UNIVERSIDAD NACIONAL DE INGENIERIA

FACULTAD DE INGENIERIA MECANICA

“DISEÑO DE UN HORNO ELECTRICO PARA EL SECADO DEL BOBINADO DE MOTORES ELECTRICOS”

INFORME DE SUFICIENCIA

PARA OPTAR EL TITULO PROFESIONAL DE: INGENIERA MECANICO ELECTRICISTA

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INDICE

Página

PROLOGO

El respectivo informe está pensado en las empresa que realizan mantenimiento de sus motores eléctricos, para poder realizar este trabajo, existe un proceso que consiste en extraer la humedad existente dentro del motor, especialmente en el bobinado del rotor y estator, esto nos ayuda aumentar la resistencia de aislamiento del motor.

En el capítulo I, trataré sobre las generalidades de hornos de secado por convección natural, se mencionara la funcionabilidad de los mismos y como se opto por este método de secado. También mencionare cuales son los objetivo del informe y las limitaciones que tendrá el horno.

En el capítulo II, hablaré de los tipos de transferencia de calor existente como la conducción, convección y radiación con sus respectivos circuitos térmicos, también daré a conocer los diferentes tipos de hornos eléctricos existentes y como se clasifican.

En el capítulo III, se detallará las condiciones iníciales y parámetros para el diseño del horno de secado de motores, a la vez mencionare las características de los motores eléctricos y el aislamiento eléctrico de los motores bobinados.

En el capítulo IV, se empezará con el diseño del horno eléctrico, cálculo de la resistencia eléctrica, el sistema eléctrico fuerza-control y mencionare en forma general el diseño mecánico de la estructura del horno.

En el capítulo V, se mostrará el cuadro de costo de todo el material utilizado y la mano de obra para la fabricación del horno eléctrico.

En las conclusiones y recomendaciones, se mencionará lo que se debe tener en cuenta en la construcción y operación de un horno eléctrico de secado.

Finalmente se adicionara las fotografías del horno eléctrico de secado, carro portacarga y carro portacarro, también los planos generales de fabricación del horno eléctrico de secado, cronograma de fabricación, tablas de propiedades de los materiales utilizados, motores eléctrico y demás anexos correspondientes al diseño del horno eléctrico de secado de motores.

CAPÍTULO I

INTRODUCCION

En el presente informe se tratara sobre la fabricación de un horno eléctrico de secado de motores eléctricos, la función de calentar el motor es de expulsar la humedad depositada a lo largo del tiempo por un mal almacenamiento o mala protección en el momento de su uso, también se mencionara los tipos de hornos eléctricos que son usados en diferentes procesos, un adecuado valor de resistencia de aislamiento nos asegura que no haiga fuga de corriente hacia tierra y/o descarga eléctrica hacia las personas hacia su alrededor.

1.1 GENERALIDADES

El horno eléctrico a diseñarse será alimentado por energía eléctrica. El proceso de secado es determinante para el control de calidad de los motores eléctricos. Dicho control de calidad está relacionado en forma directa con las diversas pruebas eléctricas realizadas al motor eléctrico. El secado del aislante del bobinado "barniz dieléctrico" de los motores eléctrico es una operación obligatoria cuando el motor a sufrido algún tipo de accidente con algún tipo de liquido no inflamable o cuando el motor ha sido mal almacenado o durante un periodo prolongado.

El presente informe es proponer el diseño de un horno cuyo funcionamiento se base en la energía eléctrica, ello para mejorar el aspecto de la seguridad, en vista de que la probabilidad de ocurrir accidentes es mayor con el uso de gas propano.

1.2 OBJETIVOS

El objetivo del presente informe es lograr un adecuado procedimiento del diseño de un horno eléctrico de secado por convección natural.

1.3 LOS ALCANCES

El horno eléctrico de secado tiene una capacidad máxima de secar motores hasta 30HP, otra limitación es la que no se puede trabajar a temperaturas mayores de 130^0C. La temperatura de operación continua que será diseñado el horno será de 90^0C.

CAPITULOII

GENERALIDADES DE HORNOS DE SECADO

2.1 SISTEMAS TERMICOS

Para proceder a realizar un análisis completo de transferencia de calor es necesario considerar los tres mecanismos de transferencia como es la conducción, convección y radiación.

2.1.1 <u>Tipos de transferencia de calor</u>

2.1.1.1Transmision de calor por conducción

La conducción es el único mecanismo de transmisión de calor posible en los medios sólidos opacos; cuando en estos existe un gradiente de temperatura, el calor se transmite de la región de mayor temperatura a la de menor temperatura, siendo el calor transmitido por conducción Q_k, proporcional al gradiente de temperatura dT/dx, y a la superficie A, a través de la cual se transfiere, pero el flujo real depende de la conductividad térmica k, que es una propiedad física del cuerpo, es decir:

$$Q_k = -kA\frac{dT}{dx} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

El signo (-) es consecuencia que el calor debe fluir hacia la zona de temperatura más baja.

2.1.1.2 Transmisión de calor por convección

Cuando un fluido T_F se pone en contacto con un sólido cuya superficie de contacto esta a una temperatura distinta T_{pF} el proceso de intercambio de energía térmica se denomina convección, existen dos tipos de convección que son la convección libre o natural y la convección forzada, en el informe daremos más énfasis a la convención natural, que procede de la variación de la densidad del fluido como consecuencia del contacto con una superficie a diferente temperatura, lo que da lugar a fuerzas ascendentes sin ninguna influencia de fuerza motriz exterior.

La convección forzada tiene lugar cuando una fuerza motriz exterior mueve un fluido con una velocidad u_F sobre una superficie que se encuentra a una temperatura T_{pF}, mayor o menor que la del fluido T_F. Como la velocidad del fluido en la convección forzada u_F es mayor que en la convección natural, se transfiere una mayor cantidad de calor para una determinada temperatura.

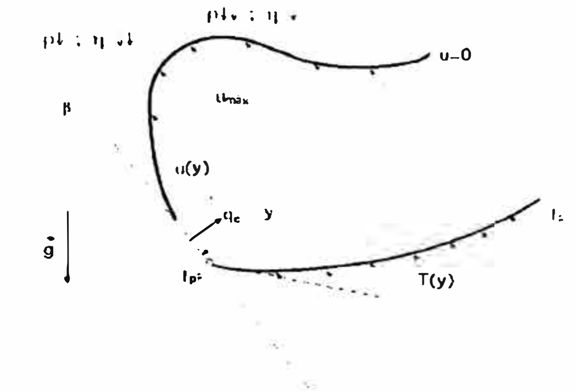


Gráfico N° 2.1 Distribución de la temperatura y velocidad en convección natural sobre un placa plana inclinada

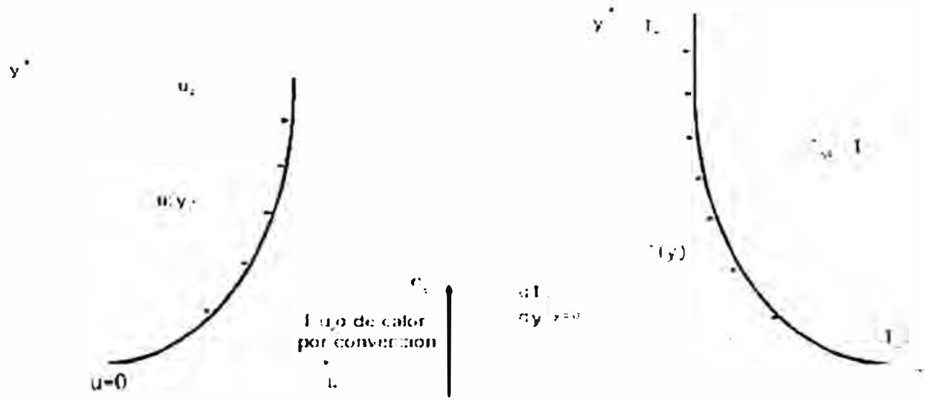


Gráfico N° 2.2 Distribución de la temperatura y velocidad sobre una placa plana en convección forzada

Independiente de que la convección sea natural o forzada, la cantidad de calor transmitida Q_c se puede escribir:

$$Q_c = h_{cF}.A.\left(T_{pF} - T_F\right) \ldots\ldots\ldots\ldots\ldots\ldots (2.2)$$

Donde:

h_{cF} : es la conductancia convectiva térmica unitaria o coeficiente de transmisión del calor por convección en la interface liquido-solido, en $W/m^2\,{}^0K$.

A : es el área superficial en contacto con el fluido, en m^2.

T_{pF} : es la temperatura de la superficie.

T_F : es la temperatura del fluido no perturbado.

2.1.1.3 Transmisión de calor por radiación

Mientras que la conducción y la convección térmica tienen lugar solo a través de un medio material, la radiación térmica puede transportar el calor a través de un fluido o del vacío., en forma de ondas electromagnéticas que se propagan a la velocidad de la luz.

La energía que abandona una superficie en forma de calor radiante depende de la temperatura absoluta a que se encuentre y de la naturaleza de la superficie.

Un cuerpo negro emite una cantidad de energía radiante de su superficie Q_r, dada por la ecuación (2.3):

$$Q_r = \sigma . A_1 . \left(T^4\right) = A.E_b \;\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.3)$$

En la que E_b es la potencia emisiva del cuerpo negro, viniendo expresado el calor radiante Q_r en W, la temperatura T de la superficie en ${}^0K$, y la constante dimensional σ de Stefan-Boltzman en unidades SI, en la forma:

$$\sigma = 5,67.10^{8} \frac{W}{m^{2}.\,^{0}K^{4}}$$

Si un cuerpo negro a $T_1(^0K)$ irradia calor a un recinto que le rodea completamente y cuya superficie es también negra a $T_2(^0K)$, es decir, absorbe toda la energía radiante que incide sobre él, la transferencia de energía radiante viene dada por la ecuación (2.4):

$$Q_r = \sigma.A_1.(T_1^4 - T_2^4) \ldots\ldots\ldots\ldots\ldots\ldots (2.4)$$

Si los dos cuerpos negros tienen entre sí una determinada relación geométrica, que se determina mediante un factor de forma F, el calor radiante transferido entre ellos es:

$$Q_r = Q_{1\leftrightarrow 2} = \sigma.A_1.F_{12}(T_1^4 - T_2^4) \ldots\ldots\ldots\ldots\ldots\ldots (2.5)$$

2.1.2 Circuitos térmicos

La analogía entre el flujo de calor y la electricidad, permite ampliar el problema de la transmisión del calor a sistemas más complejos, utilizando conceptos desarrollados en la teoría de circuitos eléctricos. Si la transmisión de calor se considera análoga al flujo de electricidad, la diferencia de temperaturas es una diferencia de potencial,

Vamos a indicar los circuitos térmicos usados en los tipos de transferencias existentes:

2.1.2.1 Circuito térmico por conducción

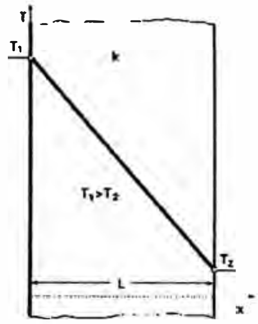


Gráfico N° 2.3 Muro plano

Del gráfico anterior, se obtiene la siguiente ecuación (2.6):

$$q = \frac{A \times K \times (T_2 - T_1)}{e} \;.................. (2.6)$$

$$q = \frac{(T_2 - T_1)}{\dfrac{e}{A \times K}} \;.................. (2.7)$$

Asignamos el valor:

$$R_K = \frac{e}{K \times A} \;.................. (2.8)$$

Donde: R_k es la resistencia por conducción

Entonces la ecuación (2.7) queda representada por la siguiente ecuación:

$$q = \frac{(T_2 - T_1)}{R_K} \;.................. (2.9)$$

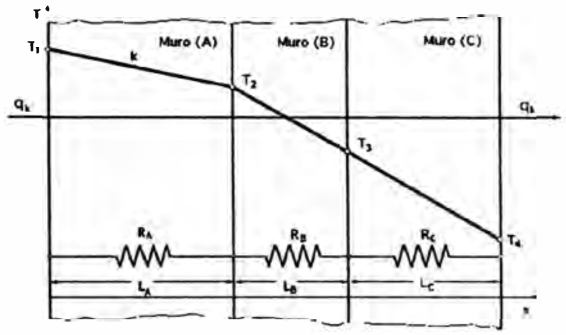


Gráfico N° 2.4 Pared compuesta

Ahora sobre una pared compuesta, se obtiene un circuito con resistencias del tipo conductivo en serie:

$$q = \frac{(T_4 - T_1)}{R_{eq\text{-}K}} \ldots\ldots\ldots\ldots\ldots\ldots (2.10)$$

Donde $R_{eq\text{-}K}$ es la resistencia equivalente de las tres paredes A, B y C, tal como se muestra en la ecuación (2.11):

$$R_{eq\text{-}K} = R_{A\text{-}K} + R_{B\text{-}K} + R_{C\text{-}K} \ldots\ldots\ldots\ldots\ldots\ldots (2.11)$$

2.1.2.2 Circuito térmico por convección

Del mismo modo vamos a representar nuestra resistencia por convección.

$$q = h_c \times A \times (T_2 - T_1) \ldots\ldots\ldots\ldots\ldots\ldots (2.12)$$

$$q = \frac{(T_2 - T_1)}{\frac{1}{h_c \times A}} \ldots\ldots\ldots\ldots\ldots\ldots (2.13)$$

Asignamos el valor:

$$R_h = \frac{1}{h_c \times A} \ldots\ldots\ldots\ldots\ldots\ldots (2.14)$$

Donde: R_h es la resistencia por convección.

Entonces la ecuación (2.13) queda representada por la siguiente ecuación:

$$q = \frac{(T_2 - T_1)}{R_h} \quad \dots\dots\dots\dots\dots\dots \; (2.15)$$

2.1.2.3 Circuito térmico por radiación

En muchos problemas industriales, la radiación se combina con otros modos de transmisión del calor.

La solución de tales problemas se puede simplificar utilizando una resistencia térmica Rr para la radiación; su definición es semejante a la de la resistencia térmica de convección y conducción.

Si el calor transferido por radiación se escribe en la forma convectiva en la que T2 es una temperatura de referencia cuya elección viene impuesta por las condiciones de convección (temperatura media del entorno en contacto con la superficie), mientras que T1 es una temperatura de referencia que viene impuesta por las condiciones de radiación (medio ambiente)

$$q = A \times \varepsilon \times \sigma \times \left(T_1^4 - T_2^4\right) \quad \dots\dots\dots\dots\dots\dots \; (2.16)$$

$$q = \underbrace{A \times \varepsilon \times \sigma \times \left(T_1^2 + T_2^2\right) \times \left(T_1 + T_2\right)}_{h_r} \times \left(T_1 - T_2\right)$$

$$q = A \times h_r \times \left(T_1 - T_2\right) \quad \dots\dots\dots\dots\dots\dots \; (2.17)$$

$$q = \frac{\left(T_1 - T_2\right)}{\dfrac{1}{A \times h_r}} \quad \dots\dots\dots\dots\dots\dots \; (2.18)$$

Asignamos el valor:

$$R_r = \frac{1}{h_r \times A} \quad \text{..................} \ (2.19)$$

Donde: R_r es la resistencia por radiación.

Entonces de la ecuación (2.18) queda representada por la siguiente ecuación:

$$q = \frac{(T_1 - T_2)}{R_r} \quad \text{..................} \ (2.20)$$

2.2 TIPOS DE HORNOS ELECTRICOS

La clasificación más completa y amplia posible atiende a diferentes aspectos, que son:

- Forma de funcionamiento. Los hornos pueden ser continuos o discontinuos (intermitentes).
- Disposición de las resistencias. Según dónde se ubiquen las resistencias, los hornos pueden ser de calefacción por la parte inferior,superior, lateral o por un extremo.
- Tipo de recinto. Adopta multitud de formas, se citan únicamente:

  - Hornos de solera.
  - Hornos de balsa.
  - Hornos de soleras múltiples.
  - Hornos de solera giratoria.

- Hornos de túnel.
- Hornos rotativos.
- Hornos de solera móvil.
- Hornos de crisol.
- Hornos de mufla.
- Hornos de cuba.

- Tipo de efecto en el producto:

  Hornos para producir efectos físicos en el producto. A su vez Pueden dividirse en:

  - Hornos de calentamiento
  - Hornos de fusión

- Hornos para producir efectos químicos en el producto.

2.3 CAMPOS DE APLICACIÓN DE LOS HORNOS ELECTRICOS

Clasificamos los campos de aplicación por los diferentes tipos de industrias con una indicación de los hornos utilizados o de las operaciones realizadas con hornos:

- Industria siderúrgica que comprende básicamente:
  - Hornos altos de reducción de mineral de hierro.
  - Mezcladores de arrabio calentados por llamas o por inducción.
  - Convertidores de acero.

- Hornos de arco para fusión de chatarra.
- Hornos de fusión por inducción de chatarra.
- Hornos de recalentar para las operaciones de laminación, forja, extrusión, de muy diferentes tipos.
- Hornos de tratamientos térmicos de barras. Redondo, chapas,
- Perfiles, bobinas, etc.
- Equipos auxiliares, tales como: precalentadores de cestas de carga
- y de cucharas de colada, hornos de laboratorio, atmosfera controladas, etc.

• Industria del aluminio que incluye en líneas generales:
  - Celdas de electrólisis ígnea para transformar alúmina en aluminio fundido.
  - Hornos de fusión y mantenimiento, a partir de chatarra o aluminio fundido.
  - Hornos de recalentar placas o redondos para laminación o extrusión.
  - Hornos de tratamientos térmicos, fundamentalmente recocido, pero también solubilización, maduración o envejecimiento.
  - Equipos auxiliares, tales como: atmósferas controladas para tratamientos térmicos, pres calentadores de matrices para extrusión, precalentadores de chatarra, etc.

Incluimos en este campo, no sólo las aleaciones de aluminio, sino también el magnesio y sus aleaciones que denominamos metales ligeros en general.

- Industria del cobre y sus aleaciones que denominamos en general metales no férricos pesados, tales como bronces, latones, cuproníqueles, alpacas, etc. Comprende básicamente:
  - Hornos de reducción de minerales.
  - Hornos de fusión de chatarra del tipo de reverbero o crisol.
  - Hornos de recalentamiento para laminación, forja, extrusión o estampación.
  - Hornos de tratamientos térmicos, fundamentalmente recocidos y del tipo adecuado al producto a tratar.
  - Equipos auxiliares, tales como: atmósfera controlada o vacía, equipos de barnizado o esmaltado de hilos de cobre, etc.

- Industria del Automovilismo que incluye la fabricación de coches, camiones, tractores, motocicletas y bicicletas. Es, tal vez, el campo de aplicaciones más variado y que exige mayor número de unidades y mayor sofisticación en los hornos, aunque su importancia económica sea inferior a la de otros campos. Distinguiremos en este campo:

- Hornos de fusión de metales férricos y no férricos.
- Hornos de tratamientos térmicos, de todos los tipos posibles prácticamente, dada la gran variedad de piezas existentes.
- Hornos de preparación y pintado de carrocerías, de gran valor económico.
- Instalaciones auxiliares, tales como: generadores de atmósferas

- Controladas, tanques de temple, cámaras de enfriamiento, desengrasadores y hornos de lavado y secado, etc.

- Fundiciones, tanto de metales férricos (fundición en todas sus variedades y acero moldeado), como de metales no férricos (pesados, cobre y sus aleaciones, y ligeros, aluminio y sus aleaciones). Distinguiremos fundamentalmente:
  - Hornos de fusión y mantenimiento.
  - Hornos de tratamientos térmicos, continuos o intermitentes, de los tipos adecuados a la producción, forma de las piezas, temperatura requerida, etc.
  - Equipos auxiliares, tales como hornos de secado de moldes y machos y, en alguna proporción, también atmósferas controladas.

- Industrias de productos manufacturados, amplio cajón de sastre donde se incluyen la fabricación de materiales eléctricos (transformadores y motores, sobre todo), la industria de electrodomésticos (fundamentalmente la serie blanca), los talleres de calderería, la fabricación de piezas mecánicas, la industria de la máquina-herramienta, la industria electrónica, etc.

  Puede incluir hornos de todos los tipos y para prácticamente todas las aplicaciones; se citan a continuación únicamente algunos ejemplos:
  - Hornos de recocido de chapa magnética.
  - Hornos de soldadura brillante de pequeñas piezas.

- Hornos de sinterizado y, en general, todos los utilizados en pulvimetalurgia.
- Grandes hornos de recocido para eliminación de tensiones de piezas fundidas y soldadas.
- Instalaciones completas formadas por varios hornos para tratamiento de herramientas.
- Hornos de recocido de bancadas de máquinas-herramientas.
- Hornos de difusión de hidrógeno en semiconductores.
- Hornos de secado al vacío de derivados de transformadores.

- Industria química, en la que incluimos la petroquímica y la farmacéutica. Citaremos como ejemplos en este campo:
  - Hornos de fabricación de ferroaleaciones (Fe-Si, Fe-Mn, Si-Mn, Fe-W, Fe-Mo, Fe-Ti, Fe-V, etc.), incluyéndose en este apartado, por la gran semejanza del procedimiento, la fabricación del silicio metal, carburo de calcio, etc.
  - Hornos de reformado (reforming) en la industria petroquímica.
  - Hornos de esterilizado de productos medicinales.

- Industria auxiliar, de gran importancia como usuaria de hornos industriales; entra dentro de este campo la fabricación de reductores, rodamientos, bujías, accesorios de tubería, frenos, direcciones, etc. Merecen mención especial los talleres de tratamiento térmico cuyos elementos de trabajo son únicamente hornos y equipos auxiliares.

- Industria cerámica y del vidrio, gran consumidora de energía, en ella incluimos la industria de fabricación del cemento. Como elementos básicos citamos:
  - Hornos rotativos de fabricación de clinker en la industria del cemento.
  - Hornos continuos tipo túnel de fabricación de piezas cerámicas
  - Industriales y hornos intermitentes, por ejemplo para cerámica artística.
  - Hornos de fusión de vidrio y de materiales cerámicos (materiales cerámicos fundidos y fibras cerámicas).
  - Hornos de tratamientos térmicos, fundamentalmente de vidrio, pero también, aplicable a piezas cerámicas.

Dentro de los campos de aplicación citados, el calentamiento por resistencias eléctricas es ampliamente utilizado en todos los procesos de baja y media temperatura (principalmente hasta 1.200°C.) siendo el número de instalaciones comparable al de hornos de llamas y netamente superior al de las calentadas por otros procedimientos (arco, inducción, alta frecuencia y especiales).

CAPÍTULO III

PARAMETROS DE DISENO DEL HORNO DE SECADO

3.1 CONSIDERACIONES INICIALES

El horno eléctrico de secado va ser de mucha utilidad en el secado del aislante del bobinado de los motores eléctricos.

El horno tiene por finalidad del secado de motores eléctricos hasta una potencia de 30HP.

También se debe de considerar que los motores eléctricos utilizan normalmente tres clases de aislamiento eléctrico en su bobinado de estator y rotor, según IEC 34.1, que son las que se muestra en la tabla siguiente:

Tabla N° 3.1 Tabla de temperatura de operación de aislantes eléctricos

CLASE	TEMP.MAX.OPERACION
B	130^0C
F	155^0C
H	180^0C

Para determinar el valor de la temperatura de operación del horno se tomo como referencias las hojas técnicas de los fabricantes de motores eléctricos, según Reliance-USA perteneciente al grupo Rockwell Automation Power Systems ellos indican que el horno de secado debe estar a una temperatura de 90^0C, según WEG Motores –Brasil el horno debe empezar de una temperatura de 80^0C después elevar 5^0C cada hora hasta llegar a la temperatura de 105^0C, dejarlo mínimo 1 hora en esa temperatura. Para nuestro caso tomaremos el criterio de los fabricantes americanos, por lo tanto nuestra temperatura de operación será 90^0C.

Si hubiera una falla o inestabilidad del horno, se colocara un dispositivo limitador de temperatura, esta temperatura máxima estará daba por la temperatura máxima de operación del aislamiento eléctrico del bobinado que tomaremos la mas critica de 130^0C (clase B). El dispositivo que usaremos para limitar esta temperatura va ser un termostato capilar seteado a 130^0C.

Otra consideración muy importante es el tamaño y peso de los motores a secar, como mencione en los alcances la máxima potencia de los motores a procesar será de 30HP. La estructura del horno será fabricado con perfiles estructural laminado, las pletinas del bastidor donde irán alojadas las resistencias eléctricas serán de acero inoxidable para mejorar las durabilidad del material ya que este se encuentra en contacto directo con las resistencias y sufren directamente el calentamiento por conducción de la temperatura de la chaqueta que se encuentra a temperatura mayores que la temperatura de operación (90^0C) hacia la pletina, dichas pletinas van a ser soldados en un solo extremo y en el otro extremos será empernado dentro de un agujero chino, este agujero nos ayudara con la expansión térmica que tendrá la pletina.

Como el proceso de secado será por convección natural, entonces el horno tendrá una apertura tipo rejilla con agujeros circulares ubicada en la parte inferior del horno para la entrada de renovación de aire, la función de la rejilla es tratar de impedir la entrada de objetos no deseados dentro del horno. El horno también tendrá una chimenea por donde pueda salir expulsado la humedad del motor. Las planchas internas del horno serán de acero inoxidable AISI 316L, según la norma ASTM A 240/A 240M – 01 el acero AISI 316L puede trabajar por encima de los 540^0C. Las planchas internas del horno también sufrirá mayor dilatación térmica comparado con los demás componentes del horno, es por eso que en la parte externa del gabinete interior se soldaran pletinas, su función de estas pletinas es de lograr una suave dilatación y contracción térmica del gabinete interior.

El gabinete exterior estará formado por planchas laminadas en frio y el acabado final del horno será pintado con pintura al horno de color crema, en la parte superior del gabinete exterior será instalado una chimenea y un disco de fe negro que funcionara como regulador para la salida del aire caliente y húmedo desde el interior del horno.

El aislante térmico que se usara será lana de vidrio, con un espesor que se calculara más adelante.

Para el sellado de la puerta se usara un marco preformado de silicona que se colocara al contorno de la parte frontal del horno, esto ayudara mucho en reducirá las pérdidas de calor hacia el exterior.

Para el control de temperatura se usara una termocupla tipo K y un controlador de temperatura digital. Si sucediera algún desperfecto de estos dispositivos y esto conlleva que la alimentación a las resistencias sigua conectado, esto dará lugar que la temperatura de operación dentro del horno se eleve hasta que se produzca un accidente fatal, para evitar este tipo de problemas se colocara un termostato capilar que limitara la temperatura máxima de operación del horno y mandara a desconectar las resistencias calefactoras, esta temperatura está relacionado con la temperatura máxima de operación del aislamiento del bobinado que es 130^0C (clase B).

Para el traslado del motor eléctrico, se utilizara un carro que llamaremos carro portacarga, este carro ingresara conjuntamente con el motor eléctrico dentro del horno todo el tiempo que dure el proceso de secado, el material del carro portacarga será fabricado de acero inoxidable.

Finalmente como el nivel inferior de la cámara de secado no está al mismo nivel del suelo, esto nos conlleva a fabricar otro carro que llevara al carro portacarga al nivel del cámara de secado, a este carro lo llamaremos carro portacarro y será fabricado de perfiles estructurales de Fe, a su vez este carro nos ayudara a movilizar el motor eléctrico fuera del horno eléctrico.

3.2 CARACTERISTIZAS DE LOS MOTORES ELECTRICOS

Las motores asíncronas son las más comunes de las maquinas industriales y tienen múltiples aplicaciones, como es el caso de las bombas, ventiladores, sierras circulares, etc.

Este tipo motores se clasifican en dos tipos:

- Jaula de ardilla.
- Rotor bobinado.

La estructura de un motor eléctrico de inducción está formado por:

3.2.1 El Estator

Es la parte inmóvil del motor y consta de:

3.2.1.1 Paquete magnético estatórico

Está formado por laminas punzonadas, estas deben llevar un aislamiento entre sí con la finalidad de reducir las pérdidas por corrientes parasitas.

En motores de mediana potencia se usan el material H23 de 0.5mm de espesor, dentro de las ranuras del paquete estatórico se instala el bobinado del motor que comúnmente es de tipo imbricado.

3.2.1.2 Bobinado estatórico

Está formado por 3 fases, cada una de ellas está desfasada respecto a la otra 120° eléctricos. Estos se hacen para cumplir unas de las condiciones para crear un campo magnético giratorio.

3.2.2 El Rotor

Es la parte móvil de la maquina, al igual que el estator posee un paquete magnético que está formado de laminas punzonadas de un espesor aproximadamente de 0.5mm.

3.2.3 El Entrehierro

Es el espacio que existe entre el diámetro interior del paquete estatórico y el diámetro exterior del rotor, la longitud del entrehierro generalmente varía entre 0.2mm a 1.5mm para potencias hasta 300hp. El entrehierro es muy importante porque es la zona donde se realiza la conversión de energía.

3.3 CLASIFICACIÓN DE LOS MOTORES ELÉCTRICOS

Se clasifican de acuerdo a su bobinado rotórico y pueden ser de rotor bobinado y jaula de ardilla.

3.3.1 Motor asincrono de rotor bobinado

Este tipo de motor se denomina de esa forma debido a que el bobinado del rotor es similar al del estator.

3.3.2 Motor asíncrono de jaula de ardilla

Cuando el bobinado está formado por barras que se colocan en las ranuras y están cortocircuitadas en sus extremos por anillos. Las barras pueden ser de cobre, latón o aluminio.

Los motores de rotor bobinado se utilizan para levantar cargas con un torque apreciable, es decir se utilizan para trabajar en: molinos, montacargas, ascensores, etc. Parte de los motores de jaula de ardilla se utilizan para arrancar en vacio, es decir sin carga como por ejemplo: en taladros, sierras circulares, etc.

3.4 AISLAMIENTO ELECTRICO DE LOS MOTORES BOBINADOS

Cuando hablamos de la condición de aislamiento nos referimos a la resistencia que existe entre este a tierra.

Para que se dé una falla a tierra, deben de ocurrir dos cosas. Primero debe crearse un camino de conducción a través del aislamiento. Conforme el aislamiento envejece se fisura y posibilita que se acumule material conductivo. Segundo, la superficie exterior del aislamiento del aislamiento se contamina de material conductivo y conduce suficiente corriente a la carcaza o núcleo del motor que está conectado a tierra.

Hoy en día los sistemas de aislamiento han mejorado notablemente y son capaces de soportar mayores temperaturas sin sacrificar su vida esperada.

La máxima temperatura de operación de un motor / generador depende principalmente de los materiales usados en su construcción, existen varias clases, pero las más usadas son:

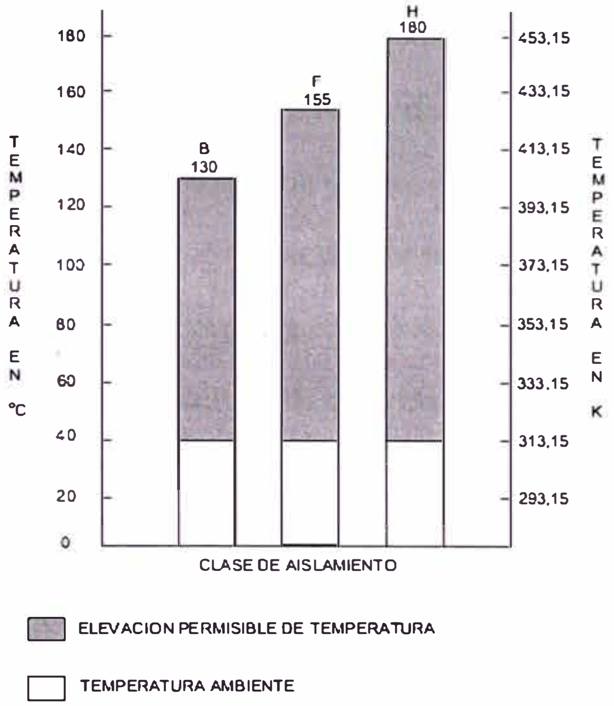


Gráfico N° 3.1 Temperatura para las distintas clases de aislamientos

Dichas temperaturas máximas, son a las cuales el aislamiento podría colapsar. Generalmente al medir la temperatura de la carcaza del motor, asumimos que el aislamiento esta en 20^{0}C mas alto que esta. Por ejemplo, si observamos que la temperatura de la carcaza de un motor de clase B es de 130^{0}C, podría estar muy seguro que la temperatura de aislamiento esta a por lo menos 150^{0}C excediendo la temperatura máxima permitida para esta clase de aislamiento.

El aislamiento pierde muy rápido sus propiedades al aumentar la temperatura, este mismo motor en vez de durar aproximadamente 15 años, duraría alrededor de 3 años.

3.5 PARAMETROS DE DISEÑO

La temperatura de operación de secado de los motores según los fabricantes es de 90^0C, como se requiere que el mantenimiento de secado para obtener una buen resistencia de aislamiento no sea demasiado lento, consideraremos que el tiempo de elevación de la temperatura de operación desde la temperatura ambiente mínima hasta 90^0C será de 1 hora, la temperatura ambiente en la condición mínima será de 13^0C. También usaremos un dispositivo de seguridad térmica, este dispositivo es un termostato capilar con perilla regulable, para evitar algún daño al bulbo capilar cuando se está maniobrando el motor dentro del horno se colocara el bulbo capilar dentro de una tubería de acero inoxidable, el valor del seteado del termostato capilar esta dado por la temperatura máxima de operación del aislante eléctrico clase B que es 130^0C, si por algún motivo de falla, la temperatura de operación del horno sigue aumentado sin ser controlado, el termostato capilar mandara una señal de control para desenergizar las resistencias.

Para determinar el tipo de estructura a usar se debe de considerar el peso de la carga a sostener, en este caso la estructura tiene que soportar el peso del motor eléctrico, carro portacarga, las paredes internas y externas, aislamiento térmico y tablero eléctrico.

Dado que las paredes internas del horno y el carro portacarga van a estar en constante cambio de temperatura, entonces se debe determinar que el material a utilizar en su fabricación va ser de acero inoxidable, con el fin de no degradar rápidamente el material.

El tamaño del volumen útil estará definido por el motor de 30 HP montado sobre el carro portacarga, se sabe que existe varios tamaños de motores para una sola potencia, tomaremos como referencia varios modelos y de ahí seleccionare el que tiene mayor tamaño, siempre manteniendo la potencia del motor en 30HP.

Para reducir las pérdidas térmicas del horno hacia el exterior, se utilizara lana de vidrio como aislante térmico; en el momento del diseño se considero tener hermeticidad al momento que la puerta este cerrada, es por eso que se le colocara un marco de silicona al contorno de la puerta, también se instalara dos picaporte en el lado frontal, uno en la parte superior y el otro en la parte inferior, la función de los picaporte es mantener las puertas presionadas con el marco de silicona, así se reduce la fuga de aire caliente por el contorno de las puertas.

En la parte superior del horno se instalara una tubería de Fe negro con su respectivo disco móvil para que el usuario pueda expulsar de forma manual el aire caliente y húmedo que se encuentra en el horno eléctrico, el usuario tendrá que retirar el disco móvil cada 02 horas, al mismo tiempo que el aire es expulsado también se está renovando el ambiente por otra masa de aire que ingresa por la parte inferior del horno.

Para el conexionado eléctrico del tablero de control y fuerza se usara cable THW excepto en la parte interior del horno donde se encuentra ubicado las resistencias calefactoras, para este caso utilizaremos cable con forro de fibra de vidrio siliconado que soporta temperatura de 210^0C.

CAPÍTULO IV

DISENO Y CÁLCULO DEL HORNO DE SECADO

4.1 ESQUEMA TRIDIMENSIONAL DEL HORNO

En el alcance se menciono que nuestro motor más grande a procesar será un motor de 30 HP, de las tablas anexadas de los fabricantes de motores tomaremos las dimensiones para el cálculo interior del horno.

En el Gráfico4.1 indicamos las dimensiones críticas que nos limitaran las dimensiones internas del horno.

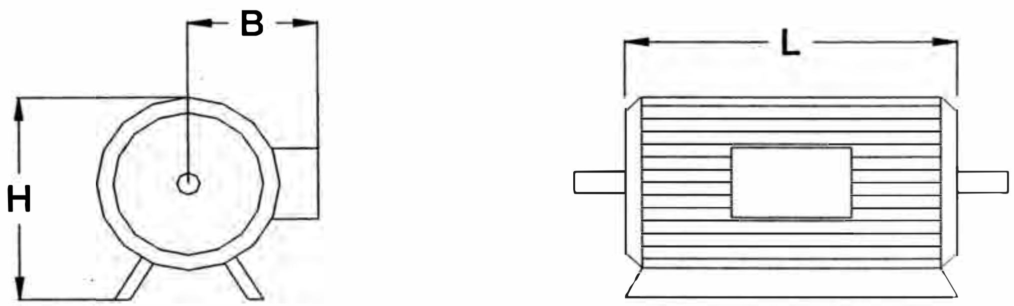


Gráfico N° 4.1 Dimensiones exteriores del motor eléctrico

De la hoja técnica del fabricante se tomo dos modelos de motores de 30HP

Modelo 160L (02 polos)

Motor de 02 polos pesa: 150 Kg.

B: 243 mm.

H: 317 mm.

L : 314 mm.

Modelo 180M (04 polos)

Motor de 04 polos pesa : 172 Kg.

B : 243 mm.

H : 317 mm.

L : 368 mm.

De los datos anteriores se selecciona el modelo 180M (02 polos) que tiene mayor peso y sus dimensiones externas son más grandes.

Sabemos que no solo el motor va ingresar dentro del horno, sino que el carro portacarga llevara al motor dentro del horno y se quedara todo el momento que dure el proceso de secado, el carro portacarga es tal como se muestra en la GráficoN° 4.2.

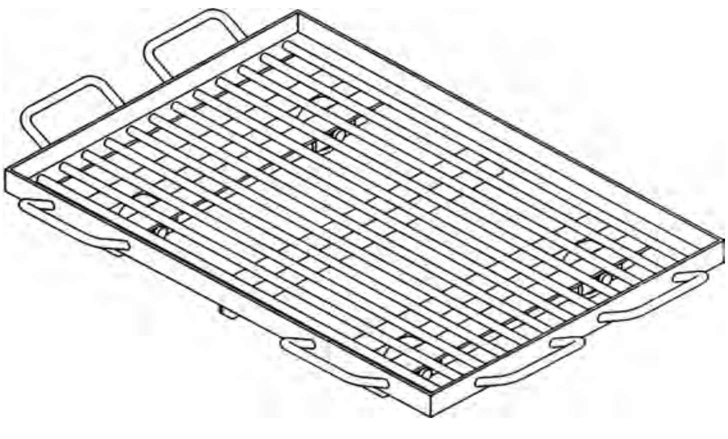


Gráfico N° 4.2 carro portacarga

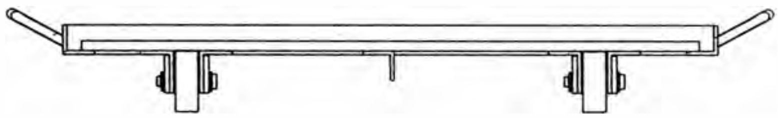


Gráfico N° 4.3 carro portacarga (vista frontal)

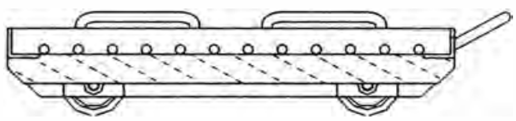


Gráfico N° 4.4 carro portacarga (vista de perfil)

El carro portacarga está diseñado para que soporte el peso del motor (172 Kg); el material del carro portacarga es de acero inoxidable tal como se considero en la condiciones iníciales. Una vez establecido las dimensiones del motor y carro portacarga se procederá a dimensionar el interior del horno de secado.

Las dimensiones interior del horno son las siguientes :

Altura (h) : 1000 mm

Ancho (w) : 1000 mm

Profundidad (d) : 700 mm

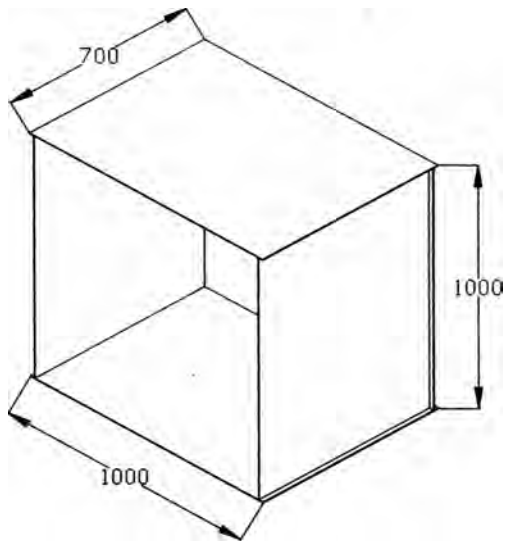


Gráfico N° 4.5 Dimensiones del interior del horno eléctrico

En el gráfico N° 4.6 se muestra donde se colocara las resistencias de calentamiento. Se considero colocar las resistencias calefactoras en la posición inferior por las siguientes razones:

La primera razón es que cuando el aire se caliente este tiende a elevarse por la diferencia de densidades, y en cada momento las resistencias estarían calentando el aire caliente que se encuentra en la parte baja del horno.

La segunda razón era de tener las resistencias ubicadas cerca de la entrada de aire, para que en el momento de la renovación de aire este fuera a chocar primero con las resistencias calientes antes de ingresar al volumen útil del horno de secado.

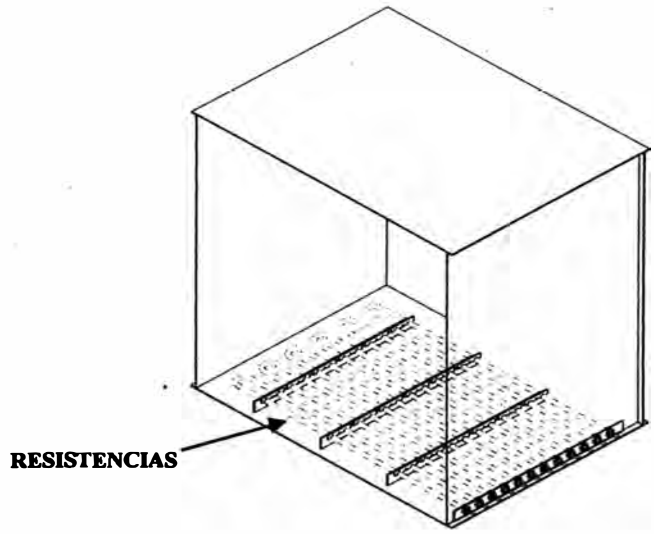


Gráfico N° 4.6 Ubicación de las resistencias eléctricas

4.2 DISEÑO DE LOS CALENTADORES ELECTRICOS ELECTRICOS

Primero determinaremos al calor que necesita cada cuerpo involucrado en el proceso para llegar a la temperatura de operación (90^{0}C):

4.2.1 Calculo de calor para el motor eléctrico (Q_{motor})

El motor eléctrico a procesar va ser de 30HP como máximo y su peso correspondiente es de m_{motor} 172 Kg. Las dimensiones externas del motor eléctrico según el modelo 180M (04 polos) es como en el gráfico N° 4.7:

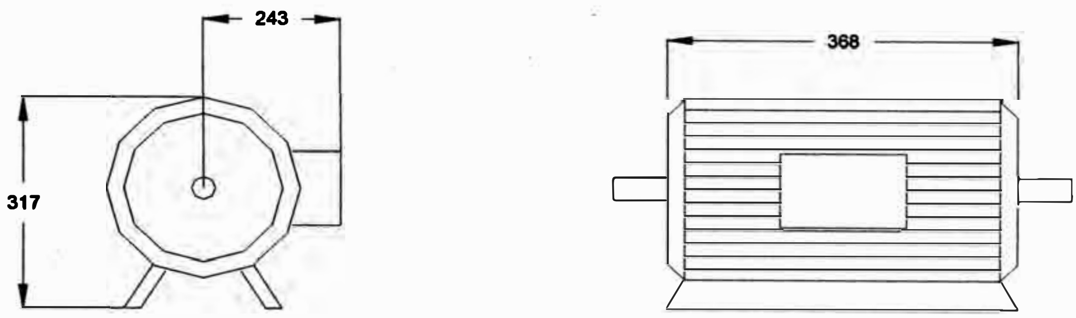


Gráfico N° 4.7 Dimensiones definitivas del motor eléctrico de 30 HP

Asumiendo que el motor es de acero al silicio, entonces el calor especifico del motor será:

$$C_{especf.motor} = 460 \ {}^{J}\!/_{Kg.^{o}K}$$

$$\rho_{motor} = 7417 \ {}^{Kg}\!/_{m^{3}}$$

Donde:

$C_{especf.motor}$: Calor especifico del motor

ρ_{motor} : densidad del motor (acero al silicio)

La gradiente de temperatura del proceso ΔT es la siguiente:

$$\Delta T = T_{\max operacion} - T_{amb minima} \quad \text{..................} \quad (4.1)$$

Donde:

$T_{\max operacion}$: Temperatura máxima de operación del horno.

$T_{amb minima}$: Temperatura ambiente mínima.

El calor que necesita el motor será:

$$Q_{motor} = m_{motor} \times C_{especf.motor} \times \Delta T \text{ .... (4.2)}$$

$$Q_{motor} = 172 \times 460 \times 77$$

$$Q_{motor} = 6092.24 \; Kj$$

4.2.2 Calculo de calor para aire (Q_{aire})

De la tabla de propiedades térmicas del aire obtenemos las siguientes propiedades para una temperatura de 13^{0}C:

$$Cp_{aire\ 13^oC} = 1.0057 \; {Kj}/{Kg.^oK}$$

$$\rho_{aire\ 13^oC} = 1.2433 \; {Kg}/{m^3}$$

Donde:

$Cp_{aire\ 13^oC}$: Calor especifico del aire a 13 ºC.

$\rho_{aire\ 13^oC}$: Densidad del aire a 13 ºC.

El volumen ocupado por el aire es el mismo volumen interno del horno, de acuerdo al esquema tridimensional del horno, las dimensiones internas del horno son las siguientes:

- Altura (h) : 1.0 m
- Ancho (w) : 1.0 m
- Profundidad (d) : 0.7 m

Por lo tanto el volumen del aire V_{aire} a calentar es:

$$V_{aire} = h \times w \times d \;.................\; (4.3)$$

$$V_{aire} = 1.0 \times 1.0 \times 0.7 = 0.7\; m^3$$

Ahora determinamos la masa del aire m_{aire} :

$$m_{aire} = \rho_{aire} \times V_{aire} \;.................\; (4.4)$$

$$m_{aire} = 1.2433 \times 0.7$$

$$m_{aire} = 0.87\; Kg$$

El calor que necesita el aire es el siguiente:

$$Q_{aire} = m_{aire} \times Cp_{aire\; 13^{o}C} \times \Delta T \;.................\; (4.5)$$

$$Q_{aire} = 0.87 \times 1.0057 \times 77$$

$$Q_{aire} = 67.4\; Kj$$

4.2.3 Calculo de Calor del las planchas internas(Q_{pl})

Sabemos que las planchas internas son de acero inoxidable, por lo tanto la densidad ($\rho_{acero\; inox.}$) es:

$$\rho_{acero\; inox.} = 8522\; {Kg}/{m^3}$$

Las planchas de las paredes, techo y piso del interior del horno tiene un espesor de 1.2 mm.

Del esquema tridimensional del horno se calculara el volumen de las planchas internas, primero vamos a calcular el área total ($A_{superficial\; plancha}$) y lo multiplicaremos por el espesor de la plancha (e_{plancha}) para así tener el volumen deseado, tal como se muestra en la ecuación (4.6):

$$V_{pl} = A_{\text{superficial plancha}} \times e_{\text{plancha}} \ldots\ldots\ldots\ldots\ldots\ldots \ (4.6)$$

$$V_{pl} = \left[1\times1 + 1\times1 + 4\left(1\times0.7\right)\right]\times0.0012$$

$$V_{pl} = 0.00576\ m^2$$

La masa de las paredes internas del horno (m_{pl}) es el siguiente:

$$m_{pl} = \rho_{acero\ inox.} \times V_{pl} \ldots\ldots\ldots\ldots\ldots\ldots \ (4.7)$$

$$m_{pl} = 8522\times0.00576$$

$$m_{pl} = 49.086\ Kg$$

Para calcular el calor necesario que necesita las planchas lo determinamos con la siguiente ecuación:

$$Q_{pl} = m_{pl}\times Ce_{pl}\times\Delta T \ldots\ldots\ldots\ldots\ldots\ldots \ (4.8)$$

Donde:

Q_{pl} : Calor que absorbe las planchas para llegar a 90^0C.

m_{pl} : Masa de la plancha interna.

Ce_{pl} : Calor especifico de la plancha interna (acero inoxidable).

ΔT : Gradiente de temperatura del proceso.

$$Q_{pl} = 49.086\times460x77$$

$$Q_{pl} = 1738.65Kj$$

4.2.4 Calculo de calor de carro portacarga ($Q_{portacarga}$)

El carro portacarga también absorberá energía térmica para llegar a la temperatura de 90^0C, el material del carro portacarga es de acero inoxidable.

$$m_{\text{portacarga}} = 42\ Kg$$

$$C_{\text{especf.portacarga}} = 460\ {}^{J}\!/_{Kg.^{o}K}$$

Por lo tanto:

$$Q_{\text{portacarga}} = m_{\text{portacarga}} \times Ce_{\text{especif.portacarga}} \times \Delta T \ldots\ldots\ldots\ldots\ldots\ldots (4.9)$$

$$Q_{\text{portacarga}} = 42 \times 460 \times 77$$

$$Q_{\text{portacarga}} = 1487.64\ Kj$$

Ahora se sumara todo el calor que se necesita todos los elementos dentro del volumen interno del horno eléctrico, para elevar su temperatura desde la temperatura ambiente 13^0C hasta la temperatura de operación 90^0C.

$$Q_{\text{elementos internos}} = Q_{motor} + Q_{aire} + Q_{pl} + Q_{portacarga} \ldots\ldots\ldots\ldots\ldots\ldots (4.10)$$

$$Q_{\text{elementos internos}} = 6092.24 + 67.4 + 1738.65 + 1487.64$$

$$Q_{\text{elementos internos}} = 9385.93\ Kj$$

Como el operario tiene que abrir la tapa de la chimenea para renovar el aire interior, entonces se tomara un porcentaje de calor hasta ahora calculado por renovación de aire, la cual ingresa por la parte inferior del horno eléctrico, tal como se muestra en el gráfico siguiente.

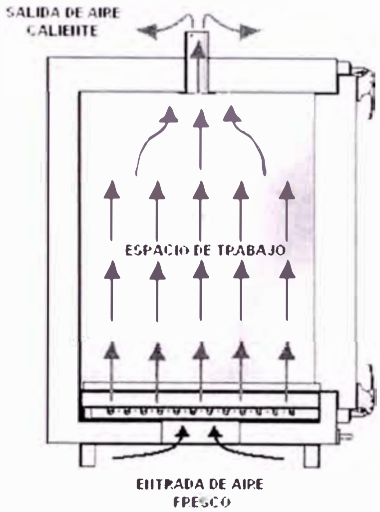


Gráfico N° 4.8 Diagrama de circulación de flujo de aire

El porcentaje tomado por renovación de aire está entre [10-20%], entonces se tomara el 20%

$$Q_{renov} = 20\% \times Q_{elementos\,internos} \;.................. (4.11)$$

$$Q_{renov} = 20\% \times 9385.93$$

$$Q_{renov} = 1877.186 \; Kj$$

El calor total sin perdidas que se necesita calentar el motor, carrito portacarga, masa de las planchas internas e incluyendo las pérdidas ya mencionadas será:

$$Q_{total\;sp} = Q_{elementos\,internos} + Q_{renov} \;.................. (4.12)$$

$$Q_{total\;sp} = 9385.93 + 1877.186$$

$$Q_{total\;sp} = 11263.116 \; Kj$$

El tiempo en que el usuario desea subir la temperatura del horno de la temperatura ambiente hasta la temperatura de operación de 90^0C es de 1 hora.

$$P_{total\ sp} = \frac{Q_{total\ sp}}{t} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4.13)$$

Donde:

$Q_{total\ sp}$: es el calor total sin perdidas (Kj)

$P_{total\ sp}$: la potencia total sin perdidas (Kw)

t : tiempo que necesita el horno en llegar a 90^0C (seg)

Despejando la formula anterior obtenemos la potencia deseada:

$$P_{total\ sp} = \frac{Q_{total\ sp}}{t}$$

$$P_{total\ sp} = \frac{11263.116}{3600}$$

$$P_{total\ sp} = 3.128\ Kw$$

4.2.5 Calculo de pérdidas de calor hacia el exterior $Q_{perdidas}$

Para reducir las pérdidas de calor hacia el exterior usaremos lana de vidrio como aislante térmico.

El calor transferido desde la parte interior del horno hacia el medio ambiente se indica en el gráfico N° 4.9 siguiente:

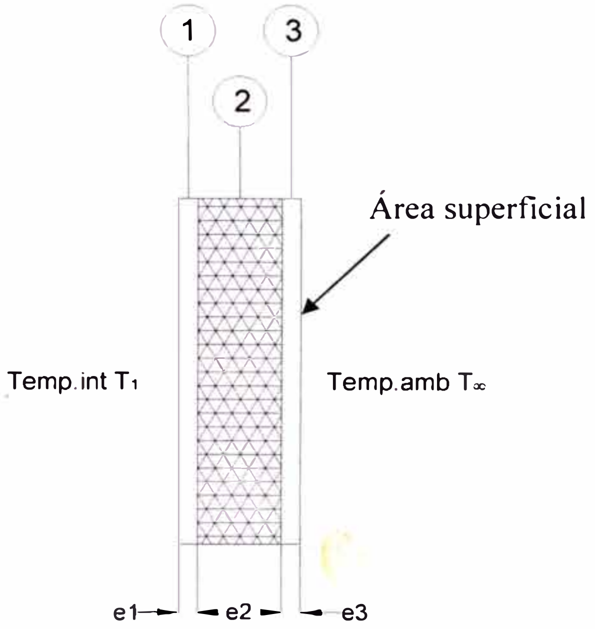


Gráfico N° 4.9 Espesor de la paredes exteriores, interior y aislante térmico

La conductividad térmica de la lana de vidrio a usar es el siguiente:

$$K_{lana\ de\ vidrio} = 0.035\,{}^{W}\!/_{mK}$$

Donde la plancha número 1 es la plancha interior del horno, la plancha número 3 es la plancha exterior "carcasa del horno" y el número 2 es el aislante térmico de lana de vidrio.

Consideremos que la temperatura superficial de las planchas internas del horno esta a la misma temperatura del ambiente interior del horno 90^0C.

De la figura anterior obtenemos la siguiente ecuación (4.14):

$$R_{ke} = \frac{1}{A_{sup}} \times \left(\frac{e_1}{K_{acero}} + \frac{e_2}{K_{aislante}} + \frac{e_3}{K_{acero}} + \frac{1}{hc_{ext}} \right) \ldots\ldots\ldots\ldots\ldots\ldots (4.14)$$

Donde:

R_{ke} : resistencia térmica equivalente por conducción y convección a través de las paredes metálicas y el aislante térmico.

e1 y e3 son los espesores de las planchas metálicas.

$e_1 = e_3 = 1.2\ mm$

e2 : espesor del aislante térmico.

K_{acero} : Conductividad térmica del acero W/mK.

$K_{aislante}$: Conductividad térmica del aislante térmico (lana de vidrio) W/mK.

hc_{ext} : Coeficiente convectivo del aire exterior W/m^{2}K.

A_{sup} : Área superficial de transferencia m^2.

Con la ecuación (4.15) se calculara las pérdidas de calor desde la parte interior del horno hacia el exterior:

$$Q_{perdidas} = \frac{T_1 - T_\infty}{R_{ke}} \qquad (4.15)$$

Donde:

T_1 : Temperatura interna del horno (90^{0}C).

T_∞ : Temperatura exterior del horno (13^{0}C).

Para calcular las pérdidas de calor desde la parte interior, se tiene que tener el valor del espesor del aislante térmico a utilizar, como no se tiene este valor, entonces voy a calcular las perdidas del calor asumiendo varios valores con espesores comerciales de aislante térmico (e_2), tal como se muestra en la siguiente tabla:

Tabla N° 4.1 Espesores de aislante térmico

Espesor (Pulg)	R_{ke}	$Q_{perdidas}$ (W)	%de reducción
1	0.162	476.4	100
2	0.313	246.2	48
3	0.464	165.9	33
4	0.615	125.2	25
5	0.766	100.5	20
6	0.918	83.9	17

Analizando la tabla N° 4.1 observamos que a medida que aumentamos el espesor del aislante térmico se logra disminuir las perdidas del calor hacia el exterior, por lo tanto por razones técnico-económicas seleccionamos el espesor de 3 Pulg.

Entonces ya determinado nuestro espesor de aislamiento el calor transferido hacia el medio ambiente es:

$$Q_{perdidas} = 165.9W$$

4.2.6 <u>Calculo de potencia de la resistencia de diseño $P_{diseño}$</u>

Primero determinamos la potencia total:

$$P_{total} = P_{total\,sp} + Q_{perdidas} \;\dots\dots\dots\dots\dots\dots\; (4.16)$$

$$P_{total} = 3128 + 165.9$$

$$P_{total} = 3.294\,Kw$$

Nuestro factor de diseño para la resistencia será de 1.5

$$P_{diseño} = 1.5 \times P_{total} \;\dots\dots\dots\dots\dots\dots\; (4.17)$$

$$P_{diseño} = 1.5 \times 3.294$$

$$P_{diseño} = 4.94\,Kw$$

4.2.7 Cálculo de la potencia de cada resistencia ($P_{c/resist}$)

Como nuestra fuente de alimentación es trifásica, entonces el número de las resistencias deben de ser de múltiplo de 3, pueden ser 3 ó 6 resistencias.

Según la tabla N° 4.2 se muestra los diámetros estándares por los fabricantes:

Tabla N° 4.2 Diámetros estándares de resistencias eléctricas

Diámetro 01	0.200”
Diámetro 02	0.246”
Diámetro 03	0.260”
Diámetro 04	0.315”
Diámetro 05	0.375”
Diámetro 06	0.430”
Diámetro 07	0.475”

De la tabla N° 4.2, seleccionamos el diámetro 07 = 0.475”

Con el compartimiento que tenemos en el horno para colocar las resistencias eléctricas, determinamos que la mejor manera de distribuir las resistencias es en forma de U, ya que esta forma nos ayudara a tener los terminales a un solo extremo para hacer la conexión eléctrica.

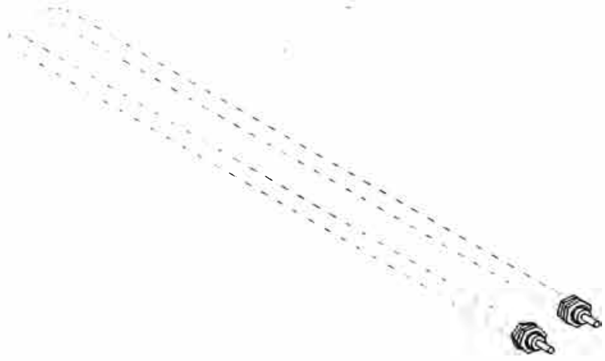


Gráfico N° 4.10 Resistencia eléctrica

Según la dimensión establecida dividiremos la potencia en 06 resistencias en forma de U.

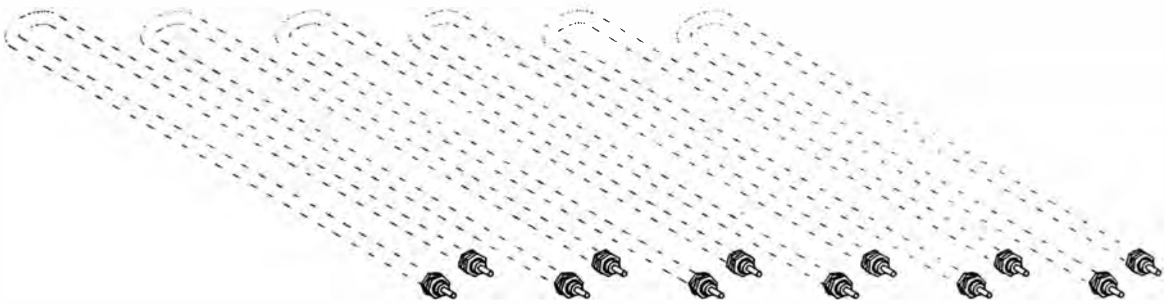


Gráfico N° 4.11 Resistencia totales

Cada resistencia tendrá la siguiente potencia:

$$P_{c/resist} = \frac{P_{diseño}}{6} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4.18)$$

$$P_{c/resist} = \frac{4.94\ Kw}{6}$$

$$P_{c/resist} = 0.823\ Kw$$

$$P_{c/resist} \approx 800\ W$$

Los terminales de las resistencias serán de tipo pin roscado para poder colocar los terminales de los cables eléctricos.

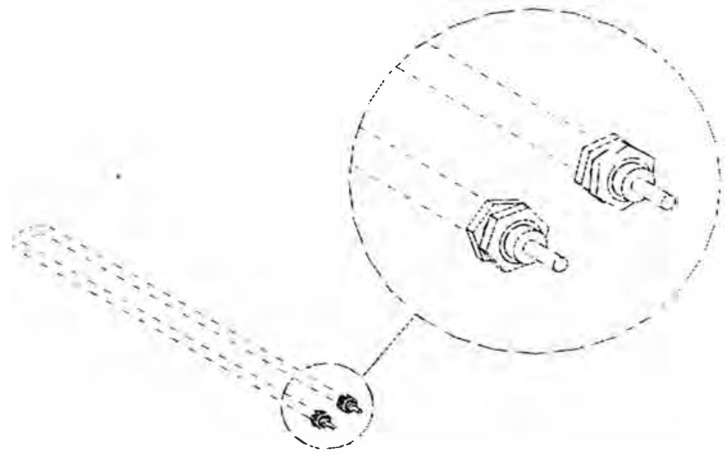


Gráfico N° 4.12 Terminal tipo pin roscado

4.2.8 Cálculo de la temperatura superficie de la resistencia (T_{sup})

Ahora para calcular la temperatura de la superficie, tendremos presente las siguientes ecuaciones:

$$q = hc \times A_{sup} \times (T_{sup} - T_{\infty}) + hr \times A_{sup} \times (T_{sup} - T_{\infty}) \quad (4.19)$$

$$q = (hc + hr) \times A_{sup} \times (T_{sup} - T_{\infty}) \quad (4.20)$$

$$q_r = \sigma \times A_{sup} \times (T_{sup}^4 - T_{\infty}^4) \quad (4.21)$$

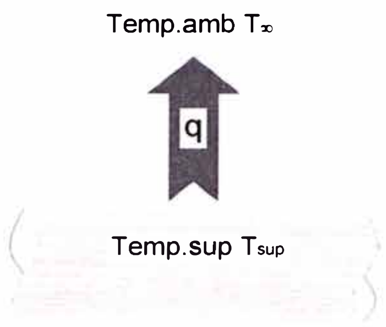


Gráfico N° 4.13 Diagrama de temperatura superficial del calentador eléctrico

Donde:

σ : constante de Stefan-Boltzman $5.67x10^{-8}$ W/m^2K^4

hc : coeficiente convectivo por convección natural W/m^2K.

A_{sup} : superficie de la resistencia m^2.

T_{sup} : Temperatura superficial de la resistencia K.

T_∞ : Temperatura ambiente K.

Ya determinado la forma de la resistencia, obtenemos el valor longitudinal de la resistencia en forma de U.

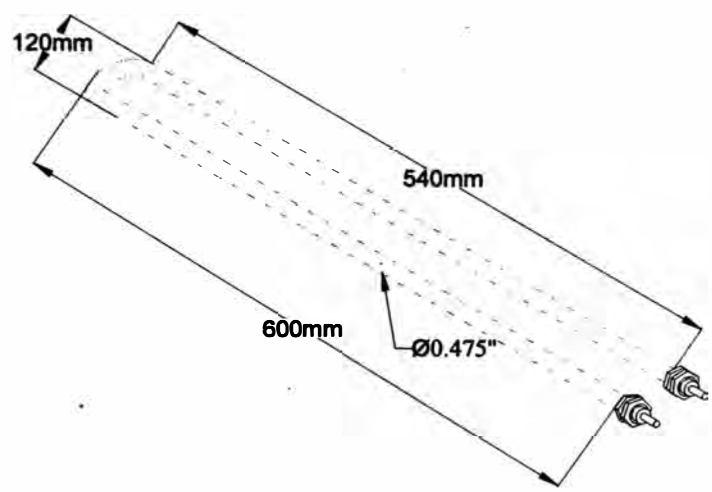


Gráfico N° 4.14 Dimensiones de la resistencia eléctrica seleccionado

$$L_{resist.} = 1.207\ m$$

El área superficial de la resistencia (A_{sup}) se calculara de la siguiente manera

$$A_{sup} = \pi \times D \times L \text{ .... } (4.22)$$

Donde:

D: diámetro de la resistencia expresado en m.

L: longitud de la resistencia expresada en m.

$$A_{sup} = \pi \times 0.01206 \times 1.249$$

$$A_{sup} = 4.73 \times 10^{-2}\ m^2$$

Sabemos que el calor radiante está dado también por la siguiente ecuación:

$$q_r = hr \times A_{sup} \times \left(T_{sup} - T_{\infty}\right) \text{ .... } (4.23)$$

Igualando la ecuación (4.21) y (4.23) obtenemos la siguiente ecuación:

$$\sigma \times A_{sup} \times \left(T_{sup}^{\ 4} - T_{\infty}^{\ 4}\right) = hr \times A_{sup} \times \left(T_{sup} - T_{\infty}\right) \text{ .... } (4.24)$$

$$hr = \frac{\sigma \times \left(T_{sup}^{4} - T_{\infty}^{4}\right)}{\left(T_{sup} - T_{\infty}\right)} \ldots\ldots\ldots\ldots\ldots\ldots (4.25)$$

Ahora reemplazo hr de la ecuación (4.25) en la ecuación (4.20)

$$q = \left(hc + \frac{\sigma \times \left(T_{sup}^{4} - T_{\infty}^{4}\right)}{\left(T_{sup} - T_{\infty}\right)} \right) \times A_{sup} \times \left(T_{sup} - T_{\infty}\right) \ldots\ldots\ldots\ldots\ldots\ldots (4.26)$$

Donde:

q : calor de la resistencia expresado en watts (800 W)

hc : coeficiente convectivo por convección natural (20 W/m^2K)

A_{sup} : Área superficial de la resistencia ($4.73 \times 10^{-2}\ m^2$)

σ : constante de Stefan-Boltzman $5.67 \times 10^{-8}\ W/m^2K^4$

T_{∞} : Temperatura ambiente (286 K)

T_{sup} : Temperatura superficial de la resistencia expresado en K

Reemplazando los valores, obtenemos la siguiente ecuación:

$$5.67 \times 10^{-8} \times T_{sup}^{4} + 20 \times T_{sup} - 22998.38 = 0 \ldots\ldots\ldots\ldots\ldots\ldots (4.27)$$

Resolviendo la ecuación obtenemos las siguientes soluciones:

- Primera raíz: 648.5 K
- Segunda raíz: (136.75,-814.58)K
- Tercera raíz: (136.75,814.58)K
- Cuarta raíz: -928.04K

Observamos que la segunda y tercera raíz son números imaginarios, por lo tanto quedan descartadas. De la cuarta raíz se obtiene una temperatura negativa ya sea en grados kelvin o Celsius, así que queda descartada, con lo cual nos quedamos con la primera raíz que se acerca a nuestro cálculo real.

De las anteriores apreciaciones consideramos que la temperatura de la superficie es la siguiente:

$$T_{sup} = 648.5\ K = 375.5^{0}C$$

En la tabla N° 4.3 se muestra los materiales de las chaquetas que utilizan los fabricantes de resistencias:

Tabla N° 4.3 Materiales de la chaqueta de resistencias

Sheath Material	Max. Allowable Sheath Temp. (°F)
Copper	350
Steel	750
MONEL®	900
Stainless Steel	1200
INCOLOY®	1600
INCONEL®	1600

La temperatura máxima de la chaqueta a seleccionar debe ser mayor que la temperatura de la superficie calculada T_{sup} .

$$T_{material\ steel} = 750^{0}F > T_{sup} = 375.5^{0}C\ (707.9^{0}F)$$

Por lo tanto la chaqueta de la resistencia será de acero (Stainless Steel).

4.2.9 Calculo de densidad de potencia de la resistencia D_{pot}

La densidad de potencia es la potencia disipada por unidad de área de la chaqueta y es crítico para el propio calentador y la expectativa de la vida útil de la resistencia

Según la tabla N° 4.4 que se muestra a continuación la densidad de potencia de una resistencia tubular para calentar aire estancado tiene que tener un valor máximo permitido de 30 w/in2 para una temperatura de 700^0F.

Tabla N° 4.4 Guía de aplicación de calentadores tubulares

Product To Be Heated	Temperature Desired (°F)	Suggested Application	Sheath Material	Work Temperature (°F)	Allowable Watt Density (W/In²)
Solids					
Molds, Platens, Dies, Pipes, Tanks	Up to 1400	Clamp-On	INCOLOY®	Up to 300 Up to 500 Up to 800 Up to 1000 Up to 1200 Up to 1400	30 20 15 10 7 2.5
Liquids					
Water, Clean	Up to 250 Up to 550	Immersion Immersion	Copper INCOLOY®	250 550	Up to 80² 40
Water Solutions, Mild Corrosion¹, Corrosive¹	Up to 200 Up to 200	Immersion Immersion	304SS INCOLOY®	200 200	50 50
Oil					
Low Viscosity Med. Viscosity High Viscosity	Up to 180	Immersion	Steel	Up to 180	23 15 6.5
Air & Gases					
Moving, 9'/sec Velocity	Up to 1500	In Ducts	INCOLOY®	500 800 1000 1200 1500	40 32 25 15 2
Still	Up to 1500	Ovens	INCOLOY®	700 1000 1200 1500	30 20 10 2

1. See Corrosion Guide in Technical section. 2. VDE - 50 W/In² max.

En nuestro caso la densidad de potencia se calculara de la siguiente manera:

$$D_{pot} = \frac{P_{c/resist}}{A_{sup}} \dots\dots\dots\dots\dots\dots (4.28)$$

$$D_{pot} = \frac{800}{0.04734} = 16.89\frac{w}{m^2}$$

$$D_{pot} = \frac{800}{0.04734} = 16899\frac{w}{m^2}$$

$$D_{pot} = 10.9\frac{w}{in^2}$$

$$D_{pot} = 10.9\frac{w}{in^2} \rangle 30\frac{w}{in^2}$$

Nuestra densidad de potencia de la resistencia es menor a la densidad de la potencia máxima permisible.

Finalmente nuestra resistencia tendrá las siguientes características:

- Potencia de resistencia: 800 W.
- Voltaje de uso: 220 VAC.
- Temperatura de trabajo: 90^0C.
- Aplicación: calentamiento de aire.
- Temperatura de la chaqueta: 375.5^0C (707.9^0F).
- Material de chaqueta: Acero (Stainless Steel)
- Terminales: tipo pin roscado.
- Las dimensiones geométricas son las siguientes:

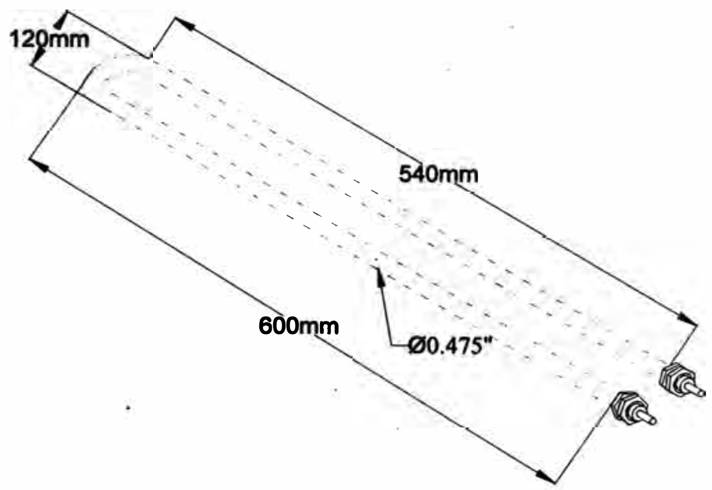


Gráfico N° 4.15 Dimensiones finales de la resistencia eléctrica

4.3 DISEÑO ESTRUCTURAL DEL HORNO

En esta sección solo se mencionara en forma general el diseño de la estructura del horno. El peso total que debe soportar la estructura será la envolvente externa e interna, el material aislante, las resistencias, el motor eléctrico y el carro portacarga. Tomando en consideración que nuestra mayor carga que soportara la estructura del horno es el peso del motor eléctrico y el peso del carro portacarga (Motor: 172 Kg, carro portacarga: 42 Kg).

