or hose assembly is to be used. If this force is otherwise unknown, it shall be taken as the sum of the product of the maximum internal area times the design pressure plus the force required to deflect the joint or hose assembly. Where expansion joints or flexible metal hose assemblies are subjected to a combination of longitudinal and transverse movements, both movements shall be considered in the design and application of the joint or hose assembly.

TABLE 121.7.2(A)
CARRYING CAPACITIES OF THREADED ASTM A 36, A 575, AND A 576 HOT ROLLED CARBON STEEL

Nominal Rod Diameter, in.	Root Area of Coarse Thread		Max. Safe Load at Rod Temp. of 650°F (345°C)	
	sq in.	sq mm	lb	kg
3/8	0.068	43.87	610	276
1/2	0.126	81.29	1,130	512
5/8	0.202	130.3	1,810	821
3/4	0.302	194.8	2,710	1 229
7/8	0.419	270.3	3,770	1 710
1	0.552	356.1	4,960	2 250
1 1/4	0.889	573.5	8,000	3 629
1 1/2	1.293	834.2	11,630	5 275
1 3/4	1.744	1 125	15,690	7 117
2	2.292	1 479	20,690	9 385
2 1/4	3.021	1 949	27,200	12 338
2 1/2	3.716	2 397	33,500	15 195
2 3/4	4.619	2 980	41,600	18 869
3	5.621	3 626	50,600	22 952
3 1/4	6.720	4 335	60,500	27 442
3 1/2	7.918	5 108	71,260	32 323
3 3/4	9.214	5 945	82,900	37 640
4	10.608	6 844	95,500	43 360
4 1/4	12.100	7 806	108,900	49 440
4 1/2	13.690	8 832	123,200	55 930
4 3/4	15.379	9 922	138,400	62 830
5	17.165	11 074	154,500	70 140

GENERAL NOTE: Tabulated loads are based on an allowable tensile stress of 12,000 psi (82.7 MPa) reduced by 25% using the root thread area as a base. [Refer to para. 121.2(A).]

Flexible metal hose assemblies, applied in accordance with para. 106.4, shall be supported in such a manner as to be free from any effects due to torsion and undue strain as recommended by the manufacturer.

121.7.2 Other Rigid Types

(A) Hanger Rods. Safe loads for threaded hanger rods shall be based on the root area of the threads and allowable stress of the material. In no case shall hanger rods less than 3/8 in. (9.5 mm) diameter be used for support of pipe NPS 2 and smaller, or less than 1/2 in. (12.5 mm) diameter rod for supporting pipe NPS 2 1/2 and larger. See Table 121.7.2(A) for carbon steel rods.

Pipe, straps, or bars of strength and effective area equal to the equivalent hanger rod may be used instead of hanger rods.

Hanger rods, straps, etc., shall be designed to permit the free movement of piping caused by thermal expansion and contraction.

(B) Welded link chain of 3/16 in. (5.0 mm) or larger diameter stock, or equivalent area, may be used for pipe hangers with a design stress of 9000 psi (62 MPa) maximum.

(C) Cast iron in accordance with ASTM A 48 may be used for bases, rollers, anchors, and parts of supports where the loading will be mainly compression. Cast iron parts shall not be used in tension.

(D) Malleable iron castings in accordance with ASTM A 47 may be used for pipe clamps, beam clamps, hanger flanges, clips, bases, swivel rings, and parts of pipe supports, but their use shall be limited to temperatures not in excess of 450°F (230°C). This material is

not recommended for services where impact loads are anticipated.

(E) Brackets shall be designed to withstand forces and moments induced by sliding friction in addition to other loads.

121.7.3 Variable Supports

(A) Variable spring supports shall be designed to exert a supporting force equal to the load, as determined by weight balance calculations, plus the weight of all hanger parts (such as clamp, rod, etc.) that will be supported by the spring at the point of attachment to the pipe.

(B) Variable spring supports shall be provided with means to limit misalignment, buckling, eccentric loading, or to prevent overstressing of the spring.

(C) It is recommended that all hangers employing springs be provided with means to indicate at all times the compression of the spring with respect to the approximate hot and cold positions of the piping system, except where they are used either to cushion against shock or where the operating temperature of the piping system does not exceed 250°F (120°C).

(D) It is recommended that the support be designed for a maximum variation in supporting effort of 25% for the total travel resulting from thermal movement.

121.7.4 Constant Supports. On high temperature and critical service piping at locations subject to appreciable movement with thermal changes, the use of constant support hangers, designed to provide a substantially uniform supporting force throughout the range of travel, is recommended.

(A) Constant support hangers shall have a support variation of no more than 6% throughout the total travel range.

(B) Counterweight type supports shall be provided with stops, and the weights shall be positively secured. Chains, cables, hanger and rocker arm details, or other devices used to attach the counterweight load to the piping, shall be subject to requirements of para. 121.7.2.

(C) Hydraulic type supports utilizing a hydraulic head may be installed to give a constant supporting effort. Safety devices and stops shall be provided to support the load in case of hydraulic failure.

(D) Boosters may be used to supplement the operation of constant support hangers.

121.7.5 Sway Braces. Sway braces or vibration dampeners shall be used to control the movement of piping due to vibration.

121.7.6 Shock Suppressors. For the control of piping due to dynamic loads, hydraulic or mechanical types of shock suppressors are permitted. These devices do not support pipe weight.

121.8 Structural Attachments

121.8.1 Nonintegral Type

(A) Nonintegral attachments include clamps, slings, cradles, saddles, straps, and clevises.

(B) When clamps are used to support vertical lines, it is recommended that shear lugs be welded to the pipe to prevent slippage. The provisions of para. 121.8.2(B) shall apply.

(C) In addition to the provision of (B) above, clamps to support vertical lines should be designed to support the total load on either arm in the event the load shifts due to pipe and/or hanger movement.

121.8.2 Integral Type

(A) Integral attachments include ears, shoes, lugs, cylindrical attachments, rings, and skirts which are fabricated so that the attachment is an integral part of the piping component. Integral attachments shall be used in conjunction with restraints or braces where multiaxial restraint in a single member is to be maintained. Consideration shall be given to the localized stresses induced into the piping component by the integral attachments. Where applicable, the conditions of para. 121.8.1(C) are to apply.

(B) Integral lugs, plates, angle clips, etc., used as part of an assembly for the support or guiding of pipe may be welded directly to the pipe provided the materials are compatible for welding and the design is adequate for the temperature and load. The design of hanger lugs for attachment to piping for high temperature service shall be such as to provide for differential expansion between the pipe and the attached lug.

Welds shall be proportioned so that the shear stresses do not exceed either 0.8 times the applicable S values for the pipe material shown in the Allowable Stress Tables, or the allowable stress values determined in accordance with para. 121.2(A), (B), or (C). If materials for attachments have different allowable stress values than the pipe, the lower allowable stress value of the two shall be used.

121.9 Loads and Supporting Structures

121.9.1 Considerations shall be given to the load carrying capacity of equipment and the supporting structure. This may necessitate closer spacing of hangers on lines with extremely high loads.

121.10 Requirements for Fabricating Pipe Supports

121.10.1 Pipe supports shall be fabricated in accordance with the requirements of para. 130.

PART 6
SYSTEMS

122 DESIGN REQUIREMENTS PERTAINING TO SPECIFIC PIPING SYSTEMS

Except as specifically stated otherwise in this Part 6, all provisions of the Code apply fully to the piping systems described herein.

122.1 Boiler External Piping; in Accordance With Para. 100.1.2(A) — Steam, Feedwater, Blowoff, and Drain Piping

122.1.1 General. The minimum pressure and temperature and other special requirements to be used in the design for steam, feedwater, blowoff, and drain piping from the boiler to the valve or valves required by para. 122.1 shall be as specified in the following paragraphs. Design requirements for desuperheater spray piping *connected to desuperheaters located* in the boiler proper are provided in para. 122.4.

(A) It is intended that the design pressure and temperature be selected sufficiently in excess of any expected operating conditions, not necessarily continuous, to permit satisfactory operation without operation of the overpressure protection devices. Also, since the operating temperatures of fired equipment can vary, the expected temperature at the connection to the fired equipment shall include the manufacturer's maximum temperature tolerance.

