



Señores
DIVISION NUEVAS CREACIONES
Superintendencia de Industria y Comercio
Ciudad
E. _____ S. _____ D _____

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO



No. 07-218419- -00005-0000

Fecha: 2010-06-17 08:21:40 Dep. 2020 DIR.NUEVASCR
Tra. 3 MODELO Eve: 1 REGDEPOSITO
Act. 593 IMPULSOPROCESAL Folios: 2

Referencia: Expediente: 07-218419
Patente de modelo de utilidad:
Dispositivo optimizador de almacenamiento de gases
Solicitante: AXGAS S.A.
Inventor: Alejandro Rivera Álvarez
Actuación: Impulso Procesal

NATALIA ANDREA PIEDRAHITA RAMIREZ identificada como aparece al pie de mi firma, obrando en mi calidad de apoderada de la sociedad AXGAS S.A., atentamente le solicito dar impulso procesal a la solicitud de trámite de la patente de modelo de utilidad denominado dispositivo optimizador de almacenamiento de gases, conforme con las siguientes:

I. HECHOS

1. Mediante formulario radicado el día 08 de noviembre de 2007, la sociedad AXGAS S.A. solicitó el registro de la patente de modelo de utilidad denominado dispositivo optimizador de almacenamiento de gases.
2. El día 24 de junio de 2008, la División de Nuevas Creaciones ordeno la publicación de la patente de modelo de utilidad de la referencia y el 31 de julio de 2008 fue publicada.
3. El día 02 de octubre de 2008, se ordeno la petición de examen de patentabilidad de la solicitud de modelo de utilidad
3. Hasta la fecha, la División de Nuevas creaciones no ha resuelto el expediente de la referencia.

II. PETICION

Solicito de la amera más atenta, dar trámite a la solicitud de la referencia y conceder el registro de la de la patente de modelo de utilidad denominado dispositivo optimizador de almacenamiento de gases.

III. NOTIFICACIONES

Las recibiré en la Secretaria de su Despacho, y/o en mi oficina situada en la Carrera 14 No. 94 A 10 oficina 402 de la ciudad de Bogotá, D.C.

Sin otro particular,



NATALIA ANDREA PIEDRAHITA

CC No.32.105.433

T.P.101.866 del C.S DE LA J.

**SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO
DIRECCIÓN DE NUEVAS CREACIONES**

2020
Bogotá, D.C.

Abogada
Natalia Andrea Piedrahita Ramírez
(Apoderada)

ASUNTO	Radicación	07 - 218 419
	Trámite	003
	Evento	001
	Actuación	430
	Oficio	109198
	Folios	024

Patente de Invención

☐

Patente de Modelo de Utilidad

☒

Como resultado del examen de fondo, realizado con fundamento en el artículo 85 en concordancia con el artículo 45 de la Decisión 486 de la Comisión de la Comunidad Andina, se le comunica:

1. De los documentos estudiados

Descripción: Folios 10 a 14; y, 22 y 23 como se radicó inicialmente

Reivindicaciones: Folios 24 como se radicó inicialmente

Dibujos: Folios 16 a 21 como se radicó inicialmente

2. Del objeto de la solicitud

Título de la solicitud: *Dispositivo optimizador de almacenamiento de gases*, folio 1

El objeto de la presente solicitud de patente de modelo de utilidad consiste en suministrar una forma de aumentar la capacidad de almacenamiento de gases comprimidos.

El problema planteado en esta solicitud es lograr un almacenamiento de mayor cantidad de gas por unidad de volumen de la cámara de almacenamiento.

Para solucionar este problema técnico la solicitud en estudio proporciona una manera de almacenar el gas mediante el enfriamiento del mismo.

Clasificación Internacional de Patentes (IPC): F17C 5/06, 9/00, 19/00

3. De la solicitud de Patente de Modelo de Utilidad

Antes de entrar en detalles específicos, se le dan al solicitante ciertas indicaciones generales, algunas de las cuales son aplicables a este caso y todas deberán ser tenidas en cuenta en las eventuales modificaciones:

El título o nombre de la invención debe concordar con lo que se reclama en el capítulo reivindicatorio. Esto es, si en las reivindicaciones se reclama un producto, tal producto debe ser mencionado en el título, y si en las reivindicaciones se reclama un procedimiento o un sistema o un método, también debe ser mencionado allí. Normalmente, el título debe contener máximo diez palabras aunque eventualmente pueden ser más. El título no debe contener palabras cuyo significado no esté reconocido dentro del sector de la técnica de que se trate. Preferiblemente, deben ser palabras cuyo significado se encuentre en el Diccionario de la Real Academia Española (DRAE).

En Colombia, la máxima autoridad en cuestiones del lenguaje es la Academia Colombiana de la Lengua. En caso de duda sobre el significado de las palabras, se debe acoger la definición que trae el Diccionario de la Real Academia Española (DRAE).

En Colombia, es de uso obligatorio el Sistema Internacional de unidades. Esto implica, también, que la coma decimal es de uso obligatorio. Cuando aparezca algún valor con unidades diferentes a las exigidas, deberá incluirse su correspondiente conversión al Sistema Internacional.

La parte técnica de la solicitud se divide en tres secciones, debidamente separadas, preferiblemente en este orden: El capítulo descriptivo, el capítulo reivindicatorio y el juego de dibujos o figuras. Se prefiere que el texto se presente escrito de manera mecánica, en una sola columna. Ninguna de estas secciones podrá llevar membretes (encabezamientos o pies de página) ajenos al contenido técnico de la solicitud.

Por lo menos el capítulo descriptivo debe estar debidamente paginado y estar escrito a doble espacio, con el fin de facilitar la referencia a los apartados del texto. Se debe evitar, en lo posible, el uso de mayúsculas corridas, hay que recordar que ese empleo equivale a gritar en el lenguaje oral. Se pueden emplear las mayúsculas para resaltar ciertos apartados del texto, pero si todo el texto está escrito en mayúsculas, nada queda resaltado.

La terminología empleada en la descripción y en las reivindicaciones debe ser igual para designar las diferentes partes, piezas, elementos, detalles o aspectos de lo que se mencione en ellas; los cuales, a su vez, deben estar designados con números o signos de referencia.

Dentro del texto de la descripción y las reivindicaciones se aconseja encerrar entre paréntesis el número o signo de referencia cada vez que se mencione el detalle correspondiente, con el fin de distinguirlo de otros tipos de números o signos que eventualmente aparezcan allí. Estos números o signos de referencia deben aparecer dentro del juego de dibujos (preferiblemente, sin paréntesis, aunque pueden estar encerrados dentro de un círculo) siempre acompañados de líneas o flechas que señalen o indiquen a qué parte, pieza, elemento o aspecto se encuentran asociados.

Las reivindicaciones deben estar numeradas individual y consecutivamente (1, 2, ... 5, 6, etc.) El capítulo reivindicatorio no debe tener subtítulos.

Normalmente se pueden encontrar dos categorías de reivindicaciones: una, la de producto; y, la otra, de procedimiento.

En las reivindicaciones se deben definir los alcances de la protección que desea el solicitante. En consecuencia, las reivindicaciones forman un cuerpo aparte de la descripción y como tal debe ser redactado: la primera vez que se mencione un nombre dentro de las reivindicaciones debería estar acompañado de un artículo indeterminado; y, la inclusión -entre paréntesis- de un número de referencia no sustituye la definición del elemento o aspecto al que se refiere, simplemente sirve de información complementaria. Se debe entender que la descripción sirve para interpretar las reivindicaciones y, en consecuencia, si en una reivindicación se reclama un aparato, por ejemplo, no se deberían mencionar aspectos del funcionamiento del aparato dentro de la reivindicación, limitándose a definir únicamente los elementos que constituyen el aparato.

Para detectar si una definición de producto está bien hecha, se debe poder responder a la cuestión: ¿cómo es el producto reclamado? Si no se puede dar una respuesta razonable, es porque el producto está mal definido o no ha sido definido en absoluto. Otra prueba común es la de invertir el razonamiento: ¿son las características definidas -en determinada reivindicación- propias de un producto? Si la definición de una característica de un producto empieza por un verbo, muy seguramente no es una característica propia del producto.

Normalmente no se puede definir un producto por el procedimiento de su obtención, porque el producto, en la mayoría de los casos, es producido en cantidades industriales por una variedad de procedimientos, muchos de los cuales no dejan trazas o huellas que se puedan detectar satisfactoriamente en el producto terminado y puesto a disposición del público.

Por lo demás, los productos industriales son bienes tangibles, son algo concreto, tienen existencia física, y por tanto son susceptibles de definición mediante sus características físicas -en la mayoría de los casos- o físico-químicas en los restantes, aunque existen unas pocas excepciones -que pertenecen a ciertas tecnologías emergentes- en donde resulta más fácil su identificación por el procedimiento de obtención, pero éste no es el caso en la presente oportunidad.

Cada una de las figuras debe estar debidamente identificada, preferiblemente con un número consecutivo: Figura 1, figura 2, ...

Las figuras deben ser realizadas siguiendo las reglas del dibujo técnico.

Se prefiere que dentro de las figuras no se incluya ningún texto. Cada uno de los detalles ilustrados en las figuras deberá estar señalado con un número o signo de referencia, el cual será el mismo en todas las figuras en donde se encuentre el detalle en cuestión. Si en alguna figura no se encuentran números de referencia, se entiende que no se va a decir nada sobre ella dentro del texto de la descripción y, entonces, es preferible que se omita tal figura. Análogamente, si en una figura no se encuentra señalado algún detalle con el respectivo número de referencia, es preferible que se omita tal detalle.

La patente de **modelo de utilidad** no puede incluir los procedimientos, por definición. Si alguna de las reivindicaciones de una solicitud de patente de modelo de utilidad reclama un procedimiento, debe ser suprimida.

De la descripción (artículo 28 D. 486)

Durante el análisis del texto de la descripción y de las ilustraciones anexadas, se observaron los siguientes defectos:

(1) Si bien el título o nombre del modelo de utilidad anuncia un *dispositivo* dentro del texto de la descripción o en los dibujos no se define ningún dispositivo en concreto. Este mismo defecto se extiende a las reivindicaciones.

(2) La reseña de las figuras, que se encuentra en el folio 22, después de los dibujos, debería estar en el folio 12, inmediatamente antes del párrafo que empieza con la expresión: *El enfriamiento del gas se logra a través...*

(3) Dentro del texto de la descripción y las reivindicaciones se deberían incluir los números de referencia -encerrados entre paréntesis- inmediatamente después de la mención de cada detalle o parte o pieza ilustrado en las figuras.

