United States Patent

[11] 3,595,299

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[21] Appl. No. 845,399
[22] Filed July 28, 1969
[45] Patented July 27, 1971
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[32] Priority July 29, 1968, Sept. 9, 1968
[33] Germany
[31] P 17 51 779.2 and P 17 76 041.7

[54] APPARATUS FOR THE EVAPORATION OF LOW-TEMPERATURE LIQUEFIED GASES

13 Claims, 19 Drawing Figs.

[52] U.S. Cl. 159/28 D, 165/157, 165/177, 165/179, 138/38
[51] Int. Cl. B01d 1/100, F28f 1/00, F28d 7/10
[50] Field of Search 138/38; 165/157, 172, 170, 177, 108; 159/28 D, 13, 28, 16 A, 16 S; 122/367 C

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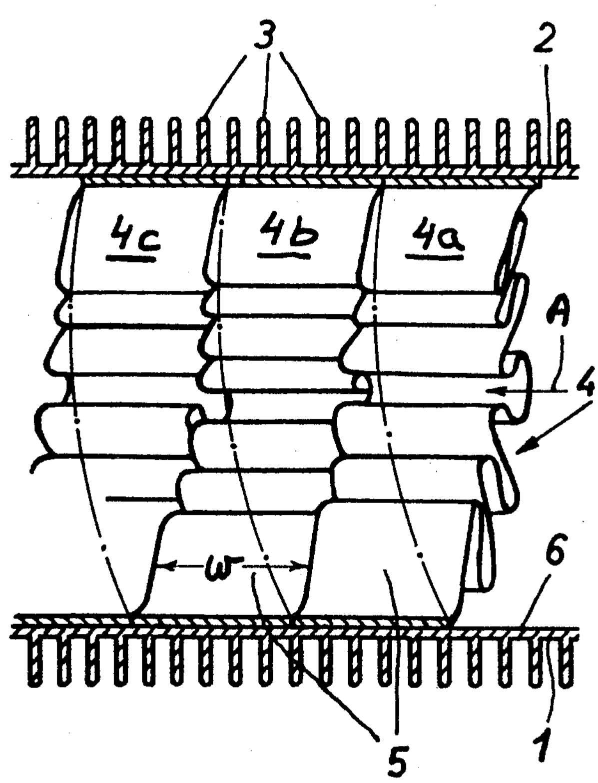
ABSTRACT: An apparatus for the evaporation of low-temperature liquefied gases which comprises a tube bundle immersed in a water bath which may be heated by steam. The tubes of the bundle each contain a plurality of turbulence-inducing baffles which are soldered or welded to the inner surface of the tube and are of plane undulating, zigzag or coiled configuration. Successive baffles may be angularly offset about the axis of the tube from one another.



