INSTITUTO TECNOLOGICO Y DE ESTUDIOS SUPERIORES DE MONTERREY

CAMPUS MONTERREY

EGADE

TECNOLÓGICO DE MONTERREY.

PROPUESTAS DE SOLUCION DE INVENTIVA A FUGAS EN UNIONES CON SOLDADURA EN INTERCAMBIADORES DE CALOR

TESIS

PRESENTADA COMO REQUISITO PARCIAL PARA OBTENER EL GRADO ACADEMICO DE: MAESTRO EN DIRECCION PARA LA MANUFACTURA

POR

JOSE LUIS GALAVIZ HERNANDEZ

MONTERREY, N. L. JULIO DE 2005

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DEDICATORIAS

A Dios por estar siempre a mi lado, permitirme alcanzar todos mis sueños y ser consejero en todas mis empresas.

A mi esposa Nany, mi fuente de inspiración y el amor de mi vida. Te amo.

A mis padres José Luis y Rosa María, gracias por darme la vida.

A toda mi familia, a través de ustedes sé de donde vengo, donde estoy y hacia donde me debo dirigir. En especial a mi tía Rosa.

A mi tía Gloria, gracias por tu apoyo y confianza.

Al Ing. Anthony L. Reens Hertz, mi guía profesional y espiritual. Por el gusto de ser.

AGRADECIMIENTOS

A la empresa por el apoyo para realizar este proyecto y en general la maestría.

Al Dr. Noel León, asesor del proyecto, gracias por sus comentarios y conocimientos que fueron de gran utilidad para la realización del proyecto.

A los sinodales, que con sus comentarios y observaciones ayudaron a dar buen fin al proyecto.

Al Dr. Hendrichs y su equipo de trabajo por su apoyo durante la maestría y en especial durante este proyecto.

RESUMEN

En el presente trabajo se plantea el problema de la pérdida de refrigerante en los puntos de unión con soldadura de los intercambiadores de calor utilizados en las unidades de aire acondicionado.

Así como el efecto negativo que ocasiona la pérdida de refrigerante en el desempeño del equipo y los gastos que se incurren por la aplicación de garantías.

Se utiliza como metodología de trabajo el análisis de patentes y la metodología TRIZ para determinar posibles alternativas de solución.

Las alternativas planteadas incluyen propuestas de mejora continua y rediseño del proceso y materiales.

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1 INTRODUCCIÓN

1.1 Problemática

Hoy en día algunos de los retos más importantes a los que se enfrenta una empresa dedicada a la manufactura son:

- Logística de suministro de materia prima y producto terminado.
- Calidad de los productos.

Estos problemas son de igual importancia ya que de nada sirve manufacturar productos de alta calidad si no se tiene la materia prima a tiempo o no se entregan en el momento y lugar preciso y viceversa.

Los esfuerzos y recursos que se invierten para alcanzar la calidad requerida son considerables. Por ejemplo: en la industria del aire acondicionado se colocan en las líneas de producción de 6 a 7 puntos de revisión de calidad de un total de 30.

Generalmente en la industria manufacturera los reclamos sobre productos que han sido vendidos y no cumplen con las características ofrecidas tienen un alto impacto negativo en la satisfacción del cliente con el producto y en los costos extras que se generan con los costos de retrabajo, reparación y partes de repuesto.

En el caso de la industria de aire acondicionado los costos se incrementan sustancialmente debido a que la garantía se aplica en el lugar donde se realizó la instalación del producto: la azotea de una vivienda, el cuarto de máquinas de un edificio o empresa, etc. Para esto generalmente se traslada personal técnico calificado, herramienta, equipo y refacciones de reemplazo hasta ese lugar, pues resultaría más costoso si se trata de desinstalar el equipo, enviarlo al centro de servicio, repararlo, regresarlo y reinstalarlo.

La operación de una empresa manufacturera de equipo de aire acondicionado puede llegar a erogar en promedio por costos de garantías aproximadamente dos millones de dólares por año.

1.1.1 Calidad de los productos

Los problemas relacionados con la calidad del producto son muy variados, pero en general se pueden concentrar en dos grandes grupos: de apariencia y de desempeño.

- Apariencia.

Los problemas de apariencia son muy fáciles de identificar y están relacionados con la estética del producto. Por ejemplo: partes de lámina con tonos de color variado, formado de lámina deficiente, mal ensamble, etiquetas mal colocadas, entre otros.

El caso de las unidades de aire acondicionado, en los inicios de su comercialización lo más importante era el desempeño de la unidad, así como la confiabilidad y efectividad de su funcionamiento, hoy en día el funcionamiento y el desempeño son características mínimas esperadas por los consumidores, mientras la apariencia y el costo toma un papel cada vez más importante en la decisión de compra.

- Desempeño.

El bajo desempeño o mal funcionamiento de un producto es determinante para generar el reclamo del consumidor que incluso puede llegar a niveles legales por incumplimiento de lo prometido por el producto.

Retomando el ejemplo de la industria del aire acondicionado, las razones de la pérdida de eficiencia o falla en las unidades es causada por muchos factores que intervienen en el funcionamiento. Los más comunes son:

→ Componentes eléctricos.

→ Compresor.

→ Falta de refrigerante.

→ Obstrucciones en el circuito de enfriamiento.

→ Rozamiento de ventilador.

→ Componentes equivocados.

→ Ensamble incorrecto.

Para cada uno de estos problemas se han desarrollado sistemas de verificación de calidad que ayuden a minimizarlos.

En la siguiente tabla se muestran los problemas relacionados con desempeño y las pruebas que se han desarrollado en la búsqueda de disminuir estos defectos.

Tabla 1. Defectos y prueba que puede detectarlo.

DEFECTO	PRUEBA DE VERIFICACION
Componentes eléctricos	→ Run test. → Hipot.
Compresor	→ Run test.
Falta de refrigerante	→ Cámara de prueba de fugas. → Prueba de explosión. → Prueba de explosión en agua. → Detector de fugas manual.
Obstrucciones en el circuito de enfriamiento	→ Run test. → Vacío de circuito.
Rozamiento de ventilador	→ Run test.
Componentes equivocados	→ Run test. → Hipot.
Ensamble incorrecto	→ Run test. → Hipot.

La criticidad de cada uno de los factores que afectan el desempeño de los equipos puede ser determinado por el impacto y su ocurrencia.

La siguiente tabla muestra el impacto que provoca cada factor en el funcionamiento y desempeño de las unidades.

Tabla 2. Defecto e impacto que provoca en la operación del equipo.

DEFECTO	IMPACTO
Componentes eléctricos	→ No arranque del equipo.
Compresor	→ No arranque del equipo. → Funcionamiento deficiente. → Nivel de ruido fuera de estándar.
Falta de refrigerante	→ Funcionamiento deficiente.
Obstrucciones en el circuito de enfriamiento	→ Funcionamiento deficiente.
Rozamiento de ventilador	→ Nivel de ruido fuera de estándar. → Daño a ventilador y componentes periféricos.
Componentes equivocados	→ No arranque del equipo. → Funcionamiento deficiente. → Daño a unidad y/o otros componentes.
Ensamble incorrecto	→ Nivel de ruido fuera de estándar. → Daño a unidad y/o otros componentes.

No obstante que se han desarrollado para cada uno de los defectos anteriores pruebas de verificación, se continúan presentando problemas de rechazo en el proceso productivo y con el usuario final. Por otra parte, la ocurrencia de cada uno de los defectos es otro factor que determina la magnitud del problema.

1.1.2 Falta de hermeticidad en unidades de aire acondicionado

La falta de hermeticidad de una unidad de aire acondicionado provoca la fuga del refrigerante y es probablemente uno de los defectos con mayor recurrencia. Este problema genera un costo económico elevado para la empresa.

La producción anual de una planta de equipo de aire acondicionado para aplicaciones residenciales principalmente consta de 69,800 unidades, entre las cuales se detectaron 1,300 unidades con algún tipo de fuga. La detección de las fugas pudo ocurrir durante la revisión final de calidad, en el centro de distribución, durante la instalación del equipo o después de iniciada la operación con el cliente final.

Definitivamente el costo por el retrabajo de las unidades varía dependiendo del punto de la cadena de valor donde se encontró el defecto, cuando la unidad falla durante la operación cotidiana con el cliente final dentro del período de garantía es sin duda el costo más elevado que se puede erogar porque la reparación se realiza sobre la unidad ya instalada.

La mencionada falta de hermeticidad del sistema de aire acondicionado es uno de los problemas más recurrentes y difíciles de resolver. El grado de dificultad depende del lugar donde se encontró, es decir, una fuga detectada en la planta es más fácil de encontrar y corregir que una fuga encontrada en una unidad que ya está instalada.

Existen varias causas que afectan la cantidad de refrigerante en las unidades por las cuales los sistemas de aire acondicionado pueden tener problemas de eficiencia. A continuación se mencionan las más importantes:

- Carga de refrigerante incorrecta.
- Mala instalación del sistema.
- Fugas en los componentes de la unidad.

La carga de refrigerante era un problema constante en la década pasada debido a que la carga se medía a través del volumen, por lo que era necesario mantener parámetros como presión y temperatura constantes que difícilmente se lograban.

En la mayoría de los casos el refrigerante se almacena en tanques estacionarios y por sus dimensiones estos tanques normalmente se localizan en el exterior de las instalaciones, expuestos al medio. El refrigerante se lleva al punto de uso a través de un sistema de bombeo. En el caso de localidades con ambiente con temperatura ambiente muy variable resultaba imposible mantener los factores de presión y temperatura constantes. Hoy en día se utiliza la medición de flujo másico, la cual ofrece alta precisión en el llenado sin que intervengan otros parámetros.

El problema de una instalación deficiente se presenta principalmente en los sistemas divididos, que son los que cuentan con condensadora y evaporadora independientes. Pueden ser varios los problemas relacionados con el refrigerante, tales como: fugas en la tubería de conexión, carga complementaria insuficiente, daño en la tubería de unidad durante las maniobras de instalación que provoca fugas, entre otras.

Las fugas en los componentes se refieren principalmente a la tubería de cobre, es un problema que no ha sido resuelto completamente y es donde se concentra la mayoría de los esfuerzos de los fabricantes de unidades de aire acondicionado que van desde tecnologías de soldadura automática hasta métodos de detección de fugas.

1.2 Planteamiento de solución

En el presente trabajo se buscará plantear alternativas de solución a la pérdida de refrigerante en las unidades de aire acondicionado para disminuir el efecto negativo en el desempeño del equipo y en los gastos que se efectúan por la aplicación de garantías.

Las razones de la búsqueda de alternativas de solución son las siguientes:

→ Disminuir la cantidad de uniones de soldadura en las unidades de aire acondicionado.

→ Simplificar el proceso de fabricación.

→ Disminuir la cantidad de componentes en los intercambiadores de calor.

→ Disminuir el uso de gases, energéticos y combustibles necesarios para efectuar los procesos de soldadura.

→ Disminuir fuentes de emisiones contaminantes (calor, gases de combustión, aceite hidráulico usado).

2 REVISIÓN BIBLIOGRÁFICA

2.1 Solución de problemas

Los problemas se catalogan en cinco niveles dependiendo el grado de dificultad que presentan. [Hipple, Abril 2005].

Nivel 1. Se refiere a los problemas simples para los cuales no se requiere un nivel especial de experiencia o capacidad en solución de problemas, por otro lado, los ingenieros reciben entrenamiento académico para este tipo de problemas.

Nivel 2. Son problemas ligeramente difíciles y los ingenieros requieren resolver contradicciones simples para alcanzar el diseño adecuado. Su solución es relativamente fácil a través de la adición de otro proceso, utilizando un recurso existente y gastando algunos recursos económicos. La tendencia natural de los ingenieros es agregar algo para resolver la contradicción simple.

Nivel 3. Estos problemas son más complicados, la contradicción es más difícil y la solución no es tan obvia. Una posible solución a este tipo de problemas es la automatización, pero se vuelve más complejo el sistema y es probable que pueda generar problemas en el futuro. Resolver este tipo de problemas sin agregar suficiente complejidad es un reto. Otra manera de atacar este tipo de problemas es utilizando fuerza bruta.[1]

Nivel 4. Los problemas de este nivel son realmente un gran problema, son los que nadie quiere enfrentar. Usualmente se utilizan parches y el problema pasa a futuras generaciones. Varios miles de horas-hombre ingeniero son utilizadas en este tipo de problemas antes de encontrar una solución.

Nivel 5. Es el tipo de problemas que usualmente requiere totalmente un nuevo nivel de ciencia.

[1] Fuerza bruta: uso de fuerza o energía de manera innecesaria.

2.2 *Innovación Efectiva*

El reto de los innovadores que desean lanzar nuevos productos y compañías siempre será grande, sin embargo, los retos pueden ser vencidos si las compañías cambian su enfoque de desarrollo al azar y su proceso de innovación tradicional y reconocen la necesidad de enfocarse en los pasos clave de la innovación: [Anónimo, Junio 2004].

→ Estrategia tecnológica.- paso vital en el proceso de innovación, las grandes oportunidades son la satisfacción de las necesidades latentes. La metodología de innovación TRIZ tiene nueve leyes de evolución, las cuales ayuda a sugerir cuales son las siguientes direcciones de innovación. [Anónimo, junio 2004].

→ Generación de concepto.- conceptual este paso ayuda a agregar patrones de invención que son identificados por TRIZ.

→ Selección de concepto.- significa tomar la mejor idea de innovación.

→ Desarrollo robusto.- muchos conceptos nuevos trabajan bien en condiciones ideales, pero el verdadero reto es que trabajen bien bajo condiciones reales en producción o durante el uso por los consumidores.

→ Tecnología en buena posición.- el proceso de experimentación de una innovación requiere de tiempo y dinero, en caso de no tenerlo es fácil caer en un proceso acelerado que termina rápidamente en el programa de comercialización.

→ Transferencia de tecnología.- es cuando la innovación es transferida a un programa de comercialización, esta debe hacerse cuidadosamente para evitar el notorio "volarse la barda". [Anónimo, junio 2004].

2.3 *Avances tecnológicos*

Los avances tecnológicos a partir de la segunda parte del siglo XX han superado sin duda los avances alcanzados por la humanidad desde sus inicios. Un radical avance obtenido fue marcado por la invención de un aparato que ayudaba a realizar operaciones matemáticas básicas en los años 50's. Desde ese momento hasta la fecha las técnicas, métodos y tecnologías han luchado entre sí, lo existente contra lo nuevo. Cuando una nueva tecnología es desarrollada para sustituir a otra normalmente la tecnología existente tiene ventaja sobre la tecnología emergente.

El hecho que la mayoría adopte una tecnología determinada facilita la permanencia de la misma. Existen muchos factores que facilitan la adopción de una tecnología determinada, a continuación se presentan los más importantes: [Winch, 1997].

→ *Aprendizaje por uso.-* cuando la mayoría maneja determinada tecnología es relativamente fácil que la tecnología sea dominada en su totalidad.

→ *Redes de externalidades.-* es el caso en el que las tecnologías ofrecen ventajas adicionales sobre su competencia.

→ *Economías de escala en producción.-* sucede cuando se lleva a cabo la aplicación de la tecnología en productos y servicios. En este caso la difusión de la tecnología depende de la cantidad de productos o servicios que se pueda ofrecer en los mercados, entre más productos o servicios sean generados, los costos de producción serán disminuidos y en consecuencia podrán ser ofrecidos en precios cada vez más accesibles al mercado.

→ *Incremento en la información de beneficios.-* cuando el conocimiento y el entendimiento de los beneficios de alguna tecnología específica son cada vez más populares automáticamente disminuye el temor de su uso y/o adquisición, por lo cual se incrementa su atractivo.

→ *Interrelaciones tecnológicas.-* cuando las tecnologías alcanzan un nivel de adopción alto, comienzan a surgir sub-tecnologías y productos que complementan y se convierten en parte de su infraestructura.

Los cambios tecnológicos no siempre son adaptados con facilidad, incluso algunos jamás alcanzan a ser adoptados y se retiran de manera inmediata.

2.4 Patentes

La protección que ofrece una patente implica que la invención, el modelo de utilidad, o el diseño industrial no pueden ser confeccionados, utilizados, distribuidos o vendidos comercialmente sin el consentimiento del titular de la patente.

En Estados Unidos el cumplimiento de los derechos de patente se hace respetar en las Oficinas de Patentes y en los Tribunales. Las Oficinas de Patentes tienen a su cargo el registro y vigilancia de los derechos que otorga una patente y puede declarar la nulidad de una patente si un tercero logra demostrar la ausencia de derecho a la misma. Los Tribunales tienen la facultad de sancionar las infracciones que se cometan contra una patente y puede declarar no válida una patente si un tercero obtiene satisfacción en un litigio relacionado con la misma.

El titular de una patente tiene el derecho de decidir quién puede -o no puede- utilizar el producto o procedimiento patentado durante el período en el que está protegida la invención, el modelo de utilidad, o el diseño industrial y puede dar su permiso, o licencia a terceros para utilizar o explotar comercialmente la invención, el modelo de utilidad o el diseño industrial de acuerdo a términos establecidos de común acuerdo. También puede vender total o parcialmente el derecho a la invención, el modelo de utilidad o el diseño industrial a un tercero, que se convertirá en el nuevo titular de la patente.

Cuando la patente expira, expira la protección y la invención, el modelo de utilidad o el diseño industrial pasan a pertenecer al dominio público; es decir, el titular deja de tener derechos exclusivos sobre la invención, el modelo de utilidad o el diseño industrial, el cual pasa a estar disponible para la explotación comercial por parte de terceros.

La solicitud de patente contiene, por lo general, el título de la invención, del modelo de utilidad, o del diseño industrial, así como una indicación sobre su ámbito técnico; debe incluir los antecedentes tecnológicos relevantes y una descripción en un lenguaje claro y con los detalles suficientes para que una persona con un conocimiento medio del ámbito en cuestión pueda comprender, utilizar o reproducir. Estas descripciones están acompañadas usualmente de dibujos, fórmulas, planos o diagramas que contribuyen a su mejor comprensión. La solicitud contiene también información que determina el alcance de protección que garantizará la patente.

Las invenciones, modelos de utilidad o diseños industriales que pueden ser protegidos, no deben ser soluciones teóricas o meras ideas; deben presentar alguna característica nueva que no se conozca en el campo existente de su ámbito técnico.

Debe producirse innovación suficiente, esto significa que no pueda ser deducido por una persona con un conocimiento medio del ámbito técnico de que se trata. Finalmente, su materia debe ser aceptada como "patentable" de conformidad a derecho. En numerosos países, las teorías científicas, los métodos matemáticos, las obtenciones vegetales o animales, los descubrimientos de sustancias naturales, los métodos comerciales o métodos para el tratamiento o diagnóstico médico (en oposición a productos médicos), el software, y tantos otros, no son patentables.

Los títulos de patente son concedidos por una Oficina nacional de patentes o por una Oficina regional que trabaja para varios países, como por ejemplo la Oficina Europea de Patentes y la Organización Regional Africana de la Propiedad Industrial. Los sistemas regionales permiten a un solicitante pedir protección para la invención, el modelo de utilidad, o el diseño industrial, en uno o más países conjuntamente, y cada país decide si brinda protección a la patente dentro de sus fronteras.

El Tratado de Cooperación en materia de Patentes (PCT), administrado por la OMPI, permite a los nacionales o empresas residentes de países miembros del tratado, que se presente una única solicitud internacional de patente que tiene el mismo efecto que las solicitudes nacionales presentadas en los países designados en la solicitud internacional. Un solicitante que desee protección puede presentar una única solicitud y pedir protección en tantos países miembros como sea necesario o desee. Actualmente, no son muchos los países miembros de este tratado pero paulatinamente se van agregando nuevas adhesiones. [OMPI, 2005].

2.5 Análisis con TRIZ

En 1950 Genrich Altshuller un examinador de la oficina de patentes en la marina Rusa, inició una variedad de alternativas de creatividad e innovación científica.

TRIZ proviene del acrónimo en ruso "Teoría de Solución de Problemas de Inventiva" acentuando la parte de inventiva.

Las investigaciones de Altshuller encontraron que todas las grandes invenciones resolvieron grandes contradicciones, en esencia estos inventos desplegaron gran creatividad. Una de las conclusiones fundamentales fue encontrar que un número limitado de principios de inventiva fueron utilizados a través de varias áreas de la industria, ciencia y tecnología [Smith, Marzo 2003].

TRIZ es un proceso de solución de problemas que se basa en resolver problemas de diseño y contradicciones de ingeniería. Se enfoca en definir un sistema ideal, abriendo recursos no-obvios y tomando ventaja de patrones de invención común en numerosas industrias y tecnologías que pueden ser usadas en modos muy amplios.

TRIZ puede ser considerado complejo, probablemente porque los problemas difíciles que se tratan de resolver no muestran a simple vista sus contradicciones, todo depende del problema.

Altshuller condensó los parámetros de ingeniería más comunes encontrados en los sistemas analizados, resultando 39. Después de estudiar los parámetros de invención en la literatura de patentes postuló los 40 principios más comunes utilizados para resolver contradicciones entre parámetros.

Es necesario familiarizarse con los 39 parámetros de ingeniería y los 40 principios de inventiva en TRIZ y como el corazón de TRIZ es resolver contradicciones de inventos pasados es necesario adicionalmente aprender a utilizar la tabla de contradicciones de TRIZ.

Tabla 3. Parámetros más comúnmente utilizados por los ingenieros.

1. Weight of moving object.	2. Weight of non-moving object.	3. Lenght of moving object.	4. Lenght of non-moving object.
5. Area of moving object.	6. Area of non-moving object.	7. Volume of moving object.	8. Volumen of non-moving object.
9. Speed.	10. Force.	11. Tensión, pressure.	12. Shape
13. Stability of of object.	14. Strenght.	15. Durability of moving object.	16. Durability of non-moving object.
17. Temperature.	18. Brightness.	19. Energy spent by moving object.	20. Energy spent by non-moving object.
21. Power.	22. Waste of energy.	23. Waste of substance.	24. Loss of information.
25. Loss of time.	26. Amount of substance.	27. Reliability.	28. Accuracy of measurement.
29. Accuracy of manufacturing.	30. Harmful factors acting on object.	31. Harmful side effects.	32. Manufacturability .
33. Ease of operations.	34. Repairability.	35. Adaptability.	36. Complexity of device.
37. Complexity of control.	38. Level of automation.	39. Productivity	

Tabla 4. Principios de inventiva de Altshuller.

1. Segmentation	2. Extraction	3. Local quality	4. Asymmetry
5. Merging	6. Universality	7. Nested doll	8. Anti-weight
9. Perliminary anti-action	10. Prior or preliminary action	11. Beforehand chushioning	12. Equipotentiality
13. Inversion	14. Speheroidality	15. Dynamicity	16. Partial or excessive action
17. Another dimension	18. Mechanical vibration	19. Periodic action	20. Continuity of useful action
21. Skipping	22. Blessing in disguise	23. Feedback	24. Intermediary
25. Self-service	26. Copying	27. Cheap short-living objects	28. Mechanics substitution
29. Pneumatics and hydraulics	30. Flexible shell and thin films	31. Porous materials	32. Color changes
33. Homogeneity	34. Discarding and recovering	35. Transformation	36. Phase trnsitions
37. Thermal expansion	38. Strong oxidants	39. Inert atmosphere	40. Composite materials

La elaboración de la tabla inicia colocando en un eje todos los parámetros de ingeniería que se desean mejorar, en el otro eje se colocan de igual forma los parámetros que se desean evitar. Las intersecciones pueden entonces sugerir un número sorprendente de los principios de inventiva que deben ser explorados.

TRIZ provee una estructura que incrementa la habilidad para encontrar un conjunto de exhaustivas ideas con las que se puede resolver un problema.

Los principios de separación son:

→ Separación de la funcionalidad en tiempo

→ Separación de la funcionalidad en espacio.

→ Separación de funciones en partes del sistema o entero.

→ Separación de la funcionalidad basada sobre una condición.

TRIZ provoca dar un paso hacia atrás y observar cuan grande es el alcance y límite del problema y así poder encontrar la causa raíz. Esto hace más creativos a quienes lo aplican [Hipple, 2005].

2.6 Fabricación de un intercambiador de calor

Los serpentines son intercambiadores de calor que forman parte de los elementos del ciclo de refrigeración. Se componen de 4 partes fundamentales:

→ Aletas de aluminio.

→ Tubería de cobre.

→ Codos de retorno.

→ Tube sheet.

2.6.1 Aletas de aluminio

La función de las aletas de aluminio es transferir calor de la tubería de cobre al medio ambiente. Su fabricación inicia con el troquelado de la hoja de aluminio para formar las aletas de aluminio. El troquelado se lleva a cabo en una prensa hidráulica a través de un troquel preparado especialmente para esta aplicación [Bravo, Julio 2004].

Las aletas de aluminio son parte muy importante del serpentín, los factores que determinan el desempeño esperado son:

→ Altura de cuello.

→ Cantidad de agujeros.

→ Tipo de troquelado (plano o enhasment).

→ Dimensiones generales.

→ Espesor de aluminio.

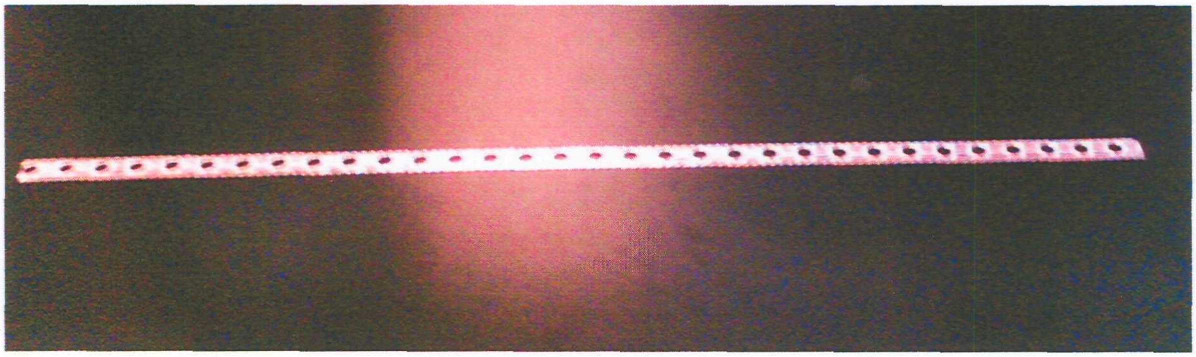


Fig. 2.1 Aleta de aluminio para serpentín de 32 agujeros.

2.6.2 Tubería de cobre

La tubería de cobre se prepara a partir de rollos en forma de bobina, la tubería se alimenta a una máquina dobladora de tubo, la cual endereza la tubería para posteriormente doblarla en forma de "U", [Bravo, Julio 2004].

Los factores determinantes de la tubería son:

→ Longitud de tubería.

→ Diámetro de tubería.

→ Diferencia en longitud de extremos "peg leg".

Fig. 2.2 Tubería de cobre

2.6.3 Codos de retorno

Los codos de retorno se utilizan para cerrar el circuito del serpentín, el proceso de fabricación es muy simple ya que solo se requiere una máquina para doblar tubería. Los codos de retorno son de espesor mayor a la tubería de cobre que se insertan en las aletas de aluminio. Una vez formados los codos de retorno se insertan en ambos extremos anillos de material de aporte para que se fundan con la soldadura automática, [Bravo, Julio 2004].

Fig. 2.3 Codos de retorno.

2.6.4 Tube sheet

El tube sheet son dos placas de lámina troquelada que se colocan en los extremos del serpentín. La función de los tube sheet es sujetar las aletas de aluminio durante el proceso de expansión, además de servir de soporte del serpentín para instalarse en la unidad de aire acondicionado, [Bravo, Julio 2004].

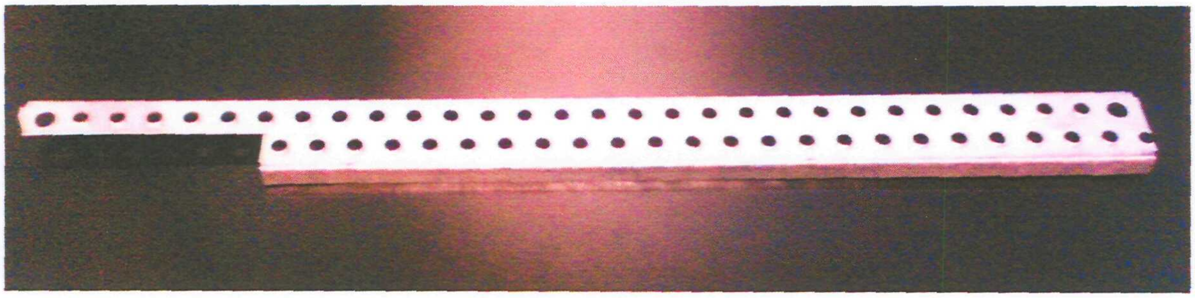


Fig. 2.4 Tube sheet

2.6.5 Ensamble de serpentín

El ensamble del serpentín se realiza sobre mesas diseñadas para manejar adecuadamente las aletas de cobre.

Fig. 2.5 Mesa para ensamble de serpentín.

El proceso inicia colocando las aletas de aluminio en las guías de la mesa hasta que se completa la cantidad de aletas requeridas según el modelo del serpentín.

Al final se coloca el segundo tube sheet para completar el ensamble, posteriormente se comienza a introducir la tubería de cobre dentro de los agujeros de las aletas de aluminio hasta completar el serpentín. Una vez terminado este proceso se pasa el serpentín al proceso de expansión, [Bravo, Julio 2004].

2.6.6 Expandido de serpentín

El proceso de expansión tiene como objetivo que la tubería de cobre se una a las aletas de aluminio por medio de fuerza mecánica. Después del proceso de expandido las aletas de aluminio, la tubería de cobre y los tube sheet forman una pieza firme para lograr una mejor transferencia de calor.

El serpentín con la tubería de cobre y con un tube sheet en cada extremo se coloca en la máquina expansora. El proceso consiste en introducir varillas dentro de la tubería de cobre, en el extremo de las varillas que entra en el serpentín se colocan puntas con el diámetro que se desea dar a la tubería de cobre. Con la acción de la entrada de las varillas en la tubería ésta se ensancha y se fija a las aletas de aluminio, [Bravo, Julio 2004].

Fig. 2.6 Proceso de expandido

2.7 Soldadura automática

La soldadura automática se realiza a través de un equipo automatizado en el cual se coloca el serpentín con la tubería de retorno y los aros de soldadura. Se alimenta mediante un transportador que lleva al serpentín al interior, una vez colocado el serpentín en posición y mediante antorcha se funde el material de aporte, quedando unida la tubería de retorno al serpentín, [Bravo, Julio 2004].

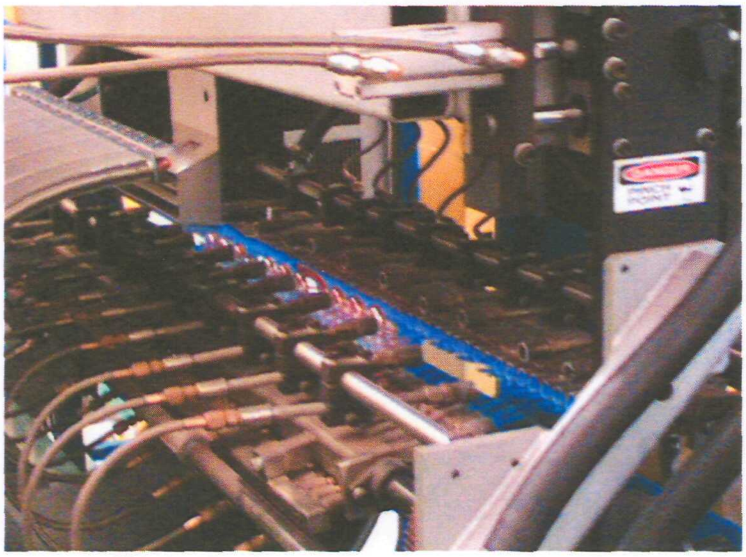


Fig. 2.7 Proceso de soldadura automática.

2.8 Procesos de soldadura

Soldar significa unir piezas metálicas de la misma o semejante composición hasta formar una sola pieza.

La soldadura se puede realizar con aportación o adición de un material que suele ser de la misma naturaleza que las piezas a soldar o también sin aportación de material.

La resistencia y cohesión que asegura la soldadura es igual o superior a la del metal de base. Cuando el metal de aportación es distinto del metal base se le llama soldadura heterogénea y cuando es igual o muy similar, soldadura homogénea.

Las variedades más importantes para soldar son:

- Soldadura blanda y fuerte.
- Soldadura autógena.
- Soldadura eléctrica.

La soldadura blanda y fuerte consiste en la aportación de un metal o aleación fundidos que se deposita entre las superficies.

Si el metal o aleación aportada se funde a una temperatura inferior a 4,500°C se llama soldadura blanda.

Cuando la temperatura para calentar el material de aportación supera los 4,500°C, se llama soldadura fuerte.

Las aleaciones más usadas para soldadura blanda son las de estaño y plomo. Este tipo de soldadura se emplea en latonería; en uniones de baja resistencia y es también la soldadura clásica de las conexiones eléctricas.

Los materiales de aporte para la soldadura blanda se suministran en forma de barras o alambre de tubo, pero a veces también en forma de granos.

Al realizar soldaduras blandas se emplea generalmente un soldador y lámpara de soldar para calentar la parte que se suelda y para fundir el material de soldadura.

La soldadura fuerte emplea cobre y aleaciones de zinc o plata. Es más resistente y menos sensible a la temperatura que la soldadura blanda.

Para calentar el sitio a soldar se utilizaba antes la lámpara de soldar de gasolina, hoy en día está generalizado el empleo de la alta temperatura del soplete de soldar.

La soldadura autógena o por fusión se realiza mediante gas, este procedimiento para soldar se utiliza para unir piezas a través de calentamiento y a través de un tercer elemento que es el material de aporte.

Para calentar el material se utiliza un mechero o soplete de soldar. El gas combustible, que es por lo general el acetileno, se produce en gasógenos especiales. Para el proceso de combustión es necesario también el oxígeno. Las llamas de acetileno y oxígeno pueden llegar a una temperatura de 3,200 °C. Por el empleo de estos gases se le ha dado al soplete el nombre de soplete oxiacetilénico.

La soldadura eléctrica por arco es un procedimiento que emplea el calor de un arco eléctrico para la fusión del material en el sitio que se quiere soldar. El arco se produce o salta entre dos conductores algo separados de polaridad distinta. Uno de los polos está constituido por las mismas piezas a soldar conectadas en un circuito eléctrico y el otro polo es el material de aporte. Ambos están conectados a una fuente de energía eléctrica o generador. Cuando se establece el arco eléctrico la temperatura se eleva en la zona por encima de los 3,000 °C, el calor provoca la fusión de las partes de la junta a soldar y la unión se consigue mediante el goteo del material de la varilla de aporte en forma de líquido en la rendija de la junta.

El depósito de metal que durante la operación de soldadura deja la varilla sobre la superficie de la pieza, se denomina cordón. Éste es el proceso de soldadura más comúnmente utilizado y se emplea principalmente para unir entre sí piezas de acero.

En la soldadura por resistencia eléctrica se hace pasar una corriente eléctrica de alta intensidad a través de los metales y en el punto de la soldadura.

La resistencia de los metales a la corriente es suficiente para fundir el metal en el punto de unión, produciéndose así la soldadura de las piezas.

En el procedimiento de soldadura por puntos se requiere de un equipo especial, el cual cuenta con dos electrodos que realizan el proceso de soldadura. El metal se coloca entre los dos electrodos y presionando una palanca o pedal los electrodos se cierran dejando en medio de ambos los materiales a unir, la corriente pasa a través del punto de metal colocado entre éstos.

La soldadura por puntos ha adquirido una gran importancia industrial en todas las aplicaciones de lámina fina como en la industria automotriz, de electrodomésticos, de juguetería, etc.

Se entiende por junta soldada la zona en la que las piezas se unen por soldadura.

La soldadura tiene como fin:

→ Aumentar la longitud de las piezas.

→ Aumentar el espesor.

→ Obtener derivaciones, refuerzos, formas complejas, oblicuas, angulares y múltiples.

Se le nombra cordón de soldadura al elemento que une las piezas en la junta de soldadura. Está formado por el material fundido de las piezas más el material de aportación, cuando lo hay. Al cordón de soldadura también se le llama costura.

Las clases de cordón se determinan por la posición y por la forma de preparación de las piezas que es necesario hacer antes de realizar la junta soldada [Carrier, Mayo 1995].

2.9 Brazing

Es el proceso de unir metales utilizando calor y una aleación como material de aporte a una temperatura por encima de los 440 °C. La temperatura de trabajo siempre debe ser inferior a la temperatura de fusión de los metales a unir.

Este proceso utiliza el calor que se suministra a los metales para fundir el material de aporte y que éste se introduzca por capilaridad entre ambos metales. El metal de aporte es distribuido entre las superficies de los metales a unir por atracción capilar.

La capilaridad es una fuerza creada por la tensión superficial entre la aleación (material de aporte) y los metales que se están uniendo, provoca la acción de jalar el material fundido además de distribuirlo alrededor de la unión.

El flujo capilar es una de las características de operación de la soldadura fuerte, es el principio físico dominante que asegura una buena unión proporcionando la acción para que ambas superficies a soldar estén mojadas por el material de aporte.

Específicamente la capilaridad está en función de la tensión superficial entre los metales base, el metal de aporte, el flux o atmósfera y el ángulo de contacto entre el metal base y el metal de aporte.

Flux es un compuesto químico aplicado a la superficie de unión que previene la oxidación durante el proceso de soldadura y absorbe algunos óxidos que no son removidos durante la limpieza de la tubería. Es importante resaltar que el flux no es un limpiador. Las áreas a soldar se liberan de contaminantes y óxidos por la acción del flux, que debe ser calentado hasta su punto de fusión para que el metal de aporte ocupe su lugar, generándose una acción capilar con el metal base varias veces mayor que la acción de capilaridad entre el flux y el metal base.

Las superficies con oxidación no permiten que el material de aporte se distribuya adecuadamente sobre el metal base. La capa de oxidación incluso no permite el contacto directo entre la aleación y el metal base y como consecuencia no hay una buena adhesión entre ambos. En caso que el proceso de soldadura utilice flux y las superficies presenten oxidación y otras impurezas éstas pueden quedar atrapadas en la unión, convirtiéndose en poros o burbujas que debilitan la resistencia de la unión.

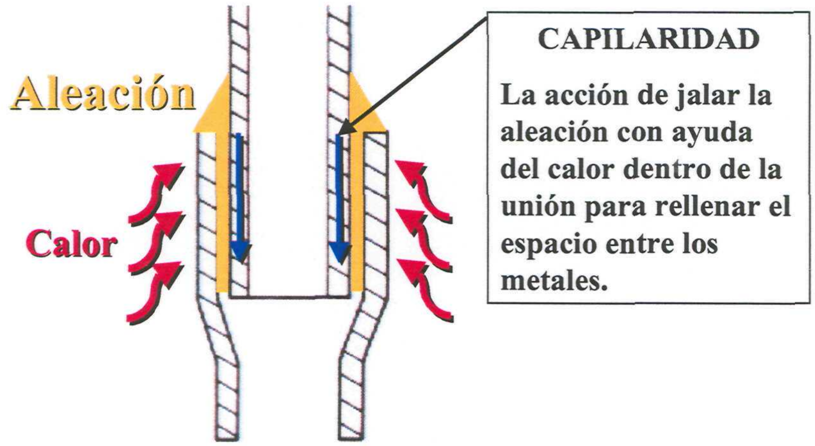


Fig. 2.8 Acción de la capilaridad en la soldadura de tubería.

La soldadura oxi-combustible utiliza una flama de gas combustible como fuente de calor en la soldadura fuerte. El gas combustible es mezclado ya sea con oxígeno o aire para producir una flama que se aplica a la pieza de trabajo hasta que se llega a la temperatura para soldar y poder colocar o introducir el metal de aporte.

Ventajas:

- Equipo de bajo costo.
- No es necesario calentar toda la pieza.
- Es posible automatizarla.
- La mayoría de los metales puede ser soldado.

Limitaciones:

- Oxidación y decoloración de la superficie.
- Los residuos de flux deben ser removidos.
- Materiales altamente reactivos como titanio y circonio no pueden ser trabajados.

- Piezas muy grandes son difíciles de calentar.

Dentro de las aplicaciones encontramos el uso de cobre, latón y otras aleaciones de cobre, así como hierro y hierro fundido.

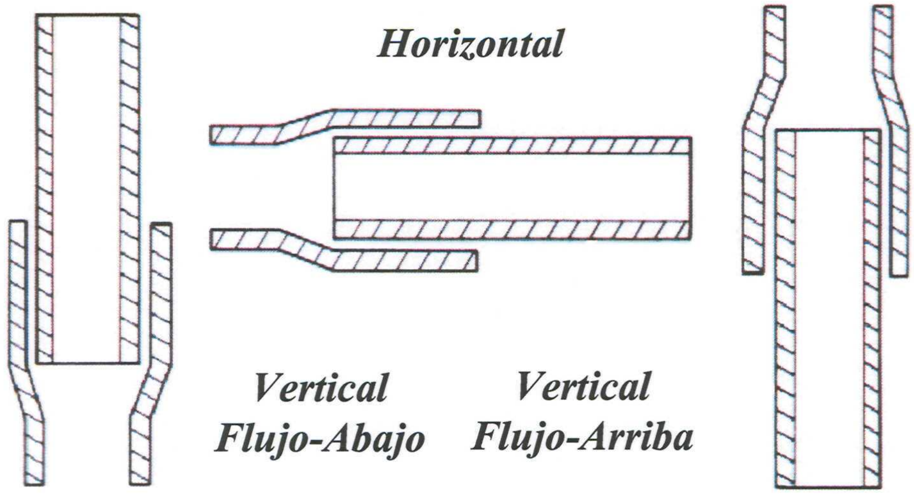


Fig. 2.9 Tipos de uniones en tubería de cobre.

La soldadura con soplete es normalmente utilizada para unir cobre en sistemas calentadores, aire acondicionado y en la industria de la refrigeración. Dentro de los gases utilizados para la soldadura oxi-combustible encontramos al acetileno, gas natural, gas butano, entre otros.

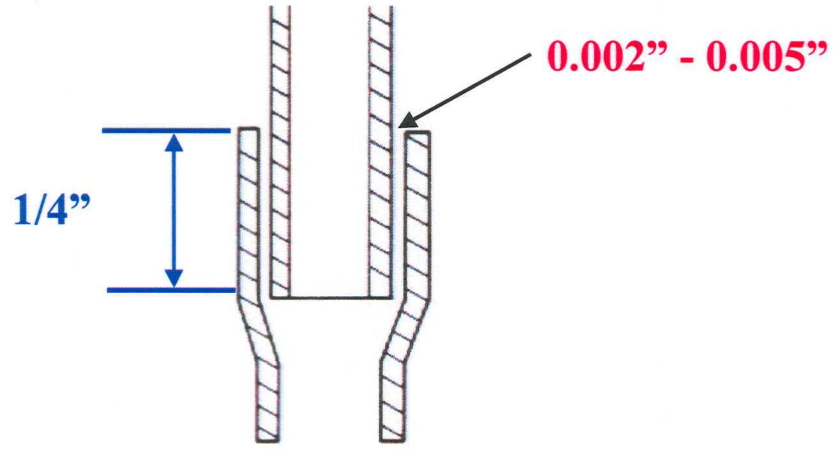


Fig. 2.10 Ensamble recomendado para soldadura de tubería de cobre.