Las vigas a utilizar en la estructura serán de perfiles estructurales ASTM A-36, en las planchas interna de acero inoxidable se soldaran unas pletinas de 3/16 para que realice la función de pulmones térmicos o dilatador térmico, este accesorio nos ayudara para que no se deformen demasiado las planchas de acero inoxidable en el momento de la dilatación y contracción térmica del material

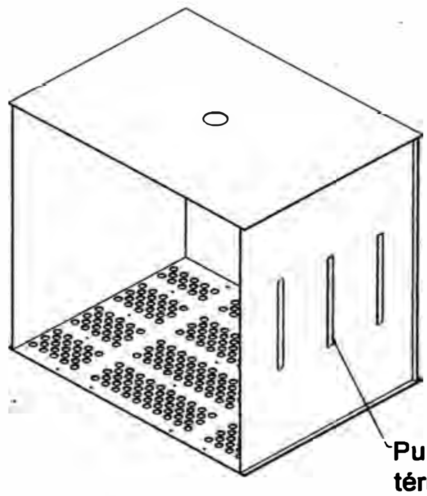


Gráfico N° 4.16 Pulmones térmicos del horno interno

Se tendrá en cuenta que para proteger contra la corrosión la estructura y los elementos de fijación se deben ser zincados, ya que la estructura estará sometida a variaciones de temperatura.

El gabinete de resistencias, también será diseñadas con ángulos estructurales, con la particularidad que las resistencias estarán apoyadas sobre pletinas de acero inoxidable, esta pletina será soldado a uno de sus extremas y en el otro extremo será empernada en un agujero chino para que se pueda mover horizontalmente al momento que se dilata el apoyo.

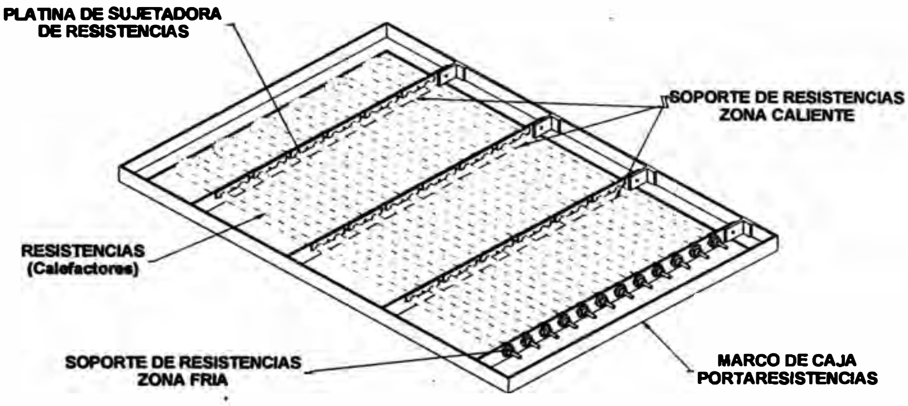


Gráfico N° 4.17 Gabinete de resistencias

La planta inferior del horno habrá una plancha agujereada tipo rejilla con la finalidad de facilitar el paso del aire que asciende de la parte inferior horno, esta ubicación de los agujeros se distribuyo de acuerdo a la estructura del horno.

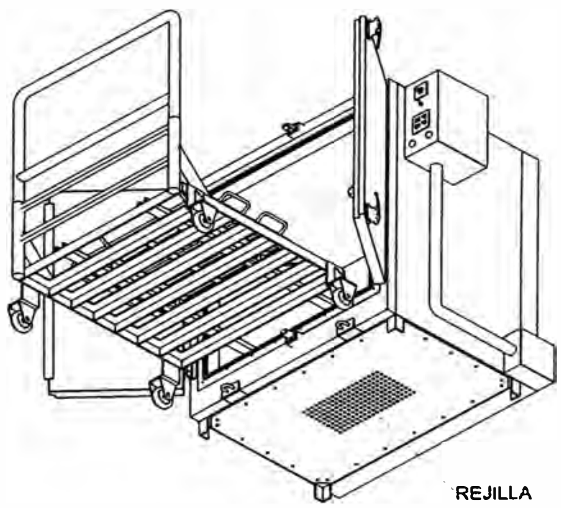
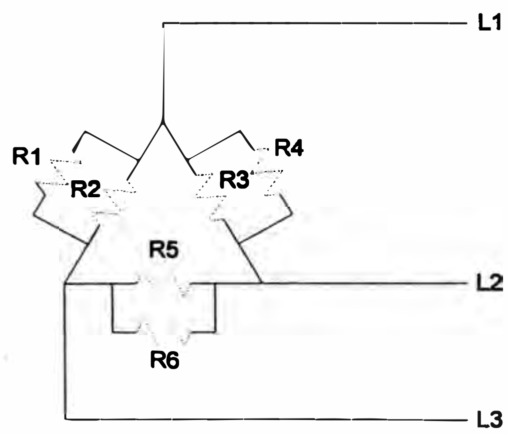


Gráfico N° 4.18 Diseño mecánico final del horno eléctrico de secado

4.4 SISTEMA ELÉCTRICO DE FUERZA Y CONTROL

Se determino que la potencia eléctrica total del horno es de 4.8 Kw, como hay 06 resistencias en U, cada resistencia consumirá una potencia de 800W.

Como se menciono anteriormente el usuario tiene la fuente de energía 220VAC trifásico, entonces las resistencias deben tener una alimentación trifásica de 220VAC, Se debe de conectar las resistencias en Delta doble como se observa en la figura grafico:



GráficoN° 4.19 Arreglo de las resistencias eléctricas

El tablero eléctrico debe estar conformado por los siguientes componentes:

- Interruptor principal
- Contactor principal
- Fusible de Fuerza
- Controlador digital de temperatura
- Pulsadores Start / Stop
- Indicadores luminosos

- Contactos auxiliares

En la entrada del circuito eléctrico se colocara un interruptor termomagnético para eliminar las sobrecargas y cortocircuitos, además como se menciono anteriormente se tendrá un controlador de temperatura que funcionara con una termocupla tipo K que sensara la temperatura de operación del horno.

Entre el interruptor principal y las resistencias eléctricas habrá un contactor trifásico, su función de este contactor es de energizar y desenergizar la resistencia, el controlador de temperatura actuara sobre la bobina del contactor para que este energice la resistencia (elevar la temperatura) y desenergizara las resistencias (cuando desee disminuir la temperatura dentro del horno).

Como el controlador de temperatura tiene la tecnología PID, esto ayudara que el controlador se autoajuste y busque automáticamente los parámetros internos para que el control tenga una buen performance, primero se tiene que simular un trabajo casi real para que el controlador adquiera los parámetros iníciales PID , para el trabajo de simulación hacemos ingresa un motor eléctrico de 30 Hp sobre el carro portacarga, luego se programa la temperatura de trabajo y el controlador empieza a recibir información de lo que esta pasando dentro del horno, observando la curva Temperatura vs Tiempo el controlador tiene que subir y bajar mínimo 03 veces la temperatura alrededor del set point del controlador, una vez realizado la simulación se observa que la temperatura de trabajo se estabilizo.

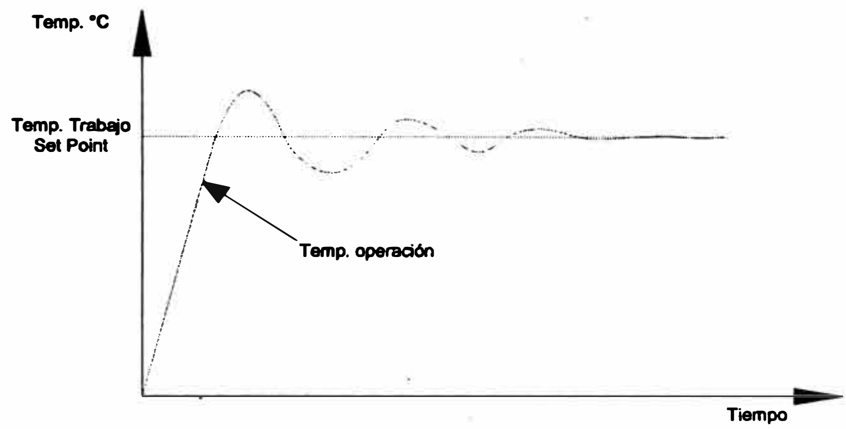


Gráfico N° 4.20 Curva de adquisición de datos del controlador de temperatura

Para el sensado de temperatura se va usar una termocupla tipo K, también se instalara un termostato de bulbo capilar como dispositivo de seguridad térmica, este dispositivo será ubicado cerca de la zona de sensado, el termostato capilar estará seteado a una temperatura de 130^{0}C, este valor es dado por la temperatura máxima de operación que tiene el aislante eléctrico de las bobinas del estator y rotor. El termostato entra a funcionar si por razones de fabricación, mala conexión o daño del sensor de temperatura no enviara la información correcta al controlador, por lo tanto este tipo de falla podría elevar la temperatura dentro del horno, la cual causaría daños a las cargas, equipo y a las personas que están cerca del horno de secado.

Para el conexionado eléctrico entre el contactor y las resistencias se debe utilizar cable de cobre estañado con forro de fibra de vidrio siliconado, este es un cable especial que resiste altas temperaturas.

4.4.1 Selección del cable de fuerza

Para el conexionado de fuerza se usara cable THW de color rojo y azul para diferenciar las fases dentro del tablero, el calibre del cable será calculado por la siguiente ecuación

$$I_{dis} = 1.25 \times \left(\frac{P_{total}}{\sqrt{3} \times V} \right) \dots\dots\dots\dots\dots\dots (4.29)$$

Donde:

I_{dis} : Corriente de diseño en A.

P : Potencia total de las resistencias en W.

V : voltaje de alimentación en V.

$$I_{dis} = \frac{1.25 \times (800 \times 6)}{\sqrt{3} \times 220}$$

$$I_{dis} = 15.72\, Amp$$

Del cuadro de Indeco para cable THW (anexo) seleccionamos el calibre 12 AWG.

4.4.2 Selección de interruptor principal

La función del interruptor es de abrir al momento que ocurre una sobre carga o cortocircuito, pero como nuestra carga es constante, entonces el interruptor solo abrirá cuando ocurre un cortocircuito. El interruptor debe tener la capacidad del doble de la corriente nominal de la carga.

$$I_{d\,interup} = 2 \times \left(\frac{P_{total}}{\sqrt{3} \times V} \right) \dots\dots\dots\dots\dots\dots (4.30)$$

$$I_{d\,interup} = 2 \times \left(\frac{800 \times 6}{\sqrt{3} \times 220} \right)$$

$$I_{d\,\text{interup}} = 25.22\,Amp$$

Según la tabla anexada seleccionamos el interruptor termomagnético tripolar C60H modelo 25002 de la marca Merlin Gerin.

4.2.3 Selección de contactor principal

Como la carga alimentar es resistivo el contactor debe ser de la clase AC1. El contactor debe ser 1.5 mayor de la corriente nominal de la carga.

$$I_{d\,contactor} = 1.5 \times \left(\frac{P_{total}}{\sqrt{3} \times V} \right) \quad \text{.................. (4.31)}$$

$$I_{d\,contactor} = 1.5 \times \left(\frac{800 \times 6}{\sqrt{3} \times 220} \right)$$

$$I_{d\,contactor} = 18.91\,Amp$$

Según la tabla anexada seleccionamos el contactor tripolar 25A , 220 VAC, modelo LC1D09M7 de la marca Telemecanique.

CAPÍTULO V

CUADRO DE COSTOS

Todos los materiales utilizados en la fabricación del horno eléctrico son materiales comprados en el mercado local.

A continuación se muestra una lista de los materiales usados en la fabricación del horno eléctrico de secado.

Tabla N° 5.1 Materia prima del horno eléctrico

Id	Nombre	Tipo	Tasa estándar
1	PERFILES DE FIERRO ESTRUCTURAL	Material	S/. 25.00
2	PERFILES DE ACERO INOXIDABLE	Material	S/. 55.00
3	PLANCHAS DE FIERRO	Material	S/. 50.00
4	PLACHAS DE ACERO INOXIDABLE	Material	S/. 125.00
5	SOLDADURA	Material	S/. 50.00
6	PLATINAS DE ACERO INOXIDABLE	Material	S/. 50.00
7	BARRA REDONDA DE ACERO INOXIDABLE	Material	S/. 150.00
8	CONTACTOR	Material	S/. 80.00
9	LLAVE PRINCIPAL	Material	S/. 40.00
10	RELAY	Material	S/. 30.00
11	RESISTENCIAS ELECTRICAS	Material	S/. 1,500.00
12	CABLES DE FUERZA	Material	S/. 40.00
13	TABLERO ELECTRICO	Material	S/. 120.00
14	CAJA DE PASO	Material	S/. 30.00
15	TUBO CONDUIT	Material	S/. 45.00
16	TERMOSTATO CON BULBO	Material	S/. 200.00

La siguiente lista se muestra el costo de la mano de obra de las personas y maquinarias utilizadas para la fabricación del horno eléctrico de secado.

Tabla N° 5.2 Mano de obra y herramientas a usar en el horno eléctrico

Id	Nombre	Tipo	Tasa estándar
1	INGENIERO	Trabajo	S/. 8.00/hora
2	SOLDADOR	Trabajo	S/. 5.50/hora
3	TORNERO	Trabajo	S/. 5.50/hora
4	FRESADOR Y TALADRADOR	Trabajo	S/. 5.50/hora
5	ELECTRICISTA	Trabajo	S/. 5.50/hora
6	COMPRADOR	Trabajo	S/. 6.00/hora
7	ALMACENERO	Trabajo	S/. 4.50/hora
8	AYUDANTE	Trabajo	S/. 3.50/hora
9	TRANSPORTISTA	Trabajo	S/. 4.50/hora
10	SENSORISTA	Trabajo	S/. 5.50/hora
11	SUPERVISOR	Trabajo	S/. 7.00/hora
12	PINTOR	Trabajo	S/. 5.00/hora
13	TORNO	Trabajo	S/. 10.00/hora
14	MAQUINA DE FRESADO	Trabajo	S/. 10.00/hora
15	TALADRO	Trabajo	S/. 6.00/hora
16	SIERRA ELECTRICA	Trabajo	S/. 4.00/hora
17	AMOLADORA	Trabajo	S/. 3.00/hora
18	MAQUINA DE SOLDAR	Trabajo	S/. 2.50/hora
19	DOBLADOR	Trabajo	S/. 2.00/hora
20	MAQUINA DE DOBLAR	Trabajo	S/. 2.00/hora

CONCLUSIONES Y RECOMENDACIONES

CONCLUSIONES

El presente informe puede ser tomado como un procedimiento para la fabricación de hornos eléctricos de secado, especialmente enfocado en la selección del calentador eléctrico y el tablero de fuerza y control.

El horno también puede operar a temperaturas menores con la cual fue diseñada ($90^{0}C$), pero con la consideración que va tomar menos tiempo en alcanzar temperaturas inferiores de operación.

El diseño interno del horno está totalmente fabricado de acero inoxidable, para evitar que las paredes internas viertan algún elemento extraño sobre el motor eléctrico.

RECOMENDACIONES

El operario debe tener todos los implementos de seguridad para maniobrar la carga antes y después del secado.

No almacene o use material inflamable o explosivo cerca del horno.

Antes de empezar el proceso se tiene que verificar que dentro del horno no haiga algún elemento extraño dentro de la caja de las resistencias.

El horno tiene su respaldo de seguridad térmica, y este se debe posicionar 20^0C superior a la temperatura de trabajo del horno.

Se deben cambiar cada 06 meses los sensores de temperatura para asegurarnos un buen sensado, a la vez verificar el cable compensado del sensado y conexionado del circuito de control.

El operario tiene que abrir la tapa de la chimenea del horno para la expulsión de humedad cada 04 horas.

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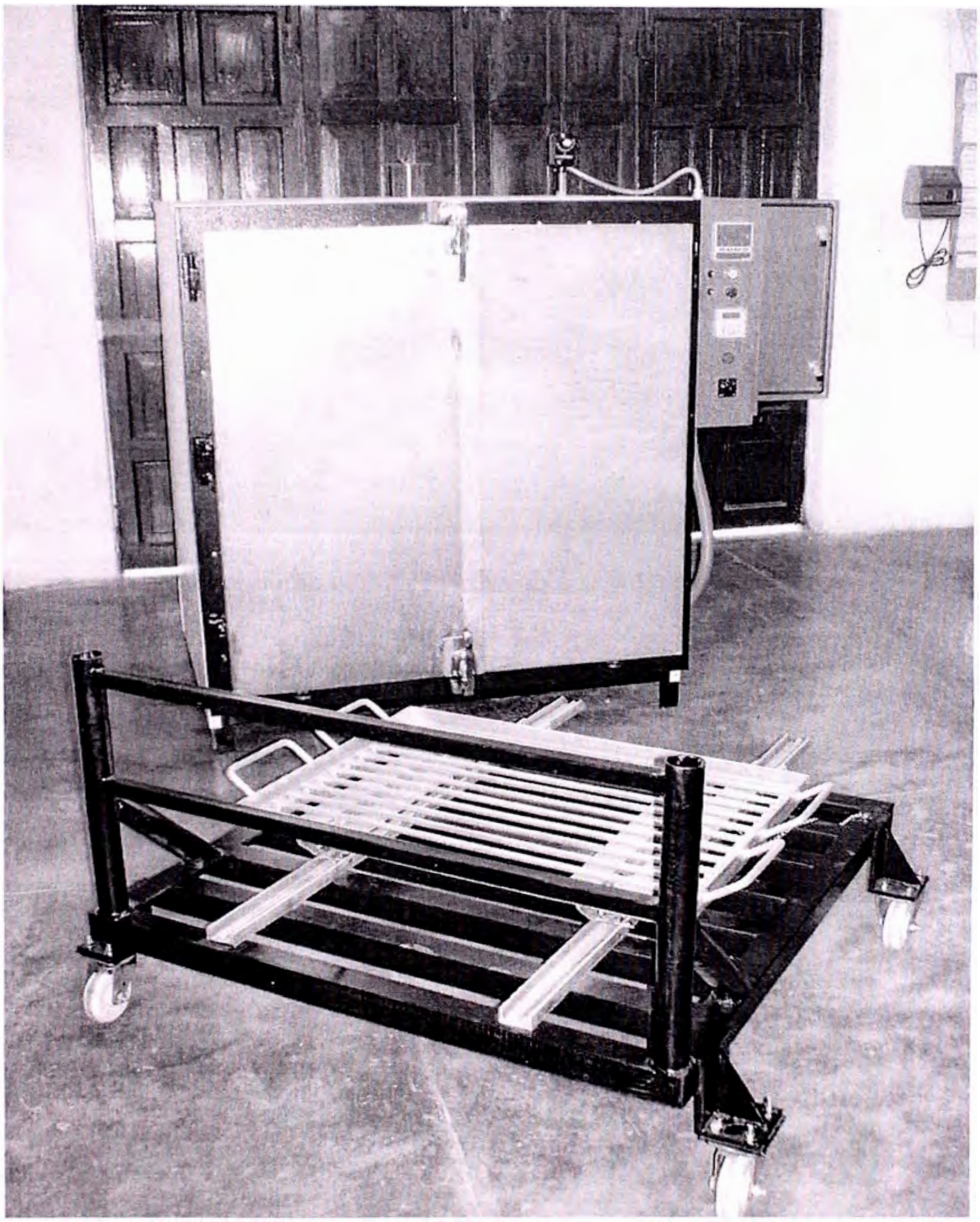
Manual de Instrucciones B-3605-9S - Manual de Instalación, Operación y Mantenimiento de los Motores Duty Master® de CA
Autor : Rockwell Automation Power Systems-USA, Abril-1999

Instrucciones para la Instalación y mantenimiento de Motores eléctricos WEG
Autor : WEG motores-Brasil

ANEXOS

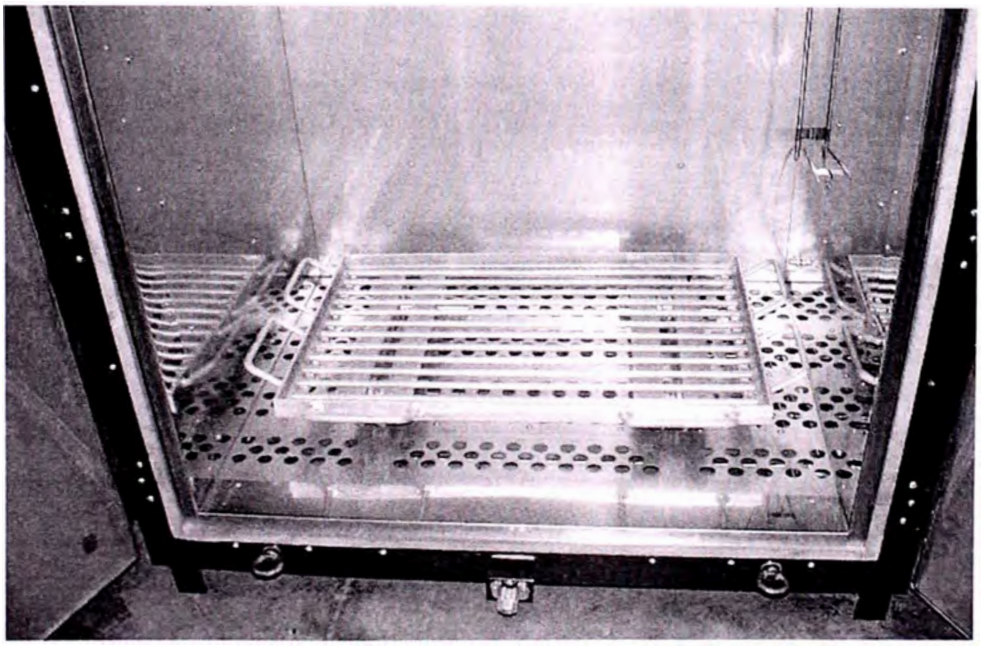
IMAGENES DE HORNO ELECTRICOS DE SECADO

FOTOS DEL HORNO ELECTRICO DE SECADO DE MOTORES



Esta Foto muestra el horno eléctrico y en la parte delantera esta el carro portacarga sobre el carro portacarro.

Esta foto muestra el horno con las puertas abierta y dentro se encuentra el carro portacarga.

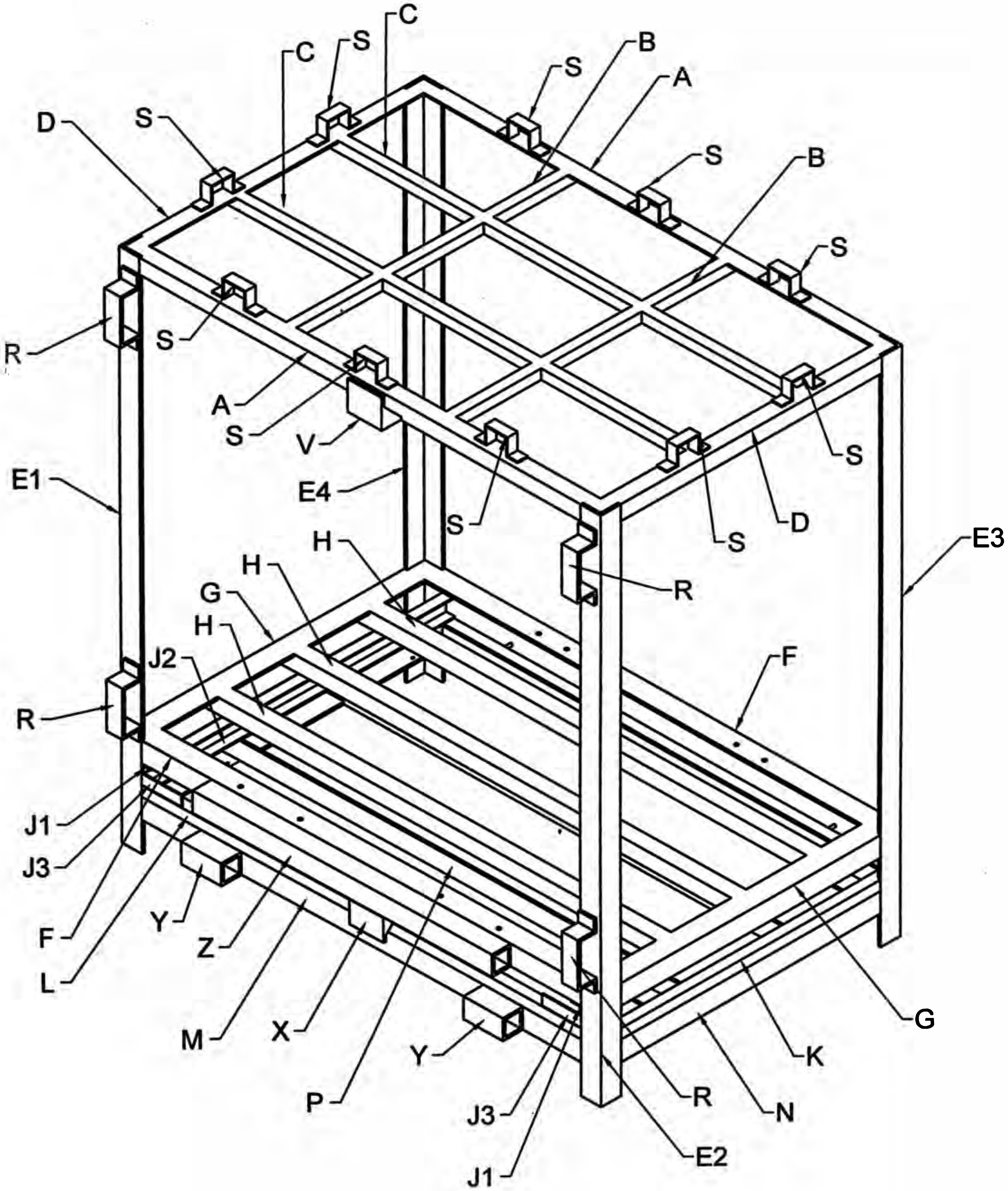


En el marco inferior frontal del horno se muestra el picaporte inferior con los cáncamos que funcionaran como tope del carro portacarro.

A continuación se muestra la chimenea del horno eléctrico de color verde, a su vez se observa el termostato con bulbo capilar y controlador de temperatura.

PLANOS GENERALES

ESTRUCTURA INTERIOR DE HORNO DE RESISTENCIAS
VISTA DE ENSAMBLAJE



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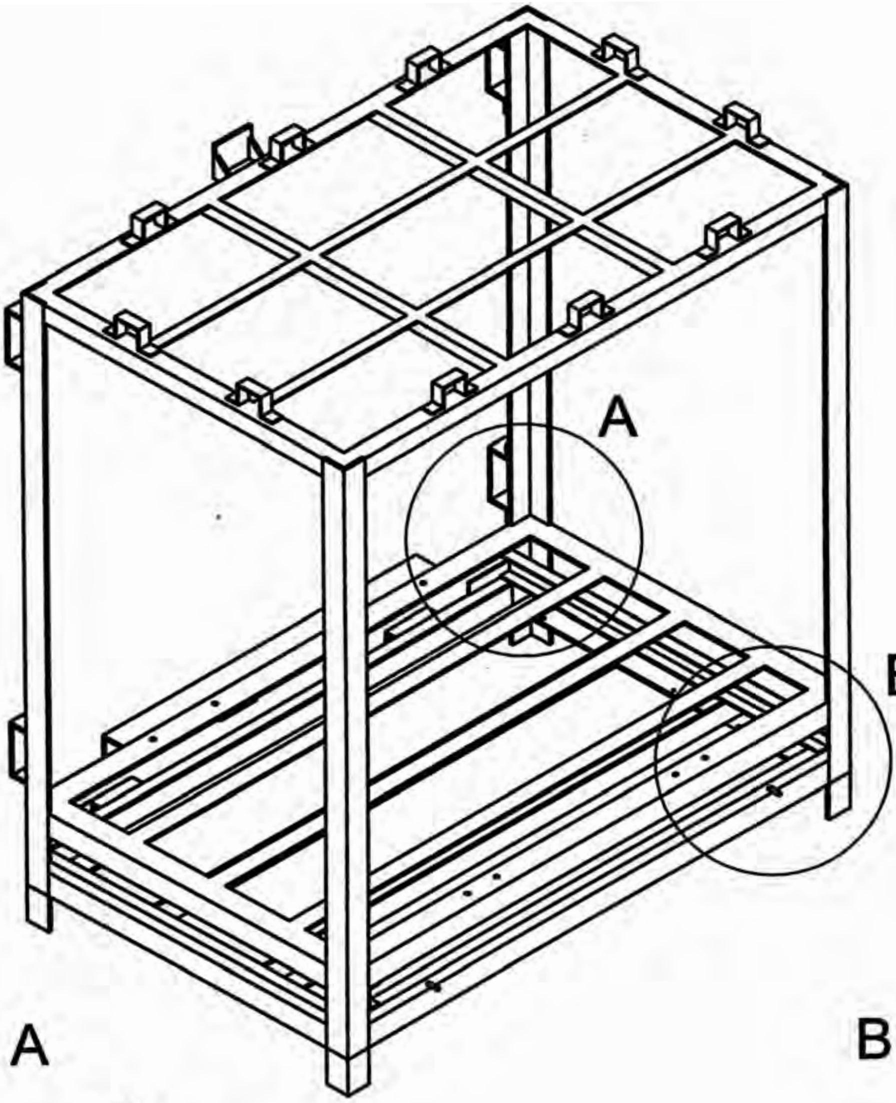
Artículo:	Piezas:	

ESTRUCTURA INTERIOR DE HORNO DE RESISTENCIAS
VISTA AUXILIAR



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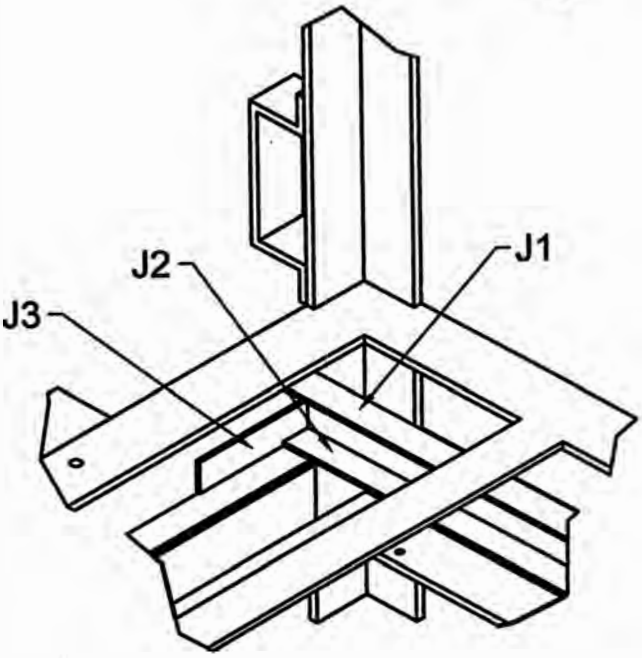

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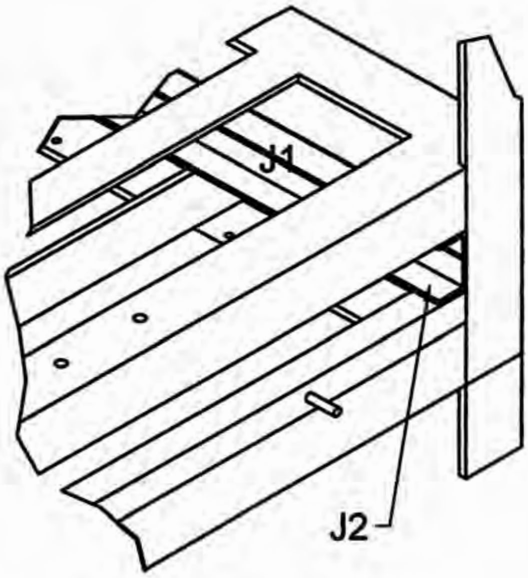

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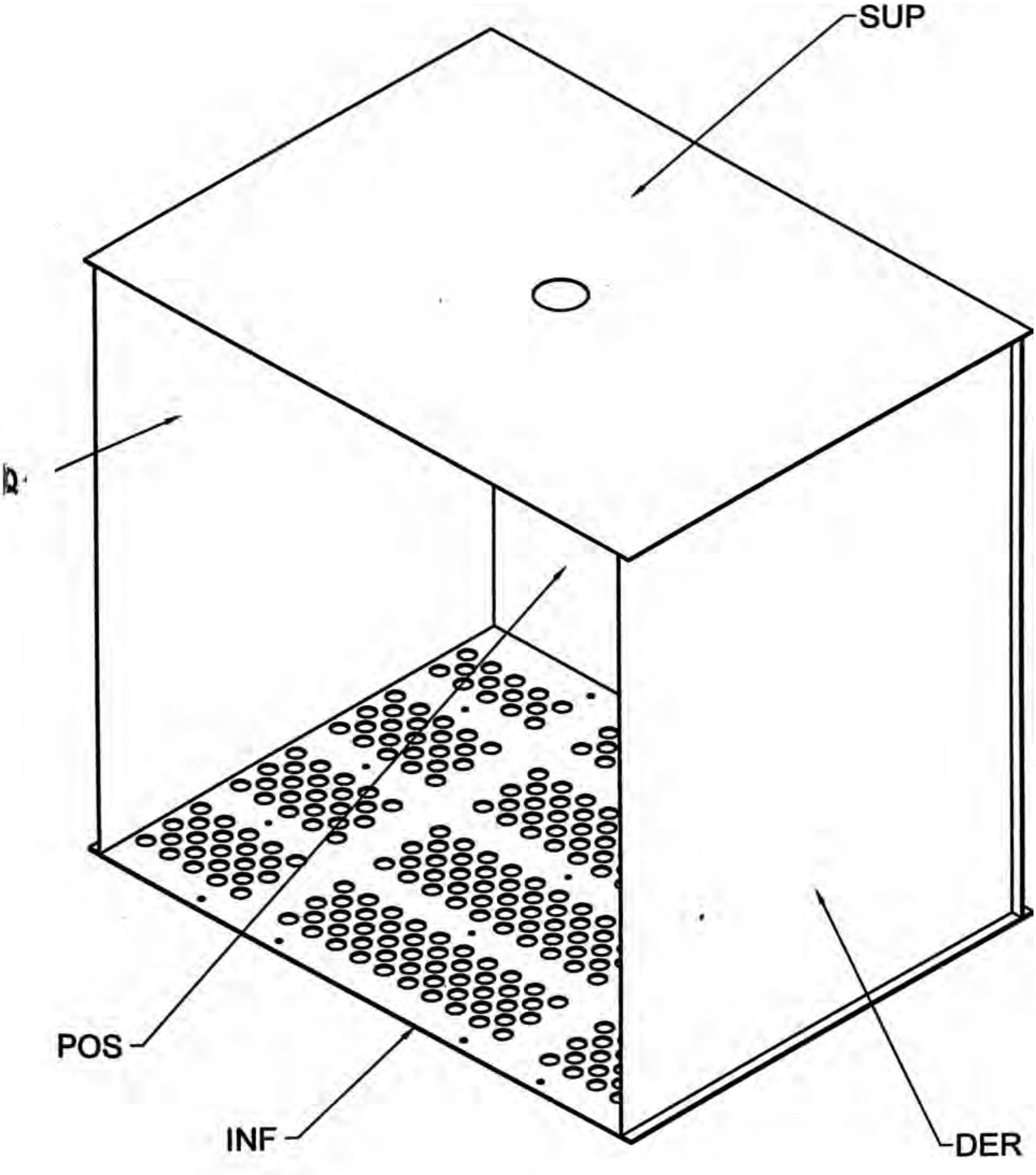
Artículo:	Piezas:	

GABINETE INTERIOR DE HORNO DE RESISTENCIAS
VISTA DE ENSAMBLAJE



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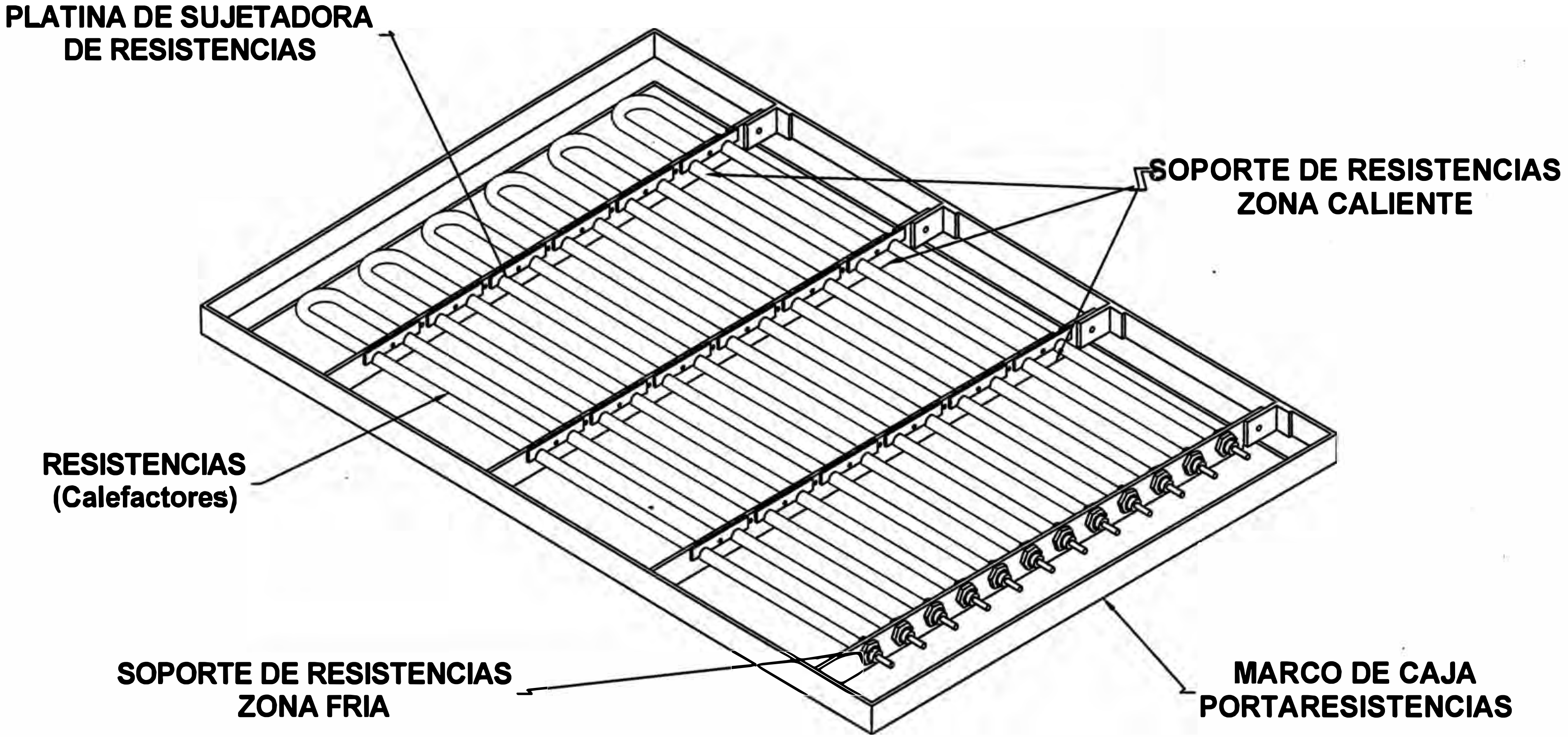
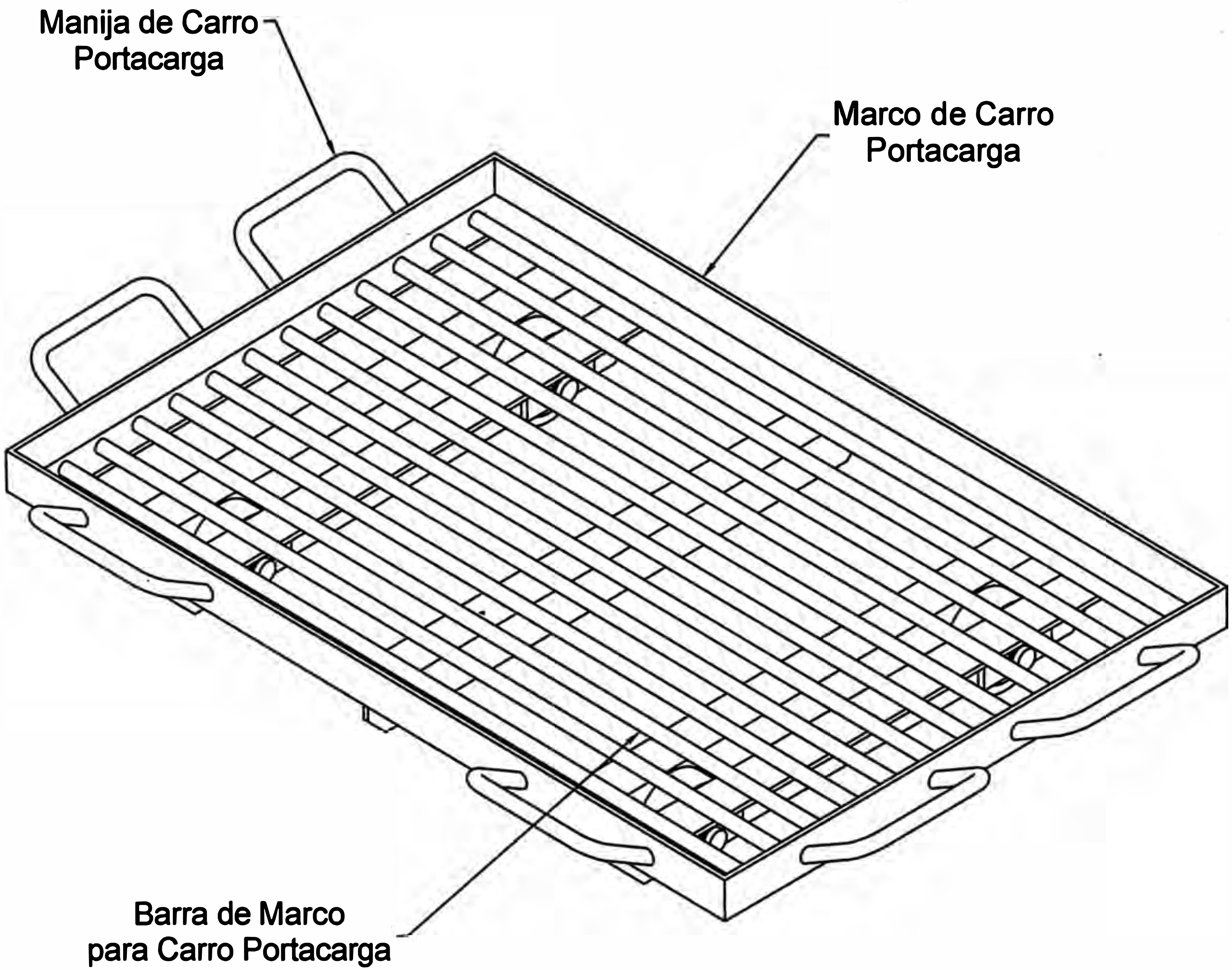
Artículo:	Piezas:	

CAJA DE RESISTENCIAS



Cotización:	Fecha:	Lámina:
Artículo:	Piezas:	

CARRO PORTACARGA



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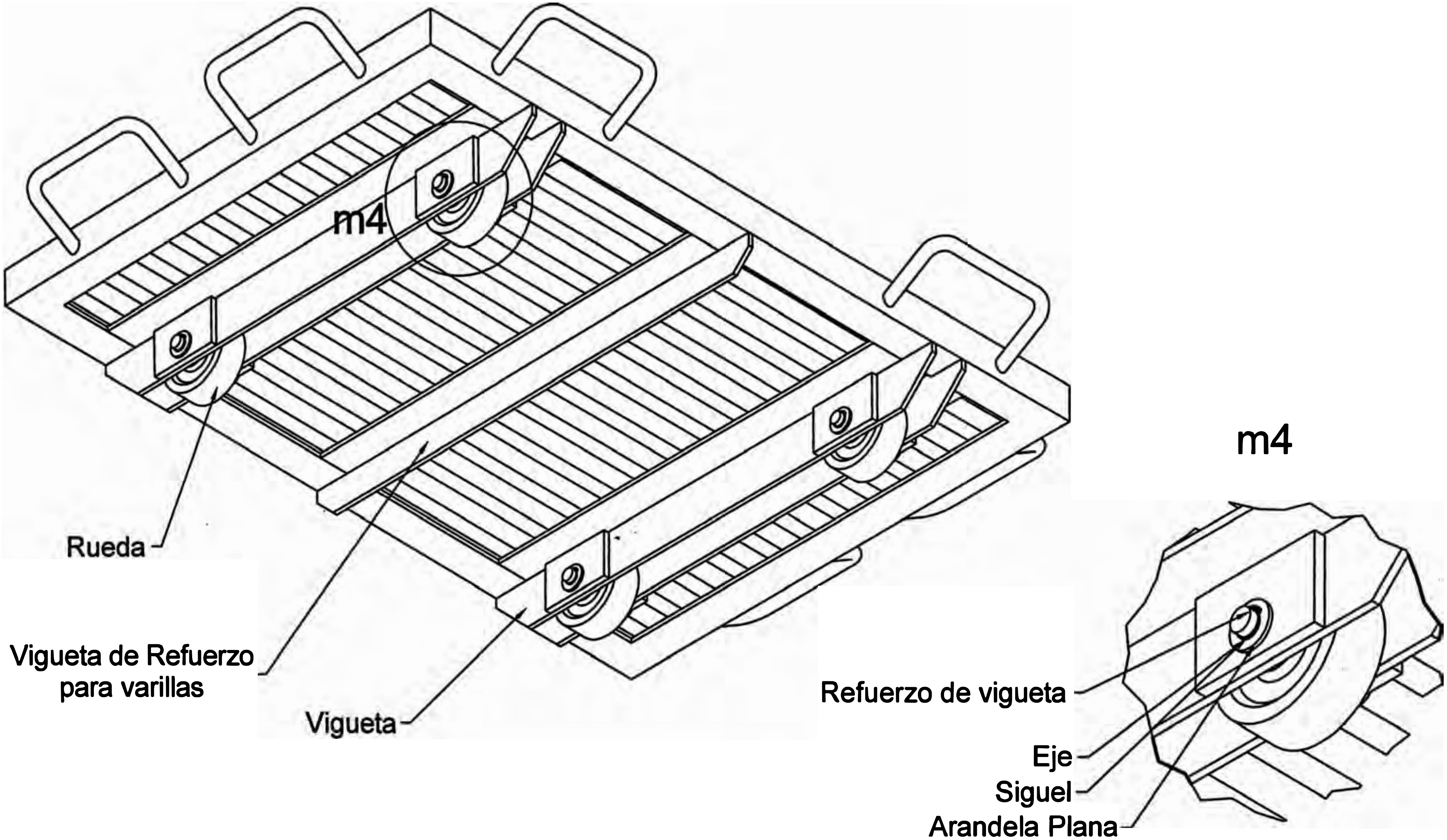
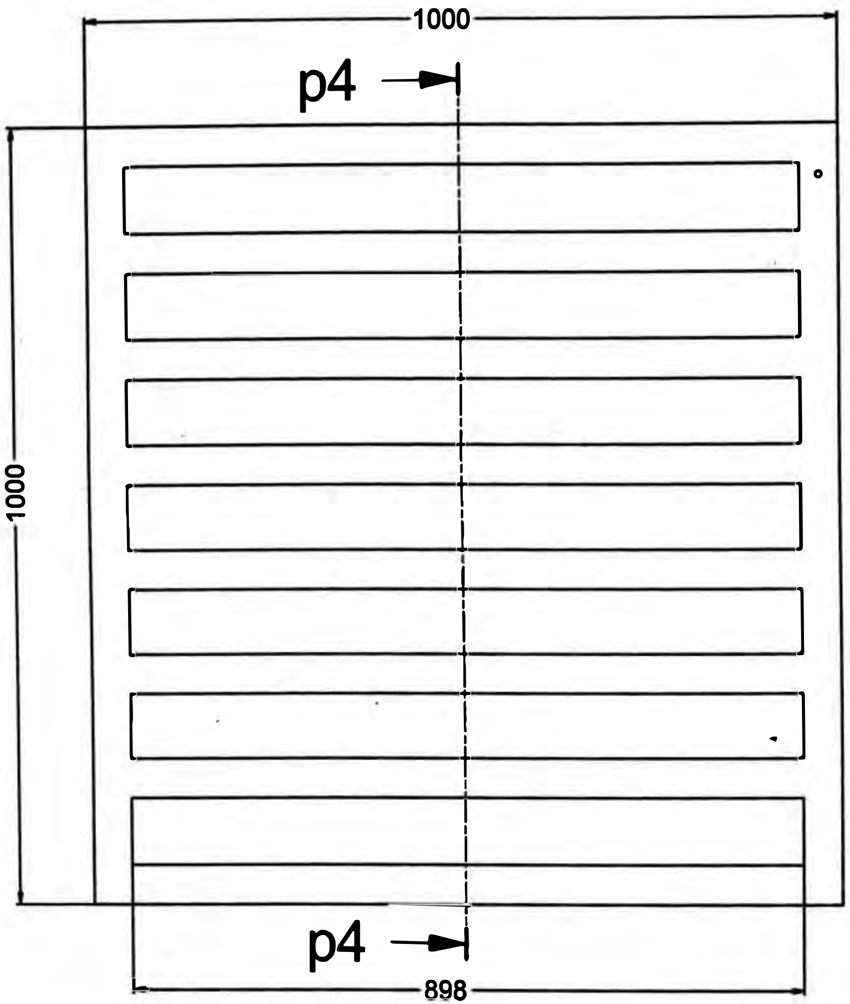
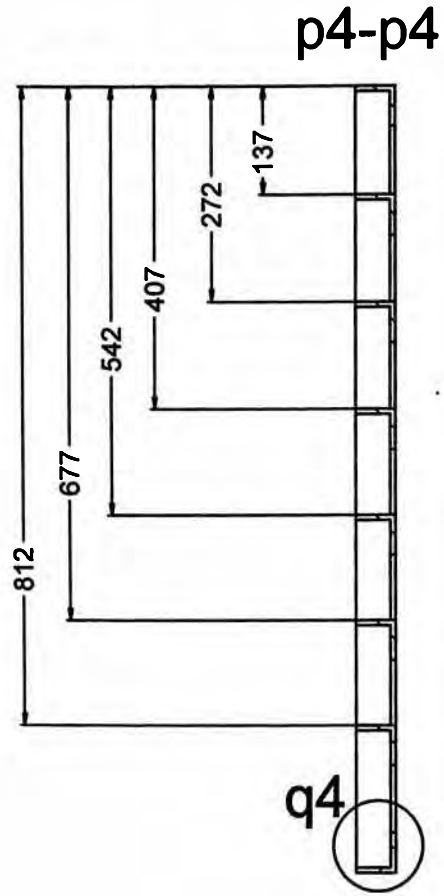
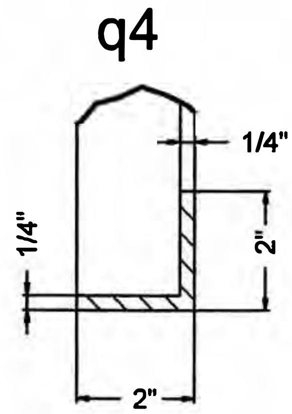


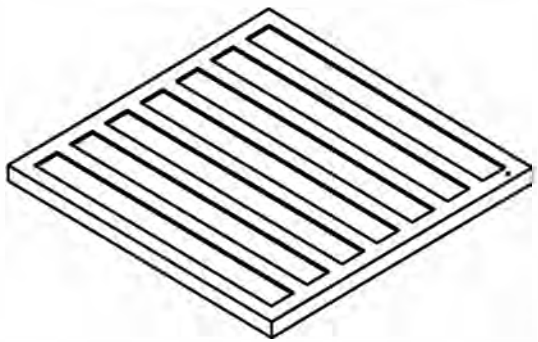
Cotización:	**Fecha:**	**Lámina:**
Artículo:	**Piezas:**	

MARCO BASE DE CARRO PORTACARRO (C1)





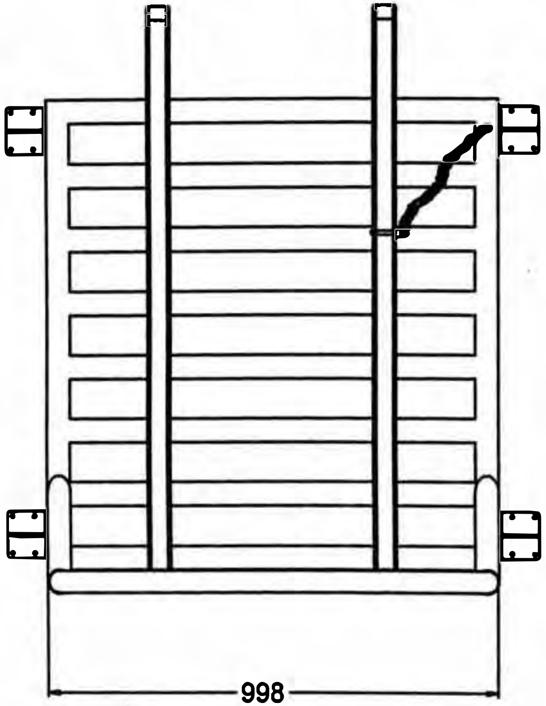


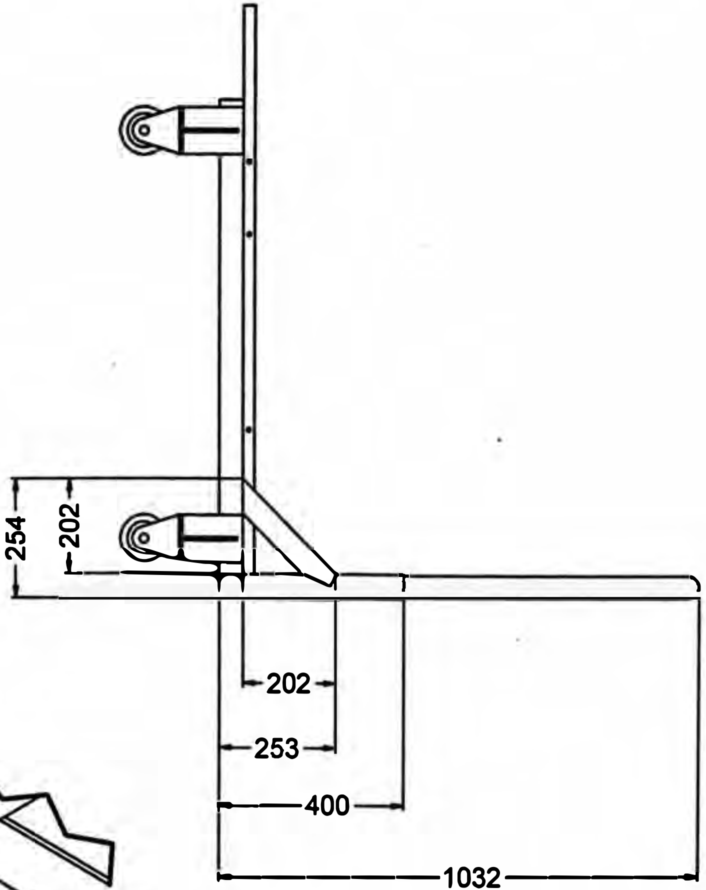


Nota : Todas las dimensiones en mm.

Seccion de Perfil:
Angulo 2"x2"x1/4"
Longitud 10000 mm (10 X 1000 mm)
Material: Estructural (laminado).
Cantidad : 01 pza.

Cotización:	Fecha:	Lámina:
Artículo:	Piezas:	





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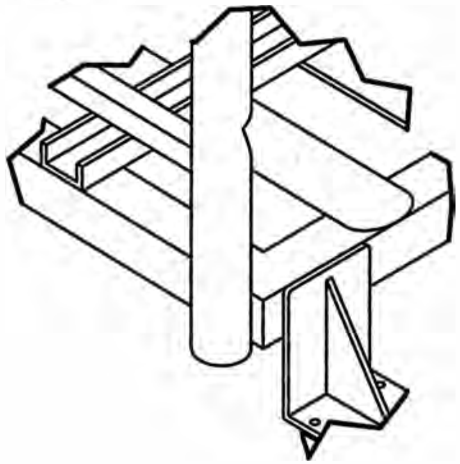

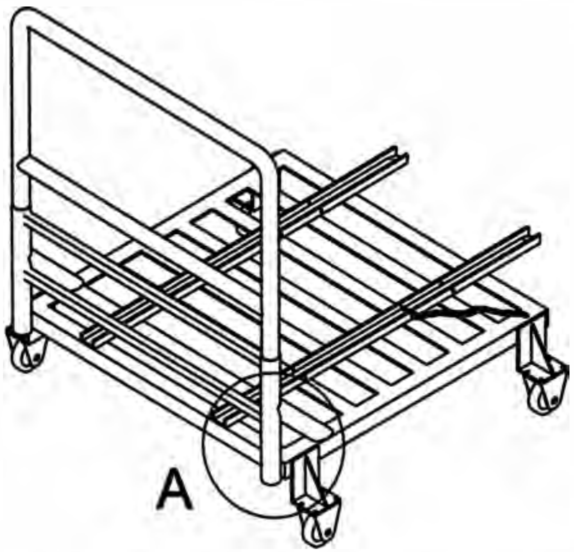

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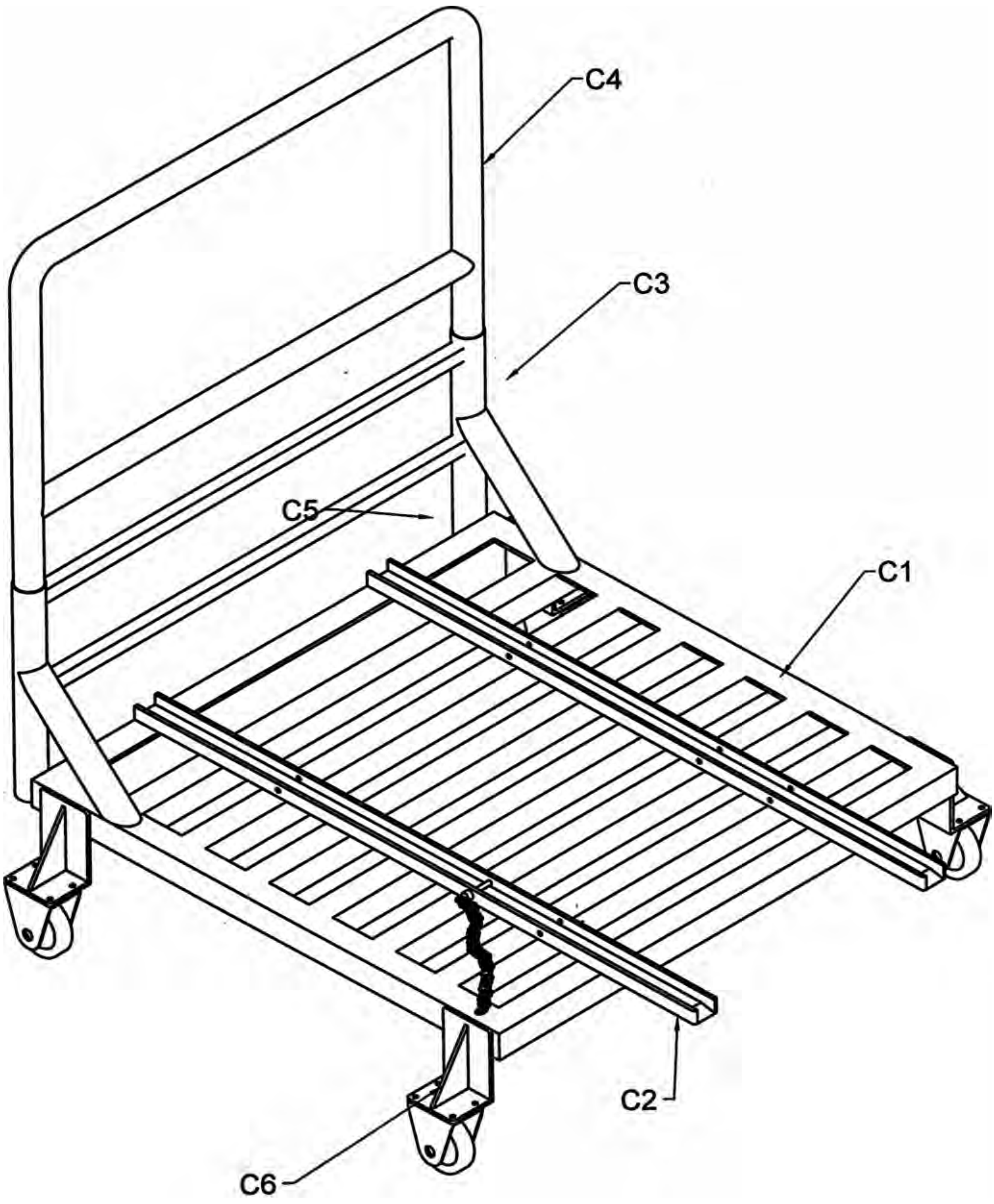
Artículo:	Piezas:	

CARRO PORTACARRO
VISTA DE ENSAMBLAJE



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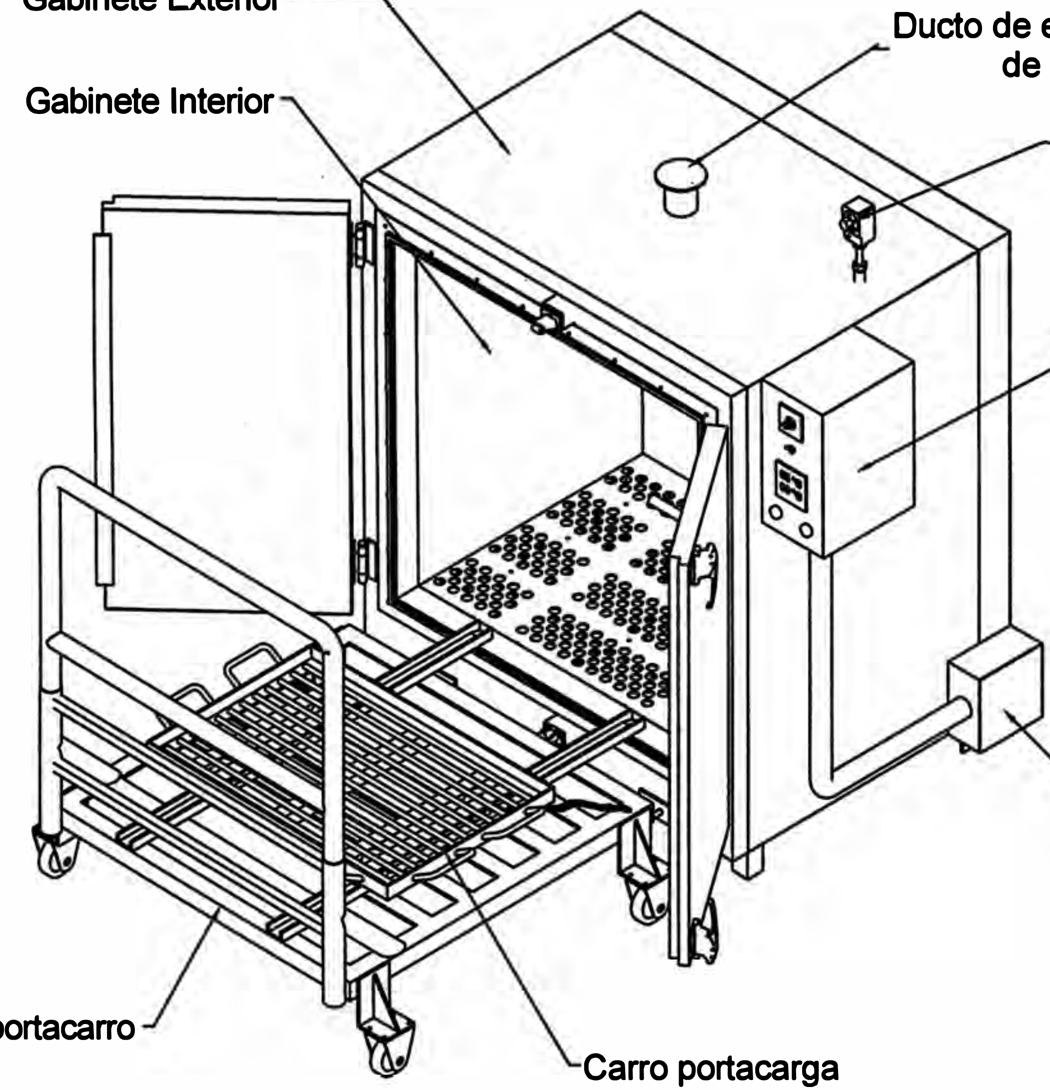
Artículo:	Piezas:	

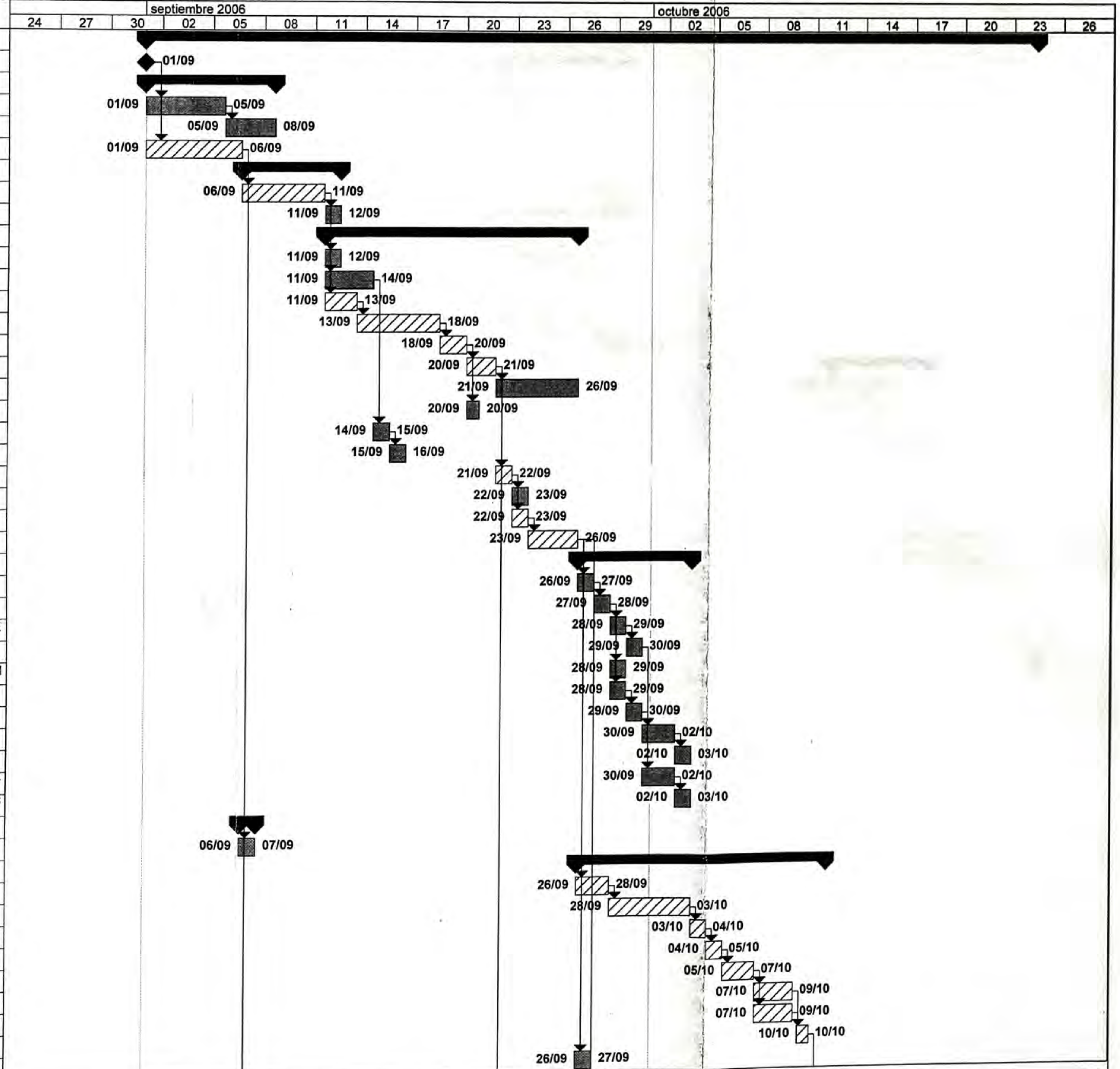
ENSAMBLE FINAL DE HORNO DE RESISTENCIAS



Cotización:	Fecha:	Lámina:
Artículo:	Piezas:	

CRONOGRAMA DE FABRICACION

Id		Nombre de tarea
1		**HORNO ELECTRICO DE SECADO DE MOTORES - CHRISTIAN GARCIA COCHACHI**
2		INICIO
3		**INGENIERIA Y DISEÑO**
4		DISEÑO MECANICO
5		DISEÑO TERMICO
6		DISEÑO ELECTRICO
7		**COSTOS Y PRESUPUESTO**
8		COSTEO DE MATERIALES EN EL MERCADO
9		SELECCIÓN DE MATERIALES A COMPRAR
10		**ESTRUTURA METALICA**
11		CORTE DE PERFILES
12		CORTE DE PLANCHAS DE FIERRO
13		CORTE DE PLATINAS
14		PERFORACION DE PERFILES,PLANCHAS Y PLATINAS
15		FRESADO DE PERFILES NO COMUNES EN EL MERCADO
16		ESMERILADO Y ACABADO FINAL DE PIEZAS PARA LA ESTRUCTURA
17		SOLDADO DE ESTRUCTURA EXTERNA
18		SOLDADO DE CAJA INFERIOR PORTA AISLANTE TERMICO
19		DOBLADO DE PLANCHA DE FIERRO PARA DUCTO DE AIRE FRESCO
20		SOLDADO DE DUCTO DE ENTRADA DE AIRE FRESCO
21		SOLDADO DE CAJA DE RESISTENCIAS ELECTRICAS
22		SOLDADO DE GUIA DE CAJA DE RESISTENCIAS
23		SOLDADO DE ESTRUCTURA BASE DE GABIENTE INTERIOR DEL HORNO
24		EMSAMBLE Y SOLDADO PERTENECIENTE A ESTRUCTURA DEL HORNO
25		**GABINETE INTERIOR DE ACERO INXODABLE**
26		CORTE DE PLANCHAS DE ACERO INOXIDABLE
27		DOBLADO DE PLANCHAS DE ACERO INOXIDABLE
28		PERFORACION DE PLANCHA DE HACER. INOX. BASE INFERIOR DEL GABINE
29		EMSAMBLADO Y PERFORADO DE GABINETE INTERIOR DEL HORNO
30		SOLDADO DE PLATINAS DE ACERO INOX (PULMONES DE DILATACION TERM
31		CORTE CIRCULAR EN TECHO DE GABINETE EXTERIOR
32		CORTE DE ANILLO DE REFUERZO DE CHIMENEA DE ACERO INOXIDABLE
33		CORTE DE TUBO DE ACERO INOXIDABLE PARA CHIMENEA
34		CORTE DE DISCO DE ACERO INOXIDABLE PARA TAPA DE CHIMENEA
35		SOLDADO DE ANILLO DE REFUERZO CON GABINETE INTERIOR (LADO TECH
36		MONTAJE ATORNILLADO DE CHIMENEA CON DISCO DE GABIENTE INTERIOF
37		**FABRICACION DE RESISTENCIAS ELECTRICAS**
38		FABRICACION DE RESISTENCIAS Y PRUEBAS ELECTRICAS
39		**GABINETE EXTERIOR**
40		CORTE DE PLANCHAS DE FIERRO
41		DOBLADO DE PLACHAS DE FIERRO
42		PERFORACION DE PLANCHAS DE FIERRO
43		SOLDADO DE PINES DE RETENCION DE AISLAMIENTO TERMICO
44		PRIMER EMSAMBLE DE GABIENTE EXTERIOR (SIN PUERTA)
45		CORTE DE PLANCHA PARA CONTRAPUERTA DE ACERO INOXIDABLE
46		CORTE DE PLANCHA PARA PUERTA DE FIERRO
47		SOLDADO DE PINES DE RETENCION DE AISLAMIENTO TERMICO (PUERTA)
48		FABRICACION DE BISAGRAS Y PORTABISAGRAS



Proyecto: PROYECTO HORNO E Fecha: vie 11/07/08	Tarea	Hito	Tarea crítica resumida	División	Agrupar por síntesis
	Tarea crítica	Resumen	Hito resumido	Tareas externas	Fecha límite
	Progreso	Tarea resumida	Progreso resumido	Resumen del proyecto	