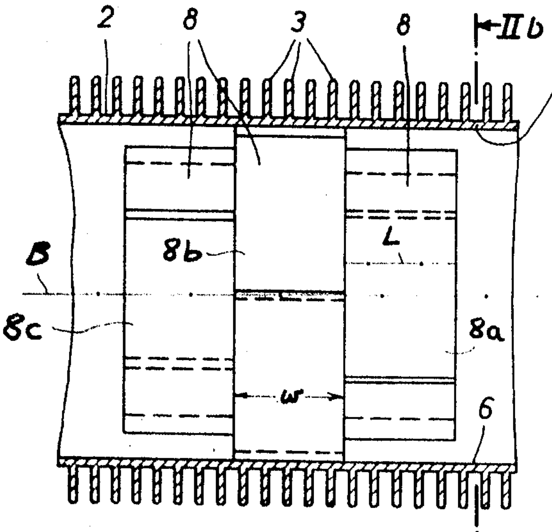


Fig. 2a

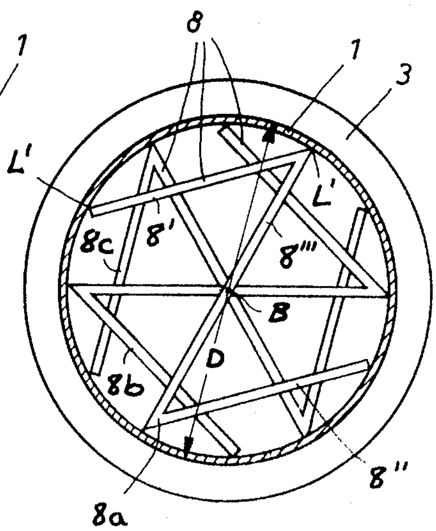


Fig. 2b

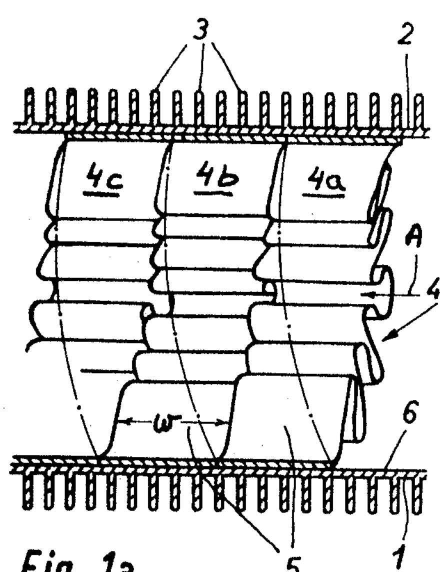


Fig. 1a

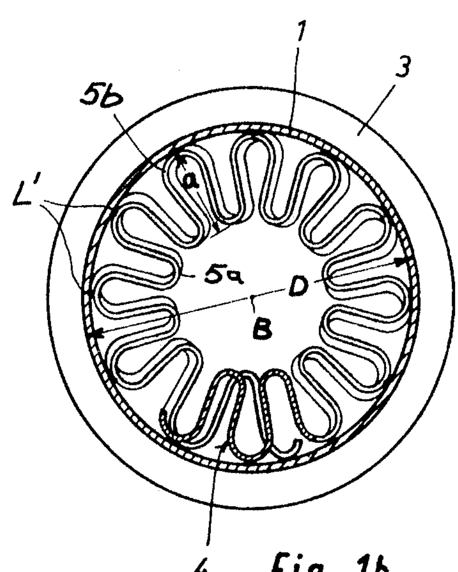


Fig. 1b

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Fig. 3

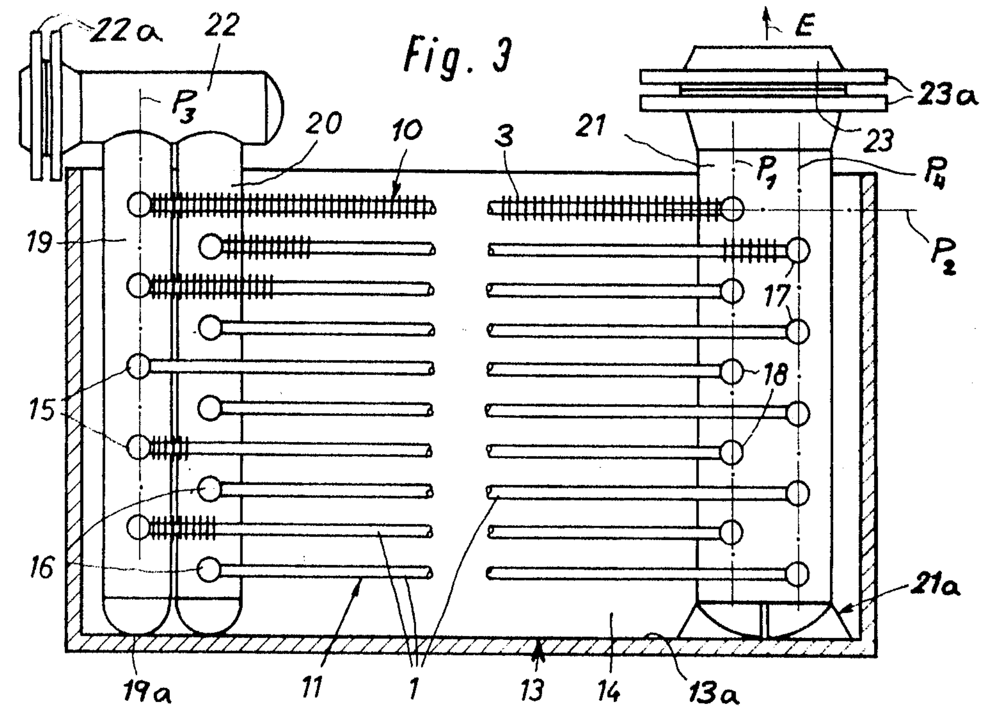

Fig. 4