Existen algunas recomendaciones básicas para la unión de tubería de cobre. La primera recomendación es en la medida de lo posible hacer uniones de posición vertical de flujoabajo (ver Fig. 2.10). Esta posición facilita la unión debido a que la acción de la fuerza de gravedad actúa en el mismo sentido de la capilaridad.

La segunda recomendación hace referencia a la tolerancia y profundidad de la penetración de la unión. En la Fig. 2.11 se muestra que la tolerancia recomendable es de 0.002 a 0.005 milésimas de pulgada y una penetración de 0.25 pulgadas. La tolerancia recomendada ofrece un ensamble fácil y el espacio suficiente para que el fenómeno de la capilaridad actúe. La profundidad de penetración es importante para asegurar que la tubería no tendrá un ensamble superficial y el material de aporte no penetre demasiado en el interior de la tubería y se convierta en una posible obstrucción del sistema.

La unión de la tubería debe ser firme, alineada cuidadosamente y soportada adecuadamente. El proceso de soldadura de oxi-combustible a diferencia de otros procesos es una técnica que requiere cuidado y precisión. La desviación de las características mencionadas afecta directamente la calidad, durabilidad y funcionamiento de la unión.

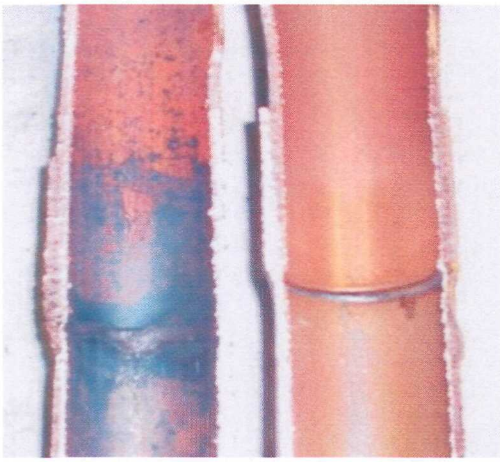
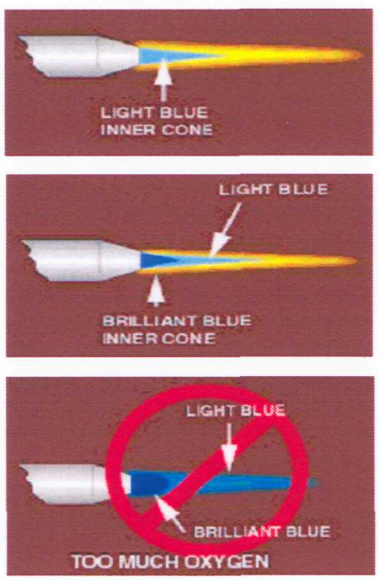


Fig. 2.11 Unión sin nitrógeno durante el proceso de soldadura (izquierda) y unión que utilizó nitrógeno en el proceso de soldadura (derecha).

La última recomendación es la utilización de una purga que libere al sistema y a las uniones de impurezas y oxidación durante el proceso de soldadura. Esta purga se puede hacer a través de un gas inerte como el nitrógeno. El flujo de nitrógeno (purga) a través del sistema no permite la formación de oxidación en las uniones, además retira cualquier material que pueda obstruir el sistema.

Uno de los parámetros que definen la calidad de la soldadura es la mezcla de los gases para formar la antorcha. Los gases a mezclar son normalmente el oxígeno y gas (natural o LP), los cuales deben ser regulados a una presión objetivo, buscando una combustión óptima.

La presión de trabajo en el caso de utilizar gas natural en una antorcha manual es de 10 psi, la presión del oxígeno debe ser de 20 psi.



Flama Neutral

Flama recomendada para las uniones de tubo de cobre.

Flama Reducida

Flama ideal para soldadura de uniones grandes en aceros.

Flama de Oxidación

El cono azul brillante es más pequeño que el neutral y el reducido. No debe usarse! Alto contenido de oxígeno.

Fig. 2.12 Tipos de flamas por la mezcla de gas y oxígeno.

Una vez que se fijaron los parámetros de presión de ambos gases el siguiente paso es revisar el porcentaje de cada uno de los gases en la formación de la flama, es importante ajustar la flama dependiendo del trabajo que se va a realizar. En la Fig. 2.12 se muestra los diferentes tipos de flama y su posible aplicación.

El siguiente paso es realizar el calentamiento de las piezas bajo el procedimiento adecuado. Para el caso de uniones en la tubería se debe calentar primero el tubo que es insertado (macho), la flama debe colocarse entre 0.5" a 1" de distancia del punto de unión de ambos tubos. El tubo opuesto (hembra) se debe calentar en el área de ensamble de ambos tubos.

Durante el calentamiento del área de inserción se funde el material de aporte formando la soldadura. En la Fig. 2.13 se observa la posición de aplicación de la flama para ambos tubos y la secuencia de calentamiento. Esto se debe realizar de manera alternada hasta que ambas piezas alcanzan el color objetivo.

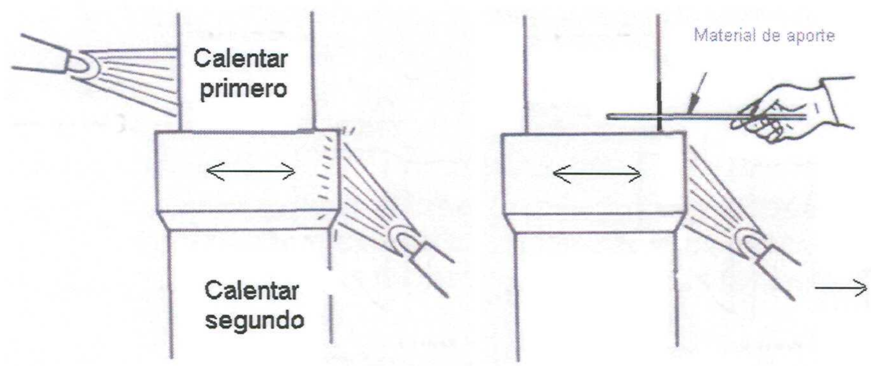


Fig. 2.13 Procedimiento de calentamiento para soldadura de tubería.

El calentamiento de las piezas se determina basándose en el cambio de color. La prontitud del proceso de producción y la velocidad con la que se alcanza el calentamiento así como la pérdida del mismo no permite que se realice algún tipo de medición numérica como temperatura.

En la Fig. 2.14 se muestra la imagen de un tubo calentado lo suficiente para realizar el proceso de soldadura y otra imagen de un tubo sobre calentado. Es importante resaltar que no mejora la calidad de la unión si los tubos son calentados más de lo necesario.

Sobre calentar el tubo puede provocar problemas en el cambio de la estructura del metal base, por otro lado en el caso de tuberías de espesor pequeño puede provocar deformación permanente.

Se debe seleccionar cuidadosamente la aleación del material de aporte, es importante que no contenga fósforo y/o metales ferrosos como el acero ya que estos componentes fragilizan la unión y puede fallar en corto plazo.

Un aspecto importante es el tiempo y forma de enfriamiento de la soldadura porque podría fracturarse. Nunca debe enfriarse con agua.

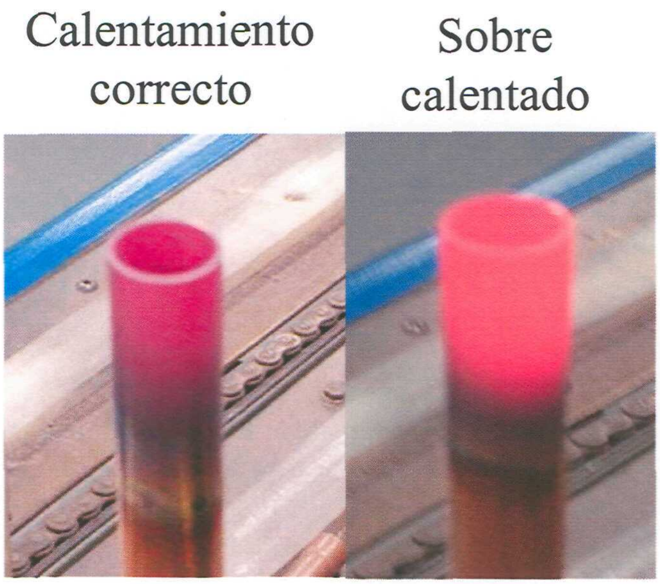


Fig. 2.14 Imagen de un tubo de cobre calentado adecuadamente y un tubo sobre calentado.

Las uniones de cobre con cobre no deben enfriarse con agua mientras se encuentre al rojo vivo, en caso de tener múltiples uniones estas se deben enfriar en el mismo orden en el que se soldaron [Carrier, Mayo 1995].

2.10 Costo de la soldadura

En un reporte publicado por la American Welding Society (AWS) y el Edison Welding Institute (EWI) se demostró que las compañías que utilizan procesos de soldadura nunca han evaluado el costo de sus procesos, la mayoría de los manufactureros no comprenden cuanto gastan y en que lo gastan.

Existen varias razones para conocer los factores que afectan los costos de los procesos de soldadura, probablemente la principal es para establecer las políticas energéticas. Un modelo preciso de costo puede facilitar la comparación de opciones de manufactura, así como también permite hacer estimaciones de ahorros que pueden ayudar a justificar una posible automatización.

2.10.1 Factores de afectan los costos de soldadura

Cuando se considera la mayor cantidad de factores para calcular los costos se obtienen resultados más precisos. Por otra parte, considerar todos los factores relevantes incrementa las oportunidades para buscar una reducción de costos.

Una manera fácil de determinar si una actividad esta relacionada con el costo de la soldadura es a través de la pregunta: ¿Se incurriría en este costo si el producto no estuviera soldado?

Cuando la pregunta anterior es contestada objetivamente, entonces cualquiera de los siguientes factores puede ser considerado para ser parte del costo de soldadura:

→ Tiempo para preparar la unión.

→ Tiempo para preparar el material para ser soldado (retiro de aceites, limpieza abrasiva).

→ Tiempo para ensamble.

→ Tiempo para precalentar la unión.

→ Tiempo para tack up.

→ Tiempo para posicionar.

→ Tiempo para soldadura.

→ Tiempo para remover escoria.

→ Tiempo para remover salpicones.

→ Tiempo para inspección.

→ Tiempo para cargar electrodos.

→ Tiempo para mover el soldador de una localización a otra.

→ Tiempo para cambiar ajustes en las máquinas de soldadura.

→ Tiempo utilizado del personal para asuntos personales.

→ Tiempo para reparar o re-trabajar soldaduras defectuosas.

→ Costos asociados con cualquier tipo de liberación de esfuerzos.

→ Costo de los electrodos.

→ Costo de materiales que sirven de escudo.

→ Costo de la energía eléctrica.

→ Costo del gas o gases.

Definitivamente el tiempo es el principal costo en que se incurre en los procesos de soldadura, sin contar que la mayoría de las aplicaciones de soldadura requieren aleaciones especiales de alto costo, o bien, son operaciones altamente automatizadas. El tiempo de las operaciones de soldadura y el salario que debe ser pagado al personal con las habilidades requeridas deberán ser aspectos dominados en los costos de soldadura.

Probablemente exista un infinito número de opciones para hacer el cálculo de los costos relacionados a la soldadura, a continuación se muestran dos de ellos.

Los modelos complejos asistidos por computadora que buscan captar cada uno de los factores que contribuyen en el costo y los modelos simplificados. Ambos modelos tienen imprecisiones.

2.10.2 Modelos simples

En los modelos simples los costos de soldadura se estiman basándose en la mano de obra, el costo de la administración, el costo de los consumibles para la soldadura y el costo de las protecciones.

En la mayoría de los casos el costo de la energía eléctrica es insignificante y en consecuencia es ignorado. Existen varios costos que son atribuidos a la administración, por ejemplo: la planta, equipo, supervisión, indirectos, etc., los cuales representan un factor importante del costo por que en algunas ocasiones son superiores al costo de mano de obra directa, en factores de 2 hasta 4 veces. Asumir que la administración y la mano de obra directa (L&O) tienen el mismo factor de costo ayuda a simplificar el modelo.

La ecuación básica para estimar costo proviene de:

Costo de soladura = (L&O) + costo de consumibles

Revisando el listado de factores de costo se puede observar que varios de los tiempos no son requeridos para realizar el proceso de soldadura. Cualquier tiempo que el soldador aplique a otra actividad es tiempo que no avanza en aplicar soldadura, el total de horas trabajadas siempre serán más que el total de horas de aplicación de soldadura, la relación de horas de aplicación de soldadura entre el total de horas trabajadas se conoce como *el factor de operación.*

Los costos de soldadura pueden ser estimados utilizando una de las tres aproximaciones básicas:

→ Costo por unidad.

→ Costo por longitud.

→ Costo por peso.

La aplicación y selección de cada uno dependerá de la aproximación que sea más apropiada.

Un punto importante y que debe ser resaltado para el uso de cualquiera de los tres métodos de estimación de costo es la criticidad del uso de las variables y su correcto dimensionamiento en las ecuaciones.

2.10.3 Costo por unidad

El método de costo por unidad es probablemente el método más efectivo cuando la aplicación de soldadura involucra piezas que se mueven a través de estaciones de trabajo. Los tipos y tamaño de la soldadura no son relevantes en este método, no importa si es soldadura con material de aporte, soldadura eléctrica o soldadura con arco. Es posible que todas se combinen cuando se utiliza este método, siempre y cuando el tiempo (el factor más importante en el costo de la soldadura) se mida y aplique correctamente. Esta es una de las razones por las que se considera este método como el más preciso de los tres, debido a que este método mide directamente la variable de costo más importante y no es necesario utilizar factores en las variables.

El costo por unidad de producción puede expresarse en dólares por unidad y puede estimarse a través de las siguientes ecuaciones:

Costo / unidad = (L&O / unidad) + (material de aporte y protección / unidad)

L&O / unidad = (tiempo relacionado a la soldadura / unidad) x (factor L&O)

Para el caso de procesos que utilizan material de aporte, como el proceso de alimentación de cable, la ecuación siguiente puede ayudar a determinar el costo:

Costo de metal rellenado / unidad = (velocidad de alimentación de cable) x (tiempo de soldadura) x (peso del electrodo / unidad de longitud) x (costo del electrodo / unidad de peso)

2.10.4 Costo por longitud

Es el método más apropiado cuando se desea determinar el costo por longitud de soldadura aplicada. La forma ideal en la que se aplica este método es cuando la soldadura se aplica en una sola pasada y tiene un tamaño de cordón de soldadura preestablecido. Los costos que ofrece este método deben variar cuando existan diferencias en la especificación de dimensiones (excepto longitud) de los cordones de soldadura.

Para este método la variable del tiempo se contiene en la medición de la velocidad de avance. Aunque el ideal del método es utilizarlo en soldaduras aplicadas en solo una pasada también puede aplicarse en soldaduras de pasadas múltiples.

Las siguientes ecuaciones son utilizadas para estimar el costo por longitud:

Costo / longitud = (costo de L&O / longitud) + (costo de material de aporte y protección / longitud)

Costo L&O / longitud = (L&O factor) / (velocidad de aplicación) x (factor de operación)

Costo de metal rellanado / longitud = {(velocidad de aplicación de alambre) x (peso del electrodo / unidad de longitud) x (costo del electrodo / unidad de peso)} / (velocidad de aplicación)

Costo de material de relleno / longitud = (factor de fundición) x (peso del electrodo / longitud) x (costo del electrodo / unidad de peso) / (velocidad de aplicación) x (% de uso del electrodo)

Costo del gas para atmósfera / longitud = (factor de flujo de gas) x (costo del gas (unidad de volumen) / (velocidad de aplicación)

Costo de protección / longitud (flux) = (peso del metal soldado / longitud) x (factor de flux aplicado a la soldadura) x (costo del flux / unidad de peso)

2.10.5 Costo por peso

El costo por peso es probablemente el método más sencillo de costeo, tal vez por esta razón es el método menos recurrido. Su aplicación ideal ocurre cuando es mayor la importancia de los volúmenes de material de aporte que la cantidad de pasadas de aplicación.

El tiempo es considerado en la medición del factor de aplicación de material de aporte (unidad de material de aporte aplicado por unidad de tiempo). Este método es la mejor estimación de costo para la soldadura de multipasos.

El costo por peso es una buena variable para evaluar cambios en el crecimiento del material aplicado en la unión. No es un método preciso cuando se aplica soldadura de un solo paso, cordones pequeños y no contabiliza bien la sobre soldadura.

La manera de contabilizar el costo por peso es a través de las siguientes fórmulas:

Costo / unidad de peso = (Costo L&O / unidad de peso) + (Costo de material de aporte y protección / unidad de peso)

Costo L&O / unidad de peso = (Factor L&O) / {(factor de aporte) x (factor de operación)}

Costo de material de aporte / unidad de peso = (costo de material de aporte / unidad de peso) / (eficiencia del electrodo)

Teóricamente los tres métodos descritos deben ofrecer resultados similares, sin embargo, es probable que presenten variaciones. Por otra parte las variables que intervienen en cada metodología son diferentes. Por ejemplo: si el factor de operación es incorrecto, los cálculos en las metodologías de longitud y peso van a ser igualmente incorrectos, pero la metodología del costo por pieza no será afectada por este error [Miller, 2004].

2.11 CuproBraze

CuproBraze es un proceso relativamente nuevo para manufacturar intercambiadores de calor, especialmente radiadores de la industria automotriz. Es un desarrollo de la ICA (International Cupper Association) y fue implementado OCS (Outokumpu Copper Strip).

Este proceso ofrece avances significativos sobre otros procesos: bajo costo, eficiente, intercambiadores compactos, amigable con el medio ambiente y bajo costo de inversión. Este material y tecnología alternativa ofrece un 10% de ahorro en costo sobre los intercambiadores de aluminio convencional.

Los niveles de desperdicio del proceso de CuproBraze son bajos, es fácilmente re-soldable y requiere menos energía en el proceso de soldadura. El proceso de soldadura requiere una temperatura de 300 °C, la cual está por debajo del punto de fusión del material. Una característica adicional es que estos sistemas son mucho menos sensibles que el aluminio al calentamiento rápido y a los ciclos de enfriamiento.

El material de aporte es una aleación no tóxica con buenas características de adhesión y fluidez. Es una aleación de cobre, tin, niquel y fósforo con un contenido metálico entre 75 y 90% dependiendo de la posición y técnica de aplicación.

El nuevo horno desarrollado por Seco/Warwick resalta algunas otras ventajas de los procesos de CuproBraze. Es un diseño compacto de carga frontal y requiere un espacio en el piso de 8 x 7 m., sin embargo, tiene un espacio de carga de trabajo de 1.2 x 1.2 x 0.4 metros, a lo largo de una larga cámara de 1.5 x 1.5 x 0.6 metros. El calentamiento consiste en sistema de alta presión, alta velocidad de recirculación de aire en atmósfera controlada y requiere de 90 kW para generar un flujo óptimo de atmósfera de nitrógeno a través del cual se obtiene la temperatura uniforme requerida para una óptima soldadura.

El proceso completo es rápido. El purgado, calentamiento y ciclo de enfriamiento se puede alcanzar en 20 minutos para un radiador sencillo de 16 kg o en 30 minutos para un radiador doble de 32 kg [CuproBraze, 2005].

Durante el desarrollo del proceso de CuproBraze se buscó alcanzar los siguientes objetivos:

→ Un radiador resistente.

→ No utilizar flux.

→ Un horno de atmósfera controlada.

→ Soldadura en solo un proceso.

→ Proceso amigable con el ambiente.

→ Reciclable.

→ Un proceso flexible.

→ Eficiencia en costos.

Las aplicaciones donde puede ser usado el proceso son:

→ Radiadores y enfriadores de aire para camiones, vehículos todo terreno y automóviles de pasajeros.

→ Calefactores.

→ Enfriadores de aceite.

→ Condensadoras y evaporadoras.

2.12 Pegamento para aluminio

2.12.1 Caso Lotus

El aluminio es un material en el que la industria automotriz siempre ha estado interesada. Por ejemplo la armadora de autos Lotus en Inglaterra ha utilizado aluminio en sus chasises por muchos años, pero los componentes de ninguno de estos han sido unidos por medio de soldadura. Todas las uniones se han hecho a través de tornillos y adhesivos.

El primer vehículo de Lotus con este sistema fue "Elise" en 1996. Al inicio de este nuevo sistema, los líderes de Lotus estaban temerosos sobre la implementación, después de 23,000 vehículos producidos sin reporte de fallas las dudas quedaron disipadas.

La principal razón por la cual no se utilizó soldadura en la estructura es que el límite de cedencia del aluminio disminuye a menos de la mitad con el calor. Lotus decidió utilizar aluminio por su bajo peso, si utilizaran la opción de soldadura sería necesario utilizar el doble del material y se perdería la razón principal.

Otra desventaja de utilizar soldadura en aluminio es que la concentración de esfuerzos se localizará en un punto o a lo largo de una línea, lo cual puede crear fatiga en el material [Kermit, Abril 2004].

2.12.2 Caso Panoz Auto Development Co.

Danny Panoz, presidente de Panoz, en conjunto con un grupo de ingenieros, mecánicos y staff de soporte crearon el "Panoz Roadster", un vehículo retro. Es un Ford modular V8 con chasis de aluminio unido por adhesivos y cubierto de una aleación de magnesio. Los componentes del chasis son de aluminio extruido y no se utiliza soldadura para unirlos, solo adhesivos.

Los esfuerzos son mejor distribuidos a través del contacto entre los rieles y los nodos en las esquinas, esto rigidiza al chasis y minimiza la flexión.

Panoz seleccionó un methylmethacrylate base elaborado por Adhesive Engineering & Supply Inc. (seabrook, NH). Trabajando en conjunto con Panoz esta compañía desarrollo el "Extreme Adhesives 5375 HS", con relación 1 a 1 el adhesivo estrctural pasó todos los requerimientos de diseño para la certificación federal del vehículo: impacto, vibración y durabilidad.

El chasis se ensambla con la ayuda de una base de referencia muy precisa. Los componentes de aluminio son básicamente rieles extruidos y nodos para las esquinas, los cuales se ensamblan entre sí. Las partes son limpiadas y deben estar completamente secas para ensamblarse en la base de referencia.

Los adhesivos son inyectados en cada una de las uniones a través de una serie de pequeños agujeros en los rieles tubulares. Para mantener la alineación y eliminar los posibles movimientos durante el secado se coloca un tornillo en cada intersección de chasis.

Usando esta técnica de ensamble con adhesivos, Panoz alcanzó una rigidez torsional por encima de 7,400 libras por grado de torsión. El chasis unido por adhesivos ha superado la prueba de Ford de 150,000 millas de tortura sin cambio de rigidez por torsión o fallas en los adhesivos.

El adhesivo 5375HS se solidifica en una habitación de temperatura controlada durante 90 minutos, después de que el chasis básico es formado por los rieles una firewall y una base son ensambladas, soldadas y fijas en el perímetro del chasis. Esto crea una estructura rígida de la cual dependen los demás componentes del chasis. El ensamble del firewall incorpora todos los puntos de montura para el windshield, las bolsas de aire, sistemas de ventilación y calefacción, dashboard, asientos y los demás módulos del chasis.

Todos los puntos atornillados y remachados para la suspensión y ensamble frontal son cargados con el adhesivo también, esto elimina el movimiento entre las partes que se unieron. Finalmente el uso de adhesivos elimina la necesidad de cosmética por el uso de soldadura [Anónimo, 2005].

2.13 Dobladoras de tubo

Actualmente uno de los procesos en la elaboración de los intercambiadores de calor es el doblado de tubos (ver 2.1.2 y 2.1.3), el doblado que se realiza es un proceso simple.

Existe una gran cantidad de fabricantes que ofrecen equipo para el doblado de tubería. A continuación se mencionan algunos.

2.13.1 Dobladora Burr Oak

En 1993 Burr Oak Tool and Gauge Company Inc. lanzó al mercado su línea estándar de dobladoras universales de tubería, estas máquinas son construidas para satisfacer las necesidades del doblado de tubería en formas complicadas.

La dobladora de tubo universal fue diseñada para altos niveles de producción con calidad en el doblado de tubos. Cuenta con un sistema automático de carga y descarga de tubería, este sistema puede alcanzar niveles de producción de incluso 1,000 partes por hora.

Este equipo utiliza las últimas innovaciones en tecnología de control para ofrecer altos niveles de producción, partes de alta calidad y flexibilidad a través de una simple operación y bajo mantenimiento [Burr Oak Tool and Gauge Company, Inc, 2005].

Fig. 2.15 Dobladora universal de tubo marca Burr Oak.

3 ANÁLISIS DEL PROBLEMA

Como se explicó en el capítulo anterior, la importancia del conocimiento del costo real de los procesos de soldadura es fundamental para la administración de los recursos y para el costo real de los productos.

Determinar los costos de soldadura no es sencillo, la selección del método de costeo es fundamental para evitar caer en error.

Para los cálculos del costo de la soldadura en los equipos de aire acondicionado se utilizará el costo por unidad por ser el más exacto. Por otra parte, el cálculo se dividirá en dos partes, la primera es la soldadura automática, la cual se desarrolla solamente en el intercambiador de calor y la segunda es la soldadura manual, la cual se desarrolla en el intercambiador de calor en proporciones mínimas y en el ensamble del circuito de refrigeración (intercambiador, compresor, etc).

A pesar de que los costos de los procesos de soldadura son trasladados al costo de la unidad y en consecuencia al precio de venta, los problemas que provoca una soldadura mal hecha pueden repercutir hasta el cliente final como se explicó en el capítulo 1.

Los reclamos de garantías por soldaduras mal hechas es uno de los retos principales para la industria en general, mensualmente se detiene el embarque del 2% de la producción mensual por problemas de fugas en soldadura.

3.1 Cálculo de costo de soldadura automática

La soldadura automática se desarrolla únicamente en el intercambiador de calor y se realiza a través de una máquina automatizada. En el caso específico de este tipo de soldadura no es muy importante la cantidad de puntos de soldadura debido a que sin importar el tamaño del intercambiador el equipo realiza en tan solo un movimiento la soldadura de todo el intercambiador.

El único concepto que cambia es la cantidad de anillos de soldadura que se utilizan, sin embargo, el costo de estos anillos no es muy representativo por lo que se tomará como un costo estándar fijo.

A continuación se muestran los cálculos.

$$Costo\ indirecto = \frac{nómina\ de\ empleados}{No.\ de\ operadores} * operadores\ soldadores$$

$$Costo\ indirecto = \frac{\$20{,}500.00}{1{,}250} * 3$$

$$Costo\ indirecto = \$49.90$$

$$Factor\ L\&O = \frac{\text{costo de operación}}{hora} + \frac{\text{costo indirecto}}{hora}$$

$$Factor\ L\&O = \frac{\$76.50}{hora} + \frac{\$49.90}{hora}$$

$$Factor\ L\&O = \$126.40$$

$$\frac{L\&O}{unidad} = \frac{Tiempo\ ciclo\ de\ soldadura}{unidad} * Factor\ L\&O$$

$$\frac{L\&O}{unidad} = \frac{28\ seg}{unidad} * \frac{1\ hr}{60\ seg} * \$126.40$$

$$\frac{L\&O}{unidad} = \$59.00$$

$$\frac{Costo\ automática}{unidad} = \frac{L\&O}{unidad} + \frac{\text{costo materiales}}{unidad}$$

$$\frac{Costo\ automática}{unidad} = \$59.00 + \$25.00 + \$2.00$$

$$\frac{Costo\ automática}{unidad} = \$86.00$$

El costo de $86.00 incluye los siguientes conceptos:

→ Operación de equipo Brazer.

→ Sueldo de tres operadores con categoría de soldadores.

→ Costo de insumos y energéticos.

→ Costo de materiales como: anillos de soldadura.

→ Costos indirectos como: soporte de empleados y proporcional de supervisión.

→ El tiempo ciclo de 28 segundos es por cada intercambiador de calor, sin importar su tamaño (dentro de los modelos actuales).

La soldadura automática es uno de los procesos críticos, a pesar de estar asistida por un equipo automatizado es indispensable un seguimiento cercano, incluso uno de los tres operadores revisa a detalle cada una de las uniones y en caso de aparecer algún detalle que pudiese ocasionar una fuga es reparado por cualquiera de los tres.

3.2 Cálculo de costo de soldadura manual

La soldadura manual se desarrolla en el intercambiador de calor y en la unión de la tubería en el circuito con el resto de los componentes.

Como se mencionó en el capítulo anterior, la soldadura en posición vertical simplifica la labor, en el caso de la soldadura en posición horizontal se requiere desarrollar más técnica y pericia por parte del operador.

La soldadura horizontal tiene mayor probabilidad de error, lo cual se traduce en la presencia de fugas y/o de utilizar material en exceso (desperdicio).

A continuación se muestra el cálculo de la soldadura manual, se calculará el costo de solamente una soldadura.

$$Costo\ indirecto = \frac{nómina\ de\ empleados}{No.\ de\ operadores} * operadores\ soldadores$$

$$Costo\ indirecto = \frac{\$20{,}500.00}{1{,}250} * 2$$

$$Costo\ indirecto = \$32.80$$

$$Factor\ L\&O = \frac{costo\ de\ operación}{hora} + \frac{costo\ indirecto}{hora}$$

$$Factor\ L\&O = \frac{\$51.00}{hora} + \frac{\$32.80}{hora}$$

$$Factor\ L\&O = \$83.80$$

$$\frac{L\&O}{unidad} = \frac{Tiempo\ ciclo\ de\ soldadura}{unidad} * Factor\ L\&O$$

$$\frac{L\&O}{unidad} = \frac{8\ seg}{unidad} * \frac{1\ hr}{60\ seg} * \$83.80$$

$$\frac{L\&O}{unidad} = \$11.17$$

$$\frac{Costo\ manual}{unidad} = \frac{L\&O}{unidad} + \frac{costo\ materiales}{unidad}$$

$$\frac{Costo\ manual}{unidad} = \$11.17 + \$41.67 + 1$$

$$\frac{Costo\ manual}{unidad} = \$53.84$$

El costo de $53.84 incluye los siguientes conceptos:

→ Sueldo de dos operadores con categoría de soldadores.

→ Costo de insumos y energéticos.

→ Costo de materiales como: varillas de soldadura.

→ Costos indirectos como: soporte de empleados y proporcional de supervisión.

→ El tiempo ciclo de 8 segundos es por cada unión de circuito, sin importar su tamaño (dentro de los modelos actuales).

La soldadura manual es indispensable en el proceso para la unión del intercambiador de calor y la tubería, que en consecuencia se une con el compresor.

La diferencia sustancial entre la soldadura manual y la automática es la complejidad de la posición de los puntos a soldar, por lo cual pensar en una posible automatización resulta complejo y costoso.

3.3 Costo total por unidad

Para calcular el costo total de la soldadura por unidad será necesario determinar que tipo de unidad es la que se quiere costear, por ejemplo: una unidad de ventana requiere de 2 soldaduras automáticas (evaporador y condensador) y 10 soldaduras manuales, de las cuales, 6 se trabajan en el evaporador y condensador, 2 en el compresor y por último 2 para cerrar los puntos de carga de refrigerante.

Para este caso seleccionaremos una unidad condensadora, la cual requiere de 1 soldadura automática y 8 soldaduras manuales.

$$\frac{Costo}{unidad} = Costo\ manual + Costo\ automática$$

$$\frac{Costo}{unidad} = \$86.00 + \$53.84$$

$$\frac{Costo}{unidad} = \$139.84$$

El costo de cada unidad producida por soldadura es de $139.84 por una unidad tipo evaporador, en el caso de las unidades de ventana el costo de la soldadura se incrementará sustancialmente debido a que el ensamble requiere dos intercambiadores de calor.

El costo por soldadura de una unidad de ventana es de aproximadamente $279.68, es decir el doble, esto se debe a que ambos intercambiadores de calor deben ser soldados con soldadura automática y se requiere el doble de puntos de soldadura en la tubería para unir ambos intercambiadores. Caso contrario en las unidades evaporadoras.

3.4 Costo de garantías

Los costos de garantías y reclamos son probablemente los temas más complicados en las organizaciones, incluso en general es uno de los indicadores que más se cuida y revisa.

Para cualquier productor los gastos y costos que se generan cuando un cliente ejerce una garantía son muy elevados e incluso puede llegar a ser superiores a la ganancia que se obtuvo por la venta de ese artículo, sin mencionar el descontento y molestia del cliente por la falla del producto.

En la industria del aire acondicionado la satisfacción del cliente es un aspecto muy delicado. La razón principal de adquirir un equipo de aire acondicionado es para crear un ambiente y temperatura de confort en un área específica. Si el producto no cubre las expectativas del cliente por alguna falla en el equipo automáticamente el indicador de confort baja y de igual forma la satisfacción del cliente.

Los equipos de aire acondicionado son aparatos que son instalados en puntos estratégicos que normalmente son de difícil acceso, además tienen un peso considerable y en consecuencia su instalación y desinstalación es complicada. Por lo cual es difícil que un cliente pueda regresarlo al punto de venta para ejercer la garantía.

El procedimiento normal es a través de un reporte telefónico del cliente al centro de servicio, se procesa y se envía a técnicos calificados, quienes asisten al punto donde se instaló el equipo para revisar el funcionamiento y detectar la posible falla.

Basándose en la revisión de los técnicos se determina si procede el reclamo de la garantía. En caso de proceder el reclamo el técnico repone o repara los componentes dañados y a través de una nota de servicio reportan las refacciones y tiempo del técnico invertido en el servicio.

Todo el proceso anteriormente descrito es muy costoso, las refacciones y horas de trabajo de un técnico especializado en refrigeración son recursos que se están invirtiendo por la baja calidad en los productos.

La figura 3.1 presenta un gráfico que muestra en miles de dólares los gastos por garantías en cada una de las familias de productos, así como el total de estos durante el año 2004.

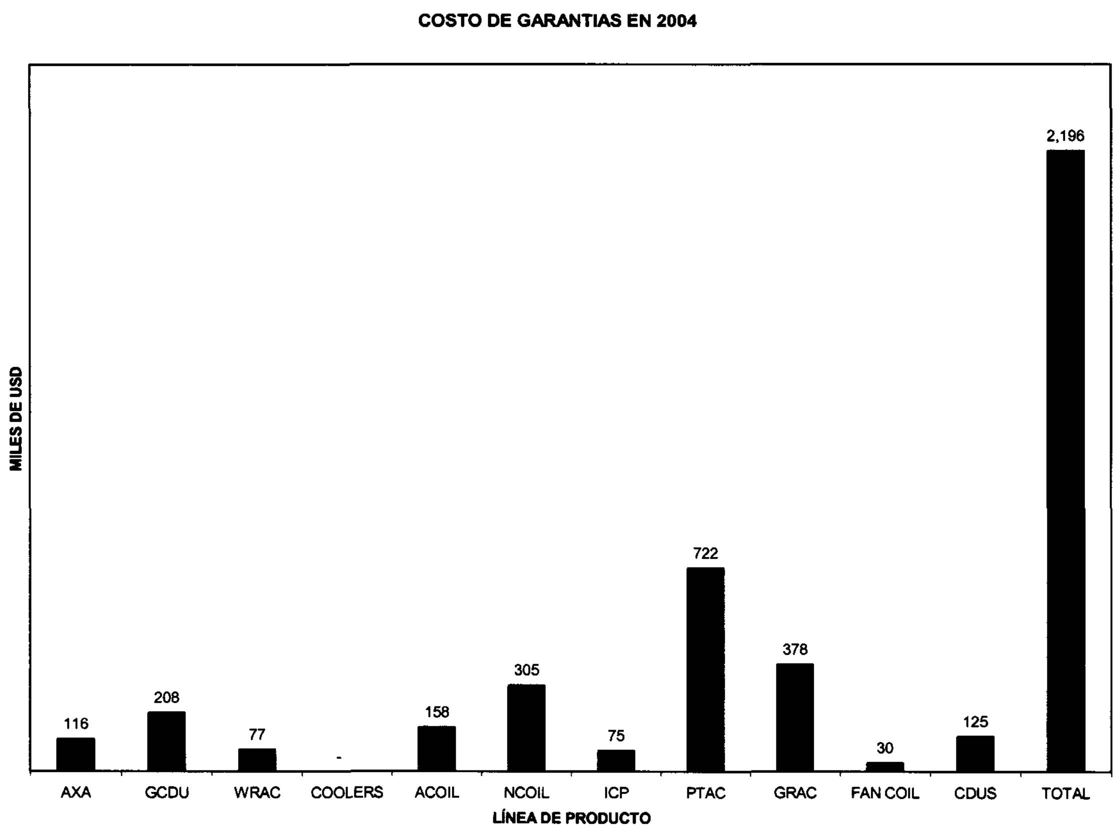


Fig. 3.1 Miles de dólares gastados por garantías.

Como se puede observar, en el 2004 los costos de garantías llegaron a los 2.2 millones de dólares, esta cifra impacta directamente a los rendimientos de la compañía y en consecuencia a la utilidad de se genera para los inversionistas.

Los costos de garantía anteriormente presentados se deben a fugas de refrigerante en el circuito de refrigeración. La causa principal de las fugas es sin duda la soldadura de baja calidad, son muy pocos los casos que ocurren por falla en el cuerpo de la tubería.

3.5 Problemas con soldadura

El uso de soldadura en los procesos de unión de tubería de cobre en los intercambiadores de calor y circuitos de refrigeración es el método actual y vigente. En general todas las unidades de aire acondicionado de cualquier fabricante utilizan este proceso productivo.

La soldadura por definición es un proceso que satisface ampliamente los requerimientos de resistencia y hermeticidad que se requiere en los equipos mencionados, sin embargo, en la práctica en las uniones que utilizan soldadura es posible que se cometan errores y la unión por soldadura quede defectuosa.

Independientemente de los problemas de bajo desempeño por la pérdida de refrigerante en las uniones no herméticas pueden causar otro tipo de problemas. Por la falta de hermeticidad (grieta o poro) y la presión de operación del equipo de aire acondicionado existe la posibilidad de una pequeña explosión en la que es probable sean lanzadas partes de la tubería y soldadura.

La exposición al ambiente del refrigerante R-22 contamina el medio, específicamente el refrigerante ataca la capa de ozono, lo cual a largo plazo tiene repercusiones trascendentes como la penetración de los rayos UV, el calentamiento global, etc.

El consumo energético en los procesos de soldadura es otro factor importante, el uso de una antorcha para lograr el calentamiento de las piezas y la fundición del material de aporte requiere de la combustión de gas natural y oxígeno, además del barrido con atmósfera inerte que se genera con nitrógeno.

3.6 Análisis de patentes

Los análisis de patentes son muy variados y pueden ser útiles para conocer diferentes aspectos de la inventiva en el ámbito mundial.

En este caso se desarrollará un análisis de patentes sobre intercambiadores de calor, que buscará cumplir los siguientes objetivos:

→ Búsqueda de las innovaciones más recientes.

→ Línea de pensamiento de inventiva.

→ Punto del ciclo de vida del producto en la que se encuentra.

→ Nivel de inventiva de los últimos 15 años.

→ Punto en el ciclo de rentabilidad.

El conocimiento de las innovaciones más recientes, apoya la búsqueda de soluciones a la problemática expuesta. Es probable que otra investigación a través de una patente solucione parcial o totalmente el problema.

Para ejemplificar la diversidad de patentes sobre intercambiadores de calor, la tabla 5 muestra patentes que refieren desde métodos de manufactura hasta nuevos diseños de intercambiadores de calor.

Tabla 5. Ejemplos de patentes de intercambiadores de calor .

No. PATENTE	FECHA	TITULO	DESCRIPCION
5,853,507	29-Dic-98	Method for manufacturing heat exchangers to allow uniform expansion of tubing	Método de tratamineto térmico del tubo de cobre para facilitar el proceso de expansión.
5,765,284	16-Jun-98	Method for constructing heat exchangers using fluidic expansion	Proceso de expansión mediante el uso de un fluido a presión dentro de la tubería de cobre que sobre pase el límite de cedencia del material.
6,551,421	22-Abr-03	Brazing foil performs and their use in the manufacture of heat exchangers	Metodología de ensamble de un intercambiador de calor.
6,546,774	15-Abr-03	Method of making a lanced and offset fin	Método para ensamblar aluminio y tubos en un intercambiador de calor.
6,488,080	**03-Dic-02**	**Refrigerator evaporator and method of manufacturing the same**	**Diseño de un intercambiador de calor y su proceso de manufactura a través de la inyección de plásticos.**
6,484,398	26-Nov-02	Heat exchanger tube manufacturing method	Método para manufacturar tubos para intercambiadores de calor.
6,451,453	17-Sep-02	Aluminum alloy strip or tube for the manufacture of brazed heat exchangers	Diseño de tubería de aleación de aluminio, su proceso de soldadura y de manufactura.
5,992,508	30-Nov-99	Thin plastic-film heat exchanger for absorption chillers	Proceso de recubrimiento con un film plástico a un intercambiador de calor para una unidad de absorción.
5,771,962	30-Jun-98	Manufacture of heat exchanger assembly by cab brazing	Manufactura de intercambiador de calor con aleación de aluminio y un flux especial.
6,660,198	09-Dic-03	Process for making a plastic counterflow heat exchanger	Proceso de fabricación de intercambiador de calor plástico que utiliza adhesivos para sellar uniones.
6,620,274	16-Sep-03	Method of repairing aluminum heat exchanger	Uso de adhesivo para reparar orificios en intercambiadores de calor de aluminio.
6,579,429	**17-Jun-03**	**Antifouling system for structure exposed to seawater and heat exchanger**	**Uso de adhesivo para unir componentes de intercambiadores de calor.**
6,527,906	04-Mar-03	Elastomer adhesive for condensing furnace heat exchanger laminate material	Aplicación de recubrimiento de silicon RTV para prevenir corrosión en un intercambiador de calor.
6,427,769	06-Ago-02	Heat exchanger having tube joined to core plate and method of manufacturing the same	Aplicación de recubrimiento en un intercambiador de calor para sellar uniones.
6,082,439	04-Jul-00	Heat exchanger assembled without brazing in which adhesive is used to seal a combined portion and a core plate	Aplicación de adhesivos para sellar uniones mecánicas en un intercambiador de calor.
4,196,923	**08-Abr-80**	**Adhesive bonding of aluminum coils**	**Unión de partes de aluminio en un intercambiador de calor con adhesivos.**

La línea de pensamiento que se sigue a través de las patentes permite conocer la estructura de las ideas y conceptos que se ponen en práctica para mejorar el producto y disminuir los efectos negativos.

Por otra parte, la posición del producto a lo largo de la curva del ciclo de vida nos ayuda a interpretar el grado de madurez, así como las acciones que pueden tomarse para desarrollarlo al máximo.

En la Fig. 3.2 se muestra la cantidad de patentes publicadas sobre intercambiadores de calor desde sus inicios en1900 a la fecha.

En el gráfico se puede observar que entre 1960 y 1975 se generaron la mayor cantidad de patentes sobre intercambiadores de calor. Para 1980 el número de invensiones bajo drásticamente, volviendo a repuntar en los 90´s y finalmente volver a descender.