(4) Cada una de las figuras debería estar designada con un número consecutivo, así, por ejemplo, en la denominada *figura 1* [no *figura #1*, como la denomina el solicitante, ver folio 12], folio 16, se encuentran tres ilustraciones diferentes, cada una de las cuales debería tener una designación propia.

(5) Los números de referencia se emplean para señalar en las figuras las partes o detalles que se mencionan dentro del texto. Siendo esto así, cada número de referencia debe estar asignado a una única pieza o parte o detalle ilustrado, independientemente de en qué figura se encuentre. Un ejemplo de la omisión de esta instrucción se puede apreciar en el número de referencia (2) de la figura 1-a, folio 16 comparado con el mismo número en la figura 4-a, folio 19.

(6) En todas las figuras se deben señalar con números de referencia los detalles ilustrados. Un ejemplo de la omisión de esta instrucción se encuentra en la figura 4-c, folio 19, donde no hay señalado ni un número de referencia.

(7) La descripción no es suficientemente completa como para que un tercero pueda ejecutarla.

La descripción no cumple con los requisitos de claridad y de completitud que exige el Art. 28 de la Decisión 486.

De las Reivindicaciones (artículo 30 D 486)

Durante el análisis del texto de las reivindicaciones se observaron los siguientes defectos:

1) En el capítulo reivindicatorio se encuentran ocho reivindicaciones independientes, todas reclamando un *dispositivo*. Esto no es admisible porque: o bien falla la concisión o bien falla el requisito de unidad de concepto inventivo. El último caso sucede si los dispositivos reclamados son definidos por características mutuamente excluyentes, esto es, no pueden existir las mismas características en dos dispositivos definidos en reivindicaciones diferentes. En la solicitud en estudio no es posible determinar cuál de las alternativas es la que se puede encontrar aquí porque en ninguna de las reivindicaciones se define un dispositivo como tal.

2) En las reivindicaciones 1 a 8, folio 24, se reclama un *dispositivo*, pero, en ninguna de ellas se definen las características tangibles que distinguen al dispositivo en cuestión. Por lo demás, ni en la descripción ni en los dibujos se establecen tampoco tales características. Las reivindicaciones 1 a 8, carecen de claridad, de definición y de sustento por esta causa.

Las reivindicaciones que dependen de una reivindicación objetada también se objetan por las mismas causas.

Las reivindicaciones no cumplen con los requisitos de claridad, de concisión y de sustento por la descripción que exige el Art. 30 de la Decisión 486.

Se deberían presentar, entonces, nuevos capítulos descriptivo y reivindicatorio, ambos completos, junto con un nuevo juego de dibujos, donde se hayan corregido todas las objeciones que se han hecho arriba. Esto con el fin de evitar -cuando solo se presentan algunas páginas sueltas corregidas- que el lector tenga que desplazarse desde un sitio a otro de la solicitud y luego regresar a donde estaba antes sin perder la ilación de la lectura, porque esto produce confusión y afecta negativamente la claridad de dichos capítulos.

No obstante lo anterior, **se le advierte al solicitante que las modificaciones sugeridas arriba podrían resultar inconducentes** toda vez que la insuficiencia en la descripción se considera un defecto insuperable. La razón de esta determinación se fundamenta en el artículo 34 D486, que a la letra dice:

El solicitante de una patente podrá pedir que se modifique la solicitud en cualquier momento del trámite. La modificación no podrá implicar una ampliación de la protección que correspondería a la divulgación contenida en la solicitud inicial.

Del mismo modo, se podrá pedir la corrección de cualquier error material.

4. De la unidad de invención (artículo 25 D 486)

Como se insinuó arriba, en el análisis preliminar del capítulo reivindicatorio, eventualmente las reivindicaciones podrían estar afectadas por falta de unidad de concepto inventivo. Esto sucedería si se reclamasen características que fuesen mutuamente excluyentes. En el momento no hay un pronunciamiento al respecto porque ninguna de las reivindicaciones 1 a 8, folio 24, define aceptablemente el dispositivo que reclama.

5. De la determinación del estado de la técnica

La fecha que se debería tener en cuenta para determinar el Estado de la Técnica es la

Fecha de presentación de la solicitud nacional 2007-11-08

Durante la búsqueda de anterioridades se encontraron los siguientes documentos, que forman parte del estado de la técnica cercano al objeto de la solicitud:

n.º	Documento	Título	Fecha de publicación
D1	Ullmann's Enc. of Industrial Chemistry; Wiley-VCH Verlag GmbH & Co. KGaA pp 1 a 10	«Heat exchange»(Intercambio de calor)	2005
D2	Britannica Concise Encyclopedia, p 852	«Heat exchanger»(Intercambiadores de calor)	2006
D3	McGraw-Hill Encyclopedia of Science & Technology, Vol 8, pp 412 y 413	«Heat exchanger»(Intercambiadores de calor)	2007
D4	Van Nostrand's Scientific Encyclopedia, Wiley-Interscience, Vol 2, pp 2418 y 2419	«Heat transfer»(Transferencia de calor)	2008

Se anexan copias de unas páginas pertinentes de estos documentos.

NOTAS: No se realizó una evaluación de los demás requisitos de patentabilidad, porque se objetó la falta de suficiencia de la descripción y porque se objetó la claridad, la definición, la concisión y el sustento de las reivindicaciones; esto es, no se pudieron realizar las comparaciones de rigor, por ausencia de materia. Una

vez hayan sido superadas las objeciones establecidas en este Concepto Técnico, se podrán hacer los exámenes correspondientes.

No obstante lo anterior, con fundamento en las enseñanzas que traen las enciclopedias citadas -especialmente la D1- como anterioridades así como en los conocimientos normales de una persona del nivel medio en la técnica se considera que el objeto de la solicitud no sería novedoso y, en consecuencia, sería inconducente realizar modificaciones en los aspectos formales. En todo caso, si se superaran las objeciones establecidas arriba, en su oportunidad, eventualmente se podrían citar algunos libros especializados en donde se encontrarían enseñanzas aún más cercanas a las del objeto de la solicitud; pero, en este momento, no hay las bases [recuérdese la sustracción de materia sobre la cual hacer comparaciones] para profundizar la búsqueda.

6. De las conclusiones:

Los requisitos de patentabilidad de la presente solicitud se encontrarían afectados negativamente por la falta de suficiencia o completitud de la descripción y por la falta de claridad de la descripción y las reivindicaciones; como, también, por la falta de sustento de estas últimas.

En cumplimiento del artículo 85 en concordancia con el artículo 45 de la Decisión 486 de la Comisión de la Comunidad Andina, se le indica al solicitante que debe dar respuesta dentro del término de treinta días contados a partir de la fecha de notificación de la presente comunicación. En caso de no dar respuesta al presente requerimiento, o si a pesar de la respuesta subsistieran los impedimentos para la concesión, se denegará la patente.

Notifíquese el presente oficio conforme a lo dispuesto en el artículo 8 de la resolución reglamentaria n.º 00210 del 15 de enero de 2001, advirtiéndole que contra él no procede recurso alguno en la vía gubernativa.



ALIX CARMENZA CÉSPEDES DE VERGEL
Directora de Nuevas Creaciones (C)

El anterior requerimiento fue notificado por fijación en lista, de fecha
22 JUL. 2010

CONCEPTO TÉCNICO n.º 2494

EXAMINADOR TÉCNICO
Código n.º 202009

Heat Exchange

RAMESH K. SHAH, Harrison Radiator Division, General Motors Corporation, Lockport, New York 14094, United States

ALFRED C. MUELLER, Church Hill, Maryland 21623, United States

1.	Introduction	6	5.3.	Extensions of the Basic Heat-Transfer Theory	47
2.	Classification of Heat Exchangers	7	5.3.1.	Longitudinal Wall Heat Conduction	47
2.1.	Classification According to Construction	7	5.3.2.	Variable Overall Heat-Transfer Coefficients	56
2.1.1.	Tubular Heat Exchangers	7	5.4.	Exchanger Pressure-Drop Analysis	57
2.1.1.1.	Shell-and-Tube Exchangers	7	5.4.1.	Plate-Fin Exchangers	57
2.1.1.2.	Double-Pipe Heat Exchangers	9	5.4.2.	Tube-Fin Exchangers	58
2.1.1.3.	Drip-Type Heat Exchangers	9	5.4.3.	Regenerators	59
2.1.2.	Plate-Type Heat Exchangers	9	5.4.4.	Plate Heat Exchangers	59
2.1.2.1.	Plate Heat Exchangers	12	6.	Single-Phase Heat-Transfer and Pressure-Drop Correlations	59
2.1.2.2.	Spiral-Plate Heat Exchangers	14	6.1.	Basic Concepts and Dimensionless Groups	59
2.1.3.	Extended-Surface Heat Exchangers	15	6.2.	Theoretical Solutions and Correlations for Simple Geometries	60
2.1.3.1.	Plate-Fin Heat Exchangers	15	6.2.1.	Fully Developed Flows	60
2.1.3.2.	Tube-Fin Heat Exchangers	17	6.2.2.	Hydrodynamically Developing Flows	64
2.1.4.	Regenerators	19	6.2.3.	Thermally Developing Flows	65
2.2.	Classification According to Process Function	19	6.2.4.	Simultaneously Developing Flows	66
2.2.1.	Condensers	20	6.3.	Empirical Correlations for Complex Geometries	66
2.2.2.	Liquid-to-Vapor Phase-Change Exchangers	23	6.3.1.	Tubular Exchangers	67
2.2.2.1.	Chemical Evaporators	23	6.3.2.	Plate Exchangers	70
2.2.2.2.	Reboilers	26	6.3.3.	Extended Surface Exchangers	70
2.2.2.3.	Waste Heat Boilers	28	7.	Two-Phase Heat-Transfer and Pressure-Drop Correlations	71
3.	Heat Exchanger Design Methodology	30	7.1.	Flow Patterns	71
4.	Criteria for Heat Exchanger Selection	30	7.2.	Two-Phase Pressure-Drop Correlations	74
4.1.	General Selection Criteria	30	7.2.1.	Intube Pressure Drop	74
4.1.1.	Design Variables	30	7.2.2.	Shellside (Tube Bundle) Pressure Drop	76
4.1.2.	General Selection Guidelines	32	7.2.3.	Other Geometries	76
4.2.	Shell-and-Tube Exchangers	33	7.3.	Heat-Transfer Correlations for Condensation	76
4.2.1.	Tubes	33	7.3.1.	Condensation Inside a Horizontal Tube	77
4.2.2.	Tube Pitch and Layout	34	7.3.2.	Condensation Inside a Vertical Tube	78
4.2.3.	Baffles	34	7.3.3.	Condensation Outside Horizontal Tube Bundles	79
4.2.4.	Shells	38	7.3.4.	Condensation over Finned Tubes	80
4.2.5.	Front-End Heads	40	7.3.5.	Condensation Outside Vertical Tube Bundles	80
4.2.6.	Rear-End Heads	40			
4.2.7.	Nozzles	42			
5.	Basic Heat-Transfer and Pressure-Drop Analysis	42			
5.1.	Basic Equations and Definitions of Heat-Transfer Analysis	42			
5.2.	Dimensionless Methods for Exchanger Heat-Transfer Analysis	45			