(B) In a forced flow steam generator with no fixed steam and waterline, it is permissible to design the external piping, valves, and fittings attached to the pressure parts for different pressure levels along the path through the steam generator of water-steam flow. The values of design pressure and the design temperature to be used for the external piping, valves, and fittings shall be not less than that required for the expected maximum sustained operating pressure and temperature to which the abutted pressure part is subjected except when one or more of the overpressure protection devices covered by PG-67.4 of Section I of the ASME Boiler and Pressure Vessel Code is in operation. The steam piping shall comply with the requirements for the maximum sustained operating conditions as used in (A) above, or for the design throttle pressure plus 5%, whichever is greater.

(C) Provision shall be made for the expansion and contraction of piping connected to boilers to limit forces and moments transmitted to the boiler, by providing substantial anchorage at suitable points, so that there shall be no undue strain transmitted to the boiler. Steam reservoirs shall be used on steam mains when heavy pulsations of the steam currents cause vibration.

(D) Piping connected to the outlet of a boiler for any purpose shall be attached by:

(D.1) welding to a nozzle or socket welding fitting;

(D.2) threading into a tapped opening with a threaded fitting or valve at the other end;

(D.3) screwing each end into tapered flanges, fittings, or valves with or without rolling or peening;

(D.4) bolted joints including those of the Van Stone type;

(D.5) blowoff piping of firetube boilers shall be attached in accordance with (D.2) above if exposed to products of combustion or in accordance with (D.2), (D.3), or (D.4) above if not so exposed.

(E) Nonferrous pipe or tubes shall not exceed NPS 3 in diameter.

(F) American National Standard slip-on flanges shall not exceed NPS 4. Attachment of slip-on flanges shall be by double fillet welds. The throats of the fillet welds shall not be less than 0.7 times the thickness of the part to which the flange is attached.

(G) Hub-type flanges shall not be cut from plate material.

(H) American National Standard socket welded flanges may be used in piping or boiler nozzles provided the dimensions do not exceed NPS 3 for Class 600 and lower and NPS $2\frac{1}{2}$ in Class 1500.

122.1.2 Steam Piping

(A) The value of P to be used in the formulas in para. 104 shall be as follows.

(A.1) For steam piping connected to the steam drum or to the superheater inlet header up to the first stop valve in each connection, the value of P shall be not less than the lowest pressure at which any drum safety valve is set to blow, and the S value shall not exceed that permitted for the corresponding saturated steam temperature.

(A.2) For steam piping connected to the superheater outlet header up to the first stop valve in each connection, the design pressure, except as otherwise provided in (A.4) below shall be not less than the lowest pressure at which any safety valve on the superheater is set to blow, or not less than 85% of the lowest pressure at

which any drum safety valve is set to blow, whichever is greater, and the S value for the material used shall not exceed that permitted for the expected steam temperature.

(A.3) For steam piping between the first stop valve and the second valve, when one is required by para. 122.1.7, the design pressure shall be not less than the expected maximum sustained operating pressure or 85% of the lowest pressure at which any drum safety valve is set to blow, whichever is greater, and the S value for the material used shall not exceed that permitted for the expected steam temperature.

(A.4) For boilers installed on the unit system (i.e., one boiler and one turbine or other prime mover) and provided with automatic combustion control equipment responsive to steam header pressure, the design pressure for the steam piping shall be not less than the design pressure at the throttle inlet plus 5%, or not less than 85% of the lowest pressure at which any drum safety valve is set to blow, or not less than the expected maximum sustained operating pressure at any point in the piping system, whichever is greater, and the S value for the material used shall not exceed that permitted for the expected steam temperature at the superheater outlet. For forced-flow steam generators with no fixed steam and waterline, the design pressure shall also be no less than the expected maximum sustained operating pressure.

(A.5) The design pressure shall not be taken at less than 100 psig [700 kPa (gage)] for any condition of service or material.

122.1.3 *Feedwater Piping*

(A) The value of P to be used in the formulas in para. 104 shall be as follows.

(A.1) For piping from the boiler to and including the required stop valve and the check valve, the minimum value of P except as permitted in para. 122.1.3(A.4) shall exceed the maximum allowable working pressure of the boiler by either 25% or 225 psi (1550 kPa), whichever is the lesser. For an installation with an integral economizer without valves between the boiler and economizer, this paragraph shall apply only to the piping from the economizer inlet header to and including the required stop valve and the check valve.

(A.2) For piping between the required check valve and the globe or regulating valve, when required by para. 122.1.7(B), and including any bypass piping up to the shutoff valves in the bypass, the value of P shall be not less than the pressure required to feed the boiler.

(A.3) The value of P in the formula shall not be taken at less than 100 psig [700 kPa (gage)] for any condition of service or material, and shall never be less than the pressure required to feed the boiler.

(A.4) In a forced flow steam generator with no fixed steam and waterline, the value of P for feedwater piping from the boiler to and including the required stop valve may be in accordance with the requirements of para. 122.1.1(B).

(B) The S value used, except as permitted in (A.4) above, shall not exceed that permitted for the temperature of saturated steam at the maximum allowable working pressure of the boiler.

(C) The size of the feed piping between the boiler and the first required valve [para. 122.1.7(B)] or the branch feed connection [para. 122.1.7(B.4)] shall, as a minimum, be the same as the boiler connection.

122.1.4 Blowoff and Blowdown Piping. Blowoff and blowdown piping are defined as piping connected to a boiler and provided with valves or cocks through which the water in the boiler may be blown out under pressure. This definition is not intended to apply to (i) drain piping, and (ii) piping such as used on water columns, gage glasses, or feedwater regulators, etc., for the purpose of determining the operating condition of the equipment. Requirements for (i) and (ii) are described in paras. 122.1.5 and 122.1.6. Blowoff systems are operated intermittently to remove accumulated sediment from equipment and/or piping, or to lower boiler water level in a rapid manner. Blowdown systems are primarily operated continuously to control the concentrations of dissolved solids in the boiler water.

(A) Blowoff piping systems from water spaces of a boiler, up to and including the blowoff valves, shall be designed in accordance with (A.1) to (A.4) below. Two shutoff valves are required in the blowoff system; specific valve requirements and exceptions are given in para. 122.1.7(C).

(A.1) The value of P to be used in the formulas in para. 104 shall exceed the maximum allowable working pressure of the boiler by either 25% or 225 psi (1550 kPa) whichever is less, but shall not be less than 100 psig [700 kPa (gage)].

(A.2) The allowable stress value for the piping materials shall not exceed that permitted for the temperature of saturated steam at the maximum allowable working pressure of the boiler.

(A.3) All pipe shall be steel. Galvanized steel pipe and fittings shall not be used for blowoff piping. When the value of P does not exceed 100 psig [700 kPa (gage)], the fittings shall be bronze, cast iron, malleable

iron, ductile iron, or steel. When the value of P exceeds 100 psig [700 kPa (gage)], the fittings shall be steel and the thickness of pipe and fittings shall not be less than that of Schedule 80 pipe.

(A.4) The size of blowoff piping shall be not less than the size of the connection on the boiler, and shall be in accordance with the rules contained in the ASME Boiler and Pressure Vessel Code, Section I, PG-59.3 and PEB-12.

(B) The blowdown piping system from the boiler, to and including the shutoff valve, shall be designed in accordance with (B.1) through (B.4) below. Only one shutoff valve is required in the blowdown system.

(B.1) The value of P to be used in the formulas in para. 104 shall be not less than the lowest set pressure of any safety valve on the boiler drum.

(B.2) The allowable stress value for the piping materials shall not exceed that permitted for the temperature of saturated steam at the maximum allowable working pressure of the boiler.

(B.3) All pipe shall be steel. Galvanized steel pipe and fittings shall not be used for blowdown piping. When the value of P does not exceed 100 psig [700 kPa (gage)], the fittings shall be bronze, cast iron, malleable iron, ductile iron, or steel. When the value of P exceeds 100 psig [700 kPa (gage)], the fittings shall be steel and the thickness of pipe and fittings shall not be less than that of Schedule 80 pipe.

(B.4) The size of blowdown piping shall be not less than the size of the connection on the boiler, and shall be in accordance with the rules contained in the ASME Boiler and Pressure Vessel Code, Section I, PG-59.3.

(C) The blowoff and blowdown piping beyond the required valves described in (A) and (B) above are classified as nonboiler external piping. The requirements are given in para. 122.2.

122.1.5 Boiler Drains

(A) Complete drainage of the boiler and attached piping shall be provided to the extent necessary to ensure proper operation of the steam supply system. The pipe, fittings, and valves of any drain line shall not be smaller than the drain connection.

