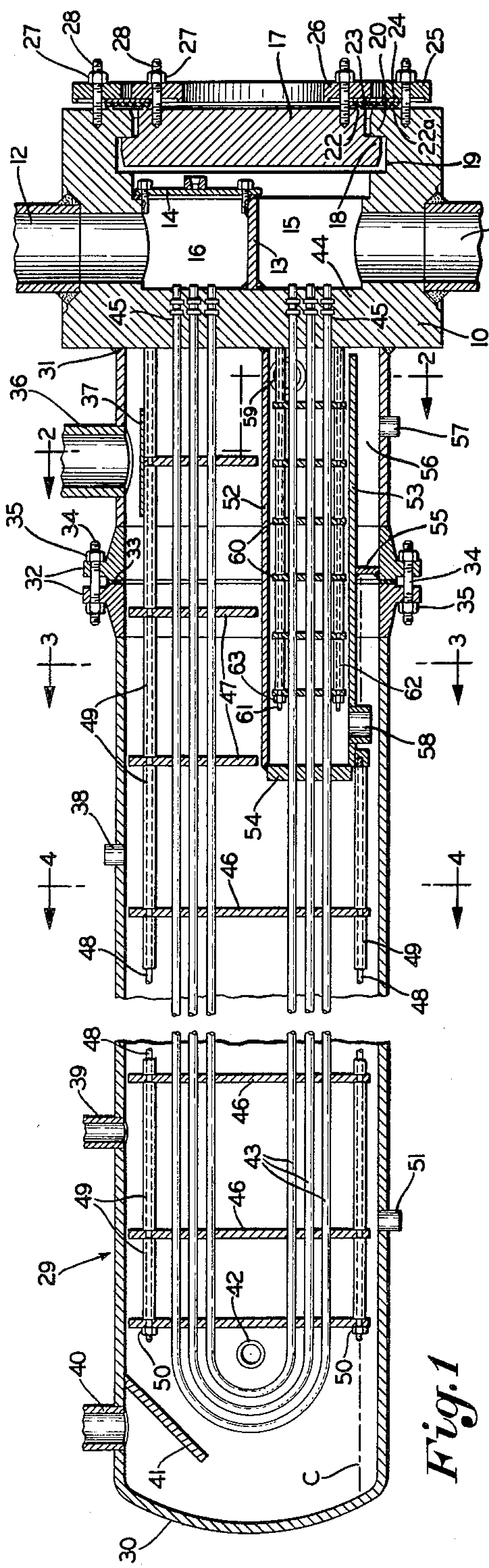
Aug. 8, 1961 C. M. DANESI 2,995,341

FEED WATER HEATER