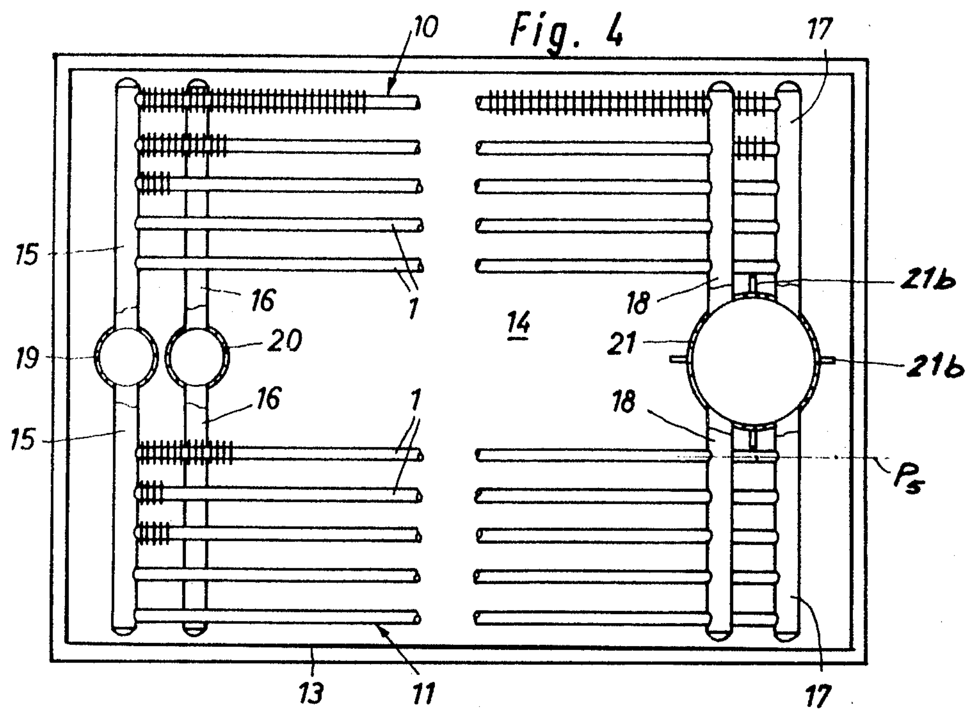

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Fig. 5

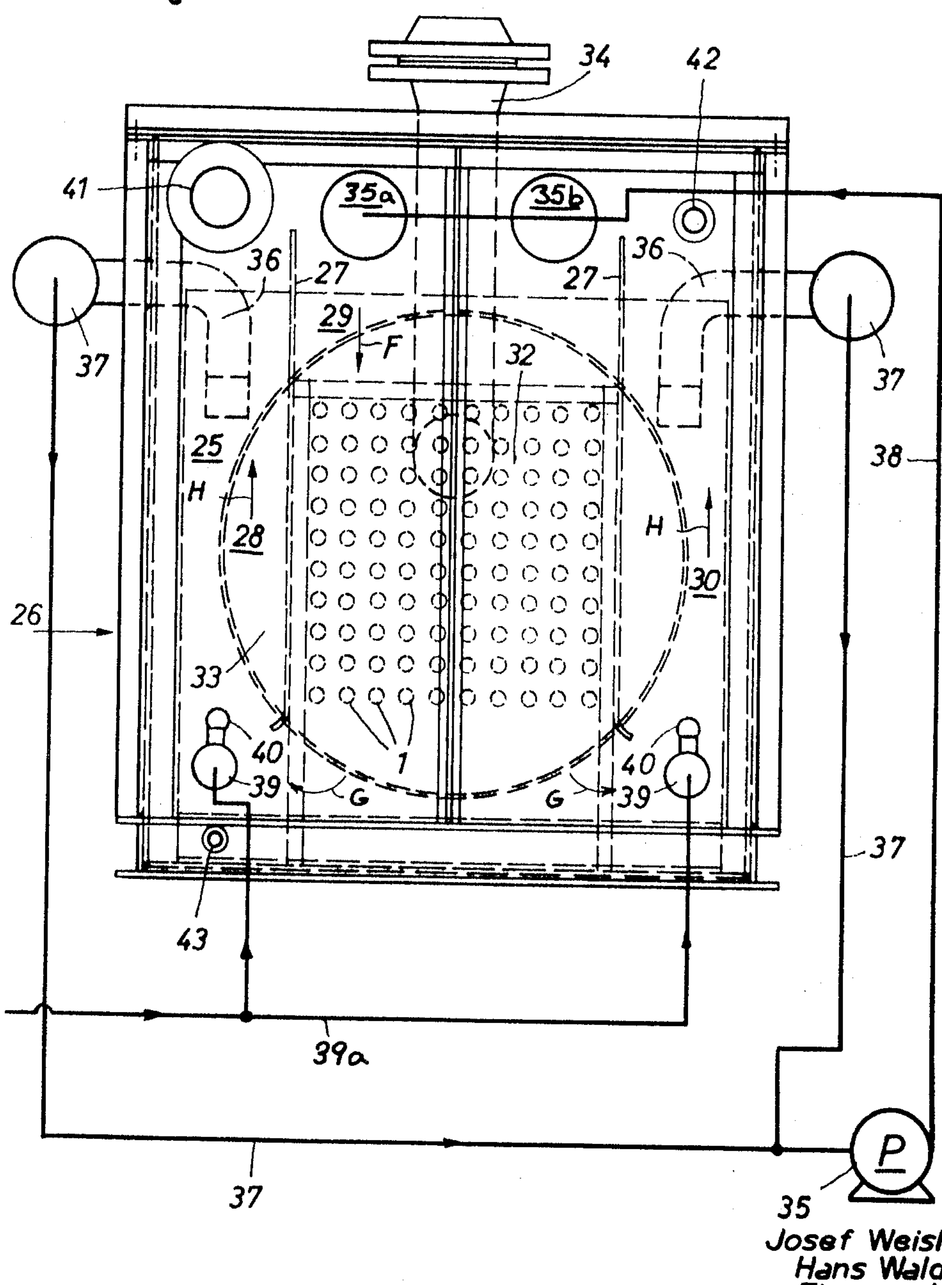

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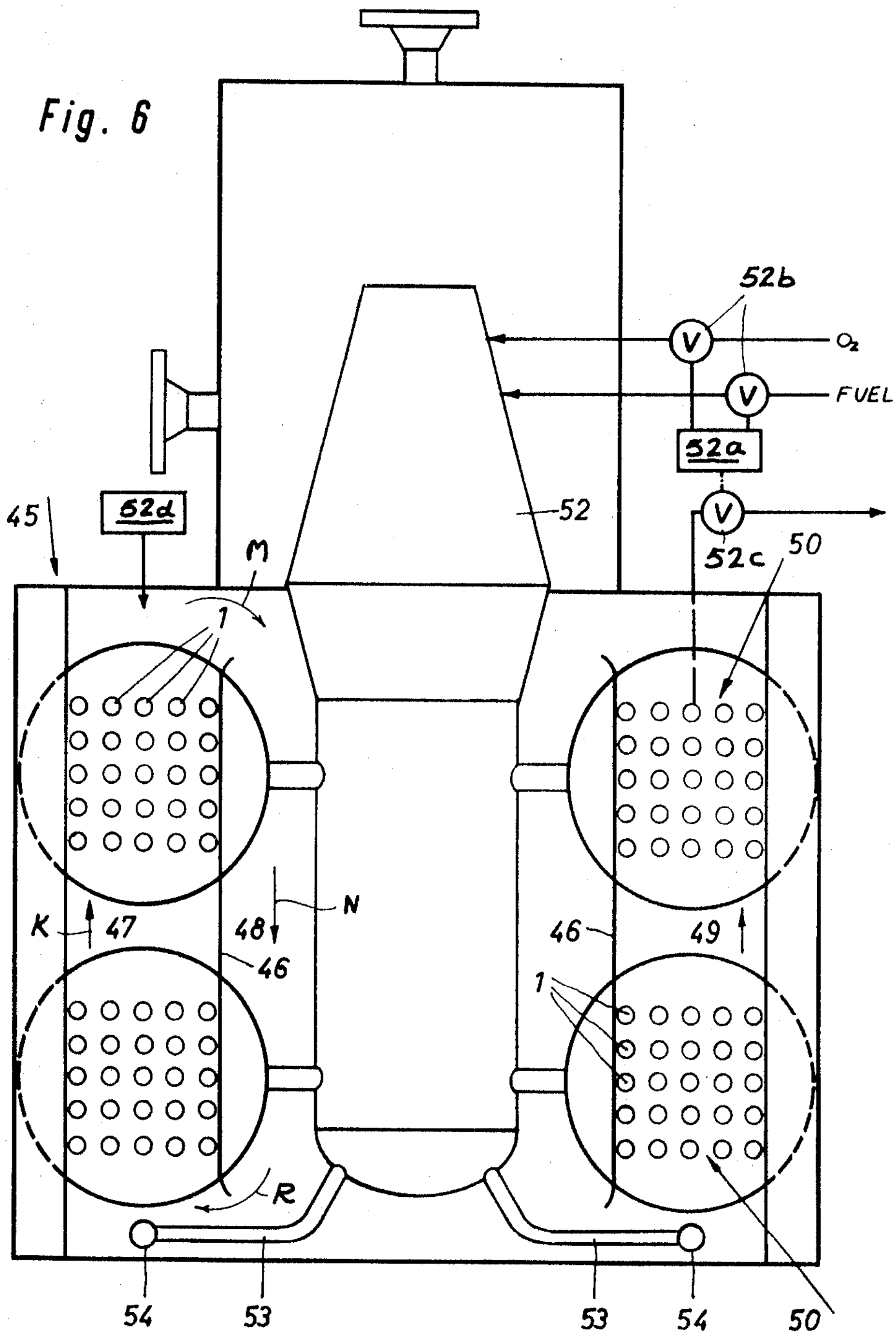
Fig. 6



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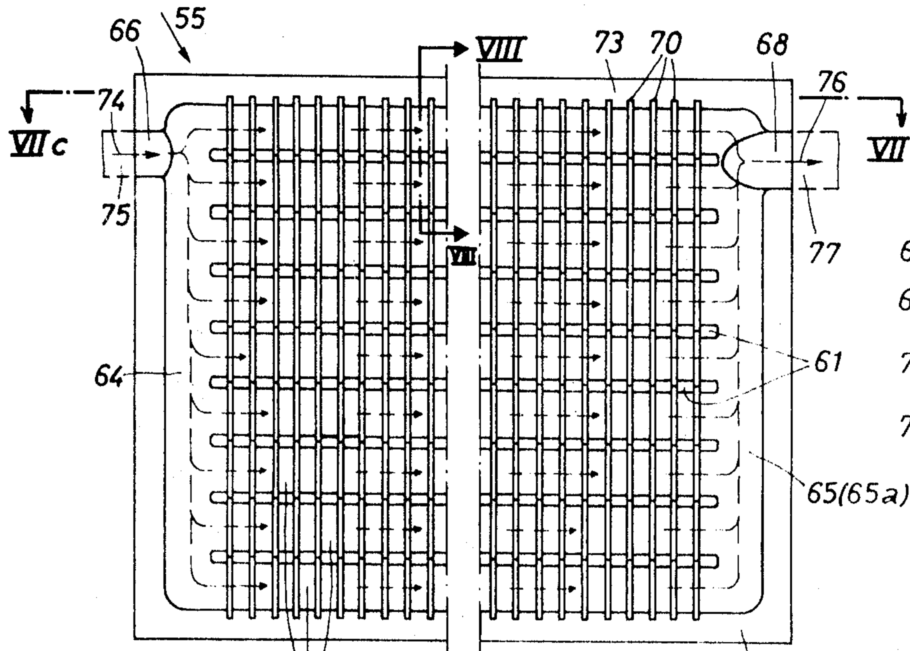