(B) If the drain lines are intended to be used both as drains and as blowoffs, then two valves are required and all conditions of paras. 122.1.4, 122.1.7(C), and 122.2 shall be met.

(C) When a drain is intended for use only when the boiler is not under pressure (pressurizing the boiler for rapid drainage is an exception), a single shutoff valve is acceptable under the following conditions: either the valve shall be a type that can be locked in the closed position or a suitable flanged and bolted connection that accepts a blank insert shall be located on the downstream side of the valve. When a single valve is used, it need not be designed for blowoff service.

(D) Drain piping from the drain connection, including the required valve(s) or the blanked flange connection, shall be designed for the temperature and pressure of the drain connection. The remaining piping shall be designed for the expected maximum temperature and pressure. Static head and possible choked flow conditions shall be considered. In no case shall the design pressure and temperature be less than 100 psig [700 kPa (gage)] and 220°F (104°C), respectively.

122.1.6 Boiler External Piping — Miscellaneous Systems

(A) Materials, design, fabrication, examination, and erection of piping for miscellaneous accessories, such as water level indicators, water columns, gage cocks, and pressure gages, shall be in accordance with the applicable sections of this Code.

(B) The value of P to be used in the Formulas in para. 104 shall be not less than the maximum allowable working pressure of the boiler except as provided by para. 122.1.1(B).

(C) Valve requirements for water level indicators or water columns, special gage glass and gage cock requirements, minimum line sizes, and special piping configurations required specifically for cleaning, access, or reliability shall be in accordance with PG-60 of Section I of the ASME Boiler and Pressure Vessel Code.

122.1.7 Valves and Fittings. The minimum pressure and temperature rating for all valves and fittings in steam, feedwater, blowoff, and miscellaneous piping shall be equal to the pressure and temperature specified for the connected piping on the side that has the higher pressure, except that in no case shall the pressure be less than 100 psig [700 kPa (gage)], and for pressures not exceeding 100 psig [700 kPa (gage)] in feedwater and blowoff service, the valves and fittings shall be equal at least to the requirements of the ASME standards for Class 125 cast iron or Class 150 steel.

(A) Steam Stop Valves. Each boiler discharge outlet, except safety valve or safety relief valve connections, or reheater inlet and outlet connections, shall be fitted with a stop valve located at an accessible point in the steam-delivery line and as near to the boiler nozzle as is convenient and practicable.

(A.1) Boiler stop valves shall provide bidirectional shutoff at design conditions. The valve or valves shall meet the requirements of para. 107. Valves with resilient

(nonmetallic) seats shall not be used where the boiler maximum allowable working pressure exceeds 1035 kPa (150 psig) or where the system design temperature exceeds 186°C (366°F). Valves of the outside screw and yoke, rising stem style are preferred. Valves other than those of the outside screw and yoke, rising stem style shall meet the following additional requirements.

(A.1.A) Each valve shall be equipped with a position indicator to visually indicate from a distance whether the valve is open or closed.

(A.1.B) Quarter turn valves shall be equipped with a slow operating mechanism to minimize dynamic loadings on the boiler and attached piping.

(A.2) In the case of a single boiler and prime mover installation, the stop valve required herein may be omitted provided the prime mover throttle valve is equipped with an indicator to show whether it is opened or closed, and it is designed to withstand the required boiler hydrostatic test.

(A.3) When two or more boilers are connected to a common header, or when a single boiler is connected to a header having another steam source, the connection from each boiler having a man-hole opening shall be fitted with two stop valves having an ample free-blow drain between them. The preferred arrangement consists of one stop-check valve (located closest to the boiler) and one valve of the style and design described in (A.1) above. Alternatively, both valves may be of the style and design described in (A.1) above.

When a second stop valve is required, it shall have a pressure rating at least equal to that required for the expected steam pressure and temperature at the valve, or a pressure rating at least equal to 85% of the lowest set pressure of any safety valve on the boiler drum at the expected temperature of the steam at the valve, whichever is greater.

(A.4) All valves and fittings on steam lines shall have a pressure rating of at least 100 psig [700 kPa (gage)] in accordance with the applicable ASME Standard.

(B) Feedwater Valves

(B.1) The feedwater piping for all boilers, except for high temperature water boilers complying with the requirements of (B.8) below, and for forced flow steam generators with no fixed steam and water line complying with the requirements of (B.9) below, shall be provided with a check valve and a stop valve or cock between the check valve and the boiler. The stop valve or cock shall comply with the requirements of (C.5) below.

(B.2) The relative locations of the check and stop (or cock) valves, as required in (B.1) above, may be reversed on a single boiler-turbine unit installation.

(B.3) If a boiler is equipped with a duplicate feed arrangement, each such arrangement shall be equipped as required by these rules.

(B.4) When the supply line to a boiler is divided into branch feed connections and all such connections are equipped with stop and check valves, the stop and check valves in the common source may be omitted.

(B.5) When two or more boilers are fed from a common source, there shall also be a globe or regulating valve in the branch to each boiler located between the check valve and the source of supply. A typical arrangement is shown in Fig. 100.1.2(B). Wherever globe style valves are used on feed piping, the inlet shall be under the disk of the valve.

(B.6) A combination stop and check valve in which there is only one seat and disk, and in which a valve stem is provided to close the valve, shall be considered only as a stop valve, and a check valve shall be installed as otherwise provided.

(B.7) Where an economizer or other feedwater heating device is connected directly to the boiler without intervening valves, the feed valves and check valves required shall be placed on the inlet of the economizer or feedwater heating device.

(B.8) The recirculating return line for a high temperature water boiler shall be provided with the same stop valve, or valves, required by (B.1) and (B.3) above. The use of a check valve in the recirculating return line is optional. A check valve shall not be a substitute for a stop valve.

(B.9) The feedwater boiler external piping for a forced flow steam generator with no fixed steam and water line may terminate up to and including the stop valve(s) and omitting the check valve(s) provided that a check valve having a pressure rating no less than the boiler inlet design pressure is installed at the discharge of each boiler feed pump or elsewhere in the feedline between the feed pump and the stop valve(s).

(C) Blowoff Valves

(C.1) Ordinary globe valves as shown in Fig. 122.1.7(C) sketch (1), and other types of valves that have dams or pockets where sediment can collect, shall not be used on blowoff connections.

(C.2) Y-type globe valves as shown in Fig. 122.1.7(C) sketch (2) or angle valves may be used in vertical pipes, or they may be used in horizontal runs of piping provided they are so constructed or installed that the lowest edge of the opening through the seat is at least 25% of the inside diameter below the center line of the valve.

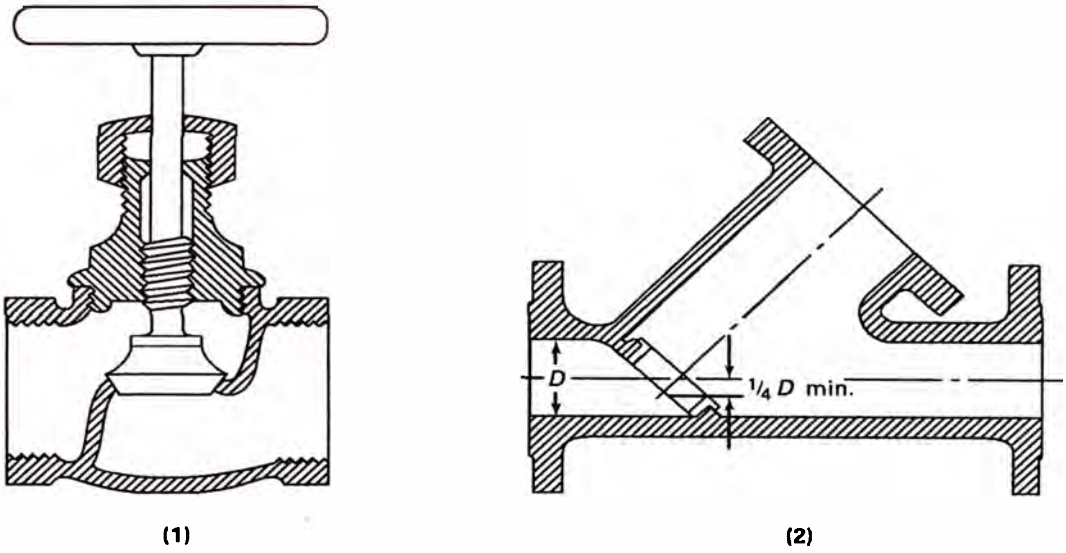


FIG. 122.1.7(C) TYPICAL GLOBE VALVES

(C.3) The blowoff valve or valves, the pipe between them, and the boiler connection shall be of the same size except that a larger pipe for the return of condensate may be used.