SUB-COOLING ZONE

Filed Jan. 8, 1959 2 Sheets-Sheet 1



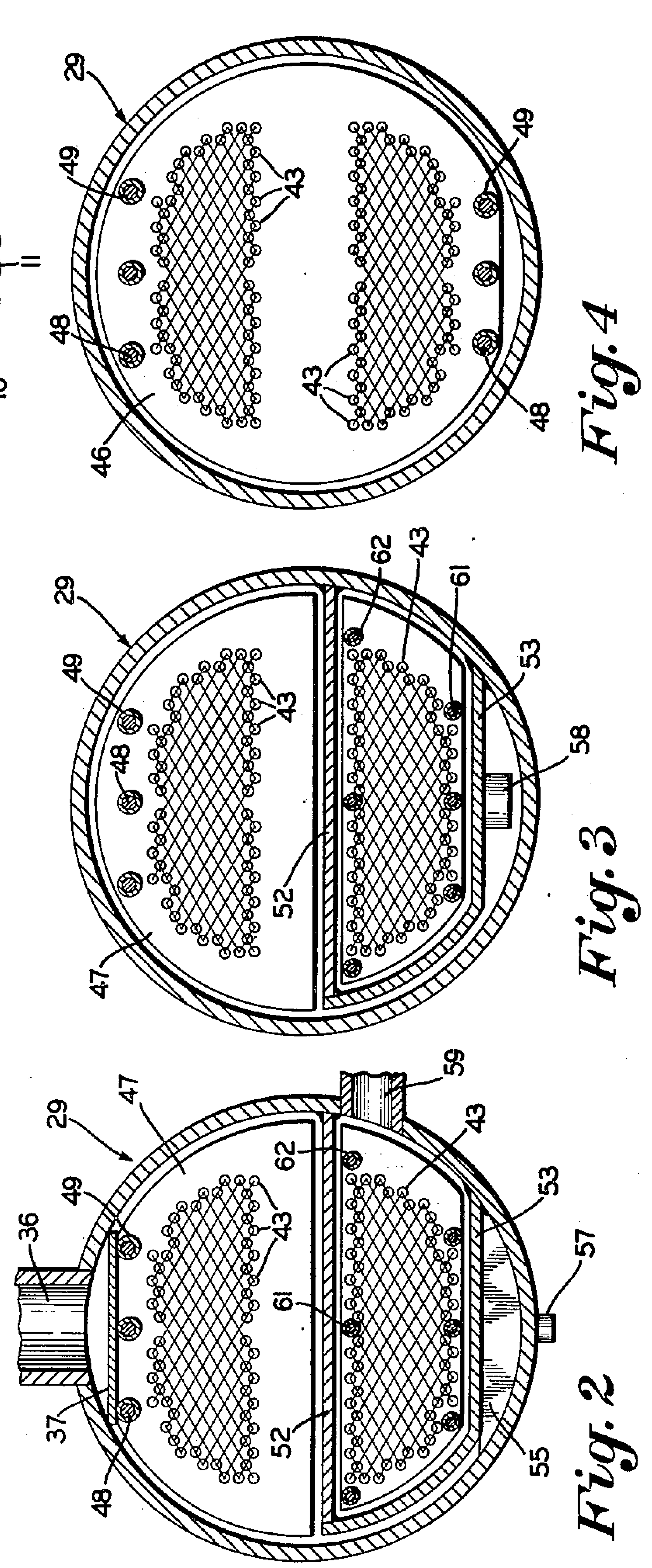