Fig. 7a

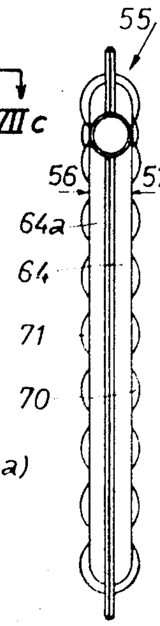

Fig. 7b

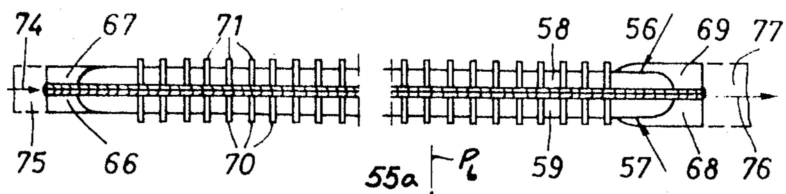

Fig. 7c

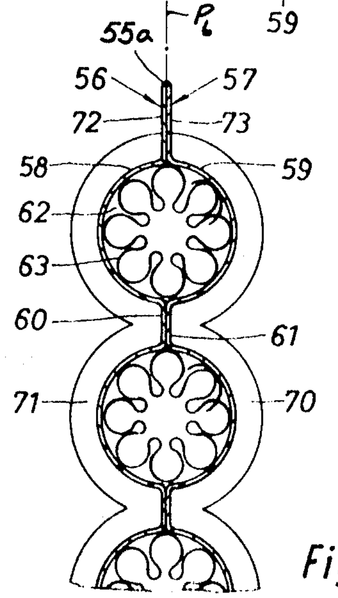

Fig. 8

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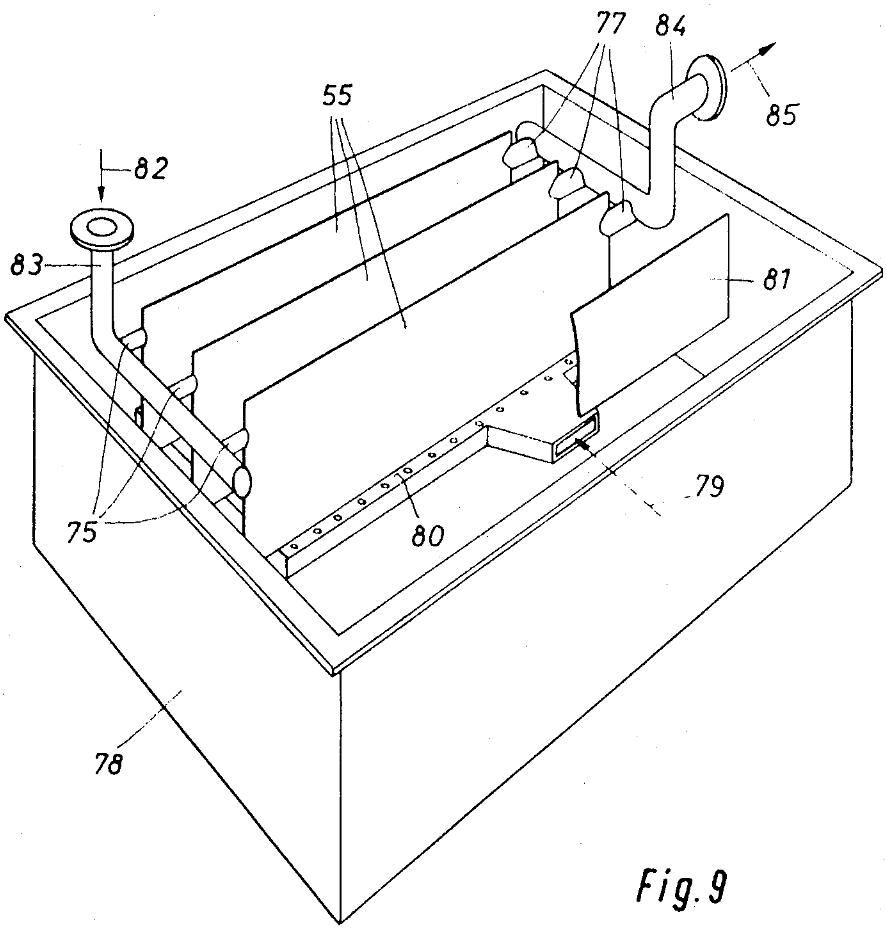

Fig. 9

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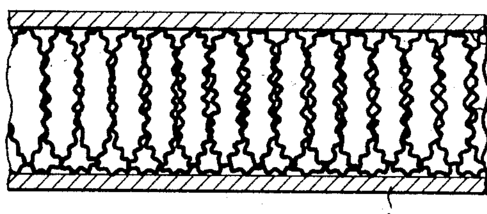


FIG. 11a

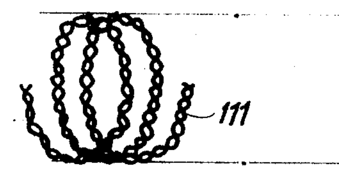


FIG. 12

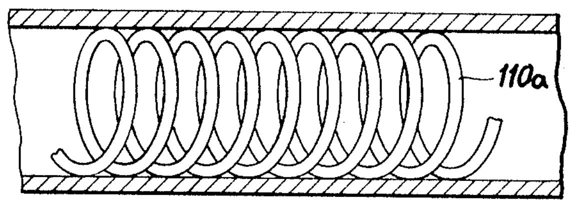
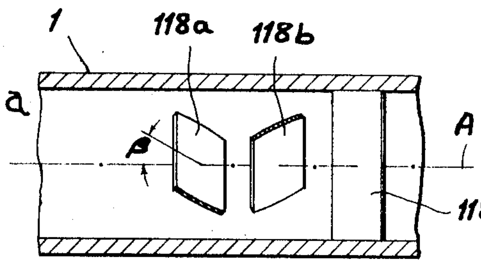


FIG. 11b

FIG. 13a



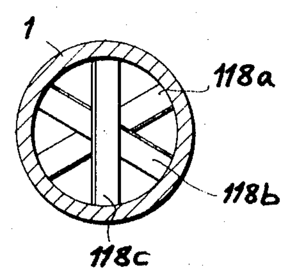


FIG. 13b

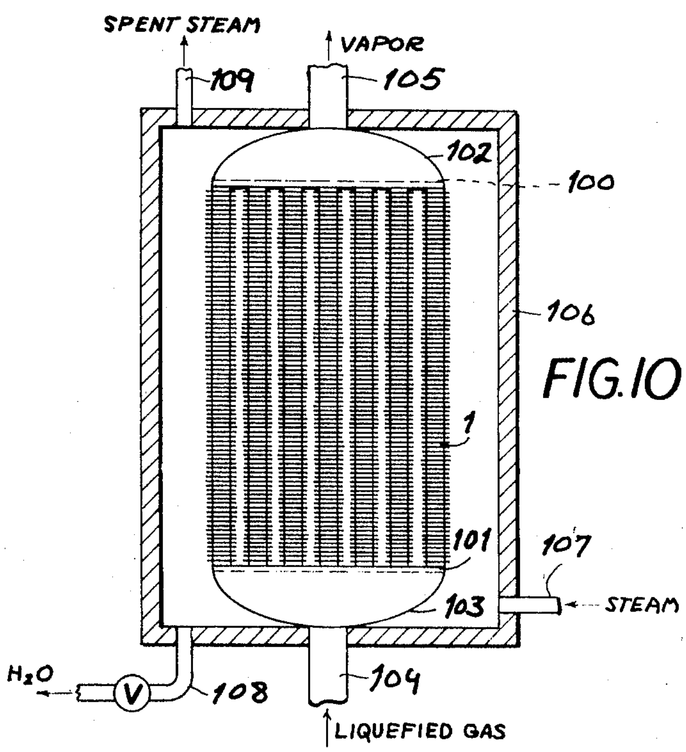


FIG. 10

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APPARATUS FOR THE EVAPORATION OF LOW-TEMPERATURE LIQUEFIED GASES

Our present invention relates to an apparatus for the evaporation of liquefied gases at low temperature and, more particularly, to an evaporator through which a low-temperature liquid is passed in heat-exchanging relationship with a heating fluid and is converted into gas in the ducts traversed by the vaporizable liquid.

Evaporators for converting liquids to gas and, especially, for transforming liquefied gases at low temperatures to the gaseous state, have heretofore been provided with ductwork through which the vaporizing liquid is passed in heat-exchanging relationship with a heating medium, the heat exchange being effected through the wall of the duct. In such systems, a problem arises with respect to heat transfer to the liquid as a result of the formation of a boundary layer of gas at the interface between the liquid traversing the ducts and the walls of the latter. Since the walls of the duct are generally at a temperature above the boiling point of the liquid, the boundary layer of liquid is first converted to gas and, in laminar flow situations, forms a layer with thermally insulating qualities between the body of liquid within the duct and the heated wall thereof. As a result, vaporization occurs only when heat is transferred across this insulating boundary layer of vapor or gas, this transfer being strongly impeded by the insulating qualities of the vapor. The latter may be considered a vapor film which may remain adherent to the wall of the evaporator or may move with the liquid or at an intermediate pace and is generally referred to as a vapor film.