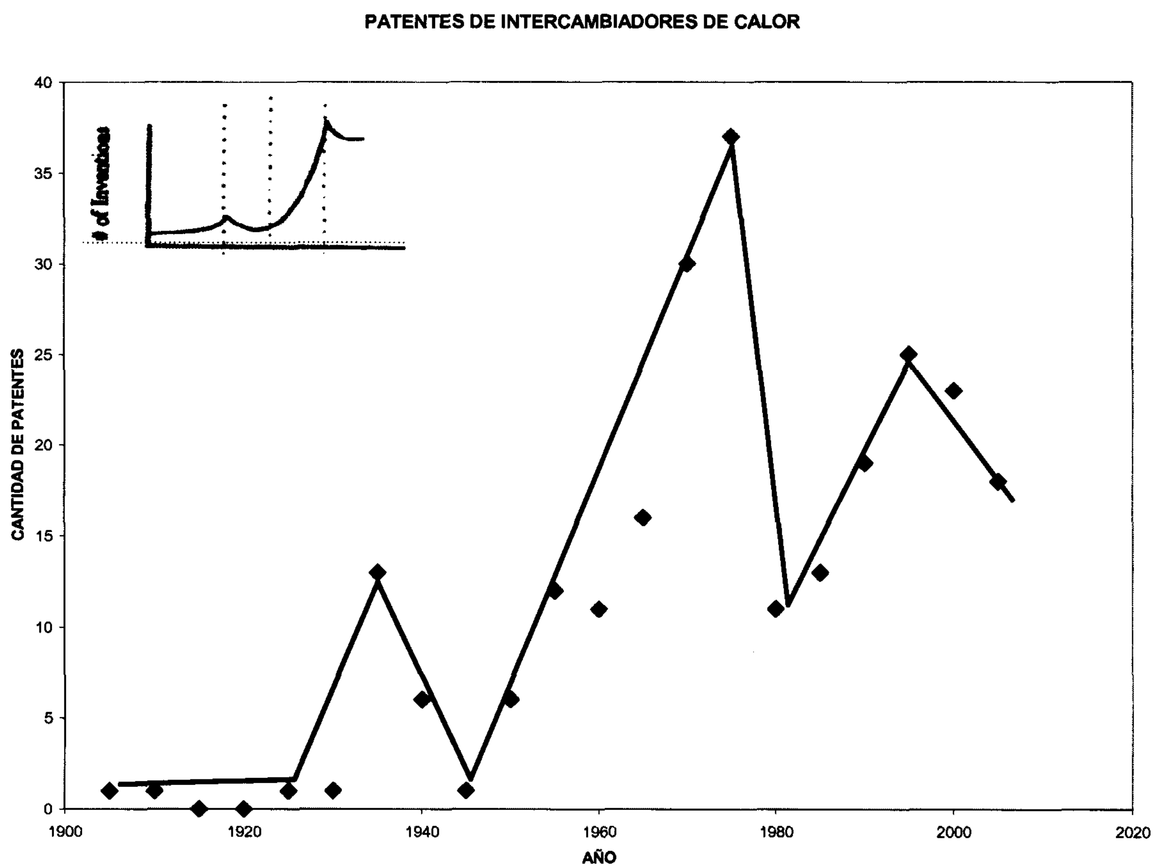


Fig. 3.2 Patentes sobre intercambiadores de calor.

Los beneficios económicos que puede redituar la creación de un nuevo producto o bien el rediseño del mismo es otro factor que debe ser medido. La rentabilidad de una patente es uno de los indicadores a través de cual es posible que los generadores de ideas pueden medir la trascendencia de sus desarrollos.

La medición de la rentabilidad es difícil, para este análisis se partió del siguiente supuesto:

"La rentabilidad de las patentes de intercambiadores de calor puede relacionarse con la cantidad de patentes que utiliza intercambiadores de calor, es decir, todo producto patentado que contenga un intercambiador de calor será contabilizado en la rentabilidad".

La razón por la cual se planteo el análisis de rentabilidad bajo este supuesto es que los intercambiadores de calor no son productos que son adquiridos por el consumidor final, es decir, son sub ensambles de otros productos que ofrecerán un servicio integral.

En el caso de la industria del aire acondicionado el intercambiador es una de las partes principales del producto y es indispensable para el funcionamiento, pero el producto que se ofrece es un equipo de aire acondicionado no un intercambiador de calor.

En el caso de la industria automotriz se utilizan intercambiadores de calor para el sistema de aire acondicionado y para el sistema de enfriamiento del motor. En ambos casos los intercambiadores de calor son indispensables, pero son solo una pequeña parte de un vehículo auto motor.

Los beneficios del rediseño o mejora de un sub ensamble o componente de un producto final se verán reflejados en la mejora de una a varias características, pero continua siendo difícil contabilizar el beneficio económico obtenido.

Por las razones expuestas es difícil contabilizar la rentabilidad económica que aporta una invención que solo es un componente de un producto final.

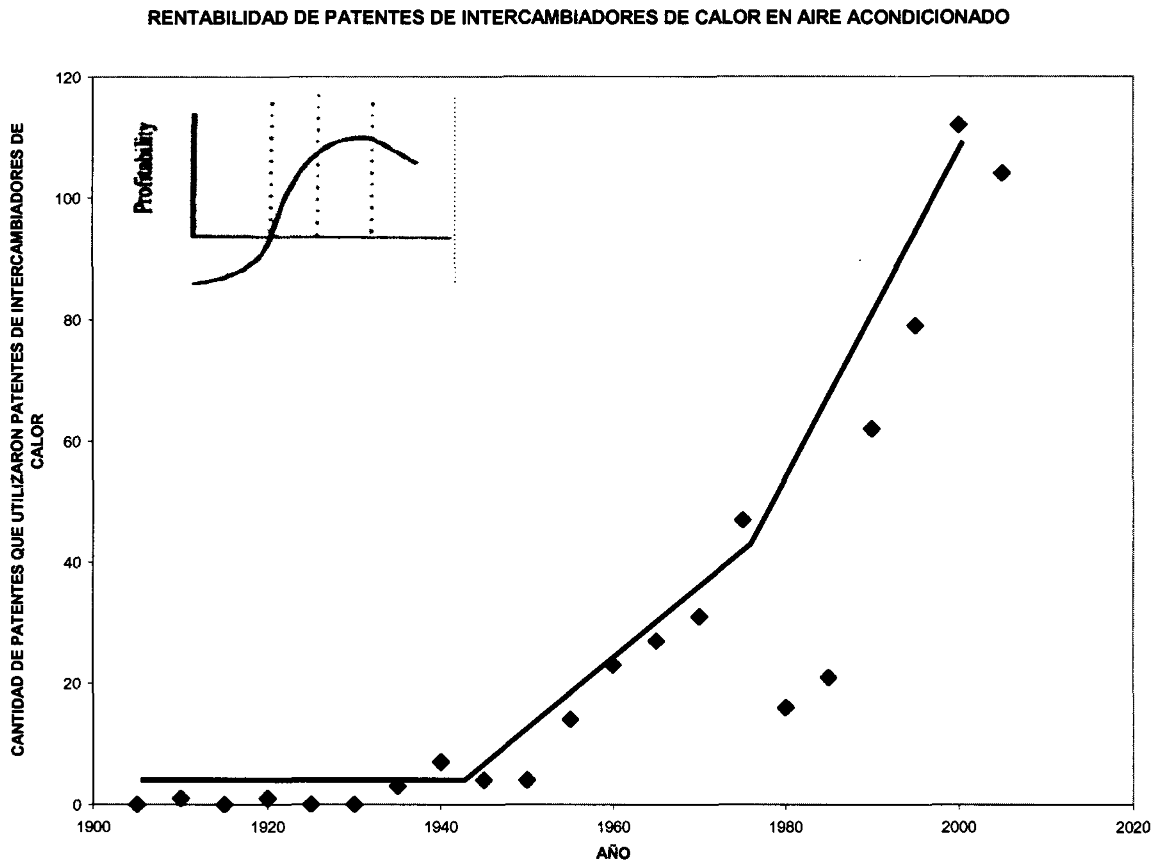


Fig. 3.3 Rentabilidad de patentes de intercambiadores de calor.

En la Fig. 3.3 se puede observar como en la década de los 80's la rentabilidad (utilización de las patentes) incremento una tendencia ascendente, a pesar que el último punto del gráfico se encuentra por debajo del anterior es difícil determinar si la curva continuará en ascenso o comenzará su descenso..

En caso que la curva inicie su descenso, es posible inferir que el descenso en el uso de patentes que utilizan intercambiadores de calor puede obedecer diferentes razones o circunstancias, como:

→ Pasó la etapa de madurez y comienza el descenso en sus rendimientos.

→ Agotamiento del proceso de mejora y se requiere un nuevo diseño.

→ En general la producción de intercambiadores de calor para equipos de aire acondicionado llegó a un nivel de conocimiento general, es decir, los fabricantes utilizan materiales y técnicas similares para su producción.

El nivel de inventiva que se emplea en el desarrollo de los productos es un parámetro muy importante, cada vez que un producto es innovado sustancialmente su curva de ciclo de vida reinicia y es de este modo que los productos permanecen en servicio.

En el gráfico 3.4 se ilustran los diferentes niveles de inventiva de las patentes a través del tiempo.

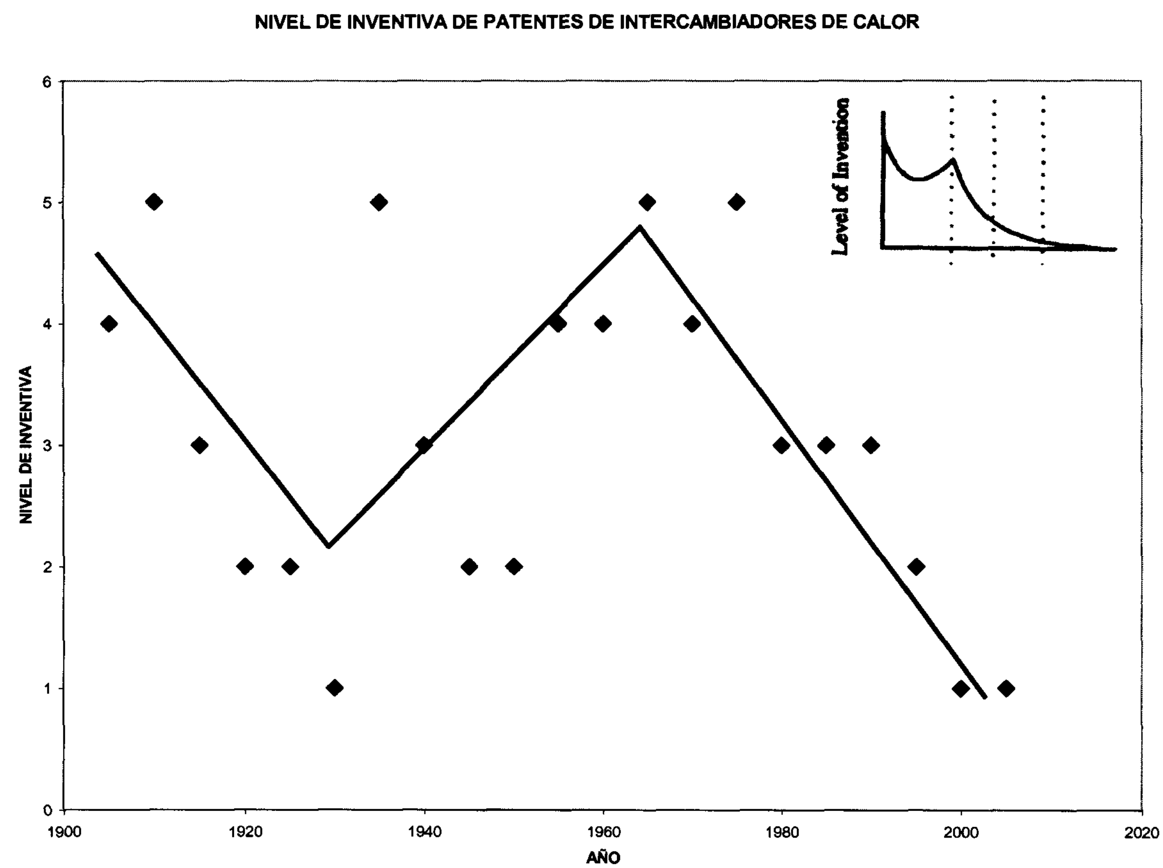


Fig. 3.4 Curva de inventiva en intercambiadores de calor.

El análisis de patentes de intercambiadores de calor se realizó bajo los siguientes límites y supuestos:

- Las patentes analizadas son de intercambiadores de calor con aplicación en la industria del aire acondicionado.
- Las patentes con nivel de innovación 4 y 5 se muestran en la tabla 6.

Tabla 6. Patentes de alto nivel de innovación en intercambiadores de calor.

No.	No. PATENTE	FECHA	TITULO	DESCRIPCIÓN
1	6,527,906	04-Mar-03	Elastomer adhesive for condensing furnace heat exchanger laminate material	Aplicación de una capa de silicón RTV en un intercambiador de calor para prevenir la corrosión, la capa de silicón incluye un adhesivo organico-silicón que reacciona con agua para adherirse.
2	5,582,024	10-Dic-96	Copper article with protective coating	Proceso para recubrimiento de intercambiadores de cobre en ambientes marinos.
3	6,488,080	03-Dic-02	Refrigerator evaporator and method of manufacturing the same	Diseño de un intercambiador de calor y su proceso de manufactura a través de la inyección de plásticos.
4	5,992,508	30-Nov-99	Thin plastic-film heat exchanger for absorption chillers	Proceso de recubrimiento con un film plástico a un intercambiador de calor para una unidad de absorción.
5	6,660,198	09-Dic-03	Process for making a plastic counterflow heat exchanger	Proceso de fabricación de intercambiador de calor plástico que utiliza adhesivos para sellar uniones.
6	6,620,274	16-Sep-03	Method of repairing aluminum heat exchanger	Uso de adhesivo para reparar orificios en intercambiadores de calor de aluminio.
7	6,579,429	17-Jun-03	Antifouling system for structure exposed to seawater and heat exchanger	Uso de adhesivo para unir componentes de intercambiadores de calor.
8	6,527,906	04-Mar-03	Elastomer adhesive for condensing furnace heat exchanger laminate material	Aplicación de recubrimiento de silicon RTV para prevenir corrosión en un intercambiador de calor.
9	6,427,769	06-Ago-02	Heat exchanger having tube joined to core plate and method of manufacturing the same	Aplicación de recubrimiento en un intercambiador de calor para sellar uniones.
10	6,082,439	04-Jul-00	Heat exchanger assembled without brazing in which adhesive is used to seal a combined portion and a core plate	Aplicación de adhesivos para sellar uniones mecánicas en un intercambiador de calor.
11	4,196,923	08-Abr-80	Adhesive bonding of aluminum coils	Unión de partes de aluminio en un intercambiador de calor con adhesivos.

Un análisis adicional a las patentes es hacer un rastreo de su uso, es decir, cuantas otras patentes las han utilizado como referencia.

Para las patentes 6527906, 6488080, 6660198, 6620274, 6579429, 6527906 y 6427769 no se encontraron patentes referenciadas a estas. Probablemente estos trabajos no han despertado interés de otro investigador por continuarlos.

La patente 5582024 que trata de un recubrimiento en intercambiadores de calor para evitar corrosión en ambientes marinos fue referenciada en las patentes de la Fig. 3.5.

1. ☐ JP9159326-A; US5806337-A; US5964103-A; ... 1997-375875
Absorption type refrigerator - has heat exchanger and high temperature regenerator, with their side surfaces being coated with oxide film
HITACHI LTD (HITA); MABUCHI K (MABU-Individual); MIDORIKAWA H (MIDO-Individual), et al.
ITO M, AIZAWA M, MABUCHI K, et al.

2. ☐ EP753709-A; EP753709-A2; JP9026280-A; ... 1997-079481
Heat exchanger for refrigeration circuit - uses refrigerant pipe with inner surface having grooves of different widths passing through plate fins
SANYO ELECTRIC CO LTD (SAOL); SANYO DENKI KK (SAOL)
ISHIKAWA A, KOBAYASHI M, AKUTSU M, et al.

Fig. 3.5 Patentes que hacen referencia a patente 5582024.

La patente 5992508 que trata un proceso de recubrimiento con un film plástico a un intercambiador de calor para una unidad de absorción fue referenciada en otras dos patentes, las cuales se muestran en la Fig. 3.6.

1. US2003029678-A1; US6810999-B2 2003-353688
Heat exchanger e.g. evaporator, condenser used in air-conditioner, includes thin coating of low surface energy material on inner surface of flow passages
OTTER J W (OTTE-Individual); CARRIER CORP (CARG)
OTTER J W

2. WO9949267-A; WO9949267-A1; AU9865170-A; ... 1999-572294
Cooling apparatus for cooling air
NAGAOKA M (NAGA-Individual); ARTHA CO LTD (ARTH-Non-standard); ALUTA KK (ALUT-Non-standard), et al.
NAGAOKA M, MORITOSHI N

Fig. 3.6 Patentes que hacen referencia a patente 5992508

La patente 6082439 que trata de la aplicación de adhesivos para sellar uniones mecánicas en un intercambiador de calor se utilizó como referencia en solo una patente. La patente se muestra en la Fig. 3.6.

1. US2002162648-A1; US6719037-B2 2003-209262
Heat exchanger manufacturing method involves applying uncured fluid sealant in openings in header, to fix portion of tubes into header
TRANSPRO INC (TRAN-Non-standard)
CROOK R F

Fig. 3.7 Patentes que hacen referencia a patente 6082439

La patente 2002162648 presenta un principio similar al de la patente 6082439, es decir, la utilización de una sustancia que trabaja como sellador sobre una superficie.

1. EP1178252-A; EP1178252-A2; DE10038153-A1; ... 2002-189731
Connector for corrugated metal pipes is manufactured without separate sleeve, and interconnecting ends of two pipes are fitted on smooth cylindrical section, with one end widened in relation to other
WITZENMANN GMBH (WITZ-Non-standard); WITZENMANN GMBH METALLSCHLAUCH-FAB PFORZ (WITZ-Non-standard)
RIETH R, MUELLER A, THUERINGER N, et al.

2. EP1077087-A; DE10014836-A1; EP1077087-A1; ... 2001-148028
Grinding roller for pulverising granular materials has hard metal bodies inserted in spaced indentations in outer surface of rolling jacket and has adhesive filling cavities between bodies and indentations
KHD HUMBOLDT WEDAG AG (KLOH)
RAMESOHL H

3. US6141870-A 2001-059750
Multilayer PCB formation involves forming metal layer on conductive coating of cavities in dielectric layer to produce tooth structure in dielectric coating and forming openings in dielectric coating to form circuit
TRZYNA P K (TRZY-Individual)
MCDERMOTT B J, SPOTTS R L, TRYZBIAK S, et al.

4. WO9747908-A; EP843794-A; WO9747908-A1; ... 1998-052429
Quick=fit pipe joint for fluid under pressure, esp in motor vehicle - has rubber or elastomer seal between outer sleeve and inner pipe
HUTCHINSON (HUTC); HUTCHINSON SA (HUTC); HUTCHINSON CO (HUTC)
GODEAU D, EXANDIER P

5. EP619351-A; EP619351-A1; CH685346-A5; ... 1994-311793
Bonding metal parts using heat-curable adhesive - involves IR irradiating roughened exterior metal surface
ALUSUISSE-LONZA SERVICES AG (SWAL); ALUSUISSE-LONZA SERVICES LTD (SWAL); ALUSUISSE TECHNOLOGY & MANAGEMENT AG (SWAL)
TIMM J, FURRER P

Fig. 3.8 Patentes que hacen referencia a patente 4196923

Una de las patentes que más apoya a este trabajo es la patente 4196923 que trata la unión de partes de aluminio en un intercambiador de calor con adhesivos. La Fig. 3.8 muestra las patentes que la utilizaron como referencia.

A pesar que la patente 4196923 fue publicada en 1980 son pocas las patentes que posteriormente hacen referencia a este trabajo (solo 4). Una posible explicación es que en su tiempo de publicación tecnológicamente hablando no era rentable o de difícil producción en serie.

Las patentes de la Fig. 3.8 en su mayoría pueden ser utilizadas como referencia para este trabajo. En el anexo 1 se incluyen copia de las patentes.

3.7 Análisis con TRIZ

TRIZ es una herramienta básica en los procesos de inventiva y mejora de productos, su uso facilita al investigador el proceso de generación de ideas y resolución de contradicciones.

Hoy en día es posible utilizar TRIZ por medio de la asistencia de algún software comercial, para el análisis presentado en este trabajo se utilizó IWB.

Los elementos que intervienen en el modelo planteado son:

→ Tubería de cobre.- la tubería de cobre es la parte interior del intercambiador de calor, que en este caso por tratarse de un intercambiador de aire acondicionado la tubería de cobre se encarga de transportar el refrigerante. La tubería de cobre incluye los accesorios que se utilizan para cerrar el circuito.

→ Aletas de aluminio.- las aletas de aluminio son los difusores de donde se inserta la tubería de cobre.

→ Proceso de expansión.- posterior a la unión de tubería de cobre y aletas de aluminio se lleva a cabo este proceso y se forma un solo elemento.

→ Soldadura.- la soldadura es el proceso necesario para cerrar el serpentín interior del intercambiador formado por tubería de cobre.

→ Fuga.- fuga es el resultado negativo de soldadura y proceso de expansión. Si el proceso de expansión no se realiza correctamente es posible que dañe tubería de cobre y si la soldadura no se realiza correctamente quedan poros en las uniones provocando la fuga.

→ Perdida de refrigerante.- es el resultado igualmente negativo de fuga. La pérdida de refrigerante generará un resultado negativo en intercambio de calor, es decir, a menor cantidad de refrigerante baja el nivel de eficiencia de intercambio de calor.

→ Intercambio de calor.- es el resultado buscado, entre mayor eficiencia es mejor.

La Fig. 3.5 muestra el modelo los elementos anteriormente descritos en el modelo de TRIZ.

A través del modelo el software recibe información de la problemática y en consecuencia puede comenzar a generar preguntas de contradicciones que ayudan al investigador en el proceso creativo.

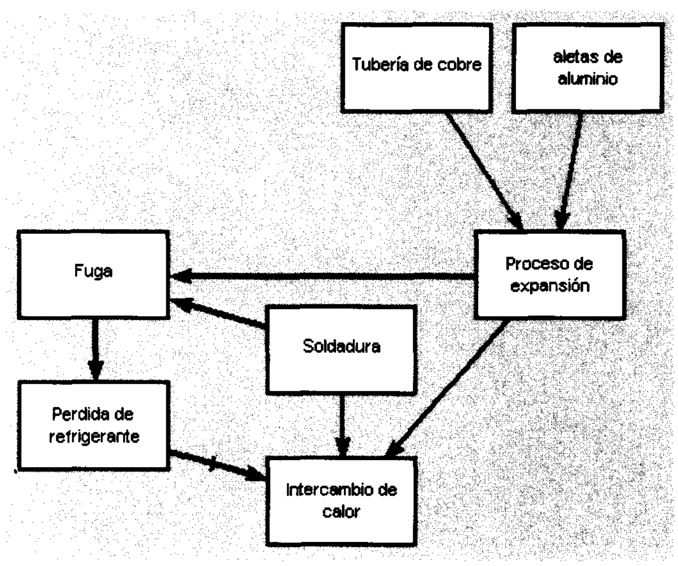


Fig. 3.9 Modelo en TRIZ.

Las preguntas que se generaron para este modelo específico son:

1. *Find an alternative way to obtain [the] (Intercambio de calor), that does not require [the] (Soldadura) and (Proceso de expansión), under condition of [the] (Perdida de refrigerante).*
2. *Find a way to enhance [the] (Intercambio de calor).*
3. *Find a way to protect [the] (Intercambio de calor) from the harmful influence of [the] (Perdida de refrigerante).*
4. *Find an alternative way to obtain [the] (aletas de aluminio), that provides or enhances [the] (Proceso de expansión).*
5. *Find a way to enhance [the] (aletas de aluminio).*
6. *Find a way to do without [the] (aletas de aluminio) for obtaining [the] (Proceso de expansión).*
7. *Find an alternative way to obtain [the] (Tubería de cobre), that provides or enhances [the] (Proceso de expansión).*
8. *Find a way to enhance [the] (Tubería de cobre).*
9. *Find a way to do without [the] (Tubería de cobre) for obtaining [the] (Proceso de expansión).*
10. *Find an alternative way to obtain [the] (Proceso de expansión), that provides or enhances [the] (Intercambio de calor), but does not cause [the] (Fuga), and does not require [the] (Tubería de cobre) and (aletas de aluminio).*
11. *Find a way to enhance [the] (Proceso de expansión).*
12. *Find a way to resolve the contradiction: [the] (Proceso de expansión) should exist to obtain [the] (Intercambio de calor), and should not exist in order to avoid [the] (Fuga).*
13. *Find a way to do without [the] (Proceso de expansión) for obtaining [the] (Intercambio de calor).*
14. *Find an alternative way to obtain [the] (Soldadura), that provides or enhances [the] (Intercambio de calor), and does not cause [the] (Fuga).*

15. Find a way to enhance [the] (Soldadura).

16. Find a way to resolve the contradiction: [the] (Soldadura) should exist to obtain [the] (Intercambio de calor), and should not exist in order to avoid [the] (Fuga).

17. Find a way to do without [the] (Soldadura) for obtaining [the] (Intercambio de calor).

18. Find a way to eliminate, reduce or prevent [the] (Fuga), under the condition of [the] (Proceso de expansión) and (Soldadura).

19. Find a way to eliminate, reduce or prevent [the] (Perdida de refrigerante), under the condition of [the] (Fuga).

Para este modelo el resultado son 19 preguntas, la cantidad de preguntas varía dependiendo de cada modelo con las variables lazos y elementos. Entre más lazos y elementos se tengan se generarán más preguntas.

Las preguntas en color azul (3 y 18) son preguntas que han sido resueltas a través de la adquisición de equipo de detección de fugas.

Las preguntas en color rojo (1, 10, 13, 16 y 17) son las preguntas seleccionadas que generan ideas de posible solución.

Las preguntas de contradicciones ayudan de alguna manera a despertar la creatividad del investigador, así como a buscar caminos diferentes probablemente no explorados. Las preguntas ayudan a la generación de direcciones de inventiva, los cuales se basan en los principios de inventiva.

Los principios de inventiva aplicables son:

→ Cushion.- crear un respaldo del sistema principal para que en caso de falla éste entre en sustitución. Ejemplo: paracaídas de reserva.

→ Homogeneous.- objetos que interactuan entre sí, deben hacerse del mismo material o de propiedades similares. Ejemplo: fabrica un contenedor del mismo material que va a contener para evitar reacciones químicas.

→ Mechanics Substitution.- reemplazar una fuerza, mecanismo o elemento bajo otro principio diferente de funcionamiento pero que ofrezca un resultado esperado. Ejemplo: cambiar una barrera física para un perro por una barrera acústica.

Los tres principios de inventiva anteriormente descritos pueden ser utilizados como base en la generación de ideas de inventiva que ayuden a solucionar el problema planteado.

En general el proceso de TRIZ es una herramienta que ayuda a la comprensión completa del problema y una manera simple de desmembrarlo para que se facilite el proceso de generación de ideas.

En el capítulo siguiente serán discutidas las propuestas de solución resultantes del presente análisis.

4 RESULTADOS Y PROPUESTAS

En general cada proceso de fabricación tiene métodos alternativos. Los productos de características similares se fabrican bajo uno de estos métodos, normalmente aquel que sea más eficiente.

Cada proceso de fabricación presenta ventajas sobre los demás y siempre se buscará optimizar alguna metodología que a la larga se convierta en mejores prácticas para el resto de la industria.

A pesar de alcanzar las mejores prácticas de un proceso de producción es importante no perder la brújula y continuar la búsqueda de procesos alternativos. La búsqueda de procesos alternativos puede basarse a partir del conocimiento propio o a través de la integración de desarrollos alcanzados para otros productos o industrias.

Hoy en día, el mundo está integrado a través de los medios electrónicos de comunicación y no resulta difícil conocer los trabajos de investigación que se realicen en cualquier parte del mundo.

4.1 Resultados del análisis de patentes

Los resultados del análisis de patentes se concentran en los tres gráficos presentados, cada uno nos ofrece información sobre el estado actual y posible futuro de los intercambiadores de calor.

La Fig. 3.2 muestra la dispersión de la cantidad de patentes por año que se generaron por intercambiadores de calor para sistemas de aire acondicionado, la línea curva sobrepuesta en el gráfico muestra una interpretación de la tendencia de los datos.

La cantidad de invensiones de cualquier producto obedece patrones preestablecidos, dicho patrón puede observarse en la parte inferior izquierda de la Fig. 3.2, es importante aclarar que el patrón de referencia representa el ciclo completo, es decir, desde su primera invención hasta el fin del producto.

La curva obtenida puede ser empatada con la curva patrón mostrada, lo que significaría la madurez de los intercambiadores de calor como producto.

En la Fig. 3.3 es posible observar un crecimiento en la década de los 80's en la utilización de intercambiadores de calor en patentes al final del gráfico se observa un punto por debajo, ¿será el inicio del descenso?.

Comparando el patrón de comportamiento, es posible inferir la posibilidad que la curva obtenida empata con la curva patrón.

En la curva mostrada en la Fig. 3.4 despliega los niveles de inventiva en los intercambiadores de calor, tratando de comparar la curva obtenida con el patrón de referencia.

Algunas otras referencias que pueden ayudar en la obtención de conclusiones son que hoy en día la mayoría de los productores de aire acondicionado hacen, producen o utilizan intercambiadores de calor similares, es decir, mismos materiales y mismos procesos de fabricación.

Por los datos presentados es posible inferir como conclusión general del análisis de patentes que el intercambiador de calor como producto en las unidades de aire acondicionado tiene un grado de madurez avanzado y resulta necesario que se presenten propuestas de innovación que permitan colocar el producto en nuevas curvas de vida de producto.

Con respecto a la revisión de referenciación de patentes es posible concluir que las ideas respecto a la utilización de adhesivos, recubrimientos y nuevas metodologías de fabricación de intercambiadores de calor no han sido exploradas, son muy pocas la patentes que hacen referencia a estos trabajos.

En comparativa a las patentes que utilizan brazing en intercambiadores de calor, la patente 5605191 trata del método de ensamble y brazing de un intercambiador de calor.

En la Fig. 4.1 muestra las patentes relacionadas con la patente 5605191.

1. ☐ US2004003918-A1; US6675883-B1; EP1380806-A2; ... 2004-061733
Multi-piece fabricated long manifold for heat exchanger, has tabs formed to either of tank or header piece, to engage openings at terminal ends of corresponding embossed beads formed to either of tank or header piece
KEUSTER R M D (KEUS-Individual); MODINE MFG CO (MODI); PANDIT N (PAND-Individual), et al.
KEUSTER R M D, PANDIT N, LIGHTNER D S, et al.

2. ☐ EP1371926-A; EP1371926-A1; DE10226753-A1 2004-055277
Heat exchanger for a vehicle comprises plate-like flow channel elements having flow channels running parallel to each other and partially parallel to the longitudinal axis of the flow channel element, and a liquid vessel
BEHR GMBH & CO (BHRT)
HEUSS H, LOESCH B, ZEEB J

3. ☐ US2002162648-A1; US6719037-B2 2003-209262
Heat exchanger manufacturing method involves applying uncured fluid sealant in openings in header, to fix portion of tubes into header
TRANSPRO INC (TRAN-Non-standard)
CROOK R F

4. ☐ WO200150080-A; EP1192402-A; FR2803378-A1; ... 2001-459138
Automobile heat exchanger comprises tube bundle between two fluid boxes through manifolds, each tube comprises several channels separated by longitudinal partition
VALEO CLIMATISATION SA (VALO); VALEO CLIMATISATION (VALO); MOREAU S (MORE-Individual)
MOREAU S

5. ☐ WO200053358-A; WO200053358-A1; AU200033650-A; ... 2000-611415
Heat exchanger for motor vehicles, e.g. radiators for engine coolant, utilizes resilient, polymeric grommets in the tube-to-header joints
TRANSPRO INC (TRAN-Non-standard)
LAMBERT M, JUGER J S

6. ☐ EP964218-A; EP964218-A2; DE19825561-A1; ... 2000-025915
Heat exchanger assembly for use in a vehicle
VALEO KLIMATECHNIK GMBH (VALO); VALEO KLIMATECHNIK GMBH & CO KG (VALO); VALEO AIR CONDITIONING TECH AG (VALO)
HAUSSMANN R

7. ☐ DE19819247-A1; BR9901334-A; US6302196-B1; ... 2000-000364
Vehicle heat exchanger and especially water/air heat exchanger or evaporator
VALEO KLIMATECHNIK GMBH & CO KG (VALO); VALEO AIR CONDITIONING TECH AG (VALO)
HAUSSMANN R

8. ☐ FR2771483-A; DE19752139-A1; FR2771483-A1; ... 1999-371895
Heat-exchanger block for road vehicle
BEHR GMBH & CO (BHRT)
DEMUTH W, HAFENBRAK P, KOHL M, et al.

9. ☐ EP930477-A; US5875837-A; EP930477-A2; ... 1999-189278
Liquid cooled two phase heat exchanger for use with air conditioning systems of vehicles
MODINE MFG CO (MODI)
HUGHES G G

10. ☐ WO9850749-A; DE19719259-A; EP929784-A; ... 1998-595985
Flat tube radiator for motor vehicle - has manifold box divided by a partition wall and contacts or passes through a slot in the tube plate, in turn having drawn collars
VALEO KLIMATECHNIK GMBH & CO KG (VALO)
HAUSSMANN R

Fig. 4.1 Patentes relacionadas

En el Anexo 1 se muestran las patentes de mayor inventiva.

4.2 Resultados de análisis con TRIZ

TRIZ ofrece soluciones completas de inventiva que va desde el planteamiento del problema hasta sugerencias de solución a través de los principios de inventiva.

Para el análisis presentado en el capítulo se propone el uso de tres de los cuarenta principios de inventiva.

4.2.1 Cushion

"Crear un respaldo que sustituya el sistema principal en caso de falla".

Básicamente el principio sugiere la utilización de una segunda opción en caso de falla o ausencia del principal.

En el caso de las fugas en los intercambiadores de calor se propone que en los puntos donde se aplica soldadura se utilice un respaldo, el cual intervenga en lugar de la soldadura en caso de fuga.

Las propuestas son:

→ Utilizar como respaldo de la soldadura un adhesivo industrial, que funcione como un segundo sellador. Hoy en día existen patentes sobre adhesivos que se utilizan para sellado de uniones en intercambiadores de calor, como las siguientes:

No. PATENTE	FECHA	TIPO	TITULO	DESCRIPCION
6,660,198	09-Dic-03	Proceso	Process for making a plastic counterflow heat exchanger	Proceso de fabricación de intercambiador de calor plástico que utiliza adhesivos para sellar uniones.
6,620,274	16-Sep-03	Proceso	Method of repairing aluminum heat exchanger	Uso de adhesivo para reparar orificios en intercambiadores de calor de aluminio.
6,082,439	04-Jul-00	Proceso	Heat exchanger assembled without brazing in which adhesive is used to seal a combined portion and a core plate	Aplicación de adhesivos para sellar uniones mecánicas en un intercambiador de calor.

La propuesta consiste en la utilización de un adhesivo marca Loctite 680, el cual fue diseñado para unir metales.

Colocar el adhesivo después de haber realizado el proceso de brazing, este trabajaría como respaldo de la soldadura en caso de encontrarse débil o con algún defecto que pudiera surgir en el futuro inmediato.

Otra posibilidad es utilizarlo solo en aquellas soldaduras que sean reparadas o que se detecten con posibilidad de fuga. Incluso utilizar el adhesivo en la reparación de fugas por garantías.

En el Anexo 2 se puede observar las características del adhesivo Loctite 680.

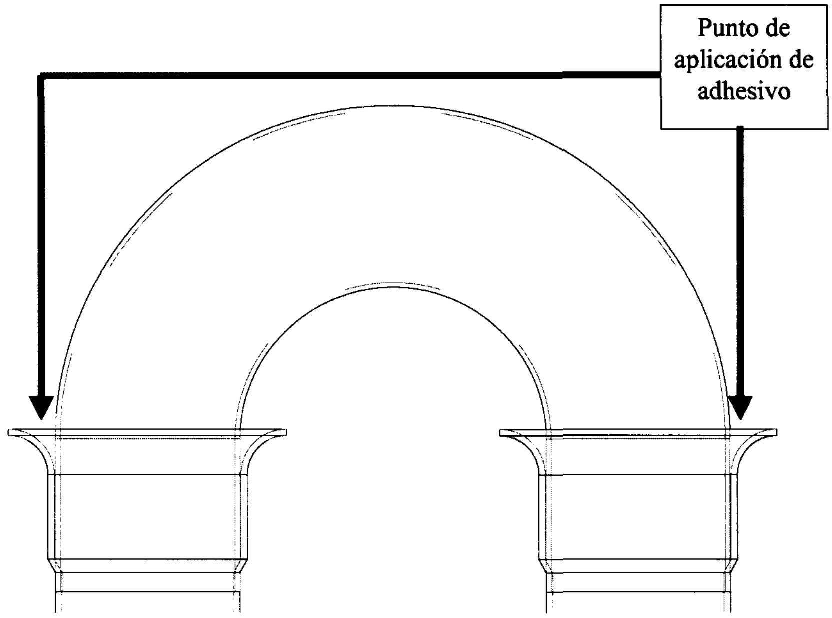


Fig. 4.2 Aplicación de adhesivo como respaldo en la unión de tubería de cobre.

→ Utilizar un recubrimiento sobre la superficie del intercambiador de calor que respalde las uniones soldadas. Algunas patentes que ya proponen esta solución se muestran a continuación:

No. PATENTE	FECHA	TIPO	TITULO	DESCRIPCION
6,527,906	04-Mar-03	Proceso	Elastomer adhesive for condensing furnace heat exchanger laminate material	Aplicación de recubrimiento de silicon RTV para prevenir corrosión en un intercambiador de calor.
6,427,769	06-Ago-02	Proceso	Heat exchanger having tube joined to core plate and method of manufacturing the same	Aplicación de recubrimiento en un intercambiador de calor para sellar uniones.

Otros beneficios que se puede obtener de este concepto es que el recubrimiento puede ayudar a evitar la corrosión sobre los elementos del intercambiador de calor.

4.2.2 Mechanics Substitution

"Reemplazo de una fuerza, mecanismo o elemento, bajo otro principio diferente de funcionamiento pero ofrezca un resultado esperado"

→ Uso de adhesivo en lugar de soldadura.

Hoy en día el uso de los adhesivos es más frecuente para todo tipo de aplicaciones en las cuales el adhesivo se somete a pruebas difíciles y este las supera con éxito. Sin embargo, no existen a la fecha adhesivos probados que ofrezcan la resistencia suficiente para soportar las condiciones mecánicas y térmicas a las que se someten las uniones soldadas.

4.2.3 Homogeneous

"Objetos que interactuan entre si, hacerlo del mismo material o de propiedades similares"

El principio de inventiva sugiere que se evite la problemática de compatibilidad de materiales, así como las uniones entre materiales.

Las propuestas son:

→ Intercambiador de calor del mismo material.

Esta propuesta involucra fabricar un intercambiador de calor de un solo material a través de un proceso de inyección de plásticos. La propuesta parte de la siguiente patente:

No. PATENTE	FECHA	TIPO	TITULO	DESCRIPCION
6,488,080	03-Dic-02	Proceso	Refrigerator evaporator and method of manufacturing the same	Diseño de un intercambiador de calor y su proceso de manufactura a través de la inyección de plásticos.

→ Intercambiador de calor del mismo material y en un solo proceso.

El proceso CuproBraze (descrito en el capítulo III) es el ejemplo perfecto de esta propuesta.

Todos los componentes del intercambiador de calor se fabrican del mismo material, es ensamblado bajo un proceso muy similar al descrito en el capítulo II pero con la variante de que la unión de los componentes se hace mediante un proceso de horneado en el cual los componentes se llevan a temperatura de fundición para que suelden entre sí. Actualmente se fabrican intercambiadores de calor para la industria automotriz en cobre mediante este proceso.

→ Serpentín interior (tubería) del intercambiador de calor de una sola pieza.

La propuesta de fabricar el serpentín interior de una sola pieza es muy simple y se enfoca principalmente al método de fabricación y manufactura.

La nueva propuesta, como se mencionó anteriormente, busca disminuir la cantidad de uniones soldadas y de simplificar el proceso de fabricación.

Los pasos de fabricación del método propuesto son:

→ Fin press.- fabricación de aletas de aluminio con modificaciones respecto a las actuales.

→ Hairpin.- la tubería de cobre no se doblará en un solo paso, a través de una dobladora de tubo universal (ver sub tema 4.4 Dobladoras de tubo) se pretende doblar de una sola pieza el circuito completo de tubería de cobre. En la siguiente figura se muestra un circuito de tubería de cobre hecha de una sola pieza, la cual no requiere puntos de soldadura.

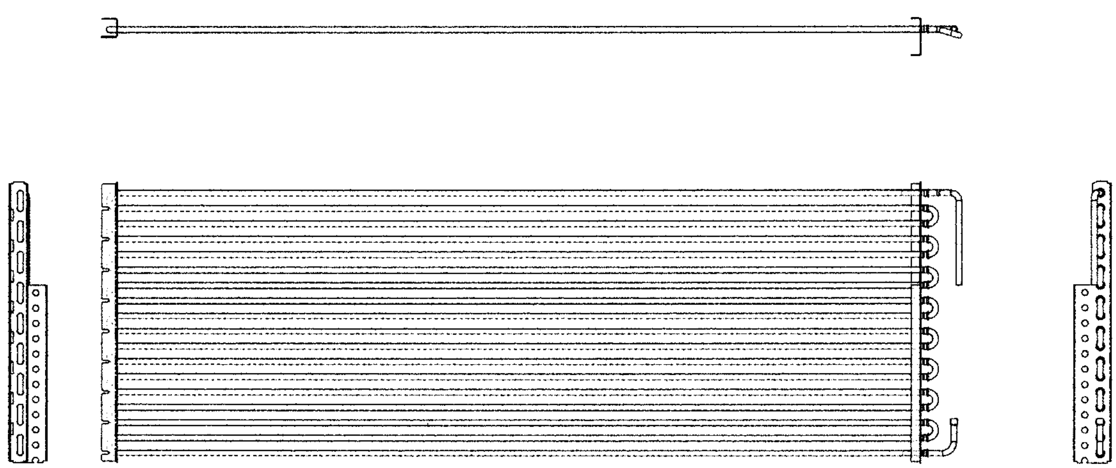


Fig. 4.3 Circuito para intercambiador de calor hecho de una sola pieza.

→ Ensamble de serpentín.- con la nueva metodología no será necesario atravesar con los tubos de cobre las aletas de aluminio, ahora solo se requiere ensamblar el circuito de cobre en las aletas de aluminio.

→ Pegado.- como el circuito de tubería de cobre está completo no será posible hacer un expandido de la tubería de cobre para unirla (fijarla) con las aletas de aluminio. Se propone el uso de un pegamento para aluminio el locktite AD-LQA-35.