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Fig. 5

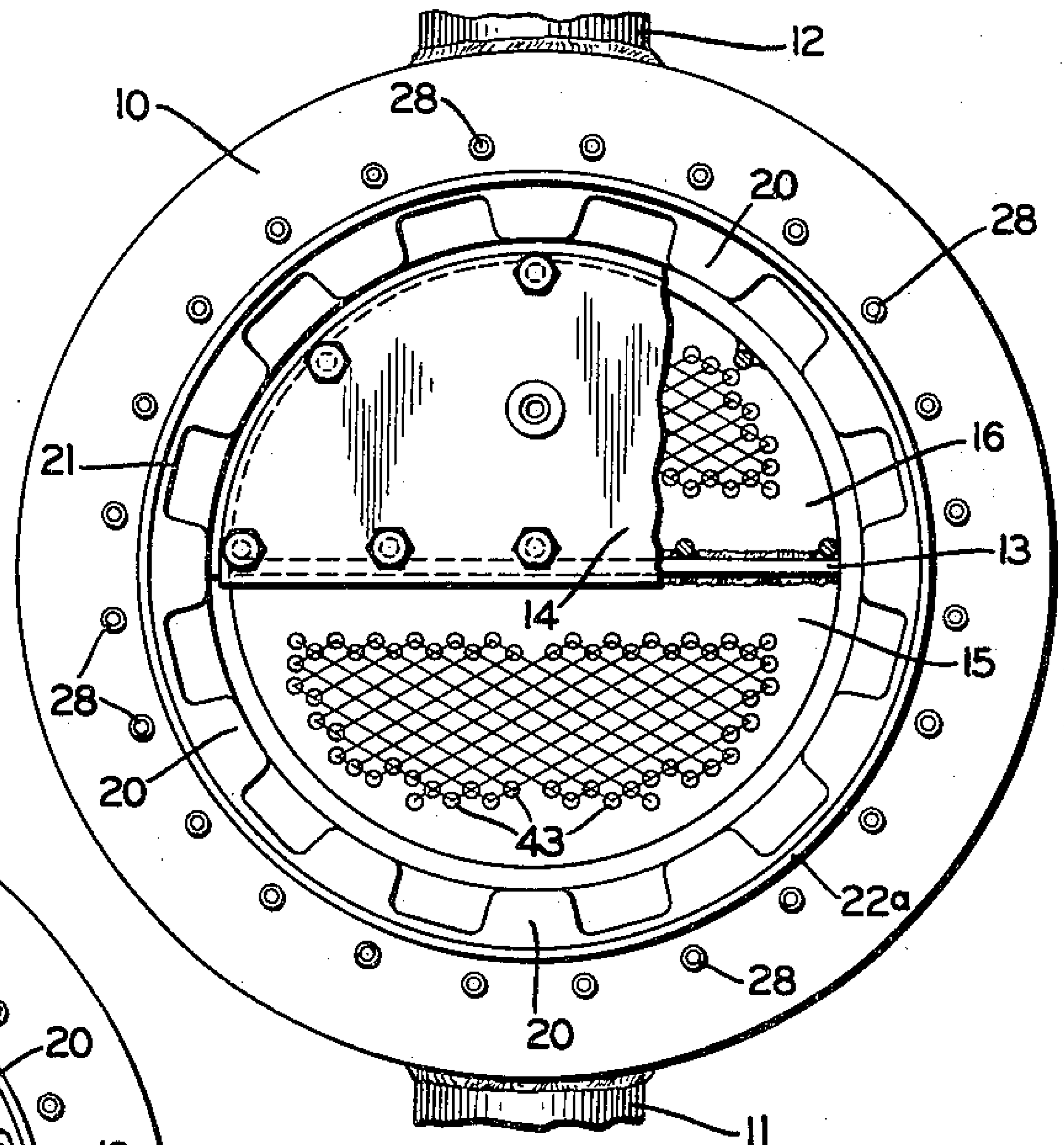