(C.4) For all boilers [except electric steam boilers having a normal water content not exceeding 100 gal (380 1), traction-purpose, and portable steam boilers; see (C.11) and (C.12) below] with allowable working pressure in excess of 100 psig [700 kPa (gage)], each bottom blowoff pipe shall have two slow-opening valves, or one quick-opening valve or cock, at the boiler nozzle followed by a slow-opening valve. All valves shall comply with the requirements of (C.5) and (C.6) below.

(C.5) When the value of *P* required by para. 122.1.4(A.1) does not exceed 250 psig [1750 kPa (gage)], the valves or cocks shall be bronze, cast iron, ductile iron, or steel. The valves or cocks, if of cast iron, shall not exceed NPS $2\frac{1}{2}$ and shall meet the requirements of the applicable ASME Standard for Class 250, as given in Table 126.1, and if of bronze, steel, or ductile iron construction, shall meet the requirements of the applicable standards as given in Table 126.1 or para. 124.6.

(C.6) When the value of *P* required by para. 122.1.4(A.1) is higher than 250 psig [1750 kPa (gage)], the valves or cocks shall be of steel construction equal at least to the requirements of Class 300 of the applicable ASME Standard listed in Table 126.1. The minimum pressure rating shall be equal to the value of *P* required by para. 122.1.4(A.1).

(C.7) If a blowoff cock is used, the plug shall be held in place by a guard or gland. The plug shall be distinctly marked in line with the passage.

(C.8) A slow-opening valve is a valve which requires at least five 360 deg turns of the operating mechanism to change from fully closed to fully opened.

(C.9) On a boiler having multiple blowoff pipes, a single master valve may be placed on the common blowoff pipe from the boiler, in which case only one valve on each individual blowoff is required. In such a case, either the master valve or the individual valves or cocks shall be of the slow-opening type.

(C.10) Two independent slow-opening valves, or a slow-opening valve and a quick-opening valve or cock, may be combined in one body and may be used provided the combined fitting is the equivalent of two independent slow-opening valves, or a slow-opening valve and a quick-opening valve or cock, and provided further that the failure of one to operate cannot affect the operation of the other.

(C.11) Only one blowoff valve, which shall be either a slow-opening or quick-opening blowoff valve or a cock, is required on traction and/or portable boilers.

(C.12) Only one blowoff valve, which shall be of a slow-opening type, is required on forced circulation and electric steam boilers having a normal water content not exceeding 100 gal (380 liter).

(D) Safety Valves

(D.1) Safety valves, relief valves, and safety relief valves shall conform to the requirements of PG-67,

TABLE 122.2

Boiler or Vessel Pressure		Design Pressure		Design Temperature	
psig	kPa (gage)	psig	kPa (gage)	°F	°C
Below 250	1 750	Note (1)		...	...
250–600	1 750–4 150	250	1750	410	210
601–900	4 151–6 200	400	2750	450	230
901–1500	6 201–10 300	600	4150	490	255
1501 and higher	10 301 and higher	900	6200	535	280

NOTE:
(1) For boiler or vessel pressure(s) below 250 psig [1750 kPa (gage)], the design pressure shall be determined in accordance with para. 122.1.4(B.1) but need not exceed 250 psig [1750 kPa (gage)].

PG-68, PG-69, PG-70, PG-71, PG-72, and PG-73 of Section I of the ASME Boiler and Pressure Vessel Code.

122.2 Blowoff and Blowdown Piping in Nonboiler External Piping

(A) From Boilers

(A.1) Blowoff piping, located between the valves described in para. 122.1.4(A) and the blowoff tank or other point where the pressure is reduced approximately to atmospheric pressure and cannot be increased by closing a valve, shall be designed for saturated steam at the appropriate pressure and temperature in accordance with Table 122.2. The provisions of para. 122.1.4(A.3) shall apply.

(A.2) Blowdown piping, located after the valve described in para. 122.1.4(B) in which the pressure cannot be increased by closing a valve, shall be designed for the appropriate pressure and temperature in accordance with Table 122.2. The provisions of para. 122.1.4(B.3) shall apply.

(A.3) When design pressure of Table 122.2 can be exceeded due either to closing of a downstream valve, calculated pressure drop, or other means, the entire blowoff or blowdown piping system shall be designed in accordance with para. 122.1.4(A) or (B), respectively.

(B) From Pressure Vessels Other Than Boilers

(B.1) The design pressure and temperature of the blowoff piping from the pressure vessel to and including the blowoff valve(s) shall not be less than the vessel design conditions.

122.3 Instrument, Control, and Sampling Piping

(A) The requirements of this Code, as supplemented by para. 122.3, shall apply to the design of instrument, control, and sampling piping for safe and proper operation of the piping itself.

(B) The term "Instrument Piping" shall apply to all valves, fittings, tubing, and piping used to connect instruments to main piping or to other instruments or apparatus or to measuring equipment as used within the classification of para. 100.1.

(C) The term "Control Piping" shall apply to all valves, fittings, tubing, and piping used to interconnect pneumatically or hydraulically operated control apparatus, also classified in accordance with para. 100.1, as well as to signal transmission systems used to interconnect instrument transmitters and receivers.

(D) The term "Sampling Piping" shall apply to all valves, fittings, tubing, and piping used for the collection of samples, such as steam, water, oil, gas, and chemicals.

(E) Paragraph 122.3 does not apply to tubing used in permanently closed systems, such as fluid-filled temperature responsive devices, or the temperature responsive devices themselves.

(F) Paragraph 122.3 does not apply to the devices, apparatus, measuring, sampling, signalling, transmitting, controlling, receiving, or collecting instruments to which the piping is connected.

122.3.1 Materials and Design. The materials utilized for valves, fittings, tubing, and piping shall meet the particular conditions of service and the requirements of the applicable specifications listed under general paras. 105, 106, 107, and 108 with allowable stresses in accordance with the Allowable Stress Tables in Appendix A.

The materials for pressure retention components used for piping specialities such as meters, traps, and strainers in flammable, combustible, or toxic fluid systems shall in addition conform to the requirements of paras. 122.7 and 122.8.

122.3.2 Instrument Piping

(A) Takeoff Connections

(A.1) Takeoff connections at the source, together with attachment bosses, nozzles, and adapters, shall be made of material at least equivalent to that of the pipe or vessel to which they are attached. The connections shall be designed to withstand the source design pressure and temperature and be capable of withstanding loadings induced by relative displacement and vibration. The nominal size of the takeoff connections shall not be less than NPS ½ for service conditions not in excess of either 900 psi (6200 kPa) or 800°F (425°C), and NPS ¾ (for adequate physical strength) for design conditions which exceed either of these limits. Where the size of the main is smaller than the limits given above, the takeoff connection shall not be less than the size of the main line.

(A.2) To prevent thermal shock to the main steam line by contact with the colder condensate return from the instrument, steam meter or instrument takeoff connections shall be lagged in with the steam main. For temperature in excess of 800°F (425°C), they may also be arranged to make metallic contact lengthwise with the steam main.

(B) Valves

(B.1) Shutoff Valves. Shutoff valves shall be provided at takeoff connections. They shall be capable of withstanding the design pressure and temperature of the pipe or vessel to which the takeoff adapters or nipples are attached.

(B.2) Blowdown Valves

(B.2.1) Blowdown valves at or near the instrument shall be of the gradual opening type. For subcritical pressure steam service, the design pressure for blowdown valves shall be not less than the design pressure of the pipe or vessel; the design temperature shall be the corresponding temperature of saturated steam. For all other services, blowdown valves shall meet the requirements of (B.1) above.

(B.2.2) When blowdown valves are used, the valves at the instrument as well as any intervening fittings and tubing between such blowdown valves and the meter shall be suitable at 100°F (40°C) for at least 1½ times the design pressure of the piping system, but the rating of the valve at the instrument need not exceed the rating of the blowdown valve.

(B.2.3) When blowdown valves are not used, instrument valves shall conform to the requirements of (B.2.1) above.

(C) Reservoirs or Condensers. In dead end steam service, the condensing reservoirs and connecting nipples, which immediately follow the shutoff valves, shall be made of material suitable for the saturated steam temperature corresponding to the main line design pressure.