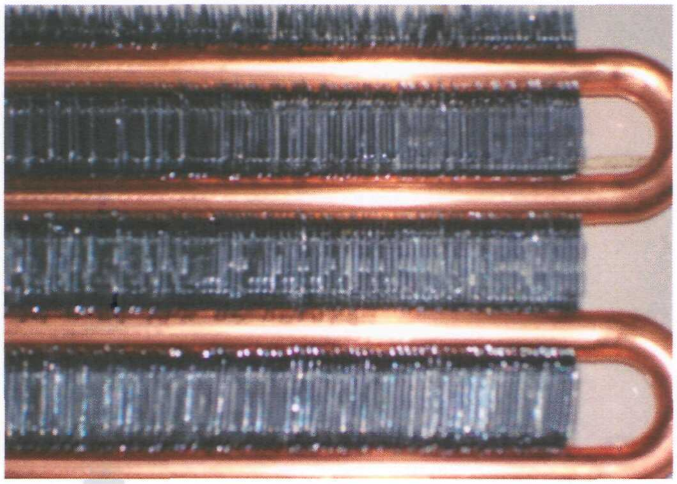


Fig. 4.4 Aletas de aluminio y tubería de cobre ensamblada bajo el nuevo procedimiento.

Con la nueva propuesta se consiguen los siguientes beneficios:

→ Disminución de pasos en procedimiento de fabricación de 5 a 4 pasos.

→ Se dejarían de utilizar 2 equipos (expander y brazer).

→ Disminución de puntos de soldadura y de posibles fugas hasta del 80% (de 45 puntos ahora se requerirán 9).

→ Ahorro en el costo de unión de aluminio con el cobre. El precio de mostrador del pegamento para aluminio es de $3.5 dólares americanos en presentación de 3.5 oz.

5 CONCLUSIONES

El aire acondicionado moderno no ha sufrido grandes modificaciones en los últimos años, esto se debe a que los desarrollos están enfocados a la manufactura y muy pocos recursos se han invertido en el desarrollo de nuevas propuestas de rediseño de unidades.

Los desarrollos más trascendentes se han reflejado en la parte de la electrónica y en los sistemas divididos.

Como en muchos otros productos la electrónica juega un papel importante en el desarrollo de los productos, en el caso del aire acondicionado se ha reflejado en los puntos de control y entrada de órdenes de funcionamiento.

Los sistemas divididos de aire acondicionado son productos que han tomado una posición importante en el mercado del aire acondicionado para el mercado mexicano, son conocidos como mini splits.

Como en muchos otros campos el mercado norteamericano pone la pauta en requerimientos y desarrollo de productos. Actualmente se trabaja intensamente en el rediseño de las unidades de aire acondicionado del mercado residencial norteamericano para dar cumplimiento al cambio de eficiencia SEER.

En Abril de 2004 el DOE en Washington anunció su apoyo al aumento de 10 a 13 SEER para la industria de la HVAC, este aumento representa un incremento de 30% en la eficiencia de las unidades. El plazo que se fijó para que el cambio en la producción y comercialización de unidades menores a 13 SEER es Enero de 2006.

Los centros de diseño de todos los fabricantes de equipo de aire acondicionado residencial se encuentran trabajando en el rediseño de las unidades, sin embargo, en general el rediseño se basa en los parámetros o estándares existentes, no están buscando rediseños radicales o revolucionarios.

Es probable que el tiempo desde el anuncio del cambio de eficiencia mínima a la fecha límite para hacerlo sea insuficiente para buscar o rediseñar unidades con conceptos nuevos. Sin embargo, los cambios en los productos no deben ser marcados solamente por los requerimientos gubernamentales, existen otros factores importantes, entre los más importantes se encuentra la competencia con otros fabricantes.

Otro punto que se cuida con el rediseño de la unidad es la manufactura de la misma, no es importante que tan revolucionario sea el nuevo producto mientras su manufacturabilidad sea complicada o difícil es probable que fracase por el alto costo de producción.

El rediseño de un producto debe sustentarse en algún beneficio que mejore alguna característica del producto (desempeño, eficiencia, estética, etc), genere un producto para un mercado no cubierto, facilite su fabricación o elimine algún punto de posible falla.

El proceso de soldadura tiene costos que en la mayoría de los casos no son contemplados dentro del producto y en consecuencia no se incluyen en el costo del producto.

Las fugas en las uniones soldadas son la problemática principal en el proceso de fabricación del serpentín.

Los puntos de soldadura que se propone eliminar son los que se realizan durante la soldadura automática, es decir, adicionalmente se podría eliminar un equipo que consume energéticos durante todo el tiempo de operación.

Una unidad condensadora de 5 toneladas de capacidad de refrigeración llega a tener hasta 45 puntos de soldadura de tubería de cobre a través de método actual. Si el método de fabricación no requiriera de la soldadura automática solo sería necesario hacer 9 soldaduras, obviamente manuales.

Las propuestas de rediseño de los intercambiadores de calor cumplen con los objetivos propuestos: disminuir los puntos de soldadura y pasos de fabricación.

Existen muchas razones por las que constantemente se diseña y rediseñan productos, la más básica es solucionar una necesidad específica.

Por otra parte, junto a los nuevos diseño y rediseños se generan desventajas o efectos secundarios, en general ningún nuevo diseño está libre de ellos y siempre es importante considerarlos.

5.1 Siguientes pasos

No todos los puntos que se requieren en el rediseño de productos han sido cubiertos con este trabajo, por lo cual resulta indispensable elaborar un plan de los pasos siguientes requeridos que validen al 100% el rediseño propuesto.

Siempre es importante identificar cual es el paso que sigue una vez alcanzado un objetivo específico.

Los pasos que siguen son:

5.1.1 Simulación de comportamiento en el ciclo de refrigeración

Con el presente trabajo se plantean propuestas de cambio en el producto y proceso de manufactura del intercambiador de calor, así como de sus componentes. No ha sido validado el comportamiento del nuevo serpentín.

La modificación propuesta a las aletas de aluminio actuales resta cantidad y tamaño, sin embargo, la intensión no es disminuir la cantidad de aluminio, simplemente es ejemplificar la geometría propuesta y sea posible realizar ensambles físicos.

Con la revisión del comportamiento en el ciclo de refrigeración del diseño de intercambiador propuesto y la nueva geometría se debe buscar el diseño y especificaciones de la nueva aleta de aluminio, que satisfaga ambas condiciones: forma geométrica y funcionamiento.

5.1.2 Pruebas de laboratorio definitivas

Las unidades de aire acondicionado en su fase de diseño son sometidas a pruebas de operación, funcionamiento y resistencia.

Las pruebas de resistencia se enfocan principalmente a la capacidad y/o modo de comportamiento de los componentes de la unidad en condiciones extremas del medio ambiente.

Entre las pruebas más frecuentes se pueden mencionar: resistencia a ambientes salinos, resistencia de materiales, etc.

5.1.3 Diseño de proceso continuo

A través del presente trabajo se propone un procedimiento de fabricación, sin embargo, como toda metodología es perfectible.

Las modificaciones que se han propuesto en la fabricación de los intercambiadores de calor modifican considerablemente los procedimientos.

Es posible considerar que esta es una buena oportunidad de alcanzar un nivel de optimización.

5.1.4 Propuestas adicionales

El mundo del aire acondicionado tiene un crecimiento en relación directa con el crecimiento poblacional, por lo cual el crecimiento del mismo está garantizado por tiempo indefinido.

Las expectativas de crecimiento son muy altas, los cambios de legislación en los Estados Unidos favorece el crecimiento por la sustitución de los equipos de menor eficiencia y el aumento de calidad de vida en las economías desarrolladas.

Por otro lado, la competencia en la industria del aire acondicionado se ha incrementado y se ha vuelto sumamente feroz. Antes de la última década del siglo XX los productores eran regionalmente localizados y solamente unos pocos eran internacionalmente conocidos.

Hoy en día la globalización de los mercados invitó a los productores asiáticos a la invasión de los mercados occidentales y con ellos empresas como LG, Samsung, entre otras establecieron operaciones y ofrecieron productos con diseños innovadores y precios competitivos, la competencia se ha vuelto fuerte y no tiene tregua.

La competencia y las nuevas regulaciones gubernamentales invitan a la generación creativa de nuevas formas de hacer negocios y productos.

En el caso específico de la producción de equipos de aire acondicionado en México empresas como Carrier son manejadas como centros de costos, limitando la posibilidad de mejorar sus productos y servicios.

El mercado nacional es soportado a través de una estrategia de adaptación de productos que fueron diseñados en Estados Unidos, lo cual reduce la capacidad de innovación (se debe trabajar dentro de la misma plataforma).

Los costos de mano de obra no son una ventaja competitiva que pueda sostenerse por mucho tiempo y de alta competencia, es indispensable revisar los recursos con los que se cuenta y como emplearlos a la brevedad.

Alterno al cambio del proceso de fabricación de los intercambiadores de calor se debe considerar retomar los recursos con los que se cuenta para retomar el diseño de las unidades. Hoy por hoy se hace un poco de rediseño de unidades que se adaptan para el mercado nacional, sin embargo, es necesario buscar nuevas ventajas competitivas además del costo de mano de obra.

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ANEXO 1

US006527906B1

(12) **United States Patent**
Otter

(10) **Patent No.: US 6,527,906 B1**
(45) **Date of Patent: Mar. 4, 2003**

(54) **ELASTOMER ADHESIVE FOR CONDENSING FURNACE HEAT EXCHANGER LAMINATE MATERIAL**

(75) Inventor: **James William Otter**, Fairfield Glade, TN (US)

(73) Assignee: **Carrier Corporation**, Syracuse, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/927,169**

(22) Filed: **Aug. 10, 2001**

(51) **Int. Cl.**[7] **C09J 5/00**
(52) **U.S. Cl.** **156/306.9**; 156/329; 165/133
(58) **Field of Search** 165/133; 156/306.9, 156/329

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Primary Examiner—Margaret G. Moore
(74) *Attorney, Agent, or Firm*—Carlson, Gaskey & Olds, P.C.

(57) **ABSTRACT**

A film is adhered to a metal plate of a condensing heat exchanger by a cured layer of silicone RTV elastomer to prevent corrosion of the condensing heat exchanger. A layer of solid silicon RTV elastomer including an organosilicone functional group is applied on the pretreated metal surface. The metal plate is heated and a protective film is then applied. The film is adhered to the surface of the metal sheet by curing the layer of silicone RTV elastomer with the water. The water reacts with the organosilicone functional groups on the silicone RTV elastomer layer, cross-linking the organosilicone functional groups to create an adhesive surface which adheres the film to the surface.

10 Claims, 1 Drawing Sheet

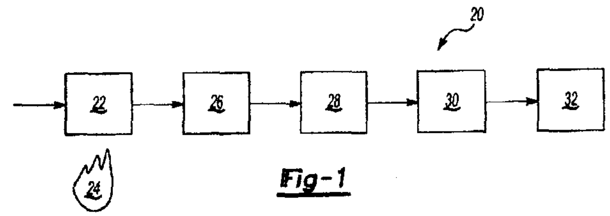

Fig-1

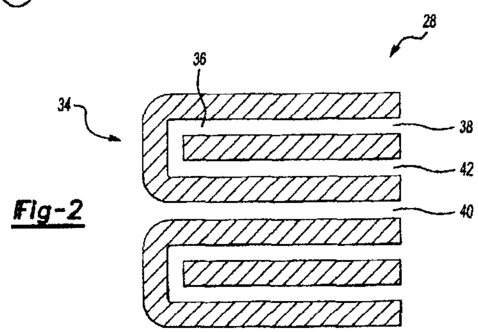

Fig-2

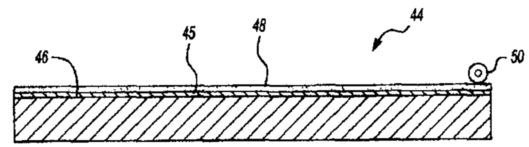

Fig-3

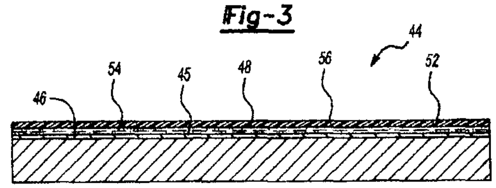

Fig-4

ELASTOMER ADHESIVE FOR CONDENSING FURNACE HEAT EXCHANGER LAMINATE MATERIAL

BACKGROUND OF THE INVENTION

The present invention relates generally to a silicone room temperature vulcanizing (RTV) elastomer layer which adheres a film to a condensing heat exchanger without utilizing a primer and adhesive.

Condensing heat exchangers are employed in condensing furnaces to increase efficiency. The condensing heat exchanger cools the heating fluid to a temperature below the dew point. As the temperature drops below the dew point, a liquid condensate, water vapor, condenses from the heating fluid. As the liquid condensate condenses, heat is transferred from the water vapor to the air to be heated. As more heat is produced, the efficiency of the system is increased.

Polypropylene films are commonly utilized to make a laminate for a condensing furnace heat exchanger to prevent corrosion by the water vapor liquid condensate. The present method of making the laminate is expensive. A primer is first applied to the pretreated steel of the condensing heat exchanger. After a bake cycle, an adhesive is applied, following again by a bake cycle. The polypropylene film is then thermally laminated to the adhesive, attaching the film to the metal surface of the condensing heat exchanger.

There are several drawbacks to utilizing the primer and adhesive of the prior art. For one, both the primer and the adhesive contain high percentages of expensive solvents which must be combusted to meet "clean air" regulations. Additionally, the formulation of the primer is occasionally changed by the manufacturer, resulting in production problems and failed inspections.

Hence, there is a need in the art for a layer which adheres a film to a condensing heat exchanger without utilizing a primer and adhesive.

SUMMARY OF THE INVENTION

The present invention relates to a silicone RTV elastomer layer which adheres a film to a condensing heat exchanger without utilizing a primer and adhesive.

A film is adhered to a metal plate of a condensing heat exchanger by a cured silicone RTV elastomer to prevent corrosion of the condensing heat exchanger. The surface of the metal plate is pretreated by a layer of phosphate or chrome. A layer of solid silicon RTV elastomer including an organosilicone functional group which cross-links with the aid of water is then applied on the pretreated metal surface. Preferably, the layer of silicone RTV elastomer is applied by a roller. The silicone RTV elastomer layer is preferably applied between 0.1 and 10 mils in thickness.

After the layer of silicone RTV elastomer is applied to the surface of the condensing heat exchanger, the metal plate is heated and a protective film is applied. The film is adhered to the surface of the metal sheet by curing the layer of silicone RTV elastomer with water a room temperature. Water cross-links the organosilicone functional groups on the silicone RTV elastomer to create an adhesive surface which adheres the film to the surface.

Accordingly, the present invention provides a silicone RTV elastomer layer which adheres a film to a condensing heat exchanger without utilizing a primer and adhesive.

These and other features of the present invention will be best understood from the following specification and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of the invention will become apparent to those skilled in the art from the following detailed description of the currently preferred embodiment. The drawing that accompany the detailed description can be briefly described as follows:

FIG. 1 illustrates a schematic diagram of a condensing furnace system;

FIG. 2 illustrates a schematic diagram of a pair of cells of a condensing heat exchanger; and

FIG. 3 illustrates a schematic diagram of a metal plate of a condensing heat exchanger with a layer of silicone RTV elastomer; and

FIG. 4 illustrates a schematic diagram of a metal plate of a condensing heat exchanger with a film applied on the layer of silicone RTV elastomer.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 schematically illustrates a condensing furnace system **20**. Air and natural gas enters a burner **22** which burns the air and natural gas by a flame **24** to produce hot combustion products. The hot combustion products pass through a primary heat exchanger **26**, which cools the hot combustion products and extracts heat to the air to be heated. To increase the efficiency of the system **20**, a condensing heat exchanger **28** is used to extract additional heat. As the hot combustion gases pass through the condensing heat exchanger **28**, the condensing heat exchanger **28** cools the combustion products to a temperature below the dewpoint of the combustion products. Water vapor begins to condense, allowing more heat to be extracted from the combustion products and increasing efficiency. As the liquid condensate condenses, heat is transferred from the water vapor to the air to be heated. An inducer fan **30** provides a source of suction on the condensing heat exchanger **28** and assists in pulling the flow of the combustion products through the system **20**. The combustion products are expelled from the system **20** through a flue **32**.

FIG. 2 illustrates a pair of cells **34** of the condensing heat exchanger **28**. Each cell **34** including a flow passage **36** through which the combustion products or flue gases flow. The hot flue gases enter the flow passage **36** through an inlet **38**. As the hot flue gases flow through the flow passage **36**, heat is transferred to the air to be heated which flows in the air passage **40** between the cells **34**. The cooled flue gases then exit the cell **34** through the outlet **42**. Although only two cells **34** are illustrated, a plurality of cells are employed in the condensing heat exchanger **28**.

A schematic view of the metal plate **44** used to form the condensing heat exchanger **28** is illustrated in FIG. 3. Preferably, the metal plate **44** is pretreated by applying a layer of phosphate or chrome **45** to the surface **46** to improve corrosion resistance. The layer of phosphate or chrome **45** additionally holds moistures and encourages the adhesion of a layer of silicone RTV (room temperature vulcanizing) elastomer **48** to the surface **46** of the metal plate **44**.

A coating of a layer of silicone RTV elastomer **48** including an organosilicone functional group is applied to the surface **46** of the metal plate **44**. Silicone is a compound containing a chain of alternating silicon and oxygen atoms with hydrocarbons attached to the silicon atoms. An organosilicone functional group is located on the end of the chain. Any organosilicone functional group which cross-links with the aid of water can be used. The silicone RTV

US 6,527,906 B1

elastomer layer **48** is applied to the surface **46** as a solid. Preferably, the layer of silicone RTV elastomer **48** is applied by a roller **50**. However, other methods of application are possible, and one skilled in the art would understand how to apply the layer of silicone RTV elastomer **48**. The high solids uncured silicone elastomer layer **48** is preferably applied as a thin layer preferably between 0.1 and 10 mils in thickness.

After the layer of silicone elastomer **48** is applied to the surface **46** of the condensing heat exchanger **28**, the metal plate **44** is heated. The film **52** is then applied over the solid layer of elastomer **48**. Preferably, the film **52** is polypropylene. The film **52** is adhered to the surface **46** of the metal sheet **30** by curing the layer of silicone RTV elastomer **48** with water **54**. Water **54** causes a reaction which cross-links the organosilicone functional groups in the solid silicone RTV elastomer layer **48**, creating an adhesive surface which adheres the film **52** to the surface **46** of the metal plate **44**.

Preferably, the water **54** which cures the silicone RTV elastomer layer **48** is contained in the film **52**. The water permeates through the film **52** and reacts with the layer of silicone RTV elastomer layer **48**, cross-linking the organosilicone functional groups. Alternatively, the water **54** is applied to the surface **46** of the metal sheet **44** prior to the application of the layer of silicone RTV elastomer layer **48**. The water can also be applied to the upper surface **56** of the film **52** after application over the layer of silicone RTV elastomer layer **48**. The water **54** permeates through the film **52** and cross-links the organosilicone functional groups. Alternatively, the water **54** is supplied by steam which permeates the film **52**.

There are several advantages to employing the silicone RTV elastomer layer **48** of the present invention to attach a film **52** to the surface **46** of a metal plate **44** of a condensing heat exchanger **28**. For one, as a primer is not used, there is a reduction to the release of volatile organic compound (VOC) during the manufacturing process. Films **52** with a lower surface energy can be adhered to the condensing heat exchanger **28** which are usually difficult to adhere by adhesives or direct thermal lamination. The silicone RTV elastomer layer **48** has high thermal resistance to flue gases and to the acidic condensate formed in the condensing heat exchanger **28**. Therefore, the temperature of the flue gases can be increased. Finally, the silicone RTV elastomer layer **48** is flexible and allows forming, whereas the adhesive of the prior art is relatively brittle.

Accordingly, the present invention provides a silicone RTV elastomer layer which adheres a film to a condensing heat exchanger without utilizing a primer and adhesive.

The foregoing description is only exemplary of the principles of the invention. Many modifications and variations of the present invention are possible in light of the above

teachings. The preferred embodiments of this invention have been disclosed, however, so that one of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specially described. For that reason the following claims should be studied to determine the true scope and content of this invention.

What is claimed is:

1. A method for adhering a film to a condensing heat exchanger comprising the steps of:

applying a layer of a room temperature vulcanizing silicone elastomer including an organosilicone functional group to said condensing heat exchanger;

applying said film to said layer of silicone elastomer; and

curing said layer of silicone elastomer to adhere said film to said condensing heat exchanger.

2. The method as recited in claim 1 wherein the step of applying said layer of silicone elastomer includes application by a roller.

3. The method as recited in claim 1 wherein said film is polypropylene.

4. The method as recited in claim 1 wherein the step of curing said layer of room temperature vulcanizing silicone elastomer includes adding water to said layer of silicone elastomer to cross-link said organosilicone functional groups.

5. The method as recited in claim 1 further comprising the step of pre-treating a surface of said heat transfer component.

6. The method as recited in claim 5 wherein the step of pre-treating said heat transfer component includes phosphating said surface of said heat transfer component.

7. The method as recited in claim 5 wherein the step of pre-treating said heat transfer component includes chromating said surface of said heat transfer component.

8. The method as recited in claim 1 wherein said layer of silicone elastomer is between 0.1 and 10 mils in thickness.

9. A heat transfer component of a condensing furnace system comprising:

a metal surface;

a film adhered to said metal surface; and

a layer of room temperature vulcanizing silicone elastomer including a cured organosilicone functional group to adhere said film to said metal surface.

10. The heat transfer component as recited in claim 9 wherein said layer of silicone elastomer is between 0.1 and 10 mils in thickness.

* * * * *

US005582024A

United States Patent [19]

Kobor

[11] Patent Number: 5,582,024

[45] Date of Patent: Dec. 10, 1996

[54] **COPPER ARTICLE WITH PROTECTIVE COATING**

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[73] Assignee: Carrier Corporation, Syracuse, N.Y.

[21] Appl. No.: 593,381

[22] Filed: Jan. 29, 1996

Related U.S. Application Data

[62] Division of Ser. No. 203,813, Mar. 1, 1994, Pat. No. 5,510,010.

[51] Int. Cl.[6] B60H 1/32

[52] U.S. Cl. 62/239; 165/133; 428/469

[58] Field of Search 165/133; 428/469; 62/239

[56] **References Cited**

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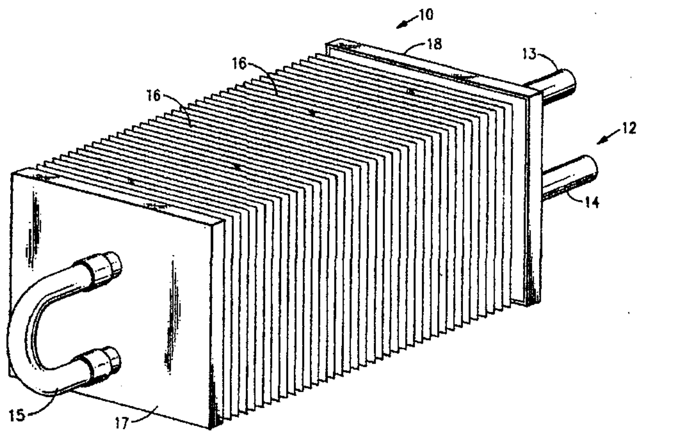
Primary Examiner—William E. Tapolcai

[57] **ABSTRACT**

A copper heat exchanger unit for operating in a harsh environment wherein the exposed surfaces of the unit are first provided with a black oxide layer and then electrocoated with a protective acrylic barrier.

3 Claims, 2 Drawing Sheets



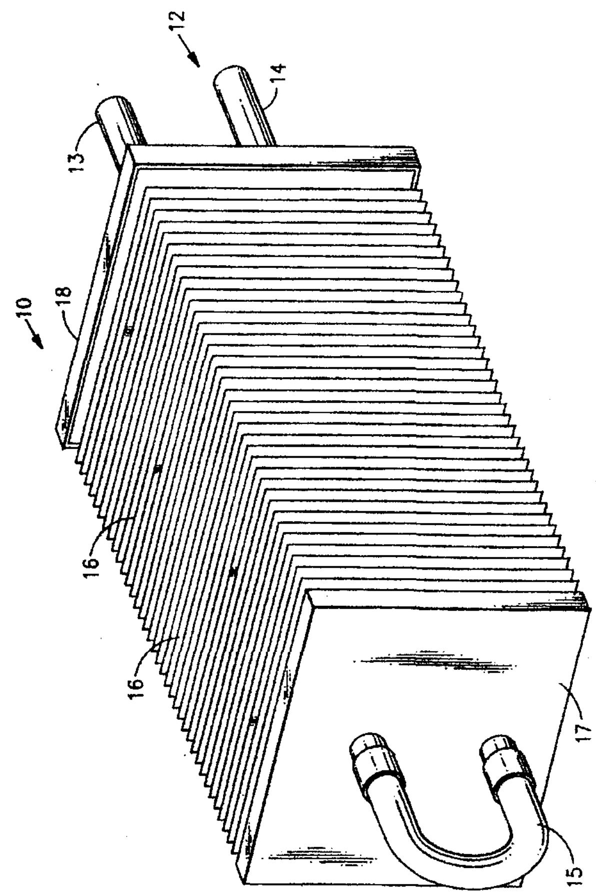


FIG.1

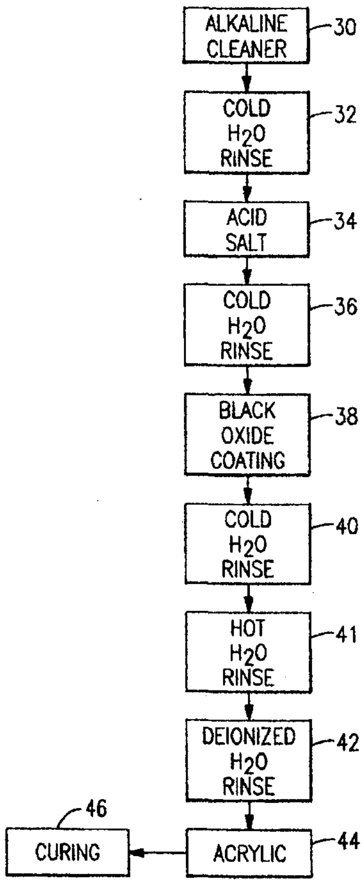


FIG.2

COPPER ARTICLE WITH PROTECTIVE COATING

This application is a division of application Ser. No. 08/203,813 filed Mar. 1, 1994, now U.S. Pat. No. 5,510,010.

BACKGROUND OF THE INVENTION

This invention relates to protecting copper articles from a corrosive environment, and in particular, to protecting copper heat exchangers used in refrigerated cargo containers.

Ocean going cargo ships now carry large containers on their open decks which serve to expand the ship's utility. Many of these containers are equipped with refrigeration systems so that they can store perishable goods for relatively long periods of time. The refrigeration systems, however, are exposed to salt, air and water which causes the exposed parts to corrode at an accelerated rate. Heat exchanger surfaces used in the refrigeration systems are particularly susceptible to salt air and salt water corrosion.

In an effort to combat the harmful effects of salt, air and water, heat exchangers used in sea going containers are typically fabricated of copper. In addition, exposed surfaces of the heat exchangers have also been coated with various, types of paints for added protection. These protective coatings have met with only with limited success for a number of reasons. First, most coating materials do not adhere well to copper and eventually the coating will flake away to expose the copper substrate. Secondly, the coating must be relatively thin so that it does not adversely effect the heat transfer characteristics of the heat exchanger. Most thin layer coatings, however, are extremely porous and thus will not establish an impenetrable protective barrier for the underlying copper.

As will be described in greater detail below, the present invention will be explained with specific reference to providing a protective barrier for a copper heat exchanger. However, it should be evident to one skilled in the art that the invention is not limited to this specific application and can be used in connection with any copper article where the need exists to protect the article from a hostile environment or the like.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to protect copper articles from a corrosive environment.

It is another object of the present invention to protect a copper heat exchanger from the harmful effects of salt air and water.

Yet a further object of the present invention is to extend the life of refrigeration systems used in sea going cargo containers.

A still further object of the present invention is to provide a protective overcoating for a copper heat exchanger that will not adversely effect its heat transfer properties, but yet will provide a relatively non-porous barrier to salt air and water.

Another object of the present invention is to provide a protective coating for a copper article that has improved adhesion properties.

These and other objects of the present invention relate broadly to a copper article, and more specifically, to a heat exchanger for use in a sea going refrigeration cargo container. The exposed surface of the articles are first treated to produce a black oxide layer over the exposed surfaces. An

acrylic outer layer is then electrocoated over the oxide layer to provide a relatively thin yet non-porous barrier that exhibits extremely good adhesion and protective properties against corrosive substances.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of these and other objects of the present invention, reference is made to the detailed description of the invention which is to be read in conjunction with the following drawings, wherein:

FIG. 1 is a perspective view of one form of copper heat exchanger used in refrigerated sea going cargo containers, and

FIG. 2 is a flow diagram showing the steps involved in providing a strongly adhesive, non-porous protective barrier to the exposed surfaces of the heat exchanger illustrated in FIG. 1.

DESCRIPTION OF THE INVENTION

Referring initially to FIG. 1, there is shown a fin coil heat exchanger, generally referenced **10**, of the type typically used in association with refrigerated cargo containers. The heat exchanger includes one or more flow circuits **12** for carrying a refrigerant through the heat exchanger unit. For the purposes of explanation, the unit illustrated in FIG. **1** contains a single flow circuit **12** consisting of an inlet line **13** and an outlet line **14** which are connected at one end of the exchanger by means of a 90° tube bend **15**. It should be evident, however, that more circuits may be added to the unit depending upon demands of the system. The unit further includes a series of radially disposed plate-like elements **16**—**16** that are spaced apart along the length of the flow circuit. The elements are supported in assembly between a pair of end plates **17** and **18** to complete the assembly.

As noted above, heat exchangers of this type that are exposed to a harsh or corrosive environment are generally fabricated of copper because of its good heat transfer properties and resistance to corrosion. Nevertheless, these copper units can and will be adversely effected when exposed to salt air and water for extended periods of time. Attempts have been made with varying degrees of success to coat these copper units with various material in an effort to extend the useful life of the unit. These coating materials oftentimes reduce the heat transfer capacity of the unit, exhibit poor adhesion properties and fail to penetrate into all areas of the unit that might be exposed to a hostile environment.

As will be explained in greater detail below, the exposed outer surfaces of the present copper heat exchanger are first pretreated to establish a black oxide coating thereon that creates a strong boundary layer much like that produced when aluminum is anodized. A thin acrylic overcoating is then electro-coated over the black oxide boundary layer to provide a strongly adhering protective barrier for extending the useful life of a unit exposed to a hostile environment. It has been found that this combination exhibits unexpected synergistic results and does not degrade the heat transfer properties of the unit. Additionally, the protective barrier is capable of penetrating deeply into remote, difficult to access areas, thus preventing early failure.

Turning now to FIG. 2, there is shown a flow process diagram depicting the process steps involved in producing a uniform protective barrier over the entire outer surface of the copper heat exchanger. Initially, the two open ends of the flow circuit are closed by suitable plugs (not shown) and the exchanger is immersed in an alkaline bath **30** containing a strong base cleaner such as MI Clean 17 manufactured by Mitchell Bradford International, which is a division of Hubbard-Hall, Inc. of Waterbury, Conn. The bath contains a 4–7% concentration of MI Clean 17 in water and the solution is heated to a temperature of about 180° F. The heat exchanger is allowed to remain in the bath for about 5 to 10 minutes to thoroughly clean and degrease all exposed surfaces of the unit.

Upon removal from the alkaline bath, the unit is bathed in a cold water rinse 32 for about one minute or a period of time which is sufficient to remove the alkaline wash from the outer surface of the exchanger. The term cold water rinse as herein used refers to one in which the rinse water is at or about an ambient temperature.

The rinsed heat exchanger is then placed in a second acidic cleansing bath 34 for about 4 to 5 minutes to remove surface oxidations. The bath, held at an ambient temperature, contains about 10% concentration of Scone M-E Acid Brite 50 (also supplied by Hubbard-Hall, Inc.) in water. Acid Brite 50 contains about 20% by weight hydrochloric acid, 11% by weight phosphoric acid and 10% by weight sulfuric acid along with other non-acidic materials which combine to thoroughly ride the outer surfaces of the heat exchanger of unwanted oxides.

The unit, upon removal from the acid cleaning bath, is immediately placed in a cold water rinse 36 for about one minute or more to remove all trace of the acid bath from the outer surfaces of the unit.

The twice cleaned-and rinsed part is now immersed in an oxidizing bath 38. The bath contains an oxidizing solution containing equal parts sodium hydroxide and sodium chloride in water. A concentration of about two pounds of oxidizer to a gallon of water is used. The oxidizer is commercially available from Hubbard-Hall, Inc. and is sold under the tradename Black Magic CB. The unit is allowed to remain in the bath for between 5 and 10 minutes at a bath temperature of about 180° F–210° F. until all exposed surfaces of the copper are thoroughly coated with a deep black colored oxide film.

The oxidation process is quickly terminated by rinsing the unit in cold water for two to three minutes and then in hot water that is heated to about 120° F. for about ten or eleven minutes. The unit is given a final rinse for about one to two minutes in deionized water at ambient temperature and. allowed to dry. These rinses are depict at 40–42 in FIG. 2.

Upon drying, the unit is coated With an acrylic paint using commercially available coating equipment 44. The paint is available from Pittsburgh Plate Glass Industries, Inc. of Springdale Pa. and is sold under the tradename Powercron 810–611 or Powercron 830–611. The oxidized unit is immersed in a bath of acrylic paint and an electrical current of ~234 amps and 200 volts applied to the unit. The unit is held in the bath for between nine and ten minutes to insure that all exposed and oxidized surfaces of the unit are fully covered with the acrylic overcoat to a thickness of between 0.0005 to 0.0010 inches. The unit is then removed from the bath and the paint cured in an oven 48 for thirty minutes at 375° F.

Copper parts that were oxidized and coated by the method described above were tested to determine the parts'ability to resist corrosion. The AC impedance of each coated part was first measured and recorded. The average impedance of the parts was found to be about 8×10^9 ohms per square centimeter and the average thickness of the acrylic coating was about 0.0007 inches. The parts were then exposed to steam spray for a period of about 48 hours and a second impedance measurement was then taken. The average impedance of the parts exposed to the steam was found to be about 7×10^8 ohms per square centimeter. Clearly these tests showed that the acrylic coating was relatively less porous than similar coating presently in use and thus provided an improved protective barrier against corrosion. Further tests also showed that the coating exhibited improved adhesive properties and resistivity to ultraviolet radiation when compared to presently employed coatings.

Although the present invention has been described with specific reference to a copper heat exchanger, it should be evident to one skilled in the art that the invention has wider applications and can be employed in conjunction with any type of copper article or part that may require extended protection from a hostile environment.

While this invention has been explained with reference to the structure disclosed herein, it is not confined to the details set forth and this invention is intended to cover any modifications and changes as may come within the scope of the following claims:

I claim:

1. A cargo container for storing perishable goods having a refrigeration unit that includes:

a copper heat exchanger having a plurality of spaced apart fins,

a uniform black oxide layer covering the outer surfaces of the heat exchanger that is formed by precleaning and degreasing exposed surfaces of said heat exchanger followed by immersing the heat exchanger in an acid bath to remove unwanted oxides from the exposed surfaces, washing the heat exchanger with water and then exposing the surfaces to an aqueous oxidizing bath, and further followed by rinsing said heat exchanger after forming said oxide layer in successive baths of cold water, hot water, and deionized water.,

an outer coating of nonconductive acrylic paint that is electrocoated over the black oxide preconditioning layer to completely cover the outer surfaces of the heat exchanger with a continuous protective barrier against corrosion.

2. The container of claim 1 wherein the acrylic paint is electrocoated to a uniform thickness of between 0.0005 and 0.001 inches.

3. The container of claim 1 wherein the heat exchanger further includes at least one flow circuit and a plurality of spaced apart fins radially disposed along the length of the flow circuit.

* * * * *

US006488080B2

(12) **United States Patent**

Lee et al.

(10) **Patent No.: US 6,488,080 B2**
(45) **Date of Patent: Dec. 3, 2002**

(54) **REFRIGERATOR EVAPORATOR AND METHOD OF MANUFACTURING THE SAME**

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(73) Assignee: **LG Electronics Inc.**, Seoul (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/727,520**

(22) Filed: **Dec. 4, 2000**

(65) **Prior Publication Data**

US 2001/0013408 A1 Aug. 16, 2001

(30) **Foreign Application Priority Data**

Feb. 11, 2000 (KR) 2000-6496

(51) **Int. Cl.**[7] **F28D 1/00**
(52) **U.S. Cl.** **165/150**; 29/890.035
(58) **Field of Search** 165/150; 29/890.035, 29/890.07

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Primary Examiner—Henry Bennett
Assistant Examiner—Terrell McKinnon
(74) *Attorney, Agent, or Firm*—Birch, Stewart, Kolasch & Birch, LLP

(57) **ABSTRACT**

An integrated refrigerator evaporator having a plurality of pipes and fins is manufactured by injection molding with plastics. According to the present invention, pipes and fins are molded by plastic plates, and a heat exchanger is formed by molding the pipes and fins into a series of "S" shapes. A first bending section formed by the heat exchanger, which is molded in a series of "S" shapes, is inserted into a mold main body to manufacture a header cap. A first header cap is manufactured by injected melted plastic material body into the mold main body under the state of covering the mold main body with a mold cap. The first header cap is engaged with a first header main body having a refrigerant inlet and outlet. The refrigerator evaporator according to the present invention results in a relatively lower product cost than the evaporator composed of a metal substance, as well as a high recyclability.

18 Claims, 6 Drawing Sheets

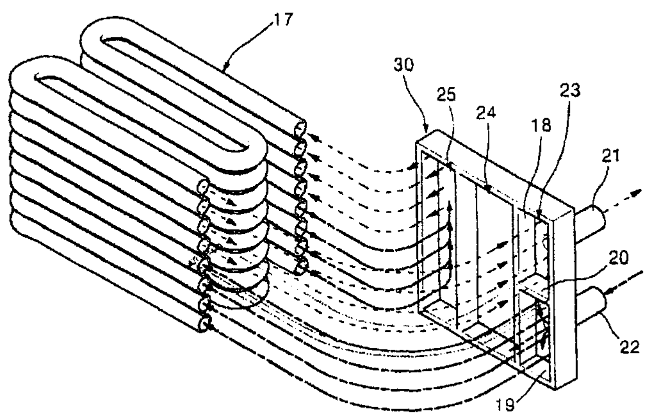


FIG. 1A
(Related Art)

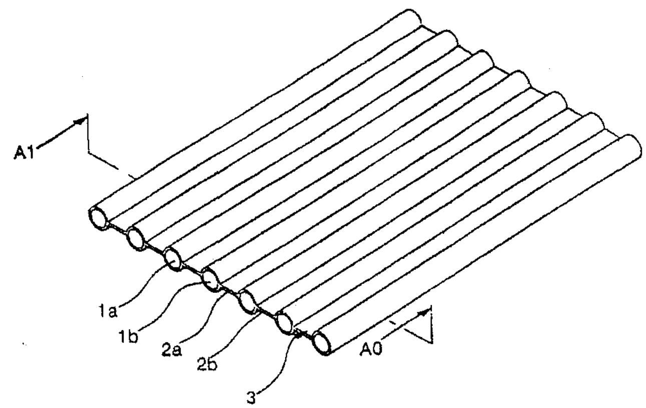


FIG. 1B
(Related Art)

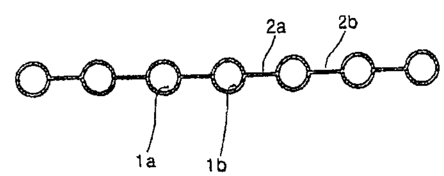


FIG. 2A

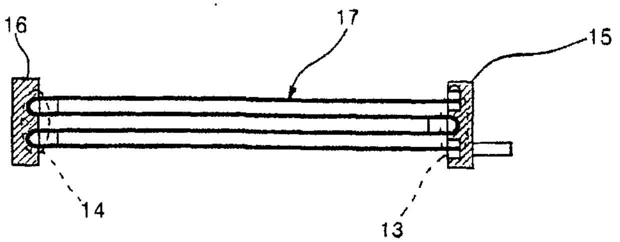


FIG. 2B

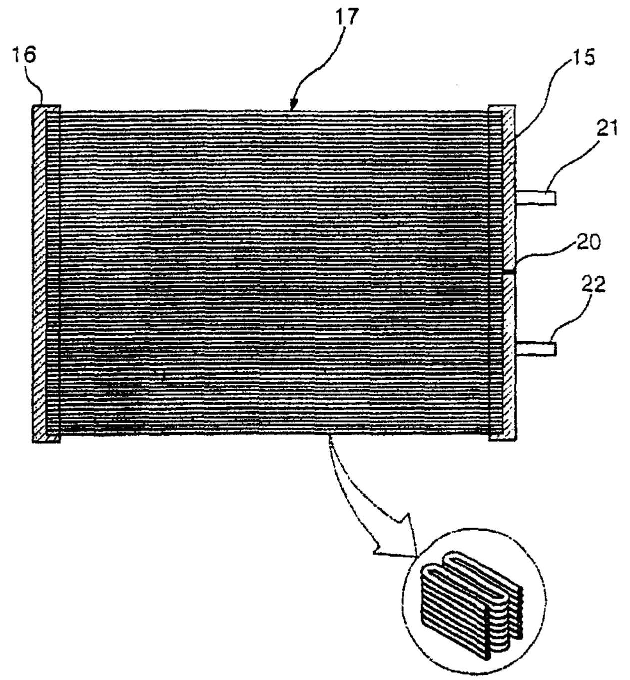


FIG. 2C

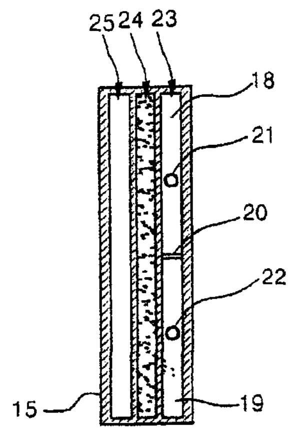


FIG. 3A

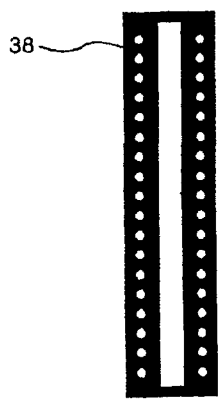


FIG. 3B

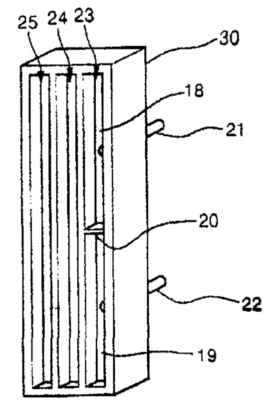


FIG. 4

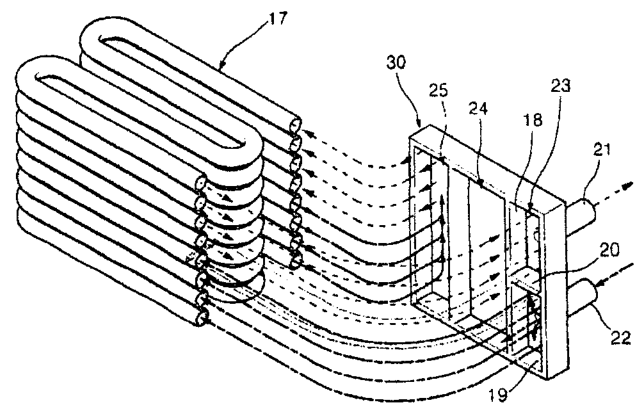


FIG. 5A

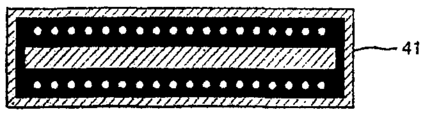


FIG. 5B

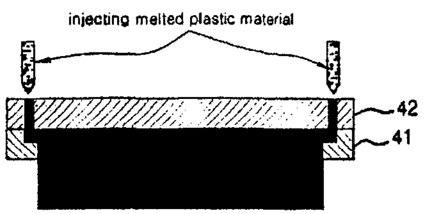
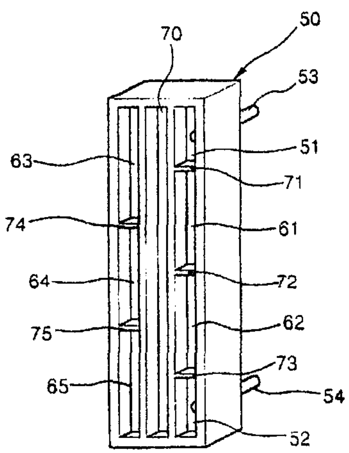


FIG. 6



REFRIGERATOR EVAPORATOR AND METHOD OF MANUFACTURING THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a refrigerator evaporator, and more particularly to a refrigerator evaporator and method of manufacturing a refrigerator evaporator of both a more improved structure and manufacturing process than the conventional one using plastic materials.