2 Heat Exchange

7.3.6.	Condensation of Mixtures	80	9.2.2.2.	Shellside Heat Transfer and Pressure Drop	98
7.4.	Heat-Transfer Correlations for Boiling and Evaporation	81	9.2.2.3.	Design Methods and Special Considerations	98
7.4.1.	Intube Forced Convective Boiling	81	9.2.3.	Vertical Thermosiphon Reboiler Design	98
7.4.2.	Intube Critical Heat Flux	83	9.2.3.1.	Pressure Balance in the Recirculation Loop	99
7.4.3.	Shellside Forced Convective Boiling	84	9.2.3.2.	Flow Regimes and Heat Transfer	99
7.4.4.	Shellside Critical Heat Flux	84	9.2.3.3.	Approximate Design Methods	100
8.	Thermal Design for Single-Phase Heat Exchangers	84	9.2.4.	Special Design Considerations	101
8.1.	Introduction	85	9.2.5.	Mean Temperature Difference	101
8.2.	Shell-and-Tube Exchangers	85	9.2.6.	Common Problems with Reboilers in Practical Applications	102
8.2.1.	Segmental Baffles	85	10.	Flow-Induced Vibrations	103
8.2.1.1.	Shellside Heat Transfer	86	10.1.	Vibration Analysis	104
8.2.1.2.	Shellside Pressure Drop	87	10.2.	Design Guidelines for Vibration Prevention	104
8.2.2.	Disk-and-Doughnut Baffles	88	10.2.1.	Tube Vibration	104
8.2.3.	Rod Baffles	88	10.2.2.	Acoustic Vibration	105
8.2.4.	Design Procedure	88	11.	Flow Maldistribution	105
9.	Thermal Design for Multiphase Heat Exchangers	89	11.1.	Causes of Flow Maldistribution	105
9.1.	Condensers	89	11.1.1.	Mechanical Design, Basic Geometry, and Tolerances	105
9.1.1.	Considerations in Condenser Design	89	11.1.2.	Self-Induced Maldistribution	105
9.1.2.	Condenser Types and Their Characteristics	90	11.1.3.	Mixed-Phase Flow	106
9.1.2.1.	Shellside Condensers	90	11.1.4.	Fouling	106
9.1.2.2.	Tubeside Condensers	91	11.2.	Consequences of Maldistribution	106
9.1.2.3.	Air-Cooled Condensers	93	11.2.1.	Shell-and-Tube Exchangers	106
9.1.3.	Condensation of Mixtures	94	11.2.2.	Other Exchangers	106
9.1.4.	Mean Temperature Difference	95	11.3.	Recommendations for Shell-and-Tube Exchangers	107
9.1.5.	Desuperheating	95	12.	Fouling	107
9.1.6.	Subcooling	95	13.	References	109
9.2.	Vaporizers	96			
9.2.1.	Kettle and Internal Reboiler Design	96			
9.2.2.	Horizontal Shellside Thermosiphon Reboiler Design	97			
9.2.2.1.	Pressure Balance in the Recirculation Loop	97			

Symbols

A	exchanger total heat-transfer area (primary plus secondary, if any) on one side, m^2 or ft^2
A_f	fin or extended surface area on one side of the exchanger, m^2 or ft^2
A_{fr}	frontal or face area of the exchanger, m^2 or ft^2
A_k	total wall cross-sectional area for longitudinal conduction, m^2 or ft^2
A_o	minimum free flow (or open) area, m^2 or ft^2
A_p	primary surface area on one side of the exchanger, m^2 or ft^2

A_w	total area for heat conduction from hot to cold fluid, m^2 or ft^2
B	coefficient [Eq. (85)], dimensionless
b	distance between two plates (fin height) in a plate-fin exchanger, m or ft
C	flow stream heat capacity rate with a subscript c or h, $C = Wc_p$, W/K or $Btu\ h^{-1}\ ^\circ F^{-1}$
C^*	heat capacity rate ratio = C_{min}/C_{max} , dimensionless
C_c	flow-stream heat capacity rate of cold fluid = $(Wc_p)_c$, W/K or $Btu\ h^{-1}\ ^\circ F^{-1}$
C_h	flow-stream heat capacity rate of hot fluid = $(Wc_p)_h$, W/K or $Btu\ h^{-1}\ ^\circ F^{-1}$

tant operating problems such as flow-induced vibration, flow maldistribution, and fouling.

2. Classification of Heat Exchangers

Heat exchangers can be classified according to transfer process, construction, flow arrangement, surface compactness, number of fluids, and heat-transfer mechanisms as shown in Figure 1 [1]. They can also be classified according to the process function (Fig. 2), industry, type of fluid, and site of installation in the plant.

2.1. Classification According to Construction

2.1.1. Tubular Heat Exchangers

Tubular heat exchangers are generally built of circular tubes, although elliptical and rectangular tubes have also been used. There is considerable design flexibility because the core geometry can be varied easily by changing the tube diameter, length, and arrangement. Tubular exchangers can be designed for any operating temperatures, pressures, and any temperature and pressure differences between the fluids, limited only by the materials of construction. They can be designed for special operating conditions: heavy fouling, highly viscous flow, corrosiveness, toxicity, radioactivity, etc. These exchangers may be further classified as shell-and-tube, double-pipe, spiral and tube-coil exchangers. Only the first two types, the most important, are described further here.

2.1.1.1. Shell-and-Tube Exchangers

Shell-and-tube exchangers are composed of round tubes mounted in a cylindrical shell with the tube axis parallel to that of the shell. One fluid flows inside the tubes, the other flows across and along the tubes. The major components of this exchanger are tubes (or tube bundle), shell, stationary or front-end head, rear-end head, baffles, and tubesheets. Detailed components for several shell-and-tube exchangers are shown in Figure 3.

A variety of internal constructions are used in shell-and-tube exchangers, depending upon the desired heat-transfer and pressure-drop performance and the methods employed to reduce thermal stresses, to prevent leakages, to provide for ease of cleaning, to contain operating pressures and temperatures, and to control corrosion. These exchangers are classified and constructed according to Tubular Exchanger Manufacturers Association (TEMA) standards [2] in the United States or modified TEMA standards in other countries.

TEMA has developed a notation system to designate major types of shell-and-tube exchangers. In this system, each exchanger is designated by a three letter combination, the first letter indicating the front-end head type, the second the shell type, and the third the rear-end head type. These are identified in Figure 4. Some of the common shell-and-tube exchangers are AES, AEP, CFU, AKT, and AJW. Other special types of shell-and-tube exchangers have front-end and rear-end heads different from those in Figure 3. These exchangers may not be identifiable by the TEMA letter designation.

The sizes of shells or tube bundles are designated by describing the shell/tube bundle nominal diameter and tube lengths (both in inches, 1 in = 2.54 cm, by TEMA). Except for the kettle reboiler, the nominal diameter is the shell inside diameter, rounded off to the nearest integer; for the kettle reboiler, the nominal diameter is the port diameter (the shell inside diameter (*ID*) near the tube fluid inlet) followed by the shell *ID*. The three letter designation of the type of the exchanger follows the size of shell. Some examples of Figure 3 are the following:

- B) Fixed tubesheet exchanger with bonnet stationary head, single pass on shellside and tubeside, 23-1/4 in (59.1 cm) shell inside diameter, 18 ft (5.49 m) tubes. Size 23-216 type BEM.
- C) Outside packed floating head exchanger with removable channel and cover, one shell pass, two tube passes, shell inside diameter 21 in (53.3 cm) with 14 ft (4.27 m) tubes. Size 21-168 type AEP.
- D) U-tube exchanger with stationary head channel integral with tubesheet and removable cover, two-pass shell with longitudinal baf-