Id		Nombre de tarea	septiembre 2006 – octubre 2006
49		CORTE Y UBICACION DEL AISLAMIENTO TERMICO	10/10 – 11/10
50		**CARRO PORTAMOTOR**	
51		SOLDADO DE PERFILES DE ACERO INOXIDABLE	21/09 – 22/09
52		DOBLADO DE BARRA DE ACERO INOXIDABLE (MANIJAS)	22/09 – 23/09
53		FRESADO DE PIEZA ESPECIALES	23/09 – 26/09
54		PERFORADO DE PIEZAS ESPECIALES	26/09 – 27/09
55		TORNEADO DE RUEDAS PORTAMOTOR	21/09 – 22/09
56		EMSAMBLE DE CARRO PORTAMOTOR	27/09 – 29/09
57		**CARRO PORTACARRO**	
58		SOLDADO DE PERFILES DE FIERRO	21/09 – 22/09
59		SOLDADO DE BARRA GUIADORA	22/09 – 25/09
60		FABRICACION DE UÑAS TIPO GARRA	25/09 – 27/09
61		DOBLADO DE TUBERIA MANGO PORTACARRO	22/09 – 23/09
62		SOLDADO DE MANGO PORTACARRO	23/09 – 25/09
63		EMSAMBLE DE CARRO PORTACARRO CON RUEDAS DE NYLON	27/09 – 29/09
64		**TABLERO ELECTRICO**	
65		ARMADO DEL TABLERO DE CONTROL Y FUERZA	11/10 – 13/10
66		PRUEBAS ELECTRICAS DEL TABLERO (SIMULANDO CARGA EXTERNA)	13/10 – 14/10
67		CABLEADO INTERNO DEL TABLERO CON LAS RESISTENCIAS ELECTRICAS	14/10 – 16/10
68		SEGUNDA PRUEBA ELECTRICA DEL TABLERO ELECTRICO (HORNO SIN CAR	16/10 – 17/10
69		**TERMOSTATO DE SOBRETEMPERATURA**	
70		FABRICACION DE TERMOSTATO DE SOBRETEMPERATURA	01/09 – 02/09
71		PRUEBAS TERMICO - MECANICO DEL HORNO (SIN CARGA)	16/10 – 17/10
72		PRUEBAS TERMICO - MECANICO DEL HORNO (CON CARGA)	17/10 – 18/10
73		PINTADO AL HORNO DEL GABIENTE EXTERIOR	18/10 – 20/10
74		PRUEBA FINAL TERMICO - MECANICO DEL HORNO (CON CARGA)	20/10 – 21/10
75		ELABORACION DEL MANUAL DE FUNCIONAMIENTO Y OPERACIÓN DEL HORNO	06/09 – 08/09
76		EMBALAJE DEL HORNO	21/10 – 23/10
77		TRANSPORTE DEL HORNO	23/10 – 24/10
78		FIN	24/10

Proyecto: PROYECTO HORNO E
Fecha: vie 11/07/08

Tarea · Tarea crítica · Progreso · Hito · Resumen · Tarea resumida · Tarea crítica resumida · Hito resumido · Progreso resumido · División · Tareas externas · Resumen del proyecto · Agrupar por síntesis · Fecha límite

TABLAS DE PROPIEDADES DE LOS MATERIALES

4.- PROPIEDADES TERMICAS DE ALGUNOS ELEMENTOS METALICOS

	Conductividad térmica "k" (W/m°K), a la temperatura de:							Propiedades a 20°C				
ELEMENTO	200°K	273°K	400°K	600°K	800°K	1000°K	1200°K	ρ Kg/m³	cp kJ/kg°C	k W/m.°K	α x 10⁶ m²/seg	T.fusión °K
Aluminio	237,0	236,0	240,0	232,0	220,0			2702	896	236,0	97,5	933
Antimonio	30,2	25,5	21,2	18,2	16,8			6684	208	24,6	17,7	904
Berilio	301,0	218,0	161,0	126,0	107,0	89,0	73,0	1850	1750	205,0	63,3	1550
Bismuto	9,7	8,2						9780	124	7,9	6,5	545
Boro	52,5	31,7	18,7	11,3	8,1	6,3	5,2	2500	1047	28,6	10,9	2573
Cadmio	99,3	97,5	94,7					8650	231	97,0	48,5	594
Cesio	36,8	36,1						1873	230	36,0	83,6	302
Cromo	111,0	94,8	87,3	80,5	71,3	65,3	62,4	7160	440	91,4	29,0	2118
Cobalto	122,0	104,0	84,8					8862	389	100,0	29,0	1765
Cobre	413,0	401,0	392,0	383,0	371,0	357,0	342,0	8933	383	399,0	116,6	1356
Germanio	96,8	66,7	43,2	27,3	19,8	17,4	17,4	5360	61,6			1211
Oro	327,0	318,0	312,0	304,0	292,0	278,0	262,0	19300	129	316,0	126,9	1336
Hafnio	24,4	23,3	22,3	21,3	20,8	20,7	20,9	13280	23,1			2495
Indio	89,7	83,7	74,5					7300	82,2			430
Iridio	153,0	148,0	144,0	138,0	132,0	126,0	120,0	22500	134	147,0	48,8	2716
Hierro	94,0	83,5	69,4	54,7	43,3	32,6	28,2	7870	452	81,1	22,8	1810
Plomo	36,6	35,5	33,8	31,2				11340	129	35,3	24,1	601
Litio	88,1	79,2	72,1					534	3391	77,4	42,7	454
Magnesio	159,0	157,0	153,0	149,0	146,0			1740	1017	156,0	88,2	923
Manganeso	7,2	7,7						7290	486	7,8	2,2	1517
Mercurio	28,9							13546				234
Molibdeno	143,0	139,0	134,0	126,0	118,0	112,0	105,0	10240	251	138,0	53,7	2883
Níquel	106,0	94,0	80,1	65,5	67,4	71,8	76,1	8900	446	91,0	22,9	1726
Niobio	52,6	53,3	55,2	58,2	61,3	64,4	67,5	8570	270	53,6	23,2	2741
Paladio	75,5	75,5	75,5	75,5	75,5	75,5		12020	247	75,5	25,4	1825
Platino	72,4	71,5	71,6	73,0	75,5	78,6	82,6	21450	133	71,4	25,0	2042
Potasio	104,0	104,0	52,0					860	741	103,0	161,6	337
Renio	51,0	48,6	46,1	44,2	44,1	44,6	45,7	21100	137	48,1	16,6	3453
Rodio	154,0	151,0	146,0	136,0	127,0	121,0	115,0	12450	248	150,0	48,6	2233
Rubidio	58,9	58,3						1530	348	58,2	109,3	312
Silicio	264,0	168,0	98,9	61,9	42,2	31,2	25,7	2330	703	153,0	93,4	1685
Plata	403,0	428,0	420,0	405,0	389,0	374,0	358,0	10500	234	427,0	173,8	1234
Sodio	138,0	135,0						971	1206	133,0	113,6	371
Tántalo	57,5	57,4	57,8	58,6	59,4	60,2	61,0	16600	138	57,5	25,1	3269
Estaño	73,3	68,2	62,2					5750	227	67,0	51,3	505
Titanio	24,5	22,4	20,4	19,4	19,7	20,7	22,0	4500	611	22,0	8,0	1953
Tungsteno	197,0	182,0	162,0	139,0	128,0	121,0	115,0	19300	134	179,0	69,2	3653
Uranio	25,1	27,0	29,6	34,0	38,8	43,9	49,0	19070	113	27,4	12,7	1407
Vanadio	31,5	31,3	32,1	34,2	36,3	38,6	41,2	6100	502	31,4	10,3	2192
Cinc	123,0	122,0	116,0	105,0				7140	385	121,0	44,0	693
Circonio	25,2	23,2	21,6	20,7	21,6	23,7	25,7	6570	272	22,8	12,8	2125

5.- PROPIEDADES TERMICAS DE ALGUNAS ALEACIONES

Propiedades a 20ºC		Densidad ρ	Calor especif	Conduct. k	Difusiv. $\alpha \times 10^5$	Conductividad térmica en (W/mºC) a la temperatura en ºC:								
Aleaciones	Composición	Kg/m³	J/kgºK	W/mºK	m²/seg	-100	0ºC	100	200	300	400	600	800	1000
Duraluminio	94-96% Al; 3-5% Cu	2787	833	164	6,680	126	159	182	194					
Siluminio	87% Al; 1,33% Si	2659	871	164	7,100	119	137	144	152	161				
Alusil	80% Al; 20% Si	2627	854	161	7,172	144	157	168	175	178				
Al-Mg-Si	97% Al; 1% Mg; 1% Si	2707	8922	177	7,311		175	189	204					
Bronce de aluminio	95% Cu; 5% Al	8666	410	83	2,330									
Bronce	75% Cu; 25% Sn	8666	343	26	0,860									
Latón rojo	85% Cu; 9% Sn; 6% Zn	8714	385	61	1,804		59	71						
Latón	70% Cu; 30% Zn	8522	385	111	3,412	88		128	144	147	147			
Plata alemana	62% Cu; 15% Ni; 22% Zn	8618	394	24,9	0,733	19,2		31	40	45	48			
Constantán	60% Cu; 40% Ni	8922	410	22,7	0,612	21		22	26					
Fundición	4% C	7272	420	52	1,702									
Acero al carbono	0,5% C	7833	465	54	1,474		55	52	48	45	42	35	31	29
	1% C	7801	473	43	1,172		43	43	42	40	36	33	29	28
	1,5% C	7753	486	36	0,970		36	36	36	35	33	31	28	28
Acero al cromo	1% Cr	7865	460	61	1,665		62	55	52	47	42	36	33	33
	5% Cr	7833	460	40	1,110		40	38	36	36	33	29	29	29
	20% Cr	7689	460	40	1,11		22	22	22	22	24	24	26	29
Acero al níquel	10% Ni	7945	460	26	0,720									
	20% Ni	7993	460	19	0,526									
	40% Ni	8169	460	10	0,279									
	60% Ni	8378	460	19	0,493									
	80% Ni	8618	0,46	35	0,872									
	Invar 36% Ni	8,137	460	10,7	0,286									
Acero al Cr-Ni	15% Cr; 10% Ni	7865	460	19	0,526									
	15% Cr; 40% Ni	8073	460	11,6	0,305									
	18% Cr; 8% Ni	7817	460	16,3	0,444		16	17	17	19	19	22	27	31
	20% Cr; 15% Ni	7833	460	15,1	0,415									
	25% Cr; 20% Ni	7865	460	12,8	0,361									
	80% Cr; 15% Ni	8522	460	17	0,444									
Acero al manganeso	1% Mn	7865	460	50	1,388									
	5% Mn	7849	460	22	0,637									
Acero al silicio	1% Si	7769	460	42	1,164									
	5% Si	7417	460	19	0,555									
Acero al tungsteno	1% W	7913	448	66	1,858									
	5% W	8073	435	54	1,525									
	10% W	8314	419	48	1,391									
Ni-Cr	90% Ni; 10% Cr	8666	444	17	0,444		17	19	21	23	25			
	80% Ni; 20% Cr	8314	444	12,6	0,343		12	14	16	17	18	23		
Mg-Al; electrol.	Mg; 7 % Al; 1,5% Zn;	1810	1000	66	3,605		52	62	74	83				

6.- PROPIEDADES DE MATERIALES DE CONSTRUCCION Y AISLANTES

MATERIAL	Temperatura °C	Densidad ρ $\frac{kg}{m^3}$	Calor específico c_p $\frac{Joules}{kg°K}$	Cond. térmica k $\frac{W}{m°K}$	Difusiv. térmica $\alpha \times 10^5$ $\frac{m^2}{seg}$
Amianto	20	383	816	0,113	0,036
Asfalto	20-55	2120		0,74-0,76	
Baquelita	20	1270		0,233	
Ladrillo común	20	1800	840	0,38-0,52	0,028-0,034
Ladrillo de carborundum (50% SiC)	20	2200		5,820	
Ladrillo de carborundum	600			18,5	
	1400			11,1	
Ladrillo de magnesita (50% MgO)	20	2000		2,680	
	200		1130	3,81	
	650			2,77	
	1200			1,9	
Ladrillo de mampostería	20	1700	837	0,658	0,046
Ladrillo de sílice (95% SiO2)	20	1900		1,070	
Ladrillo de circonio (62% ZrO2)	20	3600		2,440	
Ladrillo al cromo	200	3000	840	2,32	0,092
	550			2,47	0,098
	900			1,99	0,079
Arcilla refractaria, cocida a 1330°C	500	2000	960	1,04	0,054
	800			1,07	
	1100			1,09	
Arcilla refractaria, cocida a 1450°C	500	2300	960	1,28	0,04
	800			1,37	
	1100			1,4	
Cartón	20			0,14-0,35	
Cemento (duro)	20			1,047	
Arcilla (48,7% humedad)	20	1545	880	1,260	0,101
Carbón, (antracita)	20	1370	1260	0,238	0,013-0,015
Hormigón (seco)	20	500	837	0,128	0,049
Corcho (tableros)	20	120	1880	0,042	0,015-0,044
Corcho (expandido)	20	120		0,036	
Tierra de diatomeas	20	466	879	0,126	0,031
Tierra arcillosa (28% humedad)	20	1500		1,510	
Tierra arenosa (8% humedad)	20	1500		1,050	
Fibra de vidrio	20	220		0,035	
Vidrio, (ventanas)	20	2800	800	0,810	0,034
Vidrio, (lana de)	20	100		0,036	
	20	200	670	0,040	0,028
Granito	20	2750		3,000	
Hielo (0°C)	20	913	1830	2,220	0,124
Linóleo	20	535		0,081	
Mica	20	2900		0,523	
Corteza de pino	20	342		0,080	
Yeso	20	1800		0,814	
Plexiglás	20	1180		0,195	
Madera (chapa)	20	590		0,109	
Poliestireno	20	1050		0,157	
Goma dura (ebonita)	20	1150	2009	0,163	0,006
Goma esponjosa	20	224		0,055	
Arena seca	20			0,582	
Arena húmeda	20	1640		1,130	
Serrín	20	215		0,071	
Madera de roble	20	609-801	2390	0,17-0,21	0,011-0,012
Madera (Pino, abeto, abeto rojo)	20	416-421	2720	0,150	0,012
Láminas de fibra de madera	20	200		0,047	
Lana	20	200		0,038	

AMONIACO

Temperatura ºK	Densidad ρ (Kg/m³)	Calor específico c_p kJ/KgºC	Visc. dinám. $\eta.10^6$ (Kg/m.seg)	Visc. cinem. $\nu.10^6$ (m²/seg)	Conductiv. térmica "k" W/mºC	Dif. térmica $\alpha.10^4$ (m²/seg)	Nº de Prandtl Pr
220	0,9304	2,1980	7,25	7,60	0,01710	0,2054	0,930
273	0,7929	2,1770	9,35	11,80	0,02200	0,1308	0,900
323	0,6487	2,1770	11,04	17,00	0,02700	0,1920	0,880
373	0,5590	2,2360	12,89	23,00	0,03270	0,2619	0,870
423	0,4934	2,3150	14,67	29,70	0,03910	0,3432	0,870
473	0,4405	2,3950	16,49	37,40	0,04670	0,4421	0,840

AIRE

Temperatura ºK	Densidad ρ (Kg/m³)	Calor específico c_p kJ/KgºC.	Visc. dinám. $\eta.10^5$ (Kg/m.seg)	Visc. cinem. $\nu.10^6$ (m²/seg)	Conductiv. térmica "k" W/mºC	Dif. térmica $\alpha.10^4$ (m²/seg)	Nº de Prandtl Pr
100	3,6010	1,027	0,692	1,92	0,0092	0,0250	0,770
150	2,3675	1,010	1,028	4,34	0,0137	0,0575	0,753
200	1,7684	1,006	1,329	7,49	0,0181	0,1017	0,739
250	1,4128	1,005	1,488	10,53	0,0223	0,1316	0,722
300	1,1774	1,006	1,983	16,84	0,0262	0,2216	0,708
350	0,9980	1,009	2,075	20,76	0,0300	0,2983	0,697
400	0,8826	1,014	2,286	25,90	0,0336	0,3760	0,689
450	0,7833	1,021	2,484	31,71	0,0371	0,4222	0,683
500	0,7048	1,030	2,671	37,90	0,0404	0,5564	0,680
550	0,6423	1,039	2,848	44,34	0,0436	0,6532	0,680
600	0,5879	1,055	3,018	51,34	0,0466	0,7512	0,680
650	0,5430	1,063	3,177	58,51	0,0495	0,8578	0,682
700	0,5030	1,075	3,332	66,25	0,0523	0,9672	0,684
750	0,4709	1,086	3,481	73,91	0,0551	1,0774	0,686
800	0,4405	1,098	3,625	82,29	0,0578	1,1981	0,689
850	0,4149	1,109	3,765	90,75	0,0603	1,3097	0,692
900	0,3925	1,121	3,899	99,30	0,0628	1,4271	0,696
950	0,3716	1,132	4,023	108,20	0,0653	1,5510	0,699
1000	0,3524	1,142	4,152	117,80	0,0675	1,6779	0,702
1100	0,3204	1,160	4,440	138,60	0,0732	1,9690	0,704
1200	0,2947	1,179	4,690	159,10	0,0782	2,2510	0,707
1300	0,2707	1,197	4,930	182,10	0,0837	2,5830	0,705
1400	0,2515	1,214	5,170	205,50	0,0891	2,9200	0,705
1500	0,2355	1,230	5,400	229,10	0,0946	3,2620	0,705
1600	0,2211	1,248	5,630	254,50	0,1000	3,6090	0,705
1700	0,2082	1,267	5,850	280,50	0,1050	3,9770	0,705
1800	0,1970	1,287	6,070	308,10	0,1110	4,3790	0,704
1900	0,1858	1,309	6,290	338,50	0,1170	4,8110	0,704
2000	0,1762	1,338	6,500	369,00	0,1240	5,2600	0,702
2100	0,1682	1,372	6,720	399,60	0,1310	5,7150	0,700
2200	0,1602	1,419	6,930	432,60	0,1390	6,1200	0,707
2300	0,1538	1,482	7,140	464,00	0,1490	6,5400	0,710
2400	0,1458	1,574	7,350	504,00	0,1610	7,0200	0,718
2500	0,1394	1,688	7,570	543,50	0,1750	7,4410	0,730

INSTALACIÓN, OPERACIÓN Y MANTENIMIENTO DE LOS MOTORES DUTY MASTER RELIANCE

RELIANCE ELECTRIC

Instalación, Operación y Mantenimiento de los

Motores de Inducción Industriales Estándar de CA Reliance®

- Bastidores 180 – 449 (NEMA)
- Bastidores 112 – 280 (IEC)

MOTORES de CA

¡Soluciones en las que sí puede confiar!

Manual de Instrucciones B-3620-25S

Diciembre de 1998

Rockwell Automation

TABLA DE CONTENIDO

⚠ PELIGRO

SÓLO EL PERSONAL ELECTRICISTA CALIFICADO Y FAMILIARIZADO CON LA CONSTRUCCIÓN, LA OPERACIÓN DE ESTE EQUIPO Y CON LOS PELIGROS INVOLUCRADOS DEBERÁ INSTALAR, AJUSTAR, OPERAR O BRINDAR SERVICIO A ESTE EQUIPO. LEA Y ENTIENDA TODO EL MANUAL ANTES DE PROCEDER AL USO. EL NO SEGUIR ESTA PRECAUCIÓN PUEDE RESULTAR EN LESIONES CORPORALES GRAVES O LA MUERTE.

Los productos descritos en este manual son fabricados por o para Reliance Electric Industrial Company según sus especificaciones.

RECEPCIÓN Y MANEJO

ACEPTACIÓN

Inspeccione detenidamente el equipo antes de aceptar el envio de la compañía de transportes. Si cualquiera de los articulos indicados en la declaración de embarque o recibo expreso presentan daño o se detecta algún faltante, no los acepte hasta que el agente de la carga o de envío expreso realice la anotación apropiada en su declaración de embarque o recibo expreso. Si posteriormente se descubre alguna pérdida o daño ocultos, notifíquelo inmediatamente a su agente de carga o de servicio expreso y solicítele que realice una inspección. Nos dará mucho gusto el asistirle en la cobranza de sus reclamaciones por pérdidas o daños en el embarque; sin embargo, esta voluntad de nuestra parte no elimina la responsabilidad de la compañía de transporte para reembolsarle los costos de cobranza de reclamaciones o de reemplazo del material. No se debe deducir de la factura de Reliance Electric el costo de las reclamaciones por pérdida o daño en embarques ni deberá retenerse el pago de la factura de Reliance Electric en espera del ajuste y liquidación de dichas reclamaciones, ya que el transportista garantiza la entrega segura.

Si se hubiera incurrido en daño considerable y la situación fuera urgente, comuníquese con la oficina de ventas de Reliance Electric más cercana para obtener ayuda. Conserve un registro escrito de todas las comunicaciones.

ALMACENAMIENTO PROLONGADO – MOTORES DE CA

Si se hubiera incurrido en daño considerable y la situación fuera urgente, comuníquese con la oficina de ventas de Reliance Electric más cercana para obtener ayuda. Conserve un registro escrito de todas las comunicaciones.

CONDICIONES DE ALMACENAMIENTO – CORTO PLAZO

Es necesario seguir los requisitos de almacenamiento siguientes:

1. Los motores deberán mantenerse en sus cajas originales o en cajas con protección equivalente y almacenarse en un lugar donde no reciban exposición a temperatura, humedad, o atmósfera corrosiva extremas.
2. Si el motor estará expuesto a vibraciones inusuales en el lugar de almacenamiento deberá protegerse con material de aislamiento.
3. Todos los respiraderos y drenajes deberán poder funcionar mientras se encuentren almacenados y se deberán retirar los tapones de drenaje. Los motores deberán almacenarse de manera que el drenaje se encuentre en el punto más bajo.

PREPARACIÓN PARA ALMACENAMIENTO

Un almacenamiento inadecuado de máquinas eléctricas resultará en una fiabilidad significativamente reducida del equipo. Por ejemplo, un motor eléctrico que no se usa de manera regular y que está expuesto a condiciones atmosféricas normalmente húmedas probablemente sufrirá corrosión en los rodamientos, o las partículas de corrosión provenientes de superficies circundantes contaminarán los rodamientos. El aislamiento eléctrico puede absorber una cantidad excesiva de humedad, causando una falla de la conexión a tierra del bobinado del motor. Se recomienda seguir las preparaciones que se indican a continuación:

1. Minimice la condensación en el motor y alrededor del mismo usando desecantes u otros métodos de control de humedad.
2. Los calentadores espaciales de motores, cuando se especifica, deberán ser energizados donde exista la posibilidad de que las condiciones ambientales de almacenamiento alcancen el punto de rocío. Los calentadores espaciales son opcionales.
3. Cubra todas las superficies maquinadas externas con un material que evite la corrosión. Un producto aceptable para èste fin es Exxon Rust Ban #392.
4. Mida y anote la resistencia eléctrica del aislamiento de bobinado con un megóhmetro o con un medidor de resistencia de aislamiento. El nivel mínimo de megohmios aceptado es la capacidad nominal de kV del aislamiento +1 megohmio. Si los niveles caen por debajo de lo indicado anteriormente, comuníquese con la oficina de ventas de Reliance más cercana en su localidad. Los datos anotados serán necesarios al momento de retirar el equipo del local de almacenamiento.

5. Algunos motores tienen una abrazadera para transporte acoplada al eje a fin de evitar daños durante el transporte. La abrazadera para transporte, si se suministra, deberá retirarse y guardarse para uso futuro. Será necesario reinstalar esta abrazadera para que sujete firmemente el eje en su lugar contra el rodamiento antes de mover el motor.

6. Cuando el motor se almacena durante periodos prolongados (más de 3 meses), deberá aplicarse grasa a los motores con rodamientos que requieren grasa, según la Tabla 1, y el eje del motor deberá rotarse 15 veces como mínimo después de la aplicación de grasa. Los motores que no requieren grasa, mismos que incluyen la advertencia "Do Not Lubricate" (No aplicar grasa) en la placa del fabricante, también deberán girarse 15 veces para redistribuir la grasa en el rodamiento.

7. Retire el tapón de drenaje de grasa (en el lado opuesto a la grasera) ubicado en la parte inferior de cada soporte extremo antes de lubricar el motor. Vuelva a colocar el tapón de drenaje después de aplicar la grasa.

Tabla 1. Volumen de lubricación (Almacenamiento)

Tamaño de bastidor NEMA (IEC)	Vol. en pulgadas cúbicas (cm^3)
182 hasta 215 (112 – 132)	0,5 (8)
254 hasta 266 (160 – 180)	1,0 (16)
324 hasta 365 (200 – 225)	1,5 (25)
404 hasta 449 (250 – 280)	2,5 (41)

8. Al momento de colocar el equipo en almacenamiento por un período prolongado, deberá aplicarse grasa a los rodamientos que requieren grasa según lo indicado en la Tabla 1. Los ejes de los motores deberán rotarse por lo menos 15 revoluciones manualmente cada 3 meses, y deberá aplicarse grasa a los rodamientos cada nueve meses, según la Tabla 1. Deberá aplicarse grasa a los rodamientos al momento de retirar el equipo del lugar de almacenamiento.

   El eje de los motores que no requieren aplicación de grasa deberá rotarse 15 revoluciones cada 3 meses.

9. Todos los respiraderos deberán estar en buen estado de operación durante el almacenamiento. Los motores deberán almacenarse de manera que el drenaje se encuentre en el punto más bajo. Todos los respiraderos y drenajes en "T" automáticos deberán poder funcionar para permitir la respiración en puntos diferentes a los de los rodamientos.

10. Las unidades de calefacción, cuando se especifican, deberán estar conectadas y poder funcionar durante el almacenamiento.

11. Deberá medirse el aislamiento eléctrico de los bobinados cuando el equipo se ponga en almacenamiento. Consulte el párrafo 4 en la página 1. Al momento de retirar el equipo del almacenamiento, la lectura de resistencia de aislamiento no deberá haber caído por debajo del 50% de la lectura inicial. Cualquier caída por debajo de este punto necesitará secado eléctrico o mecánico. Consulte el "Procedimiento de Secado del Motor".

12. Cuando los motores no se guardan en sus cajas originales, sino que se retiran y se montan en otras piezas de maquinaria, el montaje deberá realizarse de manera que los drenajes, los respiraderos y las unidades de calefacción estén en buen estado de operación. Con respecto a esto, los drenajes deberán mantenerse en el punto más bajo del motor a fin de que drene automáticamente toda la condensación.

PARA ALMACENAMIENTO DURANTE PERÍODOS PROLONGADOS (MÁS DE 18 MESES)

Se aplican todos los requisitos de preparación general y de almacenamiento de corto plazo con los siguientes requisitos adicionales.

1. Se debe embalar el motor en una caja similar a las CAJAS DE EXPORTACIÓN pero el "recubrimiento" (laterales y parte superior de la caja) se ha de EMPERNAR CON PERNOS CON ROSCA PARA MADERA a la base de madera (no clavado como se hace en las cajas de exportación). Este diseño permitirá abrir y volver a cerrar la caja varias veces sin destruir el "recubrimiento".
2. El motor se sellará con una bolsa hermética de barrera de vapor con un desecante en el interior. Esta bolsa hermética brindará protección adicional durante el envío del motor al área de almacenamiento permanente.
3. Después de la primera "Inspección" para la lectura del megóhmetro, giro del eje, etc., será necesario volver a sellar la bolsa contra el vapor con cinta adhesiva para enmascarar o equivalente. Además, introduzca desecante fresco en la bolsa antes de cerrarla. Después, coloque el recubrimiento sobre el motor y vuelva a colocar los pernos para madera.
4. Si se usa una bolsa con "cierre de cremallera" en vez de una bolsa con "sello térmico", entonces cierre la cremallera en vez de usar cinta adhesiva.
5. Asegúrese de añadir desecante fresco en la bolsa después de cada inspección periódica.
6. Minimice la acumulación de agua condensada en el interior y alrededor de la máquina.

DESEMBALAJE

Después del desembalaje y la inspección para comprobar que todas las partes estén en buenas condiciones, gire el eje a mano para asegurarse que gire libremente. Se recomienda probar y volver a lubricar los equipos (aquellos que requieran grasa) que hayan estado almacenados durante algún tiempo antes de ponerlos en servicio. Consulte las secciones "Pruebas para la Condición General" y "Lubricación" para determinar el procedimiento a realizar después del almacenamiento prolongado.

El equipo con rodamientos de rodillo se envia con un bloque en el eje. Después de retirar el bloque del eje, asegúrese de reemplazar los pernos utilizados para retener el bloque del eje en posición durante el envío que se requieran en servicio.

⚠ PELIGRO

SÓLO EL PERSONAL ELECTRICISTA CALIFICADO Y FAMILIARIZADO CON LA CONSTRUCCIÓN, LA OPERACIÓN DE ESTE EQUIPO Y CON LOS PELIGROS INVOLUCRADOS DEBERÁ INSTALAR, AJUSTAR, OPERAR O BRINDAR SERVICIO A ESTE EQUIPO. LEA Y ENTIENDA TODO EL MANUAL ANTES DE PROCEDER AL USO. EL NO SEGUIR ESTA PRECAUCIÓN PUEDE RESULTAR EN LESIONES CORPORALES GRAVES O LA MUERTE.

INSTALACIÓN

INSPECCIÓN

Después de desembalar el motor, examine los datos en la placa del motor para verificar que sí coincide con el circuito de alimentación eléctrica al cual se conectará. El motor funcionará a una frecuencia no mayor del 5%, y a una tensión no mayor del 10%, por encima o por debajo de las capacidades nominales indicadas en la placa de datos, o una variación combinada de tensión y frecuencia máxima del 10% por encima o por debajo de las capacidades nominales indicadas en la placa de datos. La eficiencia, el factor de potencia y la corriente pueden variar respecto a la información indicada en la placa de datos. El desempeño dentro de estas variaciones de tensión y frecuencia no necesariamente corresponderán con los estándares establecidos para el funcionamiento a la tensión y frecuencia nominales.

Efecto Típico de la Variación de Tensión y Frecuencia en las Características de los Motores de Inducción

Variación	Par torsor de marcha durante el arranque y máximo	Velocidad sincrónica	Deslizamiento %	Velocidad a carga plena	Eficiencia			Factor de potencia/COS ⊖			Corriente a carga plena	Corriente de arranque	Aumento de temperatura, carga plena	Capacidad de sobrecarga máxima	Ruido magnético – sin carga en particular
					Carga plena	3/4 de carga	1/2 carga	Carga plena	3/4 de carga	1/2 de carga					
Variación de tensión:															
120% de la tensión	Aumento del 44%	Sin cambio	Disminución del 30%	Aumento del 1,5%	Disminución de 6-0% (1-75 HP) aumento del 0-0,3% (100-300 HP)	Disminución de 1/2- 2 puntos	Disminución de 7-20 puntos	Disminución de 5-15 puntos	Disminución de 10-30 puntos	Disminución de 15-40 puntos	Aumento del 12%	Aumento del 20%	Aumento del 5-6°C (1-75 HP) Disminución del 3-4°C (100-300 HP)	Aumento del 44%	Aumento notorio
110% de la tensión	Aumento del 21%	Sin cambio	Disminución del 17%	Aumento del 1%	Disminución leve	Prácticamente sin cambio	Disminución de 1-2 puntos	Disminución de 5-10 puntos	Disminución de 5 puntos	Disminución de 5-6 puntos	Aumento del 2-4%	Aumento del 10-12%	Aumento del 3-4°C	Aumento del 21%	Aumento leve
Función de la tensión	$(tensión)^2$	Constante	$\frac{1}{(tensión)^2}$	(Deslizamiento de velocidad sincrónica)								Tensión		$(tensión)^2$	
90% de la tensión	Disminución del 19%	Sin cambio	Aumento del 23%	Disminución del 1-1/2%	Disminución de 2 puntos	Prácticamente sin cambio	Aumento de 1-2 puntos	Aumento de 5 puntos	Aumento de 2-3 puntos	Aumento de 4-5 puntos	Aumento del 10-11%	Disminución dle 10-12%	Aumento del 6-7°C	Disminución del 19%	Disminución leve
Variación de frecuencia:															
105% de la frecuencia	Disminución del 10%	Aumento del 5%	Prácticamente sin cambio	Aumento del 5%	Aumento leve	Aumento leve	Aumento leve	Aumento leve	Aumento leve	Aumento leve	Disminución leve	Disminución del 5-6%	Disminución leve	Disminución leve	Disminución leve
Función de frecuencia	$\frac{1}{(frecuencia)^2}$	Frecuencia		(Deslizamiento de velocidad sincrónica)								$\frac{1}{Frecuencia}$			
95% de la frecuencia	Aumento del 11%	Disminución del 5%	Prácticamente sin cambio	Disminución del 5%	Disminución leve	Disminución leve	Disminución leve	Disminución leve	Disminución leve	Disminución leve	Aumento leve	Aumento del 5-6%	Aumento leve	Aumento leve	Aumento leve
1% de desequilibrio de fase	Disminución leve	Disminución leve		Disminución leve	Disminución del 2%			Disminución de 5-6%			Aumento del 1-1/2%	Disminución leve	Aumento del 2%		
2% de desequilibrio de fase	Disminución leve	Disminución leve		Disminución leve	Disminución del 8%			Disminución de 7%			Aumento del 3%	Disminución leve	Aumento del 8%		

NOTA: En esta tabla se muestran los efectos generales, los cuales pueden variar en alguna medida para capacidades nominales específicas.

UBICACIÓN

Se recomienda instalar el motor en una ubicación compatible con el envolvente y el entorno específico del motor.

Para permitir el flujo de aire adecuado, es necesario mantener las holguras indicadas a continuación entre el motor y cualquier obstrucción:

Envolventes TEFC (IC0141)	–		
Entrada de aire de cubierta del ventilador	–	Bastidor 180 – 210T	1"
		Bastidor 250 – 449T	4"
		IEC 112 – 132	2,5 cm
		IEC 160 – 280	10 cm
Ventilación	–	Envolvente equivalente a la dimensión "P" en la hoja de dimensiones del motor	
Envolventes protegidos	–		
Entrada de freno	–	Igual que TEFC	
Ventilación del bastidor	–	Ventilación lateral- envolvente un mínimo de la dimensión "P" más 5 cm (2 pulg.). Ventilación por el extremo lo mismo que la admisión.	

MEDIOS DE IZADO

⚠ ADVERTENCIA

CUANDO SE SUMINISTREN MEDIOS DE IZADO EN EL MOTOR PARA MANIPULAR EL MOTOR, NO DEBERÁN USARSE PARA IZAR EL MOTOR CON EQUIPO ADICIONAL INSTALADO, COMO ENGRANAJES, BOMBAS, COMPRESORES U OTRO EQUIPO IMPULSADO POR MOTOR. EL NO SEGUIR ESTAS PRECAUCIONES PUEDE DAR COMO RESULTADO LESIONES CORPORALES.

En el caso de conjuntos colocados en una base común, no se debe usar medio alguno de izado provisto en el motor o en el generador para izar el conjunto y la base, por el contrario, se debe izar el conjunto por medio de un estrobo alrededor la base o mediante otros medios de izado provistos en la base. En todos los casos, debe tenerse cuidado de izar el motor en la dirección considerada en el diseño de los medios de izado. De la misma manera, es necesario tomar precauciones a fin de prevenir sobrecargas peligrosas resultantes de la aceleración, de la desaceleración o de las fuerzas de impacto.

MONTAJE

Instale el motor sobre cimientos suficientemente rígidos para prevenir la vibración excesiva. Se puede instalar motores con rodamientos de rodillo y esféricos con el eje en cualquier ángulo. Los motores de rodamientos de rodillo no son apropiados para aplicaciones de servicio acoplado. Después de alinear cuidadosamente el motor con la unidad impulsada, emperne fijamente en posición.

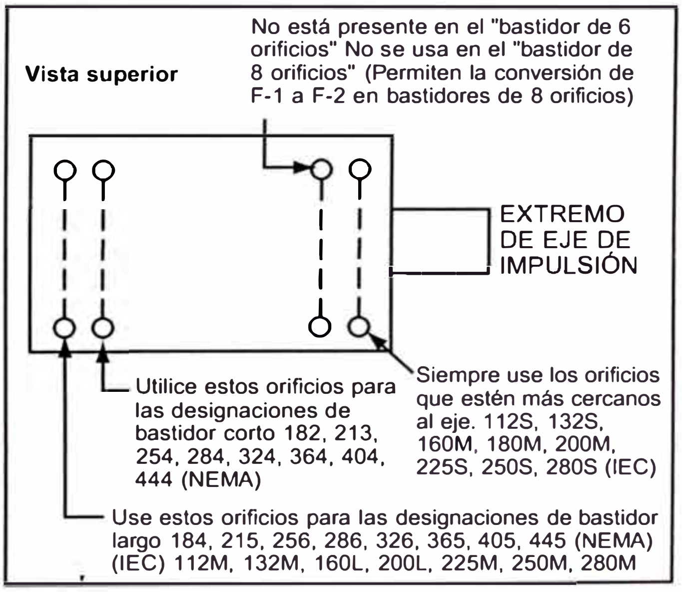
Cuando los motores, que normalmente se instalan con el eje en posición horizontal, se instalan verticalmente, quizá sea necesario proporcionar guardas adicionales para prevenir que objetos extraños penetren en las aberturas del motor y hagan contacto con las partes giratorias. Dichas guardas pueden obtenerse al momento de la compra o en un centro de servicios de reparaciones en su localidad.

Los motores a prueba de explosión se envian desde la fábrica con la caja de conductos instalada. Si se retira o se gira la caja de conductos, es necesario mantener enroscadas un mínimo de cinco (5) roscas completas en el manguito roscado para conservar la integridad contra explosiones de la caja de conductos.

Algunos motores tienen bastidores estandarizados que contienen de 6 a 8 orificios de montaje. Los bastidores de 6 orificios no son apropiados para la inversión del campo de montaje de F-1 a F-2, etc. El diagrama siguiente indica los orificios de montaje apropiados.

MONTAJE DE BASTIDORES DE MOTOR DE 6 Y 8 ORIFICIOS

IMPULSOR



La polea, rueda o engranaje utilizados en el impulsor deben localizarse en el eje, lo más cerca posible del reborde del eje. Caliente para instalar. No golpee la unidad para instalarla en el eje ya que esto dañará los rodamientos.

Impulsión por correa: Alinee las poleas de manera que la correa gire sin desviaciones; apriete la correa justo lo suficiente para evitar el deslizamiento, si la aprieta demasiado se producirá el fallo prematuro del rodamiento. Si fuera posible, el lado inferior de la correa deberá ser el lado de impulsión.

Impulsión por cadena: Instale la rueda dentada en el eje lo más cercanamente posible a la escuadra de soporte. Alinee las ruedas dentadas de manera que la cadena gire sin desviaciones. Evite la tensión excesiva de la cadena.

Conexión directa y a la impulsión por engranajes: Es esencial la alineación exacta. Fije el motor y la unidad impulsada rigidamente a la base.

PARTES GIRATORIAS

⚠ ADVERTENCIA

ES NECESARIO COLOCAR PROTECCIONES PERMANENTES CONTRA CONTACTO ACCIDENTAL CON EL PERSONAL Y SU ROPA EN LAS PARTES GIRATORIAS TALES COMO ACOPLAMIENTOS, POLEAS, VENTILADORES EXTERNOS Y EXTENSIONES DE EJES USADAS. ESTO ES PARTICULARMENTE IMPORTANTE EN LOS PUNTOS DONDE LAS PARTES TIENEN IRREGULARIDADES SUPERFICIALES COMO CHAVETAS, CHAVETEROS O TORNILLOS PRISIONEROS. EL NO SEGUIR ESTA PRECAUCIÓN PUEDE RESULTAR EN LESIONES CORPORALES.

ALGUNOS MÉTODOS SATISFACTORIOS DE PROTECCIÓN SON:

1. Cubrir la máquina y las partes giratorias asociadas con partes estructurales o decorativas del equipo impulsado.
2. Instalar cubiertas para las partes giratorias. Las cubiertas deben ser suficientemente rigidas para ofrecer una protección adecuada durante el servicio normal.

⚠ PELIGRO

EL USUARIO ES RESPONSABLE DE VELAR POR EL CUMPLIMIENTO CON LAS NORMATIVAS DEL CÓDIGO NACIONAL ELÉCTRICO Y DE CUALQUIER OTRO CÓDIGO LOCAL APLICABLE. LAS PRÁCTICAS DE CABLEADO, LOS INTERRUPTORES CON CONEXIÓN A TIERRA Y LA PROTECCIÓN CONTRA LA CORRIENTE EXCESIVA TIENEN PARTICULAR IMPORTANCIA. EL INCUMPLIMIENTO DE ESTAS PRECAUCIONES PUEDE RESULTAR EN LESIONES GRAVES O EN LA MUERTE.

⚠ PELIGRO

LOS PASOS SUBSIGUIENTES REQUIEREN LA EXPOSICIÓN DE PARTES GIRATORIAS Y DE CIRCUITOS ELÉCTRICOS. EVITE EL CONTACTO CON LA UNIDAD SI ÉSTA DEBE ESTAR FUNCIONANDO O DESCONECTE Y BLOQUEE CON LLAVE O ETIQUETE LA FUENTE DE ALIMENTACIÓN ELÉCTRICA SI FUERA NECESARIO HACER CONTACTO.

Conecte el motor a la fuente de alimentación eléctrica de acuerdo con el diagrama en la placa de datos del motor. Para la mayoría de los motores de 230/460 voltios, se llevan nueve conductores desde los bobinados del estator a fin de poder conectar el motor a 230 o a 460 voltios.

CONEXIÓN A TIERRA

En los EE.UU. consulte el *Código Nacional Eléctrico*, Artículo 430 para obtener información sobre las conexiones a tierra de los motores, el Artículo 445 para la conexión a tierra de los generadores y el Artículo 250 para obtener información sobre conexión a tierra. Al efectuar la conexión a tierra, el instalador debe asegurarse que exista una firme conexión metálica y permanente entre el punto de conexión a tierra, el motor o la caja de terminales del generador, y el motor o bastidor del generador. En instalaciones fuera de los EE.UU. consulte el código eléctrico nacional o local según sea apropiado.

Los motores con anillos elásticos de amortiguación usualmente deben equiparse con un conductor de conexión a tierra a través del miembro elástico. Algunos motores se suministran con el conductor de conexión a tierra en el lado oculto del anillo de amortiguación a fin de proteger la conexión a tierra contra daño. Se recomienda que los motores con anillos de amortiguación conectados a tierra usualmente se conecten a tierra al momento de la instalación de conformidad con las recomendaciones anteriores para efectuar las conexiones a tierra. Cuando se usen motores con anillos de amortiguación conectados a tierra en instalaciones multimotores que utilicen fusibles en grupo o protección de grupo, es necesario verificar la conexión a tierra del anillo de amortiguación a fin de determinar que sea apropiada para la capacidad nominal del dispositivo protector contra sobrecorriente del circuito de derivación que se esté utilizando.

Existen aplicaciones donde la conexión a tierra de las partes externas de un motor o generador puede resultar en mayor riesgo al aumentar la probabilidad de que una persona en el área pueda hacer contacto simultáneo con la conexión a tierra y con alguna otra parte eléctrica energizada de otro equipo eléctrico sin conexión a tierra. En equipos portátiles es difícil asegurar que se mantiene la conexión positiva a tierra al trasladar el equipo, y la instalación de un conductor a tierra puede llevar a un falso sentido de seguridad.

El usuario debe seleccionar un arrancador de motor y protección contra sobrecorriente adecuados para este motor y su aplicación. Consulte los datos de aplicación del arrancador del motor y también el Código Nacional Eléctrico o los códigos locales aplicables.

PELIGRO

CUANDO UNA CUIDADOSA CONSIDERACIÓN DE LOS RIESGOS INVOLUCRADOS EN UNA APLICACIÓN PARTICULAR INDIQUE QUE LOS BASTIDORES DE LA MÁQUINA NO DEBEN CONECTARSE A TIERRA O CUANDO LAS CONDICIONES INUSUALES DE FUNCIONAMIENTO DICTEN QUE NO SE PUEDE USAR UN BASTIDOR CONECTADO A TIERRA, EL INSTALADOR DEBE ASEGURARSE QUE LA MÁQUINA ESTÉ PERMANENTE Y EFICAZMENTE AISLADA DE LA CONEXIÓN A TIERRA. EN AQUELLAS INSTALACIONES DONDE EL BASTIDOR DE LA MÁQUINA ESTÉ AISLADO DE LA CONEXIÓN A TIERRA, SE RECOMIENDA QUE EL INSTALADOR COLOQUE LAS ETIQUETAS O LETREROS DE ADVERTENCIA APROPIADOS EN EL ÁREA O ALREDEDOR DE LA MISMA. EL INCUMPLIMIENTO DE ESTAS PRECAUCIONES PUEDE RESULTAR EN LESIONES GRAVES O EN LA MUERTE.

ARRANQUE

ADVERTENCIA

ANTES DE ARRANCAR EL MOTOR, RETIRE TODAS LAS CHAVETAS DEL EJE NO USADAS Y LAS PARTES GIRATORIAS SUELTAS PARA EVITAR QUE SALGAN IMPULSADAS POR EL MOVIMIENTO. EL NO SEGUIR ESTA PRECAUCIÓN PUEDE RESULTAR EN LESIONES CORPORALES.

PRECAUCIÓN

VERIFIQUE LA DIRECCIÓN DE GIRO DEL MOTOR ANTES DE ACOPLAR EL MOTOR A LA CARGA. EL NO SEGUIR ESTA PRECAUCIÓN PUEDE DAR COMO RESULTADO DAÑO O LA DESTRUCCIÓN DEL EQUIPO.

Antes de poner en marcha el motor, verifique los siguientes componentes:

1. El rotor debe poder girar libremente al desconectarse de la carga.
2. Se recomienda eliminar la carga de la máquina impulsada antes de arrancar inicialmente el motor.

El motor debe funcionar uniformemente sin mucho ruido. Si el motor no arranca y produce un zumbido muy marcado, quizá la carga sea demasiado grande para el motor o quizá se haya conectado erróneamente. Apague inmediatamente el motor e investigue el problema.

TAPONES DE DRENAJE

Si el motor es de tipo totalmente cerrado y enfriado por ventilador o no ventilado se recomienda retirar los tapones de drenaje de condensación si estuvieran presentes. Estos tapones están ubicados en la parte inferior de las pantallas extremas. Los motores "XT" totalmente cerrados y enfriados por ventilador están normalmente equipados con drenajes automáticos que se pueden dejar en posición tal como se recibieron.

DIRECCIÓN DE GIRO

Para invertir la dirección de giro en los motores trifásicos, desconecte la fuente de alimentación eléctrica e intercambie dos de los tres conductores eléctricos.

PRUEBAS PARA LA CONDICIÓN GENERAL

Si el motor ha estado en almacenamiento durante un período prolongado o si ha estado sujeto a condiciones adversas de humedad, verifique la resistencia del aislamiento del bobinado del estator con un megóhmetro.

Si la resistencia es menor de un megohmio, se recomienda secar los bobinados en una de las dos maneras indicadas a continuación:

1. Secar en horno a temperaturas que no excedan 90°C hasta que la resistencia del aislamiento se vuelva constante.
2. Con el rotor bloqueado, aplique una tensión baja y aumente gradualmente la corriente a través de los bobinados hasta que la temperatura en el termómetro alcance 90°C (194°F). No exceda esta temperatura.

LUBRICACIÓN INICIAL

Los motores Reliance se envían desde la fábrica con los rodamientos debidamente empaquetados con grasa y listos para funcionar. En casos donde la unidad ha estado sujeta a almacenamiento prolongado (6 meses o más) se recomienda volver a lubricarla (si requiere lubricación) antes del arranque. Si los motores están equipados con lubricación por nebulización de aceite, consulte el Manual de Instrucciones B-3654.

OPERACIÓN

⚠ ADVERTENCIA

LAS TEMPERATURAS SUPERFICIALES DEL ENVOLVENTE DEL MOTOR PUEDEN ALCANZAR TEMPERATURAS QUE PUEDEN OCASIONAR INCOMODIDAD O LESIONES AL PERSONAL QUE ACCIDENTALMENTE ENTRE EN CONTACTO CON LAS SUPERFICIES CALIENTES. DURANTE LA INSTALACIÓN, SE DEBE BRINDAR PROTECCIÓN AL USUARIO CONTRA EL CONTACTO ACCIDENTAL CON SUPERFICIES CALIENTES. EL NO SEGUIR ESTA PRECAUCIÓN PUEDE RESULTAR EN LESIONES CORPORALES.

⚠ ADVERTENCIA

ES NECESARIO COLOCAR PROTECCIONES PERMANENTES CONTRA CONTACTO ACCIDENTAL CON EL PERSONAL Y SU ROPA EN LAS PARTES GIRATORIAS TALES COMO ACOPLAMIENTOS, POLEAS, VENTILADORES INTERNOS-EXTERNOS Y EXTENSIONES DE EJES NO USADAS. EL NO SEGUIR ESTA PRECAUCIÓN PUEDE RESULTAR EN LESIONES CORPORALES.

Debido a las características inherentes de los materiales de aislamiento, las temperaturas anormalmente altas acortarán la vida útil de funcionamiento de los aparatos eléctricos. Se recomienda que sea la temperatura total, no el aumento de la temperatura, lo que se considere como la medida de la operación segura. La clase de aislamiento determina la temperatura máxima de funcionamiento seguro. La temperaturas anormalmente elevadas causan el deterioro acelerado del aislamiento. Una regla general para medir el efecto del calor excesivo consiste en que por cada 10°C de aumento en temperatura en exceso del límite máximo para el aislamiento, la vida útil del aislamiento se reducirá en un 50%.

La tensión desequilibrada o el funcionamiento de una sola fase en máquinas polifásicas puede causar calentamiento excesivo y fallo. Se requiere tan sólo un leve desequilibrio de la tensión aplicada al motor polifásico para causar grandes corrientes de desequilibrio y sobrecalentamiento consiguiente.

Se recomienda realizar verificaciones periódicas de las tensiones de fase, la frecuencia y el consumo eléctrico de un motor en funcionamiento; dichas verificaciones aseguran la exactitud de la frecuencia y la tensión aplicada al motor y proporcionan una indicación de la carga ofrecida por el aparato que acciona el motor.

Las comparaciones de estos datos con las demandas de alimentación eléctrica sin carga y con carga plena brindarán una indicación del rendimiento de la máquina completa. Se recomienda investigar y corregir cualquier desviación grave.

Los problemas del estator usualmente pueden deberse a una de las causas siguientes:

Rodamientos gastados	Funcionamiento con una sola fase
Humedad	Aislamiento deficiente
Sobrecarga	Aceite y suciedad

El polvo y la suciedad son, a menudo, factores contribuyentes. Algunas formas de polvo son altamente conductivas y contribuyen materialmente al deterioro del aislamiento. El efecto del polvo en la temperatura del motor a través de la restricción de la ventilación es la principal razón para mantener limpios los bobinados.

Usualmente, los rotores en jaula de ardilla son robustos, y ocasionan muy pocos problemas. El primer síntoma de un rotor defectuoso es la falta de par torsor. Esto puede ocasionar una disminución de velocidad acompañada de un ruido sordo o quizá no pueda poner en marcha la carga.

Esto puede deberse a una junta abierta o de alta resistencia en el circuito de barra del rotor. Dicha condición usualmente puede detectarse al ver la evidencia del calor localizado.

Motores con máximas temperaturas superficiales listadas en las placas de datos.

⚠ ATENCIÓN

EL MOTOR ESTÁ DISEÑADO PARA FUNCIONAR A LA TEMPERATURA SUPERFICIAL MÁXIMA O POR DEBAJO DE LA MISMA INDICADA EN LA PLACA DE DATOS. EL NO OPERAR CORRECTAMENTE EL MOTOR PUEDE CAUSAR QUE SE EXCEDA LA TEMPERATURA SUPERFICIAL. SI SE APLICA EN UN ENTORNO DE DIVISIÓN 2 O ZONA 2 ESTA TEMPERATURA EXCESIVA PUEDE CAUSAR LA IGNICIÓN DE MATERIALES PELIGROSOS. LA OPERACIÓN DEL MOTOR EN CUALQUIERA DE LAS CONDICIONES INDICADAS A CONTINUACIÓN PUEDE CAUSAR QUE SE EXCEDA LA TEMPERATURA MARCADA.

1. LA CARGA DEL MOTOR EXCEDE EL VALOR DE FACTOR DE SERVICIO
2. LA TEMPERATURA AMBIENTE ES MAYOR QUE EL VALOR DE LA PLACA DE DATOS
3. LAS TENSIONES EXCEDEN LOS VALORES INDICADOS EN LA PLACA DE DATOS
4. TENSIONES DESEQUILIBRADAS
5. PÉRDIDA DE LA VENTILACIÓN APROPIADA
6. OPERACIÓN CON FRECUENCIA VARIABLE
7. ALTITUD MAYOR DE 1000 METROS/3000 PIES
8. CICLOS DE SERVICIO RIGUROSO, CICLOS REPETIDOS
9. PARO DEL MOTOR
10. INVERSIÓN DE GIRO DEL MOTOR
11. OPERACIÓN CON UNA SOLA FASE

Calentadores espaciales de interruptor de motor en División 2 o Zona 2.

⚠ ATENCIÓN

LOS CALENTADORES ESPACIALES ESTÁN DISEÑADOS PARA FUNCIONAR, COMO MÁXIMO, A LA TEMPERATURA SUPERFICIAL MÁXIMA INDICADA EN LA PLACA DE DATOS. SI SE EXCEDE LA TEMPERATURA AMBIENTE O TENSIÓN MARCADAS, POSIBLEMENTE SE EXCEDA ESTA TEMPERATURA SUPERFICIAL MÁXIMA Y SE PRODUZCAN DAÑOS A LOS BOBINADOS DEL MOTOR. SI SE APLICA EN UN ENTORNO DE DIVISIÓN 2 O ZONA 2 ESTA TEMPERATURA EXCESIVA PUEDE CAUSAR LA IGNICIÓN DE MATERIALES PELIGROSOS.

LUBRICACIÓN DE RODAMIENTOS

Los motores cubiertos en este Manual de Instrucciones están equipados con diferentes tipos de rodamientos. Esta descripción cubre solamente los rodamientos antifricción y los que requieren grasa. Los rodamientos esféricos que no requieren grasa no necesitan mantenimiento periódico. Consulte la publicación VM B-3654 para los procedimientos con los rodamientos antifricción lubricados con nebulización de aceite.

RODAMIENTOS LUBRICADOS CON GRASA

Este motor se ha lubricado apropiadamente al momento de fabricación y no es necesario lubricarlo al momento de la instalación a menos que el motor haya estado en almacenamiento durante un período de seis meses o más.

La lubricación de los rodamientos antifricción debe hacerse como parte de un programa planificado de mantenimiento. Se recomienda utilizar como guía el intervalo recomendado para establecer dicho programa.

La limpieza es importante en la lubricación. Cualquier grasa utilizada para lubricar cojinetes antifricción debe ser fresca y sin contaminación. De manera similar, se debe tener cuidado de limpiar el área de entrada de la grasa del motor a fin de evitar la contaminación de la grasa.

LUBRICANTE RECOMENDADO

Para los motores que funcionen en temperaturas ambiente según se indica a continuación, use el lubricante siguiente o su equivalente:

MOTORES CON RODAMIENTOS ESFÉRICOS

TEMPERATURA DE FUNCIONAMIENTO –25°C (–13°F) a 50°C (122°F)

CHEVRON OIL	SRI NO.2
EXXON	UNIREX N2
SHELL OIL CO.	DOLIUM R
TEXACO, INC.	PREMIUM RB

TEMPERATURA MÍNIMA DE ARRANQUE –60°C (–76°F)

SHELL OIL CO.	AEROSHELL 7

MOTORES CON RODAMIENTOS DE RODILLO

TEMPERATURA DE FUNCIONAMIENTO –25°C (–13°F) a 50°C (122°F)

CHEVRON OIL	BLACK PEARL EP NO. 2
TEXACO, INC.	PREMIUM RB

PROCEDIMIENTO DE LUBRICACIÓN

Los rodamientos antifricción Reliance que requieren grasa se pueden lubricar con el motor funcionando o estacionario. Es preferible hacerlo con el motor estacionario y caliente.

1. Localice la grasera, limpie el área y reemplace el tapón de la tubería con una grasera, si el motor no estuviera equipado con graseras.
2. Si el motor estuviera equipado con un tapón de drenaje de grasa, retire el tapón y elimine cualquier grasa que pudiera bloquear el drenaje.
3. Con una grasera de pistola manual, añada el volumen recomendado del lubricante apropiado.
4. Haga funcionar el motor durante dos horas.
5. Reemplace el tapón de tubería en el drenaje de grasa.
6. La grasa quizá no salga por el drenaje. Use sólo los volúmenes indicados en la Tabla 3.

INSTRUCCIONES DE LUBRICACIÓN

1. Seleccione las condiciones de servicio de la Tabla 1.
2. Seleccione la frecuencia de lubricación de la Tabla 2.
3. Seleccione el volumen de lubricación de la Tabla 3.
4. Lubrique el motor a la frecuencia necesaria con el volumen correcto de lubricante de acuerdo con lo indicado en el PROCEDIMIENTO DE LUBRICACIÓN.

NOTA: No se recomienda mezclar lubricantes debido a posibles incompatibilidades. Si se desea cambiar de lubricante, siga las instrucciones de lubricación y repita la lubricación por segunda vez después de 100 horas de servicio. Es necesario tener cuidado para detectar signos de incompatibilidad de lubricantes, como viscosidad excesiva visible en el área de drenaje de alivio de grasa o en la abertura del eje.

CONDICIONES DE SERVICIO

Tabla 1

Condiciones Rigurosas	Ocho horas al día, carga normal o liviana, aire ambiente limpio a 40°C (104°F) como máximo
Condiciones Estándar	Funcionamiento las veinticuatro horas del día o cargas de impacto, vibración, aire ambiente contaminado con suciedad o polvo a 40 – 50°C (104 – 122°F).
Condiciones Extremas	Impactos, vibración fuertes o polvo

FRECUENCIA DE LUBRICACIÓN

Tabla 2

RODAMIENTOS ESFÉRICOS				
Velocidad	**Bastidor NEMA (IEC)**	**Condiciones Estándar**	**Condiciones Rigurosas**	**Condiciones Extremas**
1800 RPM o menos	182 (112) hasta 215 (132)	3 Años	1 Año	6 Meses
	254 (160) hasta 365 (200)	2 Años	6 a 12 Meses	3 Meses
	404 (225) hasta 449 (280)	1 Año	6 Meses	1 a 3 Meses
3600 RPM	Todos	6 Meses	3 Meses	1 Mes
RODAMIENTOS DE RODILLO				
Para los rodamientos de rodillo divida entre 2 los períodos anteriores.				

VOLUMEN DE LUBRICACIÓN

Tabla 3

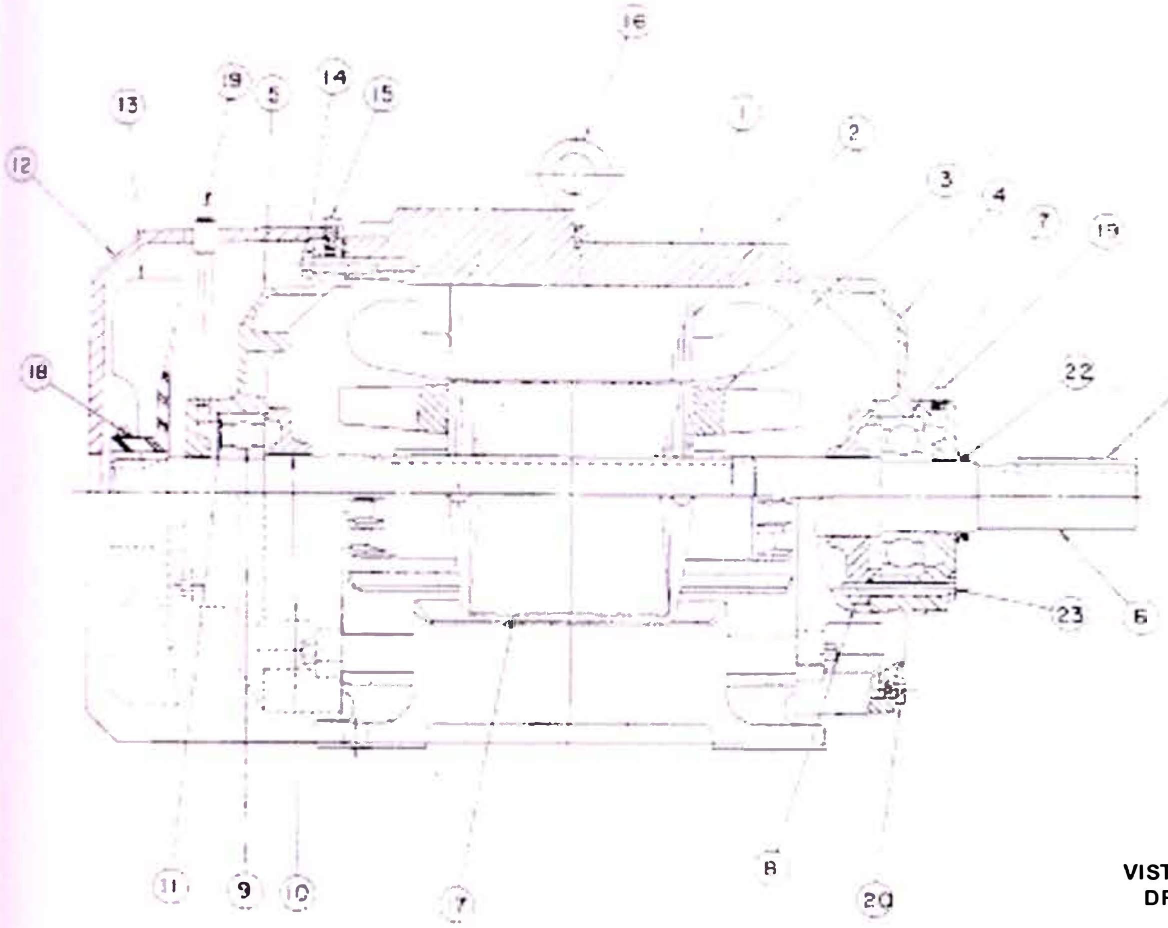
Tamaño del Bastidor NEMA (IEC)	Volumen en Pulgadas Cúbicas (cm³)
182 hasta 215 (112 – 132)	0,5 (8)
254 hasta 286 (160 – 180)	1,0 (16)
324 hasta 365 (200 – 225)	1,5 (25)
404 hasta 449 (250 – 280)	2,5 (41)

RODAMIENTOS DE REEMPLAZO

Su programa de mantenimiento no estará completo si no incluye los rodamientos de repuesto. No debe olvidarse que el rodamiento es un componente sujeto a desgaste y por lo tanto deberá reemplazarse eventualmente. Para asegurarse de poder mantener la condición de funcionamiento inicial, **recomendamos comprar repuestos directamente de Reliance Electric.**

Todos los rodamientos utilizados en los motores Reliance están sujetos a las especificaciones exactas y pruebas necesarias para satisfacer los requisitos de rendimiento. De esta manera, es posible reproducir sus rodamientos actuales. Las marcas en el rodamiento no indican la totalidad de las especificaciones.

DIAGRAMA DE SECCIÓN TRANSVERSAL Y DE IDENTIFICACIÓN DE PARTES



VISTA ALTERNATIVA DEL DRENAJE DE GRASA

GUÍA NO.	DESCRIPCIÓN DE PARTES
1	BASTIDOR
2	ESTATOR
3	ROTOR/VENTILADOR INTERNO DE ENFRIAMIENTO
4	ESCUADRA DE SOPORTE DE EXTREMO POSTERIOR
5	ESCUADRA DE SOPORTE DE EXTREMO FRONTAL
6	EJE
7	RODAMIENTO ESFÉRICO DEL EXTREMO POSTERIOR
8	TAPA INTERIOR DEL EXTREMO POSTERIOR
9	RODAMIENTO ESFÉRICO DEL EXTREMO FRONTAL
10	TAPA INTERIOR DEL EXTREMO FRONTAL
11	ARANDELA ONDULADA, EXTREMO FRONTAL
12	CUBIERTA DEL VENTILADOR
13	VENTILADOR DE ENFRIAMIENTO EXTERIOR

GUÍA NO.	DESCRIPCIÓN DE PARTES
14	PERNOS DE LA ESCUADRA DE SOPORTE DEL EXTREMO FRONTAL
15	PERNOS DE LA CUBIERTA DEL VENTILADOR
16	ARGOLLA
17	CAJA DE TERMINALES
18	ABRAZADERA DEL VENTILADOR
19	ENTRADA DE GRASA
20	DRENAJE DE CONDENSACIÓN
21	CHAVETA
22	ANILLO RECOGEDOR DE ACEITE
23	PERNOS DE LA TAPA DEL EXTREMO TRASERO
24	DRENAJE DE GRASA

NOTA: Los rodamientos que se muestran requieren grasa. No todos los componentes que se muestran pueden estar presentes en el motor. No todos los componentes en el motor aparecen en el diagrama. Los diagramas se brindan sólo para fines de referencia.

PROGRAMAS DE SERVICIO TOTAL

Reliance Electric puede proporcionar una amplia gama de programas de mantenimiento para ayudarle a reducir el tiempo de inactividad, aumentar la productividad y aumentar las utilidades. Las capacidades incluyen:

- Servicio de puesta en marcha del motor
- Mantenimiento preventivo eléctrico y mecánico del motor
- Análisis de vibración
- Servicio de reparación en furgoneta móvil
- Servicio de balanceo y alineación
- Escuelas de mantenimiento
- Asesoría técnica las 24 horas
- Servicio de modernización

Para mayor información comuníquese con la oficina de ventas de Reliance Electric en su localidad o escriba a:

Attn: Motor Tech Support
Reliance Electric
Industrial Services
375 Alpha Drive
Highland Hts., Ohio 44143
USA

PARTES DE REPUESTO

Un inventario apropiado de partes de repuesto del fabricante original constituye una parte integral de un programa apropiado de mantenimiento para protección contra el costoso tiempo de inactividad.

Se puede obtener los repuestos a través del distribuidor de repuestos Reliance Electric más cercano, o directamente de la fábrica de Reliance Electric. Al hacer pedido de partes que no tengan disponible un número de parte, brinde una descripción completa de la parte y el número de orden de compra, número de serie, número de modelo, etc. del equipo en el cual se utiliza dicha parte.

Se puede obtener una lista detallada de partes de repuesto que Reliance Electric recomienda mantener en inventario para su equipo a través de:

1. La oficina de ventas de Reliance Electric más cercana
2. El distribuidor de partes principales Reliance Electric más cercano.
3. Partes de Repuesto de Reliance Electric (Reliance Renewal Parts), Cleveland, Ohio.

Asegúrese de incluir los datos completos indicados en la placa de datos, número de orden de compra, número de serie, capacidad nominal, etc., para su equipo al hacer el pedido de la lista de partes de repuesto.

Para el número de teléfono (EE.UU.) del distribuidor de Almacenamiento de Partes Principales (Keyparts Stocking) llame al 1-800-RELIANCE.

LITERATURA ADICIONAL

La literatura adicional que cubre el mantenimiento de motores de CA se puede obtener de la División de Servicios de Reliance Electric. Las solicitudes deben presentarse a través de la oficina de ventas de Reliance Electric más cercana.

REGISTRO DE COMPRA DEL MOTOR

MOTORES DUTY MASTER
DE RELIANCE ELECTRIC

ID.______________ COMPONENTE LOCAL #__________

HP/KW VELOCIDAD TENSIÓN

O. DE C. #: Contacto de compra/Núm. de teléfono

Fecha de compra:

Comentarios sobre mantenimiento/registro de mantenimiento

Fecha	Componente	Comentarios	Iniciales

Para solicitar información adicional
6040 Ponders Court
Greenville, SC 29615 USA
Tel: (864) 297-4800
http://www.reliance.com/rpmac

Comuníquese con nosotros en www.rockwellautomation.com

En cualquier lugar que nos necesite, Rockwell Automation reúne las marcas principales en automatización industrial que incluyen controles Allen-Bradley, productos Reliance Electric de transmisión de potencia, componentes Dodge de transmisión de potencia mecánica y Rockwell Software. El singular y versátil enfoque de Rockwell Automation para ayudar a sus clientes a lograr una ventaja competitiva está respaldado por miles de asociados, distribuidores e integradores de sistemas autorizados en todo el mundo.

Oficinas principales para las Américas, 1201 South Second Street, Milwaukee, WI 53204. USA, Tel:(1) 414 382-2000. Fax: (1)414 382-4444
Oficinas principales para Europa SA/NV, Avenue Herrmann Debroux, 46, 1160 Brussels, Belgium, Tel: (32) 2 663 06 00, Fax: (32) 2 663 06 40
Oficinas principales para el Área del Pacífico Asiático, 27/F Citicorp Centre, 18 Whitfield Road, Causeway Bay, Hong Kong. Tel: (852) 2887 4788, Fax (852) 2508 1848

Rockwell Automation

Publicación B-3620-25S – Diciembre de 1998

TABLAS DE TEMPCO

ing Data

Conversion

Temperature Conversion Table

Locate temperature value for conversion in the light blue area.
Corresponding temperature in degrees Fahrenheit will be found in column to the right.
Corresponding temperature in degrees Celsius will be found in column to the left.
(For temperatures between values in chart use Interpolation Factors below)

°F	°C			°		°F	°C		°F	°C		°F	°C		°F	°C		°F
32.0	8.89	48	118.4	36.1	97	206.6	288	550	1022	560	1040	1904	832	1530	2786	1104	2020	3668
33.8	9.44	49	120.2	36.7	98	208.4	293	560	1040	566	1050	1922	838	1540	2804	1110	2030	3865
35.6	10.0	50	122.0	37.2	99	210.2	299	570	1058	571	1060	1940	843	1550	2822	1116	2040	3704
37.4	10.6	51	123.8	38	100	212	304	580	1076	577	1070	1958	849	1560	2840	1121	2050	3722
39.2	11.1	52	125.6	43	110	230	310	590	1094	582	1080	1976	854	1570	2858	1127	2060	3740
41.0	11.7	53	127.4	49	120	248	316	600	1112	588	1090	1994	860	1580	2876	1132	2070	3758
42.8	12.2	54	129.2	54	130	266	321	610	1130	593	1100	2012	866	1590	2894	1138	2080	3776
44.6	12.8	55	131.0	60	140	284	327	620	1148	599	1110	2030	871	1600	2912	1143	2090	3794
46.4	13.3	56	132.8	66	150	302	332	630	1166	604	1120	2048	877	1610	2930	1149	2100	3812
48.2	13.9	57	134.6	71	160	320	338	640	1184	610	1130	2066	882	1620	2948	1154	2110	3830
50.0	14.4	58	136.4	77	170	338	343	650	1202	616	1140	2084	888	1630	2966	1160	2120	3848
51.8	15.0	59	138.2	82	180	356	349	660	1220	621	1150	2102	893	1640	2984	1168	2130	3866
53.6	15.6	60	140.0	88	190	374	354	670	1238	627	1160	2120	899	1650	3002	1171	2140	3884
55.4	16.1	61	141.8	93	200	392	360	680	1256	632	1170	2138	904	1660	3020	1177	2150	3902
57.2	16.7	62	143.6	99	210	410	366	690	1274	638	1180	2156	910	1670	3038	1182	2160	3920
59.0	17.2	63	145.4	100	212	413.6	371	700	1292	643	1190	2174	916	1680	3056	1188	2170	3938
60.8	17.8	64	147.2	104	220	428	377	710	1310	649	1200	2192	921	1690	3074	1193	2180	3956
62.6	18.3	65	149.0	110	230	446	382	720	1328	654	1210	2210	927	1700	3092	1199	2190	3974
64.4	18.9	66	150.8	116	240	464	388	730	1346	660	1220	2228	932	1710	3110	1204	2200	3992
66.2	19.4	67	152.6	121	250	482	393	740	1364	666	1230	2246	938	1720	3128	1210	2210	4010
68.0	20.0	68	154.4	127	260	500	399	750	1382	671	1240	2264	943	1730	3146	1216	2220	4028
69.8	26.6	69	156.2	132	270	518	404	760	1400	677	1250	2282	949	1740	3164	1221	2230	4046
71.6	21.1	70	158.0	138	280	536	410	770	1418	682	1260	2300	954	1750	3182	1227	2240	4064
73.4	21.7	71	159.8	143	290	554	416	780	1436	688	1270	2318	960	1760	3200	1232	2250	4082
75.2	22.2	72	161.6	149	300	572	421	790	1454	693	1280	2336	966	1770	3218	1238	2260	4100
77.0	22.8	73	163.4	154	310	590	427	800	1472	699	1290	2354	971	1780	3236	1243	2270	4118
78.8	23.3	74	165.2	160	320	608	432	810	1490	704	1300	2372	977	1790	3254	1249	2280	4136
80.6	23.9	75	167.0	166	330	626	438	820	1508	710	1310	2390	982	1800	3272	1254	2290	4154
82.4	24.4	76	168.8	171	340	644	443	830	1526	716	1320	2408	988	1810	3290	1260	2300	4172
84.2	25.0	77	170.6	177	350	662	449	840	1544	721	1330	2426	993	1820	3308	1266	2310	4190
86.0	25.6	78	172.4	182	360	680	454	850	1562	727	1340	2444	999	1830	3326	1271	2320	4208
87.8	26.1	79	174.2	188	370	698	460	860	1580	732	1350	2462	1004	1840	3344	1277	2330	4226
	26.7	80	176.0	193	380	716	466	870	1598	738	1360	2480	1010	1850	3362	1282	2340	4244
2 89.6	27.2	81	177.8	199	390	734	471	880	1616	743	1370	2498	1016	1860	3380	1288	2350	4262
91.4	27.8	82	179.6	204	400	752	477	890	1634	749	1380	2516	1021	1870	3398	1293	2360	4280
93.2	28.3	83	181.4	210	410	770	482	900	1652	754	1390	2534	1027	1880	3416	1299	2370	4298
95.0	28.9	84	183.2	216	420	788	488	910	1670	760	1400	2552	1032	1890	3434	1304	2380	4316
96.8	29.4	85	185.0	221	430	806	493	920	1688	766	1410	2570	1038	1900	3452	1310	2390	4334
98.6	30.0	86	186.8	227	440	824	499	930	1706	771	1420	2588	1043	1910	3470	1316	2400	4352
100.4	30.6	87	188.6	232	450	842	504	940	1724	777	1430	2606	1049	1920	3488	1321	2410	4370
102.2	31.1	88	190.4	238	460	860	510	950	1742	782	1440	2624	1054	1930	3506	1327	2420	4388
104.0	31.7	89	192.2	243	470	878	516	960	1760	788	1450	2642	1060	1940	3524	1332	2430	4406
105.8	32.2	90	194.0	249	480	896	521	970	1778	793	1460	2660	1066	1950	3542	1388	2440	4424
107.6	32.8	91	195.8	254	490	914	527	980	1796	799	1470	2678	1071	1960	3560	1343	2450	4442
109.4	33.3	92	197.6	260	500	932	532	990	1814	804	1480	2696	1077	1970	3578	1349	2460	4460
111.2	33.9	93	199.4	266	510	950	538	1000	1832	810	1490	2714	1082	1980	3596	1354	2470	4478
113.0	34.4	94	201.2	271	520	968	543	1010	1850	816	1500	2732	1088	1990	3614	1360	2480	4496
114.8	35.0	95	203.0	277	530	986	549	1020	1868	821	1510	2750	1093	2000	3632	1366	2490	4514
116.6	35.6	96	204.8	282	5	1004	554	103	1886	827	1520	2768	1099	2010	3650	1371	2500	4532

Interpolation Factors

		°F	°C		°F
0.55	1	1.8	3.33	6	10.8
1.11	2	3.6	3.88	7	12.6
1.66	3	5.4	4.44	8	14.4
2.22	4	7.2	5.00	9	16.2
2.77	5	9.0	5.55	10	18.0

Useful Conversion Formulas

$°F = 9/5°C + 32$

$°C = 5/9\,(°F - 32)$

$K = °C + 273$

$°R = °F + 460$

Percent of Rated Wattage for Various Applied Voltages

							Rated Voltage								
	11	115	120	208	0	230	240	277	380	415	440	460	480	550	Applied Voltage
10	100%	91%	84%	28%	25%	23%	21%	16%	8.4%	7%	6.3%	5.7%	5.3%	4%	110
15	109%	100%	92%	31%	27%	25%	23%	17%	9.2%	7.7%	6.8%	6.3%	5.7%	4.4%	115
20	119%	109%	100%	33%	30%	27%	25%	19%	10%	8.4%	7.4%	6.8%	6.3%	4.8%	120
8			300%	100%	89%	82%	75%	56%	30%	25%	22%	20%	19%	14%	208
20				112%	100%	91%	84%	63%	34%	28%	25%	23%	21%	16%	220
0				122%	109%	100%	92%	69%	37%	31%	27%	25%	23%	17%	230
40				133%	119%	109%	100%	75%	40%	33%	30%	27%	25%	19%	240
77							133%	100%	53%	45%	40%	36%	33%	25%	277
80								188%	100%	84%	75%	68%	63%	48%	380
15									119%	100%	89%	81%	75%	57%	415
										112%	100%	91%	84%	64%	440
										123%	109%	100%	92%	70%	460
0											119%	109%	100%	76%	480
50											156%	143%	131%	100%	550

ermine the resultant wattage on a voltage not shown chart above, use the following formula:

$$\text{Wattage} = \frac{\text{Rated Wattage} \times (\text{Applied Voltage})^2}{(\text{Rated Voltage})^2}$$

Caution — Applying higher than the actual rated voltage to heating elements will increase the watt density (watts/in²), which can lead to premature heater failure and/or damage the material being heated.