2. Description of the Prior Art

In general, the refrigerator as an appliance for storing and keeping stuff such as food under low temperatures roughly consists of a storage compartment and a cooling compartment. This type of a refrigerator can be classified into four kinds according to the cooling methods: an ice refrigerator, in which a lump of ice is put on an upper part of the storage compartment to cool down inside thereof; an electric refrigerator, in which gaseous Freon is condensed and transferred to a condenser to be liquefied by discharging heat; a gas refrigerator employing an absorption freezer, which uses ammonia aqueous solution as a refrigerant; and an electronic refrigerator utilizing a Peltier element for the purposes of both cooling and heating the food according to the direction of electric current.

An evaporator is essential to any types of refrigerator, regardless of the kinds of refrigerant to be used, for exchanging latent heat with existent heat by means of evaporation of the refrigerant. Such a conventional refrigerator evaporator has been manufactured by utilizing metals such as copper or aluminum in consideration of the problems in heat exchanging efficiency and pressure endurance, etc. The following is an explanation of the method of manufacturing the conventional refrigerator evaporator made with reference to the accompanying drawings FIGS. 1A and 1B.

FIGS. 1A and 1B are a perspective view and a cross-sectional view illustrating the heat exchange plate used in the conventional refrigerator evaporator.

Referring to FIGS. 1A and 1B, refrigerant pipes 1*a*, 1*b* are first extruded by means of metal (e.g., copper, aluminum, etc.). Fins 2*a*, 2*b* are then manufactured by molding a metal panel.

Metal refrigerant pipes 1*a*, 1*b* are inserted into the fins 2*a* and 2*b* and elongated to a desired length. The metal refrigerant pipes 1*a*, 1*b* are mechanically engaged with the fins 2*a*, 2*b*.

The body incorporating the refrigerant pipes 1*a*, 1*b* into the fins 2*a*, 2*b* is the heat exchange plate 3.

And, a heat exchange plate 3 is bent in a series of "S" shapes or in the shape of a serpent to be completed as the heat exchanger.

However, since most of the refrigerator evaporator including the ones described above are composed of metal of high thermal conductivity and strength, there are some problems.

First, employing metal substance results in a relatively high material cost of the refrigerator evaporator, thereby elevating the cost of a refrigerator including a heat exchanger.

Second, employing a metal substance also requires a more complicated manufacturing process than employing a non-metal substance, thereby resulting in a high processing cost. Further, the high weight of the metal evaporator causes a problem in transportation.

Third, employing a metal substance lowers recyclability and durability of the product.

Fourth, employing a metal substance impedes modification of the design of the product.

SUMMARY OF THE INVENTION

To resolve the conventional problem described above, an object of the present invention is to provide a refrigerator evaporator having a plurality of pipes and fins which is manufactured by injection molding with plastics.

To accomplish the object, the refrigerator evaporator according to the present invention comprises a heat exchanger having a plurality of pipes for circulating a refrigerant and a plurality of fins molded in a series of "S" shapes for mechanically engaging the plurality of pipes; a first header positioned at a first bending section formed by the heat exchanger molded in a series of "S" shapes and having an inlet pipe and an outlet pipe for a refrigerant, and the first header comprises a plurality of inlet tanks, outlet tanks, return tanks and brackets for preventing distortion of the heat exchanger; and a second header engaged with a second bending section positioned corresponding to the first header, characterized in that the heat exchanger, first header and second header are integrated in plastics.

The method of manufacturing the refrigerator evaporator to achieve an object of the present invention comprises the steps of: forming a heat exchanger by molding pipes and fins with a plastic panel and molding the pipes and fins in a series of "S" shapes; inserting the first bending section formed by molding the heat exchanger in a series of "S" shapes into a mold body for forming a header cap; manufacturing a first header cap by injecting melted plastic material into the mold main body under the state of covering the mold main body with a molding cap; and engaging the first header cap with the main body of the first header having a molding inlet pipe and an outlet pipe of the refrigerant; manufacturing a second header cap by inserting a second bending section of the heat exchanger into the mold main body for manufacturing the first header cap, and by injecting the plastic melting body into the melted plastic material under the state of covering the mold main body with a mold cap; and engaging the second header cap with the second header main body.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A and 1B are a perspective view and a cross-sectional view illustrating the pipes and fins used in the conventional refrigerator evaporator.

FIGS. 2A–2C are section views of the refrigerator evaporator according to one embodiment of the present invention.

FIGS. 3A and 3B are detailed views illustrating the header.

FIG. 4 is a view illustrating the functioning process of a refrigerator evaporator according to an embodiment of the present invention.

FIGS. 5A and 5B are views illustrating the manufacturing steps of a header of the refrigerator evaporator shown in FIG. 2.

FIG. 6 is a view of the header according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The following is a detailed description of the preferred embodiment of the present invention made with reference to the accompanying drawings.

FIG. 2 is a cubic sectional view of the refrigerator evaporator according to an embodiment of the present invention.

Referring to FIGS. 2A and 2B the refrigerator evaporator according to the present invention comprises a heat exchanger 17 formed by molding a heat exchange plate (13), which consists of a plurality of fins mechanically engaging a plurality of pipes for circulating a refrigerant, in a series of "S" shapes; a first header 15 positioned at a first bending section of the heat exchanger 17 and having an inlet pipe 22 and an outlet pipe 21 for the refrigerant; and a second header 16 engaged with the second bending section 14 of the heat exchanger 17 to be positioned to correspond to the first header 15. The heat exchanger 17, the first header 15 and the second header 16 are preferably extrusion-molded or injection molded with integrated plastics.

The following is a detailed description of the heat exchange plate, and the heat exchanger 17.

The heat exchange plate includes a plurality of fins and pipes for circulating a refrigerant. The pipes are first extruded or injected by means of plastics. Fins are then manufactured by molding a plastic panel.

The plastic pipes for circulating a refrigerant are inserted into the fins and elongated to a desired length. The pipes are mechanically engaged with the fins.

The body *incorporating the pipes into the fins is the heat* exchange plate. The heat exchange plate is bent in a series of "S" shapes or in the shape of a serpent to be completed as the heat exchanger 17.

FIG. 2C is a right side sectional view of the refrigerator evaporator according to the embodiment of the present invention.

Referring to FIG. 2C, the first header 15 comprises a header tank 23 divided into an inlet tank 19 having an inlet pipe 22 and an outlet tank 18 having an outlet pipe 21 by a separating plate 20, a bracket 24 for preventing distortion of the heat exchanger 17, and a return tank 25.

FIG. 3 is a detailed sectional view of the first header 15 shown in FIG. 2C.

The first header 15 roughly comprises a header main body 30 and a header cap 38 as shown in FIG. 3. The header main body 30 further comprises a header tank 23 having an inlet tank 19 and an outlet tank 18, a bracket 24 for preventing distortion of the heat exchanger 17, which is bent in the shape of a serpent, and return tank 25. A refrigerant inlet pipe 22 and a refrigerant outlet pipe 21 are extrusion-molded, respectively, in the inlet tank 19 and the outlet tank 18. The inlet tank 19 is distinguished from the outlet tank 18 by a separating plate 20.

The following is a detailed description of the functioning process of a refrigerator evaporator according to the embodiment of the present invention.

FIG. 4 is a view illustrating the functioning process of a refrigerator evaporator according to the embodiment of the present invention.

The refrigerant comes in through the inlet pipe 22 and flows into the plurality of pipes of the heat exchanger 17 formed in the *inside of the inlet tank 19 which is placed at* the lower portion of the separating plate 20. Then, the refrigerant flows out through the other side pipe of the heat exchanger 17 via the bending sections 13 and 14, and accumulates at the lower part of the return tank 25. When the amount of the refrigerant increase as more refrigerant comes in to the inlet pipe 22, the refrigerant level rises up tot eh upper part of the return tank 25 causing the refrigerant to flow through the bending sections 13 and 14 to the outlet tank 18 placed at the upper part of the separating plate 20 via the pipe placed at the upper section of the heat exchanger 17, and eventually the refrigerant is discharged through the outlet pipe 21.

The following is a detailed description of the manufacturing process of a refrigerator evaporator according to the present invention made with reference to the accompanying drawings.

A plastic heat exchanging plate having a plurality of pipes and fins is manufactured by extrusion or injection. At this stage, the pipes are first extruded or injected by means of plastics. Fins are then manufactured by molding a plastic panel.

Plastic pipes for circulating a refrigerant are inserted into the fins and elongated to a desired length. The pipes are mechanically engaged with the fins.

The heat exchanging plate is repeatedly bent in a series of "S" shapes or in the shape of a serpent. At this stage, two bending sections 13, 14 are formed as shown in FIG. 2. Of the bending sections 13, 14 of the molding heat exchanger 17, the first bending section 13, at which the beginning and end portions of the pipes are positioned, in engaged with the first header 15 of plastic material. The second header 16 of the plastic material is mounted on the opposite side of the first bending section 13.

Accordingly, a refrigerant may flow through the pipes of the extruded or injected heat exchanger 17. Since the air passes through the inside and outside of the heat exchanger 17, a heat exchange between the refrigerant and air is automatically performed.

The first header 15 roughly comprises a header main body 30 and a header cap 38 as shown in FIG. 3. The header main body 30 further comprises a header tank 23 having an inlet tank 19 and an outlet tank 18, a bracket 24 for preventing distortion of the heat exchanger 17, which is bent in the shape of a serpent, and a return tank 25. A refrigerant inlet pipe 22 and a refrigerant outlet pipe 21 are extrusion-molded, respectively, in the inlet tank 19 and the outlet tank 18. The inlet tank 19 is distinguished from the outlet tank 18 by a separating plate 20.

Since the header of the refrigerator evaporator according to the present invention is manufactured by the following process, no additional work is required for an airtight seal between the header cap 38 and the heat exchanger 17.

FIG. 5 is a view illustrating the manufacturing steps of a header of the refrigerator evaporator shown in FIG. 2.

In other words, manufacture of the header cap 38 is completed by injecting melted plastic material into the mold main body 41 under the state of covering the mold main body 41 with a cap 42 as shown in FIG. 5. Manufacture of the first header 15 is completed by engaging the header cap 38 with the header main body 30. As a consequence, an airtight seal can be maintained between the header cap 38 and the heat exchange plate 13.

The second header 16 is extruded by the same process as above for manufacturing the first header 15 except that the refrigerant inlet 22 and outlet 21 are not molded because of any necessity. In other words, the second bending section 14 *of the pre-manufactured integrated plastic heat exchanger 17* is injected into the mold main body 41, and melted plastic material is inserted into the mold main body 41 under the state of covering the mold main body 41 with the mold cap 42 to complete the header cap of the second header 16. Subsequently, the header cap is engaged with the header main body (not illustrated in the drawings) to complete the second header.

FIG. 6 is a cross-sectional view of the refrigerator evaporator according to another embodiment of the present invention. FIG. 6 shows formation of a plurality of return tanks 63–65 in the header main body 50 by suitably forming plurlity of seperating plates 71–75 inside of the header tank and the return tank. Accordingly, a refrigerator evaporator configured to change the flow channels of the refrigerant is provided through this process.

According to a preferred embodiment of the present invention, manufacture of a heat exchanger with an integrated plastic plate serves to drastically reduce the cost of manufacturing a refrigerator evaporator, which is conventionally composed of metal substance. A simulation of the present invention proved that about 47% of the material cost and about 53% of the manufacturing cost of the heat exchanger according to the present invention could be saved in comparison with the aluminum heat exchanger.

Furthermore, the environment-friendly refrigerator evaporator according to the present invention also serves to protect the environment owning to its notable recyclability, and has a merit of long durability due to non-corrosion. Modification of any layouts of the refrigerator evaporator according to the present invention is also easier than the refrigerator evaporator composed of a metal substance.

What is claimed is:

1. A refrigerator evaporator, comprising:
   - a heat exchanger having a plurality of pipes for circulating a refrigerant and a plurality of fins molded in a series of "S" shapes for mechanically engaging the plurality of pipes;
   - a first header positioned at a first bending section formed by the heat exchanger molded in a series of "S" shapes and having an inlet pipe and an outlet pipe for a refrigerant, the first header comprising a plurality of inlet tanks, outlet tanks, return tanks and brackets for preventing distortion of the heat exchanger; and
   - a second header engaged with a second bending section positioned corresponding to the first header,
   - wherein said heat exchanger, first header and second header are integrated in plastics.

2. The refrigerator evaporator of claim 1, wherein said inlet tanks and outlet tanks are integrated tanks divided by at least one separating plate.

3. The refrigerator evaporator of claim 1, wherein a refrigerant inlet is formed at said inlet tank, and a refrigerant outlet is formed at said outlet tank.

4. A refrigerator evaporator, comprising:
   - a plastic heat exchanger having a plurality of plastic pipes for circulating a fluid and a plurality of plastic fins interconnecting said plurality of plastic pipes, the heat exchanger being bent in at least one "U" shape so as to form an inlet/outlet section at a first end of said heat exchanger and a bending section at a second end of said heat exchanger;
   - a plastic first header engaged with said inlet/outlet section of said heat exchanger, said first header including an inlet tank, an inlet orifice, an outlet tank, and an outlet orifice; and
   - a plastic first header cap integrally molded together with said first end of said plastic heat exchanger.

5. The refrigerator evaporator of claim 4, wherein said first header further includes a return tank.

6. The refrigerator evaporator of claim 4, wherein said first header further includes a bracket for preventing distortion of the heat exchanger.

7. The refrigerator evaporator of claim 4, further comprising a plastic second header engaged with said bending section of said heat exchanger.

8. The refrigerator evaporator of claim 7, further comprising a plastic second header cap integrally molded together with said second end of said plastic heat exchanger.

9. The refrigerator evaporator of claim 4, wherein said inlet orifice is an inlet pipe, and said outlet orifice is an outlet pipe.

10. The refrigerator evaporator of claim 4, wherein said heat exchanger is bent in a plurality of "U" shapes so as to form a serpentine configuration.

11. The refrigerator evaporator of claim 10, wherein said first header further includes a return tank.

12. The refrigerator evaporator of claim 11, wherein said first header further includes a bracket for preventing distortion of the heat exchanger.

13. The refrigerator evaporator of claim 12, further comprising a plastic second header engaged with said bending section of said heat exchanger.

14. The refrigerator evaporator of claim 13, further comprising a plastic second header cap integrally molded together with said second end of said plastic heat exchanger.

15. The refrigerator evaporator of claim 14, wherein said inlet tank and said outlet tank are divided by a separating plate.

16. The refrigerator evaporator of claim 15, wherein said inlet orifice is an inlet pipe, and said outlet orifice is an outlet pipe.

17. A method of manufacturing a refrigerator evaporator, comprising the steps of:
   - forming pipes and fins by means of a plastic plate;
   - manufacturing a heat exchanger by molding said pipes and fins in a series of "S" shapes;
   - manufacturing a first header cap by inserting a first bending section, which is formed by said heat exchanger molded in a series of "S" shapes, into a mold main body for manufacturing a header cap, and by injecting melted plastic material into said mold main body under the state of covering the mold main body with a mold cap; and
   - engaging said first header cap with a first header main body having an inlet pipe and an outlet pipe.

18. The method of claim 17, further comprising the steps of:
   - manufacturing a second header cap by inserting a second bending section of said heat exchanger into said mold main body, and by injecting melted plastic material into said mold main body under the state of covering the mold main body with the mold cap; and
   - engaging said second header cap with a second header main body.

* * * * *

US005992508A

United States Patent [19]

[11] **Patent Number: 5,992,508**

[45] **Date of Patent: Nov. 30, 1999**

Lowenstein et al.

[54] **THIN PLASTIC-FILM HEAT EXCHANGER FOR ABSORPTION CHILLERS**

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[73] Assignee: **Gas Research Institute**, Chicago, Ill.

[21] Appl. No.: **08/718,037**

[22] Filed: **Sep. 23, 1996**

Related U.S. Application Data

[63] Continuation of application No. 08/303,476, Sep. 9, 1994, abandoned.

[51] **Int. Cl.**[6] **F28F 7/00**

[52] **U.S. Cl.** **165/46**; 165/905

[58] **Field of Search** 165/46, 905

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Primary Examiner—John Fox

Attorney, Agent, or Firm—Dick and Harris

[57] **ABSTRACT**

A thin plastic-film heat exchanger element for apparatus, such as absorption chillers, is provided, having improved strengthening in the turning regions of the fluid passages, for enhanced resistance to bursting. A method of manufacture, for reduced wrinkling or pleating in the turning regions, is also disclosed.

8 Claims, 3 Drawing Sheets

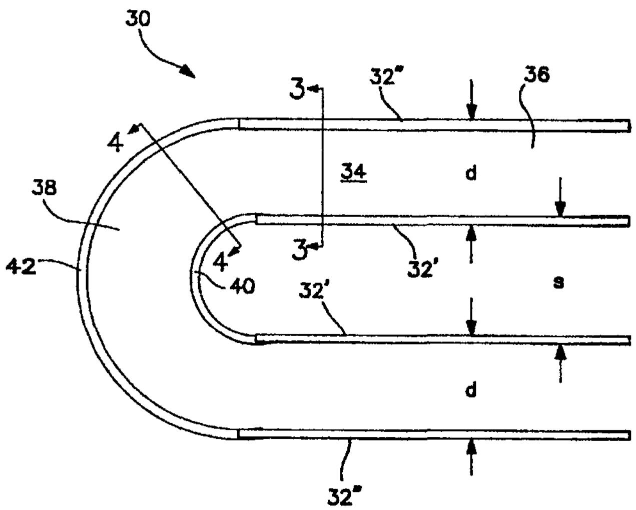


FIG. 1
PRIOR ART

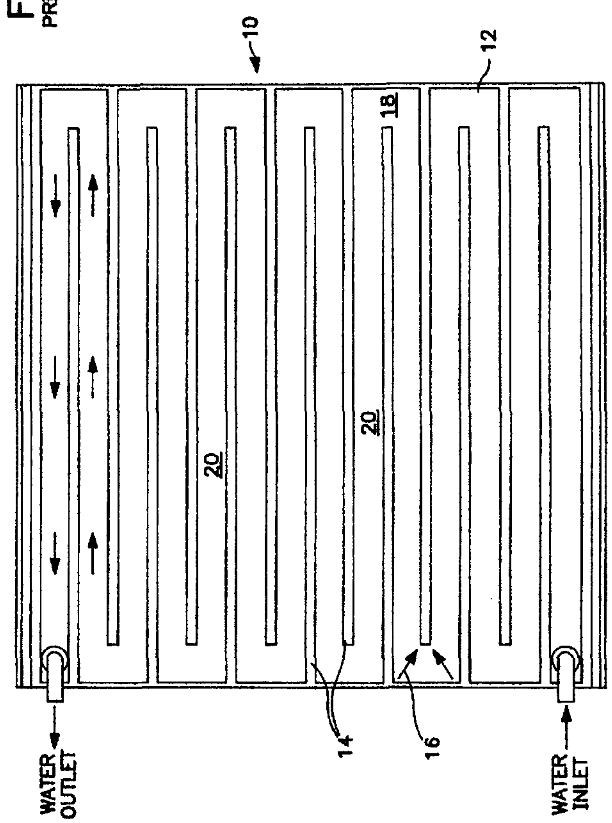
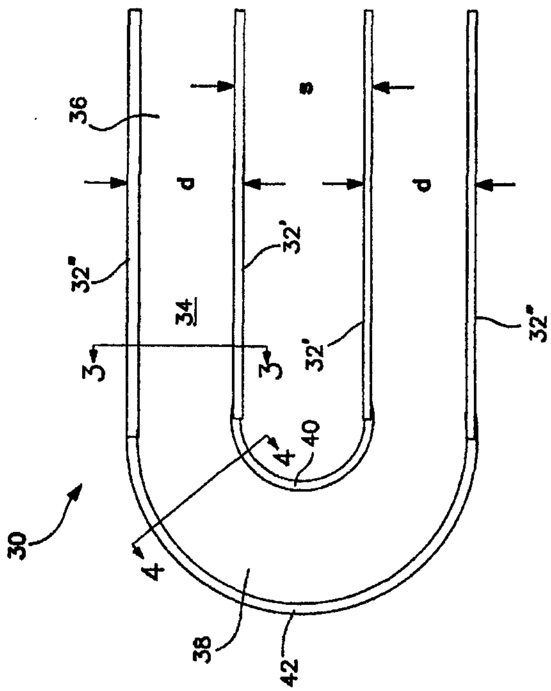


FIG. 2



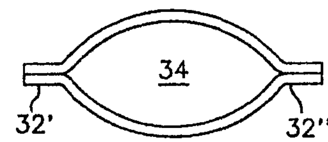


FIG. 3

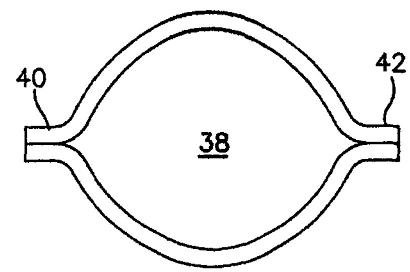


FIG. 4

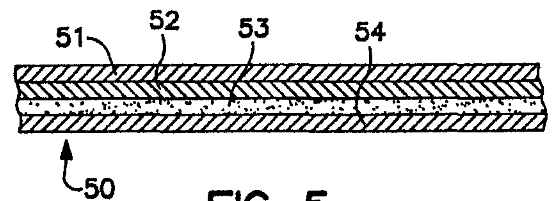


FIG. 5

THIN PLASTIC-FILM HEAT EXCHANGER FOR ABSORPTION CHILLERS

This is a file wrapper continuing application of application Ser. No. 08/303,476, filed Sep. 9, 1994, now hereby abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to heat exchanger elements of the type formed by two layers of thin-film plastic material, in which flow passages are formed by the advantageous placement of seams or welds between the two layers, for example, by heat sealing or ultrasonic welding, to produce a serpentine passage through the heat exchanger element. The present invention is further directed to such heat exchanger elements, as may be employed in the field of absorption heat pump apparatus.

2. Prior Art

Gas-fired *absorption heat pump apparatus, particularly* absorption chillers, in order to have high enough coefficients of performance, in order to be efficient and competitive with presently used, more conventional cooling apparatus, require the use of large area heat exchanger elements, in the absorber and evaporator sections of the heat pump systems. However, with increased size, comes increased weight and cost. Accordingly, alternatives to metal-construction heat exchanger elements are being sought.

One alternative which is being explored, is the use of plastic film heat exchanger elements, in which each of the one or more elements is composed of two sheets of thin plastic film, which are bound or welded to one another, with serpentine passages formed between the sheets by a plurality of seams or welds formed by thermal or ultrasonic welds.

Such heat exchanger elements typically will be situated in a working environment of less than atmospheric pressure, in a vacuum vessel and during operation, are exposed to a continuous partial vacuum. Accordingly, the material from which the heat exchanger element is constructed must be resistant to creep, particularly since such heat exchanger elements are intended to be long lifespan components (10–20 years).

An additional consideration is that the plastic material must be resistant to the migration through the material of non-condensable gases, which may be entrained in the fluid (typically water, or a water-based solution). If such gases escape through the heat exchanger walls into the vacuum vessel, then the efficiency of the absorber/evaporator is diminished. Currently known metallic heat exchanger element based systems have scheduled purges of such gases from their vacuum vessels at regular intervals. Accordingly, it would be desirable to construct a plastic film heat exchanger element which has a low enough permeability such that purges would not be required more often than with conventionally known systems.

A plastic-film heat exchanger element is disclosed in May, U.S. Pat. No. 4,933,046, in which the heat exchanger element is used as the condenser for a water purifying system. The heat exchanger element has passageways, formed by thermal welds, which are substantially rectangular in plan, and generally circular in cross-section, with cross-sectional areas which decrease, proceeding from an upper (steam) portion to a lower (condensate) portion.

Tubin, U.S. Pat. No. 4,118,946, discloses a personnel cooler, featuring a plastic film heat exchanger element configured as a vest, in which cooling fluids are disposed.

Dodds, U.S. Pat. No. 4,693,302, discloses a thin plastic sheet heat exchanger element having serpentine fluid passages formed by curvilinear patterns of welds. One embodiment is made of two films of equal thickness, resulting in fluid passages that are substantially round in shape. In another embodiment, sheets of unequal thickness are employed, which yield fluid passages which are flattened on one side.

Plastic film heat exchanger elements cannot operate at the same kinds of pressures that metal-constructed heat exchanger elements can. Accordingly, it is desirable to increase the potential operating pressure of such heat exchanger elements. The bends in the serpentine passageways are generally those portions of the heat exchanger elements which are most vulnerable to failure.

Furthermore, since additional sheet material area is necessary to accommodate the fluid passages, during manufacture, it is difficult to avoid the generation of creases or folds, in the corners of the bends. Such creases create flow inefficiencies, and create sites for fatigue and potential failure, as well.

Accordingly, it would be desirable to provide a plastic film heat exchanger element which would be substantially free of such creases or folds in the corner regions.

DISCLOSURE OF THE INVENTION

The present invention is a heat exchanger apparatus, of the type formed from two sheets of plastic material, and having a plurality of seams therebetween defining two or more liquid-tight passages through the heat exchanger apparatus, with one or more turning regions, each formed by an inner, substantially arcuate seam and an outer, substantially arcuate seam, and wherein the one or more turning regions connect the two or more passages, to define at least one liquid passage through the heat exchanger apparatus to enable a liquid heat-transfer medium to be passed therethrough for transferring heat to or from the liquid heat-transfer medium from or to the ambient surroundings of the heat exchanger apparatus. The apparatus further comprises means for facilitating resistance to bursting of the passages along the seams, from pressure exerted by the liquid heat-transfer medium which is operably disposed along the one or more turning regions.

In a preferred embodiment of the invention, the means for facilitating resistance to bursting of the passages comprises a thickening of the sheets of plastic material along the one or more turning regions.

In another preferred embodiment of the invention, the two or more liquid-tight passages extend substantially alongside one another and each passage has a predetermined diameter, the two or more liquid-tight passages being laterally separated from one another by a predetermined distance, and the means for facilitating resistance to bursting of said passages comprises the inner, substantially arcuate seam connecting a respective two of the two or more liquid-tight passages having an arc length greater than that of a semicircular arc having a diameter equal to the predetermined spacing between the respective two of the two or more liquid tight passages. Alternatively, the outer, substantially arcuate seam connecting a respective two of the two or more liquid-tight passages has an arc length greater than a semicircular arc having a diameter equal to the sum of the predetermined spacing between the respective two or more liquid-tight passages and the predetermined diameters of the respective two of the two or more liquid-tight passages.

In still another preferred embodiment, the inner, substantially arcuate seam connecting a respective two of the two or

more liquid-tight passages has an arc length greater than that of a semicircular arc having a diameter equal to the predetermined spacing between the respective two of the two or more liquid tight passages; and the outer, substantially arcuate seam connecting a respective two of the two or more liquid-tight passages has an arc length greater than a semicircular arc having a diameter equal to the sum of the predetermined spacing between the respective two or more liquid-tight passages and the predetermined diameters of the respective two of the two or more liquid-tight passages.

In one preferred embodiment of the invention, at least one of the sheets of plastic film material may be fabricated from one of the following materials: PET (sold under the name Mylar), PEEK, polysulphone, nylon 6, the material sold under the name Celcon, the material sold under the name Tedlar (polyvinyl fluoride), the material sold under the name Tefzel (ETFE) polyethylene, polypropylene, polystyrene and PVC. In another embodiment of the invention, at least one of the sheets of plastic material is a laminate of two or more layers of different plastic materials which may have the following layer structure: Mylar/PVDC/adhesive/polyethylene-EVA.

The invention also comprises a method for forming a heat exchanger apparatus of the type comprising two sheets of plastic material bonded together by a plurality of seams, and having two or more liquid-tight passages therein connected by one or more turning regions, each such turning region having an inner, substantially arcuate seam and an outer, substantially arcuate seam, to define at least one liquid passage path through the heat exchanger to enable a liquid heat-transfer medium to be passed therethrough for transferring heat to or from the liquid heat-transfer medium from or to the ambient surroundings of the heat exchanger apparatus. In particular, the method comprises the steps of: providing two sheets of plastic material; determining at least one desired liquid passage path to be defined in the heat exchanger apparatus; bonding the two sheets of plastic material to one another with a plurality of substantially continuous seams therebetween to form two or more liquid-tight passages through the heat exchanger apparatus, with one or more turning regions, each formed by an inner, substantially arcuate seam and an outer, substantially arcuate seam, the one or more turning regions connecting the two or more passages; inflating the heat exchanger apparatus by passing liquid through the liquid passage path; immersing a first end of the inflated heat exchanger apparatus into water of sufficiently high temperature to cause said plastic material to become thermoformable, so as to remove creases which may have formed in the one or more turning regions upon inflation of the heat exchanger apparatus; immersing a second, opposite end of the inflated heat exchanger apparatus into water of sufficiently high temperature to cause said plastic material to become thermoformable, so as to remove creases which may have formed in the one or more turning regions upon inflation of the heat exchanger apparatus, so as to provide a heat exchanger apparatus substantially free of creases in the one or more turning regions thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a prior art heat exchanger element;

FIG. 2 is a view of one turning region of a heat exchanger element according to the present invention.

FIG. 3 is a sectional view of the apparatus, as seen along lines 3—3 of FIG. 2;

FIG. 4 is a sectional view of the apparatus, as seen along lines 4—4 of FIG. 2;

FIG. 5 is a sectional elevation of a sheet of composite material for fabricating an apparatus according to an alternative embodiment.

BEST MODE FOR CARRYING-OUT THE INVENTION

While the present invention is susceptible of embodiment in many different forms, there is shown in the drawings and will be described herein in detail, a single preferred embodiment, with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention, and is not intended to limit the invention to the embodiment illustrated.

A prior art plastic film heat exchanger element **10** is illustrated in FIG. **1**. Two sheets **12** of thin film plastic material are bonded together by heat or ultrasonic energy, by a plurality of rectilinear seams **14**. When heat exchanger element **10** becomes "inflated" by the liquid during use, deep folds **16** may form in the turning regions **18**, which may affect the flow of the water through the passages **20** formed by seams **14**. The square, "hairpin" nature of the turning regions may also lead to a weaker overall heat exchanger structure, since the seams **14** in the vicinity of the turning regions bear greater stress from the flowing, pressurized water than do the seams forming the passages **20**.

A portion of a heat exchanger element **30**, according to the present invention is illustrated in FIG. **2**. Heat exchanger element **30** would also be formed from two sheets, typically in mirror image to one another. Seams **32'** and **32"** create the flow passages **34** comprising straight parallel portions **36**, and turning regions **38**. A typical heat exchanger element **30** will have a plurality of straight runs which are of uniform diameter d and spacing s, and the runs will be substantially parallel to one another. The seams may be formed, except as described hereinafter, by known means of thermally bonding or sealing layers of plastic sheet material.

The anticipated operational environment of heat exchanger element **30** will place considerable performance demands on the materials from which heat exchanger element **30** is made. For example, since heat exchanger element **30** is expected to have a 10–20 year lifespan, the plastic film should be from a material which has a relatively high tensile strength, and high creep resistance so as to reduce the likelihood of deformation, and/or failure through creep of the material.

In order to have an efficient heat transfer surface, the wall thickness of the plastic film should be limited to 6 mils or less, as a general consideration, since plastic materials typically have thermal conductivities which are 3 to 4 orders of magnitude less than metals. In addition, the tensile strength of plastic materials is usually 5 to 50 times less than even "weaker" metals, such as copper or brass.

In conventional metal heat exchanger elements, pressures of 60 pounds per square inch are known. These would be pressures typical of a lower floor absorption chiller for a mid- to high-rise building. Such pressures cannot presently be maintained in efficient plastic film heat exchanger elements, and so such applications cannot be considered reasonable goals for heat exchanger elements such as in the present invention. However, for smaller installations, such as rooftop units for low rise buildings, and advantageous fluid circuiting, absolute pressures for absorbers and evaporators can reasonably be kept in the range of 30 psi.

As discussed elsewhere herein, unless non-aerated water is employed in the cooling system, there will be certain amounts of oxygen and nitrogen dissolved into the water, which, due to the pressure differential across the heat exchanger element film, will tend to be driven from the water and through the film. Such gases must then be purged occasionally from the vacuum vessel for efficient operation.

Accordingly, an ideal plastic film would have a high tensile strength, low permeability, high thermal conductivity, and a resistance to creep under stress over time. An additional characteristic is that the plastic should be able to resist attack by the absorbent solution material, at absorber operating temperatures. For example, a typical absorbent solution is lithium bromide.

Candidate materials which have been contemplated are the materials known as PET (sold under the name Mylar), PEEK, polysulphone, nylon 6, the material sold under the name Celcon, the material sold under the name Tedla (polyvinyl fluoride) the material sold under the name Tefzel (ETFE), polyethylene, polypropylene, polystyrene and PVC. All of these materials have high tensile strengths of over 7000 psi. However, a review of available published statistics on such characteristics as permeability (when available), thermal conductivity, heat sealability, etc. reveals that there is no particular correlation between one characteristic and another. However, the aforementioned materials have been identified as having combinations of characteristics which make them candidates for use as single material plastic films.

As an additional possible solution to the need for a versatile material, a composite laminated film is contemplated, which would have, for example, at least an extremely thin high tensile strength layer, and a low permeability layer. A layer having thermal bonding characteristics might also be provided. One possible laminate material is commercially known as PM300S, and is made up of the following layers: Mylar/PVDC/adhesive/polyethylene-EVA. FIG. 5 is a sectional view of a portion of a composite sheet 50, showing the layers of Mylar (51), PVDC (52), adhesive (53) and polyethylene-EVA (54). The material has a film thickness of 2.5 mil, and has an oxygen permeability of 0.49 cubic centimeters per 100 square inches-days-atmospheres. A single 0.325" diameter tube fabricated from this material has an anticipated burst pressure of 60 psi, and a complete exchanger element might possibly have a burst pressure in the range of 20+ psi, since, as is known, the ultimate bursting pressure of a completed heat exchanger element will typically be far less than the experimental or theoretical pressure limit of the material, for example, as formed into a simple single tube, due the inherent susceptibility of the seams in the regions of the turning regions in the completed element.

One method of improving the resistance to bursting in the completed heat exchanger element, is to avoid the use of "hairpin" turning regions. Accordingly, in order to spread the stresses over a greater length of seam, for a given straight run tube diameter d, one or both of the inside seam 40, and outside seam 42 in the turning region 38 may be provided with an arc length greater than that of a semicircular arc having a diameter equal to the spacing between the straight runs, in the case of an inside seam 40, or of the sum of the spacing s and the sum of the diameters d of the two adjacent straight run passages. This may be accomplished by providing that seams 40 and/or 42 have increased radii of curvature, and extend around through greater than 180° in which the outer seam 42 has a diameter which extends wider than the distance between seams 32". By constructing the inside and/or outside seams of the turning regions in this manner, the stress and pressure which is imposed on the turning regions is spread out over a greater arc length, and tends to reduce the likelihood of bursting and seam failure.

A further method of reducing the likelihood of failure in the turning regions is to increase the thickness of the plastic sheets, only in the areas of the turning regions. FIG. 3 illustrates a sectional view through straight flow passage 34, while FIG. 4 illustrates a sectional view in turning region 38, showing the increased thickness of the sheet material. However, this solution only is appropriate for heat exchanger elements which are formed from single material, non-laminate sheets. Laminate sheet heat exchangers must rely upon their high-strength layers, and the previously described improved turning region construction for failure resistance.

One potential manufacturing problem which may arise, as previously described, is that upon "inflation" of the heat exchanger element, deep creases or folds form on the turning regions. This is a potential problem particularly for stiffer plastic films, such as a high density polyethylene (HDPE). A method for substantially preventing the formation of these creases is to fabricate the heat exchanger element from the flat film. Then, one end of the element is immersed in hot water (or other non-reactive fluid medium) at a predetermined temperature, while pressurizing the element at a predetermined pressure. Under the action of the pressure and heat, the turning regions in the inflated immersed end becomes thermoformed, and the creases are substantially eliminated. After cooling of the thermoformed end, this procedure is repeated for the other end of the heat exchanger element, to provide a heat exchanger element which is substantially free of creases or folds in the turning regions, during operation.

The foregoing description and drawings merely explain and illustrate the invention and the invention is not limited thereto except insofar as the appended claims are so limited, as those skilled in the art who have the disclosure before them will be able to make modifications and variations therein without departing from the scope of the invention.

We claim:

1. A heat exchanger apparatus comprising:

two sheets of plastic material having a plurality of substantially straight passage seams therebetween defining two or more substantially straight liquid passages through the heat exchanger apparatus, and further defining one or more turning regions, each turning region being formed by an inner, substantially arcuate turning region seam and an outer, substantially arcuate turning region seam,

the one or more turning regions connecting the two or more passages, in a substantially continuous manner, to define at least one substantially continuous, non-branching liquid conduit through the heat exchanger apparatus, each such at least one substantially continuous, non-branching liquid conduit having an inlet for permitting entry of liquid heat-transfer medium into the heat exchanger apparatus, and an outlet for permitting the liquid-heat transfer medium to exit the heat exchanger apparatus, the liquid conduit proceeding in a substantially continuous, non-branching manner from the inlet to the outlet, to enable a liquid heat-transfer medium to be passed therethrough for transferring heat to or from the liquid heat-transfer medium from or to the ambient surroundings of the heat exchanger apparatus; and

means for facilitating resistance to bursting of said apparatus along the turning region seams, from pressure exerted by the liquid heat-transfer medium, operably disposed along the one or more turning regions.

2. The heat exchanger apparatus according to claim 1 wherein the means for facilitating resistance to bursting of said passages comprises:

a thickening of the sheets of plastic material along the one or more turning regions.

3. The heat exchanger apparatus according to claim 1 wherein the two or more liquid passages extend substantially alongside one another and each passage has a predetermined diameter,

the two or more liquid passages being laterally separated from one another by a predetermined distance,

the means for facilitating resistance to bursting of said passages comprises the inner, substantially arcuate seam connecting a respective two of the two or more liquid passages having an arc length greater than that of a semicircular arc having a diameter equal to the predetermined spacing between the respective two of the two or more liquid passages.

4. The heat exchanger apparatus according to claim 1 wherein the two or more liquid passages extend substantially alongside one another and each passage has a predetermined diameter, and, the two or more liquid passages being laterally separated from one another by a predetermined distance,

the means for facilitating resistance to bursting of said passages comprises the outer, substantially arcuate seam connecting a respective two of the two or more liquid passages having an arc length greater than a semicircular arc having a diameter equal to the sum of the predetermined spacing between the respective two or more liquid passages and the predetermined diameters of the respective two of the two or more liquid passages.

5. The heat exchanger apparatus according to claim 1 wherein the two or more liquid passages extend substantially alongside one another and each passage has a predetermined diameter, and the two or more liquid passages being laterally separated from one another by a predetermined distance,

the means for facilitating resistance to bursting of said passages comprises the inner, substantially arcuate seam connecting a respective two of the two or more liquid passages having an arc length greater than that of a semicircular arc having a diameter equal to the predetermined spacing between the respective two of the two or more liquid passages; and

the outer, substantially arcuate seam connecting a respective two of the two or more liquid passages having an arc length greater than a semicircular arc having a diameter equal to the sum of the predetermined spacing between the respective two or more liquid passages and the predetermined diameters of the respective two of the two or more liquid passages.

6. The heat exchanger apparatus according to claim 1 wherein at least one of the sheets of plastic film material is selected from the group comprising PET (sold under the name Mylar), PEEK, polysulphone, nylon 6, Celcon, Tedlar (polyvinyl fluoride) Tefzel (ETFE), polyethylene, polypropylene, polystyrene and PVC.

7. The heat exchanger apparatus according to claim 1 wherein at least one of the sheets of plastic material is a laminate of two or more layers of different plastic materials.

8. A heat exchanger apparatus comprising:

two sheets of plastic material having a plurality of passage seams therebetween defining two or more liquid passages through the heat exchanger apparatus, and further defining one or more turning regions, each turning region being formed by an inner, substantially arcuate turning region seam and an outer, substantially arcuate turning region seam,

the one or more turning regions connecting the two or more passages, to define at least one liquid conduit through the heat exchanger apparatus to enable a liquid heat-transfer medium to be passed therethrough for transferring heat to or from the liquid heat-transfer medium from or to the ambient surroundings of the heat exchanger apparatus; and

means for facilitating resistance to bursting of said apparatus along the turning region seams, from pressure exerted by the liquid heat-transfer medium, operably disposed along the one or more turning regions,

the at least one of the sheets of plastic material being a laminate of two or more layers of different plastic materials,

the laminate of two or more layers of different plastic materials having the following layer structure:

Mylar/PVDC/adhesive/polyethylene-EVA.

* * * * *

US006660198B1

(12) **United States Patent**
Fischer

(10) **Patent No.:** **US 6,660,198 B1**
(45) **Date of Patent:** **Dec. 9, 2003**

(54) **PROCESS FOR MAKING A PLASTIC COUNTERFLOW HEAT EXCHANGER**

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(73) Assignee: **Marconi Communications, Inc.**, Cleveland, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 365 days.