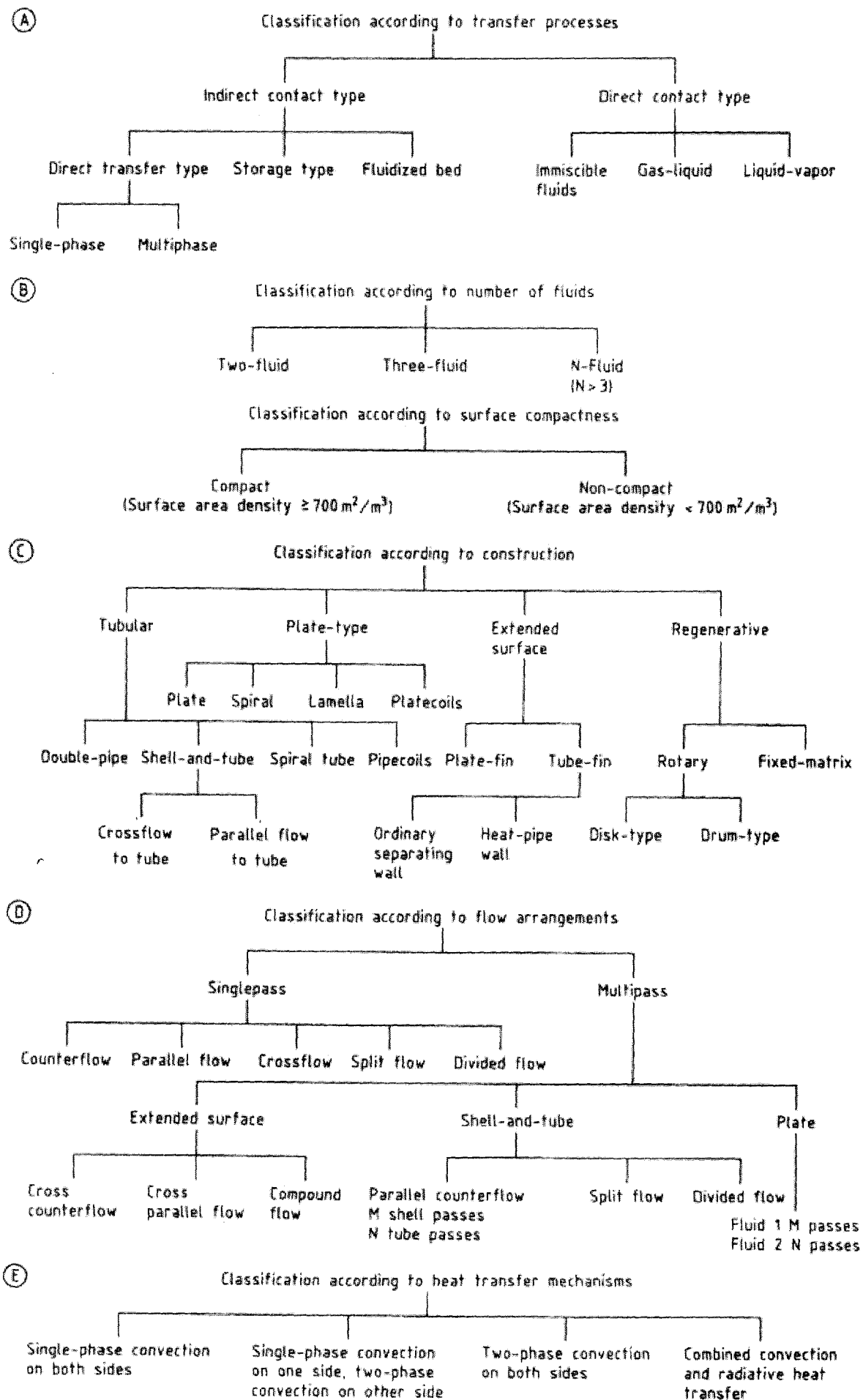


Figure 1. Classification of heat exchangers

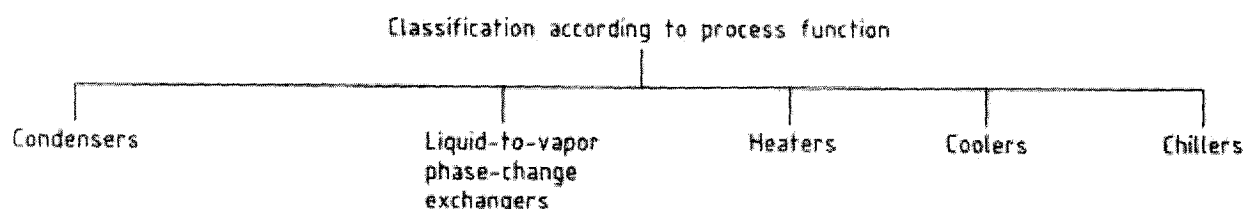


Figure 2. Classification according to process function

fe, 31 in (78.7 cm) shell inside diameter, 20 ft (6.1 m) tubes. Size 31 – 240 type CFU.

- E) Pull-through floating head kettle-type reboiler with removable channel and cover, 25 in (63.5 cm) port diameter and 44 in (1.12 m) shell inside diameter with 20 ft (6.1 m) tubes. Size 25/44 – 240 type AKT.

TEMA has set up mechanical standards for design, fabrication, and materials for three classes of heat exchangers: R, C, and B. *Class R* designates the unfired shell-and-tube heat exchangers generally used for severe conditions in petroleum and related processing. *Class C* designates the unfired shell-and-tube heat exchangers generally used for moderate conditions of commercial and general processing. *Class B* designates the unfired shell-and-tube heat exchangers used for chemical process service. Generally, Class B exchangers employ nonferrous materials, while the other heat exchangers employ ferrous materials.

Further description of the individual components of shell-and-tube exchangers is provided in Section 4.2.

2.1.1.2. Double-Pipe Heat Exchangers

Double-pipe heat exchangers usually consist of concentric pipes. One fluid flows in the inner pipe and the other flows countercurrently in the annulus between the pipes. This is perhaps the simplest heat exchanger. Flow distribution is no problem, and cleaning is done easily by disassembly. This configuration is appropriate when one or both of the fluids are at very high pressure because containment in small diameter pipe or tubing is less costly than containment in large diameter shell. Double-pipe exchangers are generally used for the small capacity applications where the total heat-transfer surface area is 50 m² (500 ft²) or less. Stacks of double-pipe or multitube-type heat exchangers are also used

in some process applications with radial or longitudinal fins.

2.1.1.3. Drip-Type Heat Exchangers

Drip or trombone exchangers are serpentine or flattened helical coil tubes with water flowing over the horizontal tubes in a falling film. They are similar to double-pipe exchangers except that the outer pipe jacket is omitted. It has the advantages of a high water side heat-transfer coefficient, easy cleaning while in operation, and no possibility of leakage of water contaminating the process fluid. Additional cooling can take place by evaporation, but this is of minor importance. Major disadvantages are the large space requirement, the need for a sump pump or sewer line, and messy operation.

2.1.2. Plate-Type Heat Exchangers

Plate-type heat exchangers are usually built of thin plates (all prime surface), which are either smooth or corrugated and are either flat or wound in an exchanger. Generally, these exchangers cannot accommodate high pressure and temperature differences. These exchangers may be further classified as plate, spiral plate, lamella, and platecoil exchangers [1], the first two types being described further.

2.1.2.1. Plate Heat Exchangers

The plate and frame or gasketed plate heat exchanger (PHE) consists of a number of thin, rectangular metal plates sealed around the edges by gaskets and held together in a frame as shown in Figure 5. The frame usually has a fixed-end cover (headpiece) fitted with the connecting ports and a movable cover plate (pressure

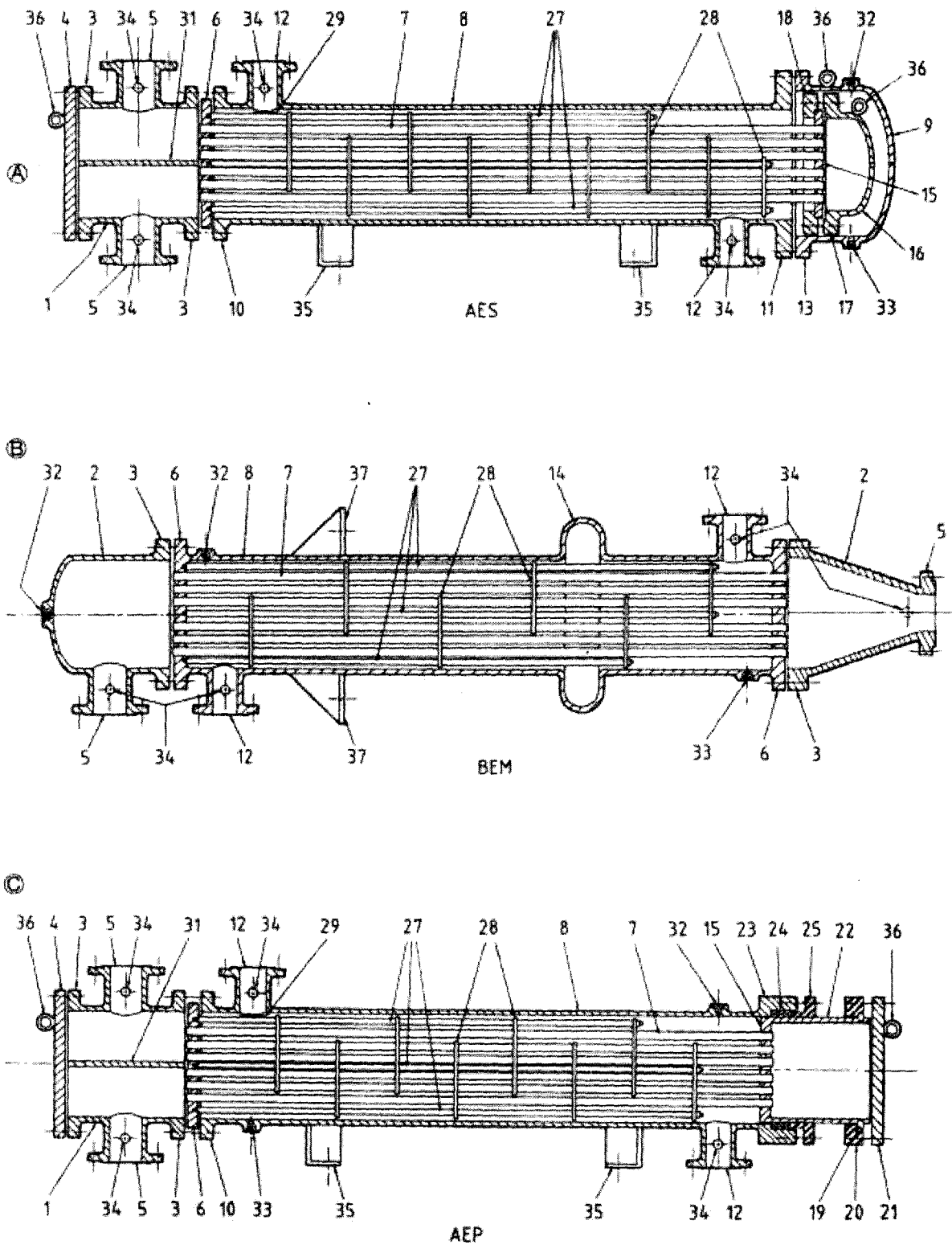


Figure 3. Shell-and-tube heat exchangers [2]

1 Stationary head-channel; 2 Stationary head-bonnet; 3 Stationary head flange-channel or bonnet; 4 Channel cover; 5 Stationary head nozzle; 6 Stationary tubesheet; 7 Tubes; 8 Shell; 9 Shell cover; 10 Shell flange-stationary head end; 11 Shell flange-rear-head end; 12 Shell nozzle; 13 Shell cover flange; 14 Expansion joint; 15 Floating tubesheet; 16 Floating head cover; 17 Floating head flange; 18 Floating head backing device; 19 Split shear ring; 20 Slip-on backing flange; 21 Floating head cover-external; 22 Floating tubesheet skirt; 23 Packing box; 24 Packing; 25 Packing gland; 26 Lantern ring; 27 Tierods and spacers; 28 Transverse baffles or support plates; 29 Impingement plate; 30 Longitudinal baffle; 31 Pass partition; 32 Vent connection; 33 Drain connection; 34 Instrument connection; 35 Support saddle; 36 Lifting lug; 37 Support bracket; 38 Weir; 39 Liquid level connection