(D) Materials for Lines Between Shutoff Valves and Instruments

(D.1) Copper, copper alloys, and other nonferrous materials may be used in dead end steam or water services up to the design pressure and temperature conditions used for calculating the wall thickness in accordance with para. 104 provided that the temperature within the connecting lines for continuous services does not exceed 406°F (208°C).

Where water temperature in the reservoir of condensers is above 406°F (208°C), a length of uninsulated steel tubing at least 5 ft (1.5 m) long shall immediately follow the condenser ahead of the connecting copper tubing to the instrument.

(D.2) The minimum size of the tubing or piping is a function of its length, the volume of fluid required to produce full scale deflections of the instrument, and the service of the instrument. When required to prevent plugging as well as to obtain sufficient mechanical strength, the inside diameter of the pipe or tube should not be less than 0.36 in. (9.14 mm), with a wall thickness of not less than 0.049 in. (1.25 mm). When these requirements do not apply, smaller sizes with wall thickness in due proportions may be used. In either case, wall thickness of the pipe or tube shall meet the requirements of (D.3) below.

(D.3) The piping or tubing shall be designed in accordance with para. 104 with consideration for water hammer.

(E) Fittings and Joints

(E.1) For dead end steam service and for water above 150°F (65°C), fittings of the. flared, flareless, or socket welding type, or other suitable type of similar design shall be used. The fittings shall be suitable for the header pressure and corresponding saturated steam temperature or water temperature, whichever applies. For supercritical pressure conditions the fittings shall be suitable for the design pressure and temperature of the main fluid line.

(E.2) For water, oil and similar instrument services, any of the following types may be used, within the pressure-temperature limitations of each.

(E.2.1) For main line hydraulic pressures above 500 psi (3450 kPa) and temperatures up to 150°F (65°C), steel fittings either of the flared, flareless, socket welded, fusion welded, or silver brazed socket type shall be used.

(E.2.2) For main line pressures up to 500 psi (3450 kPa) and temperatures up to 150°F (65°C), the fittings may be: (E.2.2.1) flared or silver brazed socket type,

inverted flared or flareless compression type, all of brass or bronze.

(E.2.3) For pressures up to 175 psi (1200 kPa) or temperatures up to 250°F (120°C), soldered type fittings may be used with water-filled or air-filled tubing under adjusted pressure-temperature ratings. These fittings are not recommended where mechanical vibration, hydraulic shock, or thermal shock are encountered.

122.3.3 Control Piping

(A) Takeoff Connections

(A.1) Takeoff connections shall be in accordance with para. 122.3.2(A.1).

(B) Valves

(B.1) Shutoff valves shall be in accordance with para. 122.3.2(B.1).

(C) Materials

(C.1) The same materials may be used for control lines as for instrument lines, except that the minimum inside diameter shall be 0.178 in. (4.52 mm) with a minimum wall thickness of 0.028 in. (0.71 mm), provided that this wall thickness is not less than that required by para. 122.3.2(D.3). If a control device has a connection smaller than $\frac{1}{4}$ in. (6.0 mm), the size reduction from the control tubing to the control device shall be made as close to the control device as possible.

(D) Fittings and Joints

(D.1) Fittings and joints shall be in accordance with para. 122.3.2(E.2).

122.3.4 Sampling Piping

(A) Takeoff Connections

(A.1) Takeoff connections shall be in accordance with para. 122.3.2(A.1).

(B) Valves

(B.1) Shutoff valves shall be in accordance with para. 122.3.2(B.1).

(B.2) Blowdown valves shall be of the gradual opening type and shall be suitable for main line design pressure and temperature.

(C) Materials

(C.1) The materials to be used for sampling lines shall conform to minimum requirements for the main line to which they connect.

(D) Fittings and Joints

(D.1) For subcritical and supercritical pressure steam, and for water above 150°F (65°C), fittings of the flared, flareless, or socket welding type, or other suitable type of similar design shall be used. The fittings shall be suitable for main line design pressure and temperature.

(D.2) For water below 150°F (65°C), fittings and joints shall be suitable for main line design pressure and temperature and shall be in accordance with para. 122.3.2(E.2).

122.3.6 Fittings and Joints

(A) All fittings shall be in accordance with standards and specifications listed in Table 126.1.

(A.1) Socket welded joints shall comply with the requirements of para. 111.3.

(A.2) Flared, flareless, and compression type fittings and their joints shall comply with the requirements of para. 115.

(A.3) Silver brazed socket type joints shall comply with the requirements of paras. 117.1 and 117.3.

(A.4) Solder type joints shall comply with the requirements of paras. 117.2 and 117.3.

(A.5) The use of taper threaded joints up to and including NPS $\frac{1}{2}$ is permitted at pressures up to 5000 psi (34 500 kPa) in dead end service from outlet end and downstream of shutoff valve located at instrument, at control apparatus, or at discharge of sample cooler.

122.3.7 Special Safety Provisions

(A) Connecting piping subject to clogging from solids or deposits shall be provided with suitable connections for cleaning.

(B) Connecting piping handling air and gases containing moisture or other extraneous materials shall be provided with suitable drains or settling chambers or traps.

(C) Connecting piping which may contain liquids shall be protected from damage due to freezing by heating or other adequate means.

122.3.8 Supports. Supports shall be furnished as specified in para. 121 not only for safety but also to protect the piping against detrimental sagging, external mechanical injury abuse, and exposure to unusual service conditions.

122.3.9 Installations

(A) Instrument, control, and sampling piping shall be inspected and tested in accordance with paras. 136 and 137.

(B) The inside of all piping, tubing, valves, and fittings shall be smooth, clean, and free from blisters, loose mill scale, sand, and dirt when erected. All lines shall be cleaned after installation and before placing in service.

122.4 Spray Type Desuperheater Piping for Use on Steam Generators and Reheat Piping 01

(A) Valves and Piping Arrangement

(A.1) Each spraywater pipe connected to a desuper-

heater shall be provided with a stop valve and a regulating (spray control) valve. The regulating valve shall be installed upstream of the stop valve. In addition, if the steam generator supplies steam to a steam turbine, a power-operated block valve[3] shall be installed upstream of the regulating valve.

(A.2) A bypass valve around the regulating valve is permitted.

(A.3) A bypass valve around the power-operated block valve is prohibited.

(A.4) On a reheater desuperheater, a drain valve shall be installed between the power-operated block valve and the regulating valve.

(A.5) If the spraywater supply is from the boiler feedwater system and its source is not downstream of the feedwater check valve required by para. 122.1.7, a check valve shall be provided in the spraywater piping between the desuperheater and the spraywater source.

(A.6) It is recommended that the valves and piping be arranged to provide a head of water on the downstream side of the stop valve.

(A.7) A typical arrangement is shown in Fig. 122.4.

(A.8) Provisions shall be made to both steam and water systems to accommodate the operating conditions associated with this service including: water hammer, thermal shock and direct water impingement. The connection for the spraywater pipe should be located per the requirements established by the manufacturer so that complete flow mixing is achieved prior to any bends, elbows, or other flow directional changes being encountered.

(A.9) Insertable-type desuperheaters, which include an integral stop and spraywater regulating valve, may be used within the limitations established by the manufacturer. If this type is used, the individual stop and regulating valves shown in Fig. 122.4 may be omitted. All other requirements described in para. 122.4 shall apply.

(A.10) For Desuperheaters Located Within Reheat Piping. The steam system to be desuperheated shall be provided with proper drainage during all water flow conditions. The drainage system shall function both manually and automatically.

(B) Design Requirements

(B.1) The value of P to be used in the formulas of para. 104 shall be as follows.

(B.1.1) For piping from the desuperheater back to the stop valve required by (A.1) above, the value of P shall be equal to or greater than the maximum allowable working pressure of the desuperheater.

(B.1.2) For the remainder of the spraywater piping system, the value of P shall be not less than the maximum sustained pressure exerted by the spraywater.

(B.2) The stop valve required by (A.1) above shall be designed for the pressure requirement of (B.1.1) above or the maximum sustained pressure exerted by the spraywater, whichever is greater.

(B.3) The S value used for the spraywater piping shall not exceed that permitted for the expected temperature.

NOTE: The temperature varies from that of the desuperheater to that of the spraywater source and is highly dependent on the piping arrangement. It is the responsibility of the designer to determine the design temperature to be used for the various sections of the piping system.