Watt Density Calculations

Band Heaters

$$\text{Watts/In}^2 = \frac{\text{Wattage}}{(\text{Diameter} \times 3.1416 \times \text{Width}) - (\text{Cold Area})}$$

Mica Strip Heaters

$$\text{Watts/In}^2 = \frac{\text{Wattage}}{\text{Heated Length} \times \text{Width}}$$

Cartridge and Tubular Heaters

$$\text{Watts/In}^2 = \frac{\text{Wattage}}{\text{Diameter} \times 3.1416 \times \text{Heated Length}}$$

Channel Strip Heaters

$$\text{Watts/In}^2 = \frac{\text{Wattage}}{\text{Heated Length} \times 3.625}$$

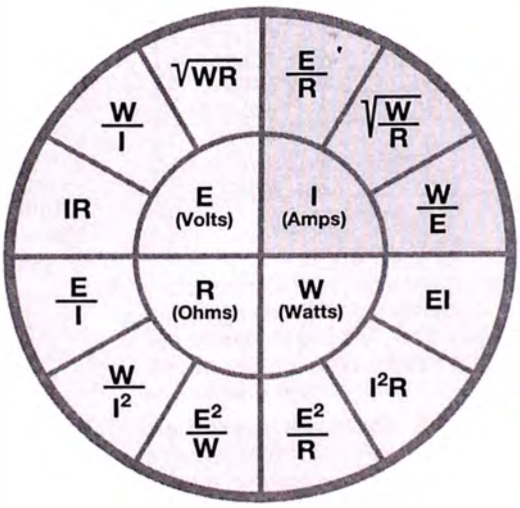
Ohm's Law

Volts

$$\text{Volts} = \sqrt{\text{Watts} \times \text{Ohms}}$$

$$\text{Volts} = \frac{\text{Watts}}{\text{Amperes}}$$

$$\text{Volts} = \text{Amperes} \times \text{Ohms}$$



Amperes

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$

$$\text{Amperes} = \sqrt{\frac{\text{Watts}}{\text{Ohms}}}$$

$$\text{Amperes} = \frac{\text{Watts}}{\text{Volts}}$$

Ohms

$$\text{Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$

$$\text{Ohms} = \frac{\text{Watts}}{\text{Amperes}^2}$$

$$\text{Ohms} = \frac{\text{Volts}^2}{\text{Watts}}$$

Watts

$$\text{Watts} = \text{Volts} \times \text{Amperes}$$

$$\text{Watts} = \text{Amps}^2 \times \text{Ohms}$$

$$\text{Watts} = \frac{\text{Volts}^2}{\text{Ohms}}$$

rmation

erage Conversion Table

	ingle Phase 240	ingle Phase 480	Volts 3 Phase Balanced Load 240	Volts 3 Phase Balanced Load 480	Watts
0.83	0.42	0.21	0.24	0.12	100
1.3	0.63	0.31	0.36	0.18	150
1.7	0.83	0.42	0.48	0.24	200
2.1	1.0	0.52	0.60	0.30	250
2.5	1.3	0.63	0.72	0.36	300
2.9	1.5	0.73	0.84	0.42	350
3.3	1.7	0.83	1.0	0.48	400
3.8	1.9	0.94	1.1	0.54	450
4.2	2.1	1.0	1.2	0.60	500
5.0	2.5	1.3	1.4	0.72	600
5.8	2.9	1.5	1.7	0.84	700
6.3	3.1	1.6	1.8	0.90	750
6.7	3.3	1.7	1.9	1.0	800
7.5	3.8	1.9	2.2	1.1	900
8.3	4.2	2.1	2.4	1.2	1000
9.2	4.6	2.3	2.6	1.3	1100
10.0	5.0	2.5	2.9	1.4	1200
10.4	5.2	2.6	3.0	1.5	1250
10.8	5.4	2.7	3.1	1.6	1300
11.7	5.8	2.9	3.4	1.7	1400
12.5	6.3	3.1	3.6	1.8	1500
13.3	6.7	3.3	3.8	1.9	1600
14.2	7.1	3.5	4.1	2.0	1700
14.6	7.3	3.6	4.2	2.1	1750
15.0	7.5	3.8	4.3	2.2	1800
15.8	7.9	4.0	4.6	2.3	1900
16.7	8.3	4.2	4.8	2.4	2000
18.3	9.2	4.6	5.3	2.6	2200
20.8	10.4	5.2	6.0	3.0	2500
22.9	11.5	5.7	6.6	3.3	2750
25.0	12.5	6.3	7.2	3.6	3000
29.2	14.6	7.3	8.4	4.2	3500
33.3	16.7	8.3	9.6	4.8	4000
37.5	18.8	9.4	10.8	5.4	4500
41.7	20.8	10.4	12.0	6.0	5000
50.0	25.0	12.5	14.4	7.2	6000
58.3	29.2	14.6	16.8	8.4	7000
66.7	33.3	16.7	19.2	9.6	8000
75.0	37.5	18.8	21.7	10.8	9000
83.3	41.7	20.8	24.1	12.0	10000

Wiring Hints

ire gauge, conductor material, and wire ulation choice depend upon current draw, ectric service voltage and operating temper- re. In high temperature environments, high perature insulation and/or nickel coated per or nickel conductors may be required.

ater terminal connections should be tight- ed with maximum torque consistent with ·nal strength. When possible, a wrench or iers should be used to support the heater ter- nal to prevent it from twisting when tight- g connections.

is good wiring practice to run thermocouple uit wiring in a separate conduit.

ermostat capillary tubing must be kept ay from heater terminals.

Selection of Hook-Up Lead Wire Gauge

Approximate Current Carrying Capacities of High Temperature insulated Nickel (Grade "A") and Nickel Plated Copper wire based on ambient temperature of 40°C (104°F).

This table should only be used as a starting point when establishing ratings for any given situation. It is recommended that design engineers desiring accurate ampacity data refer to the current National Electric Code Handbook, Article 310-15-310-84.

Current Carrying Capacity Table Ambient Temperature at 40°C (104°F)

Conductor Size AWG	Conductor Type and Temperature Rating			
	250°C (482°F) "A" Nickel	250°C (482°F) NPC 2%-10%	450°C (842°F) "A" Nickel	450°C (842°F) NCC 27%
24	4	8	4.3	9
22	5	10.8	5.6	12
20	7	15	8	18
18	9.4	20	11	23
16	12	26	14	30
14	18	39	21	45
12	25	54	26	56
10	34	73	35	75

For ambient temperatures other than 40°C (104°F), multiply the ampacities shown above by the appropriate factor shown below.

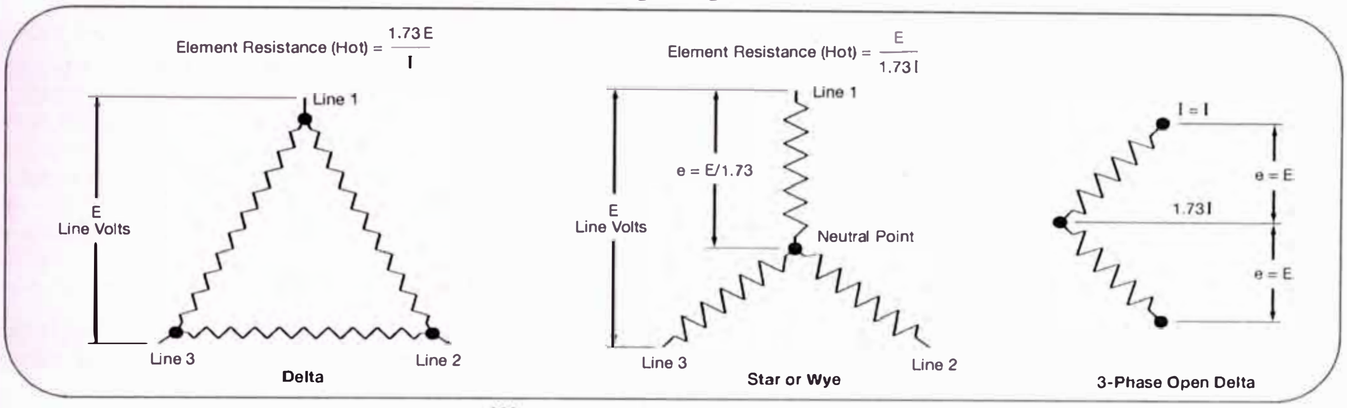
Ambient Temperature Correction Factors

Ambient Temperature °C	Wire Temperature Rating		Ambient Temperature °F
	250°C (482°F)	450°C (842°F)	
41-50	0.98	0.99	106-122
51-60	0.95	0.99	124-140
61-70	0.93	0.96	142-158
71-80	0.9	0.95	160-176
81-90	0.87	0.93	177-194
91-100	0.85	0.92	195-212
101-120	0.79	0.89	213-248
121-140	0.71	0.86	249-284
141-160	0.65	0.84	285-320
161-180	0.58	0.81	321-356
181-200	0.49	0.78	357-392
201-225	0.35	0.74	393-437
226-250	—	0.69	439-482
251-275	—	0.65	483-527
276-300	—	0.6	528-572
301-325	—	0.55	573-617
326-350	—	0.49	618-662
351-375	—	0.42	663-707
376-400	—	0.34	708-752

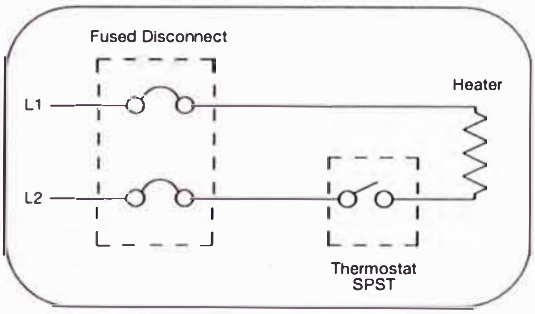
5. Safe operation of heaters equipped with NEMA 4 and NEMA 7 terminal housings depends on electrical wiring meeting the national electrical code for these locations and limiting maximum operation temperatures. Approved pressure and/or temperatures limiting controls must be used to assure safe operation in the event of system malfunctions.
6. An integral thermostat functions as a temperature control only and is not a fail-safe device. An approved pressure and/or temperature limit control should be used in the event of system malfunctions.
7. Never perform any type of service on heaters prior to disconnecting all electrical power.

CAUTION All wiring should be done in accordance with the National Electrical Code and applicable local codes.

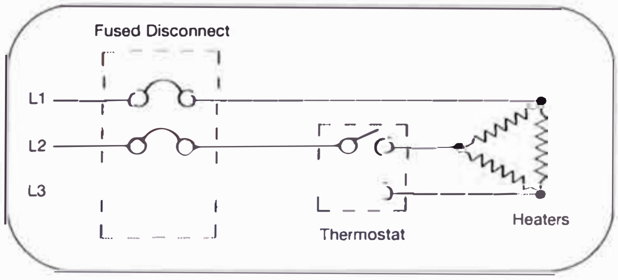
Wiring Diagrams



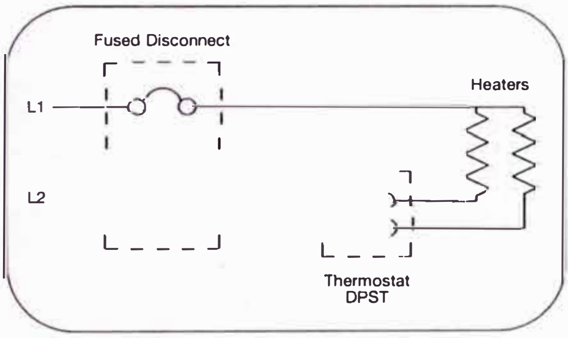
For current in 3 phase circuits: $I = \frac{W}{1.73E}$ *if elements are designed for 3 phase delta connection wattage output may be reduced to 1/3 by rewiring to 3 phase WYE.*



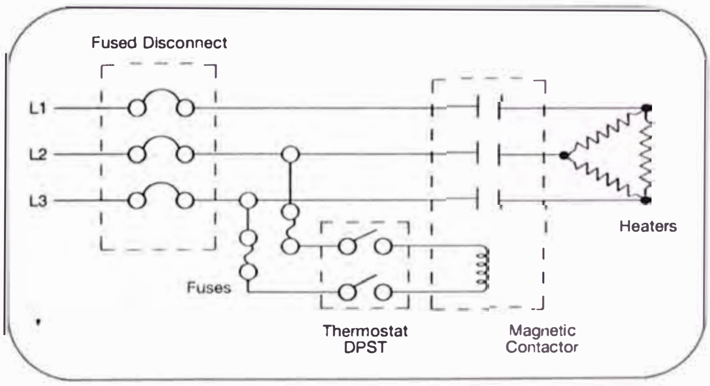
Single phase circuit with SPST thermostat.



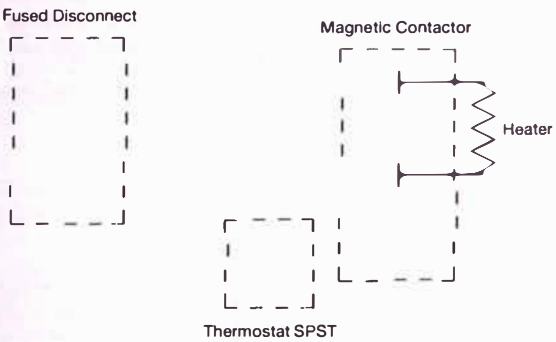
Three phase circuit with DPST thermostat.



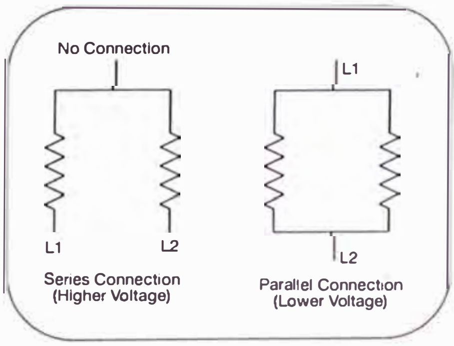
Single phase circuit with thermostat connected for half current load across each contact.



Three phase circuit when line current exceeds thermostat rating.



ngle phase circuit when line current exceeds thermostat rating.



Dual Voltage

Example: Two 120 volt heaters wired in parallel for 120 volt operation or wired in series for 240 volt operation.

Note: To reduce wattage in a system, two heaters rated at 240 volts wired in series to a 240 volt power supply will generate 1/4 of their rated wattage.

Data

ed Sheath Materials

Sheath Material Selection Guide

POLICY

not warrant any electric immersion heater against ath corrosion if such failure is the result of operat- s beyond the control of the heater manufacturer. The endations appearing in the TEMPCO catalog or ature published by TEMPCO are based on our own the research of others, and is believed to be accurate. cipate all conditions under which this information cts, or the products of other manufacturers in com- our products may be used.

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of process variables that can ter sheath selection

- chemistry
- contamination
- ture
- te (velocity) past heater
- Heater watt density
- Heating cycle (time-on, time-off)
- Galvanic behavior
- Degree of aeration

SHEATH MATERIAL SELECTION GUIDE

th material selection guide:

'on contains a mixture of various chemical compounds whose identity and are unknown or subject to change. Check with chemical supplier to ility of sheath material chosen.

ammable material

composition varies widely. Check supplier for specific recommendations.

ersion heaters not practical. Use clamp-on heaters on outside surface of t.

e loading should not exceed 20 watts per square inch.

ntrations greater than 15%, element surface loading should not exceed 20 uare inch.

watt density chart.

ts at liquid level.

stainless steel, Inconel® and Incoloy®.

Maximum Recommended Watt Densities for Various Materials

Being Heated	Maximum Operating Temperature °F	Maximum Watt Density W/in²
d Solutions	180	40
ine Solutions, Oakite	212	40
onia Pltg. Solution	50	25
halt, Tar or Heavy Com unds	200-500	4-10
ustic Soda 2%	210	45
10%	210	25
75%	180	25
greasing Solution Vapor	275	20
ectroplating Solution	180	40
ylene Glycol	300	30
Acids	150	20
l Oils		
Light Grade	180	25-30 circ.
Heavy (Bunker C)	160	8
oline	300	23
lycerine	500	10

Material Being Heated	Maximum Operating Temperature °F	Maximum Watt Density W/in²
Machine Oil SAE 30	250	15-20 non-circ.
Metal Melting Pot	500-900	20-27
Mineral Oil	400	16
Molasses	100	4-5
Molten Tin	600	20
Oil Draw Bath	600	20
Paraffin or Wax	150	16
Potassium Hydroxide	160	25
Propylene Glycol	150	20
Steel Tubing Cast Into Aluminum	500-750	50
Steel Tubing Cast Into Iron	750-1000	55
Trichlorethylene	150	20
Water (Process)	35-150	100-125 circ. 75-100 non-circ.
	212	75 circ. 50 non-circ.

Element Sheath Material

a
ng
d

	Iron & Steel	Gray Cast Iron	Cast Iron Ni. Resist	Aluminum	Copper	Lead	Monel 400	Nickel 200	304, 321, 347 Stn. Stl.	316 Stn. Stl.	Type 20 Stn. Stl.	Incoloy® 800	Inconel® 600	Titanium	Hastelloy B	Quartz	Graphite	Teflon®	*Notes
de					A					A	A								Note 2
cid, Crude	X		C	F	F	X	F	F	F	F		C	C						
Pure			X	A	F	F	A	F				C	C						
Va rs			X	C	F	X	F	F				C	C	F					
150 PSI: 400°F				C	F	X	F	F				C	C						
Aerated	X	X	X	C	X	X	X	X	X	F	F		X	A					
No Air		X	X	C	F	X	A	F	C	F	F		X	A					
	C	X	F	F	A	A	A	A	A	A	A	A	A	A	A	A	A		Note 2
70																	A	A	Note 1
80																	A	A	Note 1
Salt																	A		Note 1
Process	A																		
Bri ht Di																A		A	Note 1
	F	F		F	A	A	A	A	F	A	A	A	A	A	A	A	A		Note 2
cohol		A	A	F	A	F	A	A	A	A	A	A	A	A					
™															A				Note 1
e Cleaners									A										Note 1
Soakin Cleaners	A																		Note 1
™										A									Note 1
Molten)								C	NSU	T T	MPC								
um Acetate	X	X			F	A	F	F	F	A	A		F	A	A				
Bri ht Di																A		A	Note 1
um Chloride	X	X		X	X	X	X	X	X	X	X	X	X	X	A	A	A	A	Note 1
um Cleaners	C	C		X	X	X	A	A	A	A	F	A	A	F		X	X		Notes 1, 9
Potassium																			
Alum		X	X	X	A	F	F	F	X	C	F		F	F					
um Sulfate	X	X	X	X	X	F	X	X	F	F	F	X	X	A		A	A		Note 1
'a	X	X		C	X	C	X	X	X	X	X	C	F	A	A	A	A		
a (Anh drous) (Gas)	F				X				A	A									
	C		A	A	A	F	A	A	A	A	A		A	A					
	C		C		A	X	A	A	C	C	A		A						
'a and Oil	A																		
nium Acetate	A	F	F	A	X	X	A	A	A	A	A	A	A						
um Chloride	X	X	F	X	X	X	F	F	X	C	C	C	C	A		A	A	A	
um H droxide	F	F	F	C	X	F	X	A	A	A	A	A	A	A		X	A		
'um Nitrate	F	X	C	F	X	X	X	X	A	A	A	X	X	X		A	A		
'um Persulfate	X	X		X	X	C	X	X	F	F	F		X			A	A	A	
'um Sulfate	X	X	F	X	X	F	F	F	C	F	F	F	F	A		A	A		
cetate	F				A		A	A	A	A	A	A		A					
cohol	A	F	F	C	A		A	F	A304	A	A	A	A	A		A			Note 2
	F	A		F	X	F	F	F	A304	A	A	F	F	A		A	A		
, Oil	A			X	X				A	A									
, Dyes							A		A	A									

Corrosion Resistance Ratings:

A = ***Good***
F = ***Fair***
C = ***Depends on Conditions***
X = ***Unsuitable***
Blank = ***Data Not Available***

* ***See Notes to Material Selection Guide on Page 16-12.***

CONTINUED

ing Data

d Sheath Materials

Element Sheath Material

dia	Iron & Steel	Gray Cast Iron	Cast Iron Ni. Resist	Aluminum	Copper	Lead	Monel 400	Nickel 200	304, 321, 347 Stn. Stl.	316 Stn. Stl.	Type 20 Stn. Stl.	Incoloy® 800	Inconel® 600	Titanium	Hastelloy B	Quartz	Graphite	Teflon®	*Notes
Solutions (10%)																			
Acid 96°F	C								A	A				A					
cetate						C	A	F											
e Black D e							F	F											
H droxide Alkaline	A				A			A		A	A	A		A					
Acid 70°F						A					A								
																	A	A	Note 1
lackenin Salt																	A		Note 1
'd	X	X		X	X	X	X	X	C	F	F	X	X	X		A	A	A	
	A	A		X	X	X	X	A	A	A	A	A	A	A		A	A		
hloride				X				A	F	F			A						
droxide	F	F		X	X	X	F	A	F	A	A	F	F	X		A	A		
ulfate	F	F	F		F	F	F	F	F	F	F	F	F	A		A	A		
te									F										
kel																A		A	Note 5
de									A										Note 5
Solution																			
Oxalic Acid per																			
of H O at 212°F							A		F										
™ (Zinc Phos hate)	C		F						A	A									
'd	X	X		X	C	C	C	C	C	C	C	C	C	A	A	A	A	A	
anide									A										Note 1
ckel														A		A			Notes 1, 5
t Water)							A						F						
atin	A								A										Note 1
	A	A		F	A	A	A	A	A	A	A	A	A	A		A	A	A	Note 2
Black																A			Note 1
Fluoborate																	A	A	Note 1
Platin									A			A	A						Note 1
Chlorate	F	F		F	C	C	F	F	F	F	F	F	F			A			
loride	F	F		C	F	X	F	F	F	F	F	F	F	A	A	A	A	A	
ioxide— Gas	X	X	A	A	A	F	A	A	A'	A	A	A	A	X		A	X	X	
'oxide—Wet Gas	X	X	C	A	X	F	A	A	A	A	A	A	A	X		A	X	X	
chloride	X	X	C	X	C	A	A	A	C	F	F	A	A	A		A			
c Acid	C	C		C	C	X	C	C	A	F	A	F	A	A		A	A	A	
l	A	A		A	A	A	A	A	A	A	A	A	A	A		A	A	A	
tch	A	A		X	X		A	A	A	A	X	X	X	A		X	A	X	
oda (Lye) (Sodium																			
xide) 2%	F	F	F	X	F	X	A	A	X	F	A	A	A	A					
%, 210°F	F	F	A	X	F	X	A	A	A	A	A	A	A	A					
, 180°F	X	X	X	X	X	X	F	A	F	F	F	A	A	F					
Gas: D	X	X	F	X	X	X	F	C	C	C	F	C	F	X		A	F	F	Note 2
Wet	X	X	X	X	X	X	X	X	X	X	X	X	X	F		A	X	X	Note 2
'c Acid	X	X		X	X	X	F	F	X	X		C	C	A		A	A	A	
Acetate																A			Note 1

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latin	X	X		X	X	F	X	X	X	X	X	X	X	A		A	A	X	
cid	X	C	X	X	X	F	X	X	X	X	X	X	X	A		A	A	X	
te																A			Note 1
d	X	X	C	C	C	X	F	F	C	C	F	F	F	A	A	A	A	A	
mate										A									Note 1
cetate at 130°F							F	F	A	A		F	F						
ckel																A			Notes 1, 6
atin									A							A			Note 1
Oil							F	A											
er Oil				A				A	A	A	A	A	A						
Acid														A		A			Note 1
ri ht									A	A									Note 1
Bri ht Acid																A			
hloride	X	X		C	X	C	X	X	X	X	X	X	X	A		A	A	A	
anide	A	A		X	X		C	X	F	F	F	X	X			A	A	A	
uoborate							F	F	F	F	F	F	F				A	A	
itrate	X	X	X	X	X		X	X	F	F	F	X	X			A	A	A	
latin	A																		
hos hate									A										Note 1
Strike	A	A							A										Note 1
ulfate	X	X	F	X	C	A	X	X	F	F	A	C	X	A		A	A	A	
	A	F	F	C	F	X	F	F	F	F	F	F	F			A			Note 2
c Acid	C	C		C	C	X	F	F	F	A	A	C	F	F		A	A	A	Note 2
e™									A										
™									A										
r (Etchin)																A			Note 1
zer (3AL-13)									A	A									Note 1. Non-Chromate
c Seal	X	X																	
ne Gl col	F	A		F	F	A	F	F	A	A	A	F	F	A		A	A	A	
l 300° - 350°F	A	A	A	A	A	A	A	A	A		A		A						
Phos hate	A																		
™ DS9333																A			Note 1
™ 99	A																		
™ 511																A			Notes 1, 5
™ 514																	A	A	Note 1
™ A	A																		
Polishin																A			Note 1
ess Nickel														A		A			Note 1
less Tin (Acid)																A			Note 1
(Alkaline)										A				A					Note 1
Acid-80																	A	A	Note 1
	F	F		F	F	F	F	F	F	F	A	F	F	A		A			Note 2
oride	F	F		F	A	F	F	A	F	F	A	F	A	A		A	A	A	Note 2

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˙ g Data

ed Sheath Materials

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l col	A	F		A	F	X	F	F	F	F	F	F	F	A		A	A	A	Note 5
	X	X		A	X	X	F	F	F	A	A	F	F	A		A	A		
˙de	X	X	X	X	X	X	X	X	X	X	X	X	X	A		A	A	A	
e	X	X		X	X		X	X	F	F	A	X	X			A	A		
e	X	X	X	X	X	A	X	C	F	F	F	C	C	A		A	A		
,	C	X		X	X	X	A	A	C	C	C	C	A	A		C	X		
de	X	X	F	F	F	X	F	F	A	A	A	F	F	A		A	A		
˙d	X	X		X	F	X	C	C	X	X	A	F	C	X		A	A		
	A	A	A	A	A	A	A	A	A	A	A	A	A						
	A	A		A	A	A	F	F	A	A	A	F	F	A					Notes 2, 3, 7
Acid	X	X		X	X	A	C	C	C	F	A	C	C	A					Notes 2, 3, 7
Refined	A	A	A	A	A	A	F	F	A	A	A	F	F			A	A		Notes 2, 5
Sour	C	C		C	C	A	X	X	F	F	A	X	X			A	A		Notes 2, 3, 5
, Gl cerol	F	C	F	A	F	F	A	A	A	A	A	A	A			A	A		
	A													A		A			Note 1
˙de									A	A									Note 1
l														A		A		A	Notes 1, 5
10A Tem rin Bath								A											
Sodium Dichromate										A									Note 1
e Mar Tem rin Salt	C							C											
s - Ali hatic	A	A		A	A		A	A	A	A	A	A	A			A	A		Note 2
ns - Aromatic	A	A		A	A		A	A	A	A	A	A	A			A	A		Note 2
oric Acid < 150°F	X	X	X	X	X	X	X	X	X	X	X	X	X	X		A	A		
> 150°F	X	X		X	X	X	X	X	X	X	X	X	X	X		A	A	A	
nic Acid	X	X		F	X	X	F	F	F	F	F	F	F			A	A		
˙c Acid, Cold < 65%	X	X	X	X	X	X	C	X	X	X	X	X	X	X		X	A	A	Note 5
> 65%	F	X	X	X	X	X	C	X	X	X		X	X	X					
˙c Acid, Hot < 65%	X			X	X	X	C	X	X										
> 65%	X			X	X	X	C	X	X	X		X	X	X					
Peroxide	X	X	X	A	X	X	C	F	F	F	F	F	F	A		A	X		
																A		A	Note 1
75, #4-73, #14, #14-9,#18-P										A									Note 1
l, #2, #3, #4-C, , #4P-4, #4-80, l, #4-2, #4-2A, #4-2P, , #7-P, #8, #8-P, #8-2, #15, #17P, #18P																A			Note 1
es #12L-2, #40, #80																A		A	Note 1
																A		A	Note 1
borate																	A	A	Note 1
hate (Parkerizin)	C		F						A	A									
Deoxidizer #187, #188										A									Note 1
#191 Acid Salts																	A	A	Note 1

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	I n & Steel	Gray Cast Iron	Cast Iron Ni. Resist	Aluminum	Copper	Lead	Monel 400	Nickel 200	304, 321, 347 Stn. Stl.	316 Stn. Stl.	Type 20 Stn. Stl.	Incoloy® 800	Inconel® 600	Titanium	Hastelloy B	Quartz	Graphite	Teflon®	*Notes
'd Aluminum																			
#186										A									Note 1
ol	C				A		A	A	A	A	A		A						
									A										Note 1
	A			A	A		A	A	A	A	A	A	A				A		Note 2
								A											
olvent	F	A	A	A	F	A	F	F	A	A	A	F	F	A		A			Note 2
te	X	X		X	X	X	A	A	A	A	A	A	A	A		A	A		
Salts									A										Note 1
ed Water	F	F		X	F	X	F	F	F	A	F	F	F			X	A		
il	X	A		F	F	X	F	F	A	A	A	F	F			A	X		Note 2
Chloride	X	C	F	X	F	X	F	A	F	F	A	F	A	A		A	A		
um H droxide	A	A	A	F	A	A	F	A	A	A	A	A	A			A	A		
Nitrate	F	F		F	F	C	F	F	F	F	F	F	X	F		A	A		
um Sulfate	F	F	F	F	F	A	A	A	F	F	A	F	A	A		A	A		
'd" M629																	A	A	Note 1
Chloride	X	X	X	X	X	X	X	X	X	X	X	X	X	F		A	A		
	A	A	A	X	X	X	F	F	F	A	A	A	F	X		A			
hol (Methanol)	F	F		C	F	F	A	A	F	A	A	F	A	A		A	A		Note 2
mide	C	C		X	F	F	F	F	A	A	A	F	F	A		A			
Chloride	C	C		X	A	C	C	C	C	C	C	C	C	A		A	A		
e Chloride	X	C		C	C	F	C	F	C	F	A	C	F	A		A	A		
Oil	A	A		A	A	A	A	A	A	A	A	A	A	A		A	A		
																A		A	Note 1
	A	F	F	A	A	A	A	A	A	A	A	A	A	A		A	A	A	Note 2
e	A	A	A	F	F	A	F	F	A	A	A	F	F	A					Note 2
te Seal										A									Note 1
hloride	X	X	X	X	X	C	C	X	X	C	C	C	F	F		A	A	A	Notes 1, 5
pper Strike																			
'de Free)									A	A									Note 1
ate - Bri ht						A								A		A		A	Notes 1, 5
ate - Dull						A										A		A	Notes 1, 5
late - Watts Solution														A		A		A	Notes 1, 5
ulfate	X	X	X	X	F	F	C	F	F	F	F	C	F			A	A	A	
id, Crude	X				X	X	X	X	C	C		X	X			A		A	
Concentrated	X				X	X	X	X	F	F		X	X			A		A	
Diluted	X				X	X	X	X	A	A		X	X			A		A	
drochloric Acid	X	X		X	X	X	X	X	X	X	X	X	X	X		A	A	A	
% Phos horic Acid										C						A		A	Note 1
'um Chromate										A						A		A	Note 1
ne	A	A	A	A	F	X	A	A	A	A	A	A	A	A		A			Note 2
#67									A										Note 1
#20, 23, 24, 30, 51, 90	A																		
id	C	C	C	C	C	X	F	F	C	F	A	F	A	F		A	A	A	

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a

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'	X	X	X	F	F	X	C	F	X	X	F	X	F	X		A	A	A	
(High Alkaline																			
	A																		Note 1
r (Solvent)										A									Notes 1, 2
	A	A		A	A		F		A	A	A								Notes 2, 7
g'" (See Iron																			
)																			
th lene	F	F		C	F	F	A	A	F	F	F	F	A	A		A			
or˜									A										
- Crude < 500°F	F	F	A	A	C	C	A	C	A	A	A					A	A		Notes 2, 3, 7
> 500°F	A		A	A	X	X	X	X	A										
> 1000°F	X			X	X	X	X	X	A347										
	F	F		F		X	F		C	F	F	F	F	A	A				
										A								X	Notes 1, 5, 9
Cleaner									A									X	Notes 1, 5, 9
'										A								X	Notes 1, 5, 9
c Acid, Crude	C			X	X	C	X	X	C										
Pure < 45%	X	X	X	C	C	C	F	C	C	C	F	A	A	X					
> 45% Cold	X	X	X	X	F	C	F	C	A	F	F	A		X					
> 45% Hot	X	X	X	X	C	X	C	X	X	X	F	A	F	X					
n Bath							C		A										
d	X	X		X	X	X	X	X	F	F	F	C	C			A	A	A	
Acid Sulfate																A		A	Note 1
Bichromate	C	F	F	F		F	F	F	A347	A	A	F		F	A	A		A	
Chloride	C	X	F	X	C	C	F	F	C	F	A	C	F	A		A	A		
C anide	C	X	F	X	X	X	C	F	F	F	F	F	F	X		A	C	A	
Dichromate									A347										
H drochloric																A		A	Note 1
H droxide	X	X		X	C	X	F	A	C	C	C	C	F	X		X	A	A	
Nitrate	F	F	F	A	F	F	F	F	F	F	F	F	F	A		A	A		
Sulfate	C	C	C	A	F	A	A	F	A	A	A	F	F	A		A	A	A	
350°F	A						A												
t Dip For Copper																			
at 180°F										A									
Bri htener																A		A	Note 1
H droxide																A		A	
e Salt C anide	A								A										Note 1
Platin																A		A	Note 1
mide	X	X		X	X		C	C	X	X	C			A		A	A	A	
anide	C	C		X	X		F		A	A	A	A				A			
e									A										Note 1
trate	X	X		X	X	X	X	X	C	C	F	C	C	A		A	A		
lutions	A	A	A	X	C		A		A	A	A								Note 3
Liquid Metal	C	X		X	X	X	F	A	A			A	A			X	X		

sion Resistance Ratings:

A = ***Good***

F = ***Fair***

C = ***Depends on Conditions***

= ***Unsuitable***

– ***ta Not Available***

** See Notes to Material Selection Guide on Page 16-12.*

Element Sheath Material

Being Heated	on & Steel	Gray Cast Iron	Cast Iron Ni. Resist	Aluminum	Copper	Lead	Monel 400	Nickel 200	304, 321, 347 Stn. Stl.	316 Stn. Stl.	Type 20 Stn. Stl.	Incoloy® 800	Inconel® 600	Titanium	Hastelloy B	Quartz	Graphite	Teflon®	*Notes
Bisulfate	X	X	X	C	F	C	C	F	X	X	A		F						
Bromide	F	C		X	F	F	F	F	C	F	F	F	F			A	A	A	
Carbonate	C	C		X	A	X	F	F	F	F	A	F	F	A		C	A	A	
Chlorate	X	X		F	A	F	A	A	F	F	F	F	A	A		A	A	A	
Chloride	C	X	F	X	F	F	A	F	X	X	C	F	A	C		A	A		
Citrate	X	X		X	X	X			F	F	F					A	A	A	
C anide	C	F	C	X	X	X	C	C	A	A	A	A	A	C		A	C		
Dichromate																			
'um Bichromate)	F	F	F	C	X				F	F	F			C		A			
Hydroxide																			
Caustic Soda)																			
H hlorite	X	X	X	X	X	X	X	X	X	X	F	X	X	A	A	A	A	A	
Nitrate	F	F	A	C	C	C	F	F	A	A	A	A	A	A		A	A		
Peroxide	F	A	F	C	X	X	F	F	F	F	F		F						
m Phos hate	C	C	F	X	F	F	A	C	F	A	F	F	A	A		A	A	A	
Salic late	F	C	F		F		F	F	F	F	F	F	F			A	A	A	
m Silicate	A	F	A	X	F	X	A	A	A	A	A	A	A	A		A	A	A	Note 4
Stannate	C	C	C				F	F	F	F	F	F	F			A		A	
Sulfate	F	C		F	F	F	F	F	X	F	F	F	F	C		A	A	A	
um Sulfide	C	X	C	C	X	A	F	F	X	C	C	C	C	C		C	A	A	
r Bath	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	Note 4
Oil									A										
tar™																A		A	Note 1
< 500°F	A			A	A	C	A	A	A			A	A						
500° - 1000°F	C			C	C	X	C	C	A			A	A						
> 1000°F	X			X	X		X	X	A			A	A						
'c Acid	C	C	C	C	X	X	F	F	C	A	A	F	F	F		A	A		
Solution	A	A		A	A	A	A	A	A	A	A	A	A	A		A	A	A	Note 7
ate Nickel														A		A		A	Note 1
'c Acid	X	X		X					X	X						A		A	
	C	X	C	A	X	X	F	C	C	F	F	A	A	A		A	A		
loride	X	X	C	X	X	F	X	C		X	C	C	F			A	X	A	
'oxide	C	C		C	C	F	X	X	C	F	F	C	C	A		A	A		
c Acid < 10% Cold	X		X	C	A	F	F	C	X	C	F		X						
Hot	X	X	X	C	X	X	X	X	X	X	X		F						
10 - 75% Cold	X			X	F	F	C	C	X	X	F		X	X					
Hot	X			X	X	F	C	X	X	X	C		X	X					
75 - 95% Cold	F	F	F	X	F	F	X	X	F	F	F			X					
Hot	X	X	X	X	X	C	X	X	X	X	X			X					
Fumin	C	X	C	X	X	X	X	X	F	C	C	C	C						
us Acid	X	X		C	X	A	X	X	X	C	F		C	A					
'c Acid	C	C		C	C	X	C	C	C	A	A		A	A		A			
	A			A					A			A	A						
'c Acid		X	F	C		C	F	C	C	A	F		F	F					

CORROSION POLICY

CAUTION

TEMPCO cannot warrant any electric immersion heater against failure by sheath corrosion if such failure is the result of operating conditions beyond the control of the heater manufacturer. The facts and recommendations appearing in the TEMPCO catalog or any other literature published by TEMPCO are based on our own research and the research of others, and is believed to be accurate. We cannot anticipate all conditions under which this information and our products, or the products of other manufacturers in combination with our products may be used.

We accept NO responsibility for results obtained by the application of this information or the safety and suitability of our products, either alone or in combination with other products. It is the responsibility of the Purchaser to make the ultimate choice of sheath material based on his/her knowledge of the chemical composition of the corrosive solution, character of materials entering the solution, and controls, which he/she maintains, on the process.

ring Data

ended Sheath Materials

Element Sheath Material

edia ing d	Iron & Steel	Gray Cast Iron	Cast Iron Ni. Resist	Aluminum	Copper	Lead	Monel 400	Nickel 200	304, 321, 347 Stn. Stl.	316 Stn. Stl.	Type 20 Stn. Stl.	Incoloy® 800	Inconel® 600	Titanium	Hastelloy B	Quartz	Graphite	Teflon®	*Notes
lene	F	F		C	F	F	A	A	F	F	F	F	A	A		A			
Granodine™	F																		
ol™ FR1																			
/S . In. 640°F	A																		
ten)	F	F		X	X	X	X	X	F	F	X		X	A			X	X	Note 4
l Platin																A		A	Note 1
- Acid																	A	A	Note 1
- Alkaline	A								A										Note 1
	A	A	A	A	C	A	A	A	A	A	A	A	A	A					
vent	C																		
ane	A	C	C	F	F	F	F	F	A	F	F	F	F	A		A	A		
lene	F	C	C	F	C	X	C	C	F	F	F	F	A	A		A	A		
ne Gl col	A	A	A	A	A	A	A	A	A	A	A	A	A	A		A			
Pickle)																A		A	Note 1
Phos hate	A	A		X	C	X	C	C	C	C	C					X	F	X	
23	A																		
8, 4181, 4338										A									Note 1
ltrasonic Solution										A									Note 1
ne	C	C	C	A	F	A	A	A	A	A	A		A						
																A			Note 1
#66														A		A		A	Notes 1, 5
e™ CR-110																A		A	Note 1
me™ 5RHS																A		A	Note 1
monia Li uor 48°F	A																		
le Oil	C		C	F	X	X	A	A	A	A	A	A							
	C			C			A		F	A									
cid Mine																			
Oxidizin Salts	X		C	C	C	C	X	C	A										
xidizin Salts	C		A	A			A		X										
ionized	X	X		X	X		A	A	A	A	A	A	A						Note 10
mineralized	X	X		X	X		A	A	A	A	A	A	A						Note 10
Distilled	X	X			X	X	C	A				A	A						Note 10
otable	X	C	A	A	A	X	A	A	C	F	A	A	A	A		A			
Return Condensate	A		A	A	A	A			A	A		A							
Sea	X	X	A	X	X	A	A		C	C	A	F	F	A		A	A		
ickel Strike																A			Note 1
e and Wines	X		C		A		A	A	A	A	A	A	A						Note 2
s Nickel Strike																A			Note 1
Dichromate										A						A			Note 1
Solution									A										
olten)				X	X	X	X	X	X	X	X	X	X	X				X	
oride	C	C	C	X	X		F	F	X	X	F	X	F	C		A	A	A	
s hate										A								X	Notes 1, 5
tin Acid																A			Note 1
tin C anide	A								A										Note 1
hate	C	X	A	C .	F	A	F	C	C	C	C		F	A					Note 1
™	A								A										

Corrosion Resistance Ratings:

A = *Good* **F** = *Fair* **C** = *Depends on Conditions* **X** = *Unsuitable*

Blank = Data Not Available

* *See Notes to Material Selection Guide on Page 16-12.*

Frequently Used Conversion Factors

u. ft. = 1728 cu. in. = 0.03704 cu. yd.
. ft. = 7.481 gal.
gal. = 231 cu. in. = 0.1337 cu. ft.

al. water = 8.3 lbs.
cu. ft. Water = 62.43 lbs.

. will evaporate 3.5 lb. of water from and at 212°F
H. will raise 22.75 lb. of water from 62°F to 212°F

12 BTU = 1 KWH = 1.34 HP Hour
= 745.7 Watts
TU = 252 calories = 0.293 Watt Hours

Metric

1 in. = 2.54 cm = 25.4 mm
1 ft. = 0.3048 m
1 m = 39.37 in.

1 sq. in. = 6.4516 sq. cm.
1 sq. ft. = 0.0929 sq. m.

1 cu. in. = 16.39 cu. cm
1 cu. ft. = 0.02832 cu. m. = 28.32 liters

1 lb. = 453.6 grams
1 gal (U.S.) = 3.785 liters
1 liter = 61.024 cu. in.

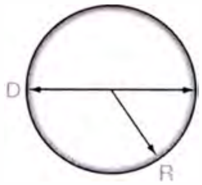
		MULTIPLY BY
eres	Cms of Mercury	76
	Feet of Water (at 4°C)	33.9
s	Inches of Mercury (at 0°C)	29.92
	Kgs/Square Cm	1.0333
	Kgs/Square Meter	10,332
	Pounds/Square Inch	14.7
	Watts	0.2931
ute	Horsepower	0.02356
te	Kilowatts	0.01757
ute	Watts	17.57
	Ounce Fluid (U.S.)	0.3382
rs	Feet	3.281×10^{-2}
rs	Inches	0.3937
ntimeters	Cubic Feet	3.531×10^{-5}
timeters	Cubic Inches	0.06102
ntimeters	Gallons (U.S. Liquid)	2.642×10^{-4}
t	Cubic Cms	28.320
t	Cubic Inches	1,728
eet	Cubic Yards	0.03704
eet	Gallons (U.S. Liquid)	7.48052
ches	Cubic Cms	16.39
hes	Cubic Feet	5.787×10^{-4}
ches	Gallons	4.329×10^{-3}
ches	Cubic Feet	35.31
eters	Cubic Yards	1.308
eters	Gallons (U.S. Liquid)	264.2
	Centimeters	30.48
	Kilometers	3.048×10^{-4}
	Millimeters	304.8
Water	Atmospheres	0.0295
ater	Inches of Mercury	0.8826
ater	Pounds/Square Foot	62.43
ater	Pounds/Square Inch	0.4335
	Cubic Cms	3,785
	Cubic Feet	0.1337
	Cubic Inches	231
	Cubic Meters	3.785×10^{-3}
	Cubic Yards	4.951×10^{-3}
quid Br. Imp.)	Gallons (U.S. Liquid)	1.20095
of Water	Pounds of Water	8.3453
ute	Cubic Feet/Hour	8.0208

TO CONVERT	INTO	MULTIPLY BY
Grams	Pounds	2.205×10^{-3}
Horsepower	Kilowatts	0.7457
Horsepower (Boiler)	BTU/Hour	33479
Horsepower (Boiler)	Kilowatts	9.803
Inches	Meters	2.540×10^{-2}
Inches of Mercury	Atmospheres	0.03342
Inches of Mercury	Feet of Water	1.133
Inches of Mercury	Pounds/Square Inch	0.4912
Kilograms	Pounds	2.205
Kilograms/Cubic Meter	Pounds/Cubic Feet	0.06243
Kilowatt Hours	BTU	3412
Liters	Cubic Feet	0.03531
Meters	Feet	3.281
Meters	Yards	1.094
Microns	Meters	1×10^{-6}
Millimeters	Feet	3.281×10^{-3}
Millimeters	Inches	0.03937
Ounces	Pounds	0.0625
Radians	Degrees	57.3
Radians	Minutes	3,438
Square Feet	Square Inches	144
Square Feet	Square Yards	0.1111
Square Inches	Square Cms	6.452
Square Inches	Square Feet	6.944×10^{-3}
Square Meters	Square Feet	10.76
Square Meters	Square Yards	1.196
Square Yards	Square Feet	9
Square Yards	Square Inches	1.296
Square Yards	Square Meters	0.8361
Watts	BTU/Hour	3.4129
Watts	Foot-Pounds/Minute	44.27
Yards	Kilometers	9.144×10^{-4}
Yards	Meters	0.9144

Volume Formulas

$= \pi D$

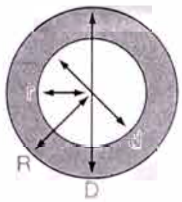
$= \frac{\pi D^2}{4}$



Ring

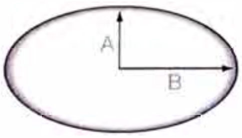
$^2 - r^2)$

$(D^2 - d^2)$



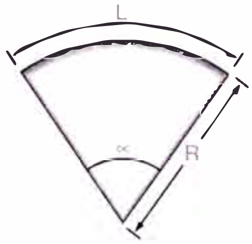
$\times B$

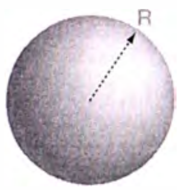
$^2 + B^2)$



$= \frac{RL}{2}$

$- \frac{2A}{R}$

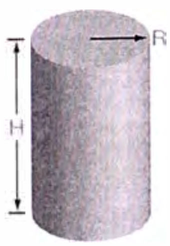




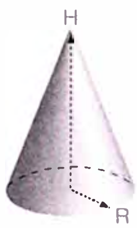
r

$(R + H)$

^2H

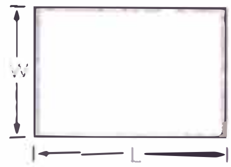


$\sqrt{(R^2 + H^2)}$



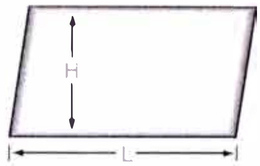
Rectangle

$A = L \times W$



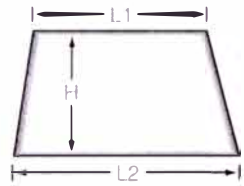
Parallelogram

$A = L \times H$



Trapezoid

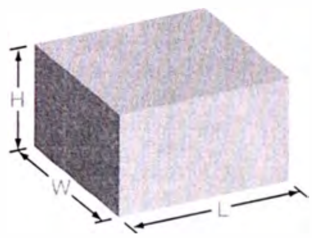
$A = \frac{(L1 + L2)\,H}{2}$



Rectangular Solid

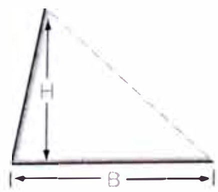
$A = 2\,(WL + LH + HW)$

$V = W \times L \times H$



Triangle

$A = \frac{B \times H}{2}$

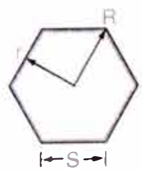


Hexagon

$S = R = 1.155r$

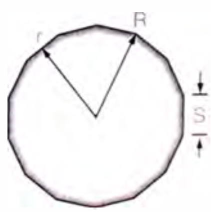
$A = 2.598\,S^2$

$= 3.464\,r^2$



Regular Polygon

$A = \frac{NSr}{2} = \frac{NS}{2}\sqrt{R2 - \frac{S^2}{4}}$



A = Area
V = Volume
C = Circumference
R = Radius
D = Diameter
S = Length of side
N = Number of sides
∝ = Angle

Fractional, Decimal and Millimeter Equivalents

Fraction	Decimals	Millimeters
1/64	.015625	0.397
1/32	.03125	0.794
3/64	.046875	1.191
1/16	.0625	1.588
5/64	.078125	1.984
3/32	.09375	2.381
7/64	.109375	2.778
1/8	.1250	3.175
9/64	.140625	3.572
5/32	.15625	3.969
11/64	.171875	4.366
3/16	.1875	4.763
13/64	.203125	5.159
7/32	.21875	5.556
15/64	.234375	5.953
1/4	.2500	6.350
17/64	.265625	6.747
9/32	.28125	7.144
19/64	.296875	7.541
5/16	.3125	7.938
21/64	.328125	8.334
11/32	.34375	8.731
23/64	.359375	9.128
3/8	.3750	9.525
25/64	.390625	9.922
13/32	.40625	10.319
27/64	.421875	10.716
7/16	.4375	11.113
29/64	.453125	11.509
15/32	.46875	11.906
31/64	.484375	12.303
1/2	.5000	12.700

1 mm = .03937"

Fraction	Decimals	Millimeters
33/64	.515625	13.097
17/32	.53125	13.494
35/64	.546875	13.891
9/16	.5625	14.288
37/64	.578125	14.684
19/32	.59375	15.081
39/64	.609375	15.478
5/8	.6250	15.875
41/64	.640625	16.272
21/32	.65625	16.669
43/64	.671875	17.066
11/16	.6875	17.463
45/64	.703125	17.859
23/32	.71875	18.256
47/64	.734375	18.653
3/4	.7500	19.050
49/64	.765625	19.447
25/32	.78125	19.844
51/64	.796875	20.241
13/16	.8125	20.638
53/64	.828125	21.034
27/32	.84375	21.431
55/64	.859375	21.828
7/8	.8750	22.225
57/64	.890625	22.622
29/32	.90625	23.019
59/64	.921875	23.416
15/16	.9375	23.813
61/64	.953125	24.209
31/32	.96875	24.606
63/64	.984375	25.003
1	1.000	25.400

.001" = .0254 mm

mm	inches	mm	inches
0.1	.0039	46	1.8110
0.2	.0079	47	1.8504
0.3	.0118	48	1.8898
0.4	.0157	49	1.9291
0.5	.0197	50	1.9685
0.6	.0236	51	2.0079
0.7	.0276	52	2.0472
0.8	.0315	53	2.0866
0.9	.0354	54	2.1260
1	.0394	55	2.1654
2	.0787	56	2.2047
3	.1181	57	2.2441
4	.1575	58	2.2835
5	.1969	59	2.3228
6	.2362	60	2.3622
7	.2756	61	2.4016
8	.3150	62	2.4409
9	.3543	63	2.4803
10	.3937	64	2.5197
11	.4331	65	2.5591
12	.4724	66	2.5984
13	.5118	67	2.6378
14	.5512	68	2.6772
15	.5906	69	2.7165
16	.6299	70	2.7559
17	.6693	71	2.7953
18	.7087	72	2.8346
19	.7480	73	2.8740
20	.7874	74	2.9134
21	.8268	75	2.9528
22	.8661	76	2.9921
23	.9055	77	3.0315
24	.9449	78	3.0709
25	.9843	79	3.1102
26	1.0236	80	3.1496
27	1.0630	81	3.1890
28	1.1024	82	3.2283
29	1.1417	83	3.2677
30	1.1811	84	3.3071
31	1.2205	85	3.3465
32	1.2598	86	3.3858
33	1.2992	87	3.4252
34	1.3386	88	3.4646
35	1.3780	89	3.5039
36	1.4173	90	3.5433
37	1.4567	91	3.5827
38	1.4961	92	3.6220
39	1.5354	93	3.6614
40	1.5748	94	3.7008
41	1.6142	95	3.7402
42	1.6535	96	3.7795
43	1.6929	97	3.8189
44	1.7323	98	3.8583
45	1.7717	99	3.8976
		100	3.9370

When You Know	Multiply by	To Find
Inches (in)	2.54	Centimeters (cm)
Feet (ft)	30.48	Centimeters (cm)
Yards (yds)	0.9	Meters (m)
Miles (mi)	1.6	Kilometers (km)

INFORMACION VARIADA DE CROMALOX

Tubular Heaters

Application Guidelines *(cont'd.)*

TUBULAR

Liquid Heating

Direct Immersion — Water and water solutions can generally be heated to any desired temperature. If liquid is under pressure, temperatures should not exceed the maximum sheath temperature of the element minus 100°F.

Note — Heated section of element must be immersed at all times when energized. Longer cold ends can be provided, if required.

Threaded fittings are available for mounting through tank walls.

Oil Heating

Steel sheath elements can be used for heating oils, heat transfer oils and other solutions not corrosive to steel sheath.

Air & Gas Heating

Use watt densities compatible with work temperatures. Refer to Technical section of this catalog. Heaters mounted horizontally must be supported to avoid sagging at high temperatures.

Proper spacing of supports may vary with application temperature, element diameter and sheath material. Generally 12 to 18" spacing of supports is adequate.

Max. Sheath Temperatures

To assure maximum life, tubular elements should not be operated beyond the temperatures in this tabulation:

Sheath Material	Max. Allowable Sheath Temp. (°F)
Copper	350
Steel	750
MONEL®	900
Stainless Steel	1200
INCOLOY®	1600
INCONEL®	1600

Metric Diameter Equivalents

Inches (±0.005)	Millimeter
0.5	12.7
0.475	12.07
0.43	10.92
0.375	9.53
0.315	8
0.26	6.6
0.246	6.25
0.2	5.08

Where air flowing over elements permits use of higher watt densities, make sure air flow is evenly distributed.

Allow approximately 1/8" per foot of element length for expansion and contraction of elements (i.e., 24" long element could expand 1/4" when energized).

Clamp-On Heating

Use watt densities compatible with work temperatures. Refer to Application Guide for Tubular Heating of Solids, Liquids, Air & Gas or use curve G-175S in Technical section. Heaters should be clamped tightly for good heat transfer but should be allowed to expand as they heat up. Heaters clamped too tightly will bow away from the heated surface which results in poor heating efficiency and possible heater failure. It is generally best to tighten the middle clamp first to hold the element. Other clamps should be tightened enough to hold, but back off 1/2 turn to allow for expansion and contraction.

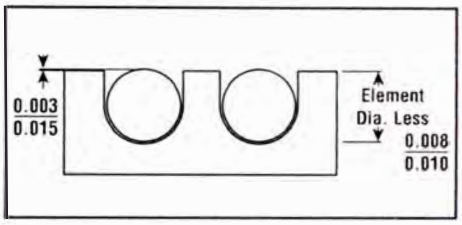
Heaters should be spaced on approximately two inch centers minimum.

Heaters are commonly installed by clamping into machined grooves for better heat transfer.

Note — Depth of groove should never exceed element diameter to assure positive clamping.

Grooves should be machined to the following tolerences:

Clamp-On Heating



WARNING — When insulation is used over elements, an air space must be provided between the elements and insulation. Insulation should never be in direct contact with heated section of elements.

Application Engineering

Is available from direct sales and engineering representatives. The largest, most experienced organization of field engineers in the country is ready to help solve any heating problem. Contact your Local Chromalox Sales office. (See back of catalog.)

Tubular Heating Application Guidelines

Product To Be Heated	Temperature Desired (°F)	Suggested Application	Sheath Material	Work Temperature (°F)	Allowable Watt Density (W/In²)
Solids					
Molds, Platens, Dies, Pipes, Tanks	Up to 1400	Clamp-On	INCOLOY®	Up to 300 Up to 500 Up to 800 Up to 1000 Up to 1200 Up to 1400	30 20 15 10 7 2.5
Liquids					
Water, Clean	Up to 250 Up to 550	Immersion Immersion	Copper INCOLOY®	250 550	Up to 80[2] 40
Water Solutions, Mild Corrosion[1], Corrosive[1]	Up to 200 Up to 200	Immersion Immersion	304SS INCOLOY®	200 200	50 50
Oil					
Low Viscosity Med. Viscosity High Viscosity	Up to 180	Immersion	Steel	Up to 180	23 15 6.5
Air & Gases					
Moving, 9'/sec Velocity	Up to 1500	In Ducts	INCOLOY®	500 800 1000 1200 1500	40 32 25 15 2
Still	Up to 1500	Ovens	INCOLOY®	700 1000 1200 1500	30 20 10 2

1. See Corrosion Guide in Technical section. 2. VDE - 50 W/In² max.

Tubular Heaters

Design & Installation Guidelines

Design Considerations

Sheath Material — For resisting corrosion inherent in the process or environment and for withstanding the sheath temperature required – Standard sheath materials are INCOLOY®, steel, copper and stainless steel (type 304). Other types of stainless steel, MONEL®, titanium and INCONEL® are available.

Job Requirements — The calculation of total heat requirements for an application is outlined in Technical section. For assistance, contact your Local Chromalox field sales engineer who will be glad to contribute his judgement, experience and knowledge in solving your heating problem.

After the specific heater size and rating has been tentatively selected, the watt density must be checked against the curves in Technical section.

If the heater selected has a watt density higher than stipulated by the curve, consider these alternatives:

1. Use more heaters of a lower watt density to obtain the required kW capacity.
2. Reduce the kW capacity needed by reducing heat losses and/or allowing for a longer heat-up time.

Watt Densities — The watt density of the element, or watts per square inch of element heated area, should be low for heating asphalt, molasses and other thick substances with low heat transferability. It can be higher for heating air, metals, liquids and other heat-conducting materials. See curves in Technical section for determining allowable watt densities.

When high operating temperatures are needed, watt density must be limited in order not to exceed the maximum sheath temperature. Watt density is given in the specifications for each tubular heater.

In general, a viscous material with low thermal conductivity requires a low watt density. Higher watt densities can be used with thinner liquids and with materials of high thermal conductivity. Premature loss of the element due to excessive temperature may result if the material's heat-take-away ability is low. Also, the material may be charred, carbonized or its chemical makeup altered by overheating.

Terminal Selection — Stocked tubulars are shipped with standard terminals, see Terminal Options in this section. Many other terminals and terminal end seals are available made to order.

CAUTION — Protect terminals from possible contamination from surrounding atmospheres such as oil fumes, chemical vapors from other processes, moisture, weather, etc. MgO insulation is hygroscopic.

Vacuums — Tubular heaters operate at higher temperatures in a vacuum because there is no air to take away the heat. Therefore, watt densities are recommended to be 20 to 30% lower. It is recommended terminals of the element be kept outside of the vacuum.

Code Compliance — Chromalox manufactures the highest quality heaters and controls and, where applicable, in compliance with such codes as the Canadian Standards Association (CSA), Underwriters Laboratories Inc. (UL) and Verification of Devices for Europe Testing and Certification Institute (VDE) and CE.

Installation Guidelines

Wiring — Must be in accordance with The National Electrical Code (NEC). It is important to use the correct wire gauge to carry the amperage required. A wire not large enough can overheat, become brittle and break. The ambient temperature must also be considered in choosing the correct type of wire and insulation. *Make sure wiring to terminals is tight. Keep terminals away from heat, if possible. (For higher temperatures, contact your Local Chromalox Sales office.)*

Mounting Methods — Elements can be supplied with threaded fittings for mounting thru walls of tanks, ovens, etc. Compression threaded fittings are also available for easy field installation. Rings, clips, brackets and washers can also be attached to elements for mounting purposes.

Easy Bending — To put heat where it is needed, tubular elements can be bent to fit most requirements. See following pages for customer bending and factory bending details. Bending should be done around a smooth round object such as a piece of pipe. For minimum bending radii, see Bending Guidelines.

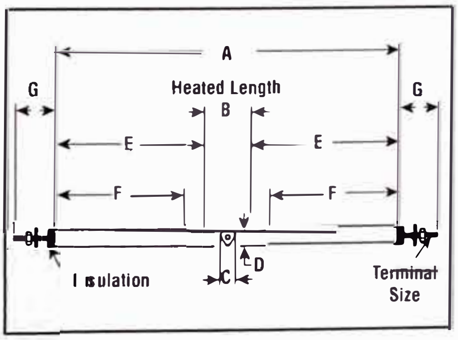
Triangular Cross-Section

These unique cross-sectioned elements are specially designed for high element surface temperature applications, and wherever extreme rigidity is required.

Triangulation — A patented extra step by Chromalox to increase insulation density and maximize heat transfer and operating life. This method of compaction increases uniformity of resistance wire spacing to help eliminate hot and cold spots. It also increases the rigidity of the element, which is an advantage in some applications.

The terminal ends of these elements are re-rounded to facilitate the use of threaded fittings or other mounting methods.

The heart shaped cross-section is recommended for certain heavy duty applications. It has added structural strength, achieved through die pressing, which resists deformation or sagging when installed in the flow of high velocity air or thick oils and compounds, or in high surface temperature air heating.



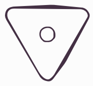
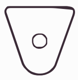
Sheath Material	Dimension (In.)							Terminal Size
	A	B	C	D	E	F	G	
Copper	1	1	3/8	21/64	3-3/8	1-1/2	1±1/16	#10-32
Steel or INCOLOY®	1	1	3/8	21/64	3-3/8	1-1/2	1±1/16	#10-32
Copper, Steel or INCOLOY®	1	1	1/2	15/32	3-7/16	2-1/2	13/16±1/16	#8-32

1. See complete heater dimensions in table on product pages.

Tubular Heaters

Modifications

World Leader in the Manufacture of Electric Heating Elements — Chromalox offers the most complete line of tubular heaters available. Standard diameters are:

Standard Diameters		Cross-Section Views
0.2 0.246 0.260 0.315 0.375 0.43 0.475	Round	
3/8" 1/2"	Triangular (heart shape)	
3/8" 7/16"	Flat Pressed	

Round Cross Section — Highly adaptable where elements must be bent — particularly if bending is performed in the field.

Triangular Cross Section — Patented process produces elements with the closest possible dimensional control.

Triangulated Cross Section — Flat pressed. Patented process provides large contact area for clamp-on applications. This means more efficient heat transfer, fewer elements since higher element ratings may be employed.

Voltage or Wattage — Heaters can be made for operation on any voltage and rated at any wattage suitable for the application within practical limits. For voltages higher than 480V, specify high voltage terminal construction. See Component section Tubular Heater (0.475 or 1/2" diameter only).

Special Wattage Distribution — Heaters can be made with higher wattages toward the end of the heated section to help offset losses in certain applications. Check with your Local Chromalox Sales office for additional information.

Tubing — Standard industrial grade wall thickness:

Repressed Bends — Tubulars can be bent to tighter radii at the factory. Bends are then repressed to ensure re-compaction of insulation for long life. Customer bending on larger radii does not require repressing. (See Factory Bending Guidelines in this section).

Sheath Length — Larger diameter heaters can be made in unspliced lengths up to 51 feet.

This eliminates the need for a spliced joint which is always a possible weak point that might cause premature heater failure.

Element Dia. (In.)	Max. Heater Length (Ft. ± 1%)
0.2	10
0.246	40
0.375	40
0.315	40
0.43	40
0.475	51
3/8	17±1/8"
1/2	17±1/8"

Note — Single-end elements have a maximum sheath length of 10 feet.

Terminal Construction — Many choices to suit your application. Tubular elements generally have a terminal for electrical connection at each end. Single end construction has both terminals at the same end.

UL and CSA — Chromalox tubular heaters can be furnished as UL Recognized and CSA Certified components with the addition of a terminal end seal. Terminal end seals can be added to stock elements and shipped in one week. (UL File E198480, Guide UBJY2, CSA File 40859). Use "end seal/moisture barrier" in place of end seal.

VDE and CE — Chromalox tubular heaters can be furnished as VDE Certified and CE certified. Contact your Local Chromalox Sales office.

Wide Choice of Sheath Materials — Available to meet a wide variety of applications. Standard sheath materials are: INCOLOY®, steel, type 304 and 316 stainless steel, copper, INCONEL® and MONEL®.

In addition, titanium and other 300 series stainless steel sheaths are available upon request. For applications requiring other materials, contact your Local Chromalox Sales office.

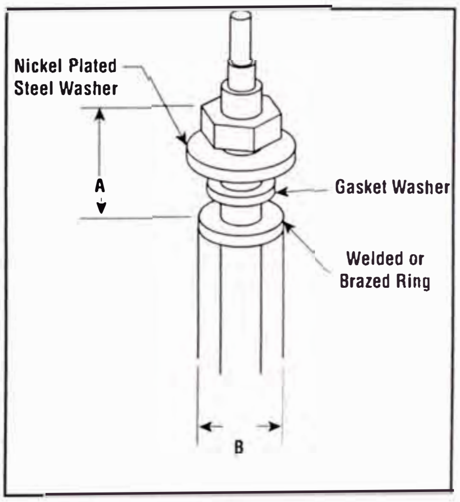
Cold Section — Longer cold ends can be supplied, as required, up to 20 inches. For longer cold ends, contact your Local Chromalox Sales office.

Factory Bending — Tighter bends can be made at the factory.

Tubular heaters can be formed to many different shapes to suit your application. This is done by specially designed bending tools and repressing dies for bending on many different radii.

Additional Features — Many additional features are available for the difficult jobs which require custom designed elements employing Chromalox's vast engineering experience.

Threaded Fittings



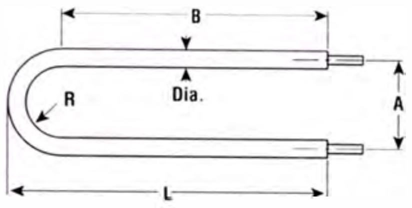
Element Dia. (In.)	Fitting Material	Mtg. Hole Dia. (In.)	Max. Wall Thickness (In.)	Thrd. Size F	Dimensions (In.) A	Dimensions (In.) B
0.246	Brass	13/32	7/32	3/8 - 24	15/32	7/8
0.315	Brass	15/32	5/16	7/16 - 28	13/16	7/8
3/8	Brass	17/32	5/16	1/2 - 28	13/16	7/8
1/2-0.475	Brass	21/32	5/16	5/8 - 24	13/16	1
0.246	Steel	13/32	7/32	3/8 - 24	15/32	7/8
0.315	Steel	15/32	5/16	7/16 - 28	13/16	7/8
3/8	Steel	17/32	5/16	1/2 - 28	13/16	7/8
1/2-0.475	Steel	21/32	5/16	5/8 - 24	13/16	1
0.246	Stainless Steel	13/32	7/32	3/8 - 24	15/32	7/8
0.315	Stainless Steel	15/32	5/16	7/16 - 28	13/16	7/8
3/8	Stainless Steel	17/32	5/16	1/2 - 28	13/16	7/8
1/2-0.475	Stainless Steel	21/32	5/16	5/8 - 24	13/16	1

Tubular Heaters

Factory Bending Guidelines

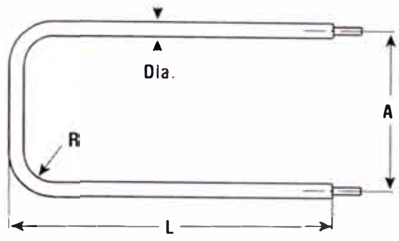
Note — OAL represents overall length.

Figure 1



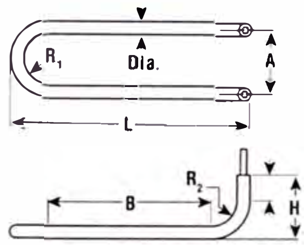
$OAL = 2L + 1.14R - 0.43" Dia.$

Figure 2



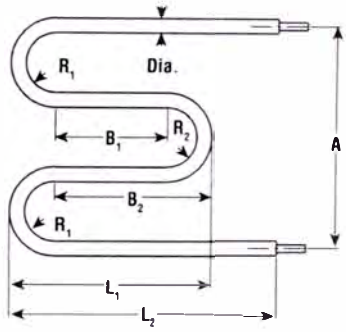
$OAL = 2L - 0.86R - 1.43" Dia. + A$

Figure 3



$OAL = 2H - 0.86R_2 - 2.86" Dia. + 2A + 1.14R_1$

Figure 4



$OAL = 2L_2 + 1.14R_1 - 1.29" Dia. + 2L_1 + 1.14R_2$

Factory Minimum Bends for Tubular Heaters

Element Dia. & Sheath	Inside $R_{1,2,3}$	Dimensions (In.)[1]				
		A	$B_{1,2}$	C	Inside D	E
∇ 1/2" INCOLOY®[5]	3/4	1-3/8	1	1-1/2	5	8
Steel & Copper	1/2	1-3/8	1	1-1/2	8	6
0.475" INCOLOY®	3/4	1-3/8	1	1-1/2	3	8
Steel & Copper	1/2	1-3/8	1	1-1/2	3	6
0.430" INCOLOY®	7/16	1-3/8	1	1	3	8
Steel & Copper	7/16	1-3/8	1	1	3	6
∇ 3/8" INCOLOY®[5]	9/16	1-3/16	1	1-1/2	3-3/4	5
Steel & Copper	3/8	1-3/16	1	1-1/2	6	3
0.375" INCOLOY®	3/8	1-3/16	1	1	2-5/8	5
Steel & Copper	3/8	1-3/16	1	1	2-5/8	3
0.315" INCOLOY®	9/16	1-3/16	1	1-1/2	2	5
Steel & Copper	5/16	1-3/16	1	1-1/2	2	3
0.260" INCOLOY®	1/4	1-1/8		1	1-7/8	5
Steel & Copper	1/4	1-1/8	1	1	1-7/8	3
0.245" INCOLOY®	3/8	1-1/16	1	1-3/16	1-1/2	5
Steel & Copper	1/4	1-1/16	1	1-3/16	1-1/2	3
0.200" INCOLOY®	1/4	1/4	1	3/4	1-1/4	5

To Order — Specify model, PCN, volts, watts, special features, if required, and quantity.