10 Heat Exchange

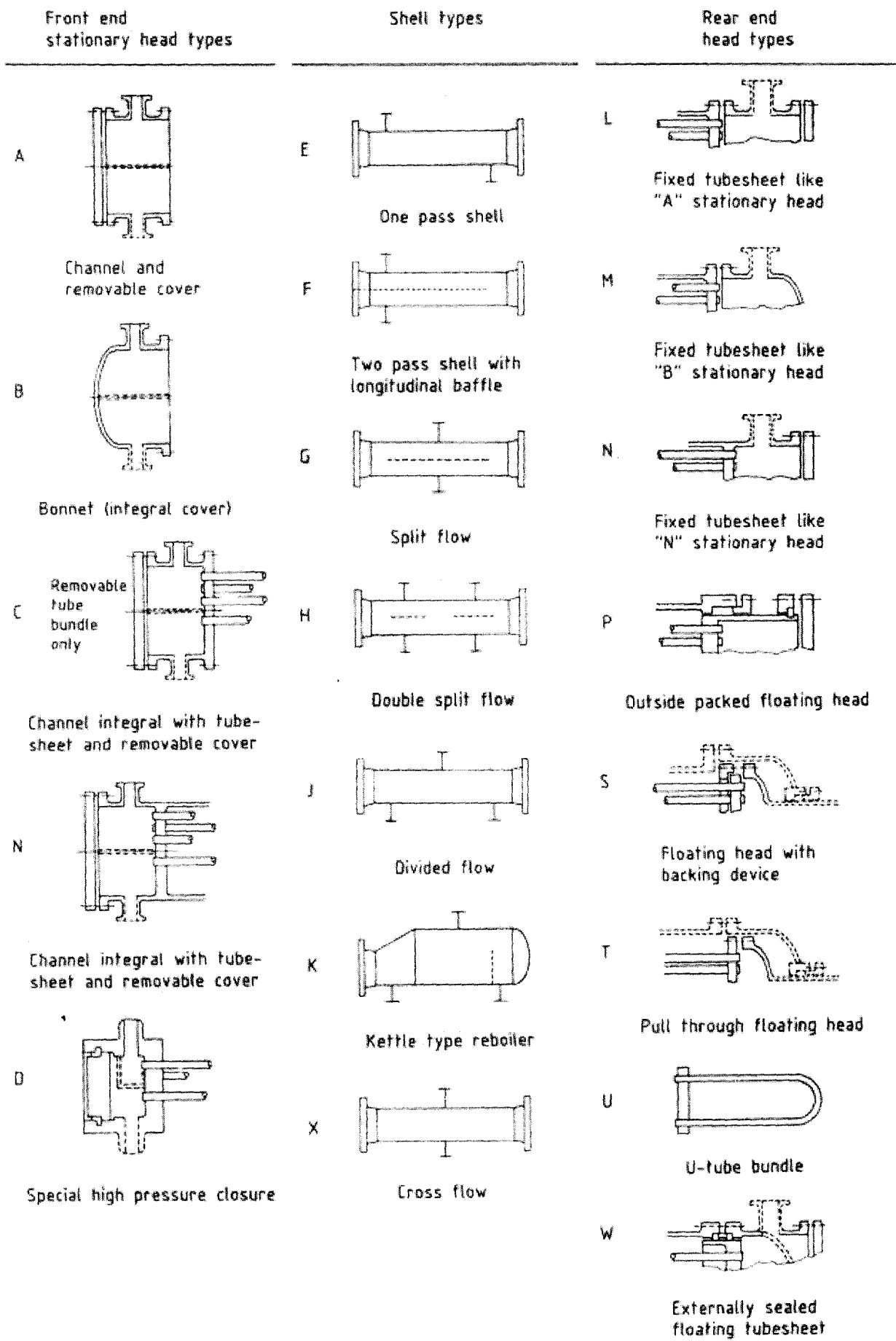


Figure 4. Standard shell types, front-end and rear-end head types [2]

FROM THE EDITORS OF THE ENCYCLOPEDIA BRITANNICA

Revised and Expanded Edition

Britannica CONCISE ENCYCLOPEDIA



ENCYCLOPEDIA
Britannica

Britannica CONCISE ENCYCLOPEDIA

Encyclopædia Britannica

First published in 1768, the *Encyclopædia Britannica* has long been the standard by which all other reference works are judged. It represents a tradition of excellence that was built, over the centuries, on meticulous scholarship and unmatched attention to detail. Today, Encyclopædia Britannica, Inc., produces a range of fine products for reference, education, and learning in different media and in many different languages. Wherever you see the Britannica name—in print, on the Internet, CD-ROM, or DVD—it is your guarantee of quality, accuracy, and authority.

© 2006 BY ENCYCLOPÆDIA BRITANNICA, INC.

Copyright Under International Copyright Union
All Rights Reserved Under International and Universal Copyright Conventions
by Encyclopædia Britannica, Inc.

Library of Congress Control Number: 2006921235
International Standard Book Number-13: 978-1-59339-492-9

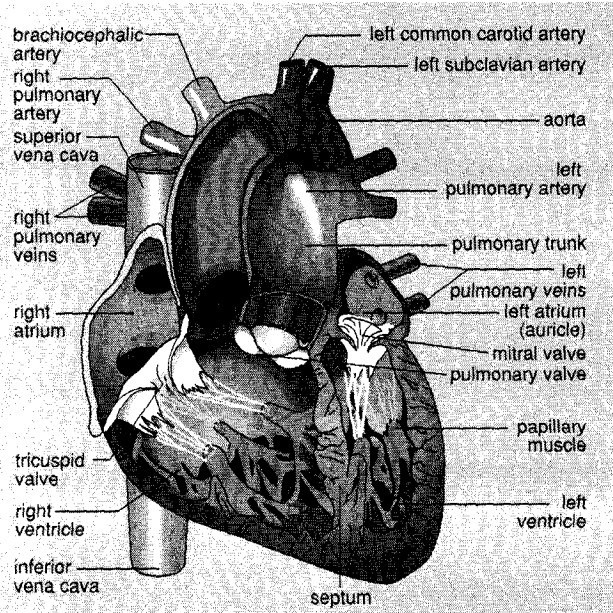
The original edition of this book, created in conjunction with Merriam-Webster, Incorporated, was published in 2000 as Merriam-Webster's Collegiate Encyclopedia.

No part of this work may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without permission in writing from the publisher.

Encyclopædia Britannica and other fine products are available on the Internet at <http://www.britannica.com>.

(Trademark Reg. U.S. Pat. Off.) Printed in Peru.

and propels it into the pulmonary circulation. The left atrium takes in blood from the pulmonary veins and sends it into the systemic circulation. Electrical signals from a natural PACEMAKER cause the heart muscle to contract. Valves in the heart keep blood flowing in one direction. Their snapping shut after each contraction causes the sounds heard as the heart-beat. See also CARDIOVASCULAR SYSTEM.



Structure of the human heart. Oxygen-rich blood from the lungs enters the heart through the pulmonary veins, passing into the left atrium and on to the left ventricle. Contraction of the muscles of the left ventricle forces blood into the aorta. The mitral valve prevents blood from moving back into the left atrium during contraction. Various arteries branch off from the aorta to supply blood to all parts of the body. Oxygen-poor blood draining from the body into the superior vena cava and inferior vena cava flows to the right atrium, through the tricuspid valve, and into the right ventricle. As the right ventricle contracts, oxygen-poor blood passes through the pulmonary valve into the pulmonary arteries and on to the lungs to receive oxygen.

© MERRIAM-WEBSTER INC.

heart attack or myocardial infarction Death of a section of HEART muscle when its blood supply is cut off, usually by a blood clot in a coronary artery narrowed by ATHEROSCLEROSIS. HYPERTENSION, DIABETES MELLITUS, high CHOLESTEROL, cigarette SMOKING, and CORONARY HEART DISEASE increase the risk. Symptoms include severe chest pain, often radiating to the left arm, and shortness of breath. Up to 20% of victims die before reaching the hospital. Diagnosis is done by ELECTROCARDIOGRAPHY and by analysis for ENZYMES in the blood. Treatment aims to limit the area of tissue death (infarct) and prevent and treat complications. Thrombolytic (clot-dissolving) drugs may be administered. BETA-BLOCKERS alleviate pain and slow the heart rate. ANGIOPLASTY or CORONARY BYPASS restores blood flow to heart muscle. Follow-up may include drugs, exercise programs, and counseling on diet and lifestyle changes.

heart clam See COCKLE

heart disease Any disorder of the heart. Examples include CORONARY HEART DISEASE, CONGENITAL HEART DISEASE, and PULMONARY HEART DISEASE, as well as rheumatic heart disease (see RHEUMATIC FEVER), HYPERTENSION, inflammation of the heart muscle (myocarditis) or of its inner or outer membrane (ENDOCARDITIS, pericarditis), and heart valve disease. Abnormalities of the heart's natural PACEMAKER or of the nerves that conduct its impulses cause ARRHYTHMIAS. Some CONNECTIVE TISSUE diseases (notably systemic LUPUS ERYTHEMATOSUS, RHEUMATOID ARTHRITIS, and SCLERODERMA) can affect the heart. HEART FAILURE may result from many of these disorders.

heart failure Inability of one or both sides of the HEART to pump enough blood for the body. Causes include PULMONARY HEART DISEASE, HYPERTENSION, and coronary ATHEROSCLEROSIS. A person with left-sided heart failure experiences shortness of breath after exertion, difficulty in breathing while

lying down and night breathlessness, and abnormally high pressure in the pulmonary veins. A person with right-sided failure experiences abnormally high pressure in the systemic veins, liver enlargement, and accumulation of fluid in the legs. A person with failure of both ventricles has an enlarged heart and a three-beat heartbeat. Treatment includes bed rest, medications such as DIGITALIS, control of excess salt and water retention, and elimination of the underlying cause. See also CONGESTIVE HEART FAILURE.

heart transplant Procedure to remove a diseased HEART and replace it with a healthy one from a legally dead donor. The first was performed in 1967 by CHRISTIAAN BARNARD. The diseased heart is removed (except for some atrial tissue to preserve nerve connections to the natural PACEMAKER). The new heart is put in place and connected to the recipient's blood vessels. Patients and donors are matched for tissue type, but the patient's IMMUNE SYSTEM must still be suppressed to prevent rejection (see IMMUNOSUPPRESSION). A successful TRANSPLANT can enable the recipient to have an active life for many years.

heartwood Dead, central wood of trees. Its cells usually contain tannins or other substances that make it dark and sometimes fragrant. Heartwood is mechanically strong, resistant to decay, and less easily penetrated by wood-preservative chemicals than other types of wood. One or more layers of living and functional sapwood cells are periodically converted to heartwood.

heartworm Species (*Dirofilaria immitis*) of FILARIAL WORM that parasitizes mammals, especially dogs. Up to 500 adult heartworms, which can grow to 6–12 in. (15–30 cm) long, live in the dog's heart, and the microfilariae (embryonic larvae) pass into the blood. Mosquitoes transfer infested blood from dog to dog. Both adult and larval heartworms tax the heart and restrict blood flow to the lungs, kidneys, and liver. By the time visible symptoms (chronic cough, labored breathing, listlessness, heart failure) develop, it may be too late for treatment. Preventive medicines and treatments, including surgery, exist.