To overcome the disadvantages of such films, earlier systems have proposed an increase in the heat exchange area, i.e. in the area of the ducts exposed to the heating medium and to the liquefied gas which is to be converted into vapor. This attempt at ameliorating a substantial inconvenience and disadvantage often is prohibitively costly not only because of the added cost of the ductwork, but also because of the correlative increase in the spatial requirements of the unit. Systems which have attempted to overcome the disadvantage by increasing the velocity of the liquid through the ductwork to promote turbulence have also proved to be impractical because of the capital cost of the means for driving the liquid through the evaporator. Consequently, this problem, which has long dominated design considerations for evaporators and the like, has not been solved heretofore in an altogether satisfactory manner and designers of such devices have long been searching for an effective answer.

It is the principal object of the present invention to provide an improved evaporator of the general character described above which will obviate the aforementioned disadvantages and provide efficient heat exchange between the heating medium and the liquefied gas to be evaporated.

A more specific object of this invention is the provision of a highly efficient water or steam-heated evaporator especially for converting low-temperature liquefied gases to vapor which evaporator requires less space and is of lower capital cost than earlier evaporators of similar vaporizing rates and capacity.

Still another object of this invention is to provide improved heat exchanger structures for use in the evaporization of low-temperature liquids to gas or vapor.

We have found that it is possible to overcome the disadvantages of earlier systems, namely, the increased area necessary for effective evaporation of the low-temperature liquids or the need for high-velocity fluid displacement means, by providing within the tubes of a tube bundle or tube sheet through which the low-boiling-point liquefied gas is conducted, a plurality of turbulence-inducing baffles of thermally conductive material in heat-conducting relationship with the wall of the tube contacted by the heating medium. The baffles of the present invention which are affixed to the walls of the tubes by soldering, welding or the like, are preferably of limited length (reference being made here to the dimension of the baffles parallel to the pipe axis). These baffles, which span the interior of the tubes and are of plane, zigzag or undulating configuration, may be composed of wire or band (sheet metal) and are set out one after another at least along part of the tube or pipe (e.g. the portion at which the liquefiable gas enters), and are angularly staggered sequentially along the tube. The tube is heated at its other surface, preferably by immersion into a liquid-heating medium (e.g. hot water and or steam).

According to a more specific feature of the invention, the liquefied gas to be evaporated is passed through the interior of the tube whose exterior is in contact with the heating medium, the tube interior receiving flat or arcuately bent webs of sheet metal defining a locus of lines somewhat parallel to the direction of flow and angularly offset from one another about the axis of the tube in the flow direction. The turbulence-generating webs or baffles successively positioned in the tube are preferably identical to one another and angularly inclined to the axis of the tube through a maximum of 45°. The baffles may, in accordance with one aspect of the invention, constituting a preferred embodiment, be corrugated sheet metal strips or bands whose corrugations extend alternately inwardly and outwardly with respect to the axis of the tube. The corrugations are preferably curvilinear and substantially sinusoidal such that the amplitude of the undulations ranges from 10 to 45 percent of the diameter of the tube in which they are received and preferably between 30 and 35 percent thereof. The amplitude of the undulations, for the purposes of the present invention, are measured from the crest of one half-cycle to the crest of the next half-cycle. The width of each of the turbulence-generating bands or strips, taken in the direction of flow of the liquid to be vaporized, should preferably range from a maximum of two tube diameters to a minimum of about 0.02 tube diameters and is preferably about 0.3 D where D is the inner diameter of the tube. It will be understood that the turbulence-generating elements which are preferably welded or soldered to the inner wall of the tube to promote conduction of heat into the body of the liquid passing therethrough from the tube wall, may also be wire coils or turns or double-wire coils in which two wires are twisted together.

According to another feature of this invention, the exterior or heated surface of each tube is provided with ribs, vanes or fins in heat-conducting relationship with the tube and preferably unitarily integral therewith so as to increase the surface area of the tube in contact with the heating medium. It has been found that the increased heating surface has an upper and lower limit with respect to optimum effectiveness and should be no greater than 600 percent in excess of the surface area exposed to the heating medium absent such surface-increasing formations. Preferably, the fins, ribs and vanes increase the surface area of the tube between 100 and 400 percent.

In accordance with yet another feature of this invention, two or more such tubes are joined in mutually parallel relationship in a tube bundle and conduct the liquid to be vaporized in parallel flow. The tube bundle is received in a vessel or duct into which the heating medium is introduced and lies either horizontally or vertically, the heating medium being circulated between and past the tubes of the bundle.

For the displacement and heating of the heating medium or to constitute the heating medium, we may provide an immersion-type burner which extends below or lies below the surface of a liquid-heating medium preferably water. Alternatively, the heating of the water bath can be effected by injecting a hot gas into the liquid water, the gas being preferably steam. In still another alternative, the heating medium may be a gas mixture, for example air and steam or exhaust-gas products, or such gas mixtures may be injected into a liquid-heating medium to act as an agitating medium. Circulation or agitation may also be effected by pumping or otherwise mechanically displacing the heating medium.

In order to permit a controlled circulation of the heating medium in the outer vessel or jacket, we prefer to subdivide the vessel or duct with one or more partitions parallel to the direction of flow, thereby creating individual compartments in which the tubes of the tube bundle are exposed to the heating medium. It will be apparent, moreover, that any other heating means will be effective as a source of heating for the generation of vapor from the liquid passed through the tube bundle, although the aforedescribed systems are preferred for technological reasons and for reasons of economy. A bath of the heating medium may, for example, be brought to the approximate temperature by electrical heating means or in heat exchange with condensing steam so as to transfer the latent heat of vaporization or condensation to the bath.

When a tube bundle having at least two parallel tubes is used in accordance with the present invention, it is preferred to form a generally planar array of such tubes by defining them between two mirror-symmetrical interconnected plates, each having semicylindrical longitudinally extending troughs registering with the troughs of the other plate to define the tubes between them. At the ends of these plates, manifold means may be provided to distribute the liquefied gas to be vaporized to the tubes and collect the vapor thereof. This arrangement provides a saving both in material and space and allows the elimination of hoods and the like which would otherwise be required as manifold structures. Moreover, an assembly of this nature allows the tubes to be placed substantially closer to one another than is the case when individual tubes are provided and permits each array of tubes to be of minimum height.

Through the use of a double-plate array of evaporator tubes, we are able to obtain numerous advantages aside from increased heat exchange efficiency and the elimination of the boundary layer of vapor which has hitherto impeded heat transfer from the exterior of a tube to the body of vaporized liquid therewithin.

Thus the very fact that the tubes of each sheet (consisting of two plates joined together in the manner described above) can be formed closer together than the tubes of earlier arrays, allows the height of the heating medium (hot water) bath to be reduced and imposes a reduced counterpressure to the blower or pump by which hot steam, gases or gas mixtures are injected into the water bath. Since the load on the blower and its capacity may be reduced, the blower itself may be smaller than would otherwise be required, thereby effecting a saving in capital expenditure. The reduction of the height of the overall assembly and the size of the blower allows the evaporator to occupy a smaller space than would otherwise be required.