(21) Appl. No.: **09/664,624**

(22) Filed: **Sep. 19, 2000**

(51) **Int. Cl.**[7] **B29C 39/10**
(52) **U.S. Cl.** **264/138**; 264/238; 264/250; 264/263; 264/275
(58) **Field of Search** 264/138, 263, 264/238, 275, 250

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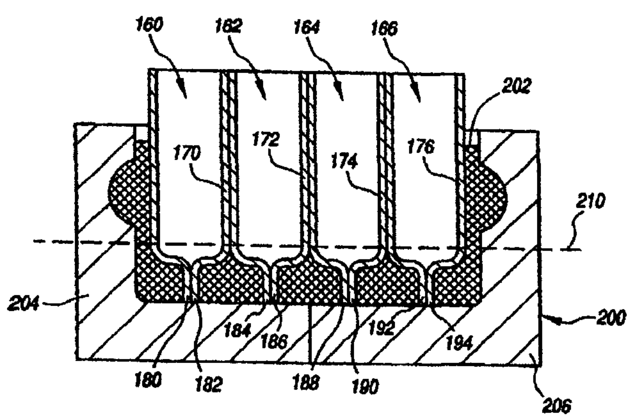
Primary Examiner—Edmund H. Lee
(74) *Attorney, Agent, or Firm*—Jones Day

(57) **ABSTRACT**

A process for making inner and outer ducts for a simple but effective plastic heat exchanger by a simple blow molding or thermoforming technique. Seals are formed by providing initially closed inner ducts which are stacked on one another and the end portions of the inner ducts are placed in a mold. A castable adhesive sealant is placed in the mold and around the stacked inner ducts. After curing, the mold and the stacked inner ducts are separated and a portion of the stack and a portion of the seal material are cut and removed. Thereafter, the outer duct is positioned about the stacked inner ducts so that two different flow paths are formed. Instead of molding the seal, a preformed seal may be press fitted to the stack of inner ducts.

5 Claims, 10 Drawing Sheets



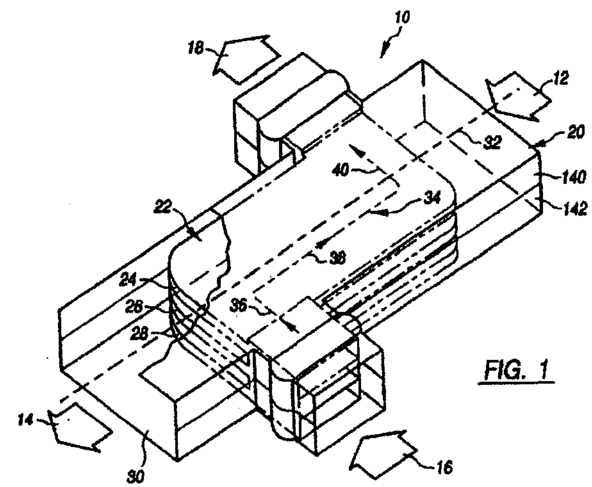


FIG. 1

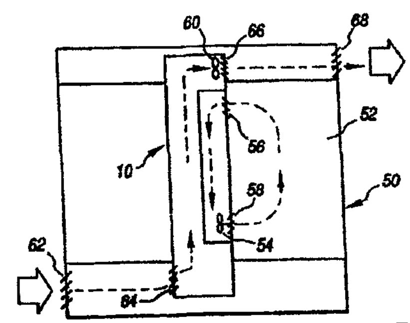


FIG. 2

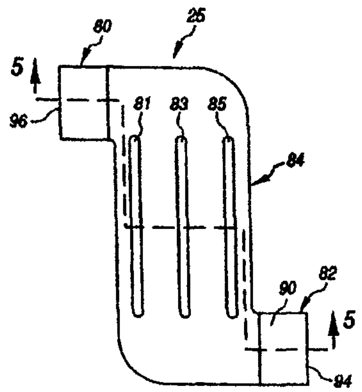


FIG. 3

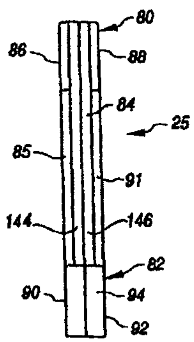


FIG. 4

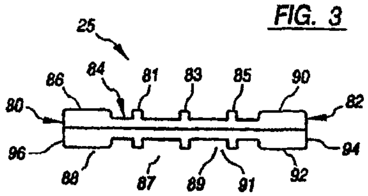


FIG. 5

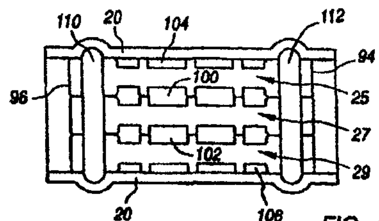


FIG. 6

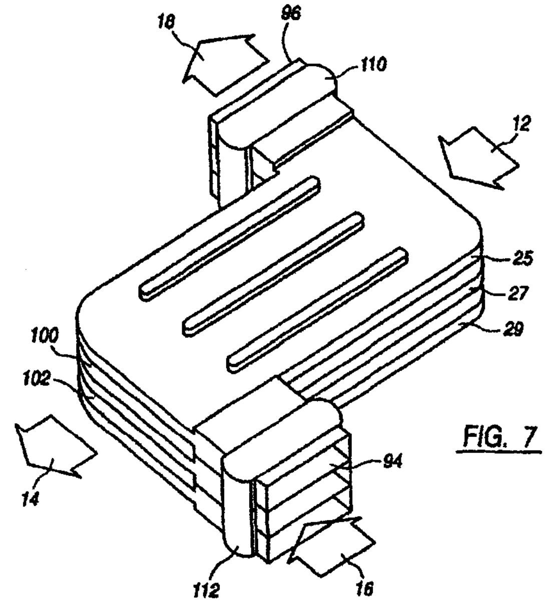


FIG. 7

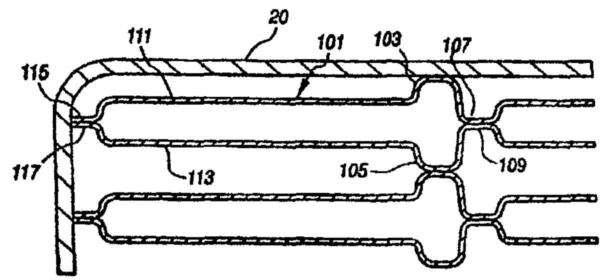


FIG. 8

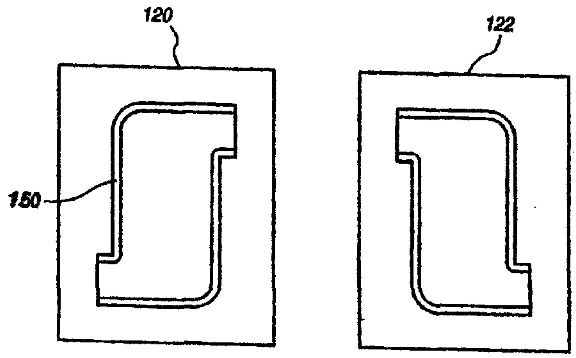


FIG. 9

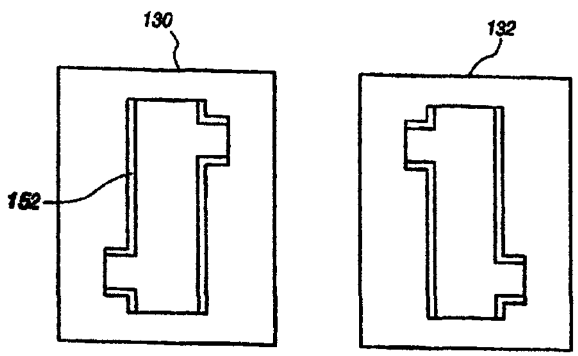


FIG. 10

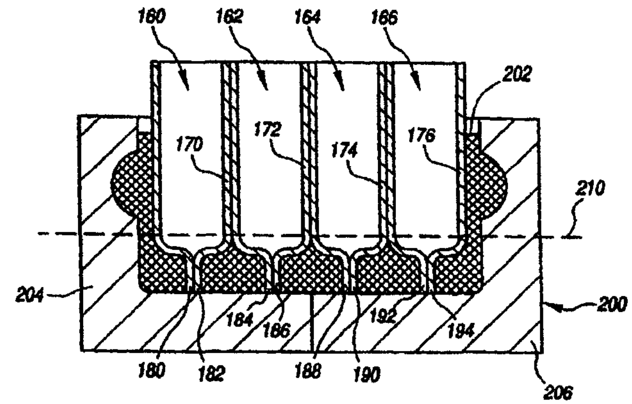


FIG. 11

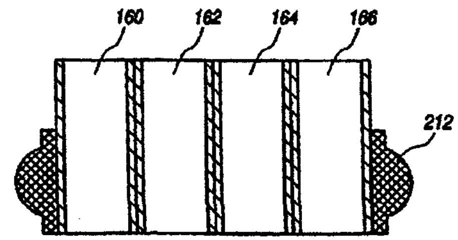


FIG. 12

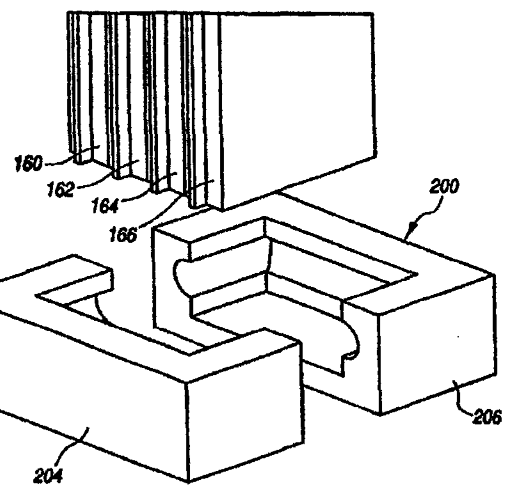


FIG. 13

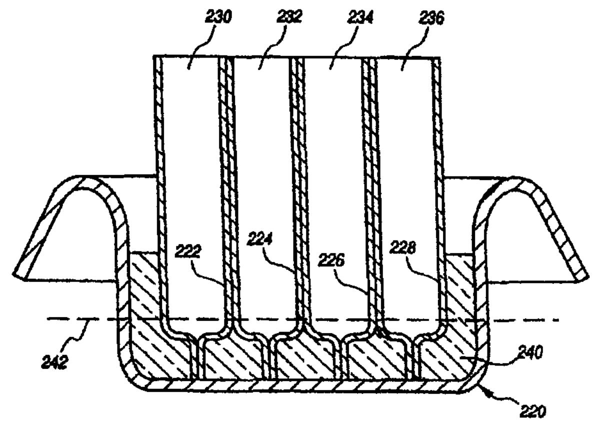


FIG. 14

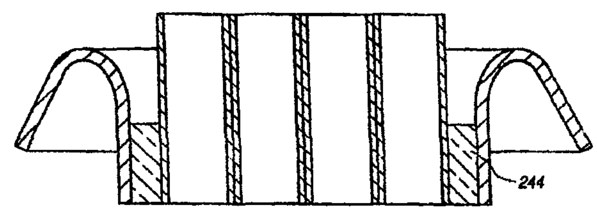


FIG. 15

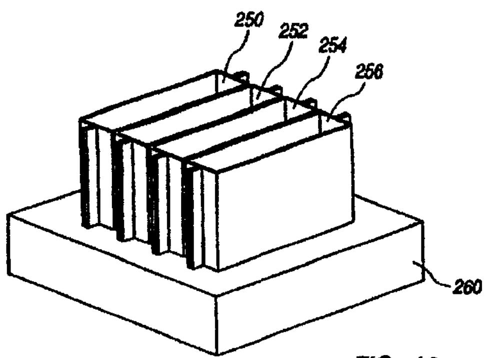


FIG. 16

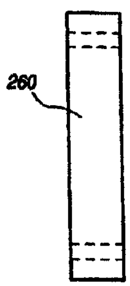


FIG. 17

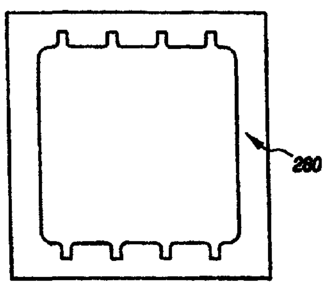


FIG. 18

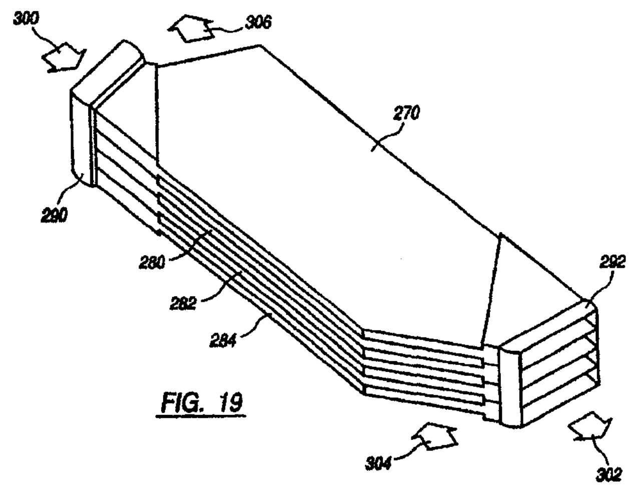


FIG. 19

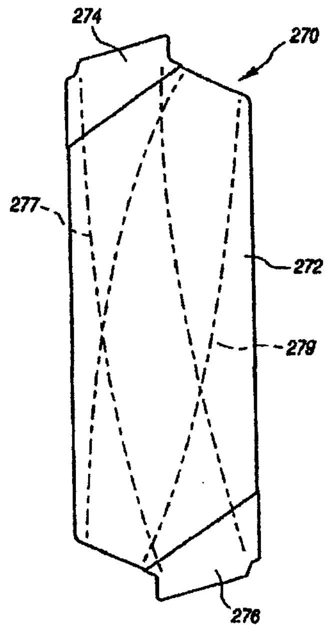


FIG. 20

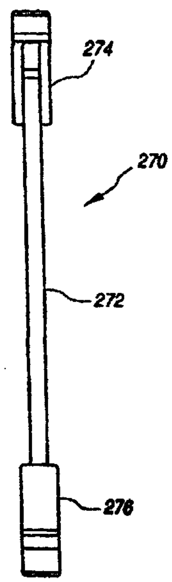


FIG. 21

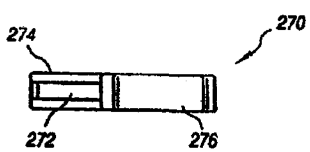


FIG. 22

PROCESS FOR MAKING A PLASTIC COUNTERFLOW HEAT EXCHANGER

BACKGROUND OF THE INVENTION

1. Field of The Invention

The present invention relates to a plastic counterflow heat exchanger and more particularly to a counterflow heat exchanger that is inexpensive to manufacture and yet is efficient and effective.

2. Description Of The Related Art

Inexpensive plastic heat exchangers are very useful because of low manufacturing cost and because such heat exchangers can be custom molded to fit specific spaces, such as those in crowded, free-standing equipment cabinets commonly used to house telecommunications equipment. In such equipment cabinets, the fluid to be cooled is air from a sealed equipment compartment. The cooling fluid, typically, is ambient air. Hence, the fluids being handled are not usually corrosive, nor is high pressure involved.

Most plastic heat exchangers are of the cross flow type as exemplified by U.S. Pat. Nos. 4,997,031 and 4,858,685; and PCT applications SE82/00393 and GB98/03368. Cross flow heat exchangers are typically constructed of rectangular panels or sheets which are stacked together and which have small projections on one of their major surfaces to space one sheet from the next. The cooled fluid enters from one side of the rectangular stack and exits from an opposite side. In a like fashion the cooling fluid enters the stack from a side 90 degrees removed from the flow of the cooled fluid and exits through an opposite side. The fluid flows alternate between sheets, and seals are provided at the corners of the stack to separate the two flows. Such seals are generally adequate in cross flow heat exchangers.

An example of a plastic counterflow heat exchanger is UK patent application No. GB 2,158,569. However, ducting to and from the heat exchanger is not addressed in the application even though it is an important consideration in the design of such units. Further, seals for plastic counterflow heat exchangers are difficult to arrange. Hence, there is still a need for effective, efficient and low cost counterflow heat exchangers.

BRIEF SUMMARY OF THE INVENTION

The present invention resolves some of the problems of the related art by providing a process for forming a plastic counterflow heat exchanger comprising the steps of molding a plurality of inner ducts, each duct having larger end portions and a smaller middle portion, stacking the inner ducts on their end portions whereby spaces exist around the middle portions, forming a seal around each stack of end portions, molding an outer duct, and positioning the outer duct about the stack of inner ducts.

It is an object of the present invention to provide a process for making a plastic counterflow heat exchanger which is simple, reliable and inexpensive. Another aim of the present invention is to provide a plastic counterflow heat exchanger having low tooling costs. Yet another aspect of the present invention is to provide a plastic counterflow heat exchanger process which allows inexpensive custom designs and dimensions for numerous different applications. Still another aspect of the present invention is to provide a plastic counterflow heat exchanger which is very efficient and highly effective.

A more complete understanding of the present invention and other objects, aspects, aims and advantages thereof will

be gained from a consideration of the following description of the preferred embodiments read in conjunction with the accompanying drawings provided herein.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. 1 is a diagrammatic isometric view, partially broken away, of a plastic heat exchanger.

FIG. 2 is a diagrammatic elevation view of an electrical cabinet illustrating the basic concept of a heat exchanger in such an environment.

FIG. 3 is a front elevation view of an inner duct that may be used in the heat exchanger shown in FIG. 1.

FIG. 4 is a side elevation view of the inner duct shown in FIG. 3.

FIG. 5 is a sectional plan view of the inner duct shown in FIGS. 3 and 4 and taken along the line 5—5 of FIG. 3.

FIG. 6 is a plan view of a heat exchanger similar to that shown in FIG. 1.

FIG. 7 is a diagrammatic isometric view of a stack of inner ducts.

FIG. 8 is a partial diagrammatic section view of a modified heat exchanger.

FIG. 9 is a front elevation view of mirror image molds for forming an inner duct.

FIG. 10 is a front elevation view of mirror image molds for forming an outer duct.

FIG. 11 is a diagrammatic plan view of a stack of inner ducts disposed in a mold.

FIG. 12 is a diagrammatic plan view of the inner ducts of FIG. 11 after removal of the mold and after a cutting operation.

FIG. 13 is a diagrammatic isometric view showing the stack inner ducts being received by an open mold.

FIG. 14 is a diagrammatic plan view of a stack of inner ducts disposed in a seal cup.

FIG. 15 is a diagrammatic plan view of the inner ducts after cutting of the seal cup and of a portion of the inner ducts.

FIG. 16 is a diagrammatic isometric view of a stack of inner ducts having a seal press fitted to the stack.

FIG. 17 is a front elevation view of the seal shown in FIG. 16.

FIG. 18 is a side elevation view of the seal shown in FIGS. 16 and 17.

FIG. 19 is a diagrammatic isometric view of another variation of a stack of inner ducts.

FIG. 20 is a front elevation view of the inner duct shown in FIG. 19.

FIG. 21 is a side elevation view of the inner duct shown in FIGS. 19 and 20.

FIG. 22 is a plan view of the inner duct shown in FIGS. 19–21.

DETAILED DESCRIPTION OF THE INVENTION

While the present invention is open to various modifications and alternative constructions, the preferred embodiments shown in the drawings will be described herein in detail. It is understood, however, that there is no intention to limit the invention to the particular forms disclosed. On the contrary, the intention is to cover all modifications, equivalent structures and methods, and alternative constructions falling within the spirit and scope of the invention as expressed in the appended claims.

Referring now to FIG. 1, there is illustrated a heat exchanger **10** with counterflowing fluid paths, one path to be cooled and represented by an arrow **12** as the fluid enters the heat exchanger and another arrow **14** as the cooled fluid exits the heat exchanger, and a fluid path for a fluid doing the cooling represented by an arrow **16** for the cooling fluid entering the heat exchanger and an arrow **18** for the cooling fluid exiting the heat exchanger. For purposes of illustration, the heat exchanger includes an outer duct **20** which is generally tubular in shape and a stack **22** of inner ducts, such as the inner ducts **24**, **26** and **28**. The stacked inner ducts are disposed in an interior chamber **30** formed within the outer duct. As can be seen, the heat exchanger **10** is simply constructed and arranged although a commercial heat exchanger will have many more inner ducts as will be explained below.

As can also be appreciated, the heat exchanger **10** of the present invention is a counterflow heat exchanger even though the cooled fluid path **12**, **14** and the cooling fluid path **16**, **18** begin and end generally perpendicular to each other. The cooled fluid path **12**, **14** establishes a first direction represented by a phantom line **32**. The cooling fluid path **16**, **18** is represented by a curved phantom line **34** which diagrammatically may be divided into an inlet portion **36**, a middle portion **38** and an outlet portion **40**. During the time that the cooling fluid path is in its middle portion, it is disposed substantially parallel to the first direction **32** but opposite to it. In this way a counterflow arrangement is created. As already mentioned, counterflow heat exchangers are more efficient when compared to cross flow heat exchangers, all other variables being equal.

It is contemplated that the heat exchanger **10** may be used in an electrical enclosure or cabinet **50** as shown in diagrammatic form in FIG. 2 where the heat exchanger is placed in a sealed equipment chamber or compartment **52**. A fan **54** draws air to be cooled from the compartment through an inlet vent **56**, through the heat exchanger along a downward flow path and then back to the compartment through an outlet vent **58**. Meanwhile, cooling air from outside the cabinet is drawn in by a fan **60** through a vent **62** in an outer wall of the cabinet, and through an inlet vent **64** of the heat exchanger. The air moves along an upwardly directed flow path through the heat exchanger in a parallel but opposite direction from the cooled air, and then through a heat exchanger outlet vent **66**. Thereafter, the cooling air is exhausted through a vent **68** in another outer wall of the cabinet. It is noted, that the heat exchanged between the two air flows takes place without the cooling or cooled air ever mixing. Thus, the compartment **52** remains sealed even though its air is cooled.

The cooling and cooled fluid flows may move in an opposite direction from that shown if desired, and the cooling fluid may be represented by the arrows **12**, **14** and the cooled fluid may be represented by the arrows **16**, **18**.

Referring now to FIGS. 3, 4 and 5, another embodiment of an inner duct is shown in more detail. The duct **25** is a curved conduit forming a fluid passage with end portions **80**, **82** and a middle portion **84**. To help understand the relative dimensions of the duct, the vertical distance of the inner duct in FIG. 3 is defined as the length, the horizontal distance is defined as the width and the vertical distance in FIG. **5** is defined as the depth. It is quite apparent that the depth dimension of the end portions **80**, **82** is about twice the depth dimension of most of the middle portion **84**. Also, the upper and lower surfaces **86**, **88**, **90** and **92**, FIG. **5**, of the end portions are planar. This configuration allows the inner ducts to be stacked on the planar end portions as shown in FIGS. **6** and **7**. When this is done, the end portions present a large area inlet **94** and a similar large area outlet **96** to the flow of fluid, such as the cooling air **16**, **18**.

The passage for fluid formed within the inner duct is initially generally horizontal through the inlet end portion **82** as shown in FIG. 3, then generally vertical through the middle portion **84** and then generally horizontal again through the outlet end portion **80**. As can be readily appreciated, the inlet and outlet flow paths of the inner duct are generally perpendicular to the flow path through the middle portion of the duct. This feature allows the flow path through the middle portion **84** of the inner duct to be approximately parallel to the direction **32**, FIG. **1**, of the flow path through the outer duct. It is to be understood that the specific design of the inner and outer ducts may be varied from what is shown depending upon the availability of space or the specific geometry of the intended enclosure.

The inner duct **25** may also include projecting ribs **81**, **83**, **85** on one side of the middle portion **84** and another set of projecting ribs **87**, **89**, **91** on the opposite side of the middle portion. These ribs strengthen the walls of the inner duct, prevent flexing due to air pressure, may be used to optimize airflow (so as to eliminate dead spots) and provide additional surfaces to contact an adjacent inner duct when stacked as shown in FIG. 6. The ribs also increase the surface area between air flows which enhances heat transfer. It is to be noted that the inner ducts **24**, **26**, **28**, FIG. **1**, are a slightly different embodiment from inner duct **25** in that no projecting ribs are formed. Hence, it is understood that more or less ribs may be used, or none at all. Also, the shape of the ribs may be varied without departing from the present invention.

Referring now to FIGS. 6 and 7, three inner ducts **25**, **27** and **29** are shown in a stacked disposition. When this is done, the larger end portions ensure that there is a space to each side of the middle portion such as the space **100** between the inner ducts **25** and **27** and the space **102** between the inner ducts **27** and **29**. There are also top and bottom spaces **104**, **106** between the inner duct **25** and the outer duct **20** and the inner duct **29** and the outer duct **20**, respectively. These spaces form fluid passageways within the outer duct, where the passageways are coincident with the spaces **100**, **102**, **104** and **106**. To ensure that there is no leakage of the cooled air flow passing through the outer duct and between the inner ducts, nor mixing of the cooled air and the cooling air, a first seal **110** is provided around the first end portions of the stacked inner ducts and a second seal **112** is provided around the second end portions of the stacked inner ducts. The fluid passages for the cooling air (or cooled air) may begin at the inlet end portions **94** of the stacked inner ducts, continue through the middle portions and exhaust through the stacked outlet end portions **96**. The fluid passageways for the cooled air (or cooling air) are formed by the spaces between the middle portions of the inner ducts inboard of the two seals **110**, **112**. In practice there will be numerous inner ducts within a single outer duct and not just the three or four shown here for illustrative purposes. The large number of inner ducts results in a large number of fluid passageways. In turn, this increases the amount of inner duct surface area between the two fluids and enhances heat transfer between them.

Referring now to FIG. **8**, yet another embodiment of the inner duct is shown. The inner duct **101** includes upper projecting rib **103** and lower projecting rib **105**. Inboard of these projecting ribs are receding ribs, upper receding rib **107** and lower receding rib **109**. The receding ribs may be used to strengthen the inner duct and to provide regions or webs for attachment, such as by welding. For example, an upper half **111** of the inner duct may be welded to a lower half **113** of the inner duct at the receding ribs **107**,**109**. This may be done to enhance the welds made along upper peripheral lip **115** and lower peripheral lip **117** of the inner duct halves. Greater strength of the walls and of the welds may be required if the pressure of the flowing air is increased. Again, the inner ducts of FIG. **8** are stacked within the outer duct **20**.

The inner ducts may be inexpensively manufactured using a pair of mirror image molds **120**, **122**, FIG. 9, and a blow molding or thermoforming technique. These techniques are well known to those skilled in the art. In a like manner, the outer duct **20** may be made inexpensively using a pair of mirror image molds **130**, **132**, FIG. 10, and a blow molding or thermoforming technique. The inner and outer ducts may be split evenly so that the molds are identical except for orientation. Referring to FIG. 1, the two halves **140**, **142** of the outer duct are clearly shown. The same is true of the two halves **144**, **146** of the inner duct **25** as shown in FIG. 4.

Each of the duct halves may include a peripheral lip, such as the lip **150**, FIG. 9 and the lip **152**, FIG. 10. As mentioned, these are used to attach the duct halves together such as by ultrasonic welding or perhaps by an adhesive. These attachment techniques are also well known by those skilled in the art. Wall thicknesses for both the inner ducts and the outer duct are within the range of 0.010 to 0.020 inches and a thermoplastic plastic material, such as polycarbonate may be used for both ducts. Less expensive plastics may also be used but other characteristics of such plastics may not meet customer requirements for use in outdoor equipment cabinets. Under some circumstances, a heat conductive resin may be desirable, and it may be desirable to use an injection molding technique for forming the ducts.

The actual size of a heat exchanger for an equipment cabinet may fall within the approximate dimensions of thirty inches in length, eighteen inches in width and six inches in depth. Also a heat exchanger may include thirty to sixty inner ducts within one outer duct.

Referring now to FIGS. 11, 12, and 13, one process for forming the seals about the end portions of the inner ducts is illustrated. A stack of four inner ducts **160**, **162**, **164**, **166** are placed adjoining one another. It is to be noted that the end portions **170**, **172**, **174**, **176**, respectively, of the four ducts are initially sealed. The end portions are formed with peripheral lips **180**, **182**, **184**, **186**, **188**, **190**, **192** and **194**, respectively. After the molded halves of the inner ducts are sealed together, the first end portions are placed into a mold **200**. Thereafter, a castable adhesive sealant **202** is placed into the mold such as by pouring. After the sealant hardens, the mold, which may be in two halves **204**, **206**, is removed. A "cut line" is established, such as represented in FIG. 11 by the horizontal phantom line **210** and a part of the end portion is removed. By initially closing the end portions, a molding procedure may be used without causing any blockage of the ducts. The cut opens the end portions, and thereby the ducts, while maintaining the seal **212** as shown in FIG. 12. Molds and castable adhesive sealants are well known by those skilled in the art.

A variation of the process is shown in FIGS. **14** and **15**. *Instead of a mold, a seal cup* **220** *is used to receive four end* portions **222**, **224**, **226**, **228** of four stacked inner ducts **230**, **232**, **234**, **236**, respectively. A castable adhesive sealant **240** is poured into the cup and then the sealant is allowed to cure. A cut line, represented by the phantom line **242**, is established and a cut is made to open the ducts and form the geometry shown in FIG. **15**. The remains of the seal cup are then removed and a seal **244** remains around the stacked inner duct end portions.

FIGS. **16**, **17** and **18** illustrate yet another variation of forming a seal around the end portions of a stacked group of inner ducts. As shown in FIG. **16**, four end portions **250**, **252**, **254**, **256** of inner ducts are stacked, and a seal **260** is force fitted over and around the stacked inner ducts. In this situation, there may be no need to seal the ends of the inner ducts nor is there a need for a cutting step. The seal itself may be formed from an extrusion that has been cut to the desired thickness. Either variation, molding the seal or press fitting the seal is a relatively inexpensive procedure in which relatively inexpensive elements are employed.

Reference is now made to FIGS. 19–22. There is illustrated still another variation of an inner duct **270** having a middle portion **272** and two end portions, an inlet end portion **274** and an outlet end portion **276**. As with the FIGS. **1** and **3** variations, the end portions have a greater depth than the middle portion to allow the inner ducts to be stacked one upon the other while providing a space between two adjacent inner ducts and between the end inner ducts and the outer duct. This is shown in FIG. **19**, where four inner ducts **270**, **280**, **282**, **284** are stacked and where the stack has surrounding seals **290**, **292** about the end portions of the inner ducts. An outer duct (not shown) is formed about the stack to form a passageway for cooling fluid flow while the cooled fluid flow passes through the inner ducts. It is to be noted that the outer duct may be formed by portions of the cabinet or an enclosure if desired or if suggested by design constraints. Thus, inner walls of the enclosure may be used as the outer duct.

An important feature of the inner duct **270** is that the inlet end portion **274** and the outlet end portion **276** form with the middle portion **272** a relatively straight flow path or passage **277** shown in broken line. Also, the arrangement of the inner ducts, when stacked, continues to exhibit a relatively straight flow path or passageway **279** shown in broken line. It can be seen that the counterflows are roughly parallel along the entire heat exchanger. This is contrasted to the FIGS. **1** and **3** variations where the inlet and outlet flow paths are *generally perpendicular to the flow paths around the middle* portions.

To illustrate the flow paths of the FIGS. **19**–**22** variation, reference is made to FIG. 19 where the inlet cooled fluid path is represented by the arrow **300**, the outlet cooled fluid path is represented by the arrow **302**, the inlet cooling fluid path is represented by the arrow **304** and the outlet cooling fluid path is represented by the arrow **306**. Once again, these paths may be reversed and the cooled fluid and cooling fluid flow paths exchanged.

The specification describes in detail several embodiments or variations of the present invention. Other modifications and variations will, under the doctrine of equivalents, come within the scope of the appended claims. For example, the halves of the ducts may be sealed without use of the lips. Or, the ducts may be molded as a single piece followed by a trimming step. Sizes and shapes may also vary. All of these are considered equivalent structures. Still other alternatives will also be equivalent as will many new technologies. There *is no desire or intention here to limit in any way the* application of the doctrine of equivalents.

What is claimed is:

1. A process for forming an inexpensive plastic counterflow heat exchanger for telecommunication equipment cabinets comprising the steps of:

providing a first thermoform mold of geometry predetermined to be accommodated by an equipment cabinet;

molding in said first mold a plurality of ducts having a first structure, each duct of said first structured ducts having enlarged opposite end portions and a smaller cross sectional middle portion,

said end portions of said first structured ducts having outer surfaces and closed ends and being offset from one another,

each middle portion of said first structured ducts having outer surfaces, interior space for fluid flow and protrusions extending away from said outer surfaces;

forming a stack with opposite end portions from a plurality of said first structured ducts by abutting outer surfaces of end portions and protrusions of adjacent first structured ducts wherein fluid flow space is formed between outer surfaces of said middle portions of said abutting adjacent first structured ducts, said process not including bonding said abutting adjacent first structured ducts;

providing sealant molds for forming a seal around each of said opposite end portions of said stack of said plurality of abutting first structured ducts;

providing a castable sealant material;

placing one end portion of said stack of said plurality of abutting first structured ducts into one of said sealant molds;

placing some of said castable sealant material into said one of said sealant molds and around said closed ends of said one end portion of said stack of said plurality of abutting first structured ducts;

curing said sealant;

cutting away a portion of said one of said sealant molds, a portion of said sealant and said closed ends of said one end portion of said abutting first structured ducts to expose said interior spaces of said middle portions of said abutting first structured ducts;

placing the other end portion of said stack of said plurality of abutting first structured ducts into another one of said sealant molds;

placing some of said castable sealant material into said another one of said sealant molds and around said closed ends of said other end portion of said stack of said plurality of abutting first structured ducts;

curing said sealant;

cutting away a portion of said another one of said sealant molds, a portion of said sealant and said closed ends of said other end portion of said abutting first structured ducts to expose said interior spaces of said middle portions of said abutting first structured ducts;

providing a second thermoform mold of geometry predetermined to be accommodated by said equipment cabinet;

forming in said second thermoform mold a duct having a second structure; and

enclosing with said second structured duct, said middle portions and the remaining sealant around said outer surfaces of said opposite end portions of said stack of said abutting first structured ducts wherein two different fluid flow paths are formed, a first path through the interior spaces of said middle portions of said abutting first structured ducts and a second path within said second structured duct and between outer surfaces of said middle portions of said abutting first structured ducts.

2. The processes claimed in claim 1 wherein:

forming said second structured duct includes the steps of providing a first duct mold part for forming a portion of said second structured duct and providing a second duct mold art for forming another portion of said second structured duct.

3. The process as claimed in claim 1 wherein:

said first mold includes two mold parts which are mirror images of one another.

4. The process as claimed in claim 1 wherein:

each of said first structured ducts includes a peripheral lip for closing said ends of said end portions.

5. The process as claimed in claim 1 wherein:

said seal mold is a seal cup.

* * * * *

US006620274B1

(12) **United States Patent**
Nagaya et al.

(10) **Patent No.: US 6,620,274 B1**
(45) **Date of Patent: Sep. 16, 2003**

(54) **METHOD OF REPAIRING ALUMINUM HEAT EXCHANGER**

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(73) Assignee: **Denso Corporation**, Kariya (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 219 days.

(21) Appl. No.: **09/639,974**

(22) Filed: **Aug. 16, 2000**

(30) **Foreign Application Priority Data**

Sep. 17, 1999 (JP) 11-262956

(51) **Int. Cl.**[7] **B32B 35/00**
(52) **U.S. Cl.** **156/94**; 156/196; 29/890.31; 29/402.01
(58) **Field of Search** 156/94, 98, 196; 29/890.031, 402.01, 402.03, 402.06, 402.18, 402.05, 402.04, 897.1; 165/76, 79

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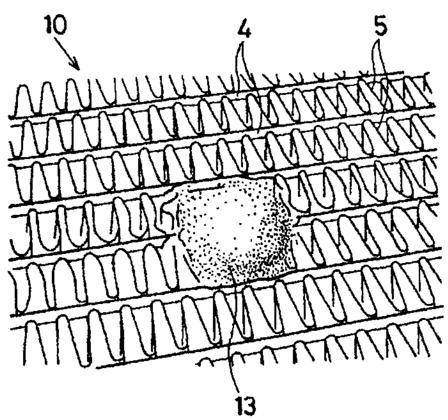
Primary Examiner—Sam Chuan Yao
Assistant Examiner—Gladys Corcoran
(74) *Attorney, Agent, or Firm*—Harness, Dickey & Pierce, PLC

(57) **ABSTRACT**

A partly damaged aluminum heat exchanger such as an aluminum radiator is repaired by closing a hole in the damaged portion with an acrylic resin adhesive material. A certain area around the damaged portion is pressed down to form a cup-shaped depressed portion. The adhesive material is supplied to the depressed portion so that it is retained therein. Then, the adhesive material is hardened by curing it under the room temperature. The hardened adhesive material completely closes the hole with a sufficient thickness and strength because it is retained in the depressed portion. The adhesive material is cured in a relatively short time because the acrylic resin is used as the adhesive material.

5 Claims, 4 Drawing Sheets



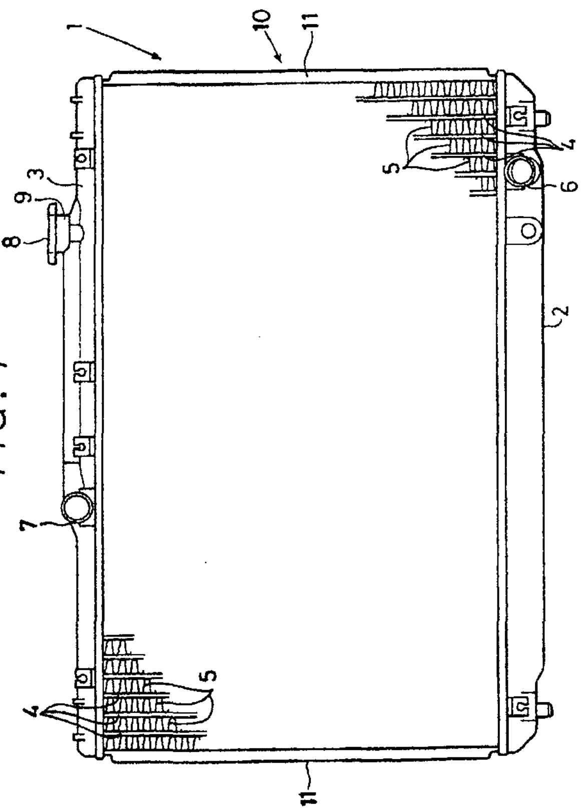


FIG. 1

FIG. 2A

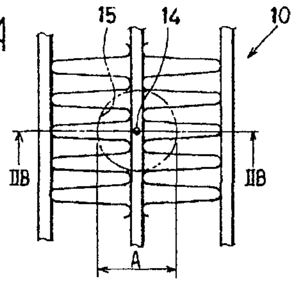


FIG. 2B

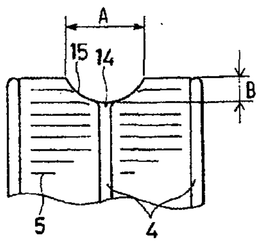


FIG. 2C

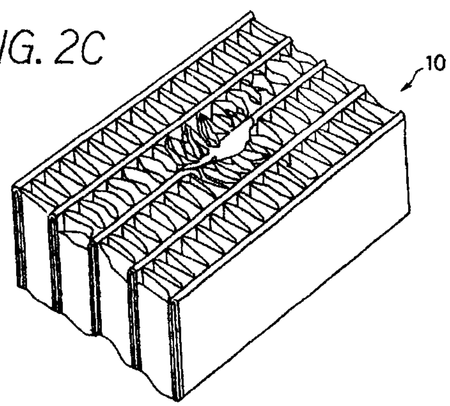


FIG. 3A

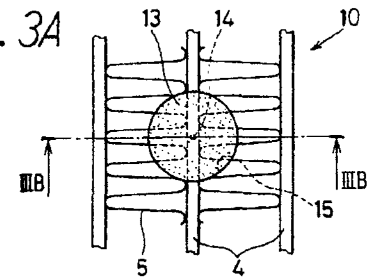


FIG. 3B

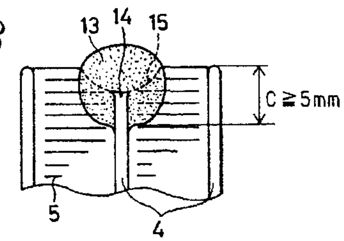


FIG. 3C

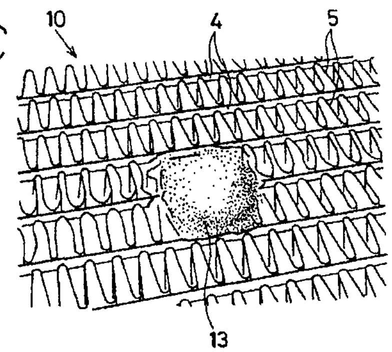


FIG. 4A PRIOR ART

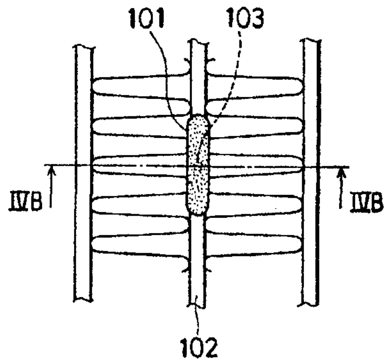
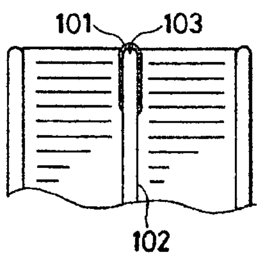


FIG. 4B PRIOR ART



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METHOD OF REPAIRING ALUMINUM HEAT EXCHANGER

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims benefit of priority of Japanese Patent Application No. Hei-11-262956 filed on Sep. 17, 1999, the content of which is incorporated *herein by reference.*

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method of repairing a heat exchanger, such as a radiator for cooling an internal combustion engine, a condenser for an automobile airconditioner, or a heater core, and more particularly to a method of closing a hole in a damaged portion of an aluminum heat exchanger.

2. Description of Related Art

Aluminum heat exchangers are getting predominantly used in recent automobiles in place of copper heat exchangers. The copper heat exchangers can be repaired by soldering with a gas burner or the like, but the aluminum heat exchangers cannot be repaired by such a manner because the melting point of aluminum is low. Accordingly, a hole formed in a damaged aluminum heat exchanger core is usually repaired by closing the hole with an epoxy-resin-type adhesive material.

However, it takes a considerably long time to repair the damaged core with the epoxy-resin-type adhesive material because a long time, e.g., two or three hours, is required to cure the epoxy resin under the room temperature. The time required for curing the epoxy resin can be shortened if a high temperature oven is used. In this case, however, it is necessary to provide a costly high temperature oven for the repairing purpose.

Further, the conventional repair work has not been sufficiently complete because the aluminum heat exchanger is repaired under a method as shown in **FIGS. 4A** and **4B**. That is, the epoxy-resin-type adhesive material **101** is directly coated on a damaged aluminum tube **102** to close a hole **103** formed therein, and then the adhesive material is cured. Therefore, the adhesive material flows over the vicinity of the hole **103**, thereby making the coated layer thin. The hole **103** is not completely closed, or the once coated adhesive material tends to be peeled off in a short time.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above-mentioned problems, and an object of the present invention is to provide an improved method of repairing the aluminum heat exchanger, and more particularly to provide such a method under which a quality repair work is performed in a short time without using a costly high temperature oven.

When an aluminum heat exchanger such as an aluminum radiator is damaged for some reason and liquid coolant contained therein leaks out from a damaged portion, the damaged portion is repaired under the method according to the present invention. The radiator is composed of upper and lower tanks, plural tubes connecting both tanks and corrugated fins disposed between neighboring tubes. All of those components are made of an aluminum alloy and brazed in a furnace to connect all the components into a single unit.