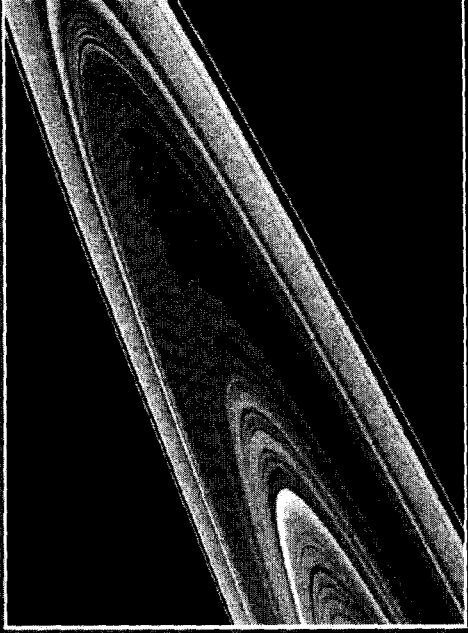
heat Energy transferred from one body to another as the result of a difference in temperature. Heat flows from a hotter body to a colder body when the two bodies are brought together. This transfer of energy usually results in an increase in the temperature of the colder body and a decrease in that of the hotter body. A substance may absorb heat without an increase in temperature as it changes from one PHASE to another—that is, when it melts or boils. The distinction between heat (a form of energy) and temperature (a measure of the amount of energy) was clarified in the 19th century by such scientists as J.-B. FOURIER, GUSTAV KIRCHHOFF, and LUDWIG BOLTZMANN.

heat capacity Ratio of heat absorbed by a material to the change in temperature. It is usually expressed as calories per degree in terms of the amount of the material being considered. Heat capacity and its temperature variation depend on differences in energy levels for ATOMS. Heat capacities are measured with a CALORIMETER and are important as a means of determining the ENTROPIES of materials. See also SPECIFIC HEAT.

heat exchanger Any of several devices that transfer HEAT from a hot to a cold FLUID. In many engineering applications, one fluid needs to be heated and another cooled, a requirement economically accomplished by a heat exchanger. In double-pipe exchangers, one fluid flows inside the inner pipe, and the other in the annular space between the two pipes. In shell-and-tube exchangers, many tubes are mounted inside a shell; one fluid flows in the tubes and the other flows in the shell, outside the tubes. Special-purpose devices such as boilers, evaporators, superheaters, condensers, and coolers are all heat exchangers. Heat exchangers are used extensively in fossil-fuel and NUCLEAR POWER plants, gas TURBINES, heating and AIR CONDITIONING, REFRIGERATION, and the chemical industry. See also COOLING SYSTEM.

heat exhaustion or heat prostration Response of the body to excessive heat. The body temperature rises moderately and heavy PERSPIRATION persists. Heat exhaustion results from inadequate water and salt intake and can lead to DEHYDRATION and collapse. It may progress to HEAT-STROKE if not treated by lying down in a cool place and drinking fluids, preferably water with salt added.

heat pump Device for transferring heat from a substance or space at one temperature to another at a higher temperature. It consists of a compressor, a condenser, a throttle or expansion valve, an evaporator, and a working fluid (refrigerant). The compressor delivers vapourized refrigerant to the condenser in the space to be heated. There, cooler air condenses



MCGRAW-HILL
ENCYCLOPEDIA OF
SCIENCE &
TECHNOLOGY

www.MHEST.com

8 GEO-HYS



On the front cover

TraR protein structure of *Agrobacterium tumefaciens*, the causal agent of crown gall disease. (Image: Argonne National Laboratory)

Library of Congress Cataloging-in-Publication Data

McGraw-Hill encyclopedia of science & technology—10th ed.

p. cm.

Includes bibliographical references and index.

ISBN 978-0-07-144143-8 (alk. paper)

1. Science—Encyclopedias. 2. Technology—Encyclopedias.

I. Title: Encyclopedia of science & technology.

II. Title: McGraw-Hill encyclopedia of science and technology.

Q121.M3 2007

503—dc22

2007006137

13-digit ISBN: 978-0-07-144143-8 (set)

10-digit ISBN: 0-07-144143-3 (set)

McGraw-Hill



A Division of The McGraw-Hill Companies

McGraw-Hill Encyclopedia of Science & Technology

Copyright © 2007, 2002, 1997, 1992, 1987, 1982, 1977, 1971, 1966, 1960 by The McGraw-Hill Companies, Inc. All rights reserved. Printed in the United States of America. Except as permitted under the United States Copyright Act of 1976, no part of this publication may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the prior written permission of the publisher.

1 2 3 4 5 6 7 8 9 0 DOW/DOW 0 1 2 1 0 9 8 7

This book set was printed on acid-free paper.

It was set in Garamond Book and Neue Helvetica Black Condensed by Aptara, Falls Church, Virginia. The art was prepared by Aptara. The book was printed and bound by R. R. Donnelley, Willard, Ohio.

in pressure in a unit mass of material at constant temperature and the heat required to cause unit change in volume at constant temperature. These are designated $\partial Q_P/\partial P$ and $\partial Q_T/\partial V$. Similarly, $\partial Q_V/\partial P$ and $\partial Q_P/\partial V$ may be called heat capacities. See SPECIFIC HEAT; THERMODYNAMIC PRINCIPLES.

Harold C. Weber

Bibliography. I. M. Klotz and R. M. Rosenberg, *Classical Thermodynamics*, 5th ed., 1994; K. C. Rolfe, *Thermodynamics and Heat Power*, 5th ed., 1998.

Heat exchanger

A device used to transfer heat from a fluid flowing on one side of a barrier to another fluid (or fluids) flowing on the other side of the barrier.

When used to accomplish simultaneous heat transfer and mass transfer, heat exchangers become special equipment types, often known by other names. When fired directly by a combustion process, they become furnaces, boilers, heaters, tube-still heaters, and engines. If there is a change in phase in one of the flowing fluids—condensation of steam to water, for example—the equipment may be called a chiller, evaporator, sublimator, distillation-column reboiler, still, condenser, or cooler-condenser.

Heat exchangers may be so designed that chemical reactions or energy-generation processes can be done within them. The exchanger then becomes an integral part of the reaction system and may be known as a nuclear reactor or catalytic reactor.

Heat exchangers are normally used only for the transfer and useful elimination or recovery of heat without an accompanying phase change. The fluids on either side of the barrier are usually liquids, but they may also be gases such as steam, air, or hydrocarbon vapors; or they may be liquid metals such as sodium or mercury. Fused salts are also used as heat-exchanger fluids in some applications.

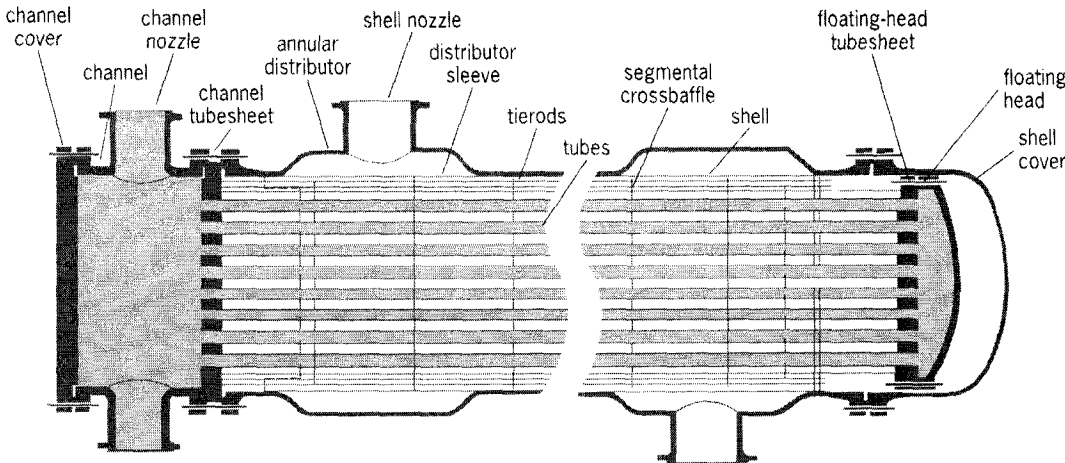
With the development and commercial adoption of large, air-cooled heat exchangers, the simplest ex-

ample of a heat exchanger would now be a tube within which a hot fluid flows and outside of which air is made to flow for cooling. By similar reasoning, any container of a fluid immersed in any fluid could serve as a heat exchanger if the flow paths were properly connected, or any container of a fluid exposed to air becomes a heat exchanger when a temperature differential exists.

Most often, the barrier between the fluids is a metal wall such as that of a tube or pipe. However, it can be fabricated from flat metal plate or from graphite, plastic, or other corrosion-resistant materials of construction. If the barrier wall is that of a seamless or welded tube, several tubes may be tied together into a tube bundle (see *illus.*) through which one of the fluids flows distributed within the tubes. The other fluid (or fluids) is directed in its flow in the space outside the tubes through various arrangements of passes. This fluid is contained by the heat-exchanger shell. Discharge from the tube bundle is to the head (heads) and channel of the exchanger. Separation of tube-side and shell-side fluids is accomplished by using a tube sheet (tube sheets).

Applications. Heat exchangers find wide application in the chemical process industries, including petroleum refining and petrochemical processing; in the food industry, for example, for pasteurization of milk and canning of processed foods; in the generation of steam for production of power and electricity; in nuclear reaction systems; in aircraft and space vehicles; and in the field of cryogenics for the low-temperature separation of gases. Heat exchangers are the workhorses of the entire field of heating, ventilating, air-conditioning, and refrigeration.