Another advantage resides in the fact that the formation of an array of tubes from a pair of plates facilitates repair, replacement and other modifications of the tube assembly including increases in the capacity of the unit since entire tube sheets may be replaced at once and entire planar arrays of tubes may be added or removed in the form of tube sheets. Furthermore, the strength and expansion/contraction characteristics of the planar array of tubes are substantially better than that of individual tubes. Finally, it may be noted that the tube array can be formed relatively simply be the use of presses adapted to stamp out the individual semicylindrical profile plates from sheet metal and simultaneously form the assembly or the individual tubes thereof with ribs, vanes or other area-increasing formations which, as noted above, may increase the overall surface area exposed to the heating medium of each tube by a maximum of 600 percent or preferably between 100 and 400 percent.

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. **1***a* is a longitudinal cross-sectional view through an evaporator tube, in accordance with the present invention;

FIG. **1***b* is an end view of the baffle shown in FIG. **1***a*;

FIG. **2***a* is a view similar to FIG. **1***a* of a modified evaporator tube provided with turbulence-inducing baffles of a different configuration;

FIG. **2***b* is a cross section taken along the line II*b*–II*b* of FIG. **2***a*;

FIG. **3** is a vertical elevational view of a tube bundle using the evaporator tubes of FIG. **1***a* and FIG. **1***b* with the surrounding water bath in section;

FIG. **4** is a plan view of the evaporator of FIG. **3**, partly broken away;

FIG. **5** is a vertical end view of a steam-heated, tube bundle evaporator, according to the invention, partly in diagrammatic form;

FIG. **6** is a vertical cross section through still another evaporator assembly, according to the invention using an immersion burner heater for the water bath;

FIG. **7***a* is an elevational view of a tube sheet or array formed from two plates, according to the present invention;

FIG. **7***b* is an end view thereof;

FIG. **7***c* is a section generally along the line VII*c*–VII*c* of FIG. **7***a*;

FIG. **8** is a fragmentary section along the line VIII–VIII of FIG. **7***a*;

FIG. **9** is a perspective view of an evaporator using the plates of FIGS. **7***a*–**7***c* and FIG. **8**;

FIG. **10** is a vertical cross-sectional view, partly in elevation, of an evaporator having vertical tubes, in accordance with the present invention;

FIG. **11***a* is a section similar to FIG. **1***a* showing a modification of the instant invention;

FIG. **11***b* is another section similar to FIG. **1***a* showing another modification of the invention;

FIG. **12** is a diagram of another type of turbulence-inducing baffle, according to the present invention.

FIG. **13***a* is a longitudinal section through yet another type of turbulence-inducing baffle, according to the present invention; and

FIG. **13***b* is an end view of the baffle shown in FIG. **13***a*.

In FIGS. **1***a* and **1***b*, we have shown a vaporizer tube **1**, through the interior of which a liquid to be evaporated is passed generally in the direction of arrow A, vapor being removed at the left-hand end of the tube. The liquid to be vaporized is thus in contact with the inner wall **6** of the tube while the outer wall **2** is in contact with a heating medium as will be described in greater detail hereinafter.

To increase the effective heat exchange area of the tube in contact with the heating medium, the outer surface **2** is provided with a multiplicity of axially spaced outwardly extending annular flanges **3** constituting transverse ribs or fins, these ribs and fins being of an area such that the surface area of tube **1** in contact with the heating medium is raised to a maximum of 600 percent and preferably between 100 and 400 percent.

Within the interior of the tube, we provide baffle means generally designated at **4** to generate turbulence and eliminate a boundary layer of vapor which otherwise tends to form at the interface between the liquid and the inner wall **6** of the tube to insulate the liquid flowing therethrough from the heated walls.

The baffle means **4** comprises a continuous sheet metal band of which three sections are shown at **4***a*, **4***b* and **4***c* successively along the tube in the direction of liquid flow (arrow A). The sheet metal band **4** is corrugated with generally sinusoidal undulations having an amplitude a between the inwardly lying crest **5***a* of one half-cycle and the outwardly lying crest **5***b* of an adjacent half cycle, the amplitude a being substantially defined by the relationship a=0.10D to 0.45D (preferably $0.30D \leq a \leq 0.35D$), where D is the internal diameter of the tube **1** (see FIG. **1***b*). At the crest **5***b*, the band **4** is soldered to the inner wall **6** against which it bears in line contact as shown in FIG. **1***b* at L′. In the embodiment shown in FIGS. **1***a* and **1***b*, the undulation amplitude a as well as the axial length w (FIG. **1***a*) are both approximately one-third the diameter D of the tube. In general, $w \leq 2D$.

The heat-conductive relationship of the baffles and the inner wall of the tube is ensured by coating the sheet metal strip **4** with solder, inserting it into the tube as illustrated in FIGS. **1***a* and **1***b* and uniformly heating the tube, e.g. in a salt bath, to solder the baffles to the tubes at their points of mutual contact which correspond to the lines L'.

In FIGS. **2a** and **2b**, we have shown a modified system wherein, in place of the curved baffles of FIGS. **1a** and **1b**, the tube **1** is provided with a sequence of baffles represented generally at **8** and of which the baffles **8a**, **8b**, **8c** have been illustrated.

The baffles **8a**, **8b** and **8c** are of zigzag or Z-shaped profile with a pair of flat flanges as represented at **8'** and **8''** which are generally parallel to one another and are connected by a diagonal web **8'''** lying along a diameter of the tube. Here, as in FIGS. **1a** and **1b**, the baffles are identical to one another and are angularly offset, soldered or connected in another way to the inner wall **6** at the points L' to ensure a good heat conductivity. The length *w* of the sheet metal angularly bent strips is defined the same way as the length *w* of the strips **4a**, **4b** and **4c** in FIG. **1a**, and is one-third of the diameter *D*. The tube of this embodiment is provided with area-increasing fins **3** as previously described.

In FIGS. **3** and **4**, we have shown a heat exchanger or evaporator in which a vessel **13** receives a hot water bath which is agitated and is represented at **14**. The means for heating, circulating and agitating the water bath may be any of those described in connection with FIGS. **5—10**. The prismatic container **13** is generally horizontal and receives a tube bundle **10**, **11** consisting of horizontally lying tubes **1** whose fins **3** may correspond to the elements described in connection with FIGS. **1a** and **1b**. Throughout the present discussion, it should be noted that each of the tubes **1** contains an array of baffles **4a—4c**, etc. and that the fins **3** along these tubes increase the surface area in contact with the hot water bath by at most 600 percent.

The evaporator structure of FIGS. **3** and **4** includes a standpipe or header **21** forming a manifold by means of which the vapor is delivered to a utilizing installation, the vapor emerging in the direction of arrow E. Flanges **23a** of the standpipe **21** serve to connect this header to a duct, conduit or other structure designed to utilize or convey the vapor. The upright header **21** is provided with a pedestal **21a** in the form of feet **21b** by means of which the header rests upon the floor **13a** of the tank **13**.

As has already been mentioned, two sets of tube bundles, represented at **10** and **11**, are provided.

The tube bundles **10** and **11** are respectively associated with a series of horizontally extending manifold tubes **18**, projecting laterally from the header **21** on opposite sides of the latter and lying in a common vertical plane P_1 as shown in FIG. **3**. The manifold tubes **18** serve as collecting conduits for respective horizontal arrays of pipes **1** which lie in respective horizontal planes such as that indicated at P_2 in FIG. **3**.