122.5 Pressure Reducing Valves

122.5.1 General. Where pressure reducing valves are used, one or more relief devices or safety valves shall be provided on the low pressure side of the system. Otherwise, the piping and equipment on the low pressure side of the system shall be designed to withstand the upstream design pressure. The relief or safety devices shall be located adjoining or as close as practicable to the reducing valve. The combined relieving capacity provided shall be such that the design pressure of the low pressure system will not be exceeded if the reducing valve fails open.

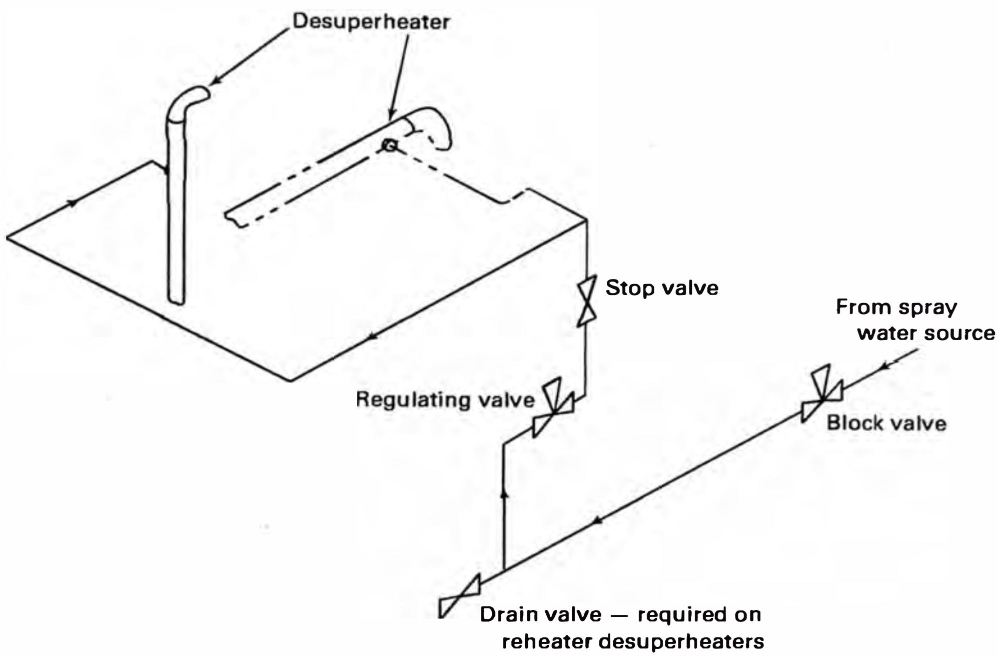
122.5.2 Bypass Valves. Hand controlled bypass valves having a capacity no greater than the reducing valve may be installed around pressure reducing valves if the downstream piping is protected by relief valves as required in para. 122.5.1 or if the design pressure of the downstream piping system and equipment is at least as high as the upstream pressure.

122.5.3 Design of Valves and Relief Devices. Pressure reducing and bypass valves, and relief devices, shall be designed for inlet pressure and temperature conditions. Safety and relief valves shall be in accordance with the requirements of para. 107.8 of this Code.

122.6 Pressure Relief Piping

Pressure relief piping within the scope of this Code shall be supported to sustain reaction forces, and shall conform to the following requirements.

[3] For information on the prevention of water damage to steam turbines used for electric power generation, see ASME TDP-1.



GENERAL NOTE: This figure is a schematic only and is not intended to show equipment layout or orientation.

01 FIG. 122.4 DESUPERHEATER SCHEMATIC ARRANGEMENT

122.6.1 Piping to Pressure-Relieving Safety Devices

(A) There shall be no intervening stop valve(s) between piping being protected and the protective device(s).

(B) Diverter or changeover valves designed to allow servicing of redundant protective devices without system depressurization may be installed between the piping to be protected and the required protective devices under the following conditions.

(B.1) Diverter or changeover valves are prohibited on boiler external piping or reheat piping.

(B.2) One hundred percent (100%) of the required relieving capacity shall be continuously available any time the system is in service.

(B.3) Positive position indicators shall be provided on diverter or changeover valves.

(B.4) Positive locking mechanisms and seals shall be provided on diverter or changeover valves to preclude unauthorized or accidental operation.

(B.5) Diverter or changeover valves shall be designed for the most severe conditions of pressure, temperature, and loading to which they are exposed, and shall be in accordance with para. 107.

(B.6) Provision shall be made to safely bleed off the pressure between the isolated protective device and the diverter or changeover valve.

122.6.2 Discharge Piping From Pressure Relieving Safety Devices

(A) There shall be no intervening stop valve between the protective device or devices and the point of discharge.

(B) When discharging directly to the atmosphere, discharge shall not impinge on other piping or equipment and shall be directed away from platforms and other areas used by personnel.

(C) It is recommended that individual discharge lines be used, but if two or more reliefs are combined, the discharge piping shall be designed with sufficient flow area to prevent blowout of steam or other fluids. Sectional areas of a discharge pipe shall not be less than the full area of the valve outlets discharging thereinto and the discharge pipe shall be as short and straight as possible and so arranged as to avoid undue stresses on the valve or valves.

(D) Discharge lines from pressure-relieving safety devices within the scope of this Code shall be designed to facilitate drainage.

(E) When the umbrella or drip pan type of connection

is used, the discharge piping shall be so designed as to prevent binding due to expansion movements.

(F) Drainage shall be provided to remove water collected above the safety valve seat.

(G) Carbon steel materials listed in Appendix A may be used for discharge piping which is subjected to temperatures above 800°F (427°C) only during operation of pressure relieving safety devices provided that:

(G.1) the duration of pressure relieving safety device operation is self-limiting;

(G.2) the piping discharges directly to atmosphere;

(G.3) material allowable stresses at temperatures above 800°F (427°C) shall be taken from Section II, Part D, Tables 1A and 1B for materials applicable to Section I and Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

122.7 Piping for Flammable or Combustible Liquids

122.7.1 General. Piping for flammable or combustible liquids including fuel and lubricating oils is within the scope of this Code. Piping for synthetic lubricants having no flash or fire point need not meet the requirements of para. 122.7.

The designer is cautioned that, among other criteria, static electricity may be generated by the flowing fluid. Additionally, the designer is cautioned of the extreme chilling effect of a liquefied gas flashing to vapor during loss of pressure. This is a factor for determining the lowest expected service temperature relative to the possibility of brittle fracture of materials. Consideration shall also be given to the pressure rise that may occur as a cold fluid absorbs heat from the surroundings.

122.7.2 Materials

(A) Seamless steel or nickel alloy piping materials shall be used in all areas where the line is within 25 ft (7.6 m) of equipment or other lines having an open flame or exposed parts with an operating temperature above 400°F (204°C). Seamless steel or nickel alloy pipe shall also be used for fuel oil systems located downstream of burner shutoff valve(s). The burner shutoff valve(s) shall be located as close to the burner as is practical.

(B) In all other areas, piping systems may include pipe or tube of steel, nickel alloy, ductile iron, copper, or brass construction. Copper tubing shall have a thickness not less than that required by para. 104.1.2(C.3), regardless of pressure. Refer also to paras. 105, 124.6, and 124.7(A)

Wherever materials other than steel or nickel alloy are used, they shall be so located that any spill resulting from the failure of these materials will not unduly expose persons, buildings, or structures, or can be readily controlled by remote valves.

(C) For lubricating oil systems, steel tubing is an acceptable alternative to steel pipe.

(D) Polyethylene (PE) and reinforced thermosetting resin (RTR) pipe may be used for flammable or combustible liquids in buried installations only. The fluid temperatures shall not exceed 140°F (60°C) and pressures shall be limited to 150 psi (1000 kPa). Where such PE or RTR pipe is used in flammable or combustible liquid service, the rules of Appendix III shall be considered mandatory. Where jurisdictional requirements mandate that double containment pipe be used, the rules of Appendix III shall be applied to both the inner and outer pipe.

Particular care must be exercised to prevent damage to RTR piping at the connection to the main or other facility. Precautions shall be taken to prevent crushing or shearing of RTR piping due to external loading or settling of backfill and to prevent damage or pull out from the terminal connection resulting from thermal expansion or contraction.

RTR piping may terminate above ground and outside a building, provided that:

(1) the above ground portion of the RTR pipe is completely enclosed in a conduit or casing of sufficient strength to provide protection from external damage and deterioration. Where a flexible conduit is used, the top of the riser must be attached to a solid support. The conduit or casing shall extend a minimum of 6 in. below grade.

(2) the RTR pipe is not subjected to excessive stresses due to external loading.