Specify for Factory Formed Tubulars:

A. Figure number.
B. A, $B_{1,2}$, C, D, E, H, J, K, $L_{1,2}$ and $R_{1,2,3}$ dimension as required.
C. N - number of turns, Dia. - Element Diameter- aid < - angle as required.
D. Material for threaded fittings.
E. Special terminal type.
F. Position of crown (flat side) of element (TC, TI, TS only).
G. Submit sketch with special details.

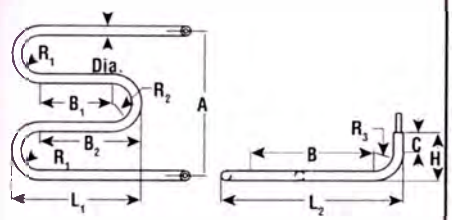
Notes —

1. These are general guidelines only. Special dimensions and configurations are possible. Contact your Local Chromalox Sales office.
2. A dimension can be less if no fittings are required.
3. C dimension may need to be greater if special fittings are used.
4. E dimension is a minimum when R dimension is less than customer minimum bending radius.
5. Heart Shaped cross-section only.

Tubular Heaters

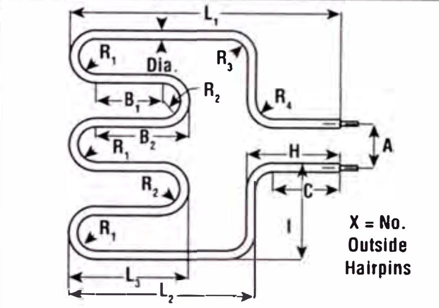
Factory Bending Guidelines *(cont'd.)*

Figure 5



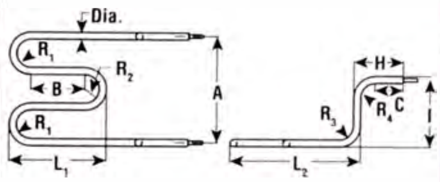
OAL = $2H + 0.86R_3 - 3.72\text{Dia.} + 2L_1 + 2L_2 + 2.28R_1 + 1.14R_2$

Figure 6



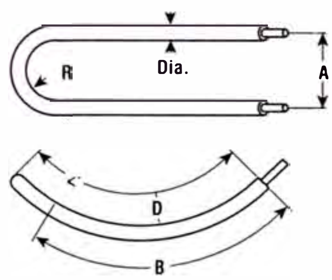
OAL = $2L_2 + 2H + 2I + 2L_3(X-1) - 0.86R_3 - 0.86R_4 - 4.86\text{Dia.} + 1.14R_1(X) + 1.14R_2(X-1) - (2X-1)0.43\text{Dia.}$

Figure 7



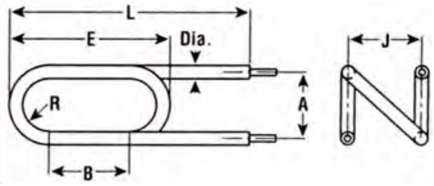
OAL = $2H + 0.86R_3 - 0.86R_4 - 6.15\text{Dia.} + 2I + 2L_1 + 2.28R_1 + 1.14R_2$

Figure 8



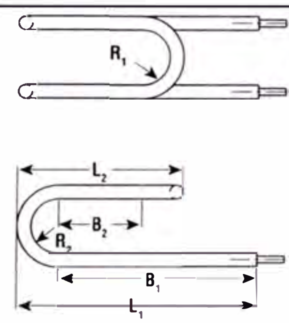
OAL = $0.0175(<^{\circ})(2D/2 + \text{Dia.}) + 1.14R + 0.43\text{Dia.}$

Figure 9



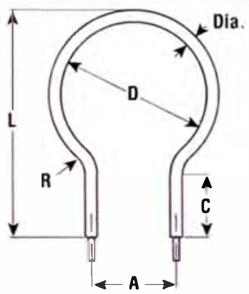
OAL = $2L + 3.42R - 1.29\text{Dia.} + 2E$

Figure 10



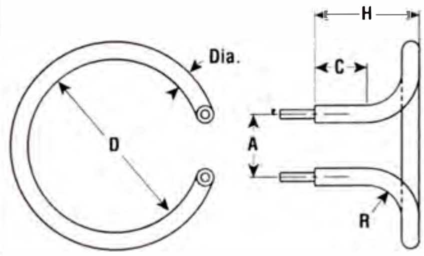
OAL = $2L_1 + 2.28R_2 - 1.29\text{Dia.} + 2L_2 + 1.14R_1$

Figure 11



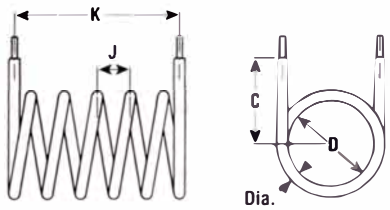
OAL = $(D + \text{Dia.})3.14 + 1.14R + 2C + 3.71\text{Dia.} - A$

Figure 12



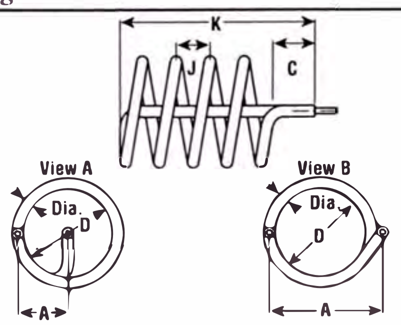
OAL = $(D + \text{Dia.})3.14 + 1.14R + 2H + 3.28\text{Dia.} - A$

Figure 13



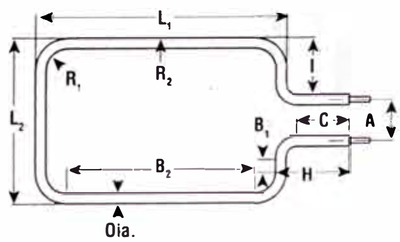
OAL = $[(D + \text{Dia.})(3.14)(\text{Number of } 360^{\circ}\text{'s})] + 2C$

Figure 14



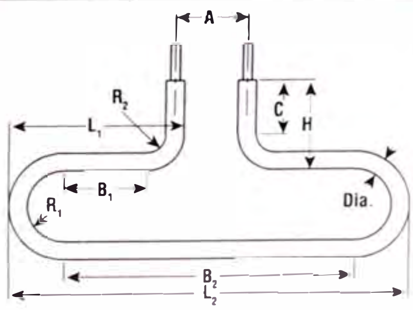
OAL = $[(D + \text{Dia.})(3.14)(\text{No. } 360^{\circ}\text{'s})] + (D/2) + K + C$

Figure 15



OAL = $2H + 2L_2 + 2L_1 - A - 1.72R_1 - 0.86R_2 - 6.29\text{Dia.}$

Figure 16

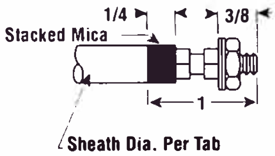
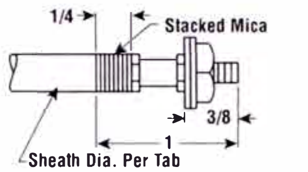
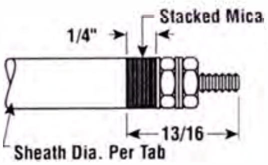
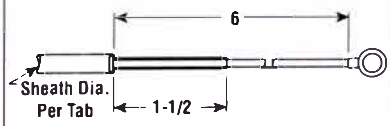
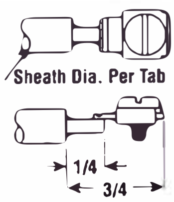
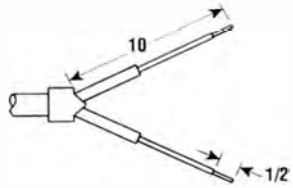
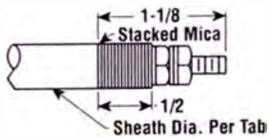
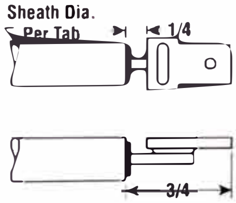
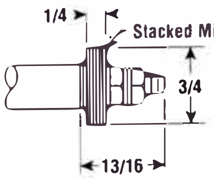
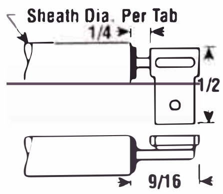
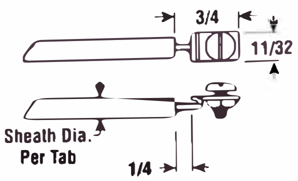
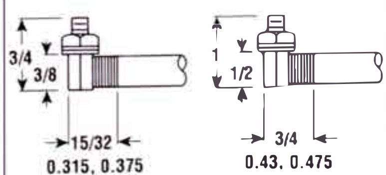


OAL = $2L_2 + 2H - A - 2.28R_1 - 0.86R_2 - 3.29\text{Dia.}$

Tubular Heaters

Terminal Options

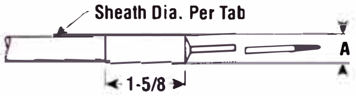
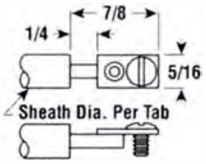
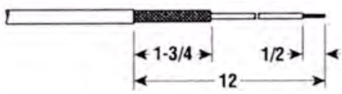
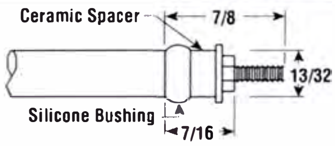
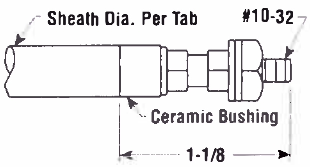
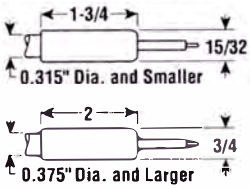
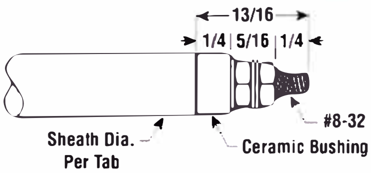
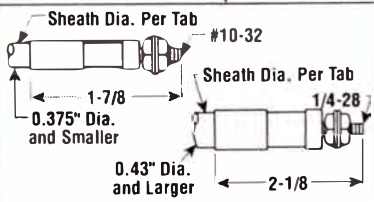
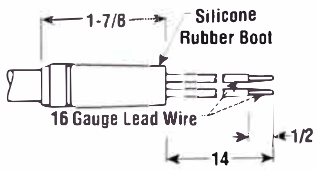
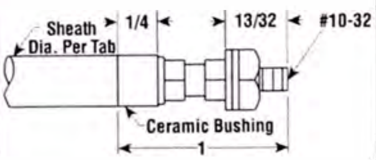
Standard, Alternate and Moisture Resistant Terminals

Type	Description	Sheath Dia. (In.)	Max. Volts	Type	Description	Sheath Dia. (In.)	Max. Volts
Standard Terminals							
3	 Welded on threaded pin (#10-32), nut and washer	0.315 0.375 0.43 0.475	480 480 480 480	**28**	 Welded on threaded pin (#8-32), nut and washer	0.246 0.25 0.26	240 240 240
4	 Threaded terminal pin (#8-32), nut and washer	0.43 0.475 0.5	480 480 480	**34**	 Leadwire with sleeving, #6 Connector	0.2	240
8	 Terminal connector - 5/16" long, #10-32 machine screw	0.246 0.25 0.26 0.315 0.375 0.43 0.475	240 240 240 240 240 240 240	**STRI/ STRS/ STRC**	 Single-end tubular termination, 10" leadwire	0.315 0.475	240 480
Alternate Terminals							
23	 Threaded terminal pin (#8-32), nut and washer	0.43 0.475 0.5	600 600 600	**30**	 Ark-Les[R] Connector	All	240
24	 Threaded terminal pin (#8-32), nut and washer	0.43 0.475 0.5	600 600 600	**30R**	 Right-angle Ark-Les[R] Connector	All	240
25	 5/16" Long #10-32 Bolt with nut	0.246 0.25 0.26 0.315 0.375 0.43 0.475	240 240 240 240 240 240 240	**37**	 Extra mechanical strength # 8-32 thread	0.315 0.375 0.43 0.475	240 240 480 480

Tubular Heaters

Terminal Options *(cont'd.)*

Standard, Alternate and Moisture Resistant Terminals

Type	Description	Sheath Dia. (In.)	Max. Volts	Type	Description	Sheath Dia. (In.)	Max. Volts
Alternate Terminals *(cont'd.)*							
38	Dia. (In.) / A: 0.315 — 3/8 0.375 — 1/2 0.43, 0.475 — 9/16  Leadwire type terminal	0.315 0.375 0.43 0.475	480 480 480 480	48	 Narrow profile terminal connector, 5/16" Long #10-32 or #8-32 machine screw.	0.246 0.25 0.26 0.315 0.375 0.43 0.475	240 240 240 240 240 240 240
47-L	 105°C leadwire, silicone sleeving	0.315 0.375 0.43 0.475	480 480 480 480	49/50	 Silicone bushing/ceramic disc seal, epoxy/RTV/silicone resin can be placed under bushing (type 49, #8-32 thread/ type 50, #10-32 thread)	0.315 0.43 0.475 0.5	480 480 480 480
47-M	 200°C leadwire, silicone sleeving	0.315 0.375 0.43 0.475	480 480 480 480	53	 Air set cement, >700°F temp.	0.315 0.375 0.43 0.475	480 480 480 480
Moisture Resistant Terminals Note: Type 26 is the only Hermetic Seal, all others are Barriers.							
13	 EPDM rubber vulcanized to sheath and leadwire, max. temp. 220º F	0.246 0.25 0.26 0.315 0.375 0.43 0.475 0.5	240 240 240 300 480 480 480 550	39/40	 Epoxy, 194°F max. temp., (type 39) RTV, 350°F max. temp., (type 40)	0.43 0.475 0.5	480 480 480
26	 Hermetic seal, 1000°F max. element temp.	0.315 0.375 0.43 0.475 0.5	240 480 480 480 480	42	 Silicone rubber boot potted with RTV sealant, 0.475" dia. single-end only	0.475	480
39/40	 Epoxy, 194°F max. temp.. (type 39) RTV, 350°F max. temp., (type 40)	0.315 0.375 0.43	480 480 480	V VP A	V Seal (280°F) V Seal Plus (392°F) A Seal (Sheath Limit) RX Seal (600°F) G Seal (1100°F)	0.26 to 0.475	480

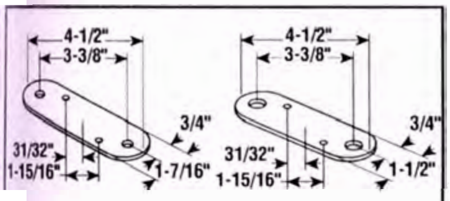
Tubular Heaters

Customer Bending & Accessories

Brackets, Discs & Clips

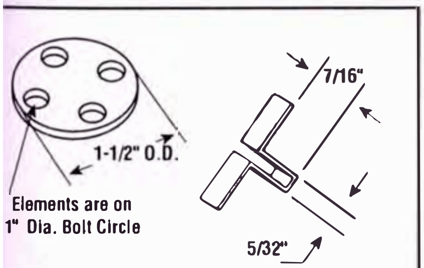
Brackets, Discs and Clips — Various types of brackets and clips can be fastened to the heaters to facilitate installation. The following are typical.

For other brackets to meet your installation requirements, contact your Local Chromalox Sales office.



Flange - Support 0.315" Element

Flange - Support 0.475" Element



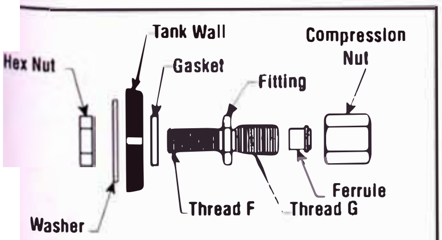
Disc

Clip-Anchor

Compression Fittings

Field Installed Compression Fittings — For 0.475, 0.315 and 0.246" diameter elements. Available in both brass and steel, these fittings have been tested to 600 psi hydrostatic pressures and may be used in tank walls for liquid immersion as well as in air ducts and a variety of other applications.

Compression fittings do not require brazing and can be field mounted in minutes. They may be positioned anywhere along the cold section of the heating element. Do not position over heated section. Cannot be installed over terminal Type #26 (Hermetic Seal), and some other terminals wider than sheath diameter.



Compression Fittings for 0.475, 0.315 and 0.246" Diameter Elements for Installation in the Field.

Customer Bending

Simple element configurations can be made easily in the field from stocked tubulars listed in this catalog. **If copper or stainless sheaths are selected, specify "To be fully annealed for bending."** Elements can be bent around any round, smooth surface of the right diameter.

Three precautions should be observed to prevent damage to the element:

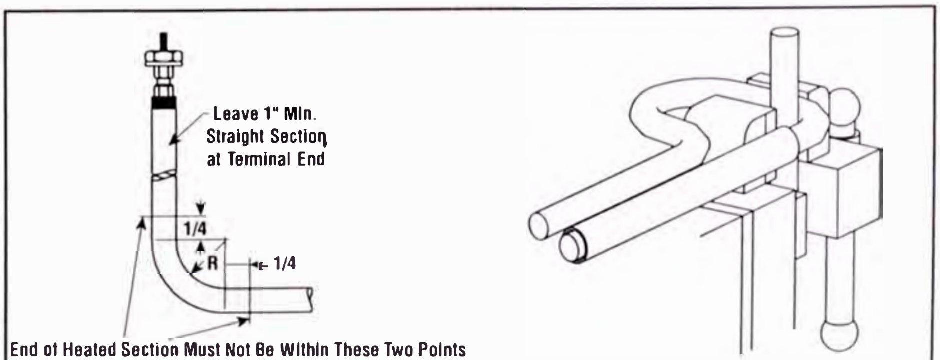
1. Radius of the round object, around which the element is bent, should be no smaller than the minimum radius for the element, as shown in the table below.
2. Sharp edges of tools should not be permitted to gouge the element sheath while bending.
3. End of cold section of the element should not fall within the bend nor come within 1/4" of either side of the bend. To locate end of cold section, see dimensions for the element on its catalog page and determine as follows:
   Example — To locate end of cold section of TRI-1645 tubular element, refer to the individual product page.
   Sheath length: 16"
   Less heated length: 9-1/8"
   Total cold length: 6-7/8"
   Cold length of each end
   (6-7/8" ÷ 2) = 3-7/16"

Terminal end bending can be done with pipe section of slightly larger diameter than sheath. A minimum 1" straight section should be left at the end. **Note —** To protect sheath, copper sheet can be bolted to vise jaws and end of pipe can be filed to remove sharp edge.

Before bending, it is best to lay out and dimension the configuration. Also, it is best to start bending from the center of the heater and work toward the terminal ends.

Sheath Material	Degree of Bend	Customer Bending — Min. Inside Radius (In.)								
		1/2"	0.475"	0.430"	3/8"	0.375"	0.315"	0.26"	0.246"	0.2"
Copper	90 180	3-1/2 3-1/2	1-1/2 1-1/2	1-5/16 1-5/16	2-5/16 2-5/16	1-1/8 1-1/8	15/16 15/16	7/8 7/8	3/4 3/4	Not Std. Mat. in this Dia.
Steel	90 180	2-1/2 2-1/2	1-1/2 1-1/2	1-5/16 1-5/16	1-7/8 1-7/8	1-1/8 1-1/8	15/16 15/16	7/8 7/8	3/4 3/4	
Alloy	90 180	2-1/2 2-1/2	1-1/2 1-1/2	1-5/16 1-5/16	1-7/8 1-7/8	1-1/8 1-1/8	15/16 15/16	7/8 7/8	3/4 3/4	5/8 5/8

1. For radii smaller than shown, special processing is required to achieve good life qualities. Contact your Local Chromalox Sales office.



Bending

Material[1]	Dimensions (In.)				Thread Size		PCN
	Elem. Dia.	Mtg. Hole Dia.	Max. Wall Thickness	Assembled Overall Length	F	G	
Brass	0.246	13/32	7/32	1-7/16	3/8-24	1/2-24	144151
Brass	0.315	15/32	5/16	1-1/2	7/16-28	1/2-24	144143
Brass	0.475	21/32	5/16	2	5/8-24	3/4-24	144135
Steel	0.246	13/32	7/32	1-3/4	3/8-24	1/2-24	143474
Steel	0.315	15/32	5/16	1-3/4	7/16-28	1/2-24	143466
Steel	0.475	21/32	5/16	2-1/8	5/8-24	3/4-24	143458

To Order—Specify PCN, material, element diameter and quantity. Available in pairs only

1. Available only in brass and steel at this time.

Technical Information

Heat Transfer Fundamentals & Thermodynamic Properties

Heat Transfer Fundamentals

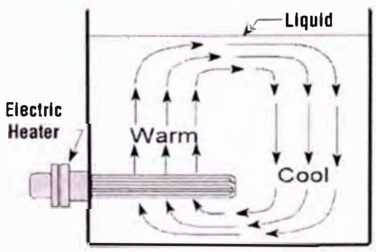
The principles of heat transfer are well understood and are briefly described below. Heat energy is transferred by three basic modes. All heating applications involve each mode to a greater or lesser degree.

- Conduction
- Convection
- Radiation

Conduction is the transfer of heat energy through a solid material. Metals such as copper and aluminum are good conductors of heat energy. Glass, ceramics and plastics are relatively poor conductors of heat energy and are frequently used as thermal insulators. All gases are poor conductors of heat energy. A combination of expanded glass or ceramic fiber filled with air is excellent thermal insulation. Typical conduction heating applications include platen heating (cartridge heaters), tank heating (strip and ring heaters), pipe tracing and other applications where the heater is in direct contact with the material being heated.

Convection is the transfer of heat energy by circulation and diffusion of the heated media. It is the most common method of heating fluids or gases and also the most frequent application of electric tubular elements and assemblies. Fluid or gas in direct contact with a heat source is heated by conduction causing it to expand. The expanded material is less dense or lighter than its surroundings and tends to rise. As it rises, gravity replaces it with colder, denser material which is then heated, repeating the cycle. This circulation pattern distributes the heat energy throughout the media. Forced convection uses the same principle except that pumps or fans move the liquid or gas instead of gravity.

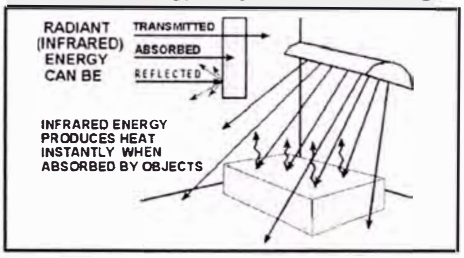
Convection in a Liquid



Typical convection heating applications include water and oil immersion heating, air heating, gas heating and comfort air heating.

Radiation is the transfer of heat energy by electromagnetic (infrared) waves and is very different from conduction and convection. Conduction and convection take place when the material being heated is in direct contact with the heat source. In infrared heating, there is no direct contact with the heat source. Infrared energy travels in straight lines through space or vacuum (similar to light) and does not produce heat energy until absorbed. The converted heat energy is then transferred in the material by conduction or convection.

Radiant Energy (Infrared) Heating



All objects above "absolute zero" temperature radiate infrared energy with warmer objects radiating more energy than cooler objects. Infrared energy radiating from a hot object (heating element) strikes the surface of a cooler object (work piece), is absorbed and converted to heat energy. Paint drying by radiant heaters is a typical application of infrared heating. The most important principle in infrared heating is that infrared energy radiates from the source in straight lines and **does not become heat energy until absorbed by the work product.**

Thermodynamic Properties

All materials have basic physical constants and thermodynamic properties. These constants are used in the evaluation of the materials and in heat energy calculations. The constants and properties most often used are:

- Specific Heat (C_p)
- Heat of Fusion (H_{fus})
- Heat of Vaporization (H_{vap})
- Thermal Conductivity (k)
- Thermal Resistivity (R)

Specific Heat (Quantity of Heat Energy) — All materials contain or absorb heat energy in differing amounts. The quantity of heat energy or thermal capacity of a particular material is called its **specific heat**.

The specific heat of a substance is defined as the amount of heat energy required to raise one pound of the material by one degree Fahrenheit. Specific heat factors are usually defined as British thermal units per pound per degree Fahrenheit **(Btu/lb/°F)**. The specific heat of most materials is constant at only one temperature and usually varies to some degree with temperature. Water has a specific heat of 1.0 and absorbs large quantities of heat energy. Air, with a specific heat of 0.24, absorbs considerably less heat energy per pound.

Heat of Fusion or Vaporization — Many materials can change from a solid to a liquid to a gas. For the change of state to occur, heat energy must be added or released. Water is a prime example in that it changes from a solid (ice) to a liquid (water) to a gas (steam or vapor). If the change is from a solid to a liquid to a gas, heat energy is added. If the change is from a gas to a liquid to a solid, heat energy is released. These energy requirements are called the **heat of fusion** and the **heat of vaporization**. They are expressed as Btu per pound **(Btu/lb)**.

- **Heat of Fusion** is the amount of energy required to transform a material from a solid to a liquid (or the reverse) at the same temperature. Water has a heat of fusion of 143 Btu/lb.
- **Heat of Vaporization** is the amount of energy required to transform a material from a liquid to a gas (or the reverse) at the same temperature. Water has a high heat of vaporization, 965 Btu/lb. Water can transfer large amounts of heat energy in the form of condensing steam.

Thermal Conductivity is the ability of a material to transmit heat energy by conduction. Thermal conductivity is identified as *"k"* and is usually expressed in British thermal units per linear inch (or foot) per hour per square foot of area per degree Fahrenheit. **(Btu/in/hr/ft²/°F) or (Btu/ft/hr/ft²/°F)**. *"k"* factors are used extensively in comfort heating applications to rate the effectiveness of building construction and other materials as thermal insulation. *"k"* factors are also used in the calculation of heat losses through pipe and tank insulation.

Thermal Resistivity or "R" is the inverse of thermal conductivity. Insulating materials are rated by "R" factors. The higher the "R" factor, the more effective the insulation.

Technical Information

Determining Heat Energy Requirements

General Applications

The objective of any heating application is to raise or maintain the temperature of a solid, liquid or gas to or at a level suitable for a particular process or application. Most heating applications can be divided into two basic situations; applications which require the maintenance of a constant temperature and applications or processes which require work product to be heated to various temperatures. The principles and calculation procedures are similar for either situation.

Constant Temperature Applications

Most constant temperature applications are special cases where the temperature of a solid, liquid or gas is maintained at a constant value regardless of ambient temperature. Design factors and calculations are based on steady state conditions at a fixed difference in temperature. Heat loss and energy requirements are estimated using "worst case" conditions. For this reason, determining heat energy requirements for a constant temperature application is relatively simple. Comfort heating (constant air temperature) and freeze protection for piping are typical examples of constant temperature applications. The equations and procedures for calculating heat requirements for several applications are discussed later in this section.

Variable Temperature Applications

Variable temperature (process) applications usually involve a start-up sequence and have numerous operating variables. The total heat energy requirements for process applications are determined as the sum of these calculated variables. As a result, the heat energy calculations are usually more complex than for constant temperature applications. The variables are:

Total Heat Energy Absorbed — The sum of all the heat energy absorbed during start-up or operation including the work product, the latent heat of fusion (or vaporization), make up materials, containers and equipment.

Total Heat Energy Lost — The sum of the heat energy lost by conduction, convection, radiation, ventilation and evaporation during start-up or operation.

Design Safety Factor — A factor to compensate for unknowns in the process or application.

Process Applications

The selection and sizing of the installed equipment in a process application is based on the **larger of two calculated heat energy requirements**. In most process applications, the start-up and operating parameters represent two distinctly different conditions in the same process. The heat energy required for start-up is usually considerably different than the energy required for operating conditions. In order to accurately assess the heat requirements for an application, each condition must be evaluated. The comparative values are defined as follows:

- **Calculated heat energy required for process start-up over a specific time period.**
- **Calculated heat energy required to maintain process temperatures and operating conditions over a specific cycle time.**

Determining Heat Energy Absorbed

The first step in determining total heat energy requirements is to determine the heat energy absorbed. If a change of state occurs as a direct or indirect part of the process, the heat energy required for the change of state must be included in the calculations. This rule applies whether the change occurs during start-up or later when the material is at operating temperature. Factors to be considered in the heat absorption calculations are shown below:

Start-Up Requirements (Initial Heat-Up)

- Heat absorbed during start-up by:
  - Work product and materials
  - Equipment (tanks, racks, etc.)
- Latent heat absorption at or during start-up:
  - Heat of fusion
  - Heat of vaporization
- Time factor

Operating Requirements (Process)

- Heat absorbed during operation by:
  - Work product in process
  - Equipment loading (belts, racks, etc.)
  - Make up materials
- Latent heat absorption during operation:
  - Heat of fusion
  - Heat of vaporization
- Time (or cycle) factor, if applicable

Determining Heat Energy Lost

Objects or materials at temperatures above the surrounding ambient lose heat energy by conduction, convection and radiation. Liquid surfaces exposed to the atmosphere lose heat energy through evaporation. The calculation of total heat energy requirements must take these losses into consideration and provide sufficient energy to offset them. Heat losses are estimated for both start-up and operating conditions and are added into the appropriate calculation.

Heat Losses at Start-Up — Initially, heat losses at start-up are zero since the materials and equipment are all at ambient temperature. Heat losses increase to a maximum at operating temperature. Consequently, start-up heat losses are usually based on an average of the loss at start-up and the loss at operating temperature.

Heat Losses at Operating Temperature — Heat losses are at a maximum at operating temperature. Heat losses at operating temperature are taken at full value and added to the total energy requirements.

Estimating Heat Loss Factors

The heat losses just discussed can be estimated by using factors from the charts and graphs provided in this section. Total losses include radiation, convection and conduction from various surfaces and are expressed in watts per hour per unit of surface area per degree of temperature **(W/hr/ft²/°F)**.

Note — Since the values in the charts are already expressed in watts per hour, they are not influenced by the time factor *"t"* in the heat energy equations.

Design Safety Factors

In many heating applications, the actual operating conditions, heat losses and other factors affecting the process can only be estimated. A safety factor is recommended in most calculations to compensate for unknowns such as ventilation air, thermal insulation, make up materials and voltage fluctuations. As an example, a voltage fluctuation (or drop) of 5% creates a 10% change in the wattage output of a heater.

Safety factors vary from 10 to 25% depending on the level of confidence of the designer in the estimate of the unknowns. The safety factor is applied to the sum of the calculated values for heat energy absorbed and heat energy lost.

Technical Information

Determining Heat Energy Requirements

Total Heat Energy Requirements

The total heat energy (Q_T) required for a particular application is the sum of a number of variables. The basic total energy equation is:

$Q_T = Q_M + Q_L$ + Safety Factor

Where:
Q_T = The total energy required in kilowatts
Q_M = The total energy in kilowatts absorbed by the work product including latent heat, make up materials, containers and equipment
Q_L = The total energy in kilowatts lost from the surfaces by conduction, convection, radiation, ventilation and evaporation
Safety Factor = 10% to 25%

While Q_T is traditionally expressed in Btu's (British Thermal Units), it is more convenient to use watts or kilowatts when applying electric heaters. Equipment selection can then be based directly on rated heater output. Equations and examples in this section are converted to watts.

Basic Heat Energy Equations

The following equations outline the calculations necessary to determine the variables in the above total energy equation. Equations 1 and 2 are used to determine the heat energy absorbed by the work product and the equipment. The specific heat and the latent heat of various materials are listed in this section in tables of properties of non-metallic solids, metals, liquids, air and gases. Equations 3 and 4 are used to determine heat energy losses. Heat energy losses from surfaces can be estimated using values from the curves in charts G-114S, G-125S, G-126S or G-128S. Conduction losses are calculated using the thermal conductivity or *"k"* factor listed in the tables for properties of materials.

Equation 1 — **Heat Energy Required to Raise the Temperature of the Materials (No Change of State).** The heat energy absorbed is determined from the weight of the materials, the specific heat and the change in temperature. Some materials, such as lead, have different specific heats in the different states. When a change of state occurs, two calculations are required for these materials, one for the solid material and one for the liquid after the solid has melted.

$$Q_A = \frac{\text{Lbs} \times C_p \times \Delta T}{3412 \text{ Btu/kW}}$$

Where:
Q_A = kWh required to raise the temperature
Lbs = Weight of the material in pounds
C_p = Specific heat of the material (Btu/lb/°F)
ΔT = Change in temperature in °F [$T_{2\,(Final)} - T_{1\,(Start)}$]

Equation 2 — **Heat Energy Required to Change the State of the Materials.** The heat energy absorbed is determined from the weight of the materials and the latent heat of fusion or vaporization.

$$Q_F \text{ or } Q_V = \frac{\text{Lbs} \times H_{fus} \text{ or } H_{vap}}{3412 \text{ Btu/kW}}$$

Where:
Q_F = kWh required to change the material from a solid to a liquid
Q_V = kWh required to change the material from a liquid to a vapor or gas
Lbs = Weight of the material in pounds
Q_{fus} = Heat of fusion (Btu/lb/°F)
Q_{vap} = Heat of vaporization (Btu/lb/°F)

Equation 3 — **Heat Energy Lost from Surfaces.** The heat energy lost from surfaces by radiation, convection and evaporation is determined from the surface area and the loss rate in watts per square foot per hour.

$$Q_{LS} = \frac{A \times \text{Ls}}{1000 \text{ W/kW}}$$

Where:
Q_{LS} = kWh lost from surfaces by radiation, convection and evaporation
A = Area of the surfaces in square feet
Ls = Loss rate in watts per square foot at final temperature (W/ft²/hr from charts)[1]

Equation 4 — **Heat Energy Lost by Conduction through Materials or Insulation.** The heat energy lost by conduction is determined by the surface area, the thermal conductivity of the material, the thickness and the temperature difference across the material.

$$Q_{LC} = \frac{A \times k \times \Delta T}{d \times 3412 \text{ Btu/kW}}$$

Where:
Q_{LC} = kWh lost by conduction
A = Area of the surfaces in square feet
k = Thermal conductivity of the material in Btu/inch/square foot/hour (Btu/in/ft²/hr)
ΔT = Temperature difference in °F across the material [$T_2 - T_1$]
d = Thickness of the material in inches

Summarizing Energy Requirements

Equations 5a and 5b are used to summarize the results of all the other equations described on this page. These two equations determine the total energy requirements for the two process conditions, start-up and operating.

Equation 5a — **Heat Energy Required for Start-Up.**

$$Q_T = \left(\frac{Q_A + Q_F\,[\text{or } Q_V]}{t} + \frac{Q_{LS} + Q_{LC}}{2}\right)(1 + SF)$$

Where:
Q_T = The total energy required in kilowatts
Q_A = kWh required to raise the temperature
Q_F = kWh required to change the material from a solid to a liquid
Q_V = kWh required to change the material from a liquid to a vapor or gas
Q_{LS} = kWh lost from surfaces by radiation, convection and evaporation
Q_{LC} = kWh lost by conduction
SF = Safety Factor (as a percentage)
t = Start-up time in hours[2]

Equation 5b — **Heat Energy Required to Maintain Operation or Process[3].**

$$Q_T = (Q_A + Q_F\,[\text{or } Q_V] + Q_{LS} + Q_{LC})(1 + SF)$$

Where:
Q_T = The total energy required in kilowatts
Q_A = kWh required to raise the temperature of added material
Q_F = kWh required to change added material from a solid to a liquid
Q_V = kWh required to change added material from a liquid to a vapor or gas
Q_{LS} = kWh lost from surfaces by radiation, convection and evaporation
Q_{LC} = kWh lost by conduction
SF = Safety Factor (as a percentage)

Equipment Sizing & Selection

The size and rating of the installed heating equipment is based on the larger of calculated results of Equation 5a or 5b.

Notes —

1. **Loss Factors** from charts in this section include losses from radiation, convection and evaporation unless otherwise indicated.
2. **Time (*t*)** is factored into the start-up equation since the start up of a process may vary from a period of minutes or hours to days.
3. **Operating Requirements** are normally based on a standard time period of one hour (t = 1). If cycle times and heat energy requirements do not coincide with hourly intervals, they should be recalculated to a hourly time base.

Technical Information

Determining Heat Energy Requirements - Heating Liquids

Typical Steps in Determining Total Energy Requirements

Most heating problems involve three basic steps:

1. **Determine** required kW capacity for bringing application up to operating temperature in the desired time.
2. **Calculate** the kW capacity required to maintain the operating temperature.
3. **Select** the number and type of heaters required to supply the kW required.

Note — Some applications, such as instantaneous heating of gas or air in ducts, comfort heating and pipe tracing only require calculation of the operating kW and selection of heaters.

Design Considerations

In order to calculate the initial and operating kW capacity requirements, the following factors should be considered:

- Specified heat-up time
- Start-up and operating temperatures
- Thermal properties of material(s) being heated
- Weight of material(s) being heated
- Weight of container and equipment being heated
- Weight of make up material (requirements per hour)
- Heat carried away by products being processed or equipment passing through heated area
- Heat absorbed due to a change of state
- Thermal properties and thickness of insulation
- Heat losses from the surface of material and/or container to the surrounding environment.

Liquid Heating Example

One of the most common electric heating applications is the direct immersion heating of liquids. The following example illustrates the steps in determining total energy requirements of a typical direct immersion application.

Application — A final rinse tank requires water at 180°F. The tank is 2 feet wide by 4 feet long by 2 feet high and is uninsulated with an open top. The tank is made of 3/8" steel and contains 100 gallons of water at 70°F at start up. Make up water with a temperature of 60°F is fed into the tank at the rate of 40 gallons per hour during the process. There is an exhaust hood over the tank and the relative humidity in the area is high. Work product is 300 lbs. of steel per hour.

Example — Heat the water to 180°F in 3 hours and heat 40 gallons per hour of make up water from 60°F to 180°F thereafter.

Specific heat of steel = 0.12 Btu/lb/°F
Specific heat of water = 1.00 Btu/lb/°F
Weight of steel = 490 lb/ft³
Weight of water = 8.345 lb/gal

To Find Initial (Start-Up) Heating Capacity —

$$Q_S = \left(\frac{Q_A + Q_C}{t} + \frac{Q_{LS}}{2}\right)(1 + SF)$$

Where:
Q_S = The total energy required in kilowatts
Q_A = kWh required to raise the temperature of the water
Q_C = kWh required to raise the temperature of the steel tank
Q_{LS} = kWh lost from surfaces by radiation, convection and evaporation
SF = Safety Factor
t = Start-up time in hours (3)

kW to Heat Water —

$$\frac{100 \text{ gal} \times 8.345 \text{ lb/gal} \times 1.0 \text{ Btu/lb } (180 - 70°F)}{3412 \text{ Btu/kW}}$$

Q_A = 26.9 kW

kW to Heat Steel Tank —

Lbs of steel = Area x thickness x 490 lbs/ft³

$$32 \text{ ft}^2 \times \frac{0.375 \text{ in.}}{12} \times 490 \text{ lb/ft}^3 = 490 \text{ lbs}$$

$$\frac{490 \text{ lbs} \times 0.12 \text{ Btu/lb } (180 - 70°F)}{3412 \text{ Btu/kW}}$$

Q_C = 1.89 kW

Heat Losses from Surfaces —

Q_{LS} = Lsw + Lsc

Where:
Q_{LS} = kWh lost from all surfaces
Lsw = Losses from the surface of the water
Lsc = Losses from the surfaces of the tank

Lsw = Surface losses from water (Graph G126S, Curve 2 fps @ 60% rh)

$$\frac{8 \text{ ft}^2 \times 550 \text{ W/ft}^2}{1000 \text{ W/kW}} = 4.4 \text{kW}$$

Lsc = Surface losses from uninsulated tank walls (Graph G125S)

$$\frac{32 \text{ ft}^2 \times 0.6 \text{ W/ft}^2 \times (180 - 70°F)}{1000 \text{ W/kW}} = 2.11 \text{ kW}$$

Heat Required for Start-Up —

$$\left(\frac{26.9 \text{ kW} + 1.89 \text{ kW}}{3 \text{ hrs}} + \frac{4.4 \text{ kW} + 2.11 \text{ kW}}{2}\right) \times 1.2$$

Q_S = 15.42 kW

To Find Heat Required for Operating —

$Q_O = (Q_{WO} + Q_{LS} + Q_{WS})(1 + SF)$

Where:
Q_{WO} = kW to heat additional water

$$\frac{40 \text{ gal} \times 8.345 \text{ lb/gal} \times 1.0 \text{ Btu/lb } (180 - 60°F)}{3412 \text{ Btu/kW}}$$

Q_{WO} = 11.7 kW

Q_{WS} = kW to heat steel 300 Lbs. x 0.12 x (180 - 60°F)/3412 = 1.27 kW

Heat Required for Operating —

Q_O = (11.7 kW + 1.27 kW + 4.4 kW + 2.11 kW) 1.2

Q_O = 23.38 kW

Installed Capacity — Since the heat required for operating (21.85 kW) is greater than the heat required for start up (15.42 kW), the installed heating capacity should be based on the heat required for operation. With 22 kW installed, the actual initial heating time will be less than 3 hours.

Suggested Equipment — Moisture resistant terminal enclosures are recommended for industrial liquid heating applications. Install two stock 12 kW MT-2120E2 or 12 kW MT-3120E2 screw plug heaters or two 12 kW KTLC-312A over-the-side heaters with an automatic temperature control. Automatic temperature control will limit the kWh consumption to actual requirements during operation. A low water level cutoff control is also recommended.

Technical Information

Determining Heat Energy Requirements

Flow Through Water Heating

Circulation heater applications frequently involve "flow through" heating with no recirculation of the heated media. These applications have virtually no start-up requirements. The equation shown below can be used to determine the kilowatts required for most "flow through" applications. The maximum flow rate of the heated medium, the minimum temperature at the heater inlet and the maximum desired outlet temperature are always used in these calculations. A 20% safety factor is recommended to allow for heat losses from jacket and piping, voltage variations and variations in flow rate.

$$Q = \frac{F \times C_p \times \Delta T \times SF}{3412 \text{ Btu/kW}}$$

Where:
Q = Power in kilowatts
F = Flow rate in lbs/hr
C_p = Specific heat in Btu/lb/°F
ΔT = Temperature rise in °F
SF = Safety Factor

Example — Heat 5 gpm of water from 70 - 115°F in a single pass through a circulation heater.

Step 1 — Determine flow rate in lbs/hr.
(Density of water is 8.35 lbs/gal)
5 gpm x 8.35 lbs/gal x 60 min = 2505 lbs/hr

Step 2 — Calculate kW:
C_p = Specific heat of water = 1 Btu/lb/°F

$$kW = \frac{2505 \text{ lbs} \times 1 \text{ Btu/lb/°F} \times (115-70°F)}{3412 \text{ Btu/kW}} \times 1.2 \text{ SF}$$

kW= 39.6 kW

Temperature Rise Vs. Water Flow[1]

Temp. Rise (°F)	Heater Rating (kW)						
	6	9	12	15	18	24	30
	Flow rate in GPH for given Temperature Rise						
20	122	184	245	306	368	490	613
30	81	122	163	204	245	327	409
40	61	92	122	153	184	245	306
50	49	73	98	122	147	196	245
60	40	61	81	102	122	163	204
70	35	52	70	87	105	140	175
80	30	46	61	76	92	122	153
90	27	40	54	68	81	109	136
100	24	36	49	61	73	98	122
110	22	33	44	55	66	89	111
120	20	30	40	51	61	81	102
130	18	28	37	47	56	75	94

1. Safety Factor and losses not included.

Flow Through Oil Heating

Oil Heating with Circulation Heaters — The procedure for calculating the requirements for "flow through" oil heating with circulation heaters is similar to water heating. The weight of the liquid being heated is factored by the specific gravity of oil. The specific gravity of a particular oil can be determined from the charts on properties of materials or can be calculated from the weight per cubic foot relative to water.

Example — Heat 3 gpm of #4 fuel oil with a weight of approximately 56 lbs/ft³ from 50°F to 100°F.

Step 1 — Determine flow rate in lbs/hr.
Specific gravity = 56 lbs/ft³ ÷ 62.4 lbs/ft³ = 0.9
3 gpm x 8.35 lbs/gal x 0.9 x 60 min = 1353 lbs/hr

Step 2 — Calculate kW:
Specific heat of fuel oil is 0.42 Btu/lb/°F

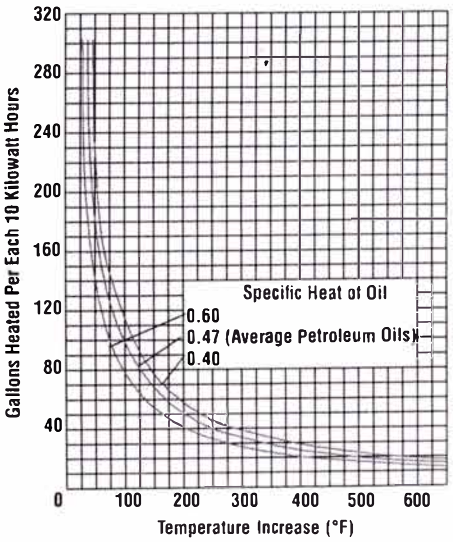
$$kW = \frac{1353 \text{ lbs} \times 0.42 \text{ Btu/lb/°F} \times (100 - 50°F)}{3412 \text{ Btu/kW}} \times 1.2 \text{ SF}$$

kW = 9.99

Suggestion — Choose watt density for fuel oil and then select heater. Use a stock NWHOR-05-015P, 10 kW circulation heater with an AR-215 thermostat.

Graph G-236 — Oil Heating

Heat Required for Various Temperature Rise (Exclusive of Losses)



CAUTION — Consult recommendations elsewhere in this section for watt density and maximum sheath temperatures for oil heating.

Heating Soft Metal with Melting Pots or Crucibles

Most soft metal heating applications involve the use of externally heated melting pots or crucibles. The following example represents a typical soft metal application.

A steel melting pot weighing 150 lbs contains 400 lbs of lead. The pot is insulated with 2 inches of rock wool and has an outside steel shell with 20 ft² of surface area. The top surface of the lead has 3 ft² exposed to the air. Determine the kilo-watts required to raise the material and container from 70°F to 800°F in one hour, and heat 250 lbs of lead per hour (70°F to 800°F) thereafter.

Melting point of lead = 621°F
Specific heat of solid lead = 0.0306 Btu/lb/°F
Specific heat of molten lead = 0.038 Btu/lb/°F
Heat of fusion/lead = 10.8 Btu/lb
Specific heat of steel crucible = 0.12 Btu/lb/°F
Radiation loss from molten lead surface = 1000 W/ft² (from curve G-128S).
Surface loss from outside shell of pot 62 W/ft² (from curve G-126S).
SF = Safety Factor 20%

To Find Start-Up Heating Requirements —

$$Q_T = \left(\frac{Q_A + Q_F + Q_L + Q_C}{t} + \frac{Q_{LS}}{2}\right)(1 + SF)$$

Where:
Q_A = kW to heat lead to melting point.
[400 lbs x 0.0306 Btu/lb/°F (621 - 70°F)] ÷ 3412
Q_F = kW to melt lead (400 lbs x 10.8 Btu/lb) ÷ 3412
Q_L = kW to heat lead from melting pt. to 800°F
[400 lbs x 0.038 Btu/lb/°F (800 - 621°F)] ÷ 3412
Q_C = kW to heat steel pot
[150 lbs x 0.12 Btu/lb/°F (800 - 70°F)] ÷ 3412
Q_{LS} = Surface losses from lead and outside shell
[(1000 W x 3 ft²) + (62 W x 20 ft²)]/2 ÷ 1000
t = 1 hour
Q_T = 9.98 kW x 1.2 = 11.99 kW

To Find Operating Requirements —

$$Q_T = (Q_A + Q_F + Q_L + Q_{LS})(1 + SF)$$

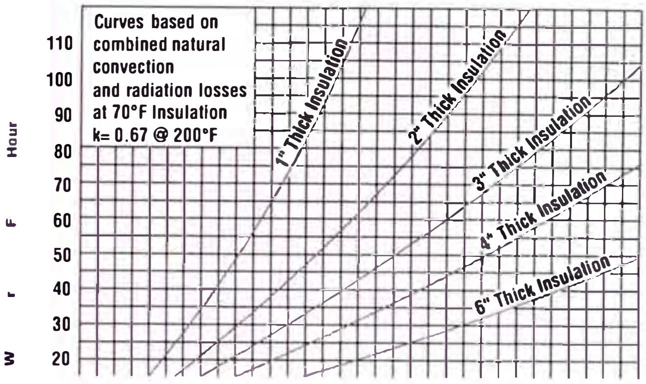
Where:
Q_A = kW to heat added lead to melting point.
(250 lbs x 0.0306 Btu/lb/°F [621 - 70°F]) ÷ 3412
Q_F = kW to melt added lead
(250 lbs x 10.8 Btu/lb) ÷ 3412
Q_L = kW to heat lead from melting pt. to 800°F
(250 lbs x 0.038 Btu/lb/°F [800 - 621°F]) ÷ 3412
Q_{LS} = Surface losses from lead and outside shell
(1000W x 3 ft²) + (62W x 20 ft²) ÷ 1000
Q_T = 6.69 kW x 1.2 = 8.03 kW

Since start-up requirements exceed the operating requirements, 12 kW should be installed.

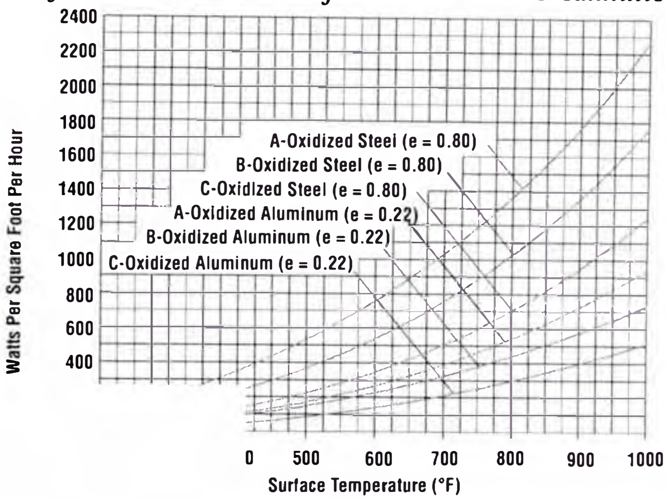
Technical Information

Heat Loss Factors & Graphs

Graph G-126S — Heat Losses from Surfaces of Insulat Walls of Ovens, Pipes, Tanks, Etc.



Graph G-125S — Heat Losses from Uninsulated Metal Surfaces Combined Losses from Convection & Radiation



Curve A shows heat loss from vertical surfaces of tanks, pipes, etc. and the top of a flat horizontal surface.

Curve B shows the combined heat loss from both the top and bottom surfaces of flat horizontal surfaces.

Curve C shows heat losses from only the bottom surface of flat horizontal surfaces.

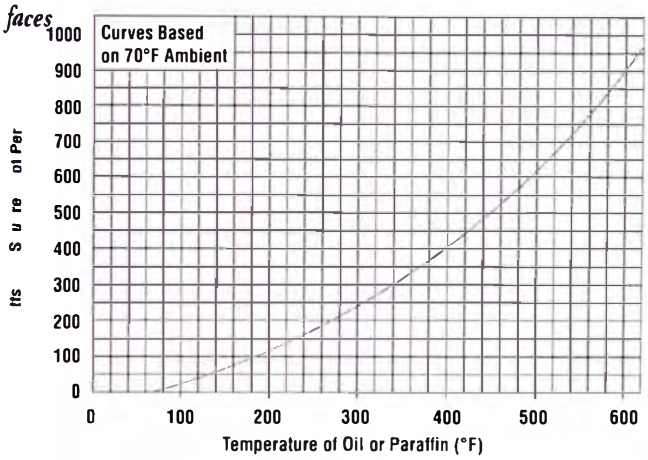
All Curves based on still air (1 fps) @ 70°F, e = emissivity.

Note — The above graph is difficult to read for surface temperatures below 250°F. To estimate heat losses for surface temperatures below 250°F, and the air is still, use the following formula:

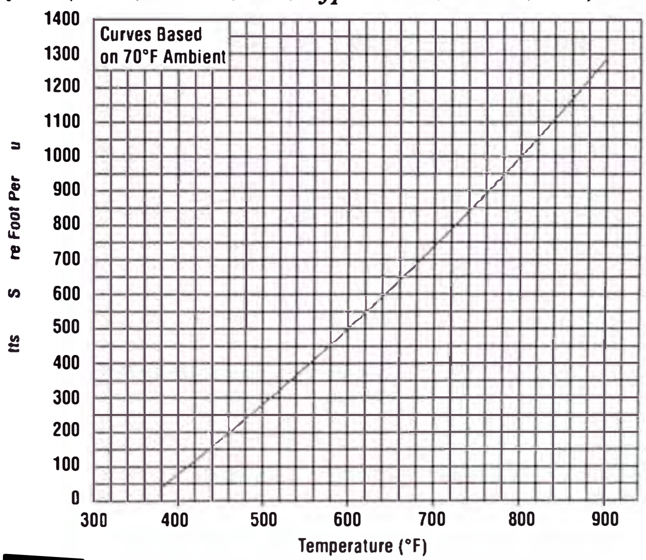
$$0.6\ W \times ft^2 \times \Delta T\ °F$$

Where:
ΔT is the temperature difference in °F between the heated surface and the ambient.

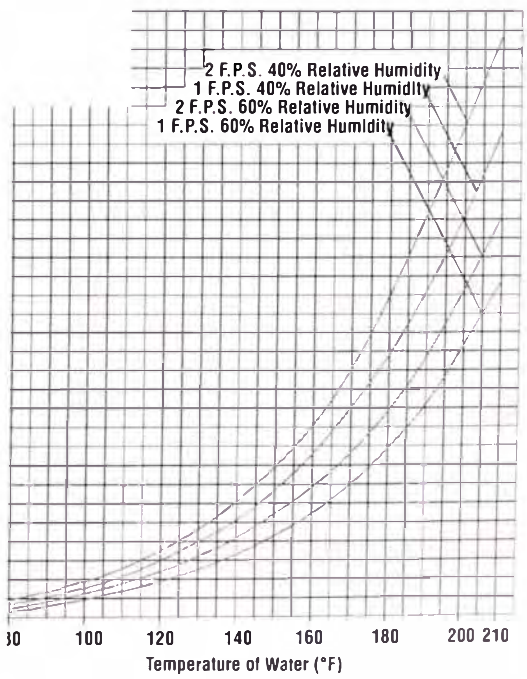
Graph G-127S — Heat Losses from Oil or Paraffin Surfaces



Graph G-128S — Heat Losses from Molten Metal Surfaces (Lead, Babbit, Tin, Type Metal, Solder, Etc.)



eat Losses from Water Surfaces



Technical Information

Determining Heat Energy Requirements

Pipe & Tank Tracing

The following tables can be used to determine the heat losses from insulated pipes and tanks for heat tracing applications. To use these tables, determine the following design factors:

- Temperature differential $\Delta T = T_M - T_A$
  Where:
  T_M = Desired maintenance temperature °F
  T_A = Minimum expected ambient temperature °F
- Type and thickness of insulation
- Diameter of pipe or surface area of tank
- Outdoor or indoor application
- Maximum expected wind velocity (if outdoors).

Pipe Tracing Example — Maintain a 1-1/2 inch IPS pipe at 100°F to keep a process fluid flowing. The pipe is located outdoors and is insulated with 2 inch thick Fiberglas® insulation. The minimum expected ambient temperature is 0°F and the maximum expected wind velocity is 35 mph. Determine heat losses per foot of pipe.

1. **Heat Loss Rate** — Using Table 1, determine the heat loss rate in W/ft of pipe per °F temperature differential. Enter table with insulation ID or IPS pipe size (1-1/2 in.) and insulation thickness (2 in.).
   Rate = 0.038 Watts/ft/°F.

2. **Heat Loss per Foot** — Calculated heat loss per foot of pipe equals the maximum temperature differential (ΔT) times heat loss rate in Watts/ft/°F.

   ΔT = 100°F - 0°F = 100°F
   Q = (ΔT)(heat loss rate per °F)
   Q = (100°F) (0.038 W/ft) = 3.80 W/ft

3. **Insulation Factor** — Table 1 is based on Fiberglas® insulation and a 50°F ΔT. Adjust Q for thermal conductivity (k factor) and temperature as necessary, using adjustment factors from Table 2.

   Adjusted Q = (Q)(1.08) = 3.80 W/ft x 1.08
   Q = 4.10 W/ft

4. **Wind Factor** — Table 1 is based on 20 mph wind velocity. Adjust Q for wind velocity as necessary by adding 5% for each 5 mph over 20 mph. Do not add more than 15% regardless of wind speed.

   Adjusted Q = (Q)(1.15) = 4.10 W/ft x 1.15
   Design heat loss per linear foot
   Q = 4.72 W/ft

Note — For indoor installations, multiply Q by 0.9.

Table 1 — Heat Losses from Insulated Metal Pipes (Watts per foot of pipe per °F temperature differential [1])

Pipe Size (IPS)	Insul. I.D. (In.)	Insulation Thickness (In.)							
		1/2	3/4	1	1-1/2	2	2-1/2	3	4
1/2	0.840	0.054	0.041	0.035	0.028	0.024	0.022	0.020	0.018
3/4	1.050	0.063	0.048	0.040	0.031	0.027	0.024	0.022	0.020
1	1.315	0.075	0.055	0.046	0.036	0.030	0.027	0.025	0.022
1-1/4	1.660	0.090	0.066	0.053	0.041	0.034	0.030	0.028	0.024
1-1/2	1.990	0.104	0.075	0.061	0.046	0.038	0.034	0.030	0.026
2	2.375	0.120	0.086	0.069	0.052	0.043	0.037	0.033	0.029
2-1/2	2.875	0.141	0.101	0.080	0.059	0.048	0.042	0.037	0.032
3	3.500	0.168	0.118	0.093	0.068	0.055	0.048	0.042	0.035
3-1/2	4.000	0.189	0.133	0.104	0.075	0.061	0.052	0.046	0.038
4	4.500	0.210	0.147	0.115	0.083	0.066	0.056	0.050	0.041
—	5.000	0.231	0.161	0.125	0.090	0.072	0.061	0.054	0.044
5	5.563	0.255	0.177	0.137	0.098	0.078	0.066	0.058	0.047
6	6.625	0.300	0.207	0.160	0.113	0.089	0.075	0.065	0.053
—	7.625	0.342	0.235	0.181	0.127	0.100	0.084	0.073	0.059
8	8.625	0.385	0.263	0.202	0.141	0.111	0.092	0.080	0.064
—	9.625	0.427	0.291	0.224	0.156	0.121	0.101	0.087	0.070
10	10.75	0.474	0.323	0.247	0.171	0.133	0.110	0.095	0.076
12	12.75	0.559	0.379	0.290	0.200	0.155	0.128	0.109	0.087
14	14.00	0.612	0.415	0.316	0.217	0.168	0.138	0.118	0.093
16	16.00	0.696	0.471	0.358	0.246	0.189	0.155	0.133	0.104
18	18.00	0.781	0.527	0.401	0.274	0.210	0.172	0.147	0.115
20	20.00	0.865	0.584	0.443	0.302	0.231	0.189	0.161	0.125
24	24.00	1.034	0.696	0.527	0.358	0.274	0.223	0.189	0.147

1. Values in Table 1 are based on a pipe temperature of 50°F, an ambient of 0°F, a wind velocity of 20 mph and a "k" factor of 0.25 (Fiberglas®). Values are calculated using the following formula plus a 10% safety margin:
   Watts/ft of pipe = $2\pi k(\Delta T) \div (Z)\ \ln(D_o/D_i)$
   Where: k = Thermal conductivity (Btu/in./hr/ft²/°F)
   ΔT = Temperature differential (°F)
   D_o = Outside diameter of insulation (in.)
   D_1 = Inside diameter of insulation (in.)
   Z = 40.944 Btu/in/W/hr/ft
   ln = Natural Log of D_o/D_1 Quotient

Table 2 — Thermal Conductivity (k) Factor of Typical Pipe Insulation Materials (Btu/in./hr/ft²/°F)

Insulation Type		Pipe Maintenance Temperature (°F)							
		0	50	100	150	200	300	400	500
Fiberglas® or Mineral Fiber Based on ASTM C-547	k value	0.23	0.25	0.27	0.30	0.32	0.37	0.41	0.45
	Adjustment factor	(0.92)	(1.00)	(1.08)	(1.20)	(1.28)	(1.48)	(1.64)	(1.80)
Calcium Silicate[2] Based on ASTMC-533	k value	0.35	0.37	0.40	0.43	0.45	0.50	0.55	0.60
	Adjustment factor	(1.52)	(1.48)	(1.60)	(1.72)	(1.80)	(2.00)	(2.20)	(2.40)
Foamed Glass[2] Based on ASTMC-552	k value	0.38	0.40	0.43	0.47	0.51	0.60	0.70	0.81
	Adjustment factor	(1.52)	(1.60)	(1.72)	(1.88)	(2.04)	(2.40)	(2.8)	(3.24)
Foamed Urethane Based on ASTMC-591	k value	0.18	0.17	0.18	0.21	0.25	Not Recommended		
	Adjustment factor	(0.72)	(0.68)	(0.72)	(0.84)	(1.00)			

2. When using rigid insulation, select an inside diameter one size larger than the pipe on pipe sizes through 9 in. IPS. Over 9 in. IPS, use same size insulation.

Table 3 — Heat Losses from Insulated Metal Tanks (W/ft²/°F)[3]

Insulation Thickness (In.)										
1/2	3/4	1	1-1/2	2	2-1/2	3	3-1/2	4	5	6
0.161	0.107	0.081	0.054	0.040	0.032	0.027	0.023	0.020	0.016	0.013

3. Values in Table 3 are based on a tank temperature of 50°F, an ambient of 0°F, a wind velocity of 20 mph and a "k" factor of 0.25 (Fiberglas®). Values are calculated using the following formula plus a 10% safety margin:
   Watts/ft² = $Y\ k(\Delta T) \div X$
   Where: Y = 0.293W/hr/btu
   k = Thermal conductivity
   X = Thickness of insulation (in.)
   Δ = Temperature differential (°F)

Note — The above information is presented as a guide for solving typical heat tracing applications. Contact your Local Chromalox Sales office for assistance in heater selection and for pipes made of materials other than metal.

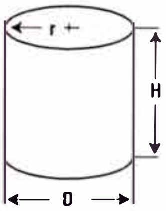
Technical Information

Determining Heat Energy Requirements

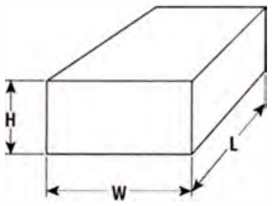
Pipe & Tank Tracing (cont'd.)

Tank tracing requires an additional calculation of the total exposed surface area. To calculate the surface area:

Cylindrical Tanks —
Area = $2 \pi r^2 + \pi DH$
$A = \pi D (r + H)$



Horizontal Tanks —
Area = $2[(W \times L) + (L \times H) + (H \times W)]$



Tank Tracing Example — Maintain a metal tank with 2 inch thick Fiberglas® insulation at 50°F. The tank is located outdoors, is 4 feet in diameter, 12 feet long and is exposed at both ends. The minimum ambient temperature is 0°F and the maximum expected wind speed is 15 mph.

1. **Surface Area —** Calculate the surface area of the tank.
   $A = \pi D (r + H)$
   $A = \pi 4 (2 + 12)$
   $A = 175.9 \text{ ft}^2$

2. **Temperature Differential (ΔT)**

   $\Delta T = T_M - T_A = 50°F - 0°F = 50°F$

3. **Heat Loss Per Foot² —** Obtain the heat loss per square foot per degree from Table 3.

   Heat loss/ft²/°F = 0.04 W/ft²/°F

4. **Insulation Factor —** Table 3 is based on Fiberglas® insulation and a 50°F ΔT. Adjust Q for thermal conductivity (k factor) and temperature as necessary, using factors from Table 2.

5. **Wind Factor —** Table 3 is based on 20 mph wind velocity. Adjust Q for wind velocity as necessary, by adding 5% for each 5 mph over 20 mph. Do not add more than 15% regardless of wind speed. **Note —** For indoor installations, multiply Q by 0.9.

6. **Calculate Total Heat Loss for Tank —** Multiply the adjusted heat loss per square foot per °F figure by the temperature differential. Multiply the loss per square foot by the area.

   $Q = 0.04 \text{ W/ft}^2/°F \times 50°F\ \Delta T = 2 \text{ W/ft}^2$
   Q = Adjusted W/ft² x tank surface area
   $Q = 2 \text{ W/ft}^2 \times 175.9 \text{ ft}^2$

Heat Loss from Tank = 351.8 Watts

Comfort Heating

For complete building and space heating applications, it is recommended that a detailed analysis of the building construction heat losses (walls, ceilings, floors, windows, etc.) be performed using ASHRAE guidelines. This is the most accurate and cost effective estimating procedure. However, a quick estimate of the kW requirements for room and supplemental heating or freeze protection can be obtained using the chart to the right.

Problem — A warehouse extension measures 20 ft long x 13 ft wide x 9 ft high. The building is not insulated. Construction is bare concrete block walls and an open ceiling with a plywood deck and built-up roof. Determine the kW required to maintain the warehouse at 70°F when the outside temperature is 0°F.

Solution —

1. **Calculate** the volume of the room.

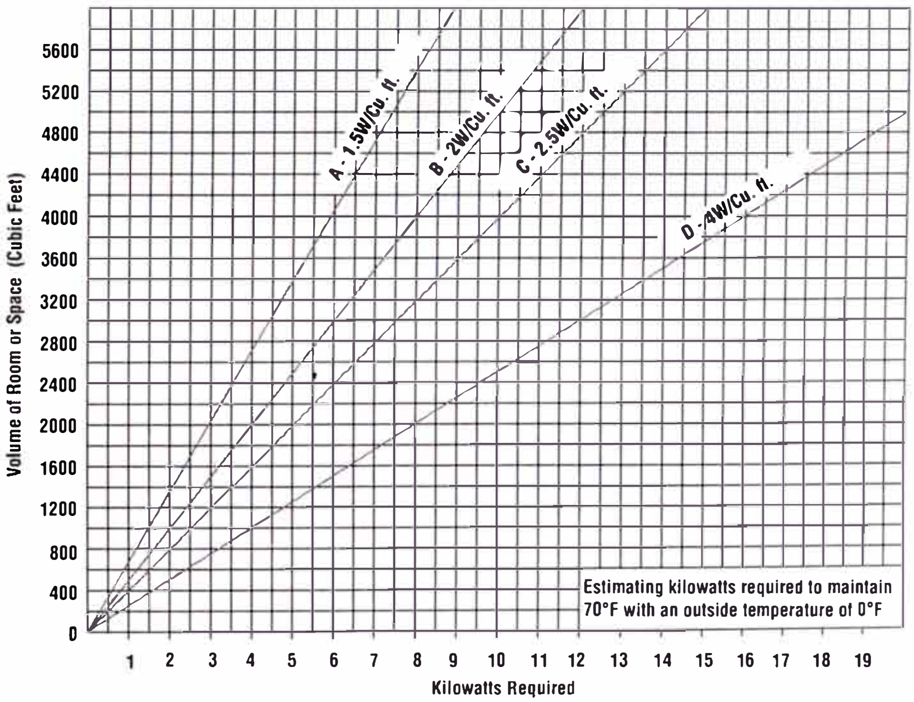
   20 ft x 13 ft x 9 ft = 2,340 ft³

2. **Refer** to the chart, use Curve D which corresponds to the building construction.

3. **Find** the intersection of 2,340 ft³ with curve D. The kilowatts required are 9.3 kW. Suggest using a 10 kW unit blower heater.

Note — If the volume of the room is larger than the chart values, divide by 2, 3, 4, etc. until the trial volume fits the curve. Then select heater from this volume. Multiply heaters selected by the number used to select the trial volume.

Comfort Heating Chart



Curve A — Rooms with little or no outside exposure. No roof or floor with outside exposure, only 1 wall exposed with not over 15% door and window area.

Curve B — Rooms with average exposure. Roof and 2 or 3 walls exposed, up to 30% door and window area. But with roof, walls and floor insulated if exposed to outside temperatures.

Curve C — Rooms with roof, walls and floor uninsulated but with inside facing on walls and ceiling.

Curve D — Exposed guard houses, pump houses, cabins and poorly constructed rooms with reasonably tight joints but no insulation. Typical construction of corrugated metal or plywood siding, single layer roofs.

Technical Information

Watt Density & Heater Selection - Guidelines

Understanding Watt Density

Watt density (W/in^2) is the heat flux emanating from each square inch of the effective heating area (heated surface) of the element.

W/in^2 = Rated Watts ÷ Effective heating area

The effective heating area is the surface area per linear inch of the heater multiplied by the heated length. For strip heaters which are rectangular in shape, the surface area per linear inch is:

1-1/2" wide = 3.45 in^2 per linear inch
1" wide = 2.31 in^2 per inch.

The heated length (HL) of strip heaters is calculated as follows:

< 30-1/2" long HL = Overall Length less 4"
≥ 30-1/2" long HL = Overall Length less 5"

For tubular elements, watt density is determined by the following formulas.

Effective heating area = π x Dia. x Heated Length

The surface area per linear inch of standard diameter tubular elements is shown below:

Size (Dia.)	In^2/in.
0.246 inch (1/4)	0.77
0.315 inch (5/16)	0.99
0.375 inch (3/8)	1.18
0.430 inch (7/16)	1.35
0.475 inch	1.49
0.500 inch (1/2)	1.57

The following example illustrates the procedure for determining the watt density of a typical tubular heater.

Example — A 12 kW screw plug heater has three 0.475" diameter elements with a "B" dimension of 32 inches and a 2 inch cold end. The watt density is:

0.475 x π x (32 in. - 2 in.) x 3 x 2 (Hairpin) = 268 in^2

12,000 Watts ÷ 268 in^2 - 45 W/in^2

For convenience in selecting equipment, all heaters in this catalog have the watt density specified for standard ratings.

Heater Selection Guidelines

Once the total heat energy requirements have been determined, the selection of the type of electric heater is based on three criteria.

- Maximum Sheath Temperature
- Sheath Material
- Recommended Maximum Watt Density

Maximum Sheath Temperature — The sheath temperature of an electric element should be limited to prevent damage to the heater and provide reasonable life. To a large extent, the maximum sheath temperature of the heating element is determined by the final operating temperature of the process. In direct immersion applications, the sheath temperature will approximate the temperature of the heated media. In clamp-on, air and gas heating applications, the operating sheath temperature can be estimated using factors derived from empirical charts and graphs.

Sheath Material — Element sheath material is selected based on the maximum allowable sheath temperature, the material being heated and corrosion resistance required. Depending on the sheath material and construction, metal sheathed electric resistance elements will operate satisfactorily at temperatures from less than -300°F (cryogenic) to approximately 1500°F. Copper sheath elements are commonly used for low temperature and direct immersion water heating. Steel is used for oil immersion and strip heater applications. Stainless steel and INCOLOY® are used for corrosive solutions, high-temperature gas or air heating and cartridge heaters. The table below lists the maximum recommended operating temperatures for common sheath materials (UL 1030):

Copper	350°F	Chrome Steel	1200°F
Iron	750°F	Stainless 300	1200°F
Steel	750°F	INCOLOY®	1600°F[1]
MONEL®	900°F	INCONEL®	1700°F[1]

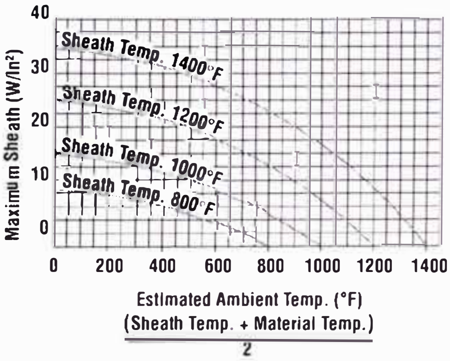
Maximum Recommended Watt Density — Some materials such as water, vegetable oils and salt baths can tolerate relatively high sheath watt densities. Other materials such as petroleum oils or sugar syrups require lower watt densities. These solutions have high viscosity and poor thermal conductivity. If the watt density is too high, the material will carbonize or overheat, resulting in damage to the heating equipment or material being heated. Other sections of this catalog provide guidelines and suggestions for sheath materials and recommended watt densities for many common heating problems.

Using the values determined in the selection criteria, choose the type of heater best suited to the application. For instance, water can be heated by direct immersion, circulation heaters or with tubular or strip heaters clamped to tank walls. The final choice of heater type will involve process considerations, appearance, available space both inside and outside, economy, maintenance, etc. The following pages cover the procedures for selecting heaters for clamp-on applications, liquid immersion heating, oil immersion heating, air or gas heating and cartridge or platen heating.

Clamp-On Heater Applications

The limiting factor in most clamp-on heater applications is the operating temperature of the heater sheath. Selecting heaters for clamp on applications requires an analysis of the maximum expected sheath temperature based on the estimated ambient temperature and the temperature of the material being heated. Graph G-175S provides a method of estimating the sheath temperature and allowable watt densities for tubular heaters for various ambient temperatures and wattage ratings.