In the embodiment illustrated in FIGS. **3** and **4**, each horizontal array of pipes **1** of the tube bundle **10** includes 10 tubes, while five manifold tubes **18** are provided in the plane P_1. Consequently, the tube bundle **10** is a rectangular parallelopipedal array of 50 tubes **1**.

At the inlet sides, the tubes of the bundle **10** communicate with horizontal arms **15** lying in a vertical plane P_3 and extending outwardly from opposite sides of a small-diameter inlet header **19** whose base **19a** is closed off and rests upon the floor **13a**.

A similar vertical header **20** serves as the collecting manifold for the horizontal tubes **16** of a tube bundle **11** whose 50 tubes **1** are interleaved, in the vertical direction, with the tubes of the tube bundle **10**. The tubes **1** of tube bundle **11** communicate with laterally extending pipes **17** of the header **21**, these pipes lying in the vertical plane P_4.

To distribute the liquefied gas to be vaporized to the headers **19** and **20**, we provide a horizontal manifold pipe **22** which communicates with the headers **19** and **20** as shown in FIG. **3**. Flanges **22a** allow pipe **22** to be connected in a supply network for the gas to be liquefied.

From FIGS. **3** and **4**, it will also be apparent that the liquid to be vaporized flows from pipe **22** through headers **19** and **20** into the manifold tubes **15** and **16** and thence in parallel through the tubes **1** to the collecting manifolds **17** and **18** and the header **21**, in the course of such flow, the liquid is vaporized by heat exchange through the walls of these tubes with hot water constituting the bath **14**. The horizontal arrays of the tubes **1** associated with each tube bundle are vertically stacked in alignment in the planes P_5 (parallel to the plane of the paper in FIG. **3** and perpendicular to the plane of the paper in FIG. **4**).

FIG. **5** illustrates another embodiment of an evaporator, in accordance with the present invention, using a steam-heated water bath and a system for circulating the heating medium constituted by this bath.

The evaporator comprises a prismatic vessel **26** of rectangular top, front and side outline, containing a water bath **25** and subdivided internally by two longitudinally extending partitions **27** into three flow compartments **28**, **29** and **30**. These partitions extend along the floor of the vessel and may be secured to this floor and to a cover hermetically sealing the interior of the vessel. In the central flow compartment **29**, we provide a tube bundle **32** consisting of horizontally oriented adjacent tubes **1** as described in connection with FIGS. **1a** and **1b** or FIGS. **2a** and **2b**, the ends of the tube bundles being provided with pressure resistant, tube-positioning plates or sheets and manifold-type fluid distribution and fluid collection domes represented at **33** (see also FIG. **10**). A duct **34** delivers liquefied gas to be vaporized to one side of the tube bundle, e.g. to dome **33**, while a similar pipe may be provided at the other end of the tube bundle to collect the vapor.

The liquid passing through the pipes **1** is in heat-exchanging relationship through the walls thereof with the hot water surrounding the tube bundle and thus absorbs the latent heat necessary for volatilization. A pump **35** circulates the heating medium of the bath along a closed transport path including a pair of inlets **35a** and **35b** through which the hot water is delivered to the central compartment **29** and flows downwardly therein (arrow F). Prior to passing through openings in the bottoms of the partitions **27** (arrow G) into the outer compartments **28** and **30**. In these compartments the circulated water passes upwardly (arrow H) into discharge ducts **36** which lead to headers **37** from which the return to the pump **35** is made. A line **38** serves to connect the pressure side of pump **35** with the inlet headers **35a** and **35b**.

By virtue of the subdivision of the interior of the vessel into individual compartments by the partitions **27**, a well-defined downward flow of water is ensured in the intermediate flow compartment **29** while an upward flow is provided in the outer compartments **28** and **30**.

The heating of the water bath is effected by means of steam and, to this end, steam distribution tubes **39** with distribution nozzles **40** extend the full length of the compartments **28** and **30** close to the floor thereof. Lines **39a** delivers steam to the distribution manifolds **39**, thereby injecting the steam into the water bath and heating the latter. The steam distribution nozzles are spaced uniformly along the manifolds **39** and are provided on the upwardly facing sides of these manifolds. An overflow **41** is provided at the upper end of the vessel to maintain the level of the water bath substantially constant and permit any increase as a result of steam condensation to flow out of the vessel. At the same small end of the container in the region of the cover, we provide an inlet fitting **42** to allow the vessel **26** to be filled with water as well as outlet fitting **43** close to the floor to permit complete draining of the vessel. The system of FIG. **5**, of course, functions in the manner previously described.

In FIG. **6**, we show a system for the evaporation of liquid wherein the heating medium is maintained at the approximate temperature by hot gas, the device making use of immersion heating. The prismatic vessel **45** is here internally subdivided by a pair of partitions **46** to provide a central compartment **48** and a pair of outer compartments **47** and **49** all of which extend longitudinally within the vessel **45**. The latter may have a rectangular outline in plan view so that the system is seen in

FIG. 6 from a small end. The compartments **47** and **49** communicate above and below the partitions **46** with the central compartment **48** and receive respective pairs of tube bundles generally represented at **50**. At each end, the tube bundles are provided with pressure resistant tube sheets in which the tubes **1** are anchored and with domes or hoods for supplying the liquid to be vaporized to the tubes **1** and for collecting the vapor emanating from the opposite end of each vaporization tube. As previously noted, the tubes of the bundle **50** may have the construction of the tubes of FIGS. **1***a* and **1***b* or FIGS. **2***a* and **2***b* and are provided with internal baffles as described in connection with these figures. The tubes **1** can have diameters of 5 to 50 mm., preferably 30 to 40 mm., and lengths of 50 to 300 tube diameters *D*, preferably 100 to 200 tube diameters. Suitable lengths are 25 cm. to 15 m.

An immersion burner **52** of conventional construction extends beneath the level of the water bath in the vessel **45** within the central compartment **48** and between the partitions **46** and is fueled by methane or oil. From the bottom of this burner, a pair of distributing manifolds **54** extend longitudinally at the bottoms of the compartments **48** and **49**, parallel to the partitions **46**, and are connected by ducts **53** to the burner **52**, the distribution manifolds **54** being perforated at spaced locations along their sides turn upwardly. Exhaust gas from the burner **52** is thus forced through the perforations in the distribution manifolds **54** and rises in the form of bubbles, upwardly in the compartments **47** and **49** to heat the water. In addition, the bubbles constitute an gaslift pump inducing a circulation of water through the tube bundles **50** in the direction of arrows K, M, N and R, the heating medium thereby passing transversely through the arrays of tubes and between the latter. The distribution pipe **54** may be replaced by porous boxes or other means for distributing gas into a liquid. The air and fuel input to the burner **52** can be automatically controlled at **52***a* via valves or the like represented at **52***b* in accordance with a sensor **52***c* in the exit line or dome of the tube bundle. Furthermore, a liquid level alarm, as represented at **52***d*, may be provided to prevent complete loss of water from the bath. The liquid to be vaporized may be introduced at 70 atmospheres gauge and is withdrawn as vapor at the other side of the tube bundle.

In FIGS. **7***a* through **7***c* and FIG. **8**, we have shown another arrangement of the tubes according to the present invention. In this embodiment, each array **55** of tubes is generally planar and is constituted by a pair of mutually facing plates **56** and **57** of mirror image symmetry and profiled or corrugated with semicylindrical formations **58** and **59**, which are separated by webs **60** and **61** lying generally parallel to the contact plane P_6.