Classifications. The exchanger type described in general terms above and illustrated by the diagram is the well-known shell-and-tube heat exchanger. Shell-and-tube exchangers are the most numerous, but constitute only one of many types. Exchangers in use range from the simple pipe within a pipe—with a few square feet of heat-transfer surface—up to the



Schematic diagram of heat exchanger.

complex-surface exchangers that provide thousands of square feet of heat-transfer area.

In between these extremes is a broad field of shell-and-tube exchangers often specifically named by distinguishing design features; for example, U tube, fin tube, fixed tube sheet, floating head, lantern-ring packed floating head, socket-and-gland packed floating head, split-ring internal floating head, pull-through floating head, nonremovable bundle with floating head or U-tube construction, and bayonet type.

Also, varying pass arrangements and baffle-and-shell alignments add to the multiplicity of available designs. Either the shell-side or tube-side fluids, or both, may be designed to pass through the exchanger several times in concurrent, countercurrent, or cross flow to the other fluids.

The concentric pipe within a pipe (double pipe) serves as a simple but efficient heat exchanger. One fluid flows inside the smaller-diameter pipe, and the other flows, either concurrently or countercurrently, in the annular space between the two pipes, with the wall of the larger-diameter pipe serving as the shell of the exchanger.

To solve new processing problems and to find more economical ways of solving old ones, new types of heat exchangers are being developed. There has been much emphasis on cramming more heat-transfer surface into less and less volume. Extended-surface exchangers, such as those built with fin tubes, are finding wide application.

Water shortage has added a new dimension to heat-exchanger design and has led to use of air-cooled exchangers.

Plate-type heat exchangers, long used in the milk industry for pasteurization and skimming, have moved into the chemical and petroleum industries. Coiled tubular exchangers and coiled-plate heat exchangers are winning new assignments. Spiral exchangers offer short cylindrical shells with flat heads, carrying inlets and outlets leading to internal spiral passages. These passages may be made with spiral plates or with spiral banks of tubes. Exchangers with mechanically scraped surfaces are finding favor for use with very viscous and pastelike materials.

A somewhat unusual type of plate heat exchanger is one in which sheets of 16-gage metal, seam- and spot-welded together, are embossed to form transverse internal channels which carry the heat-transfer medium. This type is often used for immersion heating in electroplating and pickling.

Materials of construction. Every metal seems to be a possible candidate as a material of construction in fabrication of heat exchangers. Most often, carbon steels and alloy steels are used because of the strength they offer, especially when the exchanger is to be operated as a pressure vessel. Because of excellent heat conductance, brass and copper find wide use in exchanger manufacture.

Corrosion plays a key role in the selection of exchanger construction materials. Often, a high-priced material will be selected to contain a corrosive tube-

side fluid, with a cheaper material being used on the less corrosive shell side.

For special corrosion problems, exchangers are built from graphite, ceramics, glass, bimetallic tubes, tantalum, aluminum, nickel, bronze, silver, and gold. See CORROSION.

Problems of use. Each of the fluids and the barrier walls between them offers a resistance to heat transfer. However, another major resistance that must be considered in design is the formation of dirt and scale deposited on either side of the barrier wall. It may become so great that the exchanger will have to be removed from service periodically for cleaning.

Chemical and mechanical methods may be used to remove the dirt and scale. For mechanical cleaning, the exchanger is removed from service and opened up. Perhaps the entire tube bundle is pulled from the exchanger shell if the plant layout has provided space for this to be done. If the deposit is on the inside of straight tubes, cleaning may be accomplished merely by forcing a long worm or wire brush through each tube.

More labor is required to remove deposits on the shell side. After removal of the tube bundle, special cleaning methods such as sandblasting may be necessary.

Much engineering effort has gone into the design of heat exchangers to allow for fouling. However, it has been suggested that methods are available to design heat exchangers that, by accommodating a certain amount of dirt in a thermal design, will allow heat exchangers to run forever without shutdown for cleaning. Commercial units designed in this fashion are in operation.

Another operating problem is allowance for differential thermal expansion of metallic parts. Most operating difficulties arise during the startup or shutdown of equipment. Therefore, the following general rules have been suggested: (1) Startup. Always introduce the cooler fluid first. Add the hotter fluid slowly until the unit is up to operating conditions. Be sure the entire unit is filled with fluid and there are no pockets or trapped inert gases. Use a bleed valve to remove trapped gases. (2) Shutdown. Shut off the hot fluid first, but do not allow the unit to cool too rapidly. Drain any materials which might freeze or solidify as the exchanger cools. (3) Steam condensate. Always drain any steam condensate from heat exchangers when starting up or shutting down. This reduces the possibility of water hammer caused by steam forcing the trapped water through the lines at high velocities. See CONDUCTION (HEAT); CONVECTION (HEAT); COOLING TOWER; DISTILLATION; EVAPORATOR; FURNACE CONSTRUCTION; HEAT RADIATION; HEAT TRANSFER; VAPOR CONDENSER. Raymond F. Fremed

Bibliography. N. Afgan et al. (eds.), *New Developments in Heat Exchangers*, 1996; S. Kakaç and H. Liu, *Heat Exchangers: Selection, Rating and Thermal Design*, 2d ed., 2002; T. Kuppan, *Heat Exchanger Design Handbook*, 2000; R. K. Shah and D. P. Sekulic, *Fundamentals of Heat Exchanger Design*, 2002.

Copyright ©2008 by John Wiley & Sons, Inc. All rights reserved.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey
Published simultaneously in Canada

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, (978) 750-8400, fax (978) 750-4470, or on the web at www.copyright.com. Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008, or online at <http://www.wiley.com/go/permission>.

Limit of Liability/Disclaimer of Warranty: While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives or written sales materials. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the publisher nor author shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

For general information on our other products and services or for technical support, please contact our Customer Care Department within the United States at (800) 762-2974, outside the United States at (317) 572-3993 or fax (317) 572-4002.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic formats. For more information about Wiley products, visit our web site at www.wiley.com.

Library of Congress Cataloging-in-Publication Data:

Van Nostrand's scientific encyclopedia. — 10th ed. / edited by Glenn D. Considine.

p. cm.

Includes index.

"Three volume set."

ISBN 978-0-471-74338-5 (cloth)

1. Science—Encyclopedias. 2. Engineering—Encyclopedias. I. Considine, Glenn D. II. Title: Scientific encyclopedia.

Q121.V3 2008

503—dc22

2007046658

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

a radiant beam approaching the interface in the medium 1 in the opposite direction that is absorbed in medium 2. The wave velocity in medium 1 is c . Kirchhoff's law states that the combination of the parameters on the left-hand side of Eq. (6) is again a function of temperature and frequency only, but does not depend upon the nature of the medium. A medium which absorbs all the radiation traveling into it through an interface ($\alpha_v = 1$) is called a *blackbody*. The intensity of radiation emitted by an arbitrary medium is, according to Eq. (6), in the following way related to the intensity of radiation i_{bv} emitted by a black body at the same temperature and frequency:

$$\frac{i_v}{i_{bv}} \quad (7)$$

See also **Planck Radiation Formula.**

The amount of heat transferred by radiation can be determined by use of the *Stefan-Boltzmann Law*

$$Q = bA(T_1^4 - T_2^4) \quad (8)$$

where Q is the amount of heat transferred per unit time, b is a constant, A is the area of the radiating surface, T_1 is the absolute temperature of the radiating body and T_2 is the absolute temperature of the receiving body. Various correction factors are introduced into the formula to account for the shape of the bodies, their thermal radiation characteristics and the properties of the media through which the radiant rays must pass while traveling from radiator to absorber. The thermal radiation characteristics are its emissivity, a measure of its ability to radiate at a given temperature, its absorptivity, a measure of its ability to absorb heat and its reflectivity, which measures its ability to reflect without absorbing.

Radiant energy travels in a straight line. Therefore to transmit it to an object out of sight of the radiator requires a reflector, such as a furnace wall, to deflect the rays to their objective.

It is possible to set up controlled laboratory radiation between simple plane surfaces and determine therefrom accurate coefficients to incorporate into radiation equations. However, the radiation of heat from furnace gases, consisting of non-luminous gases, luminous carbon particles in flame, ash globules, etc., to the walls and tubes of a steam generator in commercial operation at variable load, is another matter. Here, empirical data which are gathered and interpreted from field tests on similar equipment, must still be resorted to however great the designer's urge to go back to basic laws of heat transfer.

Radiant heat transfer in furnaces is roughly proportioned to the difference in the fourth power of the absolute temperatures of the radiating and receiving surfaces. The water wall surface is approximately at boiler saturation temperature, while the superheater surface varies from this to somewhat above the temperature of the steam at the superheater outlet. However, the mean radiating temperature of the furnace gases is usually over 1204°C. The fourth power of the receiving surface temperature is thus seen to be small compared to the fourth power of the transmitting surface temperature; consequently the latter controls the transmittance, and boiler tube temperature does not need to be considered a variable to be accounted for.

Figure 2 shows some of the arrangements in which radiant heat-absorbing surface is disposed. It may be used to illustrate another of the difficulties that beset the designer in following a rational or semi-rational form of radiation analysis. Projected radiant surface is one thing; actual radiant energy receiving surface may be quite a different area. For example, suppose the tubes of case (a) to be separated and spaced l_1 inches on centers. The *projected* areas of cases (a) and (c) would then be the same, but it seems obvious that re-radiation from the wall causes more of a (c) tube to receive radiant energy than is the case with an (a) tube. Also, if δ is a factor correcting projected area to *equivalent* absorbing surface, what value should be assigned to it in the case of a bank of tubes which may receive by re-radiation some radiant energy deep in the tube bank? Here δ

has a minimum value of 1, but some investigators have derived expressions which indicate that δ may have a magnitude of 3 or more.

Industrial Heat Transfer Equipment

Some of the more common cases of industrial heat transfer are:

1. Radiation from fuel beds and luminous gases to absorptive surfaces such as boilers, cylinder walls, etc.
2. Radiation from heat generators such as drying lamps.
3. Convection of heat out of combustion regions.
4. Convection of heat from hot surfaces under either free or forced convection.
5. Conduction of heat through the tubes of boilers, heaters, heat exchangers, condensers, etc.
6. Conduction in walls, pipe covering, and other so-called "heat insulators."
7. Conduction of heat through the plates of plate-type heat exchangers and regenerators.