Graph G-175S — ***Clamp-On Tubular Heaters***



The example on the following page illustrates the procedure. 12 kW is required to heat material in a steel tank from 70°F to 800°F. Heat is to be supplied by tubular electric elements clamped to the side of the tank. Since the material is heated to 800°F, INCOLOY® sheath elements must be used.

Note 1 — For sheath temperatures above 1500°F, contact your Local Chromalox Sales office for application assistance.

Technical Information

Allowable Watt Density & Heater Selection - Guidelines

Selecting Clamp-On Tubular Heaters (cont'd.)

From the chart, a maximum sheath temperature of 1200°F results in an average ambient temperature of (800°F + 1200°F) ÷ 2 = 1000°F. From the curves, the allowable watt density is 9.5 W/in². Based on size of container, 0.475 inch diameter TRI elements 28 in. long are selected.

The 0.475 TRI element has 1.49 in² per linear inch of sheath. The heated length is the overall sheath length less 6.5 inches. The allowable wattage rating on the element is (28 - 6.5) x 1.49 x 9.5 = 305 watts. The total number of elements required is 12,000W ÷ 305W = 39 elements. Order 39 elements similar to TRI-2845 except rated 305 watts. If the application requires the use of tubular elements whose overall length is not standard, each element rating would be determined as follows:

Heater Watts = (*A* - 2CE) (*Area* x 9.5W)

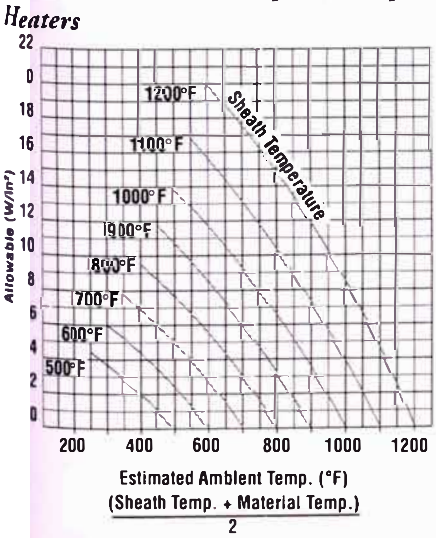
Where:

A = Sheath length, overall
CE = Cold pin length
Area = Effective heated area (in²/in.)
9.5 = recommended W/in² from G-175S

Selecting Clamp-On Strips Heaters

Graph G-130S provides a method of estimating the maximum allowable watt density for strip heaters for clamp on applications based on sheath operating temperature and various ambients.

Graph G-130S — Clamp-On Strip Heaters



Using the previous 12 kW example, determine the number of strip heaters required. An 800°F material temperature requires chrome steel strip heaters. From Graph G-130S, a maximum sheath temperature of 1200°F results in an ambient temperature of 1000°F inside the space between the thermal insulation and the vessel, (800°F + 1200°F) ÷ 2 = 1000°F.

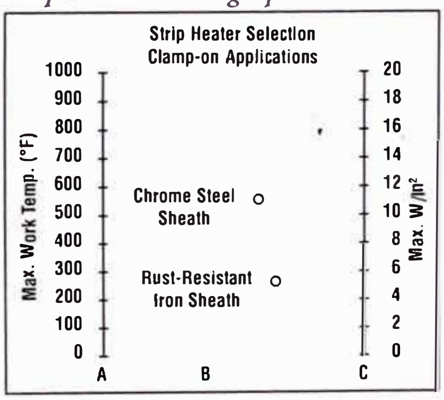
From the curve, the allowable watt density is 8 W/in². Based on the tank size, chrome steel sheathed strip heaters 24 inches long without mounting tabs were selected. To determine the number and wattage of strip heaters needed, use the formula: allowable watts per strip = (overall length minus 4" cold section) x 3.45 in² per lineal inch of sheath x 8 watts/in². Thus (25-1/2" - 4") x 3.45 x 8 = 593 (600) watts. The total number of strips required is 12,000W ÷ 600W = 20 strips. Order strips similar to OT-2507 in size but rated 600 watts. To avoid a special order, consider using 24 standard OT-2405, 500 watt strips. These heaters would have a watt density of:

500W ÷ ([23-3/4 - 4] x 3.45) = 7.35 W/in²

If the application uses 3 phase power, the total element count should be a multiple of 3 to permit a balanced electrical load.

The nomograph below may also be used for heater selection in clamp-on strip heating applications.

Strip Heater Nomograph



To Use the Graph —

1. **Select** the maximum desired work temperature on A.
2. **Choose** either chrome steel or rust-resistant iron sheath (points B) on the basis of operating temperatures.
3. **Draw** a straight line through points A and B to C. C gives the maximum allowable watts per square inch.
4. **Select** desired length heater with equivalent or less watt density.

General Recommendations for Liquid Heating Applications

Chromalox standard immersion heater ratings match the suggested watt densities for general purpose immersion heating. Extended heater life will be obtained by using the lowest watt density practical for any given application.

Standard Ratings —

Water Heaters	45 - 75 W/in²
Corrosive Solution Heaters	20 - 23 W/in²
Oil Heaters (Light Wt.)	20 - 23 W/in²
Oil Heaters (Medium Wt.)	15 W/in²
Oil Heaters (Heavy Wt.)	6 - 10 W/in²

Suggested Allowable Watt Densities for Liquids

Material	Max. Temp (°F)	Max. W/In²
Acid solutions	180	40
Alkaline solutions (Oakite)	212	40
Asphalt, tar, and other heavy or highly viscous compounds	200	10
	300	8
	400	7
	500	6
Bunker C fuel oil	160	10
Caustic soda 2%	210	45
10%	210	25
75%	180	15
Dowtherm® A	750	23
Dowtherm® A vaporizing	750	10
Dowtherm® J liquid	575	23
Electroplating tanks	180	40
Ethylene glycol	300	30
Freon	300	3
Fuel oil pre-heating	180	9
Gasoline, kerosene	300	20-23
Machine oil, SAE 30	250	18-20
Metal melting pot	500-900	20-27
Mineral oil	200	20-23
	400	16
Molasses	100	4-5
Molten salt bath	800-950	25-30
Molten tin	600	20-23
Oil draw bath	400	20-23
	600	16
Steel cast into aluminum	500-750	50
Steel cast into iron	750-1000	55
Heat transfer oils (Therminol®, Mobiltherm®, etc.)	500-650	23
Vapor degreasing solutions	275	20-23
Vegetable oil (fry kettle)	400	20-30
Water (process)	212	40-75
Water (washroom)	140	75-100

Note — The above watt densities are based on non-circulating liquids. The allowable watt density may be adjusted when heat transfer or flow rates are increased.

Technical Information
Heater Selection - Oil Heating

Watt Density & Oil Viscosity

The viscosity of oils and hydrocarbons varies widely with type and temperature. Since highly viscous liquids transfer heat poorly, sheath watt densities and operating temperatures are critical in oil heating applications. As a general rule, regular oil heaters rated 20-23 W/in² are recommended for heating light weight oils (SAE 10 to SAE 30). For medium weight oils (gear oils, etc.), 12-15 W/in² are suggested. Bunker C, tar, asphalt and other highly viscous oils may require 6-8 W/in² or less to prevent carbonization, particularly if not under flowing conditions. Some oils may have additives that will boil off or carbonize at very low watt densities. When oils of this type are encountered, a watt density test is recommended to determine a satisfactory watt density. The following charts provide guidance and suggested watt densities for various oils.

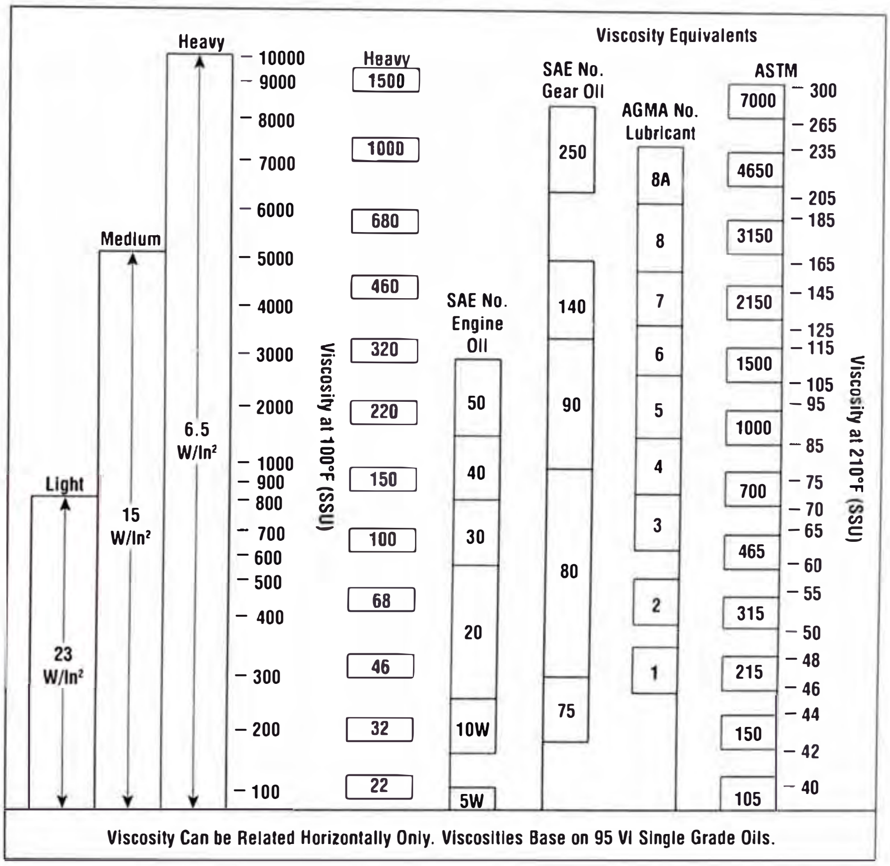
Typical Viscosities of Various Oils

Weight	Viscosity
SAE 10	90-120 SSU at 130°F
SAE 20	120-185 SSU at 130°F
SAE 30	185-255 SSU at 130°F
SAE 40	255 SSU-up (Drops to 80 at 210°F)
SAE 50	80-105 SSU at 210°F
#2 Fuel Oil	40 SSU at 100°F (Kerosene)
#4 Fuel Oil	45-120 SSU at 100°F
#5 Fuel Oil	150-400 SSU at 100°F
Bunker C	500-2,000 SSU at 100°F
#6 Fuel Oil	3,000 SSU at 122°F (Very Viscous)

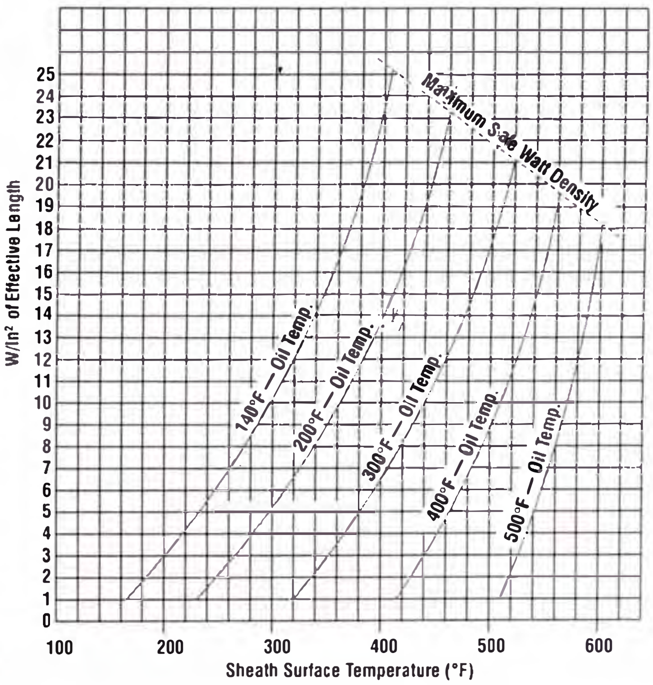
Viscosity Conversion

Seconds Saybolt Universal (SSU)	Kinematic Viscosity Centistokes (Cst)	Seconds Saybolt Furol (SSF)
31	1	—
35	2.56	—
40	4.30	—
50	7.4	—
60	10.3	—
70	13.1	12.95
80	15.7	13.7
90	18.2	14.44
100	20.6	15.24
150	32.1	19.3
200	43.2	23.5
250	54	28
500	110	51.6
1,000	220	100.7
5,000	1,100	500
10,000	2,200	1,000
20,000	4,400	2,000

Centistokes = Centipoise/specific gravity
Centipoise x 2.42 = Lbs/ft/hr



Graph G-122S — Surface Temperatures of Oil Immersion Blade Heater for Various Oil Temperatures & Watt Densities



Notes —

1. Curves based on natural convection of machine oil or its equivalent having an SAE viscosity rating of 30 (5 centipoises at 200°F).
2. Effective Length of Immersion Heater = "B" Dimension.
3. Area Per Linear Inch of 1-1/2' Wide Immersion Blades = 3.75 Sq. In.
4. Area Per Linear Inch of 1' Wide Immersion Blades = 2.63 Sq. In.
5. In No Case, Exceed 27 Watts Per Sq. In.

TECHNICAL INFORMATION

Technical Information

Determining Energy Requirements - Air & Gas Heating

Air & Gas Heating

Air and gas heating applications can be divided into two conditions, air or gas at normal atmospheric pressure and air or gas under low to high pressure. Applications at atmospheric pressure include process air, re-circulation and oven heating using duct or high temperature insert air heaters. Pressurized applications include pressurized duct heating and other processes using high pressures and circulation heaters. Procedures for determining heat energy requirements for either condition are similar except the density of the compressed gas and the mass velocity of the flow must be considered in pressurized applications. Selection of equipment in both conditions is critical due to potentially high sheath temperatures that may occur.

Determining Heat Requirements for Atmospheric Pressure Gas Heating

The following formulas can be used to determine kW required to heat air or gas:

Equation A —

$$kW = \frac{CFM \times lbs/ft^3 \times 60\ min \times C_p \times \Delta T \times SF}{3412\ Btu/kW}$$

Where:
CFM = Volume in cubic feet per minute
Lbs/ft^3 = Density of air or gas at initial temperature
C_p = Specific heat of air or gas at initial temperature
ΔT = Temperature rise in °F
SF = Suggested Safety Factor

For quick estimates of air heating requirements for inlet temperatures up to 120°F, the following formula can be used.

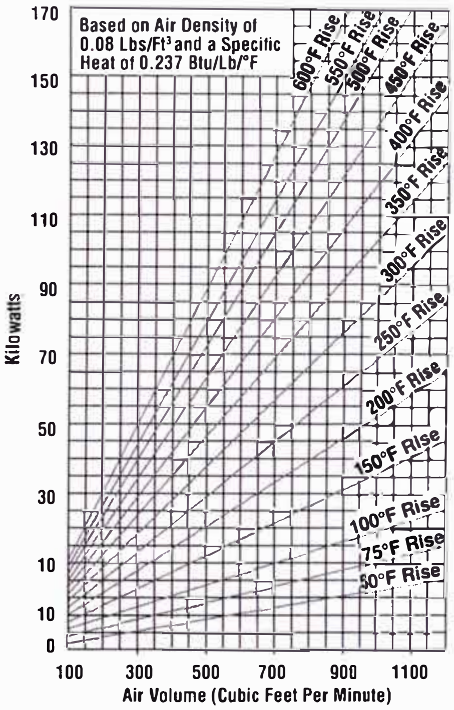
$$kW = \frac{SCFM \times \Delta T \times 1.2\ SF}{3{,}000}$$

Where:
SCFM = Volume of air in cubic feet per minute at standard conditions[1] (70° F at standard atmospheric pressure)
3,000 = Conversion factor for units, time and Btu/lb/°F
1.2 SF = Suggested safety factor of 20%

Graph G-176S — When airflow (ft^3/min) and temperature rise are known, kW requirements can be read directly from graph G-176S.
Note — Safety factors are not included.

Note 1 — Based on an average density of 0.08 lbs/ft^3 and a specific heat of 0.24 Btu/lb/°F. For greater accuracy, use Equation A and values from the Properties of Air Chart in this section.

Graph G-176S —Air Heating



Process Air Heating Calculation Example — A drying process requires heating 450 ACFM of air[1] from 70°F to 150°F. The existing duct- work measures 2 ft wide by 1 ft high and is insulated (negligible losses). To find heating capacity required, use Equation A:

$$kW = \frac{450\ ACFM \times 0.08 \times 60 \times 0.24 \times 80}{3412\ Btu/kW} \times 1.2\ SF$$

kW = 14.58

Heater Selection

Finstrip® (CAB heaters), Fintube® (DH heaters) or tubular elements (TDH, ADH and ADHT heaters) will all work satisfactorily in low temperature applications. Finstrips or finned tubular elements are usually the most cost effective. Tubular elements are recommended for high temperatures. Once the desired type of heating element is selected, the next step is to calculate the air velocity and estimate sheath temperatures to verify that maximum operating temperatures are not exceeded. Calculate the air velocity over the elements and refer to allowable watt density graphs for estimated operating temperature.

Calculating Air Velocity — Air velocity can be calculated from the following formula:

$$Velocity\ (fps) = \frac{Flow\ (ACFM)}{Area\ of\ Heater\ (ft^2) \times 60\ sec.}$$

Low Temperature Heater Selection — A ypical heater selection for the previous example might be a type CAB heater with finstrip elements. Available 15 kW stock heaters include a CAB-1511 with chrome steel elements or a CAB-152 with iron sheath elements, both rated at 26 W/in². From the product page, the face area of a 15 kW CAB heater is 1.19 ft²:

$$Velocity\ (fps) = \frac{450\ ACFM}{1.19\ ft^2 \times 60\ sec.} = 6.3\ fps$$

Estimating Sheath Operating Temperature — The maximum operating sheath temperatures for finstrips are 750°F for iron and 950°F for chrome steel. Using graph G-107S for iron sheath finstrips, a 150°F outlet temperature and a watt density of 26 W/in² requires a velocity in excess of 9 ft/sec to keep sheath temperatures below maximum permissible levels. With only 6.3 fps in the application, a CAB-152 heater with iron sheath elements is not suitable. Using graph G-108S for chrome sheath finstrips, approximately 3 ft/sec. air velocity results in a maximum of 900°F sheath temperature. Since this is lower than the actual velocity of 6.3 fps, a CAB-1511 with chrome steel finstrips is an acceptable heater selection. (Use graphs G-100S, G-105S,G-106S and G-132S for air heating with regular strip and finstrip heaters.)

High Temperature Heater Selection — Type TDH and ADHT heaters with tubular elements are recommended for high temperature applications. Steel sheath tubulars may be used where the sheath temperature will not exceed 750°F. Finned tubulars can be used in applications up to a maximum sheath temperature of 1050°F. INCOLOY® sheath tubulars may be used for applications with sheath temperatures up to 1600°F. Allowable watt densities for tubulars and finned tubulars can be determined by reference to graphs G-136S and G-151-1 through G-156-1.

Estimating Sheath Operating Temperature — Select a heater for a high temperature application with an inlet air temperature of 975°F and a velocity of 4 ft/sec. Since the temperature is above 750°F, an INCOLOY® sheath must be used. Using graph G-152-1 the allowable watt density is 11 W/in² for sheath temperatures of 1200°F or 22 W/in² for temperatures of 1400°F. In this application, a stock ADHT heater[2] with a standard watt density of 20 W/in² can be used.

Note 2 — Special ADHT duct heaters, derated to the required watt density, can be supplied when element ratings less than the standard 20 W/in² are needed.

echnical Information

owable Watt Density & Heater Selection - Air Heating

'r & Gas Heating with Strip and instrip® Heaters

om Designs — Strip and finstrip heaters re frequently mounted in banks by the end er. Graphs G-105S and G-106S on this page n be used in conjunction with other graphs o determine maximum watt density for rtually any custom design low temperature eating application.

raph G-105S — Strip Heaters
o use this graph:

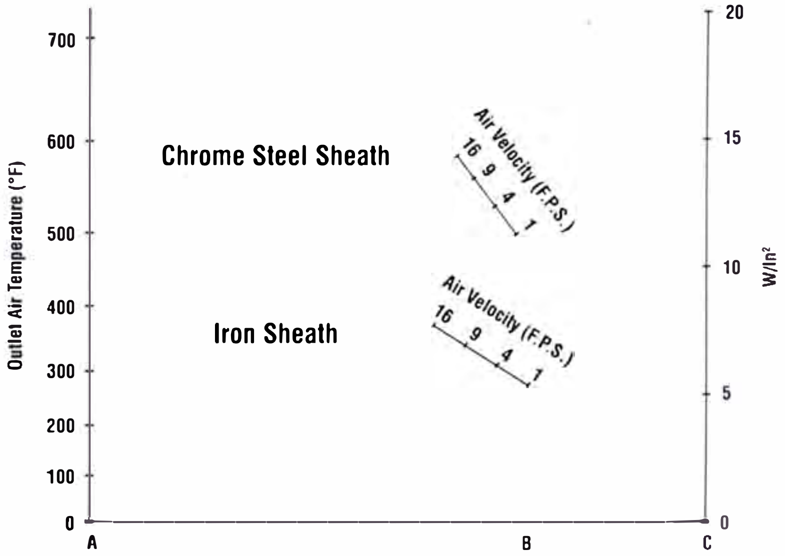
1. **Select** maximum desired outlet air temperature on line A.
2. **Choose** either chrome steel sheath or rust resisting iron sheath (points B) on the basis of operating conditions.
3. **Select** minimum anticipated air velocity on B. **Note** — natural circulation is equal to approximately one foot per second.
4. **Draw** a straight line through points A and B to a reading on C. Read maximum allowable watts per square inch from line C.
5. **Select** desired length heater with an equivalent watt density or less from the product page in this catalog.

Graph G-106S — Finstrip® Heaters
To use this graph:

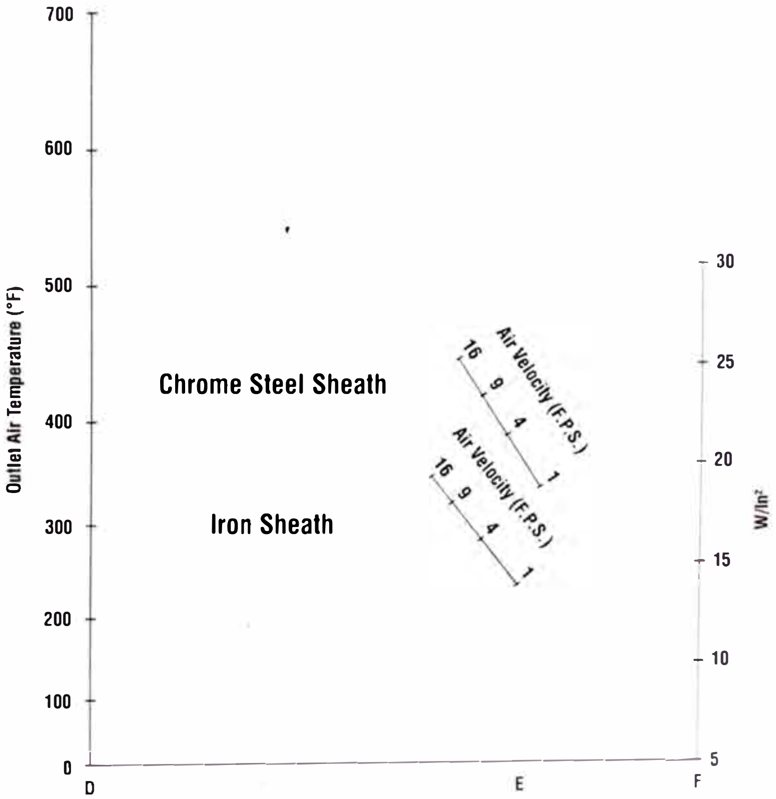
1. **Select** maximum desired outlet air temperature on line D.
2. **Choose** either chrome steel sheath or rust resisting iron sheath (points E) on the basis of operating conditions.
3. **Select** minimum anticipated air velocity on B. **Note** — natural circulation is equal to approximately one foot per second.
4. **Draw** a straight line through points D and E to a reading on F. Read maximum allowable watts per square inch from line F.
5. **Select** desired length heater with an equivalent watt density or less from the product page in this catalog.

Recommendations for Custom Installations — Strip heaters should always be mounted sideways in the ductwork with the narrow edges facing the air stream. The total number of elements installed should be divisible by 3 so that the heater load will be balanced on a three phase circuit.

Graph G-105S — Strip Heater Air Heating-Selection of Watt Density



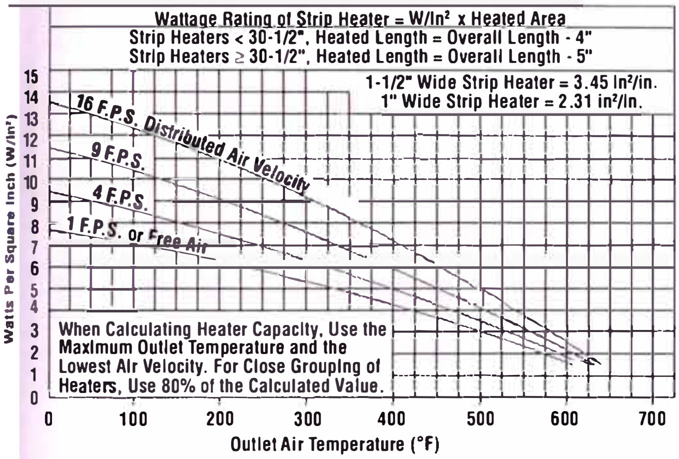
Graph G-106S — Finstrip® Heater Air Heating-Selection of Watt Density



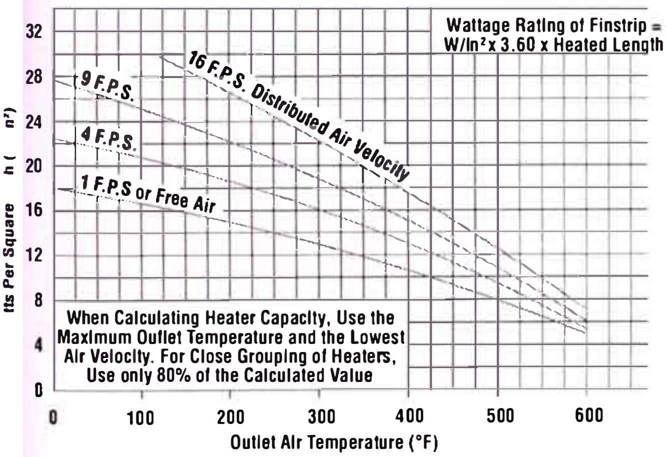
Technical Information

Allowable Watt Density & Heater Selection - Air Heating

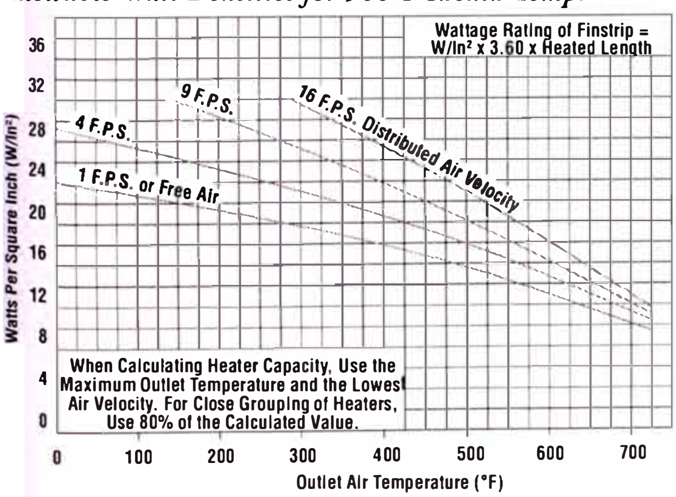
Graph G-132S — Strip Heater (Iron) Air Heating
Allowable Watt Densities for 700°F Sheath Temp.



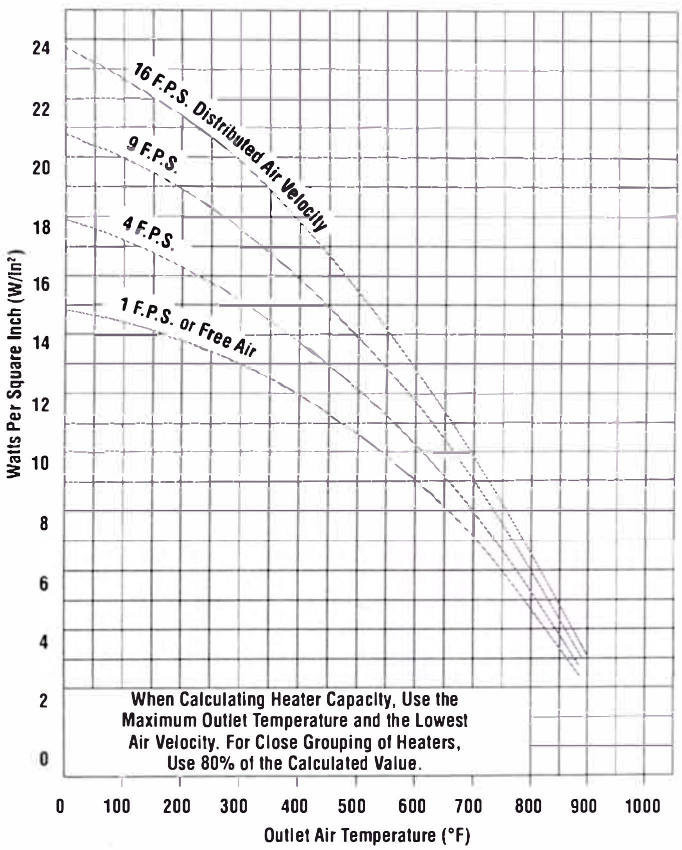
Graph G-107S — Finstrip® (Iron Sheath) Air Heating
Allowable Watt Densities for 700°F Sheath Temp.



Graph G-108S — Finstrip® (Chrome Steel) Air Heating
Allowable Watt Densities for 900°F Sheath Temp.

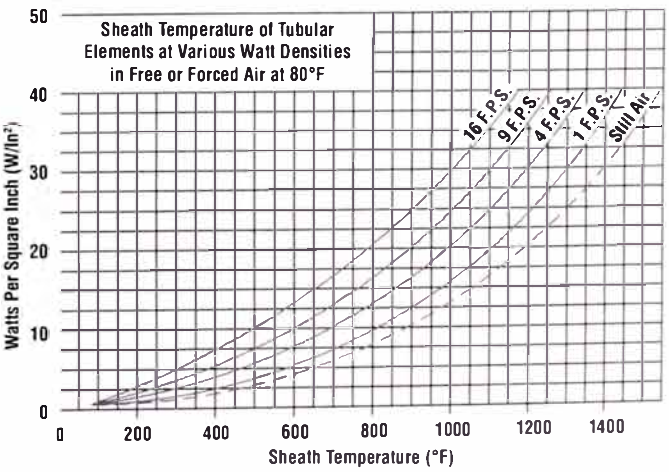


Graph G-100S — Strip Heater (Chrome) Air Heating
Allowable Watt Densities for 1000°F Sheath Temp.



Notes —
Strip Heaters < 30-1/2", Heated Length = Overall Length - 4"
Strip Heaters ≥ 30-1/2", Heated Length = Overall Length - 5"
1-1/2" Wide Strip Heater = 3.45 in./in.
1" Wide Strip Heater = 2.31 in./in.

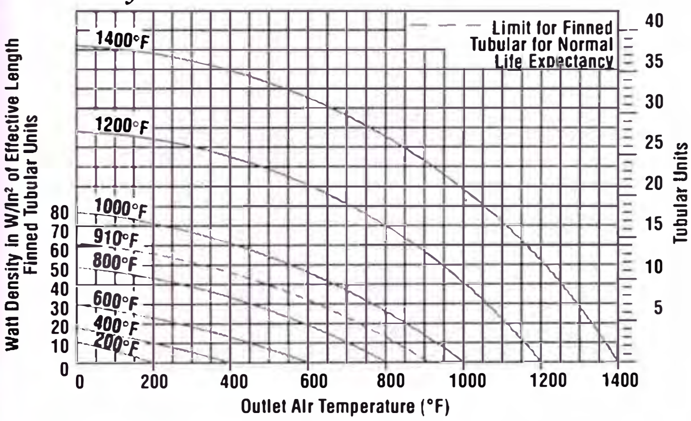
Graph G-136S — Tubular Heater Air Heating



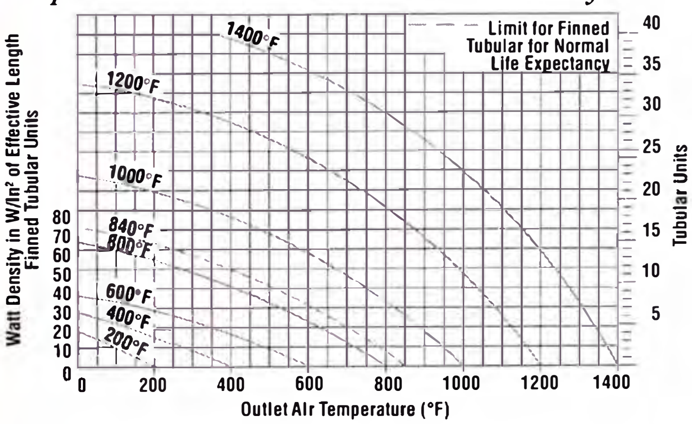
Technical Information

Allowable Watt Density & Heater Selection - Air Heating

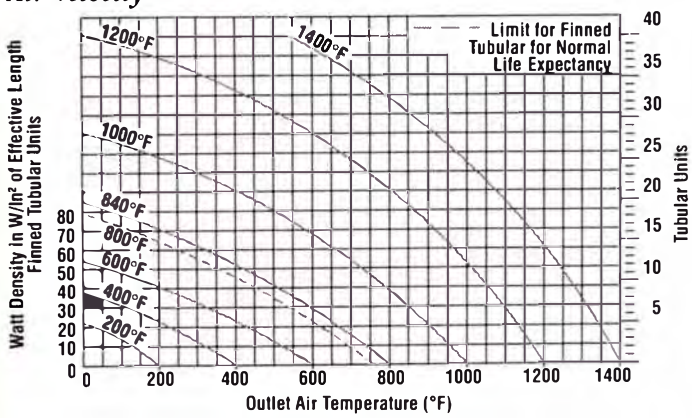
*Graph G-151-1 — **Fintube® & Tubular Heaters Sheath Temperatures with 1 FPS Distributed Air Velocity***



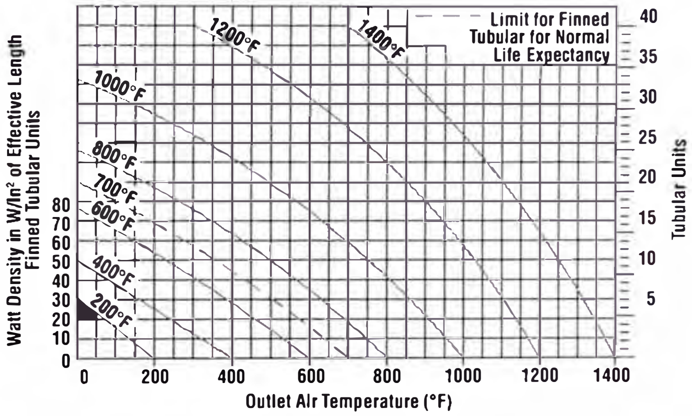
*Graph G-152-1 — **Fintube® & Tubular Heaters Sheath Temperatures with 4 FPS Distributed Air Velocity***



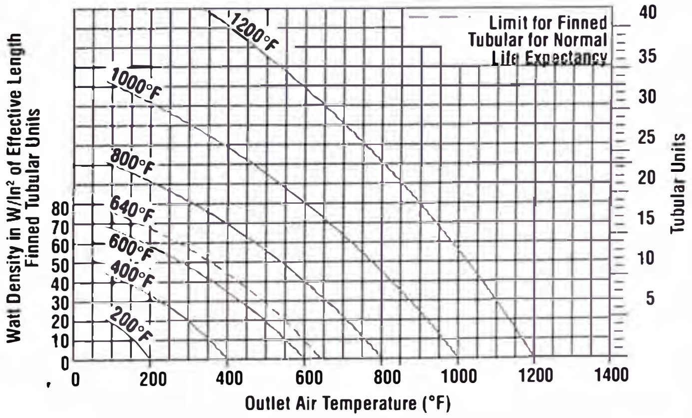
*Graph G-153-1 — **Fintube® & Tubular Heaters Sheath Temperatures with 9 FPS Distributed Air Velocity***



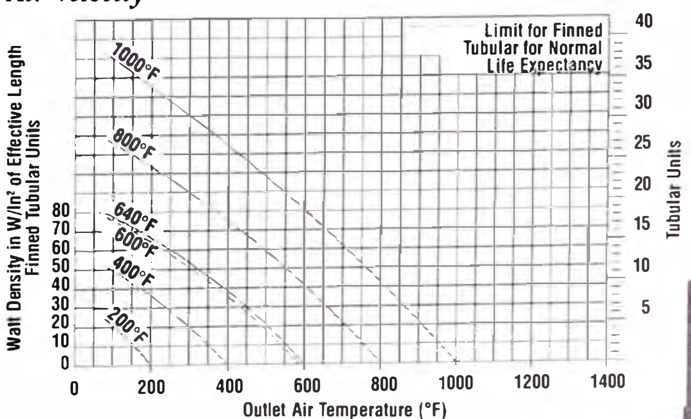
*Graph G-154-1 — **Fintube® & Tubular Heaters Sheath Temperatures with 16 FPS Distributed Air Velocity***



*Graph G-155-1 — **Fintube® & Tubular Heaters Sheath Temperatures with 25 FPS Distributed Air Velocity***



*Graph G-156-1 — **Fintube® & Tubular Heaters Sheath Temperatures with 36 FPS Distributed Air Velocity***



Technical Information

Determining Energy Requirements - Air & Gas Heating

Air & Gas Heating — Cryogenics

Industrial gases are usually stored in a liquid state with heat being added to vaporize and boil off the gas as usage requires. General heat equations apply except that pipes, tubes and vessels containing the cryogenic fluid or gas frequently represent a heat source rather than a heat loss. If the size and materials of the tanks or vessels are known, then heat calculations for the temperature rise can be performed as in standard vessel heating or boiler problems. The following example is typical of a cryogenic heating application.

Problem — Vaporize and preheat 30,000 SCFH of liquid Nitrogen (N_2) from -345°F to 70°F at atmospheric conditions. The properties of N_2 from Cryogenic Gas Tables are: Boiling point, -320°F Specific heat Btu/lb/°F = 0.474 (liq.), 0.248 (gas) Latent heat of vaporization = 85.7 Btu/lb Atm. density of N_2 at 32°F = 0.0784 lb/ft³.

Solution — Amount of liquid N_2 to be vaporized 30,000 SCFH x 0.0784 lb/ft³ = 2,352 lbs/hr

1. **Raise** liquid from -345°F to -320°F (boiling point) ΔT = 25°F.

$$kW = \frac{Wt \times C_p \times \Delta T \times SF}{3412\ Btu/kW}$$

Where:
Wt = Weight of material in lbs
C_p = Specific heat of the liquid N_2
ΔT = Temperature rise in °F
SF = Suggested safety factor of 20%

$$kW = \frac{2{,}352\ lbs \times 0.474 \times 25}{3412\ Btu/kW} \times 1.2 = 9.8\ kW$$

2. **Vaporize** the liquid N_2

$$kW = \frac{2{,}352\ lbs \times 85.7}{3412\ Btu/kW} \times 1.2 = 70.9\ kW$$

3. **Raise** the temperature of the N_2 from boiling point -320°F to 70°F — ΔT = 390°F.

$$kW = \frac{2{,}352\ lbs \times 0.248 \times 390}{3412\ Btu/kW} \times 1.2 = 80\ kW$$

Total kW/hr required = 9.8 + 70.9 + 80 = 169.7

Equipment Recommendations — Generally, cryogenic applications utilize both a vaporizer unit and a gas preheater. High watt density heaters immersed in the cryogenic fluid can be used for the vaporizer. Standard circulation heaters and watt densities are recommended for gas preheating. Protect the heater terminals from frost and moisture with element seals and liquid tight terminal covers.

Material Recommendations — Ordinary carbon steel is subject to brittle fracture at temperatures below -20°F and is generally not recommended. Stainless steel, high nickel bearing alloys or aluminum alloys may be used. Use Teflon® for gaskets as Teflon® remains pliable at low temperatures.

Air & Gas Heating — Batch Ovens

Most oven applications consist of heating work product inside an insulated enclosure. Heat loss calculations involve the determination of the heat requirements to heat the enclosure and work product using heated air circulated by natural or forced convection. Any make up or ventilation air must also be considered. The following example outlines the calculation of the heat required for a typical oven heating application.

Problem — An oven with inside dimensions of 2 ft H x 3 ft W x 4 ft D is maintained at 350°F. The oven has sheet steel walls with 2 inches of insulation and is ventilated with 400 cfh (ft³/hr) of 70°F air which exhausts to the outside to remove fumes. The oven is charged with 250 lbs of coated steel parts on a steel tray weighing 40 lbs. The process requires the parts to be heated from 70°F to 350°F in 3/4 hour.

Weight of steel = 290 lbs
Specific heat of steel — 0.12 Btu/lb/°F
Weight of air = 0.080 lbs/ft³ at 70°F
Specific heat of air = 0.24 Btu/lb/°F
Temperature rise = 280°F
Surface losses with 2 inch insulation = 18 W/ft²/hr at 280°F temperature difference (Graph G-126S)
Surface area of oven = 52 ft²
Time = 3/4 hr (0.75)
Airflow rate = 400 ft³/hr

Solution —

1. **Calculate** kWh required to heat metal.

$$kW = \frac{290\ lbs \times 0.12\ Btu/lb/°F \times 280°F}{3412\ Btu/kW} = 2.86\ kW$$

2. **Calculate** kWh required to heat ventilated air

$$kW = \frac{400\ cfh \times 0.080\ Lbs \times 0.24\ C_p \times 280\ \Delta T \times 0.75\ t}{3412\ Btu/kW} = 0.47 kW$$

Where:
cfh = Air flow rate (400)
Lbs/ft³ = Density of air (0.080)
C_p = Specific heat of air (0.24)
ΔT = Temperature rise (280)
= Time in hours (0.75)

3. **Calculate** surface losses. Since the oven is already at temperature, losses are at full value.

$$kW = \frac{18\ W/ft^2/hr \times 52\ ft^2\ area \times 0.75\ hr}{1{,}000\ W/kW} = 0.70\ kW$$

4. **Total** kW = 2.86 + 0.47 + 0.70 = 4.03 kW
5. **For Oven Applications**, add 30% to cover door losses and other contingencies. kWh required (including safety factor) is

$$kWh = \frac{kW}{t} = \frac{4.03\ kW}{0.75\ hrs} = 5.37\ kW \times 1.3 = 6.98\ kW$$

Equipment Recommendations — Several process air heaters, including strip heaters, finstrips, bare tubulars or type OV oven heaters, are suitable for oven heating applications.

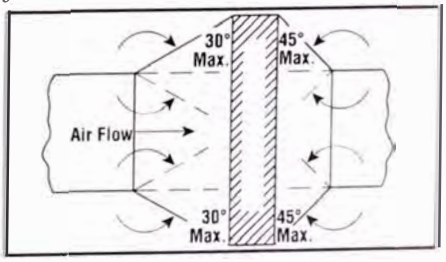
Pressure Drop for Process Air Heaters

The pressure drop through TDH and ADH process air heaters with bare tubular or finned tubular elements, CAB heaters with finstrip elements, and ADH and DH air heaters with finned tubular elements will vary considerably depending on product design and construction. Chromalox sales engineering can provide pressure drop calculations for virtually any duct heater (or circulation heater) application. Graphs G-112S3, G-189S1, G-227-2, and G-227ADH on the following page provide guidance for estimating the pressure drop for many Chromalox process air heaters[1]. Graph G-189S1 can be used for most finned tubular applications providing the elements are mounted in a three or six row configuration.

Transitions in Ducts — In some air distribution systems, the duct heater may be considerably larger or smaller than the associated ductwork. The duct heater can be adapted to different size ductwork by installing a sheet metal transition. The transition must be designed so that the slope on the upstream side of the equipment is limited to 30° (see below). On the leaving side, the slope should not be more than 45°.

Note 1 — Contact the factory for pressure drop calculations for duct heaters mounted lengthwise or in series and for GCH gas circulation heaters. These applications require special calculations for proper application and air handler sizing.

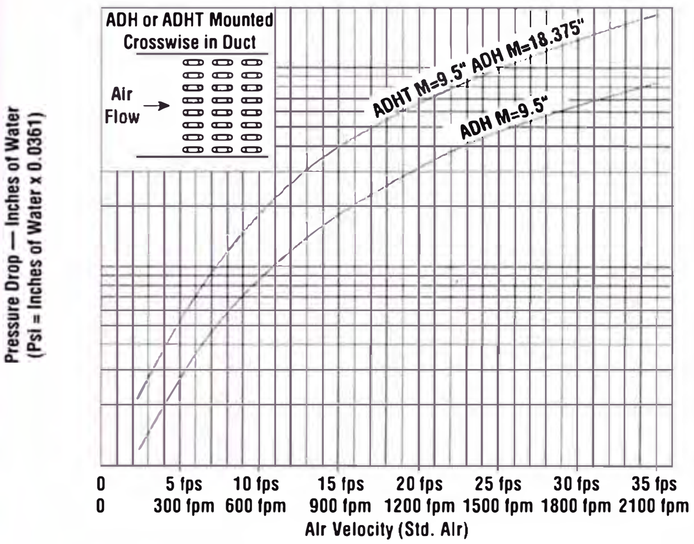
Recommended Dimensions for Duct Transitions



Technical Information

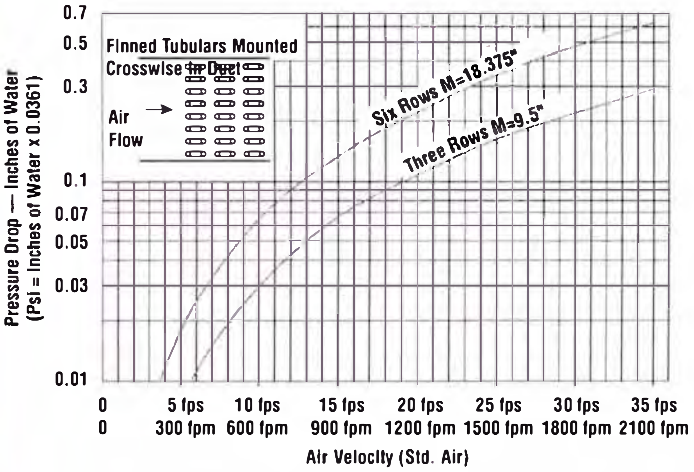
Determining Pressure Drop - Air and Gas Heating

Graph G-227ADH — Pressure Drop Vs. Velocity ADH and ADHT Tubular Element Air Heaters



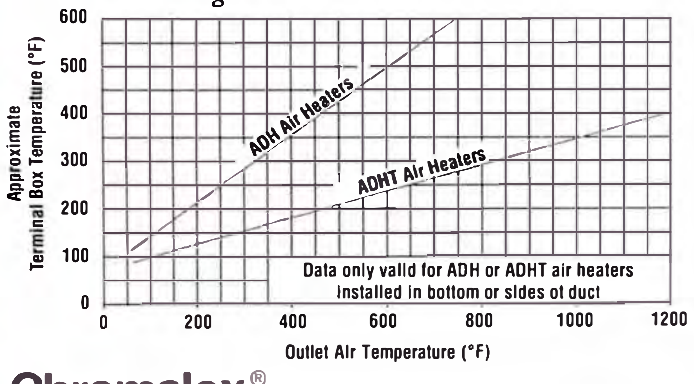
Note — Contact factory for pressure drop calculations for ADH/ADHT air heaters mounted lengthwise in duct and ADHT heaters where M is greater than 9.5"

Graph G-189S1 — Pressure Drop Vs. Velocity Fintube® Elements and Air Heaters

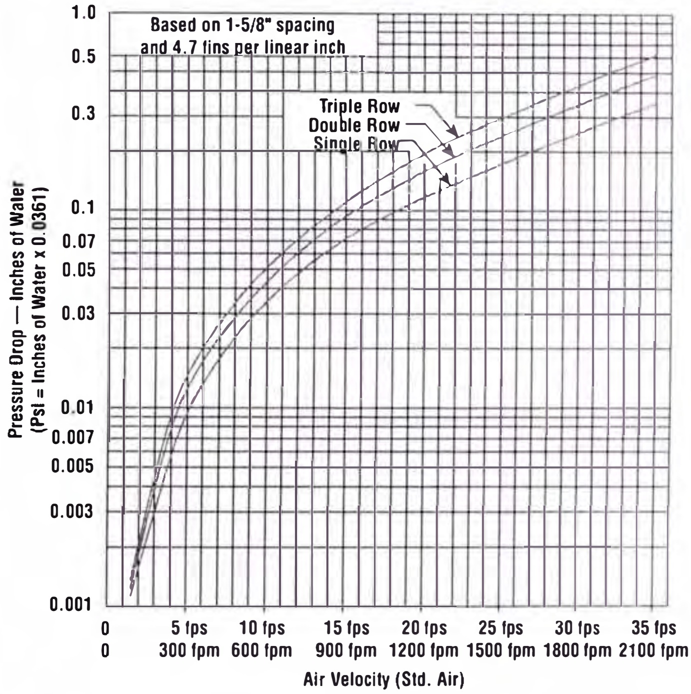


Note — Contact factory for pressure drop calculations for finned tubular element air heaters mounted lengthwise in duct.

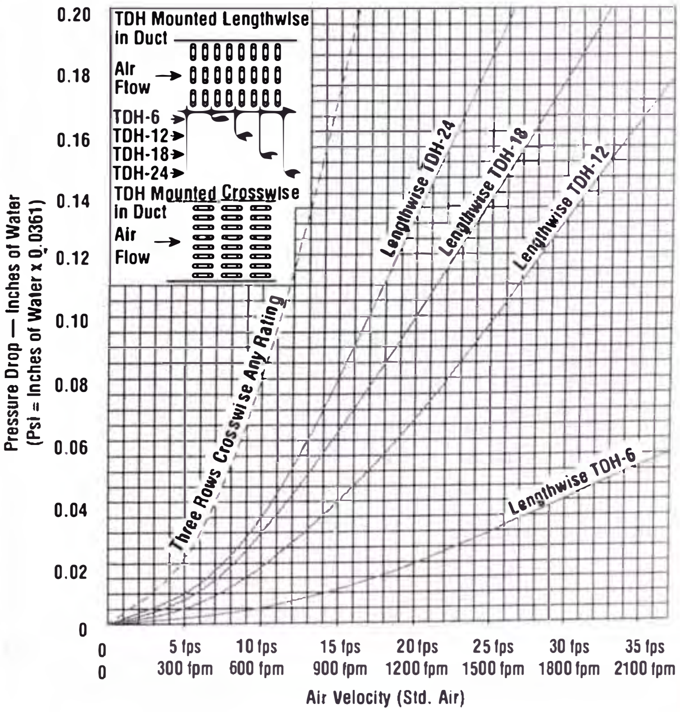
Graph ADHTB — ADH/ADHT Terminal Box Temperatures Field Wiring Selection Guide



Graph G-112S3 — Pressure Drop Vs. Velocity Finstrip® and CAB Air Heaters



Gra
TDH



Technical Information

Determining Energy Requirements - Air & Gas Heating

Air & Gas Heating with Circulation Heaters

To calculate the heat energy requirements for heating compressed air or gases, the first step is to determine the flow rate in pounds per hour. If the density of the air or gas under the actual pressure is known, the kW requirements can be calculated directly. The following example illustrates this procedure.

Example — Heat 20 ACFM of air at 30 psig from 60°F to 210°F. From the Properties of Air Chart, the density of air at 60°F and 30 psig is 0.232 lb/ft³ with a specific heat of 0.24 Btu/lb/°F. The kW required can be calculated from the formula:

$$kW = \frac{ACFM \times lbs/ft^3 \times 60\ min \times C_p \times \Delta T \times SF}{3412\ Btu/kW}$$

Where:

ACFM = Actual flow in ft³/min at inlet temperature and gauge pressure (psig)

Lbs/ft³ = Actual density at inlet temperature and gauge pressure (psig)

C_p = Specific heat of air or gas at inlet temperature and gauge pressure (psig)

ΔT = Temperature rise in °F

SF = Suggested Safety Factor

$$kW = \frac{20 \times 0.232 \times 60 \times 0.24 \times (210 - 60°F) \times 1.2}{3412}$$

$$kW = \frac{278.4\ lbs/hr \times 24 \times 150 \times 1.2}{3412} = 3.52\ kW$$

When the density and specific heat of a gas at a specific temperature and pressure are unknown, the actual flow rate can be converted to a known pressure and temperature using the physical laws of gases.

Example — Heat 45 ACFM of Nitrogen (N_2) at 35 psig from 50°F to 300°F. From the Physical and Thermodynamic Properties of Common Gases Chart, the density of Nitrogen at 70°F is 0.073 lb/ft³ with a specific heat of 0.2438 Btu/lb/°F. Convert 45 ACFM at 35 psig and 50°F to SCFM of Nitrogen at 70°F using the following formula:

$$SCFM = ACFM \times \frac{Actual\ psia}{14.7\ psia} \times \frac{Standard\ T}{Actual\ T}$$

SCFM = Std. ft³/min at 14.7 psia and 70°F

ACFM = Actual flow in ft³/min at inlet temperature and gauge pressure (psig)

Actual psia = gauge pressure in lb/in² + 14.7 psia

14.7 psia = absolute pressure in lb/in²

T = °Rankine (°F + 460)

$$SCFM = 45 \times \frac{(35 + 14.7)}{14.7\ psia} \times \frac{(70 + 460)}{(50 + 460)}$$

SFCM = 158.1 ft³/min

Using the calculated SCFM in place of ACFM in equation A, the kW required is:

$$kW = \frac{158.1 \times 0.073 \times 60 \times 0.2438 \times (300 - 50) \times 1.2}{3412}$$

kW = 14.8 kW

Determining Maximum Sheath & Chamber Temperatures

When heating air or gases in insulated pipe chambers or circulation heaters, the pipe wall temperature will normally exceed the outlet gas temperature. Excessively high wall and/or sheath temperatures can create an unsafe or dangerous condition. Maximum sheath and chamber temperatures can be estimated using the mass velocity of the gas and Graph G-237. In the above air heating example, assume a 4.5 kW Series 3 heater rated 23 W/in² has been selected. From Chart 236, the free cross sectional area of a Series 3 (3 inch) heater is 0.044 ft². Calculate mass velocity from the following equation:

$$\underset{(lbs/ft^2/sec)}{Mass\ Velocity} = \frac{Flow\ lbs/hr}{Free\ area\ ft^2} \div 3{,}600\ \frac{sec}{hr}$$

$$Mass\ Velocity = \left(\frac{278\ lbs/hr}{0.044\ ft^2}\right) \div 3{,}600\ \frac{sec}{hr}$$

*Chart 236 — **Circulation Heaters Free Internal Cross Sectional Area***

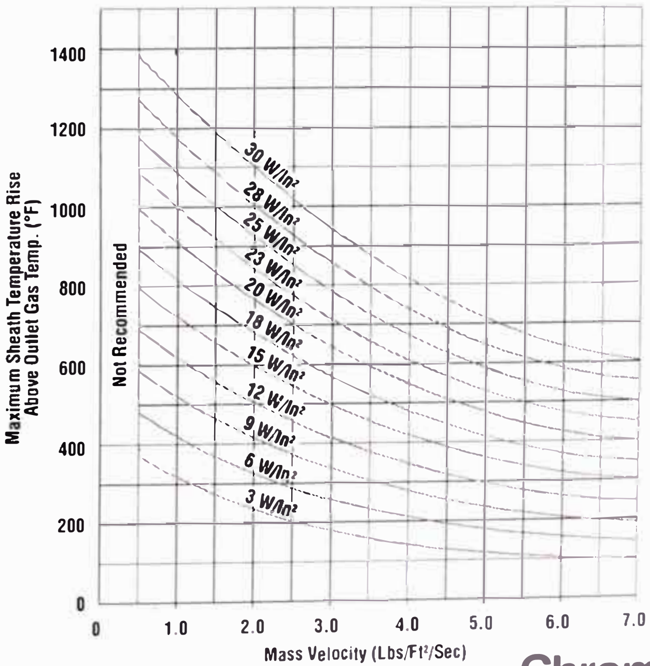
Pipe Body Nom. IPS (Std.)	Total Area (Ft²)	Free Area (Ft²)	No. 0.475" Elements
2	0.023	0.018	2
3	0.051	0.044	3
5	0.139	0.124	6
8	0.355	0.303	18
10	0.566	0.481	27
12	0.785	0.696	36
14	0.957	0.847	45
16	1.268	1.091	72
18	1.622	1.357	108

Mass Velocity = 1.75 lbs/ft²/sec

On Graph G-237, locate the mass velocity (1.75) on the horizontal axis. From that point, locate a 23 W/in² curve. Read across to the vertical axis (sheath temperature rise above outlet temperature) to 880°F. Adding 880°F + 210°F (outlet temp.) = 1090°F sheath temperature. Averaging the sheath and outlet temperatures (1090°F + 210°F ÷ 2), yields a maximum chamber temperature of 650°F.

Since the maximum chamber wall temperature is less than 750°F, a stock GCH heater with a carbon steel vessel and INCOLOY® elements rated 23 W/in² can be used.

*Graph G-237 — **Sheath Temperature Vs. Mass Velocity***



hnical Information

g Solids - Platens, Dies & Molds

lculation of heating requirements for solid materials (such as platens, dies lds) is similar to other applications. The g is a typical application problem:

le — A plastic forming process uses 20 lastic (*Cp* = 0.45 Btu/lb/°F) per hour. stic is pliable at 300°F and is formed by l platens, each 24 in. long x 12 in. wide thick and weighing 245 lbs. The platens preheated to 300°F in the closed posi- in 30 minutes. The top and bottom of tens (press side) are insulated with 1/2" insulation.

Heat Up — To heat the steel platens .12 Btu/lb/°F)

$$\frac{\text{Lbs} \times Cp \times \Delta T}{3412\ \text{Btu/kW} \times t}$$

$$\frac{245\ \text{lbs} \times 2 \times 0.12\ \text{Btu/lb/°F} \times (300 - 70°\text{F})}{3{,}412\ \text{Btu/kW} \times 0.5\ \text{hrs.}}$$

.93

s from exposed edges during heat-up: Graph G-125S, Curve "A", for oxidized .) Edge area = 2 (2 ft) + 2 (1 ft) x 0.5 ft = 3 ft²

$$\frac{3\ \text{ft}^2 \times 200\ \text{W/ft}^2\text{/hr}}{1000\ \text{W/kW}} = 0.6\ \text{kW/hr}$$

s by conduction from top and bottom lated surfaces of the platen —

$$= \frac{\text{Area ft}^2 \times k \times \Delta T}{3412\ \text{Btu/kW} \times d}$$

e:
.45 Btu/hr/in/Ft²/°F thermal conductivity id insulation (Properties of Non-metallic) *d* = thickness of insulation (0.5 inch)

$$\frac{2(2\ \text{ft}^2) \times 0.45 \times (300 - 70°\text{F})}{3412\ \text{Btu/kW} \times 0.5\ \text{in.}} = 0.24\ \text{kW/hr}$$

ge losses 0.6 kW + 0.24 kW ÷ 2 = 0.42 r

r start up = 7.93 + 0.42 x 1.2 SF = 10.0 kW

rating Requirements — (Assume losses opening and closing the platens are igible.) To heat plastic:

$$\frac{\text{lbs} \times 0.45\ \text{Btu/lb/°F} \times 300-}{3412\ \text{Btu/kW}} = 0.61\ \text{kW}$$

s = 0.6 kW + 0.24 kW = 0.84 kW
kW = 0.61 kW + 0.84 kW = 1.45 kW
red kW = 1.45 kW x 1.2 SF = 1.74 kW

Since the heat-up requirement is greater than that for operation, install 10 kW.

Heater Selection — While most platen and die heating applications are accomplished with cartridge heaters, strip or tubular heaters may also be used by inserting them into grooved slots in the metal. (See clamp-on heater applications.) When selecting cartridge heaters, it is essential that the following factors be considered to ensure reasonable heater life and sufficient heat.

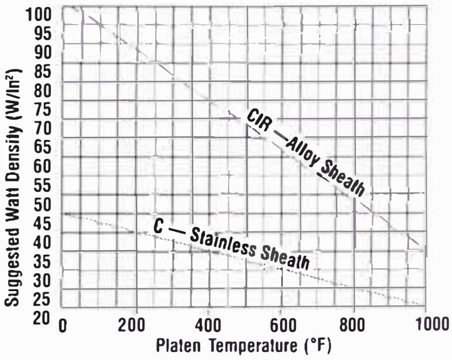
1. **Select Watt Density —** The maximum permissible sheath watt densities for INCOLOY® sheath (CIR) cartridge heaters for a given metal temperature are shown on Graph G-235A. These curves plot the recommended watt densities for various hole clearances. Graph G-201 is useful for determining watt density for optimum life when selecting type CIR heaters.

2. **Determine Proper Fit —** When cartridge heaters are installed in a machined or drilled hole, the hole should be sized to the nominal diameter of the heater. For best fit, holes should be drilled slightly undersized and reamed to the nominal heater diameter. Actual diameters of standard cartridge heaters are 0.003 to 0.005" smaller than nominal. This allows for easy installation when cold. Sheath expansion upon heating provides an interference fit and maximum heat transfer.

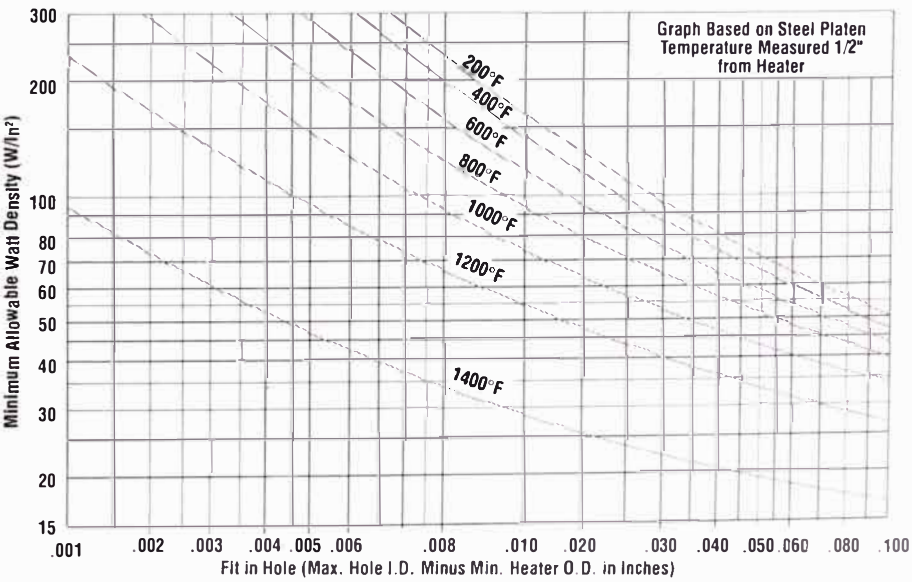
3. **Protect Cartridge Heaters from External Contamination —** Contamination can occur when moisture, oil, etc. enters the sheath through the lead wires or terminal end. (The end opposite the lead wires is protected by a seal welded end disc.) Contamination frequently causes short life and dielectric failure. Special moisture resistant terminal constructions are available and hermetic seals can be supplied when severe contamination problems are present.

4. **Provide Mechanical Protection for the Lead Wires —** Most high temperature lead wire electrical insulations have little resistance to mechanical abrasion. Special constructions using sleeving or conduit for mechanical protection are available.

Graph G-201 — Suggested Watt Density Limits for Optimum Life



Graph G-235A — Maximum Watt Density Vs. Platen Temperature for Various Fits Using Type CIR Cartridge Heaters



Technical Information

Heating Exchangers - Heating & Cooling

General Information

In addition to direct heating with electric heating elements, Chromalox can provide heat exchangers for use with circulating hot or cold water systems or with steam as the heating media. The heat exchangers are designed to heat water solutions in plating baths and other corrosive applications and are available in Stainless Steel, Titanium or Teflon®. Check the Corrosion Guide in this section for proper sheath material selection. The procedures and calculations for using these heat exchangers are shown below: The procedures are based on closed and insulated tanks (see note below).

Using Steam Heating Media

The heating capacity requirements for using steam as the heating media can be determined from the following formula:

$$\frac{V \times \Delta T \times S_{PF}}{1000} = ft^2/hr$$

Where:

V = Gallons of liquid to be heated

ΔT = Desired temperature rise or change in temperature °F

S_{PF} = Steam pressure factor from Table 1

Ft^2 = Square feet of heat exchanger required to provide heat up in one hour

Calculation Procedure

1. **Determine** gallons in tank to be heated.
2. **Subtract** the temperature of the solution to be heated from the desired temperature.
3. **Locate** the usable steam pressure in Table 1 and determine the Steam Pressure Factor.
4. **Apply** the Steam Pressure Factor to the above equation and solve for area in square feet.
5. **Select** the heat exchanger from the product pages that matches the requirements.

Table 1 — Steam Pressure Factor

Exchangers	Steam Pressure Available (psig) 5	10	15	20	25	30	Above 30
Metal	0.55	0.50	0.42	0.37	0.30	0.27	Note[1]
Teflon®	2.2	2.0	1.7	1.5	1.3	1.1	Note[1]

1. Contact your Local Chromalox Sales office for recommendations for steam pressures over 30 psig.

Using Hot Water Heating Media

The heating capacity requirements for using hot water as the heating media can be determined from the following formula:

$$\frac{V \times \Delta T \times 8.33}{U \times (T_1 - T_2)} = ft^2/hr$$

Where:

V = Gallons of liquid to be heated

ΔT = Desired temperature rise or change in temperature °F

U = Factor for coil type
U factor for Metal Coils — 90
U factor for Teflon® Coils — 40

T_1 = Temperature of incoming hot water media

T_2 = Final temperature of solution to be heated

Ft^2 = Square feet of heat exchanger required to provide heat up in one hour

Calculation Procedure

1. **Determine** gallons in tank to be heated.
2. **Subtract** the initial temperature of the solution to be heated from the desired temperature.
3. **Determine** the proper U factor for the particular type heat exchanger selected.
4. **Determine** temperature of incoming hot water supply.
5. **Apply** the above equation and solve for area in square feet.
6. **Select** the heat exchanger from the product pages that matches the requirements.

The above equation gives the square feet of heat exchanger needed to complete the heat up operation in one hour. If more time is available, the coil surface area (ft²) may be reduced by dividing the square feet from the above equation by the heat up time available. The correction factor can be used for time periods up to 4 hours maximum.

Note — When heating open tanks, the heat loss from the water surface must be added to the heating requirements (see Graph G-114S).

Using Cold Water Cooling Media

In electroplating operations, considerable heat is added to the plating solution by the plating current. Frequently it is desirable to cool the plating bath without diluting or upsetting the chemical balance by introducing cold water directly into the solution. Heat exchangers provide the ideal solution to this problem. The cooling capacity requirements for using cold water as the cooling media for a plating bath can be determined from the following formula:

$$\frac{V_R \times A_R \times 3.412 \text{ Btu/W}}{U \times (T_1 - T_2)} = ft^2/hr$$

Where:

V_R = Voltage of rectifier

A_R = Amperage or current of rectifier

U = Factor for coil type
U factor for Metal Coils — 90
U factor for Teflon® Coils — 40

T_1 = Final temperature of solution to be cooled

T_2 = Temperature of incoming cold water media

Ft^2 = Square feet of heat exchanger required to provide cool down in one hour

Calculation Procedure

1. **Determine** the watts of energy from the rectifier by multiplying the volts times amps. Convert watts to Btu by dividing by 3,412.
2. **Determine** the proper U factor for the particular type heat exchanger selected.
3. **Determine** temperature of incoming cold water supply.
4. **Subtract** the temperature of the cooling water from the desired temperature of the solution to be cooled. **CAUTION** — If the difference in temperature is less than 15°F, contact your Local Chromalox Sales office for assistance in determining proper coil size.
5. **Apply** the above equation and solve for area in square feet.
6. **Select** the heat exchanger from the product pages that matches the requirements.

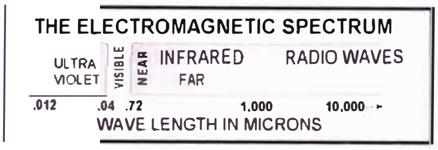
Technical Information

Radiant Infrared Heating - Theory & Principles

Infrared Theory

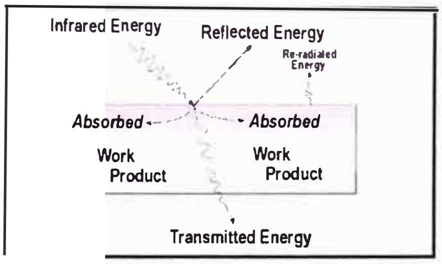
Infrared energy is radiant energy which passes through space in the form of electromagnetic waves (Figure 1). Like light, it can be reflected and focused. Infrared energy does not depend on air for transmission and is converted to heat upon absorption by the work piece. In fact, air and gases absorb very little infrared. As a result, infrared energy provides for efficient heat transfer without contact between the heat source and the work piece.

Figure 1



Infrared heating is frequently missapplied and capacity requirements underestimated due to a lack of understanding of the basic principles of radiant heat transfer. When infrared energy from a source falls upon an object or work piece, not all the energy is absorbed. Some of the infrared energy may be reflected or transmitted. Energy that is reflected or transmitted does not directly heat the work piece and may be lost completely from the process (Figure 2).

Figure 2

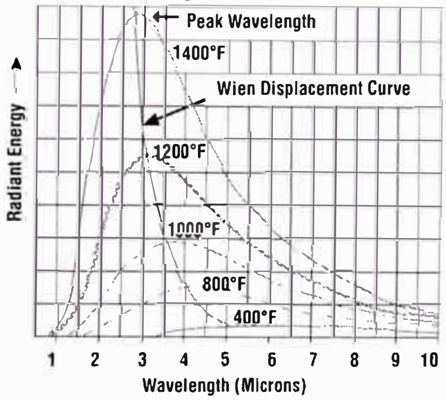


Another important factor to consider in evaluating infrared applications is that the amount of energy that is absorbed, reflected or transmitted varies with the wave length of the infrared energy and with different materials and surfaces. These and other important variables have a significant impact on heat energy requirements and performance.

Infrared Emitters & Source Temperatures — The amount of radiant energy emitted from a heat source is proportional to the surface temperature and the emissivity of the material. This is described by the Stefan-Boltzmann Law which states that radiant output of an ideal black body is proportional to the fourth power of its absolute temperature. The higher the temperature, the greater the output and more efficient the source.

Emissivity and an Ideal Infrared Source — The ability of a surface to emit radiation is defined by the term *emissivity.* The same term is used to define the ability of a surface to absorb radiation. An ideal infrared source would radiate or absorb 100% of all radiant energy. This ideal is referred to as a "perfect" black body with an *emissivity* of unity or 1.0. The spectral distribution of an ideal infrared emitter is below.

Spectral Distribution of a Blackbody at Various Temperatures



Note — As the temperature increases, the peak output of the source shifts to the left of the electromagnetic spectrum with a greater percentage of the output in the near infrared range. This is referred to as the Wien Displacement Curve and is an important factor in equipment selection.

Emissivity — In practice, most materials and surfaces are "gray bodies" having an emissivity or absorption factor of less than 1.0. For practical purposes, it can be assumed that a poor emitter is usually a poor absorber. For example, polished aluminum has an emissivity of 0.04 and is a very poor emitter. It is highly reflective and is difficult to heat with infrared energy. If the aluminum surface is painted with an enamel, emissivity increases to 0.85 - 0.91 and is easily heated with infrared energy. Table 1 lists the emissivity of some common materials and surfaces.

Absorption — Once the infrared energy is converted into heat at the surface, the heat travels into the work by conduction. Materials such as metals have high thermal conductivity and will quickly distribute the heat uniformly throughout. Conversely, plastics, wood and other materials have low thermal conductivity and may develop high surface temperatures long before internal temperatures increase appreciably. This can be an advantage when using infrared heating for drying paint, curing coatings or evaporating solvents on non-metal substrates.

Reflectivity — Materials with poor emissivity frequently make good reflectors. Polished gold with an emissivity of 0.018 is an excellent infrared reflector that does not oxidize easily. Polished aluminum with an emissivity of 0.04 is an excellent second choice. However, once the surface of any metal starts to oxidize or collect dirt, its emissivity increases and its effectiveness as an infrared reflector decreases.