Fig. 6

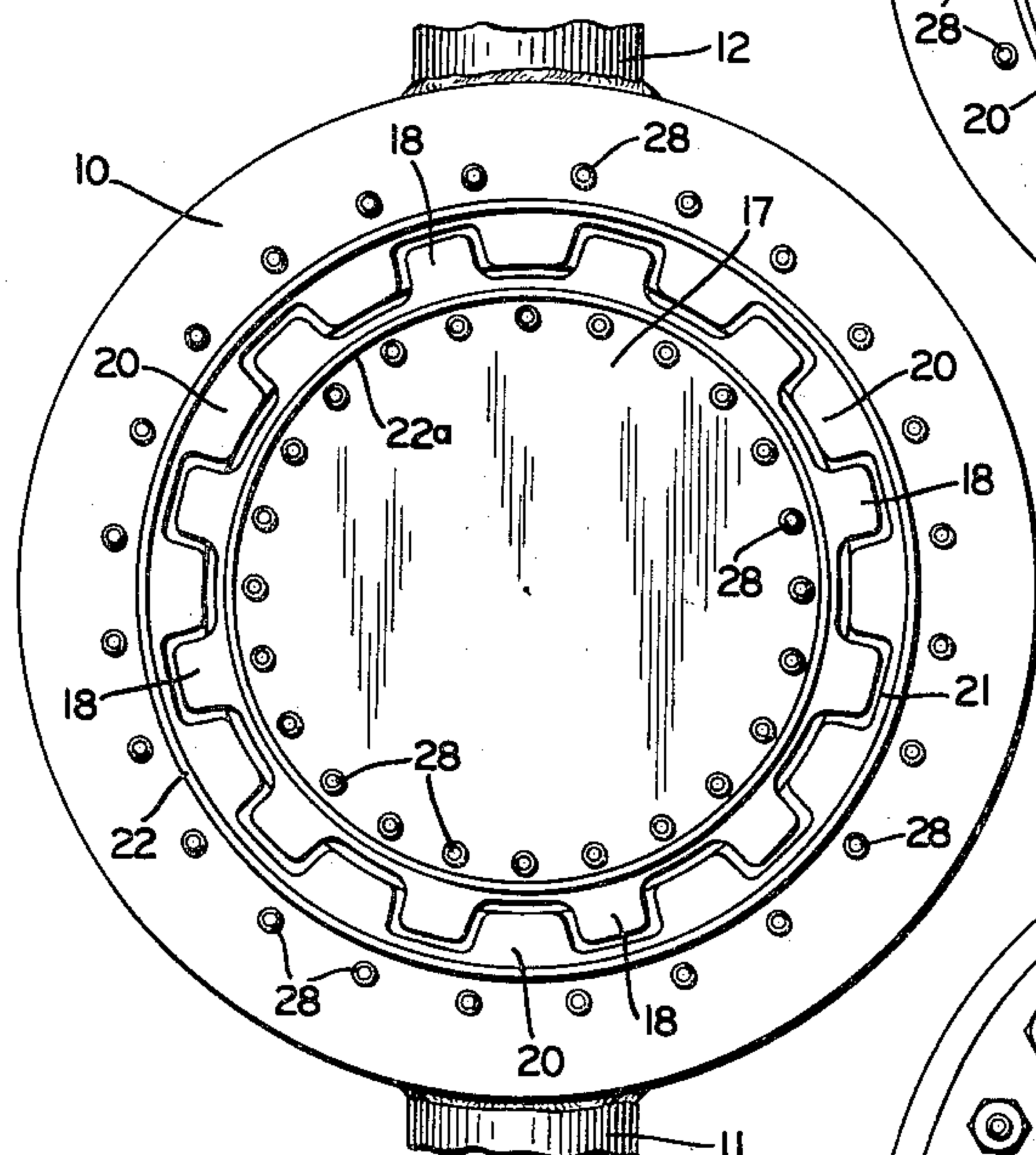
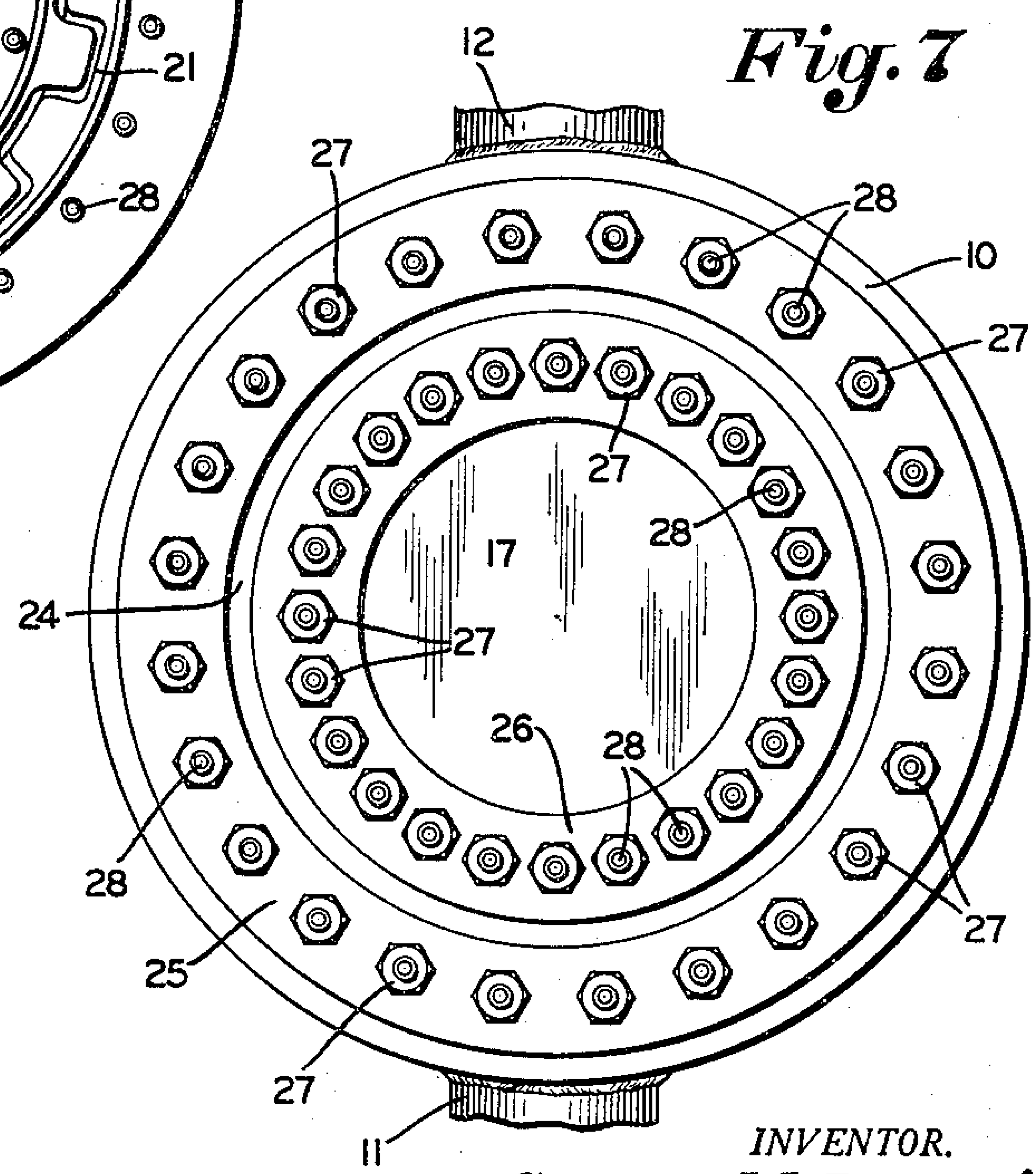