When the plates **56** and **57** are brought together and welded, e.g. along the edges as shown at **55***a* and between the webs **60, 61**, the mutually registering semicylindrical formations **58** and **59** constitute tubes **60** which, as has been described in connection with FIGS. **1***a* and **1***b* and FIGS. **2***a* and **2***b*, receive corrugated sheet metal bands **63** or similarly acting baffles.

The plates **56** and **57** are stamped from sheet metal and are of rectangular configuration (FIG. **7***a*) while being formed with ribs **70** and **71** transverse to the tube axis and the plane P_6 as represented at **70** and **71** during the stamping or pressing operation. The bands **63** can be soldered in place and the plates **56** and **57** soldered together by coating the mutually contacting faces with solder prior to assembling the sheet and thereafter uniformly heating it in a salt bath.

At the inlet and exit sides of the sheet **55**, the plates **56** and **57** are hollowed out to define semitubular profiles **64, 64***a* and **65, 65***a* extending transversely to the tube **62** and communicating with them to form integral manifolds delivering fluid to and collecting fluid from these tubes as represented in broken lines in FIG. **7***a*. Short semitubular formations **66** and **68** of the mating plates form inlet and outlet fittings for the sheet which are designed to receive ducts **75** and **77** to introduce fluid as shown at **74** and remove vapor as shown at **76**. Webs **72** and **73** along the outlines of the tube array are welded together by continuous seams as previously described and are somewhat wider than the webs **60** and **61** between the tubes. The web **60** and **61** can of course be spotwelded or seamwelded by conventional techniques.

In FIG. **9**, we show a device incorporating the tube sheets **55** of FIGS. **7***a* to **7***c* and FIG. **8**. The tube sheets **55** (three in some in the embodiment illustrated) are connected by fitting **75** and **77** to an inlet manifold **83** and an outlet manifold **85**. The vaporizable liquid is introduced into the inlet manifold (arrow **82**) while vapor is recovered at the larger cross section outlet manifold as represented by arrow **85**. An immersion-type burner of the character previously described may be used to heat the water bath within the vessel **78** in which the tube sheets **55** are immersed while partitions, e.g. as represented at **81**, are provided to promote circulatory flow of the water. The burner discharges exhaust gas through the distributor **80** which is of boxlike construction and is formed at its upwardly facing side with perforations discharging hot gas into the water to heat the latter and inducing a circulatory flow of water as previously described. A system of the type shown in FIG. **9** effects a saving, because of increased efficiency, of at least 10 percent in the length of the tubes, for a given flow cross section of vaporizable fluid.

In FIG. **10**, we show an arrangement in which the tubes **1** of the tube bundle (see FIGS. **1***a*, **1***b* and FIGS. **2***a*, **2***b*) extend vertically and are anchored in pressure resistant plates **100** and **101** while a pair of domes or hoods **102, 103** serve to collect vapor immersing from the tube **1** and to deliver the liquefied gas thereto. A supply pipe **104** communicates with the hood **103** while an outlet pipe **105** communicates with the hood **102**. The tube bundle is received in a housing **106** to which steam is delivered at **107** and condenses along the tubes **1**, any excess steam being removed at **109** while an outlet **108** is provided to drain the vessel **106**. This device, of course, operates similarly to the device previously described. As shown in FIG. **11***a*, the tube **1** may be provided inwardly with a coil of undulating wire as represented at **110**, the contact region between the generally helical coil and the inner wall **6** of the tube **1** being soldered. FIG. **11***b* shows the tube **1** with a simple regular helical coil **110'** which serves, like the coil **110**, to break up the peripheral vapor film.

FIGS. **13***a* and **13***b* show the tube **1** provided with three baffles **118***a—c* each consisting of a simple small sheet of metal and which each lie along a diameter of the tube. Here, however, each baffle forms an angle β with the longitudinal axis A of the tube **1**, which is also the direction of flow therethrough. This angle β may be as much as 45°, but is here only 30°. In this manner, each baffle **118***a—c* very effectively breaks up the flow through the tube **1** thereby making it quite turbulent.

We claim:

1. An evaporator for the vaporization of a low-boiling-point liquid comprising a metallic tube forming a fluid passageway for said liquid and having a closed tubular heat-conductive wall adapted to contact a heating medium along the exterior side of said wall and the liquid to be vaporized along the interior side of said wall; baffle means disposed along said interior side of said wall and in heat-conducting relationship therewith for generating turbulence in said liquid and preventing the formation of an insulating gas boundary layer between said interior side of said wall and said liquid; means for introducing said liquid into the interior of said tube at one end thereof; means for removing vapor of said liquid at the other end of said tube; a vessel at least partly enclosing said tube and receiving a heating medium in contact with the exterior of said tube, said baffle means being received within said tube and of generally elongated configuration with a length in the direction of flow through said tube which is a small fraction of the length of the tube, said baffle means including a plurality of baffle members offset axially along the tube and angularly about the axis of the tube with respect to one another, each member being formed as a strip of sheet metal bent at longitudinally spaced intervals therealong and having crests in line contact with said interior side of said wall while presenting a folded longitudinal edge to the through-flowing liquid and a broad surface generally parallel to said axis; and means for displacing said heating medium past said tube.

2. The evaporator defined in claim 1 wherein said heating medium is at least in part constituted by a water bath and said baffle members are generally helical members contacting the inner wall of said tube at least at longitudinally spaced locations therealong and affixed thereto at regions of contact.

3. The evaporator defined in claim 2 wherein said baffle members are sheet metal band of undulating configuration, said band having an amplitude between the crests of successive half-cycle undulations ranging between 10 and 45 percent of the internal diameter of said tube.

4. The evaporator defined in claim 3 wherein said amplitude ranges between 30 and 35 percent of the internal diameter of said tube.

5. The evaporator defined in claim 1 wherein said baffle members have the form of angularly bent sheet metal bands having substantially planar surfaces.

6. The evaporator defined in claim 5 wherein said baffle members each are of Z-shaped configuration with a pair of mutually parallel flanges lying along chords of the interior of said tube and a web connecting said flanges and lying along the tube diameter.

7. The evaporator defined in claim 2 wherein said baffle member is composed of a ribbon of sheet metal and has its folds parallel to the tube axis, the dimension of the sheet metal baffle member parallel to the tube axis not exceeding twice the internal diameter of said tube.

8. The evaporator defined in claim 7 wherein the dimension of the sheet metal baffle members parallel to the tube axis is about 0.3 times the inner diameter of the tube.

9. The evaporator defined in claim 2 wherein said tube is formed at its exterior with formations increasing the surface area of said tube in contact with said heating medium by at most 600 percent.

10. The evaporator defined in claim 1 wherein said formations are transverse fins increasing the surface area of the exterior of said tube by 100 to 400 percent.

11. The evaporator defined in claim 2 wherein at least two such tubes in mutually parallel relationship form a tube bundle, the means for removing vapor being formed as an outlet manifold at said other end of said tube and said means for introducing liquid into the interior of said tube forming an inlet manifold.

12. The evaporator defined in claim 11 wherein said tubes of said tube bundle are oriented horizontally in said vessel.

13. The evaporator defined in claim 11 wherein said tubes of said tube bundle are oriented vertically in said vessel.