*Table 1 — **Approximate Emissivities***

Metals	Polished	Rough	Oxidized
Aluminum	0.04	0.055	0.11-0.19
Brass	0.03	0.06-0.2	0.60
Copper	0.018-0.02	—	0.57
Gold	0.018-0.035	—	—
Steel	0.12-0.40	0.75	0.80-0.95
Stainless	0.11	0.57	0.80-0.95
Lead	0.057-0.075	0.28	0.63
Nickel	0.45-0.087	—	0.37-0.48
Silver	0.02-0.035	—	—
Tin	0.04-0.065	—	—
Zinc	0.045-0.053	—	0.11
Galv. Iron	0.228	—	0.276
Miscellaneous Materials			
Asbestos			0.93-0.96
Brick			0.75-0.93
Carbon			0.927-0.967
Glass, Smooth			0.937
Oak, Planed			0.895
Paper			0.924-0.944
Plastics			0.86-0.95
Porcelain, Glazed			0.924
Quartz, Rough, Fused			0.932
Refractory Materials			0.65-0.91
Rubber			0.86-0.95
Water			0.95-0.963
Paints, Lacquers, Varnishes			
Black/White Lacquer			0.8-0.95
Enamel (any color)			0.85-0.91
Oil Paints (any color)			0.92-.096
Aluminum Paint			0.27-0.67

Transmission — Most materials, with the exception of glass and some plastics, are opaque to infrared and the energy is either absorbed or reflected. Transmission losses can usually be ignored. A few materials, such as glass, clear plastic films and open fabrics, may transmit significant portions of the incident radiation and should be carefully evaluated.

Controlling Infrared Energy Losses — Only the energy absorbed is usable in heating the work product. In an unenclosed application, losses from reflection and re-radiation can be excessive. Enclosing the work product in an oven or a tunnel with high reflective surfaces will cause the reflected and re-radiated energy to be reflected back to the work product, eventually converting most of the original infrared energy to useful heat on the work product.

Technical Information

Radiant Infrared Heating - Source Evaluations

Evaluating Infrared Sources

Commonly available infrared sources include heat lamps, quartz lamps, quartz tubes, metal sheath elements, ceramic elements and ceramic, glass or metal panels. Each of these sources has unique physical characteristics, operating temperature ranges and peak energy wavelengths. (See characteristics chart below.)

Source Temperature & Wave Length Distribution — All heat sources radiate infrared energy over a wide spectrum of wavelengths. As the temperature increases for any given source:

1. The total infrared energy output increases with more energy being radiated at all wavelengths.
2. A higher percentage of the infrared energy is concentrated in the peak wavelengths.
3. The energy output peak shifts toward the shorter (near infrared) wavelengths.

The peak energy wavelength can be determined using Wien's Displacement Law.

$$\text{Peak Energy (Microns)} = \frac{5269 \text{ microns/°R}}{\text{Source Temp. (°F)} + 460}$$

$$\text{Source 1400°F} = \frac{5269 \text{ microns/°R}}{1400°F + 460} = 2.83 \text{ microns}$$

$$\text{Source 500°F} = \frac{5269 \text{ microns/°R}}{500°F + 460} = 5.49 \text{ microns}$$

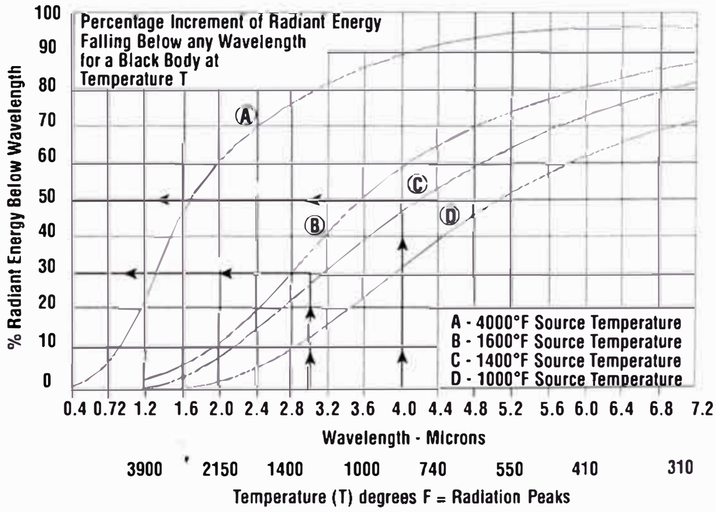
Absorption by Work Product Materials in Process Applications — While most materials absorb long (far) infrared wavelengths uniformly, many materials selectively absorb short (near) infrared energy in bands. In process heating applications this selective absorption could be very critical to uniform and effective heating.

For process heating, it is recommended that the infrared source have a peak output wavelength that best matches the selective absorption band of the material being heated. When the major absorption wavelengths of the material being heated are known, the chart below provides guidance in selecting the most efficient heat source. The relative percentage of radiant energy emitted by specific source and falling in a particular wavelength range can be determined from the chart.

Example — Plastic materials are known to have high infrared absorption rates in wavelengths between 3 and 4 microns. Select a source which provides the most effective output to heat plastics in the 3 and 4 micron range.

1. **Enter Bottom of Chart** at 3 and 4 microns, read up to corresponding points on selected element curve (use 1400°F metal sheath in this example).
2. **From These Points,** move left to read the corresponding percentages (29% and 51%).
3. **The Difference** between these two values (22%) is the percentage of radiant energy emitted by the element within selected wavelengths limits.
4. **To Obtain** the maximum percentage of the energy emitted by a given element in the desired wavelength band, multiply the percentage in 3 above by the conversion efficiency for the selected element (comparison chart 56% x 22% = 12.2%).

In this example, a high temperature source (quartz lamp 4000°F) with a peak in the 1.16 micron range, while more energy conversion efficient, would not be as effective as a lower temperature metal sheath or panel heaters with a peak in the 2.8 to 3.6 micron range. Quartz tubes (1600°F) would provide similar peak wavelengths.



Characteristics of Commercially Used Infrared Heat Source

Infrared Source	Tungsten Filament		Nickel Chrome Resistance Wire			Wide Area Panels	
	Glass Bulb	T3 Quartz Lamp	Quartz Tube	Metal Sheath	Ceramic	Ceramic Coated	Quartz Face
Source Temperature (°F)	3000 - 4000°F	3000 - 4000°F	Up to 1600°F	Up to 1500°F	Up to 1600°F	200 - 1600°F	Up to 1700°F
Brightness	Intense white	Intense White	Bright Red to Dull Orange	Dull to Bright Red	Dark to Dull Red	Dark to Cherry Red	Dark to Cherry Red
Typical Configuration	G-30 Lamp	3/8" Dia. Tube	3/8 or 1/2" Tube	3/8 or 1/2" Tube	Various Shapes	Flat Panels	Flat Panels
Type of Source	Point	Line	Line	Line	Small Area	Wide Area	Wide Area
Peak Wavelength (microns)	1.16	1.16	2.55	2.68	3 - 4	2.25 - 7.9	2.5 - 6
Maximum Power Density	1 kW/ft²	3.9 kW/ft²	1.3 - 1.75 kW/ft²	3.66 kW/ft²	Up to 3.6 kW/ft²	3.6 kW/ft²	5.76 kW/ft²
Watts per Linear Inch	N/A	100	34 - 45	45 - 55	N/A	N/A	N/A
Conversion Efficiency Infrared Energy	86%	86%	40 - 62%	45 - 56%	45 - 50%	45 - 55%	45 - 55%
Response Time Heat/Cool	Seconds	Seconds	1 - 2 Minutes	2 - 4 Minutes	5 - 7 Minutes	5 - 8 Minutes	6 - 10 Minutes
Color Sensitivity	High	High	Medium	Medium	Medium	Low to Medium	Low to Medium
Thermal Shock Resistance	Poor	Excellent	Excellent	Excellent	Good	Good	Good
Mechanical Ruggedness	Poor	Fair	Good	Excellent	Good	Good	Fair
Chromalox Model	—	QR	QRT	RAD, URAD	RCH	CPL, CPLI, CPH	CPHI

Technical Information

Radiant Infrared Heating - Process Applications

Application Parameters

Typical industrial applications of radiant heating include **curing** or **baking** (powders, paints, epoxies, adhesives, etc.), **drying** (water, solvents, inks, adhesives, etc.) and **product heating** (preheating, soldering, shrink fitting, forming, molding, gelling, softening, and incubating). The following are general guidelines that can be used in evaluating and resolving most radiant heating problems. Unfortunately, the process is so versatile and its applications so varied that it is not feasible to list solutions to every problem.

To determine heat energy requirements and select the best Chromalox infrared equipment for your application, it is suggested the problem be defined using a check list similar to below. Several of the key factors on the list are discussed on this and following pages:

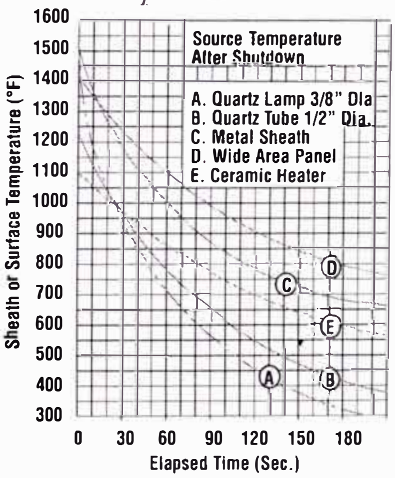
1. Product to be heated
2. Physical dimensions and weight/piece
3. Surface coating or solvents, if any
4. Infrared absorption characteristics
5. Production rate (lbs/hr, pieces/hr, etc.)
6. Work handling method during heating (continuous, batch or other)
7. Element response time (if critical)
8. Power level requirements in kW/ft² based on Time/Temperature relationship (if known)
9. Starting work temperature
10. Final work temperature
11. Ventilation (if present or required)
12. Available power supply
13. Space limitations

Infrared Absorption Characteristics — As previously discussed, many materials, particularly plastics, selectively absorb infrared radiation. The following chart provides data on some common plastic materials and the recommended source temperatures for thermoforming applications.

Plastic	Absorption Band(s) (microns)	Ideal Source Temperature (°F)
LPDE	3.3 - 3.9	877 - 1170
HDPE	3.2 - 3.7	950 - 1170
PS	3.2 - 3.7 (6.4 - 7.4)	950 - 1170 245 - 355
PVC	1.65 - 1.8 (2.2 - 2.5)	2440 - 2700 1625 - 1910
PMMA	1.4 - 2.2	1910 - 3265
PA-66	1.9 - 2.8 (3.4 - 5)	1405 - 2285 585 - 1075
Cellulose	2.2 - 3.6	990 - 1910
Acetate	(5.2 - 6)	440 - 545

Element Response Time — Some applications, such as continuous web heating of paper or plastic film, require quick shutdown of heaters in case of work stoppage. In these applications, residual radiation from the infrared heaters and associated equipment must be considered. Residual radiation from the element is a function of the operating temperature and mass. Quartz lamps and tubes have relatively low mass and the infrared radiation from the resistance wire drops significantly within seconds after shutdown. However, the surrounding quartz envelope acts as a secondary source of radiation and continues to radiate considerable energy. Metal sheathed elements have more mass and slightly slower response time. Wide area panels have the most mass and the slowest response time for both heat up and cool down. The following chart shows the average cool down rate of various sources after shutdown. Actual cool down of the source and work product will vary with equipment design, product temperature, ambient temperature and ventilation.

Source Temperature Vs. Time



Time-Temperature Relationship — A critical step in the evaluation of a radiant heating application is to determine the time necessary to develop work piece temperature and the elapsed time needed to hold temperature in order to obtain the desired results (curing or drying). The following chart shows time/temperature relationships for several typical infrared applications and materials.

Curing	Substrate	Surface Temp (°F)	W/In²	Time (min)
Alkyd Paint	Steel	320	3.9	3
Epoxy Paint	Steel	356	8.1	5
Acrylic Paint	Steel	392	8.1	2
Powder Coat	Steel	400	13	6

Drying & Heating	Substrate	Surface Temp (°F)	W/In²	Time (sec)
Glass Bottles	—	104	6.4	30
Adhesives	Paper	—	3.2	30
Heating				
PVC Shrinking	—	300	3.2	60
ABS Forming	—	340	9.7	—

Deriving Time-Temperature Information from Empirical Testing — If specific information is not readily available for a particular work product, a simple but effective test will usually provide enough preliminary data to proceed with a design. Place one or more radiant heaters in a position with the radiation directed at a work product sample. The distance between the face of the heater and the sample should approximate the expected spacing in the final application. Position the sample so that it is totally within the radiated area. Energize the heater(s) and record the time necessary to reach desired temperature. Calculate the W/in² falling on the work piece using the exposed area of the work product and the maximum kW/ft² at the face of the heater as listed in the product catalog page. If the data is not available and a sample test can not be performed, the following table provides a few suggested watt densities as guidance.

Application	W/In² on Work Heat Up	W/In² on Work Hold
Paint Baking	4-6	1 - 2
Metal Dry Off	15	8
Thermoforming	10 - 15	—
Fusing or Embossing (plastic films)	5-6	—
Silk Screen Drying	5-6	—

Contact your Local Chromalox Sales office for further information or assistance in determining time/temperature requirements for a particular application.

Power Level or Radiation Intensity — In most process applications, more than one radiant heater is needed to produce the desired results. When heaters are mounted together as close as possible, the net radiant output of the array is defined as the maximum power level or radiation intensity. The catalog pages for radiant heaters indicate the maximum kW/ft² at the face of each heater. Typical ranges for radiation intensity (power level) are as follows:

Radiant Intensity or Power Level	Heater Output (kW/Ft²)
Low	1 - 2
Medium	2 - 3
High	Over 3

Technical Information

Radiant Infrared Heating - Process Applications

Determining kW Required — It is difficult to develop simple calculations for radiant heating applications because of the many variables and process unknowns. Design data gained from previous installations or from empirical tests is frequently the most reliable way of determining installed kW requirements. Total energy requirements can be estimated with conventional heat loss equations. The results of conventional equations will provide a check against data obtained from nomographs or empirical testing. As a minimum, conventional equations should include the following.

1. **Calculate the Sensible Heat** required to bring work to final temperature. Base calculations on specific heat and pounds of material per hour.
2. **Determine Latent Heat of Vaporization (when applicable).** Latent heat of vaporization is normally small for solvents in paints and is frequently ignored. However, when water is being evaporated, the kilowatt hours required may be quite significant.
3. **Ventilation Air (when applicable).** The rise in air temperature for work temperatures, 350°F or less, can usually be estimated as 50% of final work temperature rise. For higher work temperatures, assume air and work temperature are the same.
4. **Conveyor Belt or Chain Heat Requirements.** Assume temperature rise of conveyor to be the same as work temperature rise.
5. **Wall, Floor and Ceiling Losses for Enclosed Ovens.** For uninsulated metal surfaces, refer to Graph G-125S. For insulated walls, refer to Graph G-126S.
6. **Oven End Losses.** For enclosed ovens, this will depend on shape of end area and whether or not air seals are used. If silhouette shrouds are used, a safety factor of 10% is acceptable.
7. **The Sum of The Losses** calculated in 1-6 above will be the minimum total heat energy requirement based on conventional heat loss equations.

Infrared Heating Equations — Infrared energy requirements can also be estimated by using equations and nomographs developed specifically for infrared applications.

Product Heating — For product heating, the following equation can be used

$$kW = \frac{Lbs/hr \times C_p \times \Delta T\,°F}{3412\ Btu/kW \times Efficiency(RE) \times VF \times \epsilon}$$

Where:
Lbs/hr = Pounds of work product per hour
C_p = Specific heat in Btu/lb/°F
ΔT = Temperature rise in °F
Efficiency (RE) = Combined efficiency of the source and reflector
VF = View Factor is the ratio of the infrared energy intercepted by the work product to the total energy radiated by the source. For enclosed ovens, use a factor of 0.9. For other applications, refer to the view factor table.
ϵ = Absorption (emissivity) factor of the work product

Drying & Solvent Evaporation — Removing solvent or water from a product requires raising the product temperature to the vaporization temperature of the solvent and adding sufficient heat to evaporate it. To calculate heat requirements for solvent evaporation, the following information must be known.

1. Pounds of solvent to be evaporated per hour
2. Pounds of work product per hour
3. Initial temperature of product and solvent
4. Specific heat of product
5. Specific heat of solvent
6. Vaporization temperature of solvent (ie: water = 212°F)
7. Heat of vaporization of solvent
8. Source/reflector efficiency
9. View factor
10. Absorption factor (emissivity)

WARNING — Hazard of Fire. Flammable solvents in the atmosphere constitute a fire hazard. When flammable volatiles are released in continuous process ovens, the National Fire Prevention Association recommends not less than 10,000 ft³ of air be removed from the oven per gallon of solvent evaporated. Reference NFPA Bulletin 86 "Ovens and Furnaces", available from NFPA, P.O. Box 9101, Quincy MA 02269.

For drying, use the following equation.

$$kW = \frac{Q_{WP} + Q_S + Q_{LH}}{3412\ Btu/kW \times Efficiency(RE) \times VF \times \epsilon}$$

Where:
Q_{WP} = Btu required by work product to raise the temperature from initial to vaporization temperature
Q_S = Btu required by solvent to raise the temperature from initial to vaporization temperature
Q_{LH} = Btu required for the latent heat of the vaporization of the solvent
Efficiency (RE) = Combined efficiency of the source and reflector
VF = View Factor for enclosed ovens, use a factor of 0.9. For other applications, refer to the view factor table.
ϵ = Absorption (emissivity) factor of the work product

Controls — Most control systems for infrared process heating can be divided into two categories, open loop or manual systems and closed loop, fully automatic systems.

Open Loops or Manual Systems — The simplest and most cost effective control system is an input controllers (percentage timer) such as the Chromalox VCF Controller operating a magnetic contactor. The timer cycles the radiant heaters on and off for short periods of time (typically 15 - 30 seconds). This control system works best with metal sheath heaters, which have sufficient thermal mass to provide uniform radiation. It can be used with quartz tube or quartz lamp heaters by using special circuitry to switch from full to half voltage rather than full on and full off.

Closed Loop or Automatic Systems — Since infrared energy heats the work product by direct radiation, closed loop control systems that depend on sensing and maintaining air temperature are relatively ineffective (except in totally enclosed ovens). In critical applications where temperature tolerances must be closely held, non-contact temperature sensors operating SCR control panels are recommended. Non-contact temperature sensors can be positioned to measure only the work product temperature. Properly positioned, non-contact temperature sensors and SCR control panels can provide very accurate radiation and product temperature control.

Technical Information

Radiant Infrared Heating - Process Applications

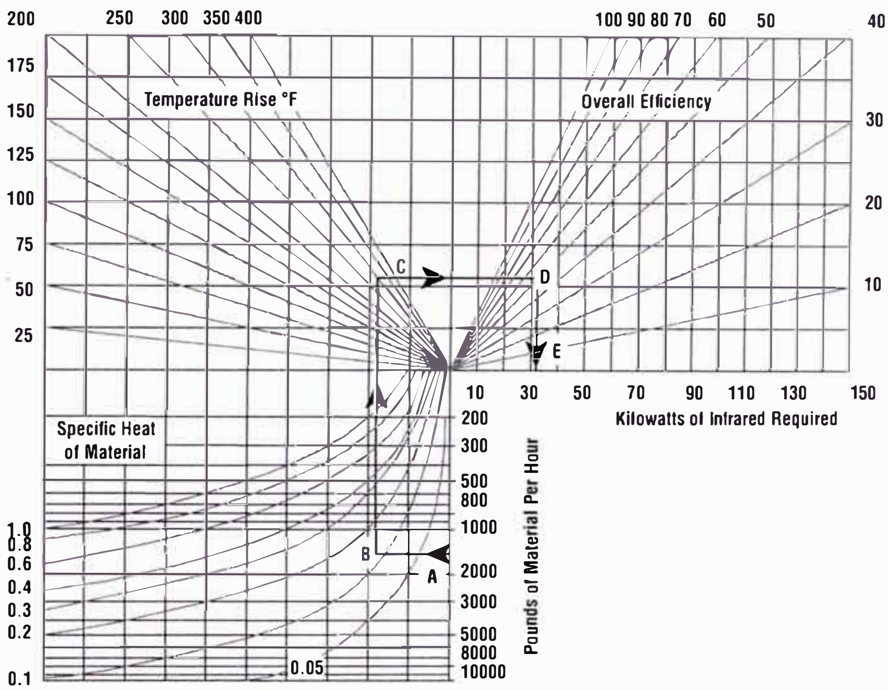
Nomograph for Product Heating — For product heating, the nomograph at the right can be used. The nomograph does not take into account heat energy requirements for air ventilation. To estimate the kW for total product heating:

1. **Determine** pounds of material per hour to be heated (A)
2. **Read across** to the specific heat of the material (B)
3. **Read up** to desired temperature rise in °F (C)
4. **Read across** to overall efficiency (D). Overall efficiency = Product Absorption Factor x View Factor x Source Efficiency. Determine Product Absorption Factor (surface emissivity) of the work product (ie: ϵ = 0.85 for enamel sheet metal). Determine View Factor (use 0.9 as a view factor for well designed or enclosed ovens). Determine Source efficiency. Typical Source/Reflector efficiencies are:

Quartz Lamps	0.70 to 0.80
Quartz Tubes	0.60 to 0.70
Metal Sheath	0.55 to 0.65

5. **Read down** to Kilowatts required (E).

Estimating Total Kilowatts for Product Heating



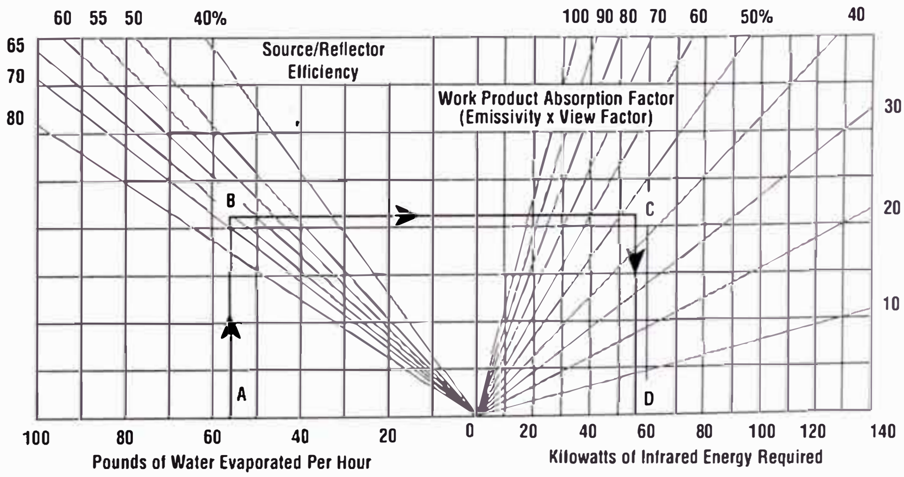
Nomograph for Drying — The nomograph to the right can be used to estimate Kilowatts required to evaporate water from the surfaces of work product. Graph is based on an initial starting product temperature of 70°F. It does not take into account heat energy requirements for air circulation or ventilation.

1. **Determine pounds** of water (solvent) per hour to be evaporated (A)
2. **Read up** to Source/Reflector efficiency (B). Depending on the configuration and cleanliness of the reflector, typical Source/Reflector efficiencies are:

Quartz Lamps	0.70 to 0.80
Quartz Tubes	0.60 to 0.70
Metal Sheath	0.55 to 0.65

3. **Read across** to Work Product Absorption Factor (C). This value is based on the emissivity of the work product surface (ie: ϵ = 0.85 for enameled sheet metal) and the view factor of the oven or space. Use 0.9 as a view factor for well designed or enclosed ovens.
4. **Read down** to Kilowatts required (D).

Estimating Infrared Kilowatts for Drying



Note — To evaporate solvents other than water, calculate the energy required to heat the solvent to vaporization temperature using the weight, specific heat and temperature rise. Calculate the latent heat of vaporization and add to the energy required to heat the solvent to vaporization temperature.

echnical Information

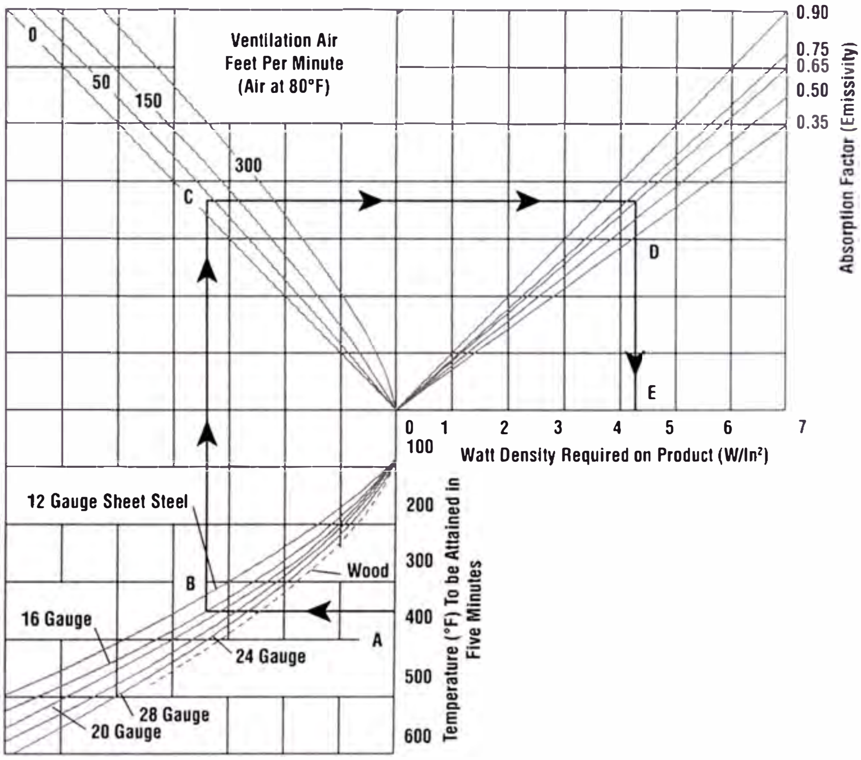
diant Infrared Heating - Process Applications

aking & Curing — The nomograph to the right can be used to determine the watt density required on the work product for baking and curing of paints and coating.

cquers are cured primarily by evaporation of the solvent and can be cured by infrared in 2 - 15 minutes. Enamels are cured primarily by polymerization and require a longer time (15 - 20 minutes). Varnishes, japans and house paints cure mainly by oxidation but can usually can be accelerated by infrared heating. To find approximate watt density needed for baking:

1. **Locate** temperature product is to reach in five minutes (A)
2. **Read across** to line representing gauge of the material being heated (B)
3. **Read up** to ventilation air in feet per minute over surface of the product (C). If not known, estimate feet per minute based on cubic feet per minute of ventilation or circulating air divided by the the approximate cross sectional area of the oven. In applications with no forced ventilation, use 2 - 5 fpm.
4. **Read right** to the absorption factor for the work product surface or coating (ie: ϵ = 0.85 for enameled sheet metal) (D)
5. **Read down** to watt density required on the product surface (E).

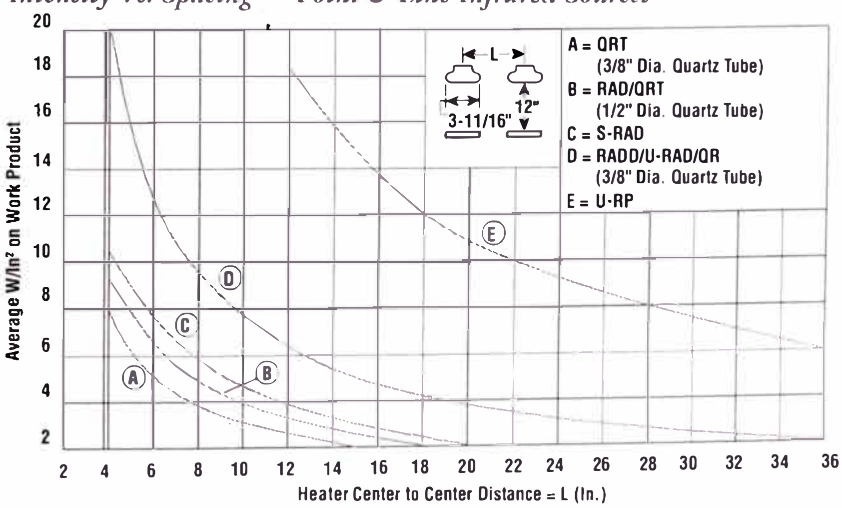
Estimating Watt Density for Curing or Baking



Determining Heater Fixture Spacing — Having determined the total required kilowatts and the desired W/in² on the work product, the next step is to deterine the spacing and the number of heaters. In most conveyor type oven applications, a 12" spacing from the face of the heater to the work product produces uniform distribution of the radiation. The graph to the right shows centerline to centerline spacing of Chromalox radiant heaters to obtain various intensities on the work based on a spacing of 12" from the face of the heater to the work product. Specific applications may require the distance to be increased or decreased.

The graph is applicable to line or point infrared sources installed in reflectors. Refer to view factor charts for ceramic heaters and flat panel infrared sources.

Intensity Vs. Spacing — Point & Line Infrared Sources

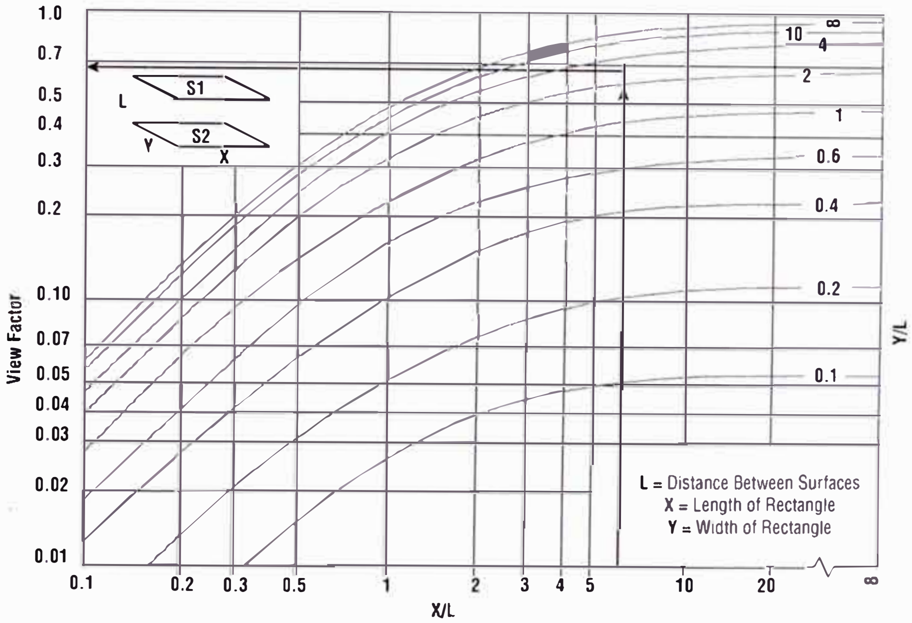


Technical Information

Radiant Infrared Heating - Process Applications

View Factor for Flat Panels — While the radiation pattern from line and point infrared sources can be controlled by reflectors, the radiation pattern from flat panels is diffused and the infrared energy is emitted from a large area. Consequently, the shape of the source and the target are a significant factor in determining the Watt density falling on the work product. For parallel surfaces in applications such as thermoforming or web heating, the incident energy falling on the work product is determined by a "View Factor". View factor is defined as the percentage or fraction of infrared energy leaving the surface of a flat panel (source) which is intercepted by the surface of the work product (target). The view factor for parallel surfaces (rectangles) can be determined from the graph. **Example** — Find the view factor for a 12 by 24" panel heater mounted 4" from a continuous web infrared drying application. X/L = 24" ÷ 4" = 6, Y/L = 12" ÷ 4" = 3. Read left from the intercept of X/L = 6 and Y/L = 3 with a view factor of 0.7.

View Factor for Two Parallel Surfaces



Radiant Oven Heating Example — A manufacturer of 66 gallon electric water heaters wishes to bake the paint on sheet metal jackets (open top and bottom) at 350°F. The jackets weigh 33 lbs, are 26" in diameter by 45" high with an outside area of 25.5 ft². The process requires 20 jackets be painted per hour. The jackets will be suspended from a conveyor chain on 9 ft centers and will be rotated as they move. The chain weighs 12 lbs/ft. The heaters will be installed in a tunnel oven with 2 inches of insulation and reflective walls. The oven is 8 ft long, 4 ft wide and 7 ft high and has end openings 3 ft by 6 ft. Preliminary test results show the jackets must be baked for six minutes for a satisfactory finish. The paint weighs 7.25 lbs/gal, contains 50% volatiles and covers 212 ft² per gallon. Assume a room temperature of 70°F

Specific heat of steel = 0.12 Btu/lb/°F
Boiling point of solvent = 170°F
Specific heat of solvent = 0.34 Btu/lb/°F
Latent heat of vaporization = 156 Btu/lb

Heat Required for Operation —

1. **Heat Absorbed by Jackets —** (20 jackets/hr x 33 lbs = 660 lbs/hr)

$$\frac{660 \text{ lbs/hr} \times 0.12 \text{ Btu/lb/°F} \times (350 - 70°\text{F})}{3412 \text{ Btu/kW}} = 6.5 \text{ kW}$$

2. **Heat Absorbed by Solvent** — Solvent volume

$$\frac{25.5 \text{ ft}^2 \times 20 \text{ jackets/hr} \times 50\%}{212 \text{ ft}^2\text{/gal}} = 1.20 \text{ gal/hr}$$

Heat required to heat solvent to 70°F

$$\frac{1.2 \text{ gph} \times 7.25 \text{ lb/gal} \times 0.34 \text{ Btu/lb} \times (170\text{-}70°\text{F})}{3412 \text{ Btu/kW}} = 0.1 \text{ kW}$$

Heat required to vaporize solvent

$$\frac{1.20 \text{ gph} \times 7.25 \text{ lb/gal} \times 156 \text{ Btu/lb}}{3412 \text{ Btu/kW}} = 0.4 \text{ kW}$$

Heat absorbed by solvent = 0.1 + 0.4 = 0.5 kW

3. **Heat Required by Ventilation Air** — (NFPA recommendation is a minimum of 10,000 cubic feet per gallon of solvent evaporated.)
   Density of air = 0.080 lbs/ft³.
   Specific heat of air = 0.240 Btu/lb/°F

Note — Ventilation air is heated by re-radiation and convection from the work, oven walls, etc. Air temperature is always less than the work temperature. Assume a 200°F air temperature.

Volume = 1.20 gph x 10,000 ft³ = 12,000 ft³/hr

$$\frac{12{,}000 \text{ ft}^3\text{/h} \times 0.08 \text{ lb/ft}^3 \times 0.24 \text{ Btu/lb/°F} \times (200\text{-}70°\text{F})}{3412 \text{ Btu/kW}}$$

Heat absorbed by ventilation air = 8.78 kW

4. **Conveyor Chain & Hangers** — Normally the conveyor chain is outside the radiation pattern of the heaters and is heated by convection from air in the tunnel. Since the heat absorbed by the air has already been accounted for, the heat absorbed by the conveyor may be ignored. (Conveyor speed should provide 6 minutes in the 8 foot heated area.)

Total Heat Absorbed —

6.5 kW + 0.5 kW + 8.8 kW = 15.8 kW

Heat Losses — Heat losses from oven surface with 2 inches of insulation (Graph G-126S) = 12 W/ft². Assume inside surface temperature of wall and ceiling = 250°F, ΔT = 180°F)
Wall area 7 ft x 8 ft x 2 ft = 112 ft²
Ceiling and floor area 8 ft x 4 ft x 2 ft = 64 ft²
Open tunnel ends = 3 ft x 6 ft x 2 ft = 36 ft²

Heat loss from outside surfaces of oven

$$\frac{176 \text{ ft}^2 \times 12 \text{ W/ft}^2}{1000 \text{ W/kW}} = 2.1 \text{ kW/hr}$$

Heat loss from open oven ends (assume the open ends are equal to an uninsulated metal surface under the same conditions as the oven surfaces) (See Graph G-125S.)

$$\frac{36 \text{ ft}^2 \times 0.6 \text{ W/ft}^2 \times 180°\text{F}}{1000 \text{ W/kW}} = 3.89 \text{ kW/hr}$$

Total Heat Losses — 2.1 kW + 3.98 kW = 5.99 kW

Total Heat Capacity Required for Operation — 15.8 kW + 5.99 kW = 21.8 kW/hr

As with any process heat calculation, it is not possible to account for all the variables and unknowns in the application. A safety factor is recommended. For radiant heating applications, a safety factor of 1.4 is suggested.

Total Heat Required = 21.8 x 1.4 = 30.5 kWh

Technical Information

Radiant Infrared Heating - Comfort Heating

Indoor Spot Heating

Infrared spot heating of work stations and personnel in large unheated structures or areas has proven to be economical and satisfactory. The following guidelines may be used for spot heating applications (areas with length or width less than 50 feet).

1. **Determine** the coldest anticipated inside ambient temperature the system must overcome. If freeze protection is provided by another heating system, this temperature will be 40°F.
2. **Determine** the equivalent ambient temperature desired (normally 70°F is the nominal average).
3. **Subtract** 1 from 2 to determine the theoretical increase in ambient temperature (ΔT) expected from the infrared system. If drafts are present in the occupied area (air movement over 44 feet per minute (0.5 mph) velocity), wind shielding or protection from drafts should be considered.
4. **Determine** the area to be heated in ft². This is termed the "design or work area" (A_D) (Fig. 1).
5. **Multiply** the design area by one watt per square foot times the theoretical temperature increase (ΔT) desired as determined in Step 3 (minimum of 12 watts per square foot). The design factor of one watt per square foot density assumes a fixture mounting height of 10 feet. Add 5% for each foot greater than 10 feet in mounting height. Avoid mounting fixtures below 8 feet.
6. **Determine** fixture mounting locations
   a) In areas where the width dimension is 25 feet or less, use at least two fixtures mounted opposite each other at the perimeter of the area and tilted at an angle. This provides a greater area of exposure to the infrared energy by personnel in the work area. Tilt the fixtures so that the upper limit of the fixture pattern is at approximately six feet above the center of the work station area (Figure 2).
   b) When locating fixtures, be sure to allow adequate height clearance for large moving equipment such as cranes and lift trucks.
   c) Avoid directing infrared onto outside walls.
7. **Estimate** (tentatively) the radiated pattern area. Add length of fixture to the fixture pattern width (W) to establish pattern length (L). Pattern Area = L x W (Fig. 3).

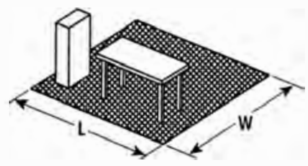


Figure 1 — Design Area

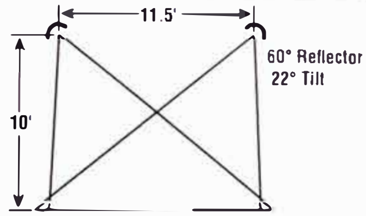


Figure 2 — Tilted Infrared Fixtures for Spot Heating

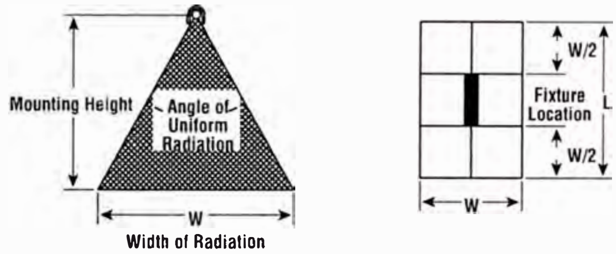


Figure 3 — Pattern Area

8. **Divide** the design area (Step 4) into the pattern area (Step 7).

   $$Q = \frac{\text{Pattern Area}}{\text{Design Area}}$$

   If the pattern area is equal to or greater than the design area, quotient (Q) will be equal to or greater than 1 and coverage is adequate. If Q is less than 1, the design area exceeds the pattern area of individual fixtures. Adjust the heater locations and patterns or add additional fixtures with patterns overlapping as necessary, to ensure adequate coverage.
9. **Multiply** quotient (Q in Step 8) by the increase in theoretical temperature (ΔT of Step 3) by the design area (A_D of Step 4) to determine the amount of radiation to be installed.

   Radiation (Watts) = $Q \times \Delta T \times A_D$
10. **Many Types** of radiant heaters are available for comfort heating applications including ceiling, wall and portable floor standing models. Choose specific fixtures from the product pages. It is preferred that half the wattage requirements be installed on each side of the work station in the design area.

Controls — Manual control by percentage timers may be adequate for a small installation. To provide better control of comfort levels in varying ambient temperatures, divide the total heat required into two or three circuits so that each fixture or heating element circuit can be switched on in sequence. Staging can be accomplished by using multistage air thermostats set at different temperatures.

Indoor Area Heating

In many industrial environments, area heating (areas with length or width greater than 50 ft) can be accomplished economically with multiple infrared heaters. For quick estimates, determine the minimum inside temperature and use a factor of 0.5 watts per square foot of design area for each degree of theoretical temperature. If the calculated heat loss of the structure, including infiltration or ventilation air, is less than the quick estimate, select the lower value. Locate heaters uniformly throughout the area with at least a 30% overlap in radiation pattern.

Outdoor Spot Heating

The same guidelines outlined under Indoor Spot Heating should be followed except that watts per square foot for each degree of theoretical ambient temperature increase should be doubled (approximately 2 watts per square foot for each 1°F). This factor applies to outdoor heating applications with little or no wind chill effect on personnel. If wind velocities are a factor in the application, determine the equivalent air temperature from the Wind Chill Chart in NEMA publication HE3-1971 or other information source.

Note — Increasing the infrared radiation to massive levels to offset wind chill can create discomfort and thermal stress. In outdoor exposed applications, a wind break or shielding is usually more effective.

Technical Information

Electrical Fundamentals & Three Phase Calculations

Ohm's Law

The relationship between Wattage (heat) output and the applied Voltage of electric resistance heating elements is determined by a precise physical rule defined as Ohm's Law which states that the current in a resistance heating element is directly proportional to the applied Voltage. Ohm's Law is traditionally expressed as:

$$I = \frac{E}{R}$$

Where: I = Amperes (Current)
E = Voltage
R = Ohms (Resistance)

The same equation using the conventional abbreviation for voltage is:

$$I = \frac{V}{R}$$

Where: I = Amperes (Current)
V = Voltage
R = Ohms (Resistance)

An unknown electrical value can be derived by using any two known values in one of the variations of Ohm's Law shown at the right.

OHM'S LAW

VOLTS

$\text{VOLTS} = \sqrt{\text{WATTS X OHMS}}$

$\text{VOLTS} = \frac{\text{WATTS}}{\text{AMPERES}}$

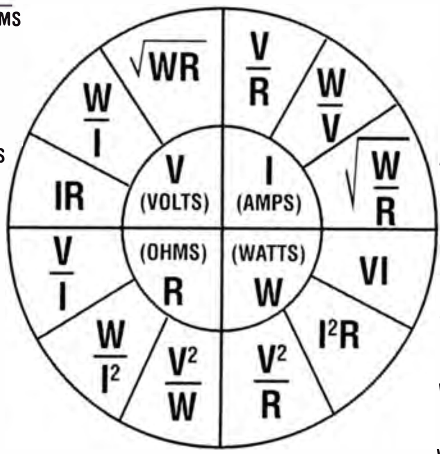
VOLTS = AMPERES X OHMS

OHMS

$\text{OHMS} = \frac{\text{VOLTS}}{\text{AMPERES}}$

$\text{OHMS} = \frac{\text{WATTS}}{\text{AMPERES}^2}$

$\text{OHMS} = \frac{\text{VOLTS}^2}{\text{WATTS}}$



AMPERES

$\text{AMPERES} = \frac{\text{VOLTS}}{\text{OHMS}}$

$\text{AMPERES} = \frac{\text{WATTS}}{\text{VOLTS}}$

$\text{AMPERES} = \sqrt{\frac{\text{WATTS}}{\text{OHMS}}}$

WATTS

WATTS = VOLTS x AMPERES

$\text{WATTS} = \text{AMPERES}^2 \text{ x OHMS}$

$\text{WATTS} = \frac{\text{VOLTS}^2}{\text{OHMS}}$

Voltage & Wattage Relationships

An electric resistance element only produces rated Wattage at rated Voltage. It is common for electric heating elements and assemblies to be connected to a wide range of operating Voltages. Since the Wattage output varies directly with the ratio of the square of the Voltages, the actual Wattage can be calculated for any applied Voltage. The relationship is expressed by the equation below,

$$W_A = W_R \times \left(\frac{V_A^2}{V_R^2}\right)$$

Where: W_A = Actual Wattage
W_R = Rated Wattage
V_A = Applied Voltage
V_R = Rated Voltage

Percent of Rated Wattage for Various Applied Voltages

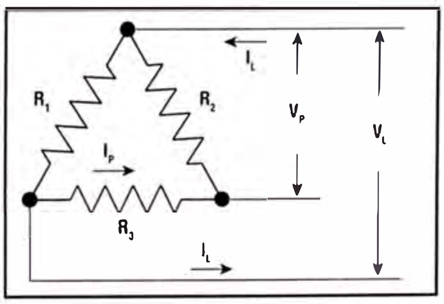
Applied Voltage	Rated Voltage 110	115	120	208	220	230	240	277	380	415	440	460	480	575
110	100	91	84	28	25	23	21	16	8.4	7.0	6.2	5.7	5.2	3.7
115	109	100	92	31	27	25	23	17	9.0	7.6	6.7	6.2	5.7	4.0
120	119	109	100	33	30	27	25	19	10	8.4	7.4	6.8	6.3	4.3
208	—	—	300	100	89	82	75	56	30	25	22	20	19	13
220	—	—	—	112	100	91	84	63	34	28	25	23	21	15
230	—	—	—	122	109	100	92	69	37	31	27	25	23	16
240	—	—	—	133	119	109	100	75	40	33	30	27	25	17
277	—	—	—	—	—	—	133	100	53	45	40	36	33	23
380	—	—	—	—	—	—	—	188	100	84	74	68	63	44
415	—	—	—	—	—	—	—	—	119	100	89	81	75	52
440	—	—	—	—	—	—	—	—	—	112	100	91	84	58
460	—	—	—	—	—	—	—	—	—	123	109	100	92	64
480	—	—	—	—	—	—	—	—	—	—	119	109	100	70
550	—	—	—	—	—	—	—	—	—	—	156	143	131	91
575	—	—	—	—	—	—	—	—	—	—	171	156	144	100
600	—	—	—	—	—	—	—	—	—	—	186	170	156	109

Three Phase Equations (Balanced)

Ohm's Law, as stated above, applies to electrical resistance elements operated on single phase circuits. Ohm's Law can be modifed to calculate three phase values by adding a correction factor for the phase Voltage relationships. The three phase equations shown can be applied to any balanced Delta or Wye circuit. The terms used in the equations are identified below:

V_L = Line Voltage
V_P = Phase Voltage
I_L = Line Current (Amps)
I_P = Phase Current (Amps)
W_T = Total Watts
$R_1 = R_2 = R_3$ = Element Resistance
W_C = Wattage per Circuit (Equal Circuits)
R_C = Circuit Resistance in Ohms Measured Phase to Phase

3Ø Delta

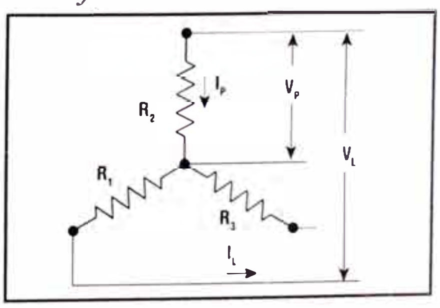


$V_P = V_L$
$W_T = 1.73\, I_L \times V_L$
$I_P = I_L \div 1.73$
$W_C = 1.73\, I_L \times V_L \div$ # Circuits
$R_C = (2 \times V_L^2) \div W_C$

$V_L = V_P$
$W_T = 3\,(V_L^2 \div R_1)$
$I_L = I_P \times 1.73$
$R_C = V_L^2 \div 0.5 W_C$

Note — For Open Delta connections, see next page.

3Ø Wye



$V_P = V_L \div 1.73$
$W_T = 1.73\, I_L \times V_L$
$I_P = I_L$
$W_C = 1.73\, I_L \times V_L \div$ # Circuits
$R_C = (2 \times V_L^2) \div W_C$

$V_L = V_P \times 1.73$
$W_T = V_L^2 \div R_1$
$I_L = I_P$
$R_C = V_L^2 \div 0.5\, W_C$

Note — For Open Wye connections, see next page.

Technical Information

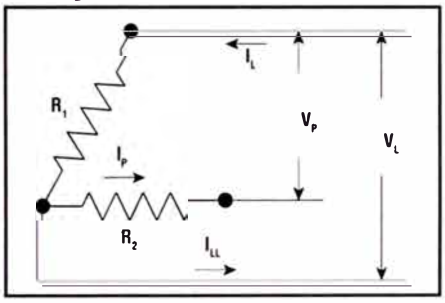
Three Phase Equations & Heater Wiring Diagrams

Open Delta & Wye

Three phase heating circuits are most efficient when operated under balanced conditions. If it is necessary to operate an unbalanced load, the equations below can be used to calculate the circuit values for open three phase Delta or Wye circuits. The terms used in the equations are identified below:

V_L = Line Voltage
V_P = Phase (Element) Voltage
I_L = Line Current (Amps)
I_{LL} = Line Current (Unbalanced Phase)
I_P = Phase Current (Amps)
W_T = Total Watts
R_1 = $R_2 = R_3$ = Element Resistance
R_C = Circuit Resistance in Ohms Measured from Phase to Phase

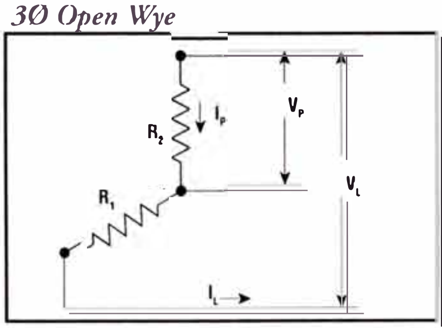
3Ø Open Delta



$V_P = V_L$	$V_L = V_P$
$W_T = 2V_L \times I_L$	$W_T = 2\,(V_L^2 \div R_1)$
$I_P = I_L$	$I_L = I_P$
$W_C = 2V_P \times I_P$	$I_{LL} = 1.73 \times I_P$

The loss of a phase or failure of an element in a three (3) element Delta circuit will reduce the wattage output by 33%.

3Ø Open Wye

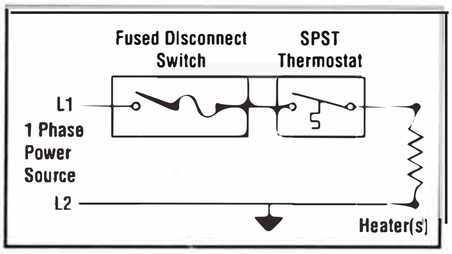


$V_P = V_L \div 2$	$V_L = V_P \times 2$
$W_T = I_L \times V_L$	$W_T = V_L^2 \div 2R_1$
$I_P = I_L$	$I_L = I_P$
$R_C = V_L^2 \div W_C$	

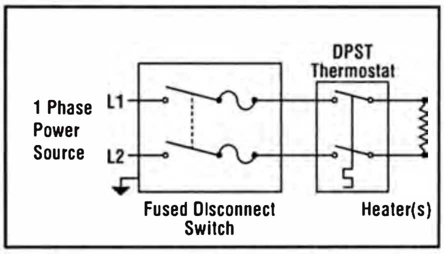
The loss of a phase or failure of an element in a three (3) element Wye circuit will reduce the wattage output by 50%. Heating elements are basically in series on single phase power.

Typical Heater Wiring Diagrams

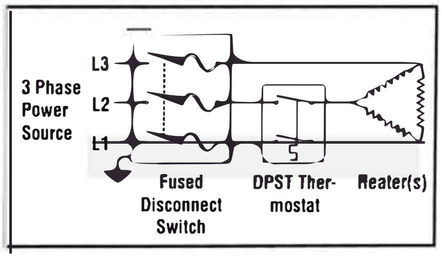
The following diagrams show typical heater wiring schematics.



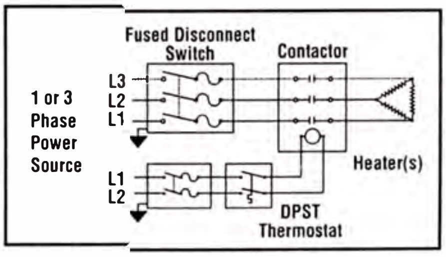
Single Phase 120 VAC heater circuit where line voltage and current do not exceed thermostat rating.



Single Phase AC circuits where line voltage and current do not exceed thermostat rating.

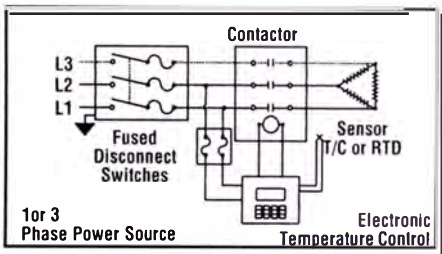


Three Phase AC heater circuit where line voltage and current do not exceed thermostat rating. Circuit does not have a "positive" off.

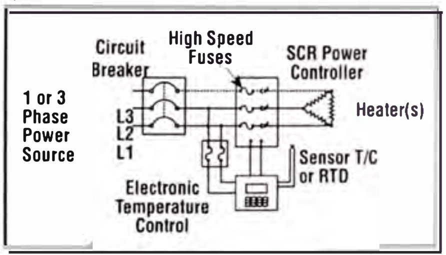


Single or Three Phase AC heater circuit where line voltage and current exceed thermostat rating. Separate control circuit can use a single pole or double pole thermostat. Control circuit requires over-current protection.

WARNING — Hazard of Electric Shock. Any installation involving electric heaters must be effectively grounded in accordance with the National Electrical Code to eliminate shock hazard.



Single or Three Phase AC heater circuit using electronic temperature controllers and contactors. Controller and contactor holding coil must be rated for the same voltage as the heater circuit. Control circuit requires over- current protection.



Single or Three Phase AC heater circuit using an electronic temperature controller and a SCR (solid state) power controller. Controller must be rated the same voltage as the heater circuit. Control circuit requires over-current protection. All electrical wiring to electric heaters must be installed in accordance with the National Electrical Code or local electrical codes by a qualified person.

Wiring & Ambient Temperatures

Ambient temperatures must be considered when selecting wiring materials for electric heater circuits. Heating equipment and processes may cause associated wiring to operate well above ambient temperatures. These temperatures may result from heat conducted from the heater terminals, radiation from heated surfaces or simply high ambient air temperatures. Nickel plated copper or nickel alloy conductors with high temperature insulation should always be used in high temperature areas. Outside these areas, conventional wiring materials can usually be used. 60°C building wire is usually not suitable unless otherwise indicated.

Wiring in Severe Conditions

Moist or wet locations require gasketed terminal and junction boxes to protect equipment and wiring. Rigid conduit is recommended. Hazardous Locations require the use of approved explosion-proof terminal and junction boxes. Rigid conduit or mineral insulated (MI) cable is mandatory in Division 1 areas. Some Hazardous Locations may require conduit seals (EYS) adjacent to the equipment.

Technical Information

Wiring Practices for Electric Heaters

Wire Insulation & Conductors

The selection of wiring materials to be used in a particular application depends upon the service Voltage and the anticipated operating temperatures. The table below lists some of the more common code wire constructions according to their temperature limitations. Insulated wires should be derated for elevated ambient temperatures and should never be used above their temperature rating. The operating temperature of unplated copper wire should be limited to 200°C (392°F) maximum. A complete listing of wire construction and allowable current carrying capacities is shown in the National Electric Code Article 310.

General Purpose Wiring

Max. Conductor Temperature °C	°F	Wire Type (600V)	Construction (Copper Conductors)
60	140	TW	Thermoplastic
75	167	RHW	Rubber
		THW	Thermoplastic
90	194	RHH	Heat Resistant Rubber
		THWN	Heat Resistant Thermoplastic
		XHHN	Heat Resistant Cross-link Thermoplastic
		MTW	Heat Resistant Cross-link Thermoplastic
200	392	FEP	Teflon®

High Temperature Wiring Materials

Max. Conductor Temperature °C	°F	Wire Type (600V)	Construction (Nickel Plated Copper or Nickel Conductors)
250	482	TGT	Teflon® - Glass - Teflon®
		TGGT	
450	842	MGS	Mica - Glass - Silicone
		MGT	Mica - Glass - Teflon®
594	1100	Bare	Maganese Nickel Wire or Bus Bars with Ceramic Insulators

Note — High temperature wiring materials are available for field application.

Contactor Sizing

Contactors are normally rated for inductive and resistive loads. Most electric resistance heaters have negligible inrush or inductive current. Select contactors based on resistive load ratings. Using the formulas shown in the paragraphs on wire sizing to determine the amp load per pole (phase). Select a contactor with the next highest current rating. Use a two pole contactor for single phase (two-wire) power and a three pole contactor for balanced Delta or Wye three phase loads. For heater loads with high inrush current, refer to product data information for maximum amperage.

Thermocouple Wire & Cable

Thermocouples and extension lead wires are color coded to aid in identification and to avoid inadvertent cross wiring. The following charts indicate the colors used of different alloys.

Thermocouple Color Coding

Type	Positive Color (+)	Alloys
J	White	Iron/Constantan
K	Yellow	Chromel/Alumel
T	Blue	Copper/Constantan
E	Purple	Chromel/Constantan
R	Black	Platinum/Platinum (with 13% Rhodium)
S	Black	Platinum/Platinum (with 6% Rhodium)
N	Orange	Nicrosil/Nisil

Note — Negative (-) conductor identified with red colored insulation.

Thermocouple Extension Wire Colors

Type	Positive	Negative	Color Overall	Positive Color (+)
T	TPX	TNX	Blue	Blue
J	JPX	JNX	Black	White
E	EPX	ENX	Purple	Purple
K	KPX	KNX	Yellow	Yellow
R or S	SPX	SNX	Green	Black
B	BPX	BNX	Gray	Gray

Note — Negative (-) conductor identified with red colored insulation.

Electrical Noise & Controls

Electrical "noise" refers to extraneous electrical voltages that interfere with legitimate control signals. Most electrical noise is introduced by electromagnetic coupling with fluorescent lights, contactors, power wiring, switches and other arcing devices. Shield control circuit wiring and keep thermocouple wires separate from power wiring. Trace shielded thermocouple lead wires in a separate conduit for maximum protection.

Temperature Limits for Controls

Most mechanical controls and thermostats (control bodies) can withstand a wide range of ambient temperatures ranging from below freezing to over 140°F. Electronic controls, transformers, contactors and other electrical devices are more temperature sensitive and extreme temperatures will usually shorten the life of the component. Most electrical and electronic equipment will function accurately in ambient temperatures ranging from about 30°F to about 130°F. Triacs and SCR controls frequently require special cooling for full load ratings when operated over 120°F. Refer to the installation instructions or contact the device manufacturer for recommendations.

Wiring Hints for Electric Heaters

The following are some general recommendations for wiring electric heating elements and assemblies. These recommendations are only suggestions and are not intended to conflict with the National Electric Code or local codes.

WARNING — Hazard of Electric Shock. Any installation involving electric heaters must be effectively grounded in accordance with the National Electrical Code to eliminate shock hazard. All electrical wiring to electric heaters must be installed in accordance with the National Electrical code or local electrical codes by a qualified person.

1. Repetitive heating and cooling can cause wiring connections to loosen over time. High amperage through a loose terminal can cause overheating and terminal failure. All heater terminal connections should be tightened to a maximum torque consistent with terminal strength. Use a second wrench or pliers to prevent twisting heater terminals.
2. Use stranded wire in applications where the power wires to heater terminal connections may be subject to movement. When using solid wire or bus bar on heater terminals, provide expansion loops between points of support to minimize damaging stresses due to expansion and contraction.
3. Solder or silver braze lead connections to heating elements that may be subject to extreme temperatures or vibration. Use a minimum of flux to complete the connection and keep flux from contaminating the heating element. Remove residual flux to prevent corrosion of the electrical joint.
4. Keep thermostat capillary tubing and thermocouple wiring clear of heater terminals to prevent accidental short circuits. Sleeving or insulated tubing is recommended.
5. Use wiring suitable for the anticipated operating temperatures. Unless the heater is specifically marked for use with low temperature copper wiring, high temperature alloy conductors are recommended for connections to the heater terminals.
6. Do not use rubber, wax impregnated or plastic covered wire inside terminal enclosures of heaters in high temperature applications. These insulations will deteriorate and give off fumes which can contaminate the heating elements and cause short circuits.

Technical Information

Wiring Practices for Electric Heaters *(cont'd.)*

Selecting Wire Size (AWG)

The size (wire gauge) of the electrical conductor for a particular application will depend upon the Amperage (current) which the heating load will draw from the power source. Current can be calculated by Ohm's Law. To calculate amperage, use the following formulas. On a single phase (two-wire) power supply, the amperage per line is calculated by:

$$1\text{ Ph Amperage} = \frac{\text{Total Circuit Wattage}}{\text{Line Voltage}}$$

On three phase power circuits with balanced Delta or Wye heating loads, line amperage is calculated by:

$$3\text{ Ph Amperage} = \frac{\text{Total Circuit Wattage}}{\text{Line Voltage x 1.73}}$$

Table II lists amperages for common kW ratings.

Allowable Ampacities

Once the load current has been determined, wire size for the calculated amperage may be selected from tables in Article 310 of the National Electrical Code (NEC). As a guide, Table III at the right lists recommended ampacities for the more common insulated wires for high temperature applications. Current ratings for 90°C wire in a 30°C ambient are included for reference.

Corrections for Elevated Ambient Temperatures

The recommended current carrying capacities of 200°C and 250°C wire are valid if conductor temperatures do not exceed 104°F (40°C). Operating temperatures in excess of 104°F (40°C) require the application of a temperature correction factor for the corresponding wire.

Example — Size 14 AWG, type TGT wire is capable of handling 39 Amperes at 104°F (40°C) but must be reduced to 0.85 (85%) or 33 Amperes when operated at 212°F (100°C).

Multiple Insulated Wires in Conduit

The wire size selected above may be used in the heating circuit with three (3) wires enclosed in rigid or flexible conduit to protect the wiring. If more than 3 conductors are installed in the same conduit, another current correction factor must be used. For 4 to 6 conductors in a single conduit use 80% of the recommended current-carrying capacity. For 7 to 24 conductors use 70%.

Table II — Amperage (Current) for Typical kW Heater Ratings

	Single Phase					Three Phase Balanced Load				
kW	**120V**	**208V**	**240V**	**440V**	**480V**	**208V**	**240V**	**440V**	**480V**	**575V**
1	8.4	4.8	4.2	2.3	2.1	2.8	2.5	1.4	1.3	1.0
2	16.7	9.7	8.4	4.6	4.2	5.6	4.9	2.7	2.5	2.0
3	25.0	14.5	12.5	6.9	6.3	8.4	7.3	4	3.7	3.0
4	33.4	19.3	16.7	9.1	8.4	11.2	9.7	5.3	4.9	4.0
5	41.7	24.1	20.9	11.4	10.5	13.9	12.1	6.6	6.1	5.0
6	50.0	28.9	25.0	13.7	12.5	16.7	14.5	7.9	7.3	6.0
7.5	62.5	36.1	31.3	17.1	15.7	20.9	18.1	9.9	9.1	7.5
10	83.4	48.1	41.7	22.8	20.9	27.8	24.1	13.2	12.1	10.0
12	100.0	57.7	50.0	27.3	25	33.4	29	15.8	14.5	12.1
15	125.0	72.2	62.5	34.1	31.2	41.7	36.2	19.7	18.1	45.1
20	167.0	96.2	83.4	45.5	41.7	55.6	48.2	26.3	24.1	20.1
25	209.0	121	105	56.9	52.1	69.5	60.3	32.9	30.1	25.1
30	—	145	125	68.2	62.5	83.4	72.3	39.4	36.2	30.2
50	—	241	209	114	105	139	121	65.7	60.3	50.3
75	—	—	313	171	157	209	181	98.6	90.4	75.4
100	—	—	417	228	209	278	241	132	121.0	100.0

Table III — Allowable Ampacities

Three Insulated Conductors in a Raceway or Conduit				Single Conductor[1,2] in Free Air (200°C Ambient)		
Conductor Type	Copper	Copper	Nickel or Nickel Coated Copper	Nickel Coated Copper	Nickel	
Insulation Type	THHN XHHW MTW	FEP PFA SRG	TGT TGGT TFE	MGT MGS	MGT MGS	
Ambient Temp.	30°C (86°F)	40°C (104°F)	40°C (104°F)	200°C (392°F)	200°C (392°F)	
	Maximum Conductor Temperature (Insulation Limits)					
Size AWG	90°C (194°F)	200°C (392°F)	250°C (482°F)	450°C (842°F)	450°C (842°F)	
14	25	36	39	44	23	
12	30	45	54	58	31	
10	40	60	73	77	42	
8	55	83	93	100	53	
6	75	110	117	—	—	
	Correction Factors for Elevated Ambient Temperatures					
Ambient (°C)	For ambient temperature exceeding the values in the above table, multiply the allowable ampacities by the appropriate factor below.					Ambient (°F)
36 - 40	0.91	1.00	1.00	—	—	96 - 104
41 - 45	0.87	0.97	0.98	—	—	105 - 113
46 - 50	0.82	0.96	0.97	—	—	114 - 122
51 - 55	0.76	0.95	0.95	—	—	123 - 131
56 - 60	0.71	0.94	0.94	—	—	132 - 140
61 - 70	0.58	0.9	0.93	—	—	141 - 158
71 - 80	0.41	0.87	0.9	—	—	159 - 176
81 - 90	—	0.83	0.87	—	—	177 - 194
91 - 100	—	0.79	0.85	1.22	—	195 - 212
101 - 120	—	0.71	0.79	1.19	—	213 - 248
121 - 140	—	0.61	0.72	1.16	1.16	249 - 284
141 - 160	—	0.5	0.65	1.12	1.12	285 - 320
161 - 180	—	0.35	0.58	1.06	1.06	321 - 356
181 - 200	—	—	0.49	1.00	1.00	357 - 392
201 - 225	—	—	0.35	0.92	0.92	393 - 437
226 - 250	—	—	—	0.87	0.87	438 - 542
250 - 300	—	—	—	0.70	0.70	543 - 572
300 - 350	—	—	—	0.49	0.49	573 - 662

1. Data derived or extrapolated from values and criteria set forth in NEC Article 310.
2. MGT & MGS insulated wire is intended to be used for interconnection of strip heaters and elements located in high temperature ambients and is not intended for general purpose wiring. Do not use these Amp ratings for three insulated conductors inside raceways or conduits.

Components
Overview

Component Heaters include the basic types of heating elements:

- **Tubular Elements**
- **Thin Blade Heaters**
- **Strip Heaters**
- **Ring & Disc Heaters**
- **Band & Nozzle Heaters**
- **Cartridge Heaters**
- **Flexible Heaters**
- **Specialty Heaters**

Component heaters may be used by themselves to solve many heating problems. They may also be incorporated into more complex heating systems, providing a complete thermal solution for your heating requirements.

Chromalox carries the widest selection of standard component heaters in many shapes, sizes and wattages. Chromalox is the "First Choice for Thermal Solutions".

Applications

With component heaters, most often the shape and size will be the determining factor in most heater applications. Brief descriptions of each heater type follow, with selection guidelines that lead to a detailed description on individual product pages.

Tubular heating elements perform exceptional heat transfer by conduction, convection or radiation to heat liquids, air, gases and surfaces. In most heater assemblies, tubular element design configurations vary — round, triangular, flat press and formed. Bends are made to customer requirements Custom built from 0.200" to 0.475" diameters, a multitude of sheath materials with sheath temperature capabilities up to 1600°F, watt densities to fit many applications and up to 600 volts. Available with over 20 optional terminations and many stocked accessories.

Thin blade heater elements provide more surface area than standard tubular elements to offer greater wattage or lower watt densities. Select from many sheath materials with watt densities to 75 W/in² and sheath temperatures as high as 1200°F. Heating elements can be as long as 120" and are capable of being formed into many configurations for heating via immersion, direct surface contact or convection. Three wire construction within the element provides uniform heating. Available in single or 3-phase current terminations with a 120 to 240 volt range.

ponents

lication Guidelines

tions (cont'd.)

ng/Disc heating elements are rugged y to install for heat transfer by ction or convection to heat liquids, air, and surfaces with sheath temperatures 600°F and watt densities to 35 W/in². on applications include drying, melting, and curing. Strip heater sizes range .5" wide to 2.5" and lengths to 72" long. bolt or clamp to many surfaces. ring heaters can provide concentrated small areas. Select from many sheath als, termination styles, operating ratures, sizes, voltages, wattage ratings ounting devices.

heaters grip tightly to cylindrical s to supply uniform heat transfer, l to the heater life. Chromalox band rs are flexible and come in one or two-construction for easy installation and removal. They accommodate diameters as small as 15/16" and as large as 20" and are capable of reaching sheath temperatures up to 1600°F. Stainless steel braids and conduit protect terminations and resist contamination. Completely customize your heater by specifying exact physical dimensions, material, electric ratings and terminations.

Cartridge heaters are high efficiency heating elements. Diameters of cartridge heaters range from 0.25" to 1.25". Watt densities from 25 W/in² to 200 W/in² and sheath temperatures to 1600°F. Optional end seals resist contaminants and moisture from entering inside the heater. Chromalox provides a variety of sizes, wattage ratings, voltages and protective features to meet many challenging applications.

Flexible heaters are very versatile and provide solutions to a vast number of low-to-medium temperature applications. Heaters are manufactured with rugged light-weight materials providing chemical and moisture resistance with operating temperatures to 390°F. Wire elements are durable and wound precisely within the structure for optimal performance. A variety of electrical, shape and contour fittings to meet many specifications.

Cast-in heaters are custom designed for contour and multi-plane, clamp-on applications. Many sizes and contours are available to accommodate machined and cast contact surfaces that require close tolerances. Holes, cutouts or slots to accommodate thermocouples or machine obstructions provided when required. From as short as 2.5" and as long as 30", cast-in heaters provide operating temperatures to 1200°F with watt densities to 40W/in². Select from aluminum alloys, bronze alloys and iron cast materials.

lar Heaters — Section Outline

Tubular Heaters — Selection Guidelines

Type	Sheath	Diameter (In.)	Model	Page
Round	INCOLOY®	0.475	TRI	A-13
		0.475	TRID	A-14
		0.475	TRIW	A-14
		0.430	TRI	A-15
		0.375	TRI	A-16
		0.315	TRI	A-17
		0.260	TRI	A-19
		0.246	TRI	A-20
		0.200	TSSM	A-21
	Stainless Steel	0.475	TRSS	A-22
		0.475	TRSSH	A-23
		0.475	TRSSN	A-23
	Steel	0.475	TRS	A-24
		0.475	TRSCD	A-24
		0.475	TRSC	A-25
		0.315	TRS	A-27
	Copper	0.475	TRC	A-28
		0.475	TRCC	A-28
		0.315	TRC	A-30
Heart Shaped	INCOLOY®	0.5	TI	A-31
		0.375	TI	A-33
		0.375	RTU	A-35
		0.375	UTU	A-37
		0.375	UTU-LT	A-40
		0.430	UTUA-LT	A-41
		0.375	URPT	A-42
		0.375	LMS	A-43
	Steel	0.5	TS	A-44
		0.375	TS	A-45
Flat Pressed	INCOLOY®	0.375, 0.4375	ATS	A-47
		0.375, 0.4375	ATU	A-47
Round/Single End	INCOLOY®	0.475	STRI	A-48
		0.315	STRI	A-49
	Steel	0.475	STRS	A-50
		0.315	STRS	A-51
	Copper	0.475	STRC	A-52
		0.315	STRC	A-53
Hopper Heater	INCOLOY®		FSRM	A-54
Thin Blade	Stainless Steel		CTB	A-55

Components
Selection Guidelines

Strip, Ring & Disc Heaters — Section Outline

Strip, Ring & Disc Heaters — Selection Guidelines

Type	Size (In.)	Model	Page
Strip	1-1/2	OT S & SE ST PT TH STTH	A-62 A-63 A-64 A-64 A-65 A-65
Strip	3/4 2-1/2 1 1 3/4 3/4 1/2 1-1/8 1-11/16 1-11/16	SN WS SNH NH NS NSL NSA SSNHM SSE SSEM	A-66 A-66 A-67 A-67 A-68 A-68 A-69 A-69 A-70 A-70
Explosion-Proof		AEPS	A-71
Ring		A HSN HSW RHSW	A-72 A-73 A-73 A-73
Disc		HSP	A-74

Band & Nozzle Heaters — Selection Guidelines

Type	Size (In.)	Model	Page
One-Piece Band	1-1/2 2-1/2	DB DBW	A-75 A-76
Two-Piece Band	1-1/2 2	HB HBT	A-77 A-78
One-Piece/Mica Ins. Two-Piece/Mica Ins.		MB-1 MB-2	A-79 A-81
Ceramic Band		CB	A-82
One-Piece Nozzle		HBA HBZ	A-88 A-89

Cartridge Heaters — Section Outline

Cartridge Heaters — Selection Guidelines

Type/Sheath	Size (In.)	Model	Page
INCOLOY®	1/4 - 3/4	CIR	A-96
INCONEL® 600	.495, .685, .935	MZ	A-103
Stainless Steel	15/16, 1-1/4	C-DE C-LD	A-101 A-101
Brass	15/16 - 1-19/64	C-HD	A-102
Split	3/8 - 1	SST/QST	A-105
Screw Base		SCB	A-107
Sleeve Adapter		Accessory	A-107
Heavy Duty		CTRH	A-108
Stud Heater		CBH	A-109

Flexible Heaters — Section Outline

Flexible Heaters — Selection Guidelines

Type	Description	Model	Page
Slicone Rubber	General Purpose Enclosure & Air	SL-N SL-B	A-115 A-116
Silicone Rubber	Drum	SLDH	A-117
Heavy Duty Woven	Drum Heaters with Thermostat	PHD PHDT	A-120 A-120
Thermal Insulation	Drum	IBG	A-121

Specialty Heaters — Selection Guidelines

Type	Model	Page
Soft Metal Melting Pot	P	A-122
Heavy Duty Hot Plate	ROPH	A-123

Tubular Heaters

Application Guidelines

- **Up to 172" Lengths (Std.)**
- **75 - 10,000 Watts (Std.)**
- **120, 240 and 480 Volt (Std.)**
- **3 - 53 W/In^2 (Std.)**
- **Max. Sheath Temp.**
  - **Copper — 350°F**
  - **Steel — 750°F**
  - **Stainless Steel — 1200°F**
  - **INCOLOY® — 1600°F**

Applications

Extremely Versatile Heat Source — Highly adaptable, the tubular element, in its many forms and as a component of Chromalox packaged heaters and systems, has vastly increased the scale of electric heating applications. The heaters' mechanical and electrical flexibility are important to process engineers and product designers alike, as heating requirements can be matched accurately by proper selection from a great variety of element lengths, sheaths, diameters and watt densities.