122.7.3 Piping Joints

(A) Welded joints shall be used between steel or nickel alloy piping components where practicable. Where bolted flanged joints are necessary, the gasket material shall be suitable for the service. Threaded joints, where unavoidable for connecting to equipment, valves, specialties, or instruments, shall be:

(A.1) in piping of a thickness no less than extra strong regardless of pressure;

(A.2) limited as prescribed in para. 114; and

(A.3) assembled with extreme care to assure leak tightness, using thread sealant suitable for the service.

(B) Threaded joints in copper or brass pipe shall be subject to the same limitations as for steel pipe in (A.1), (A.2), and (A.3), above.

(C) Copper tubing shall be assembled with flared, flareless, or compression type joints as prescribed in

para. 115, or brazed in accordance with para. 117. Soft solder type joints are prohibited.

(D) RTR pipe shall be adhesive bonded in accordance with the pipe manufacturer's recommended procedures.

(E) Pipe joints dependent on the friction characteristics or resiliency of combustible materials for mechanical or leak tightness of piping shall not be used inside buildings.

(F) Steel tubing shall be assembled with fittings in accordance with para. 115, or with socket weld fittings.

122.7.4 Valves and Specialties. Valves, strainers, meters, and other specialties shall be of steel or nickel alloy construction. As an alternative, ductile or malleable iron or copper alloy valves and specialties may be used, subject to the restrictions in paras. 124.6 and 124.7, where metal temperatures do not exceed 400°F (204°C).

122.8 Piping for Flammable Gases, Toxic Gases or Liquids, or Nonflammable Nontoxic Gases

Although some gases are liquefied for storage or transport, they shall be considered as gases if their Reid vapor pressure is greater than 40 psia [2068.6 mm Hg (absolute)] at 100°F (37.8°C).

122.8.1 Flammable Gas

(A) Some of the common flammable gases are acetylene, ethane, ethylene, hydrogen, methane, propane, butane, and natural or manufactured gas used for fuel. It shall be the designers' responsibility to determine the limiting concentrations (upper and lower explosive limits) and the properties of the gas under consideration. The use of explosive concentrations shall be avoided, or the piping shall be designed to withstand explosive forces.

The designer is further cautioned of the extreme chilling effect of gas during rapid expansion. This is a factor for determining the lowest expected service temperature relative to the possibility of brittle fracture of materials.

(B) Materials. Steel piping, subject to the limitations in para. 105, shall be used for all flammable gases, except as otherwise permitted in (B.2), (B.3), and (B.4) below.

(B.1) Pipe joints shall be welded where practicable, except bolted flanged joints with suitable gaskets may be used where necessary. Threaded joints, where unavoidable for connecting to equipment, valves, specialties, or instruments, shall be:

(B.1.1) in piping of a thickness no less than extra strong regardless of pressure or material;

(B.1.2) limited as prescribed in para. 114, except threaded joints and compression fittings to maximum nominal size of NPS $^3/_4$ (DN 20) for pressure to 5000 psi (34,000 kPa) are permitted at the connection to the refillable storage containers pressure regulators; and

(B.1.3) assembled with extreme care to assure leak tightness, using thread sealant suitable for the service.

(B.2) For hydrogen systems, the following alternative materials may be used:

(B.2.1) seamless steel tubing with welded joints;

(B.2.2) seamless copper or brass pipe or tubing with brazed, threaded, or compression fitting joints. Threaded fittings shall not exceed NPS $^3/_4$ (DN 20). For protection against damage, tubing shall be installed in a guarded manner that will prevent damage during construction, operation, or service. Valves with suitable packing, gages, regulators, and other equipment may also consist of copper alloy materials. Safety relief devices shall be vented individually, and connected vent piping shall be designed to convey the fluid, without pockets, to the outside atmosphere; and then directed away from equipment ventilation systems, and vents from other systems.

(B.3) For fuel gas instrumentation and control, seamless copper tubing subject to the following restrictions may be used:

(B.3.1) the design pressure shall not exceed 100 psi (690 kPa);

(B.3.2) tubing shall not exceed $^5/_8$ in. (15.9 mm) nominal outside diameter;

(B.3.3) all joints shall be made with compression or flared fittings;

(B.3.4) copper tubing shall not be used if the fuel gas contains more than 0.3 grains (19.4 mg) of hydrogen sulfide per 100 cu ft/min (47 liters/sec) of gas at standard conditions;

(B.3.5) consideration shall be given in the design to the lower strength and melting point of copper compared to steel. Adequate support and protection from high ambient temperatures and vibration shall be provided.

(B.3.6) tubing shall be installed in a guarded manner that will prevent damage during construction, operation, and service.

(B.4) Polyethylene (PE) pipe may be used for natural gas service in buried installations only. The fluid temperatures shall not exceed 140°F (60°C), nor be below −20°F (−30°C) and pressures shall be limited to 100 psi (690 kPa). Pipe joints shall be heat fused in accordance with manufacturer's recommended procedures. Where PE pipe is used in flammable gas service, the rules of Appendix III shall be considered mandatory.

(C) Valves and Specialties. Valves, strainers, meters, and other specialities shall be of steel or nickel alloy construction. As as alternative, ductile iron or copper alloy valves and specialities may be used, subject to the restrictions in paras. 124.6 and 124.7, where metal temperatures do not exceed 400°F (204°C).

(D) For in-plant fuel gas distribution system(s) where the use of a full-relieving-capacity relief valve(s) as described in para. 122.5 could create an undue venting hazard, an alternative pressure limiting design may be substituted. The alternative design shall include all provisions below:

(D.1) Tandem Gas Pressure Reducing Valves. To protect the low pressure system, two gas pressure reducing valves capable of independent operation shall be installed in series. Each shall have the capability of closing off against the maximum upstream pressure, and of controlling the pressure on the low pressure side at or below the design pressure of the low pressure system, in the event that the other valve fails open. Control lines must be suitably protected, designed, and installed so that damage to any one control line will not result in over pressurizing the downstream piping.

(D.2) Trip Stop Valve. A fail-safe trip stop valve shall be installed to automatically close, in less than 1 sec, at or below the design pressure of the downstream piping. It shall be a manually reset design. The pressure switch for initiating closure of the trip stop valve shall be hardwired directly to the valve tripping circuit. The pressure switch shall be mounted directly on the low pressure piping without an intervening isolation valve. The trip stop valve shall be located so that it is accessible and protected from mechanical damage and from weather or other ambient conditions which could impair its proper functioning. It may be located upstream or downstream of the tandem gas pressure reducing valves. The trip stop valve and all upstream piping shall be designed for the maximum upstream supply pressure. The trip stop valve may also serve as the upstream isolation valve of a double-block and vent gas supply isolation system. Provision shall be made to safely bleed off the pressure downstream of the trip stop valve.

(D.3) Safety Relief Device. The low pressure system shall be protected from any leakage through the pressure reducing valves, when closed, by a safety relief device(s) constructed and designed in accordance with paras. 107.8.3 and 122.5.3, and sized for the possible leakage rate.

122.8.2 Toxic Fluids (Gas or Liquid)

(A) For the purpose of this Code, a toxic fluid is one that may be lethal, or capable of producing injury and/or serious illness through contact, inhalation, ingestion, or absorption through any body surface. It shall be the designers' responsibility to adopt the safety precautions published by the relevant fluid industry which may be more stringent than those described in this Code for toxic fluids. In addition, the piping shall be installed in such a manner that will minimize the possibility of damage from external sources.

**TABLE 122.8.2(B)
MINIMUM WALL THICKNESS REQUIREMENTS FOR TOXIC FLUID PIPING**

	Carbon & Low Alloy Steel (App. A, Tables A-1 & A-2)	Stainless & Nickel Alloy Steel (App. A, Tables A-3 & A-4)
DN 50 (NPS 2) & smaller	Extra strong	Sch. 10S
Larger than DN 50 (NPS 2)	Standard weight	Sch. 5S

(B) Preferably, pipe and pipe fittings should be seamless steel. Wall thickness shall not be less than that in Table 122.8.2(B).

If the fluid is known to be corrosive to the steels in Table 122.8.2(B), the materials and wall thickness selected shall be suitable for the service. (Refer to para. 104.1.2.)

(C) Piping joints shall be made by welding, or by steel socket welding or welding neck flanges with suitable gaskets. Socket welded joints shall not be larger than DN 65 (NPS $2\frac{1}{2}$). Backing rings used for making girth butt welds shall be removed after welding. Miter welds are not permitted. Fabricated branch connections (branch pipe welded directly to run pipe) are not permitted. Threaded joints, where unavoidable, may be used provided that all of the following requirements are met.