Fig. 7



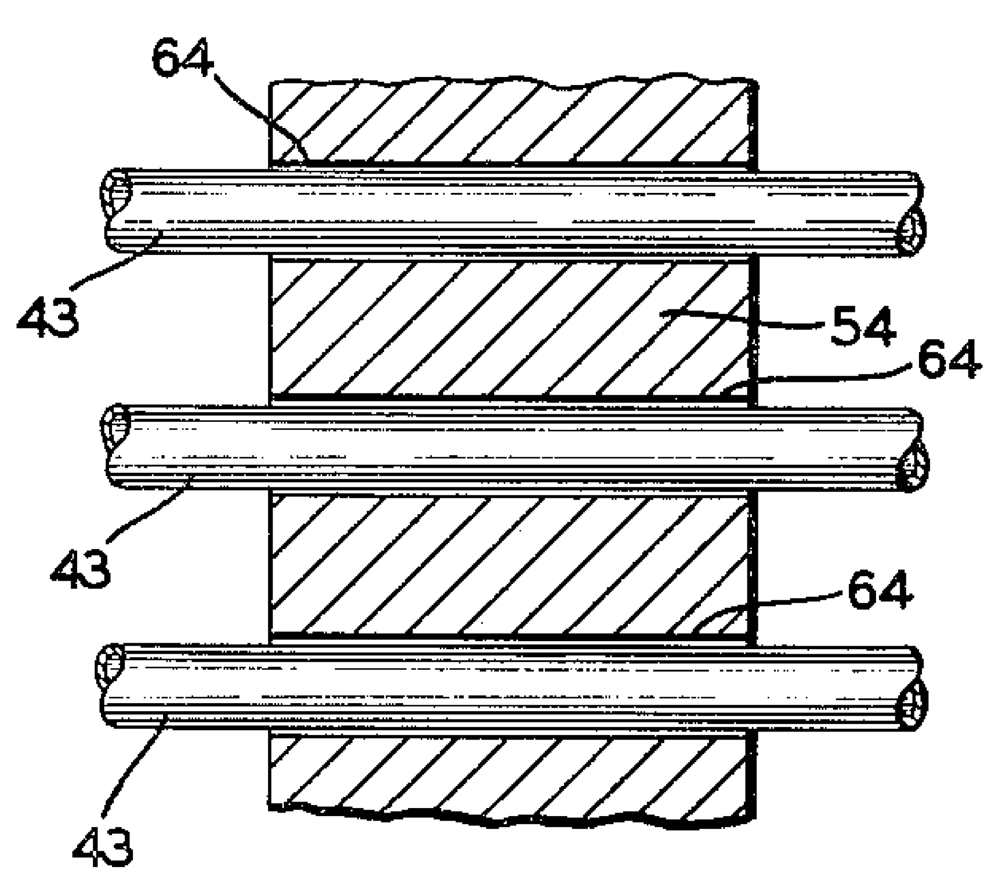


Fig. 8

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FEED WATER HEATER SUB-COOLING ZONE

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Filed Jan. 8, 1959, Ser. No. 785,995
11 Claims. (Cl. 257—32)

The invention relates to heat exchangers and more particularly to feed water heaters of the shell and tube type wherein provision is made for sub-cooling the condensate, and it has for an object the provision of an improved construction of sub-cooling zone, and this application is a continuation-in-part of my copending application, Serial No. 527,256, filed August 9, 1955, now abandoned.

In heat exchangers of this type in which the feed water is preheated by bled steam, it is desirable to provide a sub-cooling zone in which certain portions of the tubes are submerged in the condensate in the shell in order to extract further heat from the condensate and obtain more efficient use of the heat in the steam.