Product Uniformity — Electric tubular heating elements provide a method of applying the exact amount of heat required at a specific area. When used with appropriate temperature control, product repeatability is assured.

Increased Production — Adding heat to a process often leads to increased production. For example, drying time may be reduced by heating the air or the product being dried. Chemical and cleaning processes are often more efficient when heated and a more consistent finished product results.

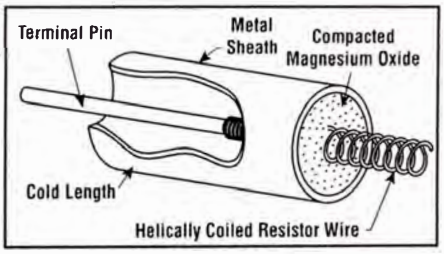
Less Down Time — Chromalox quality tubular elements with properly applied watt density and sheath material will provide long life, less down time and little or no maintenance.

Construction

Chromalox tubular elements are used for practically the entire range of electric resistance heating applications.

A metal sheath material is selected. The proper size resistance wire for the heating element is carefully selected and verified by computer calculations to ensure the longest service life possible. The high quality resistor wire is carefully tested and inspected to meet rigid specifications prior to being coiled. The resistance wire is then welded to a terminal pin to assure positive connection. The wire is centered in a metal sheath and insulated with high quality magnesium oxide which is highly compacted around it and acts as an electrical insulator. This material readily conducts the heat from the coiled resistor to the metal sheath and puts the heat where it is required, which results in maximum heater life.

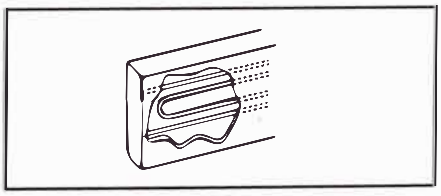
The highly compacted magnesium oxide holds the terminal pin securely allowing maximum torque of eight inch pounds when tightening terminal hardware



Typical Installations

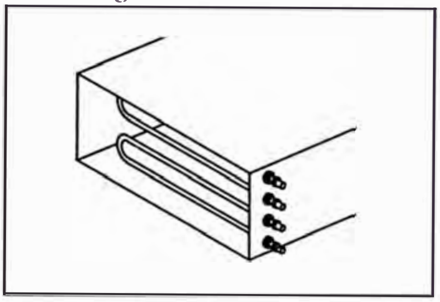
In Free Air — For applications like ovens and drying cabinets, tubular elements are compact, rugged heat sources. Their formability permits fitting around other oven components and work protrusions, concentrating heat at any point.

In Free Air



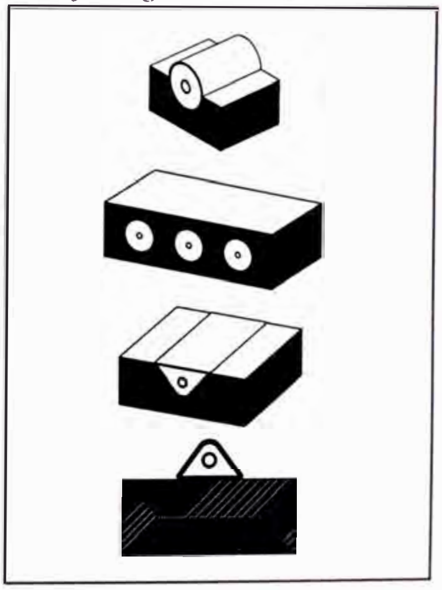
In Moving Air — Compression fittings, factory mounted fittings or brackets will mount a tubular element in a duct or air heating chamber.

In Moving Air



In Transferring Heat to Metal Parts - Dies, Molds, Platens — The available diameters, lengths, ratings, watt densities, cross-sections, and maximum temperatures provide the solution for a given job.

Transferring Heat to Metal



In Liquids — Tubular elements listed may be mounted through the side wall of a tank with compression fittings or by factory mounted fittings.

In Liquids

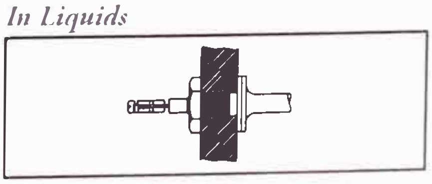


TABLA DE MOTORES WEG

CONFORME IEC 72

CARCASA (ABNT)	DIMENSIONES DE LA BRIDA TIPO "FF" - "B5"									
	BRIDA (ABNT)	C	LA	ØM	ØN	ØP	ØS	T	ß	CANT. DE AGUJ.
56	FF 100	35	8	100	80j6	120	7	3.0	45°	4
63	FF 115	40	10	115	95j6	140	10	3.0	45°	4
71	FF 130	45	10	130	110j6	160	10	3.5	45°	4
80	FF 165	50	12	165	130j6	200	12	3.5	45°	4
90 S	FF 165	56	12	165	130j6	200	12	3.5	45°	4
90 L	FF 165	56	12	165	130j6	200	12	3.5	45°	4
100 L	FF 215	63	14	215	180j6	250	15	4.0	45°	4
112 M	FF 215	70	14	215	180j6	250	15	4.0	45°	4
132 S	FF 265	89	14	265	230j6	300	15	4.0	45°	4
132 M	FF 265	89	14	265	230j6	300	15	4.0	45°	4
160 M	FF 300	108	15	300	250j6	350	19	5.0	45°	4
160 L	FF 300	108	15	300	250j6	350	19	5.0	45°	4
180 M	FF 300	121	15	300	250j6	350	19	5.0	45°	4
180 L	FF 300	121	15	300	250j6	350	19	5.0	45°	4
200 M	FF 350	133	15	350	300j6	400	19	5.0	45°	4
200 L	FF 350	133	15	350	300j6	400	19	5.0	45°	4
225 S/M	FF 400	149	16	400	350j6	450	19	5.0	22°30'	8
250 S/M	FF 500	168	18	500	450j6	550	19	5.0	22°30'	8
280 S/M	FF 500	190	18	500	450j6	550	19	5.0	22°30'	8
315 S/M	FF 600	216	22	600	550j6	660	24	6.0	22°30'	8
355 M/L	FF 740	254	22	740	680j6	800	24	6.0	22°30'	8

CONFORME NORMA NEMA MG1 11.34 Y MG1 11.35

CARCASA (ABNT)	DIMENSIONES DE LA BRIDA TIPO "C" - "NEMA"								
	BRIDA (ABNT)	C	ØM	ØN	ØP	ØS	T	ß	CANT. DE AGUJ.
63	FC 95	40	95.2	76.2 h8	135	1/4" 20 UNC	4	45°	4
71	FC 95	45	95.2	76.2 h8	143	1/4" 20 UNC	4	45°	4
80	FC 95	50	95.2	76.2 h8	120	1/4" 20 UNC	4	45°	4
90 S	FC 149	56	149.2	114.3 h8	165	3/8" 16 UNC	4	45°	4
90 L	FC 149	56	149.2	114.3 h8	165	3/8" 16 UNC	4	45°	4
100 L	FC 149	63	149.2	114.3 h8	168	3/8" 16 UNC	4	45°	4
112 M	FC 184	70	184.2	215.9 h8	220	1/2" 13 UNC	7	45°	4
132 S	FC 184	89	184.2	215.9 h8	220	1/2" 13 UNC	7	45°	4
132 M	FC 184	89	184.2	215.9 h8	220	1/2" 13 UNC	7	45°	4
160 M	FC 184	108	184.2	215.9 h8	255	1/2" 13 UNC	7	45°	4
160 L	FC 184	108	184.2	215.9 h8	255	1/2" 13 UNC	7	45°	4
180 M	FC 228	121	228.6	266.7 h8	281	1/2" 13 UNC	7	45°	4
180 L	FC 228	121	228.6	266.7 h8	281	1/2" 13 UNC	7	45°	4
200 M	FC 228	133	228.6	266.7 h8	330	1/2" 13 UNC	7	45°	4
200 L	FC 228	133	228.6	266.7 h8	330	1/2" 13 UNC	7	45°	4
225 S/M	FC 279	149	279.4	317.5 h8	349	5/8" 11 UNC	7	22°30'	8
250 S/M	FC 279	168	279.4	317.5 h8	392	5/8" 11 UNC	7	22°30'	8
280 S/M	FC 355	190	355.6	406.4 h8	450	5/8" 11 UNC	7	22°30'	8
315 S/M	FC 355	216	368.3	419.1 h8	455	5/8" 11 UNC	7	22°30'	8

CARGAS AXIALES Y RADIALES ADMISIBLES PARA MOTORES CON FRECUENCIA DE 50/60 Hz (kgf)

POLOS / POSICION	2 POLOS					4 POLOS					6 POLOS					8 POLOS				
CARCASA	I	II	III	IV	R	I	II	III	IV	R	I	II	III	IV	R	I	II	III	IV	R
56	14	16	15	15	21	20	22	21	21	26	25	27	26	26	30	29	30	29	29	33
63	19	21	20	20	28	28	31	29	29	35	34	35	35	35	40	38	41	39	39	45
71	26	29	27	27	35	37	41	38	38	46	46	50	47	47	53	52	56	54	54	59
80	32	39	34	34	46	48	55	50	50	58	59	66	62	62	67	68	75	71	71	73
90	31	42	35	35	51	48	59	52	52	62	61	72	65	65	71	71	82	75	75	78
100	41	54	46	46	71	64	80	70	70	90	81	99	88	88	103	96	113	102	102	114
112	60	90	66	81	103	91	136	98	122	130	115	167	123	153	149	136	191	143	177	164
132	79	120	93	93	144	131	169	145	145	181	169	207	182	182	209	198	236	212	212	229
160	87	167	114	114	185	156	236	183	183	234	204	284	231	231	268	243	323	270	270	295
160	125	200	150	150	225	216	299	243	243	284	271	378	306	306	325	320	435	358	358	369
200	121	237	170	164	304	216	357	267	267	383	278	444	338	338	438	332	511	397	397	485
225	125	272	178	178	302	226	414	294	294	429	299	509	376	376	490	357	588	441	441	542
250	119	315	191	191	395	232	475	320	320	498	308	589	411	411	570	373	677	484	484	630
280	89	345	183	183	481	200	576	337	337	607	286	715	443	443	695	370	811	530	530	767
315	127	529	280	280	479	171	753	400	400	648	271	884	494	494	742	357	1013	602	602	816
355	116	583	310	310	524	140	840	440	440	1009	254	935	608	608	1156	308	1037	610	610	1272

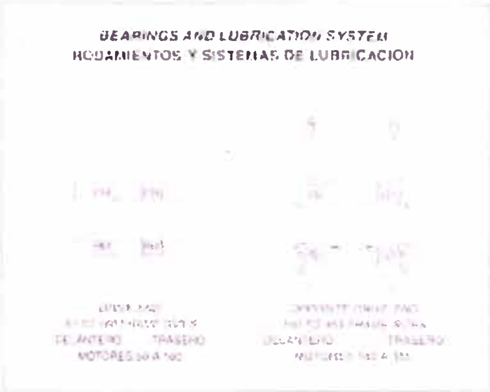
POSICION I - MOTOR VERTICAL CON PUNTA DE EJE HACIA ABAJO Y FUERZA ACTUANDO HACIA ABAJO
POSICION II - MOTOR VERTICAL CON PUNTA DE EJE HACIA ABAJO Y FUERZA ACTUANDO PARA ARRIBA
POSICION III - MOTOR HORIZONTAL CON CARGA ACTUANDO HACIA DENTRO
POSICION IV - MOTOR HORIZONTAL CON CARGA ACTUANDO HACIA DENTRO
POSICION R - CARGAS RADIALES SOBRE EL EJE

NOTAS:

1.- LOS VALORES DE LAS TABLAS DE CARGAS ESTAN CONSIDERADAS PARA UNA VIDA UTIL DE ALREDEDOR DE 20,000 HORAS (MOTOR OPERANDO EN 60 Hz. Y CON ACOPLAMIENTO DIRECTO).

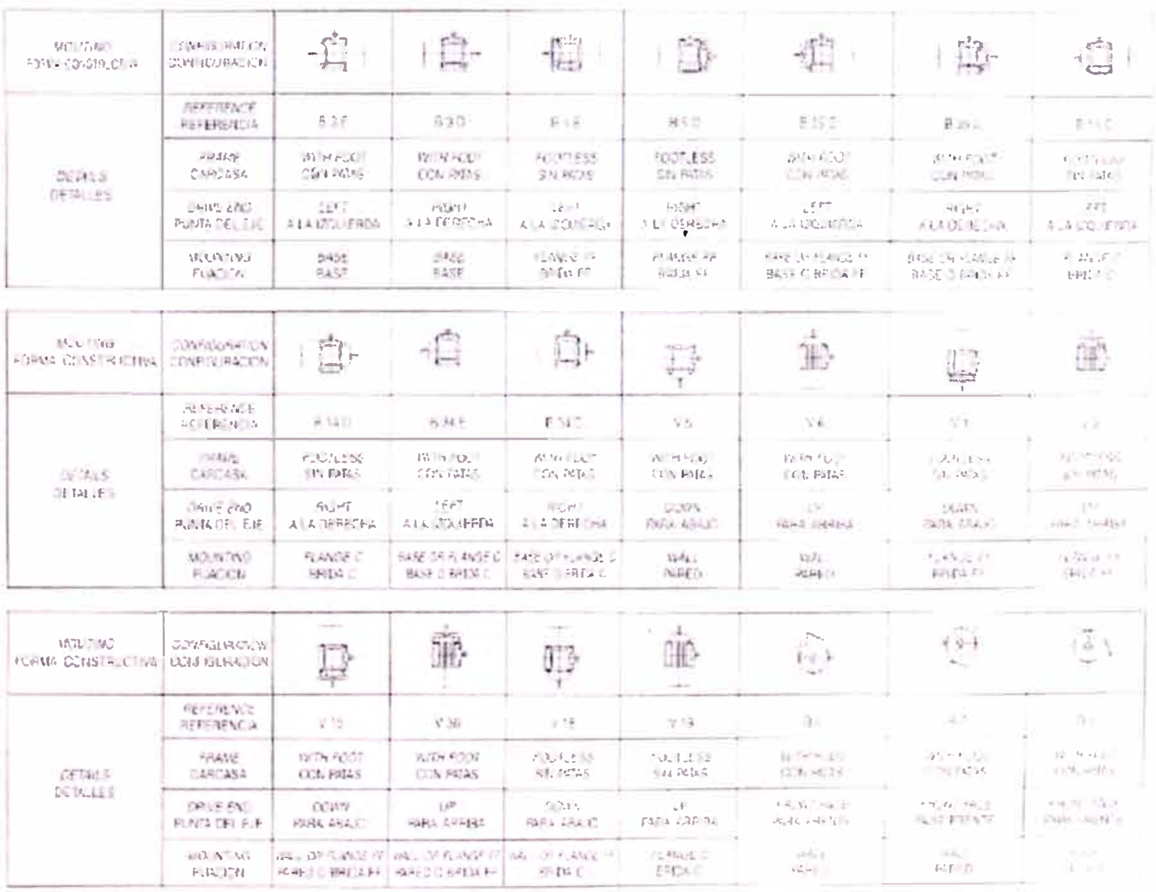
2.- PARA MOTORES QUE OPERAN EN 50 Hz LA VIDA UTIL ESTIMADA ES DE 24,000 HORAS.

3.- LAS CARGAS AXIALES Y RADIALES NO PUEDEN ASOCIARSE EN UN MISMO MOTOR, CARGAS MAYORES BAJO CONSULTA.



CONFORME NORMA DIN 42677 Y DIN 42948

Carcasa (ABNT)	DIMENSIONES DE LA BRIDA TIPO "C" DIN - "B14"							
	BRIDA (ABNT)	C	ØM	ØN	ØP	ØS	T	Cant. de Agujeros
56	FC 95	36	65	50 j6	80	M5	2.5	4
63	C 80	40	75	60 j6	90	M5	2.5	4
71	C 90	45	85	70 j6	105	M6	2.5	4
80	C 105	50	100	80 j6	120	M6	3.0	4
90 S	C 120	56	115	95 j6	140	M8	3.0	4
90 L	C 140	56	115	95 j6	140	M8	3.0	4
100 L	C 160	63	130	110 j6	160	M8	3.5	4
112 M	C 160	70	130	110 j6	160	M8	3.5	4
132 S	C 200	89	165	130 j6	200	M10	3.5	4
132 M	C 200	89	165	130 j6	200	M10	3.5	4



CARACTERISTICAS DE DESEMPEÑO

Motor IP55 - Uso General; Motor IPW55 - Uso Naval; Ambientes Agresivos.

Potencia		Carcasa	Velocidad	Intensidad Nominal				Torque / Cupla			Eficiencia (n%)			Factor de Potencia (cos φ)			Factor de Servicio	GD² DEL ROTOR	Peso
				220 V		380 V													
(HP)	(kW)	(IEC)	(rpm)	In(A)	Ia(A)	In(A)	Ia(A)	Cn (Kgm)	CP/Cn (%)	Cmáx/Cn (%)	50%	75%	100%	50%	75%	100%		(Kgm²)	(Kg)
2 POLOS - 50 Hz																			
1/8	0.09	56a	2860	0.58	2.8	0.33	1.6	0.03	400	300	44	53	59	0.51	0.62	0.69	1.1	0.0006	3.4
1/6	0.12	56b	2760	0.66	2.5	0.38	1.4	0.04	290	220	51	59	60	0.61	0.75	0.80	1.1	0.0006	3.4
1/4	0.18	63a	2840	0.95	4.2	0.55	2.4	0.06	315	250	52	59	63	0.61	0.73	0.79	1.1	0.0014	4.5
1/3	0.25	63b	2820	1.15	6	0.66	3.2	0.08	330	320	59	67	70	0.61	0.70	0.82	1.1	0.0014	4.5
1/2	0.37	71a	2870	1.7	10	0.95	6	0.12	315	325	61	70	75	0.63	0.71	0.79	1.1	0.0022	9.0
3/4	0.55	71b	2860	2.3	14	1.3	8	0.18	255	290	64	72	75	0.70	0.78	0.85	1.1	0.0025	9.5
1	0.75	80a	2860	3.3	20	1.9	11	0.25	310	240	65	71	73	0.63	0.73	0.82	1.1	0.0048	15.0
1.5	1.1	80b	2840	4.5	29	2.6	17	0.37	310	230	71	75	75	0.70	0.80	0.86	1.1	0.0056	17.0
2	1.5	90S	2885	6.6	52	3.8	30	0.51	340	280	72	78	78	0.52	0.68	0.77	1.1	0.0100	21.0
3	2.2	90L	2870	8.3	61	4.8	35	0.74	360	320	75	60	81	0.71	0.80	0.86	1.1	0.0120	23.5
4	3.0	100L	2890	11.0	88	6.4	51	1.00	320	255	76	81	81	0.80	0.87	0.87	1.1	0.0170	29
5.5	4.0	112M	2910	14.5	123	8.4	71	1.30	310	280	81	83	83	0.72	0.82	0.88	1.1	0.0280	38
7.5	5.5	132Sa	2920	20.5	160	11.8	92	1.80	280	300	60	83	84	0.68	0.78	0.84	1.1	0.0550	52
10	7.5	132S	2910	27	189	16	109	2.45	280	290	81	83	84	0.69	0.79	0.85	1.1	0.0640	57
15	11.0	160Ma	2940	40	332	23	192	3.70	300	290	75	60	81	0.79	0.90	0.90	1.1	0.1750	93
20	15.0	160M	2940	50.0	410	29	237	5.00	290	270	82	85	85	0.80	0.88	0.91	1.1	0.2360	107
25	18.5	160L	2920	61	519	35	300	6.10	295	280	84	86	86	0.81	0.90	0.92	1.1	0.3100	129
30	22.0	160M	2960	73	577	42	333	7.40	350	300	86	88	88	0.80	0.88	0.90	1.1	0.3700	144
40	30.0	200L	2950	95	790	55	457	10.0	300	280	88	89	89	0.86	0.90	0.91	1.1	0.7200	225
50	37.0	200L	2960	116	1136	67	657	12.0	300	280	89	92	92	0.83	0.88	0.91	1.1	0.8200	240
60	45.0	225S/M	2945	138	1092	80	608	15.0	300	210	88	91	91	0.84	0.89	0.92	1.1	1.3000	315
75	55.0	250S/M	2960	174	1479	100	855	18.0	300	300	86	89	91	0.82	0.88	0.92	1.1	1.9500	420
100	75.0	280S/M	2940	237	1707	137	986	25.0	300	280	84	88	90	0.84	0.89	0.91	1.1	2.6000	545
125	90.0	280S/M	2950	294	2206	170	1275	30.0	290	270	85	87	89	0.85	0.90	0.92	1.1	3.4000	575
150	110.0	315S/M	2965	351	2458	203	1421	36.0	240	270	89	92	93	0.85	0.88	0.89	1.0	5.1000	703
180	132.0	315S/M	2975	417	3002	241	1735	43.0	210	235	88	92	93	0.88	0.90	0.90	1.0	6.1000	800
220	162.0	315S/M	2975	514	3597	297	2079	53.0	160	200	91	93	93	0.88	0.89	0.89	1.0	7.1000	900
270	199.0	355M/L	2980	614	5527	355	3195	65.0	230	240	89	91	92	0.89	0.91	0.92	1.0	7.5000	1270
300	220.0	355M/L	2980	683	5467	395	3160	72.0	230	240	92	93	93	0.89	0.91	0.91	1.0	8.500	1390
350	255.0	355M/L	2970	813	6506	470	3760	85.0	240	280	91	92	92	0.88	0.90	0.90	1.0	10.0000	1460
400	295.0	355M/L	2980	908	7266	525	4200	96.0	230	240	92	93	93	0.89	0.91	0.92	1.0	11.0000	1500
4 POLOS 50 Hz.																			
1/12	0.06	56a	1435	0.60	1.3	0.35	0.74	0.04	285	285	33	42	46	0.44	0.52	0.57	1.1	0.0006	3.3
1/8	0.09	56b	1410	0.78	2.3	0.45	1.3	0.06	280	250	39	48	52	0.44	0.52	0.58	1.1	0.0006	3.3
1/6	0.12	63a	1400	0.87	3.0	0.5	1.8	0.08	300	285	45	52	56	0.45	0.56	0.65	1.1	0.0014	4.8
1/4	0.18	63b	1380	1.05	4.1	0.61	2.4	0.12	280	265	47	56	60	0.44	0.54	0.75	1.1	0.0014	4.8
1/3	0.25	71a	1420	1.3	5.5	0.75	3.2	0.16	320	310	58	65	69	0.42	0.63	0.73	1.1	0.0041	9.6
1/2	0.37	71b	1400	1.8	9.0	1.0	5.0	0.25	330	270	56	65	69	0.59	0.7	0.78	1.1	0.0048	10.0
3/4	0.55	80a	1420	3.1	15	1.8	8.5	0.37	335	275	53	62	66	0.54	0.64	0.71	1.1	0.0087	14.0
1	0.75	80b	1420	4.2	23	2.4	13.0	0.51	335	265	55	63	65	0.55	0.65	0.72	1.1	0.0094	14.7
1.5	1.1	90S	1440	5.0	28	2.9	16.0	0.75	265	325	65	70	72	0.58	0.7	0.8	1.1	0.0160	19.60
2	1.5	90L	1430	6.4	38	3.7	22	1.0	200	230	74	76	76	0.56	0.71	0.81	1.1	0.0250	24.0
3	2.2	100La	1430	9.0	60	5.2	35	1.5	295	280	78	80	80	0.56	0.71	0.8	1.1	0.0240	29.0
4	3	100L	1425	11.6	84	6.7	48	2.0	290	295	81	82	82	0.59	0.74	0.83	1.1	0.0300	32.5
5.5	4	112M	1450	16.0	126	9.5	75	2.7	280	330	82	86	86	0.53	0.68	0.76	1.1	0.0600	40
7.5	5.5	132S	1470	21.5	168	12.5	98	3.6	255	230	80	82	82	0.59	0.74	0.82	1.1	0.1310	54
10	7.5	132Ma	1460	26	221	15	128	4.9	220	345	83	85	85	0.73	0.84	0.89	1.1	0.1440	63
12.5	9.2	132M	1450	31	254	18	153	6.1	215	280	85	89	89	0.68	0.81	0.88	1.1	0.1640	65
15	11	160M	1450	38	331	22	191	7.4	245	310	83	85	85	0.76	0.85	0.89	1.1	0.3100	103
20	15	160L	1455	50	400	29	232	10	270	320	87	88	88	0.80	0.87	0.9	1.1	0.3900	118
25	18.5	180M	1450	63	485	37	285	12	215	300	89	90	90	0.7	0.81	0.86	1.1	0.5500	146
30	22	180L	1450	77	747	45	437	15	190	300	86	88	88	0.77	0.83	0.85	1.0	0.6600	165
40	30	200L	1465	98	755	57	439	20	240	350	88	90	91	0.73	0.83	0.88	1.1	1.3000	237
50	37	225S/M	1470	125	813	72	468	25	200	265	87	88	89	0.72	0.82	0.87	1.1	1.7000	265
60	45	225S/M	1475	150	865	87	496	30	230	240	90	91	91	0.72	0.81	0.87	1.1	2.0000	300
75	55	250S/M	1475	182	1420	105	819	36	380	300	89	90	91	0.72	0.83	0.88	1.1	3.4000	430
100	75	280S/M	1470	236	1581	136	911	49	280	200	89	91	92	0.78	0.87	0.89	1.1	5.7000	560
125	90	280S/M	1470	295	1682	170	969	59	275	200	90	92	92	0.78	0.86	0.89	1.1	6.7000	630
150	110	315S/M	1480	353	2189	204	1265	72	285	280	90	92	92	0.76	0.86	0.89	1.0	10.500	810
160	135	315S/M	1485	425	3188	246	1845	87	295	305	92	93	93	0.75	0.85	0.88	1.0	12.500	900
220	165	315S/M	1485	510	3876	295	2242	107	210	350	92	93	93	0.83	0.88	0.9	1.0	14.100	990
270	200	355M/L	1485	614	4605	354	2665	130	230	210	93	94	94	0.83	0.89	0.9	1.0	16.000	1130
300	220	355M/L	1485	687	5427	397	3136	145	220	210	92	93	94	0.83	0.89	0.9	1.0	19.000	1400
350	255	355M/L	1485	804	5869	464	3387	170	220	215	92	93	93	0.87	0.9	0.91	1.0	21.500	1520
400	295	355M/L	1485	918	7069	530	4081	193	235	220	92	93	93	0.87	0.9	0.91	1.0	24.000	1580
450	330	355M/L	1485	1034	7548	597	4358	220	230	220	91	92	92	0.88	0.9	0.91	1.0	27.000	1660

CARACTERISTICAS DE DESEMPEÑO

Motor IP55 - Uso General; Motor IPW55 - Uso Naval; Ambientes Agresivos.

Potencia		Carcasa	Velocidad	Intensidad Nominal				Torque / Cupla			Eficiencia (η%)			Factor de Potencia (cos φ)			Factor de Servicio	GD^2 DEL ROTOR	Peso
				220 V		380 V													
(HP)	(kW)	(IEC)	(rpm)	In(A)	Ia(A)	In(A)	Ia(A)	Cn (Kgm)	CP/Cn (%)	Cmáx/Cn (%)	50%	75%	100%	50%	75%	100%		(Kgm^2)	(Kg)
6 POLOS 50 Hz																			
1/8	0.09	63b	915	0.87	2.2	0.50	1.3	0.09	210	230	34	40	43	0.46	0.56	0.63	1.1	0.0014	4.5
1/5	0.15	71a	910	1.3	3.5	0.75	2.0	0.15	235	205	34	41	46	0.49	0.59	0.66	1.1	0.0035	9.0
1/4	0.18	71b	920	1.6	5.6	0.93	3.3	0.19	255	230	38	45	49	0.42	0.52	0.60	1.1	0.0041	10.0
1/2	0.37	80a	950	2.6	10.4	1.5	6.0	0.37	205	185	47	56	60	0.43	0.54	0.62	1.1	0.0091	14.0
3/4	0.55	80b	950	2.8	9.8	1.6	5.7	0.57	220	210	56	64	66	0.56	0.68	0.78	1.1	0.0110	16.0
1	0.75	90S	950	4.5	21	2.6	12.0	0.77	220	245	55	61	64	0.47	0.59	0.68	1.1	0.0220	21.0
1.5	1.1	90L	945	5.7	29	3.3	16.5	1.10	220	255	67	71	72	0.47	0.60	0.70	1.1	0.0260	23.5
2	1.5	100L	950	8	43	4.6	25	1.50	245	285	71	73	74	0.44	0.56	0.65	1.1	0.0390	29
3	2.2	112M	960	11	61	6.3	35	2.20	225	290	70	73	75	0.45	0.59	0.70	1.1	0.0580	36
4	3	132S	965	14	87	8.0	50	3.00	175	255	72	74	75	0.54	0.67	0.74	1.1	0.1150	50
5.5	4	132Mb	975	17	128	10.0	75	4.00	235	255	78	82	83	0.56	0.68	0.75	1.1	0.1900	62
7.5	5.5	132M	960	22.5	160	13.0	92	5.60	250	245	81	83	83	0.59	0.72	0.78	1.1	0.1900	66
10	7.5	160M	975	30	222	17.3	128	7.50	185	260	83	85	85	0.56	0.69	0.76	1.1	0.4100	101
15	11	160L	970	43	301	25	175	11.0	170	255	83	85	85	0.64	0.74	0.79	1.1	0.5800	124
20	15	180L	975	55	371	32	214	15.0	215	300	86	87	87	0.59	0.72	0.80	1.1	0.9200	163
25	18.5	200L	980	71.0	461	41	267	18.6	190	300	85	86	86	0.63	0.73	0.79	1.1	1.4000	225
30	22	200L	980	83	498	48	288	22.0	190	300	88	90	90	0.60	0.72	0.78	1.1	1.7000	240
40	30	225S/M	980	112	675	65	390	30.0	240	300	87	89	89	0.59	0.70	0.77	1.1	2.8000	300
50	37	250S/M	980	133	866	77	501	37.0	250	230	87	89	90	0.62	0.73	0.81	1.1	4.7000	430
60	45	280S/M	980	151	828	87	479	45.0	220	250	88	90	92	0.75	0.83	0.84	1.1	7.5000	560
75	55	280S/M	985	192	1152	111	666	54.0	210	230	89	91	92	0.66	0.76	0.82	1.1	8.8000	632
100	75	315S/M	985	249	1669	144	965	74.0	215	245	90	91	92	0.77	0.82	0.84	1.0	14.000	770
125	90	315S/M	985	311	2024	180	1170	89.0	220	260	90	92	92	0.77	0.83	0.84	1.0	16.000	880
150	110	315S/M	985	377	2263	218	1308	109.0	220	250	91	93	93	0.76	0.81	0.83	1.0	18.000	972
180	132	315S/M	985	464	2689	268	1554	131.0	220	245	91	93	93	0.69	0.79	0.81	1.0	20.000	1035
220	162	355M/L	985	559	3744	323	2164	160.0	205	230	91	93	93	0.79	0.81	0.82	1.0	22.000	1240
270	199	355M/L	985	668	4341	386	2509	196.0	210	230	92	93	94	0.79	0.82	0.83	1.0	26.000	1350
300	220	355M/L	985	744	4538	430	2623	218.0	215	225	93	93	94	0.80	0.82	0.83	1.0	30.000	1460
350	255	355M/L	990	882	5736	510	3315	255.0	220	240	93	94	94	0.80	0.81	0.82	1.0	33.000	1560
400	295	355M/L	990	995	6665	575	3853	290.0	215	240	93	94	94	0.80	0.82	0.83	1.0	37.000	1630

8 POLOS 50 Hz

1/10	0.07	71a	685	0.74	1.6	0.43	0.9	0.10	200	240	34	42	45	0.41	0.48	0.55	1.1	0.0041	9.6
1/8	0.09	71b	690	1.1	2.6	0.64	1.5	0.13	240	230	31	38	43	0.35	0.43	0.5	1.1	0.0041	9.6
1/4	0.18	80a	715	1.5	6.2	0.87	3.6	0.25	250	275	42	51	56	0.42	0.50	0.56	1.1	0.0091	13.0
1/3	0.25	80b	710	2.0	6.8	1.2	3.9	0.33	235	260	44	53	57	0.42	0.50	0.58	1.1	0.0110	14.5
1/2	0.37	90S	715	2.0	6.8	1.2	3.9	0.50	160	300	62	69	70	0.47	0.60	0.69	1.1	0.0220	20.0
3/4	0.55	90L	715	3.8	14.8	2.2	8.6	0.75	240	300	55	64	69	0.39	0.48	0.55	1.1	0.0260	22.5
1	0.75	100La	720	5.2	26	3.0	15.0	1.00	270	300	57	65	70	0.38	0.47	0.54	1.1	0.0390	27
1.5	1.10	100L	710	6.9	28	4.0	16.0	1.51	250	230	62	68	70	0.41	0.52	0.60	1.1	0.0490	31
2	1.50	112M	715	8.9	41	5.1	23.5	2.06	225	235	65	73	75	0.39	0.49	0.58	1.1	0.0700	35
3	2.2	112Ma	720	12.6	66	7.3	38.0	2.98	215	275	66	73	75	0.33	0.53	0.61	1.1	0.1150	52
4	3.00	132S	720	15.5	85	9.0	49.5	3.98	225	270	66	74	77	0.46	0.57	0.65	1.1	0.1640	64
5.5	4.00	132M	725	24.0	137	14.0	79.8	4.90	205	240	76	80	81	0.34	0.43	0.50	1.1	0.3300	92
7.5	5.50	160M	730	31.0	158	18.0	91.8	7.40	180	275	75	80	82	0.39	0.49	0.57	1.1	0.4100	101
10	7.50	160L	730	43.0	215	25.0	125	10.0	150	205	79	81	82	0.40	0.50	0.55	1.1	0.5800	123
15	11.00	160L	730	53.0	292	30.5	168	14.8	155	250	85	88	88	0.43	0.55	0.62	1.1	1.0000	170
20	15.00	200L	725	61.0	244	35.0	140	19.6	170	210	83	86	87	0.56	0.67	0.73	1.1	2.1000	238
25	18.50	225S/M	720	76.1	441	44.0	255	24	155	275	83	86	86	0.55	0.68	0.74	1.1	2.7500	268
30	22.00	225S/M	735	91.7	596	53.0	345	29	160	260	87	88	89	0.53	0.66	0.71	1.0	3.4000	314
40	30.00	250S/M	730	104	644	60.0	372	39	175	260	88	91	91	0.68	0.78	0.82	1.0	5.5000	430
50	37.00	250S/M	735	133	826	77.0	477	49	160	270	88	89	90	0.64	0.77	0.81	1.0	8.5000	560
60	45.00	280S/M	735	157	1023	91.0	592	58	170	225	88	90	91	0.61	0.74	0.81	1.0	10.500	620
75	55.00	280S/M	735	197	1164	114	673	73	170	210	88	90	91	0.68	0.78	0.81	1.0	16.600	765
100	75.00	315S/M	735	260	1609	150	930	97	180	205	90	91	91	0.66	0.77	0.82	1.0	18.700	860
125	90.00	315S/M	740	317	2089	183	1208	121	160	200	91	92	92	0.69	0.78	0.83	1.0	21.100	960
150	110.00	315S/M	740	389	2647	225	1530	145	205	235	91	92	92	0.68	0.77	0.81	1.0	26.000	1210
180	132.00	355M/L	740	464	3338	268	1930	174	200	230	91	92	93	0.66	0.77	0.81	1.0	30.000	1350
220	162.00	355M/L	740	571	3711	330	2145	213	190	220	92	93	93	0.64	0.75	0.80	1.0	34.000	1480
270	199.00	355M/L	740	701	4764	405	2754	260	195	220	92	93	93	0.66	0.76	0.80	1.0	38.000	1620
300	220.00	355M/L	740	761	5100	440	2948	290	185	220	92	93	94	0.70	0.77	0.81	1.0	42.000	1700

CARACTERISTICAS DE DESEMPEÑO

Motor IP55 - Uso General; Motor IPW55 - Uso Naval; Ambientes Agresivos.

Potencia		Carcasa	Velocidad	Intensidad Nominal				Torque / Cupla			Eficiencia (η%)			Factor de Potencia (cos φ)			Factor de Servicio	GD² DEL ROTOR	Peso
				220 V		380 V													
(HP)	(kW)	(IEC)	(rpm)	In(A)	Ia(A)	In(A)	Ia(A)	Cn (Kgm)	CP/Cn (%)	Cmáx/Cn (%)	50%	75%	100%	50%	75%	100%		(Kgm²)	(Kg)
2 POLOS - 60 Hz																			
1/6	0.12	56a	3370	0.74	2.93	0.43	1.69	0.04	310	240	44.0	53.0	58.0	0.57	0.67	0.74	1.15	0.0007	3.3
1/4	0.18	56b	3345	1.06	4.45	0.61	2.57	0.05	280	280	45.0	55.0	60.0	0.59	0.69	0.76	1.15	0.0007	3.4
1/3	0.25	63a	3360	1.13	5.33	0.65	3.08	0.07	270	245	62.0	69.0	71.0	0.57	0.71	0.80	1.15	0.0014	4.9
1/2	0.37	63b	3370	1.59	7.67	0.92	4.43	0.11	295	280	68.0	72.5	73.0	0.63	0.75	0.82	1.15	0.0014	4.9
3/4	0.55	71a	3410	2.25	12.2	1.30	7.02	0.16	270	250	64.0	73.0	75.0	0.62	0.75	0.84	1.15	0.0022	9.0
1	0.75	71b	3410	2.94	18.3	1.70	10.60	0.21	280	270	68.0	76.0	77.0	0.66	0.79	0.85	1.15	0.0025	10.0
1.5	1.1	80a	3430	4.33	28.2	2.50	16.3	0.31	280	270	73.0	78	78.5	0.67	0.79	0.86	1.15	0.0048	13.5
2	1.5	80b	3425	5.46	36.0	3.15	20.8	0.42	300	280	77.5	80	81.0	0.74	0.84	0.88	1.15	0.0056	15.0
3	2.2	90S	3480	8.31	62.4	4.80	36.0	0.62	310	300	75.0	79.0	81.5	0.68	0.80	0.86	1.15	0.0100	20.0
4	3	90L	3470	10.8	88.3	6.24	51.0	0.83	355	310	79.0	81.5	82.5	0.71	0.82	0.87	1.15	0.0120	23.5
5	3.7	100L	3470	13.0	84.4	7.53	48.7	1.03	300	300	81.5	84.0	84.5	0.75	0.84	0.88	1.15	0.0170	29.0
6	4.5	112Ma	3500	15.3	132.5	8.83	76.5	1.23	300	310	83.0	85.0	85.5	0.76	0.85	0.89	1.15	0.0320	40.0
7.5	5.5	112M	3500	19.4	142.4	11.2	82.2	1.53	310	320	84.0	86.5	86.5	0.74	0.83	0.87	1.15	0.0322	41.0
10	7.5	132S	3520	25.5	187.1	14.7	108.0	2.10	310	300	84.5	86.5	87.5	0.78	0.85	0.87	1.15	0.0640	54.0
12.5	9	132Ma	3500	31.0	242.5	17.9	140.0	2.60	300	270	83.0	87.0	88.0	0.80	0.87	0.89	1.15	0.0750	67.0
15	11.0	132M	3515	36.4	310.0	21.0	179.0	3.00	340	300	85.0	89.0	89.5	0.80	0.87	0.89	1.15	0.0836	71.0
20	15	160Ma	3550	49.0	400.1	28.3	231.0	4.10	320	300	85.5	88.0	89.0	0.84	0.88	0.89	1.15	0.175	93.0
25	18.5	160M	3540	58.9	516.2	34.0	298.0	5.00	300	280	86.0	88.5	89.5	0.88	0.92	0.92	1.00	0.236	107.0
30	22	160L	3540	70.7	587.2	40.8	339.0	6.10	310	300	86.0	88.5	89.5	0.88	0.91	0.92	1.00	0.310	125.0
40	30	200M	3550	96.6	658.2	55.8	380.0	8.10	330	310	88.0	89.7	90.2	0.85	0.88	0.89	1.00	0.650	208.0
50	37	200L	3550	117.8	855.6	68.0	494.0	10.10	340	315	89.0	90.8	91.5	0.86	0.89	0.90	1.00	0.720	247.0
60	45	225S/M	3545	136.7	1139.7	78.9	658.0	12.10	280	240	87.0	91.2	92.5	0.88	0.91	0.92	1.00	1.060	270.0
75	55	225S/M	3545	174.1	1437.6	100.5	830.0	15.20	320	305	88.0	91.8	92.8	0.84	0.87	0.90	1.00	1.300	314.0
100	75	250S/M	3550	233.0	1624.7	134.5	938.0	20.00	205	270	90.4	82.5	93.5	0.86	0.88	0.89	1.00	1.950	420.0
125	90	280S/M	3550	290.6	2026.5	167.8	1170.0	25.00	220	270	90.5	93.0	93.7	0.82	0.87	0.89	1.00	2.800	540.0
150	110	280S/M	3550	347.6	2424.9	200.7	1400.0	30.00	200	230	90.7	93.3	94.0	0.83	0.87	0.89	1.00	3.400	576.0
175	132	315S/M	3570	405.6	3031.1	234.2	1750.0	35.00	210	240	91.7	93.5	94.0	0.86	0.88	0.89	1.00	5.100	703.0
200	150	315S/M	3570	457.3	3327.3	264.0	1921.0	40.00	205	230	92.0	93.5	94.2	0.85	0.89	0.90	1.00	6.100	800.0
250	185	315S/M	3570	581.1	4027.0	335.5	2325.0	50.00	210	230	92.4	93.7	94.3	0.86	0.88	0.89	1.00	7.100	900.0
300	220	355M/L	3575	695.4	5194.4	401.5	2999.0	60.00	205	220	91.0	93.3	94.0	0.88	0.88	0.89	1.00	7.500	1270.0
350	225	355M/L	3575	455.0	6386.1	262.7	3687.0	70.00	200	210	91.5	93.5	94.1	0.89	0.90	0.90	1.00	8.500	1390.0
400	295	355M/L	3580	914.0	7738.8	527.7	4468.0	80.00	210	220	91.5	93.5	94.3	0.89	0.90	0.90	1.00	10.00	1460.0
450	330	355M/L	3580	1026.1	8688.0	592.4	5016.0	90.00	220	230	92.0	94.0	94.5	0.89	0.90	0.90	1.00	11.00	1500.0
4 POLOS 60 Hz																			
1/8	0.09	56a	1710	0.92	2.77	0.53	1.60	0.05	300	330	36.0	44.5	50.0	0.42	0.48	0.53	1.15	0.0007	3.3
1/6	0.12	56b	1680	1.07	3.12	0.62	1.80	0.07	285	235	39.0	47.0	52.0	0.44	0.52	0.58	1.15	0.0007	3.3
1/4	0.18	63a	1695	1.11	4.50	0.64	2.60	0.10	245	280	53.0	60.0	64.0	0.47	0.59	0.68	1.15	0.0014	4.8
1/3	0.25	63b	1680	1.44	6.24	0.83	3.60	0.15	300	285	53.0	61.0	65.0	0.47	0.59	0.69	1.15	0.0014	4.8
1/2	0.37	71a	1700	1.92	9.53	1.11	5.50	0.21	225	245	62.0	68.5	71.0	0.49	0.61	0.71	1.15	0.0041	9.6
3/4	0.56	71b	1680	2.77	13.9	1.60	8.00	0.32	265	265	68.0	71.5	72.0	0.50	0.62	0.70	1.15	0.0041	9.6
1	0.75	80a	1715	2.96	21.1	1.71	12.2	0.42	330	320	74.4	77.5	78.0	0.65	0.77	0.84	1.15	0.0087	14.0
1.5	1.1	80b	1705	4.33	30.1	2.50	17.4	0.63	285	245	75.0	78.0	79.0	0.66	0.78	0.85	1.15	0.0094	14.7
2	1.5	90S	1720	5.94	40.0	3.43	23.1	0.83	335	310	79.0	81.0	81.5	0.56	0.70	0.80	1.15	0.0180	19.8
3	2.2	90L	1720	8.7	56.1	5.00	32.4	1.30	320	310	81.0	82.5	83.0	0.62	0.74	0.81	1.15	0.0250	24.0
4	3	100La	1720	10.8	75.3	6.24	43.5	1.70	220	265	79.0	83.0	83.5	0.70	0.82	0.86	1.15	0.0240	29.0
5	3.7	100L	1730	14.1	105.8	8.13	61.1	2.10	305	330	80.0	84.0	85.0	0.64	0.75	0.81	1.15	0.0300	32.0
6	4.5	112Ma	1720	16.7	116.7	9.6	67.4	2.50	220	280	85.0	86.0	86.0	0.66	0.77	0.81	1.15	0.0650	41.0
7.5	5.5	112M	1735	20.6	159.3	11.9	92.0	3.10	265	335	84.5	86.5	87.0	0.64	0.77	0.81	1.15	0.0650	42.0
10	7.5	132S	1750	26.2	190.5	15.1	110.0	4.10	215	275	86.0	87.5	87.5	0.73	0.83	0.85	1.15	0.1310	55.0
12.5	9	132Ma	1760	31.2	266.7	18.0	154.0	5.10	215	245	86.0	87.5	87.5	0.75	0.85	0.89	1.15	0.1580	63.0
15	11	132M	1750	37.4	318.7	21.6	184.0	6.10	245	355	87.0	88.0	88.5	0.75	0.84	0.88	1.15	0.2100	67.0
20	15	160M	1745	49.2	415.7	28.4	240.0	8.20	235	350	87.5	89.0	89.5	0.74	0.84	0.88	1.15	0.339	106.0
25	18.5	160L	1750	60.1	472.8	34.7	273.0	10.20	225	300	88.5	89.5	90.5	0.75	0.85	0.89	1.15	0.3900	116.0
30	22	180M	1755	72.7	647.8	42.0	374.0	12.20	240	360	88.5	90.5	91.0	0.80	0.86	0.88	1.15	0.5000	151.0
40	30	200M	1770	96.1	727.5	55.5	420.0	16.20	250	270	89.3	91.2	91.7	0.78	0.85	0.88	1.15	1.1200	211.0
50	37	200L	1770	119.2	836.6	68.8	483.0	20.00	245	255	90.5	92.0	92.4	0.80	0.86	0.88	1.15	1.3000	237.0
60	45	225S/M	1770	140.6	795.0	81.2	459.0	24.00	190	215	92.0	93.0	93.0	0.84	0.88	0.89	1.00	1.7000	265.0
75	55	225S/M	1765	177.7	999.4	102.6	577.0	30.00	180	200	92.4	92.8	93.0	0.83	0.87	0.88	1.00	2.0000	291.0
100	75	250S/M	1770	238.3	1662.8	137.6	960.0	40.00	260	245	92.0	93.0	93.5	0.75	0.83	0.87	1.00	3.4000	427.0
125	90	280S/M	1775	293.6	1991.9	169.5	1150.0	50.00	240	250	91.0	93.0	93.8	0.77	0.85	0.88	1.00	5.7000	545.0
150	110	280S/M	1770	347.3	2168.5	200.5	1252.0	60.00	230	230	92.0	93.5	94.1	0.82	0.87	0.89	1.00	6.7000	615.0
175	132	315S/M	1775	409.8	2657.0	236.6	1534.0	70.00	210	220	93.0	93.7	94.1	0.82	0.87	0.88	1.00	10.500	790.0
200	150	315S/M	1780	466.4	2991.3	269.3	1727.0	80.00	200	200	93.2	94.3	94.5	0.82	0.87	0.88	1.00	12.500	878.0
250	185	315S/M	1780	575.0	3732.6	332.0	2155.0	100.00	210	200	93.0	94.0	94.5	0.82	0.87	0.89	1.00	14.500	966.0
300	220	355M/L	1780	699.7	4877.5	404.0	2816.0	120.00	210	200	93.2	94.0	94.5	0.82	0.87	0.88	1.00	16.000	1300.0
350	225	355M/L	1780	805.4	5774.7	465.0	3334.0	140.00	220	210	93.8	94.5	94.7	0.83	0.88	0.89	1.00	19.000	1370.0
400	295	355M/L	1780	917.5	6580.1	529.7	3799.0	160.00	210	200	93.8	94.5	95.0	0.82	0.87	0.89	1.00	21.500	1484.0
450	330	355M/L	1785	1020.5	7421.8	589.2	4285.0	180.00	215	205	93.8	95.0	95.0	0.83	0.88	0.90	1.00	24.000	1545.0
500	370	355M/L	1785	1131.5	8454.1	653.3	4881.0	200.00	220	200	93.8	95.0	95.2	0.82	0.88	0.90	1.00	27.000	1630.0

CARACTERISTICAS DE DESEMPEÑO

Motor IP55 - Uso General; Motor IPW55 - Uso Naval; Ambientes Agresivos.

Potencia		Carcasa	Velocidad	Intensidad Nominal				Torque / Cupla			Eficiencia (η%)			Factor de Potencia (cos φ)			Factor de Servicio	GD² DEL ROTOR	Peso
				220 V		380 V													
(HP)	(kW)	(IEC)	(rpm)	In(A)	Ia(A)	In(A)	Ia(A)	Cn (Kgm)	CP/Cn (%)	Cmáx/Cn (%)	50%	75%	100%	50%	75%	100%		(Kgm²)	(Kg)
6 POLOS - 60 Hz																			
1/8	0.09	63a	1090	0.69	2.08	0.40	1.20	0.08	200	195	39.0	46.5	50.0	0.50	0.59	0.66	1.15	0.0014	4.8
1/6	0.12	63b	1085	1.00	2.77	0.58	1.60	0.11	205	195	40.0	48.5	52.0	0.50	0.58	0.64	1.15	0.0014	4.8
1/4	0.18	71a	1100	1.40	4.16	0.81	2.40	0.16	210	220	43.0	50.5	53.0	0.46	0.55	0.63	1.15	0.0035	9.0
1/3	0.25	71b	1110	1.73	5.54	1.00	3.20	0.22	220	205	46.0	52.5	55.0	0.42	0.51	0.58	1.15	0.0041	9.6
1/2	0.37	80a	1150	2.25	11.1	1.30	6.40	0.31	275	340	60.0	66.5	69.0	0.45	0.57	0.66	1.15	0.0091	13.0
3/4	0.55	80b	1135	2.77	13.0	1.60	7.50	0.47	185	205	64.0	69.0	71.0	0.50	0.62	0.72	1.15	0.0095	13.5
1	0.75	90Sa	1160	3.91	20.8	2.26	12.0	0.61	220	275	65.0	68.0	73.0	0.48	0.61	0.68	1.15	0.0220	19.5
1.5	1.1	90S	1135	5.46	24.1	3.15	13.9	0.94	170	240	71.0	74.0	75.0	0.54	0.66	0.71	1.15	0.0220	19.5
2	1.5	100La	1150	7.19	38.1	4.15	22.0	1.2	190	240	70.0	75.0	77.0	0.49	0.61	0.70	1.15	0.0380	29.0
3	2.2	100L	1150	10.0	65.8	5.80	38.0	1.9	275	320	74.0	78.0	78.5	0.52	0.64	0.74	1.15	0.0490	31.0
4	3	112M	1150	13	76.2	7.50	44.0	2.5	195	285	78.0	82.0	83.0	0.52	0.64	0.72	1.15	0.0580	36.0
5	3.7	132Sa	1150	14.1	79.7	8.13	46.0	3.1	170	250	82.0	84.5	85.0	0.67	0.76	0.81	1.15	0.1150	50.0
6	4.5	132S	1150	17.8	100.5	10.3	58.0	3.7	180	265	83.0	85.0	85.5	0.60	0.70	0.76	1.15	0.1150	52.0
7.5	5.5	132Ma	1160	21.1	150.7	12.2	87.0	4.7	185	220	83.0	85.5	86.0	0.62	0.74	0.80	1.15	0.1650	63.0
10	7.5	132M	1150	28.2	188.8	16.3	109.0	6.2	200	260	84.5	86.5	87.0	0.61	0.73	0.79	1.15	0.1900	66.0
12.5	9	160Ma	1175	36.0	270.2	20.8	156.0	7.6	200.0	250	84.0	86.5	87.5	0.59	0.70	0.77	1.15	0.4100	98.0
15	11	160M	1175	41.9	325.6	24.2	188.0	9.5	180	255	85.5	88.0	89.0	0.58	0.71	0.78	1.15	0.4100	100.0
20	15	160L	1170	54.9	436.5	31.7	252.0	12.2	180	270	86.0	89.0	89.5	0.61	0.73	0.79	1.15	0.5800	126.0
25	18.5	180L	1170	65.5	372.4	37.8	215.0	15.3	225	230	89.5	90.2	90.2	0.65	0.76	0.82	1.15	0.9200	170.0
30	22	200L	1180	79.0	519.6	45.6	300.0	18.3	235.0	290	90.5	91.0	91.0	0.68	0.77	0.81	1.15	1.400	225.0
40	30	200L	1175	103.2	614.9	59.6	355.0	24.00	185	265	90.8	91.7	91.7	0.66	0.78	0.82	1.15	1.700	240.0
50	37	225S/M	1185	140.3	850.4	81.0	491.0	30.00	225	265	90.5	91.8	92.0	0.64	0.71	0.75	1.00	2.800	305.0
60	45	250S/M	1175	149.8	940.5	86.5	543.0	36.00	215	260	91.0	92.3	92.5	0.69	0.79	0.84	1.00	3.300	475.0
75	55	250S/M	1175	182.2	1015.0	105.2	586.0	46.00	190.0	230	91.4	92.5	92.8	0.73	0.82	0.86	1.00	4.000	480.0
100	75	280S/M	1180	251.1	1325.0	145.0	765.0	61.00	200.0	210	92.0	92.8	93.0	0.72	0.80	0.83	1.00	7.500	625.0
125	90	280S/M	1180	314.0	1680.1	181.3	970.0	76.00	190.0	210	92.0	93.0	93.0	0.72	0.80	0.83	1.00	8.800	710.0
150	110	315S/M	1185	359.7	2050.7	207.7	1184.0	90.00	200.0	230	93.0	93.5	94.1	0.74	0.83	0.86	1.00	16.00	980.0
175	132	315S/M	1185	419.2	2514.9	242.0	1452.0	106.00	200.0	220	93.0	94.1	94.1	0.74	0.83	0.86	1.00	18.00	1080.0
200	150	315S/M	1185	478.0	2736.6	276.0	1580.0	121.00	210.0	230	93.0	94.0	94.2	0.75	0.83	0.86	1.00	20.00	1150.0
250	184	355M/L	1190	643.3	3065.7	371.4	1770.0	150.00	220.0	210	93.5	94.2	94.2	0.70	0.77	0.80	1.00	22.00	1380.0
300	220	355M/L	1185	771.1	3117.7	445.2	1800.0	180.00	210.0	200	93.5	94.0	94.3	0.70	0.78	0.80	1.00	26.00	1500.0
350	255	355M/L	1190	897.7	5577.2	518.3	3220.0	210.00	200.0	190	94.0	94.3	94.5	0.70	0.78	0.80	1.00	30.00	1630.0
400	295	355M/L	1190	1022.8	6373.9	590.5	3680.0	240.00	235.0	210	94.0	94.5	94.8	0.71	0.78	0.80	1.00	33.00	1730.0
450	330	355M/L	1190	1148.3	6538.5	663.0	3775.0	270.00	230.0	210	94.0	95.0	95.0	0.71	0.78	0.80	1.00	37.00	1820.0
8 POLOS - 60 Hz																			
1/12	0.06	63b	810	0.78	1.56	0.45	0.90	0.07	245	225	21.0	26.5	30.0	0.42	0.49	0.55	1.15	0.0014	4.4
1/8	0.09	71a	820	1.04	2.42	0.60	1.40	0.10	195	225	31.0	37.0	40.0	0.44	0.53	0.60	1.15	0.0041	9.6
1/6	0.18	80a	860	1.2	4.85	0.69	2.80	0.20	240	275	45.0	51.0	54.0	0.37	0.47	0.55	1.15	0.0091	13.0
1/4	0.12	71b	810	1.3	2.77	0.75	1.60	0.14	185	200	34.0	41.0	44.0	0.41	0.49	0.56	1.15	0.0041	9.6
1/3	0.21	80b	860	1.73	6.93	1.00	4.00	0.27	215	260	45.0	52.0	56.0	0.40	0.49	0.57	1.15	0.0091	13.0
1/2	0.37	90Sa	870	2.77	11.6	1.60	6.70	0.41	210	270	49.0	57.0	61.0	0.41	0.50	0.57	1.15	0.0220	20.0
3/4	0.55	90La	870	3.98	17.1	2.30	9.90	0.62	220	230	50.0	58.0	62.0	0.39	0.49	0.58	1.15	0.0260	20.5
1	0.75	90L	865	4.92	20.1	2.84	11.6	0.82	220	270	59.0	65.0	68.0	0.38	0.49	0.58	1.15	0.0260	20.5
1.5	1.1	100La	850	5.92	26	3.42	15.0	1.20	200	235	69.0	73.5	74.5	0.45	0.57	0.66	1.15	0.0390	27.5
2	1.5	112Ma	870	7.74	41.6	4.47	24.0	1.60	180	265	67.0	73.0	77.0	0.39	0.50	0.65	1.15	0.0680	30.0
3	2.2	132Sa	870	10.5	57.2	6.06	33.0	2.50	170	235	71.0	75.5	78.0	0.46	0.58	0.71	1.15	0.1150	55.5
4	3	132Ma	865	15.1	74.5	8.72	43.0	3.30	185	300	72.0	76.0	79.0	0.44	0.55	0.65	1.15	0.1150	63.0
5	3.7	132M	870	16.6	95.3	9.60	55.0	4.10	205	275	74.0	78.0	80.0	0.44	0.55	0.73	1.15	0.1640	64.5
7.5	5.5	160Ma	880	26.7	176.7	15.4	102.0	6.10	165	250	74.0	80.0	84.0	0.40	0.50	0.65	1.15	0.3300	89.0
10	7.5	160L	875	34.1	207.8	19.7	120.0	8.20	140	240	79.0	82.0	85.0	0.46	0.57	0.67	1.15	0.4100	121.0
15	11	180L	870	46.2	233.8	26.7	135.0	12.30	130	200	88.0	90.0	90.0	0.52	0.63	0.70	1.15	0.8500	160.0
20	15	180L	870	62.4	346.4	36.0	200.0	16.50	165	205	88.0	90.0	90.0	0.50	0.61	0.69	1.15	1.000	165.0
25	18.5	200L	870	72.1	439.9	41.6	254.0	20.00	155	280	90.0	91.0	91.0	0.58	0.68	0.74	1.15	2.100	237.0
30	22	225S/M	880	88.9	474.6	51.3	274.0	24.00	190	240	89.0	91.0	91.0	0.58	0.68	0.72	1.00	2.750	270.0
40	30	225S/M	880	117.8	588.9	68.0	340.0	33.00	190	240	91.0	91.5	91.5	0.59	0.68	0.72	1.00	4.000	305.0
50	37	250S/M	880	142.0	928.4	82.0	536.0	41.00	170	230	90.0	91.0	91.0	0.61	0.70	0.75	1.00	5.500	430.0
60	45	250S/M	875	157.8	956.1	91.1	552.0	49.00	175	230	90.0	91.5	91.5	0.63	0.74	0.78	1.00	6.400	440.0
75	55	280S/M	885	207.8	1486.1	120.0	858.0	61.00	180	240	90.0	91.5	92.0	0.60	0.71	0.76	1.00	8.800	560.0
100	75	280S/M	880	272.3	1692.2	157.2	977.0	81.00	190	255	91.0	92.5	92.5	0.65	0.73	0.77	1.00	10.30	640.0
125	90	315S/M	890	345.7	2026.5	199.6	1170.0	101.00	200	220	92.0	93.5	93.5	0.66	0.73	0.75	1.00	18.70	860.0
150	110	315S/M	890	408.1	2469.9	235.6	1426.0	121.00	200	215	92.0	93.8	93.8	0.64	0.73	0.76	1.00	21.00	960.0
180	132	355M/L	890	482.2	2944.5	278.4	1700.0	145.00	210	205	92.0	93.5	94.0	0.64	0.74	0.77	1.00	26.00	1200.0
200	150	355M/L	890	535.9	3221.6	309.4	1860.0	160.00	205	200	93.0	94.0	94.0	0.65	0.74	0.77	1.00	30.00	1350.0
250	185	355M/L	890	657.7	3917.9	379.7	2262.0	200.00	220	210	93.0	94.0	94.5	0.67	0.76	0.78	1.00	34.00	1480.0
300	220	355M/L	890	807.5	4208.9	466.2	2430.0	240.00	200	195	93.0	94.5	94.8	0.63	0.73	0.76	1.00	38.00	1600.0
350	255	355M/L	890	927.9	4399.4	535.7	2540.0	280.00	220	210	94.0	95.0	95.0	0.67	0.75	0.77	1.00	42.00	1700.0

TABLA DE INDECO

ESPECIFICACIONES CONDUCTORES THW - 90 mm²

CALIBRE CONDUCTOR	NUMERO HILOS	DIAMETRO HILO	DIAMETRO CONDUCTOR	ESPESOR AISLAMIENTO	DIAMETRO EXTERIOR	DIAMETRO EXTERIOR	PESO	
							AIRE	DUCTO
mm²		mm	mm	mm	mm	Kg/Km	A	A
CABLES								
2,5	7	0,67	2,0	0,80	3,5	32	37	27
4	7	0,85	2,5	0,80	4,1	47	45	34
6	7	1,03	3,0	0,80	4,6	67	61	44
10	7	1,41	3,7	1,10	6,0	115	88	62
16	7	1,75	4,6	1,50	7,9	187	124	85
25	7	2,20	5,8	1,50	9,1	278	158	107
35	7	2,59	6,9	1,50	10,1	374	197	135
50	19	1,83	8,1	2,00	12,3	519	245	160
70	19	2,20	9,7	2,00	14,0	724	307	203
95	19	2,59	11,4	2,00	15,7	981	375	242
120	37	2,09	12,9	2,40	18,0	1245	437	279
150	37	2,33	14,3	2,40	19,4	1508	501	318
185	37	2,59	16,2	2,40	21,2	1866	586	361
240	37	2,99	18,5	2,40	23,5	2416	654	406
300	37	3,35	21,0	2,80	26,5	3041	767	462
400	61	2,95	23,5	2,80	29,3	3846	908	541
500	61	3,34	26,6	2,80	32,4	4862	1037	603

NO MAS DE TRES CONDUCTORES POR DUCTO

- TEMPERATURA AMBIENTE 30°C

Fecha de Actualizacion: 2008-04-21

ESPECIFICACIONES CONDUCTORES THW - 90 AWG / MCM

CALIBRE CONDUCTOR	SECCION NOMINAL	NUMERO HILOS	DIAMETRO HILO	DIAMETRO CONDUCTOR	ESPESOR AISLAMIENTO	DIAMETRO EXTERIOR	PESO	AMPERAJE (*)	
								AIRE	DUCTO
AWG/MCM	mm²		mm	mm	mm	mm	Kg/Km	A	A
CABLES									
14	2,1	7	0,62	1,8	0,80	3,4	28	35	25
12	3,3	7	0,77	2,2	0,80	3,9	41	40	30
10	5,3	7	0,98	2,8	0,80	4,4	60	56	40
8	8,4	7	1,22	3,7	1,10	6,0	101	80	56
6	13,3	7	1,53	4,6	1,50	7,8	165	107	75
4	21,1	7	1,93	5,8	1,50	9,0	245	141	96
2	33,6	7	2,44	7,3	1,50	10,6	369	192	130
1	42,4	19	1,69	8,4	1,80	11,6	463	220	147
1/0	53,4	19	1,94	8,6	2,00	12,8	575	260	170
2/0	67,4	19	2,18	9,6	2,00	13,9	710	300	197
3/0	85,1	19	2,45	10,8	2,00	15,1	877	350	226
4/0	107,2	19	2,75	12,2	2,40	17,2	1115	406	260
250	126,7	37	2,14	13,3	2,40	18,3	1296	457	290
300	151,9	37	2,35	14,5	2,40	19,5	1534	505	321
350	177,5	37	2,53	15,7	2,40	20,7	1769	569	350
400	202,8	37	2,64	18,5	2,40	23,3	2089	615	378
500	253,1	37	3,03	18,7	2,80	24,5	2520	699	429

NO MAS DE TRES CONDUCTORES POR DUCTO

- TEMPERATURA AMBIENTE 30°C

TABLA DE SCHNEIDER

Contactores tripolares Serie D y Contactores Serie F

Contactores tripolares Serie D

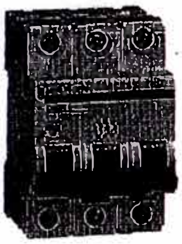
Contactores tripolares para comando de motores y circuitos de distribución
(Aptos para coordinación Tipo 2)
Contactores LC1D09 a D150.

Contactor tripolar LC1D

Referencia TeSys	HP220V	HP440V	AC3	AC1	Contactos Auxiliares	Tensión Bobina	Cantidad Indivisible	Precio S/.
LC1D09B7	3	5.5	9	25	1NA+1NC	24VAC	1	76.16
LC1D09E7	3	5.5	9	25	1NA+1NC	48 VAC	1	76.16
LC1D09F7	3	5.5	9	25	1NA +1NC	110 VAC	1	76.16
LC1D09M7	3	5.5	9	25	1NA+1NC	220 VAC	1	76.16
LC1D09Q7	3	5.5	9	25	1NA+1NC	380 VAC	1	76.16
LC1D09R7	3	5.5	9	25	1NA+1NC	440 VAC	1	76.16
LC1D12B7	4	7.5	12	25	1NA+1NC	24VAC	1	86.37
LC1D12F7	4	7.5	12	25	1NA+1NC	110 VAC	1	86.37
LC1D12M7	4	7.5	12	25	1NA+1NC	220 VAC	1	86.37
LC1D12Q7	4	7.5	12	25	1NA+1NC	380 VAC	1	86.37
LC1D12R7	4	7.5	12	25	1NA+1NC	440 VAC	1	86.37
LC1D18B7	5.5	12	18	32	1NA+1NC	24VAC	1	123.01
LC1D18E7	5.5	12	18	32	1NA+1NC	48 VAC	1	123.01
LC1D18F7	5.5	12	18	32	1NA+1NC	110 VAC	1	123.01
LC1D18M7	5.5	12	18	32	1NA+1NC	220 VAC	1	123.01
LC1D18Q7	5.5	12	18	32	1NA+1NC	380 VAC	1	123.01
LC1D18R7	5.5	12	18	32	1NA+1NC	440 VAC	1	123.01
LC1D25B7	7.5	15	25	40	1NA+1NC	24VAC	1	170.24
LC1D25F7	7.5	15	25	40	1NA+1NC	110 VAC	1	170.24
LC1D25M7	7.5	15	25	40	1NA+1NC	220 VAC	1	170.24
LC1D25Q7	7.5	15	25	40	1NA+1NC	380 VAC	1	170.24
LC1D25R7	7.5	15	25	40	1NA+1NC	440 VAC	1	170.24
LC1D32B7	10	20	32	50	1NA+1NC	24VAC	1	239.94
LC1D32F7	10	20	32	50	1NA+1NC	110 VAC	1	239.94
LC1D32M7	10	20	32	50	1NA+1NC	220 VAC	1	239.94
LC1D32Q7	10	20	32	50	1NA+1NC	380 VAC	1	239.94
LC1D32R7	10	20	32	50	1NA+1NC	440 VAC	1	239.94
LC1D38M7	12	25	38	50	1NA+1NC	220 VAC	1	269.19
LC1D40B7	15	30	40	60	1NA+1NC	24VAC	1	280.68
LC1D40F7	15	30	40	60	1NA+1NC	110 VAC	1	280.68
LC1D40M7	15	30	40	60	1NA+1NC	220 VAC	1	280.68
LC1D40Q7	15	30	40	60	1NA+1NC	380 VAC	1	280.68
LC1D40R7	15	30	40	60	1NA+1NC	440 VAC	1	280.68
LC1D50B7	20	40	50	80	1NA+1NC	24VAC	1	358.12
LC1D50F7	20	40	50	80	1NA+1NC	110 VAC	1	358.12
LC1D50M7	20	40	50	80	1NA+1NC	220 VAC	1	358.12
LC1D50R7	20	40	50	80	1NA+1NC	440 VAC	1	358.12
LC1D65B7	25	50	65	80	1NA+1NC	24VAC	1	443.52
LC1D65F7	25	50	65	80	1NA+1NC	110 VAC	1	443.52
LC1D65M7	25	50	65	80	1NA+1NC	220 VAC	1	443.52
LC1D65R7	25	50	65	80	1NA+1NC	440 VAC	1	443.52
LC1D80F7	30	61	80	125	1NA+1NC	110 VAC	1	551.17
LC1D80M7	30	61	80	125	1NA+1NC	220 VAC	1	551.17
LC1D80R7	30	61	80	125	1NA+1NC	440 VAC	1	551.17
LC1D95F7	34	68	95	125	1NA+1NC	110 VAC	1	805.25
LC1D95M7	34	68	95	125	1NA+1NC	220 VAC	1	805.25
LC1D95R7	34	68	95	125	1NA+1NC	440 VAC	1	805.25
LC1D115F7	40	80	115	200	1NA+1NC	110 VAC	1	918.82
LC1D115M7	40	80	115	200	1NA+1NC	220 VAC	1	918.82
LC1D150F7	54	108	150	200	1NA+1NC	110 VAC	1	1108.87
LC1D150M7	54	108	150	200	1NA+1NC	220 VAC	1	1108.87
LC1D150R7	54	108	150	200	1NA+1NC	440 VAC	1	1108.87

Interruptores automáticos C60H y C32H-DC
Interruptores limitadores

Interruptor termomagnético tripolar C60H



C60H
Tripolar

3 polos protegidos

Tensión de empleo: 230-440 VAC
Curva C: Disparo magnético entre 5 y 10 In.

Referencia	Tipo	In (A)	IEC60898-1 400VAC (A)	Poder de corte 230VAC (kA)	IEC60947-2 400VAC (kA)	440VAC (kA)	Cantidad Indivisible	Precio S/.
25000	C60H	16	10000	30	15	10	1	125.22
25001	C60H	20	10000	30	15	10	1	125.22
25002	C60H	25	10000	30	15	10	1	125.22
25003	C60H	32	10000	30	15	10	1	125.22
25004	C60H	40	10000	30	15	10	1	144.32
25005	C60H	50	10000	30	15	10	1	144.32
25006	C60H	63	10000	30	15	10	1	144.32

Interruptor de protección para circuitos de corriente continua C32H-DC

C32H-DC
Bipolar

Uso:
Mando y protección contra las sobreintensidades de circuitos alimentados en corriente continua.

Bipolares

Tensión de empleo: 250 VDC:
Disparo magnético entre 7 y 10 In.

Referencia	Tipo	In (A)	Poder de corte 125VDC (KA)	250VDC (KA)	Cantidad Indivisible	Precio S/.
20542	C32 H-DC	2	20	10	1	227.49
20544	C32 H-DC	6	20	10	1	223.08
20546	C32 H-DC	16	20	10	1	240.52
20547	C32 H-DC	20	20	10	1	240.52

Poder de corte de los interruptores automáticos en corriente continua

La elección del interruptor automático C60 ó C120 para la protección de una instalación en corriente continua depende esencialmente de los criterios siguientes:

- La intensidad nominal que permite elegir el calibre.
- La tensión nominal que permite determinar el número de polos en serie que deben participar en el corte.
- La intensidad de cortocircuito máxima en el punto de instalación que permite definir el poder de corte.
- El tipo de red (ver tabla adjunta).

(entre paréntesis, el número de polos implicados en el corte)

Tipo	Calibres	Poder de corte Tensión ≤ 60 V	125 V	125 V	250 V	Coeficiente aplicado al umbral magnético
C32H-DC	1 a 40	-	10 (1P)	20 (2P)	10 (2P)	especial DC
C60N	6 a 63	15 (1P)	20 (2P)	30 (3P)	40 (4P)	1.38
C60H	1 a 63	20 (1P)	25 (2P)	40 (3P)	50 (4P)	1.38
C120N	63 a 125	10 (1P)	10 (1P)	-	10 (2P)	1.4