(C.1) The pipe thickness shall not be less than extra strong regardless of pressure or type of material.

(C.2) The requirements of para. 114 shall be met except that threaded joints to a maximum nominal size of DN 20 (NPS $\frac{3}{4}$) for pressure to 34,500 kPa [gage] (5000 psig), or to a maximum nominal size of DN 50 (NPS 2) for pressure to 345 kPa [gage] (50 psig) are permitted at the connections to the refillable storage containers and their associated pressure regulators, shutoff valves, pumps, and meters.

(C.3) Threaded joints are assembled with extreme care to assure leak tightness. The requirements of para.

135.5 shall be met. A thread sealant, suitable for the service, shall be used, except where the joint is to be seal welded.

(D) Steel valves shall be used. Bonnet joints with tapered threads are not permitted. Special consideration shall be given to valve design to prevent stem leakage to the environment. Bonnet or cover plate closures and other body joints shall be one of the following types:

(D.1) union;

(D.2) flanged with suitable gasketing and secured by at least four bolts;

(D.3) proprietary, attached by bolts, lugs, or other substantial means, and having a design that increases gasket compression as fluid pressure increases;

(D.4) threaded with straight threads sufficient for mechanical strength, metal-to-metal seats, and a seal weld made in accordance with para. 127.4.5, all acting in series.

(E) Tubing not larger than $^5/_8$ in. (16 mm) O.D. with socket welding fittings may be used to connect instruments to the process line. An accessible root valve shall be provided at the process lines to permit isolating the tubing from the process piping. The layout and mounting of tubing shall minimize vibration and exposure to possible damage.

(F) The provisions of para. 102.2.4 are not permitted. The simplified rules for analysis in para. 119.7.1 (A.3) are not permitted. The piping system shall be designed to minimize impact and shock loads. Suitable dynamic analysis shall be made where necessary to avoid or minimize vibration, pulsation, or resonance effects in the piping. The designer is cautioned to consider the possibility of brittle fracture of the steel material selected over the entire range of temperatures to which it may be subjected.

(G) For dry chlorine service between −29°C (−20°F) and 149°C (300°F), the pipe material shall not be less in thickness than seamless extra strong steel.

(H) Toxic fluid piping shall be pneumatic leak tested in accordance with para. 137.5. Alternatively, mass spectrometer or halide leak testing in accordance with para. 137.6, and a hydrostatic test in accordance with para. 137.3 may be performed.

122.8.3 Nonflammable Nontoxic Gas

(A) Piping for nonflammable and nontoxic gases, such as air, oxygen, carbon dioxide, and nitrogen, shall comply with the requirements of this Code, except as otherwise permitted in (B) (below). The designer is cautioned of the extreme chilling effect during rapid expansion. This is a factor for determining the lowest expected service temperature relative to the brittle fracture of the material selected.

(B) Threaded joints with or without compression fittings to a maximum nominal size of NPS $^3/_4$ for pressures to 5000 psi (34,500 kPa) are permitted at the connection to the refillable storage containers, pressure regulators, shutoff valves, and meters. Refer to Para. 114.

122.9 Piping for Corrosive Liquids and Gases

Where it is necessary to use special material, such as glass and plastics, not listed in Table 126.1, for conveying corrosive or hazardous liquids and gases, the design shall meet the requirements of para. 104.7.

122.10 Temporary Piping Systems

Prior to test and operation of the power plant and its included piping systems, most power and auxiliary service piping are subjected to flushing or chemical cleaning to remove internal foreign material such as rust particles, scale, welding or brazing residue, dirt, etc., which may have accumulated within the piping during the construction period. The flushing or cleaning operation may be accomplished by blowing out with steam or air, by hot oil circulation of oil systems, by acid or caustic fluid circulation, or by other flushing or cleaning methods. Temporary piping, that is piping attached to the permanent piping system whose function is to provide means for introducing and removing the fluids used in the flushing or cleaning operations, shall be designed and constructed to withstand the operating conditions during flushing and cleaning. The following minimum requirements shall apply to temporary piping systems.

(A) Each such system shall be analyzed for compliance with para. 103.

(B) Connections for temporary piping to the permanent piping systems which are intended to remain, shall meet the design and construction requirements of the permanent system to which they are attached.

(C) The temporary systems shall be supported such that forces and moments due to static, dynamic and expansion loadings will not be transferred in an unacceptable manner to the connected permanent piping system. Paragraphs 120 and 121 shall be used as guidance for the design of the temporary piping systems supporting elements.

(D) The temporary systems shall be capable of withstanding the cyclic loadings which occur during the flushing and cleaning operations. Particular attention

shall be given to the effects of large thrust forces which may be generated during high velocity blowing cycles. Where steam piping is to be subjected to high velocity blowing operations, continuous or automatic draining of trapped or potentially trapped water within the system shall be incorporated. Supports at the exhaust terminals of blowdown piping shall provide for restraint of potential pipe whip.

(E) Where necessary, temporary systems containing cast iron or carbon steel material subject to chemical cleaning shall be prewarmed to avoid the potential for brittle failure of the material.

(F) Where temporary piping has been installed and it does not comply with the requirements of this Code for permanent piping systems, it shall be physically removed or separated from the permanent piping to which it is attached prior to testing of the permanent piping system and prior to plant startup.

122.11 Steam Trap Piping

122.11.1 Drip Lines. Drip lines from piping or equipment operating at different pressures shall not be connected to discharge through the same trap.

122.11.2 Discharge Piping. Trap discharge piping shall be designed to the same pressure as the inlet piping unless the discharge is vented to atmosphere, or is operated under low pressure and has no stop valves. In no case shall the design pressure of trap discharge piping be less than the maximum discharge pressure to which it may be subjected. Where two or more traps discharge into the same header, a stop valve shall be provided in the discharge line from each trap. Where the pressure in the discharge piping can exceed the pressure in the inlet piping, a check valve shall be provided in the trap discharge line. A check valve is not required if either the stop valve or the steam trap is designed to automatically prevent reverse flow and is capable of withstanding a reverse differential pressure equal to the design pressure of the discharge piping.

122.12 Exhaust and Pump Suction Piping

Exhaust and pump suction lines for any service and pressure shall have relief valves of suitable size unless the lines and attached equipment are designed for the maximum pressure to which they may accidentally or otherwise be subjected, or unless a suitable alarm indicator, such as a whistle or free blowing relief valve, is installed where it will warn the operator.

122.13 Pump Discharge Piping

Pump discharge piping from the pump up to and including the valve normally used for isolation or flow control shall be designed for the maximum sustained pressure exerted by the pump and for the highest coincident fluid temperature, as a minimum. Variations in pressure and temperature due to occasional inadvertent operation are permitted as limited in para. 102.2.4 under any of the following conditions:

(A) during operation of overpressure relief devices designed to protect the piping system and the attached equipment;

(B) during a short period of abnormal operation, such as pump overspeed; or

(C) during uncontrolled transients of pressure or temperature.

122.14 District Heating and Steam Distribution Systems

122.14.1 General. Where pressure reducing valves are used, one or more relief devices or safety valves shall be provided on the low pressure side of the system. Otherwise, the piping and equipment on the low pressure side of the system shall be designed to withstand the upstream design pressure. The relief or safety devices shall be located adjoining or as close as practicable to the reducing valve. The combined relieving capacity provided shall be such that the design pressure of the low pressure system will not be exceeded if the reducing valve fails open.

122.14.2 Alternative Systems. In district heating and steam distribution systems where the steam pressure does not exceed 400 psi (2750 kPa) and where the use of relief valves as described in para. 122.14.1 is not feasible (e.g., because there is no acceptable discharge location for the vent piping), alternative designs may be substituted for the relief devices. In either case, it is recommended that alarms be provided which will reliably warn the operator of failure of any pressure reducing valve.

(A) Tandem Steam Pressure Reducing Valves. Two or more steam pressure reducing valves capable of independent operation may be installed in series, each set at or below the safe working pressure of the equipment and piping system served. In this case, no relief device is required.

Each pressure reducing valve shall have the capability of closing off against full line pressure, and of controlling the reduced pressure at or below the design pressure of the low pressure system, in the event that the other valve fails open.

(B) Trip Stop Valves. A trip stop steam valve set to close at or below the design pressure of the low pressure system may be used in place of a second reducing valve or a relief valve.