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When such a radiator is damaged, a hole is formed through a wall of the tube, and the coolant leaks out form the hole.

A certain area around the damaged portion including the hole is pressed down to form a cup-shaped depressed portion. The size of the depressed portion is made sufficiently large, preferably with the diameter of 2–20 times the size of the hole and with the depth of 1–8 mm. The depressed portion is degreased, washed and dried, and then an adhesive material composed of acrylic resin and a hardener is supplied to the depressed portion. The adhesive material retained in the depressed portion is cured for about 20 minutes under the room temperature. Thus, the hole in the damage portion is closed with the hardened adhesive material.

Since the adhesive material is retained in the depressed portion while it is being cured and is partly impregnated into the corrugated fins, the adhesive material having a sufficient thickness firmly sticks to the damaged portion without being peeled off afterwards. Since the acrylic resin is used as the adhesive material, it is quickly cured under the room temperature without using a high temperature oven.

The repairing method according to the present invention is applicable not only to the aluminum radiators but to other aluminum heat exchangers such as condensers or heater cores used in automotive air-conditioners.

Other objects and features of the present invention will become more readily apparent from a better understanding of the preferred embodiment described below with reference to the following drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front view showing an aluminum heat exchanger;

FIG. 2A is a partial front view showing a damaged portion of a heat exchanger tube and a depressed portion formed for *repairing the damaged portion;*

FIG. 2B is a cross-sectional view showing the depressed portion, taken along a line IIB—IIB in **FIG. 2A**;

FIG. 2C is a perspective view showing the damage portion on a heat exchanger core;

FIG. 3A is a partial front view showing a repaired portion with an adhesive material filling the depressed portion;

FIG. 3B is a cross-sectional view showing the repaired portion, taken along a line IIIB—IIIB in **FIG. 3A**;

FIG. 3C is a perspective view showing the repaired portion;

FIG. 4A is a partial front view showing a portion repaired under a conventional method; and

FIG. 4B is a cross-sectional view showing the conventional repaired portion, taken along a line IVB—IVB in **FIG. 4A**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment the present invention will be described with reference to **FIGS. 1-3C**. First, referring to **FIG. 1**, the structure of a heat exchanger to which the repairing method of the present invention is applied will be described. The aluminum heat exchanger **1** shown in **FIG. 1** is used as a radiator for cooling an internal combustion engine of an automobile vehicle. The aluminum heat exchanger **1** is a conventional radiator composed of a lower tank **2**, an upper tank **3** and a heat exchange core **10** having plural tubes **4** and plural corrugated fins **5**. The tubes **4** connect the upper tank 3 and the lower tank 2, and the corrugated fins 5 are disposed between neighboring tubes. The tubes 4 and the corrugated fines 5 are alternately laminated and brazed together, forming the core 10.

The lower and upper tanks 2, 3 are respectively formed into an elongate cup-shape by pressing an aluminum alloy plate. An outlet pipe 6 is connected to a side of the lower tank 2, and an inlet pipe 7 is connected to a side of the upper tank 3. A supply pipe 9 for supplying additional coolant into the radiator 1 is also connected on the upper tank 3. A cap 8 having a pressure valve and a negative pressure valve is removably disposed to close an opening of the supply pipe 9.

The tube 4 having a flat-oval cross-section is formed, by presswork, from an aluminum alloy plate containing aluminum as a main component. The corrugated fin 5 is formed into a wave-shape, by roller-work, from the similar aluminum alloy plate containing aluminum as a main component. Louvers (not shown) are formed on the corrugated fin 5 for obtaining a high heat exchange efficiency.

At both sides of the core 10, side plates 11 are disposed to increase the mechanical strength of the core 10 and to serve as brackets for mounting the radiator on a vehicle. Hot coolant fed into the upper tank 3 from the engine flows down to the lower tank 2 through the tubes 4 and is supplied again to the engine. The hot coolant is cooled down in the radiator 1, while it flows down from the upper tank 3 to the lower tank 2, by exchanging heat between the coolant and cooling air flowing through the radiator in the direction perpendicular to the flat surface thereof.

Referring to FIGS. 2A–3C, a method of repairing the damaged portion of the aluminum core 10 of the heat exchanger 1 will be described. The aluminum heat exchanger 1, such as a radiator used for cooling the engine or a condenser used in the air-conditioning system, is mounted on an automobile vehicle at a place where cooling air is easily supplied thereto. Therefore, gravels or small stones rolled up by vehicle wheels may hit the aluminum core 10, and thereby the core may be damaged and a hole may be formed in the tube 4 of the aluminum core 10. The aluminum core 10 may be damaged by other causes, for example, the core may be accidentally hit with a tool while the parts in the engine compartment are being repaired.

When the aluminum core 10 is damaged and the coolant in the heat exchanger leaks out, the aluminum core has to be repaired. First, a portion of the core 10 around the damaged portion 14, i.e., a hole formed in the tube 4, is deformed by hitting with a hammer or the like to form a depressed portion 15, as shown in FIGS. 2A and 2B. The depressed portion 15 is formed, so that the diameter "A" thereof becomes in a range of 2–20 times the diameter of the hole 14 and the depth "B" thereof becomes in a range of 1–8 mm.

A perspective view of the depressed portion 14 thus formed is shown in FIG. 2C. The aluminum corrugated fins 5 around the hole 14 are bent down and flattened to form a cup-shaped depressed portion 15. The cup-shaped depressed portion 15 is so made that the acrylic-resin-type adhesive material is retained therein while the adhesive material is being cured. The size of the depressed portion 15 has to be sufficiently large to secure a certain thickness and an adhesive surface area of the adhesive material and to prevent the adhesive material from being pealed off.

After the depressed portion 15 is formed, the aluminum core 10 is degreased with alcohol, and then it is washed and dried under the room temperature. Then, the acrylic-resin-type adhesive material 13, which is contained in a capsule in a form of paste, is supplied to the depressed portion 15, as shown in FIGS. 3A and 3B. The supplied adhesive material 13 is retained in the depressed portion 15, and some part thereof is impregnated into the corrugated fins 5 as shown in FIG. 3B. The adhesive material 13 is supplied so that the depth "C" of the impregnation measured from the surface of the core 10 becomes deeper than, e.g., 5 mm. To supply the adhesive material 13 to the depressed portion 15, the capsule containing the adhesive material may be set to a machine for injecting the adhesive material.

The adhesive material 13 retained in the depressed portion 15 and impregnated into the corrugated fins 5 is cured under the room temperature for a predetermined period, e.g., for about 20 minutes. The hardened adhesive material 13 firmly closes the hole 14, and thus the repair work is completed. The reason why the acrylic-type resin is used as the adhesive material in place of a conventional epoxy-type resin is that the acrylic resin can be hardened under the room temperature in a shorter period. The adhesive material 13 includes a hardener in addition to the acrylic-type resin as the main component. FIG. 3C shows a perspective view of the portion repaired under the above-described method.

The damaged portion of the aluminum core 10 can be repaired without removing the lower and upper tanks 2, 3 from the core 10 in the above-described manner. Alternatively, the damaged core 10 can be repaired after removing the tanks therefrom.

Since the acrylic-type resin is used as the adhesive material 13, the adhesive material is hardened in a short period of about 20 minutes under the room temperature without using a high temperature oven. Accordingly, the repair work is completed within about 30 minutes including the work for forming the depressed portion 15 around the damaged portion 14. Since the depressed portion 15 is formed before the adhesive material is supplied to the damaged portion 14, the adhesive material is retained in the depressed portion 15 while it is being cured, and accordingly a required thickness of the adhesive material is secured. Therefore, the hole 14 can be completely closed with the adhesive material. Since the adhesive material 13 is impregnated into the corrugated fins 5 around the damaged portion 14 with a certain depth, e.g., 5 mm, the adhesive material 13 is prevented from being peeled off after it is hardened. The damaged aluminum core 10 is completely repaired under the method of the present invention without causing the coolant leakage again after the repair work.

Though the repairing method of the present invention is applied to the radiator in the above embodiment, it is of course applicable to other aluminum heat exchangers including a condenser and a heater core for use in an air-conditioning system. Though one hole of the damaged portion is repaired in the above embodiment, two or more holes can be repaired in the same manner. Also, if there are plural holes close to one another, it is possible to make a depressed portion covering those holes and to repair the core in the same manner as described above.

The conventional epoxy-type resin may be usable in the repair method of the present invention though it requires a longer time or a higher temperature to cure the same. Thermosetting or thermoplastic resins other than the acrylic resin may be used in the repair method of the present invention, as long as they have characteristics suitable to the repair work.

While the present invention has been shown and described with reference to the foregoing preferred embodiment, it will be apparent to those skilled in the art

that changes in form and detail may be made therein without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. A method of repairing a damaged portion of an aluminum heat exchanger, the aluminum heat exchanger comprising a core having a plurality of tubes and a plurality of corrugated fins, both the tubes and the fins being alternately laminated on one another forming the core, the core being adapted to allow cooling air to flow therethrough, the method comprising:

forming a cup-shaped depressed portion around the damaged portion by pressing down the corrugated fins; and

filling the cup-shaped depressed portion and its vicinity with an adhesive material so that the adhesive material is retained within the cup-shaped depressed portion.

2. The repairing method as in claim 1, wherein:

the adhesive material is composed of acrylic resin and a hardener.

3. The repairing method as in claim 1, wherein:

the aluminum heat exchanger is an aluminum radiator for cooling an internal combustion engine.

4. The repairing method as in claim 2, wherein:

the cup-shaped depressed portion is formed with a diameter in a range of 2–20 times the damaged portion and with a depth in a range of 1–8 mm.

5. The repairing method as in claim 1, wherein:

the damaged portion is a hole formed through a wall of the tube.

* * * * *

USUU6579429B2

(12) United States Patent
Inagaki et al.

(10) **Patent No.: US 6,579,429 B2**
(45) **Date of Patent: Jun. 17, 2003**

(54) **ANTIFOULING SYSTEM FOR STRUCTURE EXPOSED TO SEAWATER AND HEAT EXCHANGER**

(75) Inventors: **Shuichi Inagaki**, Yokosuka (JP); **Shigeru Sakurada**, Kisarazu (JP); **Shoji Nakashima**, Yokohama (JP); **Tadahiko Ooba**, Tokyo (JP)

(73) Assignees: **Kabushiki Kaisha Toshiba**, Tokyo (JP); ***Nakabohtec Corrosion* Protecting Co., Ltd.**, Tokyo (JP)

(21) Appl. No.: **09/995,806**

(22) Filed: **Nov. 29, 2001**

(65) **Prior Publication Data**

US 2002/0108849 A1 Aug. 15, 2002

(30) **Foreign Application Priority Data**

Nov. 29, 2000 (JP) 2000-362991

(51) **Int. Cl.**[7] **C23F 13/00**
(52) **U.S. Cl.** **204/196.02**; 204/196.01; 204/196.03; 204/196.37
(58) **Field of Search** 204/196.01, 196.02, 204/196.03, 196.37; 205/734, 738, 740

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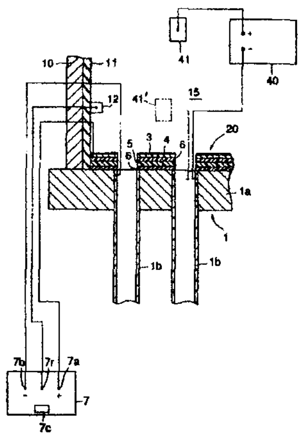
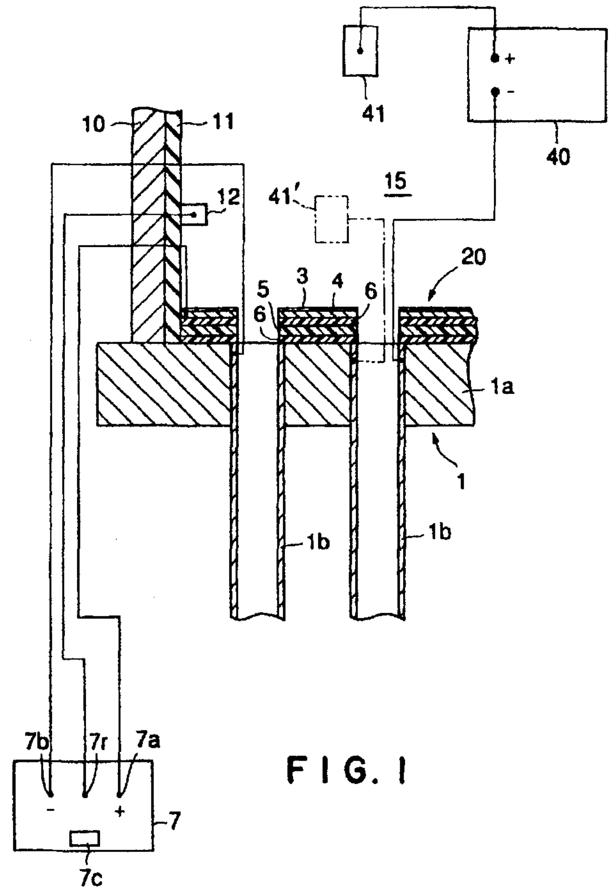
Primary Examiner—Bruce F. Bell
(74) *Attorney, Agent, or Firm*—Foley & Lardner

(57) **ABSTRACT**

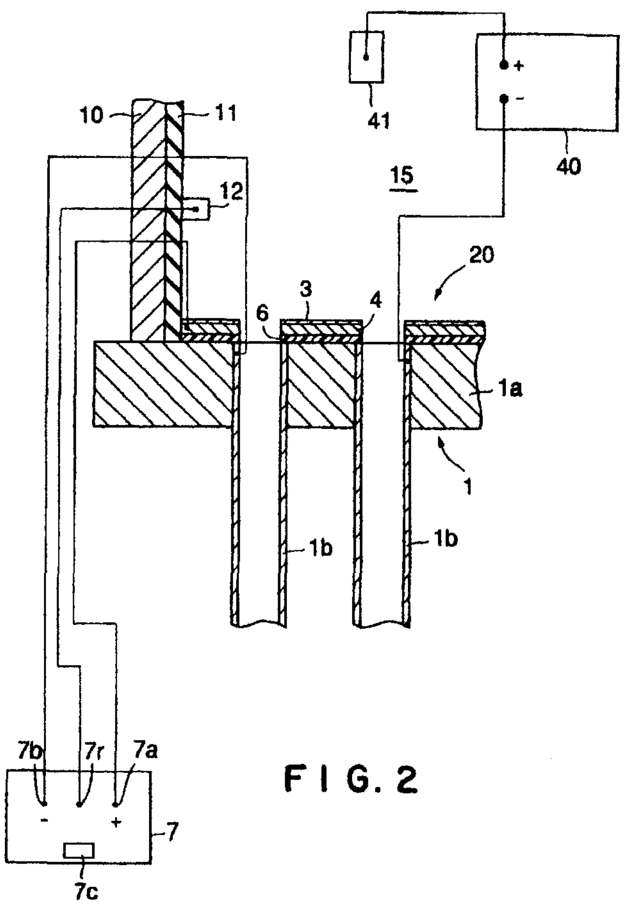
A titanium sheet (**4**) serving as an anode-forming member is fixed on a tube plate (**1***a*) of a heat exchanger (**1**) via a insulting sheet (**5**) and an insulating adhesive (**6**). The sheet (**4**) is coated with a film (**3**) of an electrochemically active, stable electrical catalyst. A dc power unit (**7**) has a positive electrode (**7***a*) electrically connected to the sheet (**4**), and a negative electrode (**7***b*) electrically connected to the tubes (**1***b*). The inner surfaces of the tubes (**1***b*) are used as a cathode for electrolysis for oxygen generation. An automatic potential controller (**7***c*) adjusts potential difference between the electrodes (**7***a*, **7***b*) such that oxygen is generated in seawater while generation of chlorine in seawater is suppressed. An external dc power unit (**40**) and a cathodic protection electrode (**41**) supply a cathodic protection current to the tubes (**1***b*).

12 Claims, 6 Drawing Sheets





F I G. 1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12
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FIG. 2

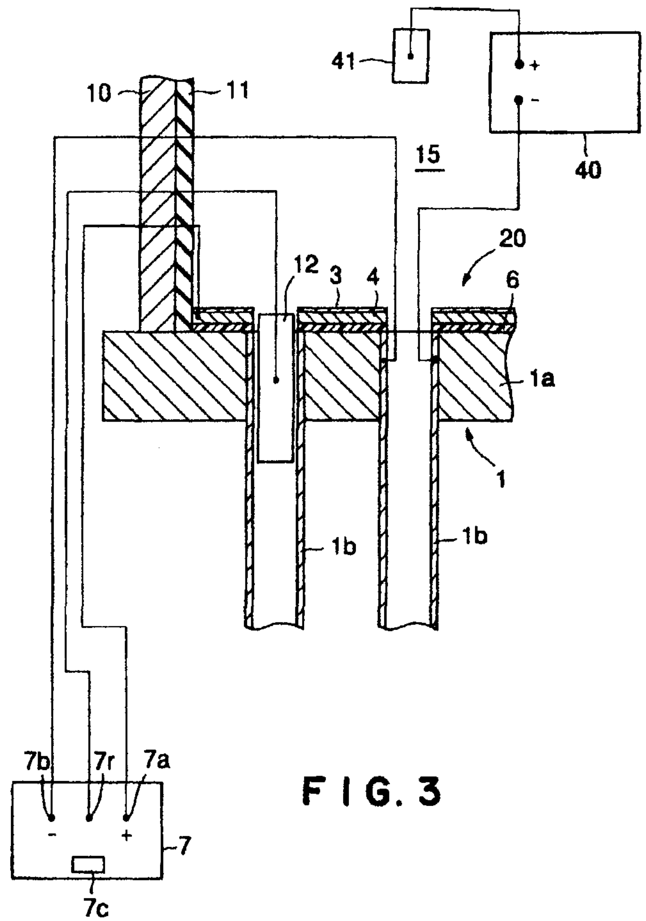
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FIG. 3

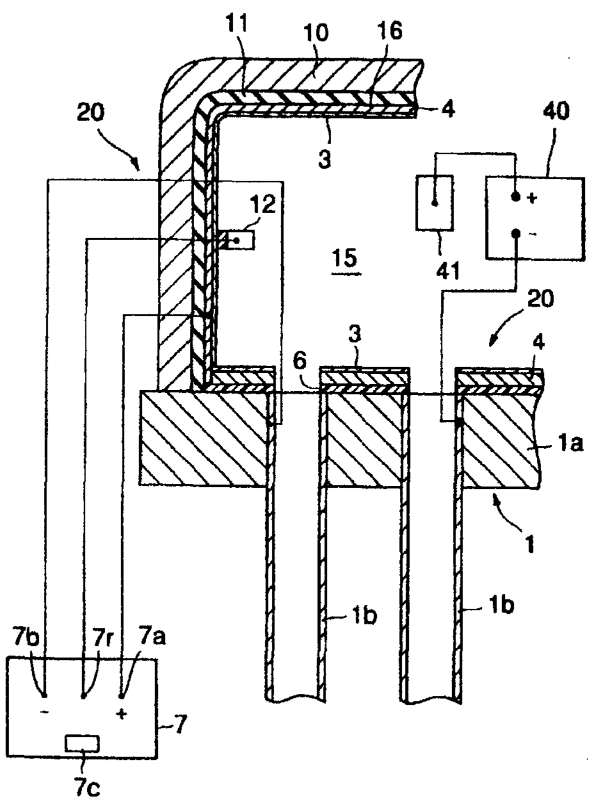
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FIG. 4

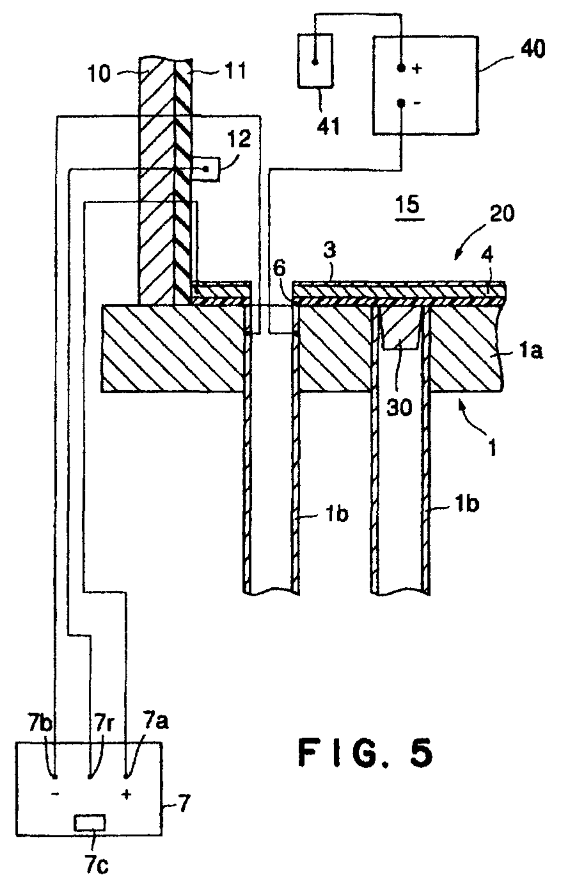
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FIG. 5

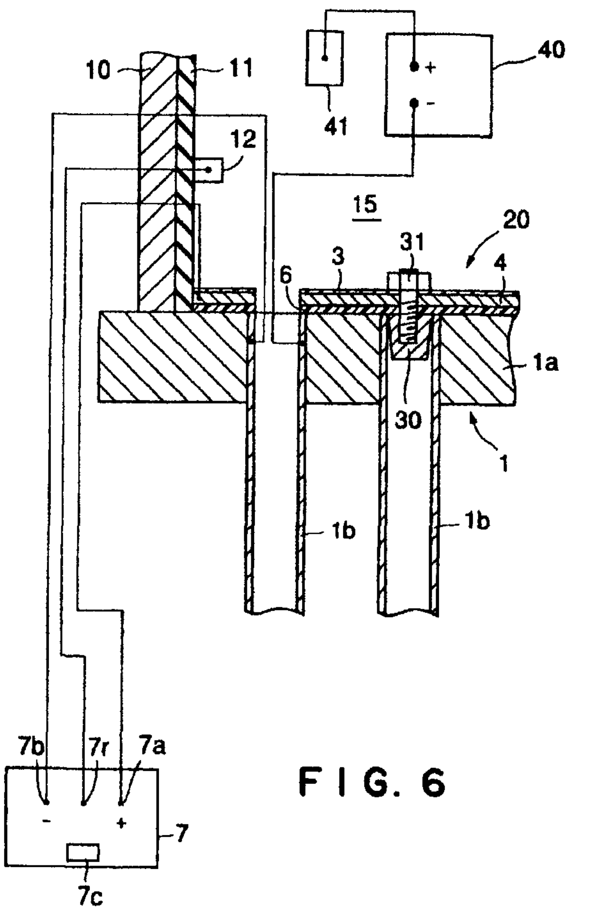

FIG. 6

ANTIFOULING SYSTEM FOR STRUCTURE EXPOSED TO SEAWATER AND HEAT EXCHANGER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an antifouling system for preventing marine organisms from attaching themselves to surfaces exposed to seawater of a structure exposed to seawater. More particularly, the present invention relates to an antifouling system including an electrical catalyst coat formed on a surface, exposed to seawater, of a structure, and capable of generating oxygen to prevent marine organisms from attaching themselves to the surface.

2. Description of the Related Art

Mussels, barnacles, hydrozoan and the like (hereinafter, referred to inclusively as "marine organisms") attach themselves to the inlet and the outlet tube plate supporting heat transfer tubes of a heat exchanger installed in a power plant using seawater as cooling water. These marine organisms clog end parts of the heat transfer tubes to obstruct the insertion of cleaning swabs in the heat transfer tubes and/or cover the inner surface of the heat transfer tubes. Therefore, the power plant is unavoidably subject to frequent shutdown for work to remove the marine organisms from the heat transfer tubes. Those marine organisms are more likely to attach themselves to titanium tube plates and titanium heat transfer tubes, which are corrosion resistant in seawater, than to attach themselves to tube plates and heat transfer pipes which are made of copper alloys.

Larval marine organisms pass through a strainer to penetrate into a rubber-lined steel water box of the heat exchanger. They adhere to the rubber-liner of the steel water box, grow thereon, and fall off therefrom. This result in clogging of heat transfer tubes.

For the purpose of exterminating those marine organisms and preventing marine organisms from attaching themselves to the tubes (i.e., "antifouling"), various measures are taken. Such measures include: pouring chlorine or a chlorine compound into environmental seawater; coating surfaces exposed to seawater with an antifouling paint containing a toxic ion generating pigment; and generating toxic ions, such as chlorine ions or copper ions, through the electrolysis of seawater.

Although these measures exercise effective antifouling functions, the management of the quantity and concentration of those chemicals is not simple when dealing with quantities of seawater and, therefore, the chemical concentration of seawater is liable to be excessively large. Consequently, it is highly possible that the seawater containing an antifouling chemical causes environmental contamination. Thus, there is a trend in recent years to inhibit or control the use of the aforesaid methods.

Recently, many researchers and technicians are engaged in research-and-development activities to develop safe antifouling measures which will not cause environmental pollution. For example, antifouling silicone paints are nontoxic and do not cause environmental pollution. However, collision of shells and foreign substances with the silicone paints shortens the effective antifouling life of the silicone paints. Coating work using antifouling silicone paints requires a high cost. Antifouling silicone paints cannot be applied to structures having large surfaces and existing structures by simple, easy coating work. The antifouling effect of antifouling silicone paints is reduced in still seawater. Due to the above disadvantages, antifouling silicone paints have not been prevalently applied to practical uses.

JP-B (Kokoku) No. Hei 01-46595 discloses another antifouling method. In this method, a film of an electrical catalyst, such as a mixed crystal of platinum group metals or a mixture of such a mixed crystal and oxides of such platinum group metals, is formed on the surfaces of structural members. Water or seawater is electrolyzed using the electrical catalyst as an anode to generate sufficient oxygen substantially without producing chlorine gas in order that the adhesion of organisms living in water to and the deposition of scales on the surfaces of the structural members are suppressed.

However, in this known antifouling method, the electrical catalyst is directly coated on the titanium structural members, which are immersed in water or seawater as an anode. Thus, metallic members of a heat exchanger electrically connected to the titanium structural members, such as members of the water box and water tubes usually formed of steels and lined with rubber, are subject to anodic loading. Therefore, if a part of the rubber lining should be accidentally broken, a current flows through a part of the steel member corresponding to the broken part of the rubber lining and the steel member is corroded abnormally.

This known antifouling method subjects a structure having structural members coated with the film of the electrical catalyst to an electric resistance heating process to heat the component members at a temperature in the range of 350 to 450° C. for several hours to activate the electrical catalyst. Such a heating process is possible to damage the structure and costly and hence this known antifouling method has not been prevalently applied to practical uses.

Generally, only the heat transfer tubes and the tube plates of a titanium heat exchanger are formed of titanium, and the body, the water box, the supply pipes for carrying seawater to the heat exchanger, and the discharge pipes for discharging seawater into the sea are formed of steels. Since the steel water box, the steel seawater supply pipes and the steel discharge pipes are electrically connected to the titanium members, those steel members are subject to galvanic corrosion when immersed in seawater and are corroded intensely. Therefore, the surfaces to be exposed to seawater of those steel members are coated with rubber linings to protect the same from corrosion.

If the rubber lining coating the steel member should be broken, the titanium member electrically connected to the steel member must be loaded at a cathodic potential by a cathodic protection method which reduces the potential of the steel member to a protective potential. However, since the cathodic protection method uses the titanium member as an anode, the steel water box, the steel supply tubes and steel discharge tubes electrically connected to the titanium member are loaded at a cathodic potential. Consequently, it is theoretically impossible to use the cathodic protection method, and an electric current flows through a part of the steel member corresponding to a broken part of the rubber lining to cause the abnormal corrosion of the steel part.

Japanese patent laid-open publication No. P2000-119884A (Kokai) discloses an antifouling system that generates oxygen on the surfaces to be wetted with seawater of a structure exposed to seawater to suppress the adhesion of marine organisms to the surfaces exposed to seawater. In the antifouling system, a titanium sheet, on which the electrical catalyst is pre-coated, is used as an anode-forming member. The titanium sheet is fixed on a titanium tube plate, via an insulating adhesive layer. A conductive member disposed on a rubber lining coating a wall of a water box (usually made of steel) of the heat exchanger. A positive electrode of a dc power unit is connected to the anode-forming member or the electrical catalyst, and a negative electrode of the dc power unit is connected to the conductive member. The dc power unit is internally provided with an automatic potential controller that adjusts potential difference between the positive and the negative electrode such that oxygen is generated while generation of chlorine in seawater is suppressed.

In the above system, since a titanium sheet is provided with the pre-coated electrical catalyst, such titanium sheet can be easily bonded to the surface of the titanium tube plate at an ordinary temperature using the insulating adhesive. Thus, any destructive thermal stress will not be induced in the components and the assembled structure of the heat exchanger. In addition, the anode-forming member is electrically insulated from a structural member, such as a titanium tube plate, by the insulating adhesive. Thus, even if a rubber lining coating the steel member is broken accidentally, the abnormal corrosion of the steel member electrically connected to the titanium tube plate (e.g., a wall of a water box of the heat exchanger) can be prevented. This is because a cathodic protection current is supplied to the metallic member by the dc power unit.

The antifouling system disclosed in P2000-119884A is very effective when the heat exchanger is provided with highly corrosion-resistant titanium heat transfer tubes which do not need to be protected by the cathodic protection method. However, when the heat exchanger is provided with heat transfer tubes formed of an aluminum brass inferior to titanium in corrosion resistance and needing protection from corrosion by the cathodic protection method, the control of a current that flows through the antifouling system, i.e., the control of the potential difference, is difficult and it is possible that the antifouling effect of the antifouling system is reduced. This is because a cathodic protection current that flows through the aluminum brass heat transfer tubes and an antifouling current that flows through the conductive member interfere with each other.

The performance of this antifouling system will be more specifically described on the basis of numerical values. Suppose that an antifouling current density necessary to maintain the anode-forming member attached to a tube plate of a heat exchanger at a potential of 1.0 V to generate oxygen is 0.5 A/m^2. The tube plate of a heat exchanger for a 1000-MW power plant has an area of about 18 m^2 and an antifouling current that flows from the tube plate into seawater is about 3 A. An anticorrosion current necessary for the cathodic protection of the aluminum brass tubes (current that flows toward the tube plate, i.e., a current that flows through the aluminum brass tubes) is on the order of 60 A, which is about twenty times the antifouling current of about 3 A. Whereas the control of the high cathodic protection current is easy, the control of the low antifouling current, which is about 1/20 of the cathodic protection current, is difficult when those currents flow in opposite directions, respectively, in seawater contained in the water box and hence the antifouling effect cannot be properly maintained.

In some cases, the water box and the pipes electrically connected to the heat transfer tubes must be protected by a cathodic protection method even if the heat exchanger is provided with titanium heat transfer tubes which does not need to be protected by a cathodic protection method. In such a case, the interference between the antifouling current and the cathodic protection current causes a problem.

SUMMARY OF THE INVENTION

The present invention has been made to solve the aforesaid problems and it is therefore an object of the present invention to provide an antifouling system for a heat exchanger, capable of preventing the interference between an antifouling current and a cathodic protection current, and of surely and easily achieving the control of the antifouling current, i.e., the control of potential.

According to the first aspect of the present invention, an antifouling system for protecting a structure exposed to seawater from fouling is provided. The antifouling system includes: an anode-forming member arranged on a surface of a member, which is to be protected from fouling, of the structure via an insulating member; an electrical catalyst of an electrochemically active, stable material coating the anode-forming member; a dc power unit having: a positive electrode connected to the anode-forming member or the electrical catalyst; a negative electrode connected to a metallic member forming at least part of the structure and wetted with seawater; and an automatic potential controller that adjusts potential difference between the positive and the negative electrode such that oxygen is generated while generation of chlorine in seawater is suppressed; and a cathodic protection current supply system that supplies a cathodic protection current to the metallic member wetted with seawater and forming at least part of the structure.

According to the second aspect of the present invention, an antifouling system for protecting a heat exchanger including a plurality of heat transfer tubes formed of a metal, and a tube plate formed of a metal and supporting the heat transfer tubes, is provided. The antifouling system includes: an anode-forming member arranged on a surface of a member, which is to be protected from fouling, of the heat exchanger via an insulating member; an electrical catalyst of an electrochemically active, stable material coating the anode-forming member; an electrical catalyst of an electrochemically active, stable material coating the anode-forming member; a dc power unit having: a positive electrode connected to the anode-forming member or the electrical catalyst film; a negative electrode electrically connected to the heat transfer tubes of the heat exchanger; and an automatic potential controller that adjusts potential difference between the positive and the negative electrode such that oxygen is generated while generation of chlorine in seawater is suppressed; and a cathodic protection current supply system that supplies a cathodic protection current to the heat transfer tubes, or to a component member of the heat exchanger, the component member being wetted with seawater and electrically connected to the heat transfer tubes, wherein inner surfaces of the heat transfer tubes are used as a cathode for electrolysis for oxygen generation.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent form the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a schematic sectional view of an antifouling system in a first embodiment according to the present invention;

FIG. 2 is a schematic sectional view of a first modification of the antifouling system shown in FIG. 1;

FIG. 3 is a schematic sectional view of a second modification of the antifouling system shown in FIG. 1;

FIG. 4 is a schematic sectional view of a third modification of the antifouling system shown in FIG. 1;

FIG. 5 is a schematic sectional view of an antifouling system in a second embodiment according to the present invention; and

FIG. 6 is a sectional view of a first modification of the antifouling system shown in FIG. 5.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments according to the present invention will be described hereinafter with reference to the accompanying drawings. Referring to FIG. 1 showing an antifouling system **20** in a first embodiment according to the present invention for a heat exchanger **1** in a schematic sectional view, the heat exchanger **1** includes a plurality of heat transfer tubes **1***b* formed of an aluminum brass, and a tube plate **1***a* formed of a naval brass supporting those heat transfer tubes **1***b*. The antifouling system is intended to prevent the fouling of an outer surface on the side of seawater **15** of the tube plate **1***a*. The heat exchanger **1** is provided with a water box **10** on the side of seawater **15**. The inner surfaces of walls forming the water box **10** are coated with a rubber lining **11**.

The antifouling system **20** has an insulating sheet **5**. The insulating sheet **5** is bonded to the outer surface of the tube plate **1***a* with an insulating adhesive resin layer **6**. A titanium sheet **4**, i.e., anode-forming member, of a thickness in the range of 0.1 to 0.3 mm is bonded to the upper surface of the insulating sheet **5** with an insulating adhesive resin layer **6** so as to cover the upper surface substantially entirely.

An electrochemically active, stable electrical catalyst film **3** is formed on the upper surface of the titanium sheet **4** by applying an electrical catalyst in a film to a surface of the titanium sheet **4** and heating the titanium sheet **4** having the surface coated with the film of the electrical catalyst at a temperature in the range of 350 to 450° C. for several hours by a heating process using resistance heating. Formation of the electrical catalyst film **3** is carried out prior to adhesive-bonding of the titanium sheet **4** to the insulating sheet **5**. The electrical catalyst forming the electrical catalyst film **3** is a metal of a platinum group metal, an oxide of a platinum group metal, cobalt oxide, manganese dioxide, or a mixed crystal or a composite of cobalt oxide and manganese dioxide.

The insulating adhesive layer **6** is formed of an elastic adhesive containing, as principal components, an epoxy resin, an epoxy-amine resin and a modified silicone polymer. This adhesive has high insulating strength and exerts stable adhesive strength in seawater of temperatures in the range of 0 to 50° C. The insulating sheet **5** is excellent in seawater resistance and is a sheet that is not deteriorated by seawater, such as a vinyl chloride sheet or a fiber-reinforced plastic sheet.

As shown in FIG. 1, the titanium sheet **4** and the insulating sheet **5** are provided with a plurality of openings respectively coinciding with the heat transfer pipes **1***b*, and having a diameter equal to the inside diameter of the heat transfer pipes **1***b*.

A reference electrode **12** projects from a part near the titanium sheet **4** of a sidewall of the water box **10**, and extends above the titanium sheet **4**.

The antifouling system **20** is provided with an external dc power unit **7** having a positive electrode **7***a* electrically connected to the titanium sheet **4**, i.e., an anode-forming member, a negative electrode **7***b* electrically connected to the heat transfer pipes **1***b*, i.e., conductive members, and a reference electrode **7***r* electrically connected to the reference electrode **12**.

The dc power unit **7** is internally provided with an automatic potential controller **7***c* to control the potential difference between the positive electrode **7***a* and the negative electrode **7***b* such that the generation of chlorine in seawater **15** is suppressed and oxygen is generated in seawater **15**. More specifically, a proper potential difference between the positive electrode **7***a* and the negative electrode **7***b* is lower than a SCE reference voltage of 1.20 V at which seawater is electrolyzed to generate chlorine and higher than an oxygen generating voltage of 0.52 V at which oxygen is generated in standard seawater. The reference electrode **12** monitors the potential of the titanium sheet **4**, and the automatic potential controller **7***c* controls the potential difference between the positive electrode **7***a* and the negative electrode **7***b* on the basis of data provided by the reference electrode **12**.

The heat transfer tubes **1***b* formed of the aluminum brass is inferior in resistance to the corrosive action of seawater and hence the same are protected from corrosion by a cathodic protection method. The cathodic protection method may be of either an external power supply system or a sacrificial anode system. The antifouling system **20** shown in FIG. 1 employs a cathodic protection method of an external power supply system. The heat transfer tubes **1***b* are connected electrically through an external dc power unit **40** for cathodic protection to a cathodic protection electrode **41**. A cathodic protection current flows from the cathodic protection electrode **41** into the heat transfer tubes **1***b*.

In the event that sacrificial anode system is used for the cathodic protection method, as indicated by chain lines in FIG. 1, a sacrificial anode **41'** is electrically connected to the heat transfer tubes **1***b* instead of the dc power unit **40** and electrode **41**.

In the first embodiment, the heat transfer tubes **1***b* are connected to the negative electrode **7***b* of the dc power unit **7** to use the inner surfaces of the heat transfer tubes **1***b* as cathodes for seawater electrolysis. Thus, an antifouling current and a cathodic protection current flow in the same direction. Therefore, interference between the antifouling current and the cathodic protection current is negligible, and the control of the antifouling current for potential control can be surely and easily achieved. Thus, the dc power unit **7** is able to hold the potential of the titanium sheet **4**, i.e., the potential of the electrical catalyst film **3**, easily in the range of 0.52 to 1.20 V. Consequently, the generation of chlorine on the surface of the electrical catalyst film **3** can be suppressed and oxygen can be generated to prevent marine organisms from attaching themselves to the surface of the electrical catalyst film **3**.

Since the titanium sheet **4** coated beforehand with the electrical catalyst film **3** is bonded with the insulating adhesive resin layer **6** to the insulating sheet **5** bonded to the tube plate **1***a*, the titanium sheet **4** can be easily bonded to the insulating sheet **5** at an ordinary temperature, and hence destructive thermal stress, which is induced in the heat exchanger **1** if the electrical catalyst film **3** is subject to a thermal activation process after being attached to the heat exchanger **1**, will not be induced in the heat exchanger **1**.

Since the insulating adhesive resin layers **6** and the insulating sheet **5** are interposed between the titanium sheet **4** and the surface on the side of seawater **15** of the tube plate **1***a*, the tube plate **1***a* and the titanium sheet **4** are electrically insulated and the abnormal corrosion of metal members electrically connected to the tube plate **1***a* can be prevented.

The insulating adhesive resin layers **6** formed of an elastic adhesive containing, as principal components, an epoxy resin, an epoxy-amine resin and a modified silicone polymer, and having stable adhesive strength in seawater of temperatures in the range of 0 to 50° C. exert stable, durable adhesive strength. The elastic insulating adhesive resin layers **6** is effective in enhancing the durability of the electrical catalyst film **3** and the titanium sheet **4** with which foreign matters collide.

The vinyl chloride sheet or the fiber-reinforced plastic sheet serving as the insulating sheet **5** is excellent in corrosion resistance in seawater, resistant to degradation and highly workable. The openings coinciding with the heat transfer tubes **1***b* can be easily formed in the insulating sheet **5**. The openings can be easily formed in both the titanium sheet **4** and the insulating sheet **5** after bonding together the titanium sheet **4** and the insulating sheet **5** with the insulating adhesive resin layer **6**.

The reference electrode **12** disposed near the titanium sheet **4**, i.e., the anode-forming member, is able to monitor the potential of the titanium sheet **4** accurately to ensure accurate potential control.

If the insulating performance of the insulating adhesive resin layer **6** is satisfactory, the insulating sheet **5** may be omitted. As shown in FIG. **2**, the titanium sheet **4** may be directly bonded to the tube plate **1***a* with the insulating adhesive resin layer **6** without using the insulating sheet **5**.

The position of the reference electrode **12** is not limited to that shown in FIG. **1**. For example, the reference electrode **12** may be inserted in the heat transfer tube **1***b* so as to project into seawater **15** as shown in FIG. **3**. When the reference electrode **12** is inserted in the heat transfer tube **1***b* as shown in FIG. **3**, the reference electrode **12** is closer to the titanium sheet **4**, i.e., the anode-forming member, and hence more accurate potential control is possible.

The titanium sheet **4** coated with the electrical catalyst film **3** may be bonded to the surface of the rubber lining **11** covering the surfaces on the side of seawater **15** of the walls of the water box **10** with an adhesive resin layer **16** as shown in FIG. **4**, and oxygen may be generated on the surface of the electrical catalyst film **3**, suppressing the generation of chlorine. The adhesive resin layer **16** does not need to be insulating.

An antifouling system **20** in a second embodiment according to the present invention will be described with reference to FIG. **5**, in which parts like or corresponding to those of the antifouling system in the first embodiment are denoted by the same reference characters and the description thereof will be omitted to avoid duplication.

The antifouling system **20** in the second embodiment for a heat exchanger has plugs **30** fitted respectively in end parts of some of heat transfer tubes **1***b* of the heat exchanger. The outer end surface on the side of seawater **15** of the plug **30** is substantially flush with the outer surface of a tube plate **1***a*. Preferably, the plugs **30** are made of the same material as the heat transfer tubes **1***b* in view of preventing galvanic corrosion in seawater.

A titanium sheet **4** is provided with openings of a diameter equal to the inside diameter of the heat transfer tubes **1***b* only at positions corresponding to the heat transfer tubes **1***b* excluding those provided with the plugs **30**.

The titanium sheet **4** is bonded to outer surface of the tube plate **1***a* and the outer end surfaces of the plugs **30** with an insulating adhesive resin layer **6**. A thus increased bonding area further stabilizes the adhesion of the titanium sheet **4** to the tube plate **1***a*.

Although the adhesion of the titanium sheet **4** to the tube plate **1***a* increases when the number of the plugs **30** is increased, it is desirable that the number of the plugs **30** is not greater than 3% of the number of the heat transfer tubes **1***b* because the heat exchanging efficiency of the heat exchanger reduces with the increase of the number of the plugged heat transfer tubes **1***b*.