Heat exchangers perform many functions within a manufacturing facility. Often they are given special names, even though they remain fundamentally heat exchangers. These include:

Chiller—a device which cools fluids to temperature below those obtainable with ordinary cooling water by using the vaporization of a refrigerant. The fluid to be cooled is routed through the tubes while the low-boiling refrigerant vaporizes from a pool of liquid in the shell.

Partial Condensers—Many overhead vapors from distillation columns in petroleum-refinery services are a mixture of light and heavy hydrocarbons and noncondensable gases, i.e., gases that are not condensed at the outlet temperature and pressure of the condenser (air, hydrogen sulfide, methane, and other light ends). These vapors are routed through the shell side while water is used as the cooling medium on the tube side of the unit. Condensation on the shell side begins at the saturation temperature of the heavy components and continues over a decreasing temperature range until part of the lighter components are condensed. Part of the existing liquid is sent back to the tower as reflux, while the remainder is further refined or passes to the trim cooler and storage.

Trim Cooler—This unit condenses the last remaining light-end vapors and cools the liquid to the ultimate storage temperature (often about 100°F: 38°C) by using cooling water. This cooling usually is not conducted in the main condenser because it would reduce column pressure.

Thermosiphon Reboiler—Flow of the vaporizing fluid depends upon the difference in static head between the column of liquid flowing from the tower to the reboiler and the partially vaporized column of liquid returning from the exchanger to the tower.

Reboilers—These exchangers operate in conjunction with a distillation tower to vaporize enough liquid to assure vaporization of the overhead product. A hot process stream of steam may be used as the heating medium. Most reboilers are shell-and-tube exchangers located at the base of the tower. The vaporizing fluid is routed through the shell side of the exchanger.

Forced-circulation Reboiler—A pump is used to provide more positive circulation than available with the thermosiphon effect, e.g., in the vaporization of viscous fluids.

Vapor Heat Exchanger—Units of this type preheat a cool stream of process fluid by using heat from partially condensing vapor. The objective is to conserve heat and eliminate the requirement for a separate preheater.

Air-cooled Exchanger—As used in the petroleum industry, air-cooled exchangers normally comprise two headers joined by a horizontal bank of finned tubes. Usually two motor-driven fans located above (induced draft) or below (forced draft) the tubes are used to circulate the air over the finned surface.

Superheater—A unit of this type heats vapor above the saturation temperature.

Waste-heat Boiler—A unit of this type generates steam and is similar to a regular steam generator except that hot gas or liquid produced by a chemical reaction (often combustion) is the heating medium.

Types of Heat Exchangers. In terms of heat exchange for recovering and recycling thermal energy, the shell-and-tube heat exchanger of the type

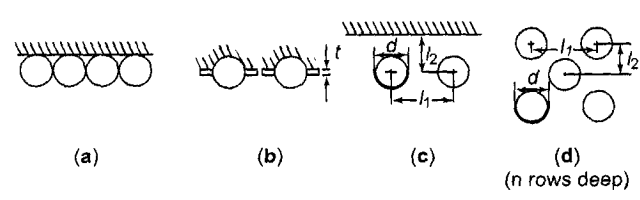


Fig. 2. Arrangements of radiant heat-absorbing surface.

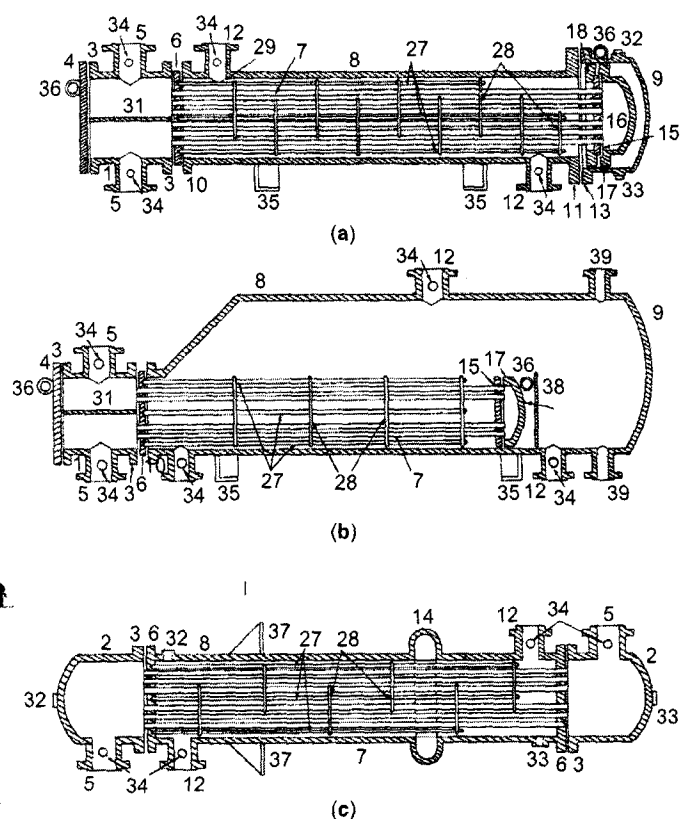


Fig. 3. Three common types of shell-and-tube heat exchangers: (a) Type AES, internal-floating-head exchanger (with floating-head backing device); (b) Type AKT, kettle-type floating-head reboiler; and (c) Type BEM, fixed-tube sheet exchanger. (Sketches adapted from specification diagrams from the Standards of Tubular Exchange Manufacturers Association.) Legend: (1) Stationary head, channel, (2) stationary head bonnet, (3) stationary-head flange, channel, or bonnet, (4) channel cover, (5) stationary-head nozzle, (11) stationary tube sheet, (12) tubes, (13) shell, (9) shell cover, (10) shell flange, stationary-head end, (11) shell flange, rear-head end, (12) shell nozzle, (13) shell cover flange, (14) expansion joint, (15) floating tube sheet, (16) floating-head cover, (17) floating-head flange, (18) floating-head backing device, (19) split shear ring, (20) slip-on backing flange, (21) floating-head cover, external, (22) floating tube sheet skirt, (23) packing-box flange, (24) packing, (25) packing follower ring, (26) lantern ring, (27) tie rods and spacers, (28) transverse baffle, (29) impingement baffle, (30) longitudinal baffle, (31) pass partition, (32) vent connection, (33) drain connection, (34) instrument connection, (35) support saddle, (36) lifting lug, (37) support bracket, (38) weir, and (39) liquid-level connection.

shown in Fig. 3 for many decades has been the most common type. It can be used with liquid on both sides, gas on both sides, or liquid on one side and gas on the other side. The most common requirement is for liquid-liquid exchangers. Heat exchangers may be used strictly for processing purposes—that is, materials need to be heated (or cooled) prior to entering some processing application, such as reacting, distilling, vaporizing, and the like. Or heat exchangers may be used simply for recovering the energy from hot fluids for use elsewhere.

Although immensely improved over the years from the standpoint of design efficiency, resistance to corrosion, and ease of maintenance, among other objectives, the fundamental design has remained unchanged. However, within the past few years, the plate-and-frame heat exchanger has been introduced. See Fig. 4. This type of exchanger consists of a frame that carries a series of closely spaced metal plates that have been pressed, with a corrugated trough pattern. The plates, which are clamped between a fixed head and movable follower, have corner ports to permit the passage of process and service liquids. There are elastomeric gaskets around the ports and plate edges to avoid leakage. The plates are grouped into passes within the heat exchanger. The product and service fluids flow countercurrent to each other between the parallel passages in each pass. Initially, plate-and-frame exchangers were used for liquid-liquid thermal exchange purposes.

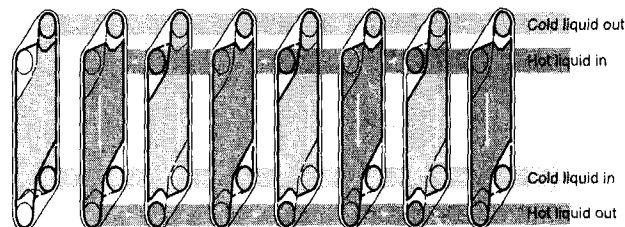


Fig. 4. Principle of plate-and-frame heat exchanger. (After Carlson.)

Increasingly, they are finding use in condensing and boiling applications, where their compact size and thinner material requirements for wetted parts offer advantages over other types of heat-exchange designs.

Less commonly used are the heat-transfer configurations shown in Figs. 5 through 9.

Heat Storage

It is often necessary to store heat in rather large quantities in specially designed apparatus. Hot water, of course, is one of the easiest forms in

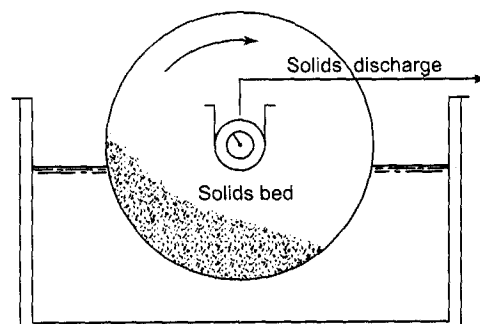


Fig. 5. Plain rotating shell used for both heating and cooling. For high-range heating, tempered combustion gases may be used instead of water.

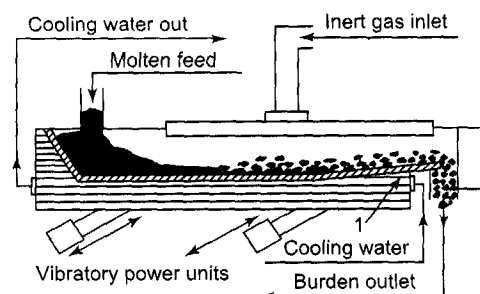


Fig. 6. Vibrating-type heat-transfer equipment for batch solidification. Sometimes referred to as a *caster*, the machine is used widely in a number of industries. After cooling and solidification, intense vibratory action shatters cake into lumps.

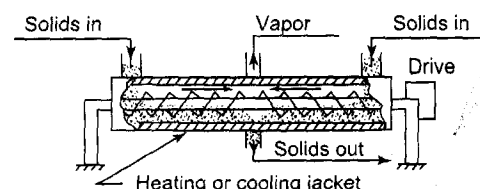


Fig. 7. Tank equipped with mixing ribbon spirals provides considerable agitation and is useful for melting or cooking dry powdered solids. Heat-transfer efficiency is only moderate because of the relatively deep beds of solid particles.