The titanium sheet **4** may be fastened to the plugs **30** with insulating bolts **31** as shown in FIG. **6**. The insulating bolts **31** may be formed of an insulating material, such as a resin or a ceramic material, or may be formed of a metal and coated with an insulating film. When the titanium sheet **4** is thus fastened to the plugs **30** with the insulating bolts **31**, the titanium sheet **4** can be firmly fastened to the tube plate **1***a* and the number of the plugged heat transfer tubes **1***b* can be reduced. The titanium sheet **4** may be fastened to the tube plate **1***a* with insulating bolts **31**.

Although the heat transfer tubes **1***b* are formed of the aluminum brass and the tube plate **1***a* is formed of the naval brass in each of the antifouling systems shown in FIGS. **1** to **6**, the heat transfer tubes **1***b* and the tube plate **1***a* may be formed of other materials. For example, the heat transfer tubes **1***b* may be formed of an aluminum brass and the tube plate **1***a* may be formed of an aluminum bronze; the heat transfer tubes **1***b* may be formed of a so-called super stainless steel and the tube plate **1***a* may be formed of a naval brass; the heat transfer tubes **1***b* may be formed of a super stainless steel and the tube plate **1***a* may be formed of an aluminum bronze; or the heat transfer tubes **1***b* and the tube plate **1***a* may be formed of a super stainless steel.

Both the heat transfer tubes **1***b* and the tube plate **1***a* may be formed of titanium. Since titanium is highly corrosion-resistant, the heat transfer tubes **1***b* and the tube plate **1***a* do not need cathodic protection. However, in some cases, the cathodic protection method is applied to other component members of the heat exchanger, such as the water box and pipes, connected to the heat transfer tubes **1***b* or the tube plate **1***a*. In such a case, it is possible that the antifouling current and the cathodic protection current interfere with each other and hence application of the present invention is effective.

Although the antifouling systems according to the present invention has been described as applied to the component members of the heat exchanger, the present invention is not limited thereto in its practical application and is applicable to all kinds of structures exposed to seawater and having problems relating to interference between the antifouling current and the cathodic protection current.

As apparent from the foregoing description, the antifouling system of the present invention, prevents interference between the antifouling current and the cathodic protection current effectively, and controls the antifouling current and the potentials of the component members with reliability.

Although the invention has been described in its preferred embodiments with a certain degree of particularity, obviously many changes and variations are possible therein. It is therefore to be understood that the present invention may be practiced otherwise than as specifically described herein without departing from the scope and spirit.

What is claimed is:

1. An antifouling system for protecting a structure exposed to seawater from fouling, said system comprising:
   - an anode-forming member arranged on a surface of a member, which is to be protected from fouling, of the structure via an insulating member;
   - an electrical catalyst of an electrochemically active, stable material coating the anode-forming member;
   - a dc power unit having:
     - a positive electrode connected to the anode-forming member or the electrical catalyst;
     - a negative electrode connected to a metallic member forming at least part of the structure and wetted with seawater; and
     - an automatic potential controller that adjusts potential difference between the positive and the negative electrode such that oxygen is generated while generation of chlorine in seawater is suppressed; and
   - a cathodic protection current supply system that supplies a cathodic protection current to the metallic member wetted with seawater and forming at least part of the structure.

2. The antifouling system according to claim **1**, wherein the cathodic protection current supply system comprises a dc power unit having a positive electrode connected to a cathodic protection electrode wetted with seawater and a negative electrode connected to the metallic member.

3. The antifouling system according to claim **1**, wherein the cathodic protection current supply system comprises a sacrificial anode.

4. An antifouling system for protecting a heat exchanger including a plurality of heat transfer tubes formed of a metal, and a tube plate formed of a metal and supporting the heat transfer tubes, said system comprising:
   - an anode-forming member arranged on a surface of a member, which is to be protected from fouling, of the heat exchanger via an insulating member;
   - an electrical catalyst of an electrochemically active, stable material coating the anode-forming member;
   - an electrical catalyst of an electrochemically active, stable material coating the anode-forming member;
   - a dc power unit having:
     - a positive electrode connected to the anode-forming member or the electrical catalyst film;
     - a negative electrode electrically connected to the heat transfer tubes of the heat exchanger; and
     - an automatic potential controller that adjusts potential difference between the positive and the negative electrode such that oxygen is generated while generation of chlorine in seawater is suppressed; and
   - a cathodic protection current supply system that supplies a cathodic protection current to the heat transfer tubes, or to a component member of the heat exchanger, the component member being wetted with seawater and electrically connected to the heat transfer tubes,
   - wherein inner surfaces of the heat transfer tubes are used as a cathode for electrolysis for oxygen generation.

5. The antifouling system according to claim **4**, wherein the cathodic protection current supply system comprises a dc power unit having a positive electrode connected to a cathodic protection electrode wetted with seawater and a negative electrode connected to the metallic member.

6. The antifouling system according to claim **5**, wherein:
   - plugs are fitted in end parts of some of the plurality of heat transfer tubes;
   - the anode-forming member is provided with openings in parts thereof coinciding with open ends of the heat transfer tubes in which plugs are not fitted, and is not provided with any openings in parts thereof coinciding with the closed ends of the heat transfer tubes in which the plugs are fitted; and
   - the anode-forming member is bonded to an outer surface of the tube plate and end surfaces of the plugs with an insulating adhesive layer acting as the insulating member.

7. The antifouling system according to claim **6**, wherein the parts of the anode-forming member coinciding with the plugs are fastened to the plugs with an insulating bolts.

8. The antifouling system according to claim **4**, wherein the cathodic protection current supply system comprises a sacrificial anode.

9. The antifouling system according to claim **4**, wherein the member to be protected from fouling is the tube plate of the heat exchanger.

10. The antifouling system according to claim **4**, wherein the member be protected from fouling is an inner surface of a wall forming a water box of the heat exchanger, the inner surface is coated with a lining of rubber or a resin, and the anode-forming member is arranged on the lining, which acts as the insulating member.

11. The antifouling system according to claim **4**, wherein a seawater-corrosion-resistant insulating sheet of vinyl chloride or a seawater-corrosion-resistant fiber-reinforced plastic sheet, acting as the insulating member, is arranged between the member be protected from fouling and the anode-forming member.

12. The antifouling system according to claim **4**, wherein the anode-forming member is bonded to the member to be protected from fouling with an insulating adhesive layer acting as the insulating member.

* * * * *

US006427769B2

(12) **United States Patent**
Horie et al.

(10) **Patent No.: US 6,427,769 B2**
(45) **Date of Patent: Aug. 6, 2002**

(54) **HEAT EXCHANGER HAVING TUBE JOINED TO CORE PLATE AND METHOD OF MANUFACTURING THE SAME**

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(73) Assignee: **Denso Corporation**, Kariya (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/326,223**

(22) Filed: **Jun. 3, 1999**

(30) **Foreign Application Priority Data**

Jun. 4, 1998 (JP) 10-156042

(51) **Int. Cl.**[7] **F28F 9/04**; F28F 9/02; F28F 13/18

(52) **U.S. Cl.** **165/178**; 165/133; 165/173; 29/890.043

(58) **Field of Search** 165/178, 173, 165/175, 153, 133, 79; 29/890.038, 890.043

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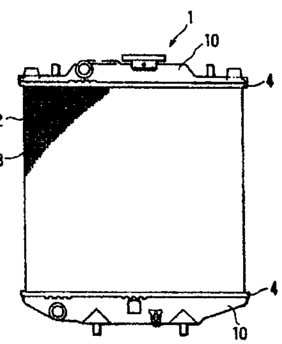
Assistant Examiner—Tho V Duong
(74) *Attorney, Agent, or Firm*—Harness, Dickey & Pierce, PLC

(57) **ABSTRACT**

A heat exchanger has a tank for accommodating a heat medium therein and a tube connected to the tank through a core plate. Specifically, an end portion of the tube is inserted into a connection hole of the core plate and is mechanically joined thereto. A joined portion of the tube and the core plate is covered with adhesive through a wettability improving film for improving wettability of the adhesive to the joined portion. As a result, a sealing property between the tube and the core plate is easily and stably improved by the adhesive.

21 Claims, 4 Drawing Sheets



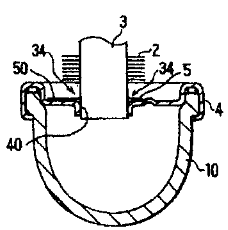


FIG. 1

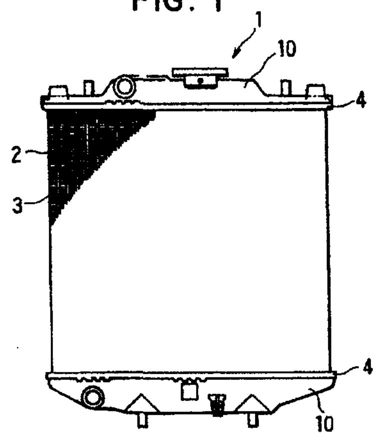


FIG. 2A

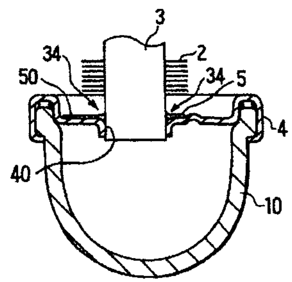


FIG. 2B

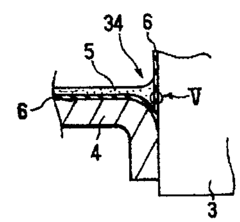


FIG. 3

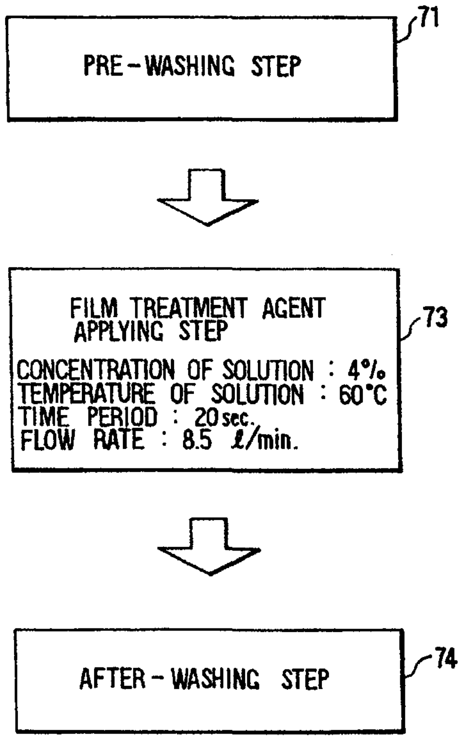


FIG. 4

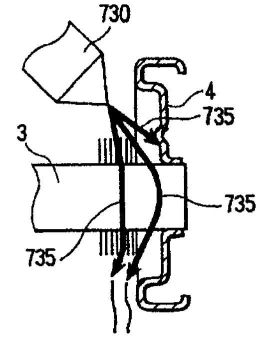


FIG. 5A

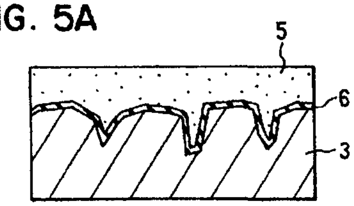


FIG. 5B

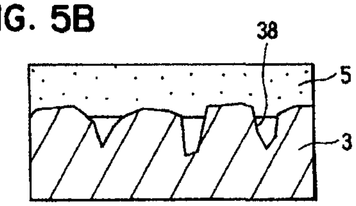


FIG. 6

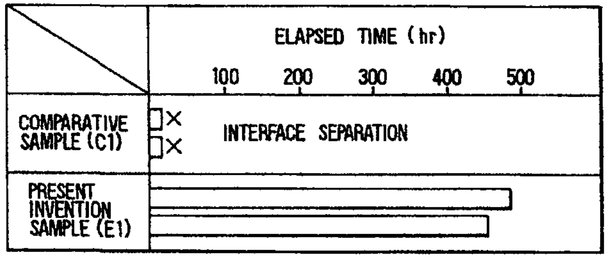
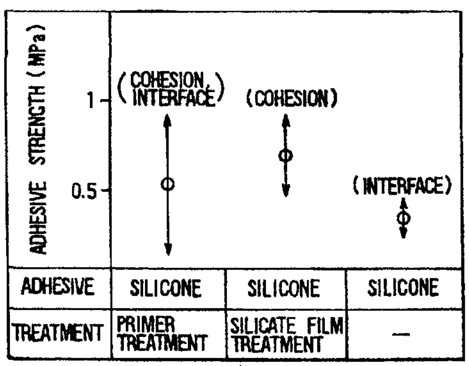


FIG. 7



HEAT EXCHANGER HAVING TUBE JOINED TO CORE PLATE AND METHOD OF MANUFACTURING THE SAME

CROSS REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of Japanese Patent Application No. 10-156042, filed on Jun. 4, 1998, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a heat exchanger and a method of manufacturing the same with adhesive for securing a sealing property between a tube and a tank.

2. Description of the Related Art

A heat exchanger typically has tanks for accommodating heat medium therein, and plural tubes coupled with radiation fins and connected to the tanks through core plates. Specifically, end portions of the tubes are inserted into connection holes provided in the core plates, and joined thereto. After that, the core plates are attached to the tanks. The core plates and the tubes must secure a sufficient sealing property at joining portions therebetween for preventing leakage of the heat medium therefrom. Conventionally, the core plates and the tubes have been brazed to one another with the sufficient sealing property.

Recently, methods other than brazing for joining the core plates and the tubes have been proposed to rationalize the manufacturing process. For instance, mechanical processing such as crimping is carried out to produce pushing force between outer circumference surfaces of the tubes and the connection holes of the core plates so that the tubes are joined to the core plates by the pushing force. The mechanical joining method described above, however, easily produce minute clearances at the joining portions to lessen the sealing property. Therefore, this method requires a countermeasure for improving the sealing property.

To solve this problem, JP-U-61-18986 proposes a method in which sealing agent such as adhesive is applied to the joining portions after the mechanical joining is carried out. However, the sealing property cannot be sufficiently improved only by applying the sealing agent. It was confirmed by an immersion test that the joined core plates and the tubes dipped into an engine cooling water were separated from one another in a short period of time.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above problem. An object of the present invention is to provide a heat exchanger having a core plate and a tube joined to each other with a sufficient sealing property and a method of stably and easily manufacturing the same.

According to the present invention, a heat exchanger has a tank for accommodating a heat medium therein, a core plate fixed to the tank and having a connection hole, and a tube having an end portion fixedly inserted into the connection hole of the core plate. The tube and the core plate are made of one of aluminum and aluminum alloy, and are mechanically joined to each other at a joined portion thereof. Further, an adhesive is disposed on a specific region of the joined portion through a wettability improving film interposed therebetween for improving a wettability of the adhesive to the specific region.

The wettability improving film makes the adhesive securely adhered to the joined portion therethrough. Specifically, because the wettability improving film has a good wettability to the adhesive, the adhesive can fill minute concave portions of the specific region even when surface roughness of the specific region is large. As a result, the sealing property between the tube and the core plate is improved.

The tube and the core plate can be mechanically joined to each other with the specific region covered with the wettability improving film. The wettability improving film may be formed before or after the tube and the core plate are joined to each other. After that, the adhesive is formed on the specific region through the wettability improving film.

The wettability improving film may be formed by jetting out a solution onto the specific region, and be formed by dipping the specific region into a solution. Accordingly, the heat exchanger can be easily and stably manufactured with a high sealing property.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and features of the present invention will become more readily apparent from a better understanding of the preferred embodiments described below with reference to the following drawings.

FIG. 1 is a front view showing a heat exchanger of a preferred embodiment according to the present invention;

FIG. 2A is a cross-sectional view showing a joined portion of a tube and a core plate in the heat exchanger;

FIG. 2B is an enlarged view showing the joined portion of FIG. 2A;

FIG. 3 is a flow chart showing a process of forming a wettability improving film;

FIG. 4 is an explanatory view showing a state where solution for forming the wettability improving film is jetted out;

FIGS. 5A and 5B are explanatory views showing a difference of adhesive states in two cases where the wettability improving film is provided and is not provided;

FIG. 6 is a chart specifically showing an effect of the adhesiveness (durability) of the adhesives when the wettability improving film is provided and is not provided; and

FIG. 7 is a chart showing adhesive strengths of the adhesives when the wettability improving film is provided and is not provided.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A heat exchanger in a preferred embodiment of the present invention will be explained referring to FIGS. 1 to 4. As shown in FIG. 1, the heat exchanger 1 in the present embodiment is used as an automotive radiator, and has tanks 10 for accommodating heat medium therein, plural tubes 3 coupled with radiation fins 2, and core plates 4 for connecting the tubes 3 to the tanks 10. End portions of the tubes 3 are inserted into connection holes 40 provided in the core plates and are joined thereto. As shown in FIGS. 2A and 2B, the tubes 3 and the core plates 4 are joined to one another by mechanical processing with adhesive 5 interposes therebetween for maintaining a sealing property. The adhesive 5 is applied to surfaces of the tubes 3 and the core plates 4 on which a wettability improvement film 6 for improving the wettability of the adhesive 5 is formed.

When manufacturing the heat exchanger 1, first, the tubes 3 are inserted to the corresponding connection holes 40 of the core plates 4. In this state, each inside diameter of the tubes 3 is enlarged from inside thereof using a mandrel or the like having a diameter slightly larger than that of the tubes 3. Accordingly, the tubes 3 are pushed against the connection holes 40 with force, thereby being mechanically joined to the core plates 4.

Next, in the present embodiment, the wettability improvement film 6 is formed after the tubes 3 and the core plates 4 are joined to one another as described above. The formation of the wettability improvement film 6 is carried out by applying a solution containing 3% to 5% treatment agent including a silicate (Trade Name : GILDAON produced by Central Chemical Co.), like a shower, onto a specific film formation region where the adhesive 5 is to be formed.

Specifically, as shown in FIG. 3, after pre-washing step 71 is carried out on the tubes 3 and the core plates 4, film treatment agent applying step 73 and after-washing step 74 are successively carried out. At the pre-washing step 71, hot water of 60° C. is jetted out from a shower for approximately 20 seconds to wash the joined tubes 3 and the core plates 4. At the film treatment agent applying step 73, the solution including GILDAON of 30 g–50 g/liter in concentration and 60° C. in temperature is applied onto the film formation region for approximately 20 seconds. At this step, as shown in FIG. 4, the solution 735 jetted out from an injection nozzle 730 like a shower is selectively sprayed onto the film formation region in proximity to the joined portion.

AT the film treatment agent applying step 73, because the solution includes the silicate system film material and the tubes 3 and the core plates 4 are made of aluminum alloy, when the solution is applied to the tubes 3 and the core plates 4, the wettability improvement film 6 can be formed with an extremely thin thickness during a short period of time (approximately 10 seconds) by chemical reactions on the tubes 3 and the core plates 4. Then, the washing using hot water is carried out at the after-washing step 74 substantially in the same manner as that at the pre-washing step 71 to remove extra treatment agent and the like.

Subsequently, the adhesive 5 is applied to the joined portions between the tubes 3 and the core plates 4. In the present embodiment, silicone system adhesive is used as the adhesive 5. The application of the adhesive 5 is carried out by a dispenser or the like from a side of the core plates 4 to seal the peripheries of the tubes 3. After that, the tanks 10 are attached to the core plates 4, thereby forming the heat exchanger 1 shown in FIG. 1.

Next, effects of the present embodiment will be explained. In the heat exchanger 1, the wettability improvement film 6 is formed before applying the adhesive 5 with large wettability to the adhesive 5. Therefore, the adhesive 5 closely adheres to the surfaces of the tubes 3 and the core plates 4 through the wettability improvement film 6 even when the surface roughnesses of the tubes 3 and the core plates 4 are large. Since the adhesive 5 can invade even into minute clearances surrounded by the wettability improvement film 6 due to the large wettability thereof, as shown in FIG. 2B, the adhesive 5 can fill the joined portions 34 without forming empty spaces. As a result, the sealing property at the joined portions 34 is improved by the adhesive 5.

Further, the tubes 3 and the core plates 4 are mechanically joined to each other to produce mechanical stress which makes the joining strength therebetween large. Therefore, it is sufficient for the adhesive 5 to have only a function for improving the sealing property. The silicone system adhesive can be used to exhibit the adhesive property. As a result, according to the present invention, the sealing property

between the core plates 4 and the tubes 3 can be provided without performing brazing thereof.

Incidentally, there is a case where MgO contained in aluminum (Al) as an additive is deposited on the Al surface to inhibit the adhesiveness between the adhesive and the Al surface. Generally, alkaline metals work as described above, and MgO is a basic oxide having a large base strength. In the present embodiment, however, because the Al surface is covered with the silicate film or the like, the adhesive can maintain its adhesiveness to the Al surface.

The sealing property between the tubes 3 and the core plates 4 in the heat exchanger 1 was experimentally evaluated in comparison with a comparative sample C1 in which the silicone system adhesive 5 described above was coated onto the joined portions 34 without interposing the wettability improvement film 6 therebetween. The other features of the comparative sample C1 were substantially the same as those of the heat exchanger 1 (herebelow, referred to as the present invention sample E1).

Specifically, two present invention samples E1 and two comparative samples C1 filled with LLC were prepared, and put within a thermostatic chamber kept at 130° C. The results are shown in FIG. 6, in which a horizontal axis indicates elapsed time (Hr) of the test. According to the figure, in the comparative examples C1 without having the wettability improvement film, the adhesives were separated from the joined portions 34 at extremely short time periods. As opposed to this, in the present invention samples E1 having the wettability improvement film, the adhesives were not separated from the joined portions 34 even after 400 Hr was elapsed. As a result, it was confirmed that the present invention sample (heat exchanger 1) could exhibit excellent durability (sealing property) by providing the wettability improvement film 6.

Also, the states of the adhesives 5 of the present invention sample E1 and the comparative example sample C1 were observed at interface portions between the tube 3 and the adhesives 5, one of which is indicated by an arrow V in FIG. 2B as an example. The results are schematically shown in FIGS. 5A and 5B. FIG. 5A shows the state of the present invention sample E1, while FIG. 5B shows the state of the comparative sample C1. As shown in FIG. 5A, in the present invention sample E1, the wettability improvement film 6 was formed along the surface irregularity of the tube 3, and the adhesive 5 was adhered thereon entirely along the shape while filling minute concave portions of the tube 3. As opposed to this, as shown in FIG. 5B, in the comparative sample C1, the adhesive did not fill concave portions 38 provided by the surface irregularity of the tube 3. This implies insufficient adhesiveness capable of reducing the durability. It is presumed that the insufficient adhesiveness of the comparative sample C1 is caused by the fact that the wettability improvement film 6 is not formed.

The effect of the wettability improvement film 6 was further studied using three samples, one of which had the silicate system film as the wettability improvement film 6 as described above, another one of which had an organic film formed by a primer treatment that is conventionally carried out as a coating surface treatment, and another one of which did not have the wettability improvement film 6. The silicone system adhesive was used as the adhesive 5 as well as in the present embodiment. The comparison was carried out by measuring adhesive strengths (MPa). Specifically, two test pieces made of aluminum alloy were adhered to one another with an adhesive thickness of 2 mm at an adhesive area of 10 mm×25 mm. Then, the strength was measured by

a tensile tester such as an auto graph with 5 mm/min. in an elastic stress rate.

The results are shown in FIG. 7. In FIG. 7, a vertical axis indicates the adhesive strengths. As shown in the figure, the two samples having the organic film formed by the primer treatment and the silicate system film as the wettability improved films mainly underwent cohesive separation, while the sample without having the wettability improvement film underwent interface separation. This means that the samples having the wettability improvement films exhibit adhesive strengths larger than that of the sample without having the wettability improvement film. Further, the sample having the organic film has the larger variation and the lower stability than those of the sample having the silicate system film.

The reason is considered as follows. That is, at the primer treatment, silane coupling agent diluted with organic solution is coated on the surface of the tube and the like, and accordingly, the organic film having the adhesiveness to the silicone adhesive 5 is formed on the surface through a reaction between moisture contained in atmosphere and the silane coupling agent described above. This primer treatment is further accompanied by volatilization of the solution, hydrolysis of primer components, and the like, and therefore requires a period of time in a range of approximately 5 to 10 minutes for forming the organic film. As a result, the organic film easily has large variation in thickness due to the film formation mechanism described above. The large thickness of the organic film can result in breakage and interface separation of the organic film.

To the contrary, when the silicate system film is formed, as described in the above present embodiment, the film can be formed in an extremely short period of time (approximately 10 sec.). Therefore, the thickness of the wettability improvement film 6 is suppressed at an extremely thin range of approximately 200 Å to 500 Å. As a result, the film can be stably formed with desirable characteristics described above.

While the present invention has been shown and described with reference to the foregoing preferred embodiments, it will be apparent to those skilled in the art that changes in form and detail may be made therein without departing from the scope of the invention as defined in the appended claims.

For instance, the region where the adhesive 5 is to be applied is entirely covered with the wettability improvement film 6 in the present embodiment; however, it is not always required. For instance, only the outer surfaces of the tubes 3 where the wettability of the adhesive 5 becomes easily small may be covered with the wettability improving film 6. To the contrary, the tubes 3 and the core plates 4 may be covered with the wettability improving film 6 at a wider region including the region where the adhesive 5 is applied due to a reason for a manufacturing process. The method of mechanically joining the tubes 3 to the core plates 4 is not limited to the method described above, and may be performed by caulking or the like.

The silicate system film as the wettability improving film may be made of sodium silicate, magnesium silicate, calcium silicate, potassium silicate, or the like. Otherwise, the wettability improving film may be made of phosphate system film such as zinc phosphate, titanium phosphate, or zirconium phosphate. The phosphate system film can exhibit the same effects as that of the silicate system film. Although the tubes and the core plates 4 are made of aluminum alloy in the present embodiment, they may be made of aluminum.

The adhesive may be made of high polymer material to have a low elastic modulus and good thermal cycle characteristics. Further, the adhesive may be made of silicone system adhesive described above or denatured material thereof. In this case, cracks of the adhesive can be prevented from being produced by thermal cycles and the like, resulting in improved durability. Employed as the silicon system adhesive is, for instance, additive type or condensed type silicone such as dimethyl silicone, methyl phenyl silicone, or phenyl silicone. Employed as the denatured material of the silicone system adhesive is, for instance, fluorine denatured silicone, epoxy denatured silicone, or the like.

In the embodiment described above, the wettability improving film 6 is formed after the tubes 3 and the core plates 4 are joined to each other. In this case, the wettability improving film 6 can be formed on the tubes 3 and the core plates 4 at the same time, resulting in simplified manufacturing process. However, it may be formed before the tubes 3 and the core plates 4 are joined to each other. The wettability improving film is formed by applying the solution like shower onto the specific surfaces of the tubes 3 and the core plates 4; however the specific surfaces of the tubes 3 and the core plates 4 may be dipped into the solution to have the wettability improving film thereon.

What is claimed is:

1. A heat exchanger comprising:
- a tank for accommodating a heat medium therein;
- a core plate fixed to the tank and having a connection hole; and
- a tube coupled with a radiation fin, and having an end portion fixedly inserted into the connection hole of the core plate, wherein:
  - the tube and the core plate are made of one of aluminum and aluminum alloy, and are mechanically joined to each other at a joined portion thereof; and
  - an adhesive is disposed on a specific region of the joined portion of the tube and the core plate through a wettability improving film interposed therebetween for improving a wettability of the adhesive to the specific region, to maintain a sealing property between the tube and the core plate; wherein:
    - the adhesive is made of one selected from a group consisting of a silicone system material and a denatured material of the silicone system material;
    - the wettability improving film is a silicate system film; and
    - a thickness of the wettability improving film is approximately 200A–500A.

2. The heat exchanger of claim 1, wherein the adhesive is made of a high polymer material.

3. The heat exchanger of claim 1, wherein the heat exchanger is an automotive radiator.

4. The heat exchanger of claim 1, wherein the specific region is an outer surface of the tube in close proximity to the joined portion.

5. A method of manufacturing a heat exchanger having a tank for accommodating a heat medium therein and a tube connected to the tank through a core plate, the method comprising steps of:
- inserting an end portion of the tube into a connection hole provided in the core plate, the tube and the core plate being made of one of aluminum and aluminum alloy;
- mechanically joining the end portion of the tube to the core plate with a specific region at a joined portion therebetween, the specific region being covered with a wettability improving film made of an inorganic compound; and

forming an adhesive for improving a sealing property at the joined portion, on the specific region through the wettability improving film capable of improving a wettability of the adhesive to the specific region; wherein:

the adhesive is made of one selected from a group consisting of a silicone system material and a denatured material of the silicone system material;

the wettability improving film is a silicate system film; and

a thickness of the wettability improving film is approximately 200A–500A.

6. The method of claim **5**, further comprising a step of forming the wettability improving film before forming the adhesive, by jetting out a solution like a shower onto the specific region of the tube and the core plate joined to each other.

7. The method of claim **5**, further comprising a step of forming the wettability improving film before forming the adhesive, by dipping the specific region of the tube and the core plate joined to each other into a solution containing a component for forming the wettability improving film.

8. The method of claim **5**, wherein the wettability improving film is formed on the specific region after the end portion of the tube and the core plate are mechanically joined to each other.

9. The method of claim **5**, wherein the heat exchanger is an automotive radiator.

10. The method of claim **5**, wherein the specific region is an outer surface of the tube in close proximity to the joined portion between the tube and the core plate.

11. The method of claim **5**, further comprising:

before forming the adhesive, forming the wettability improving film; and washing a surface of the wettability improving film.

12. The method of claim **11**, wherein the surface of the wettability improving film is washed by water.

13. A method of manufacturing a heat exchanger having a tank for accommodating a heat medium therein and a tube connected to the tank through a core plate, the method comprising steps of:

inserting an end portion of the tube into a connection hole provided in the core plate, the tube and the core plate being made of one of aluminum and aluminum alloy;

mechanically joining the end portion of the tube to the core plate with a specific region at a joined portion therebetween;

covering said specific region with a wettability improving solution to produce a wettability improving film, the wettability improving film being a silicate system film having a thickness of approximately 200A–500A;

rinsing said wettability solution from said specific after a specified period of time; and

forming an adhesive for improving a sealing property at the joined portion, on the specific region through the wettability improving film capable of improving a wettability of the adhesive to the specific region.

14. The heat exchanger according to claim **13**, wherein said wettability improving solution is made of an inorganic compound.

15. The heat exchanger according to claim **13**, wherein said specified period of time is less than one minute.

16. A heat exchanger comprising:

a tank for accommodating a heat medium therein;

a core plate fixed to the tank and having a connection hole; and

a tube coupled with a radiation fin, and having an end portion fixedly inserted into the connection hole of the core plate, wherein:

the tube and the core plate are made of one of aluminum and aluminum alloy, and are mechanically joined to each other at a joined portion thereof; and

an adhesive is disposed on a specific region of the joined portion of the tube and the core plate through a wettability improving film interposed therebetween for improving a wettability of the adhesive to the specific region, to maintain a sealing property between the tube and the core plate; wherein:

the adhesive is made of one selected from a group consisting of a silicone system material and a denatured material of the silicone system material; and

the wettability improving film is a phosphate system film.

17. The heat exchanger of claim **16**, wherein the adhesive is made of a high polymer material.

18. The heat exchanger of claim **16**, wherein the adhesive is made of one selected from a group consisting of a silicone system material and a denatured material of the silicone system material.

19. The heat exchanger of claim **16**, wherein the heat exchanger is an automotive radiator.

20. The heat exchanger of claim **16**, wherein a thickness of the wettability improving film is less than 500A.

21. The heat exchanger of claim **16**, wherein the specific region is an outer surface of the tube in close proximity to the joined portion.

* * * * *

ANEXO 2

LOCTITE®

LOCTITE® 680™

September 2004

PRODUCT DESCRIPTION

LOCTITE® 680™ provides the following product characteristics:

Technology	Acrylic
Chemical Type	Methacrylate ester
Appearance (uncured)	Green liquid[LMS]
Fluorescence	Positive under UV light[LMS]
Components	One component - requires no mixing
Viscosity	Medium
Cure	Anaerobic
Secondary Cure	Activator
Application	Retaining
Strength	High

LOCTITE® 680™ is designed for the bonding of cylindrical fitting parts, particularly where low viscosity is required. The product cures when confined in the absence of air between close fitting metal surfaces and prevents loosening and leakage from shock and vibration.

TYPICAL PROPERTIES OF UNCURED MATERIAL

Specific Gravity @ 25 °C 1.1

Flash Point - See MSDS

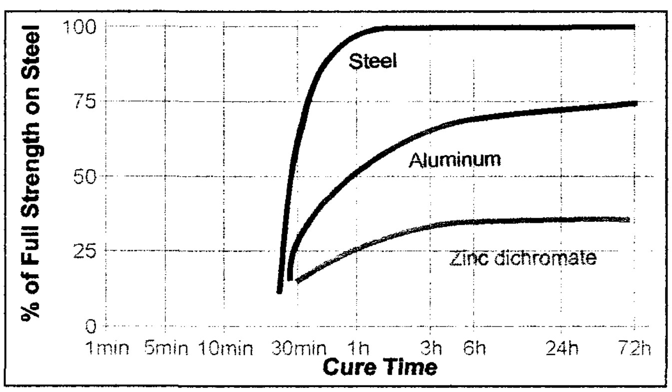
Viscosity, Brookfield - RVT, 25 °C, mPa·s (cP):

Spindle 3, speed 20 rpm 750 to 1,750[LMS]

TYPICAL CURING PERFORMANCE

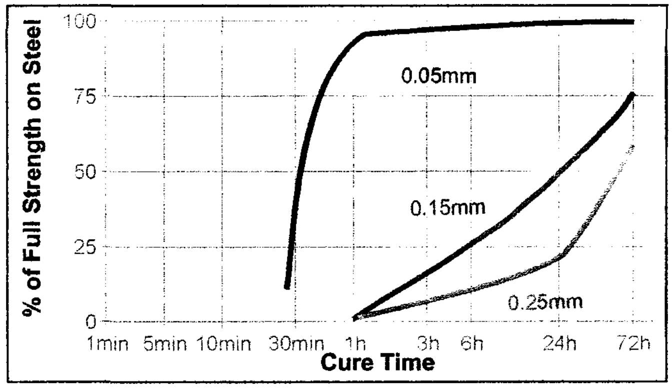
Cure Speed vs. Substrate

The rate of cure will depend on the substrate used. The graph below shows the shear strength developed with time on steel pins and collars compared to different materials and tested according to ISO 10123.



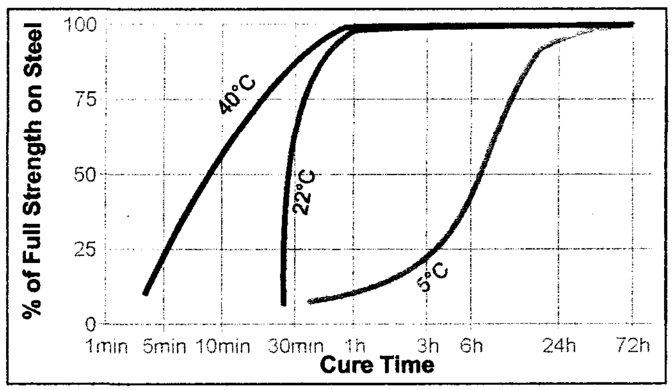
Cure Speed vs. Bond Gap

The rate of cure will depend on the bondline gap. The following graph shows shear strength developed with time on steel pins and collars at different controlled gaps and tested according to ISO 10123.



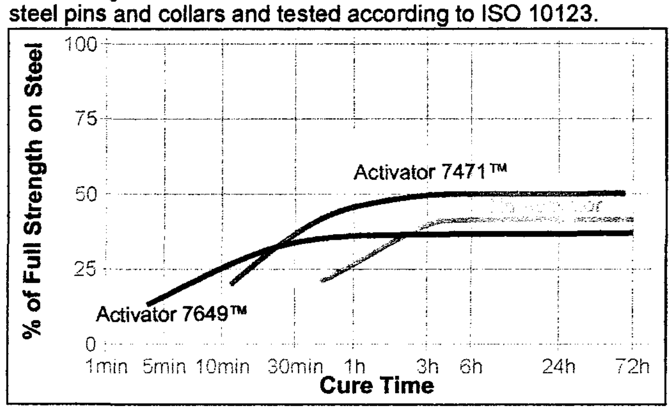
Cure Speed vs. Temperature

The rate of cure will depend on the temperature. The graph below shows the shear strength developed with time at different temperatures on steel pins and collars and tested according to ISO 10123.



Cure Speed vs. Activator

Where cure speed is unacceptably long, or large gaps are present, applying activator to the surface will improve cure speed. The graph below shows shear strength developed with time using Activator 7471™ and 7649™ on zinc dichromate steel pins and collars and tested according to ISO 10123.



TYPICAL PROPERTIES OF CURED MATERIAL

Physical Properties:

Coefficient of Thermal Expansion, ASTM D 696, K^{-1}	80×10^{-6}
Coefficient of Thermal Conductivity, ASTM C 177, W/(m·K)	0.1
Specific Heat, kJ/(kg·K)	0.3
Elongation, at break, ASTM D 412, %	<1

TYPICAL PERFORMANCE OF CURED MATERIAL

Adhesive Properties

After 24 hours @ 22 °C

Compressive Shear Strength, ISO 10123:

Steel pins and collars	N/mm²	≥19.3[LMS]
	(psi)	(≥2,800)

After 1 hour @ 93 °C, tested @ 22 °C

Compressive Shear Strength, ISO 10123:

Steel pins and collars	N/mm²	≥24.1[LMS]
	(psi)	(≥3,500)

TYPICAL ENVIRONMENTAL RESISTANCE

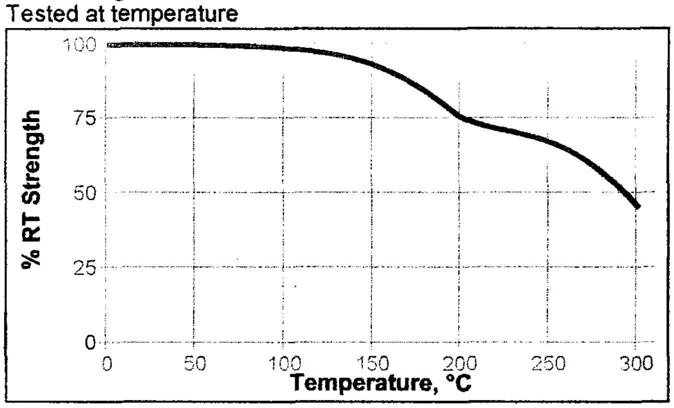
Cured for 1 week @ 22 °C

Compressive Shear Strength, ISO 10123:

Steel pins and collars

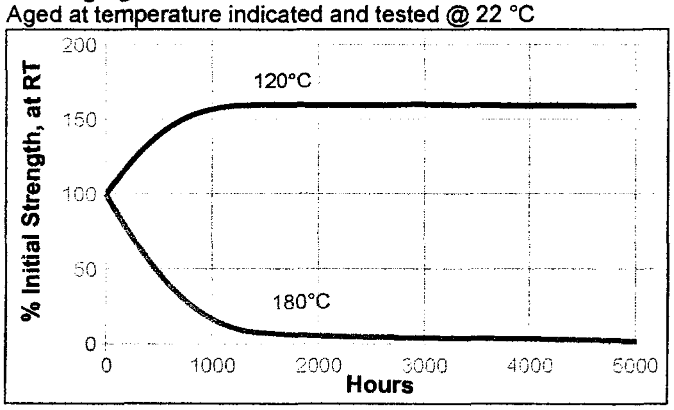
Hot Strength

Tested at temperature



Heat Aging

Aged at temperature indicated and tested @ 22 °C



Chemical/Solvent Resistance

Aged under conditions indicated and tested @ 22 °C.

		% of initial strength		
Environment	**°C**	**100 h**	**500 h**	**1000 h**
Motor Oil	125	100	100	100
Unleaded gasoline	22	100	100	100
Brake fluid	22	80	75	75
Water glycol 50/50	87	100	90	80
Ethanol	22	95	95	95
Acetone	22	80	80	80

GENERAL INFORMATION

This product is not recommended for use in pure oxygen and/or oxygen rich systems and should not be selected as a sealant for chlorine or other strong oxidizing materials.

For safe handling information on this product, consult the Material Safety Data Sheet (MSDS).

Where aqueous washing systems are used to clean the surfaces before bonding, it is important to check for compatibility of the washing solution with the adhesive. In some cases these aqueous washes can affect the cure and performance of the adhesive.

This product is not normally recommended for use on plastics (particularly thermoplastic materials where stress cracking of the plastic could result). Users are recommended to confirm compatibility of the product with such substrates.

Directions for use

For Assembly

1. For best results, clean all surfaces (external and internal) with a Loctite cleaning solvent and allow to dry.
2. If the material is an inactive metal or the cure speed is to slow, spray with Activator 7471™ or 7649™ and allow to dry.
3. **For Slip Fitted Assemblies**, apply adhesive around the leading edge of the pin and the inside of the collar and use a rotating motion during assembly to ensure good coverage.
4. **For Press Fitted Assemblies**, apply adhesive thoroughly to both bond surfaces and assemble at high press on rates.
5. **For Shrink Fitted Assemblies** the adhesive should be coated onto the pin, the collar should then be heated to create sufficient clearance for free assembly.
6. Parts should not be disturbed until sufficient handling strength is achieved.

For Disassembly

1. Apply localized heat to the assembly to approximately 250 °C. Disassemble while hot.

For Cleanup

1. Cured product can be removed with a combination of soaking in a Loctite solvent and mechanical abrasion such as a wire brush.

Loctite Material Specification[LMS]

LMS dated August 23, 1999. Test reports for each batch are available for the indicated properties. LMS test reports include selected QC test parameters considered appropriate to specifications for customer use. Additionally, comprehensive controls are in place to assure product quality and consistency. Special customer specification requirements may be coordinated through Henkel Quality.

Storage

Store product in the unopened container in a dry location. Storage information may be indicated on the product container labeling.

Optimal Storage: 8 °C to 21 °C. Storage below 8 °C or greater than 28 °C can adversely affect product properties. Material removed from containers may be contaminated during use. Do not return product to the original container. Henkel Corporation cannot assume responsibility for product which has been contaminated or stored under conditions other than those previously indicated. If additional information is required, please contact your local Technical Service Center or Customer Service Representative.

Conversions

(°C x 1.8) + 32 = °F
kV/mm x 25.4 = V/mil
mm / 25.4 = inches
N x 0.225 = lb
N/mm x 5.71 = lb/in
N/mm² x 145 = psi
MPa x 145 = psi
N·m x 8.851 = lb·in
N·mm x 0.142 = oz·in
mPa·s = cP

Note

The data contained herein are furnished for information only and are believed to be reliable. We cannot assume responsibility for the results obtained by others over whose methods we have no control. It is the user's responsibility to determine suitability for the user's purpose of any production methods mentioned herein and to adopt such precautions as may be advisable for the protection of property and of persons against any hazards that may be involved in the handling and use thereof. In light of the foregoing, **Henkel Corporation specifically disclaims all warranties expressed or implied, including warranties of merchantability or fitness for a particular purpose, arising from sale or use of Henkel Corporation's products. Henkel Corporation specifically disclaims any liability for consequential or incidental damages of any kind, including lost profits.** The discussion herein of various processes or compositions is not to be interpreted as representation that they are free from domination of patents owned by others or as a license under any Henkel Corporation patents that may cover such processes or compositions. We recommend that each prospective user test his proposed application before repetitive use, using this data as a guide. This product may be covered by one or more United States or foreign patents or patent applications.

Trademark usage

Reference 1.1