For this purpose, a sub-cooling chamber or envelope is provided within the shell, surrounding portions of the tubes adjacent to the feed water inlet thereto, condensate from the shell being discharged through this sub-cooling chamber and submerging those portions of the tubes located therein.

Various problems have arisen in the past, where such a sub-cooling zone was desired. One construction in general use provided for filling the lower third of the shell with water of condensation. Since it was necessary to maintain this water level and at the same time provide for fluctuations therein, a horizontal band across the shell without tubes therein had to be maintained for the water level. Because of the U-tube construction, there were as many tube ends in the upper half of the shell as in the lower half thereof, so that this tube-free band increased the effective diameter of the equipment, and therefore the size, weight and cost thereof.

In order to overcome this disadvantage, heat exchangers have been made with a sub-cooling zone in the form of an envelope or chamber, within and sealed from the remainder of the shell, the inlet end portions of the tubes being located therethrough, and submerged in the condensate for sub-cooling, the remainder of the tubes being surrounded by steam, providing a most effective and efficient use of the heat supplied in heating the feed water.

Horizontal heat exchangers provided with such a sub-cooling envelope, usually require an external hot well and piping therefor for conveying condensate from the shell to the sub-cooling envelope.

Two major problems are involved in the use of such an envelope, one being the replaceability of tubes in the event of tube failure, and the other being to take care of differential expansion of the tubes and the envelope walls and at the same time to maintain a seal between the tubes and the apertures in the end wall of the envelope through which the tubes pass, in order to prevent direct mixing of the steam with the water.

Various methods have been proposed for solving these problems, none of which are commercially practical or satisfactory. For instance, it has been proposed to expand the tubes within the opening through the end wall to prevent leakage of steam therethrough, and to either design the equipment so that the portions of the tubes within the envelopes would bow where there was relatively greater expansion, or to mount the end wall of the envelope in a movable manner and provide a packing around the periphery thereof. Neither of these methods is considered satisfactory or commercially practical, one reason being because of the difficulty in replacing tubes.

It has also been suggested that an expansion joint be provided in the envelope wall, but such a construction would be quite complicated and would undoubtedly increase the diameter of the shell to at least as much as the prior embodiment now in general use.

It has also been suggested to form a laminated end wall for the envelope, of two thin spaced plates with a rubber plate clamped therebetween, the tube-receiving apertures in the rubber plate being of smaller diameter than the tubes, so as to seal around the tube when they were inserted therethrough, but this construction is not considered completely satisfactory.

Another suggestion was to place a rubber O-ring around each tube and within the tube opening in the end wall of the envelope, but this method is not considered satisfactory because of problems involved in cutting the grooves for the O-rings, in placing the O-rings therein and in assembling the tubes therethrough.

It has also been proposed to control the expansion of the tubes within the wall openings to very close tolerances without seating or locking the tubes within the tube-receiving openings, but this appears to involve too critical manufacturing procedures to be practical.

It was further proposed to form a labyrinth of grooves in each tube-receiving opening in the end wall, with the expectation that the pressure drop across the series of grooves would result in condensation of the steam, but this method is not considered commercially practical.

The present invention contemplates a construction of sub-cooling zone for feed water heaters in which the end wall of the envelope comprises a relatively thick plate with tube-receiving openings therein formed very accurately to substantially exactly the outer diameter of the tubes so that the tubes will have only a sliding fit through such openings with only a very few thousandths of an inch clearance.

The clearance spaces between the tubes and the openings are so small that any steam or other vapor from the shell leaking through the clearance spaces will condense into water before it reaches the interior of the envelope, thus providing a satisfactory seal between the tubes and the holes in the end wall through which the tubes pass, in order to prevent mixing of the steam with the water, and at the same time providing for easily replacing the tubes in event of tube failure.

It is therefore an object of the invention to provide a sub-cooling zone in a feed water heater which overcomes the difficulties and disadvantages of present practice, and which eliminates the necessity of an external hot well and piping for conveying condensate from the shell to the sub-cooling zone.

Another object is to provide a feed water heater having a sub-cooling envelope or chamber therein comprising spaced upper and lower walls extending horizontally within the shell from the head barrel or water box and having a relatively thick end wall connected thereto, the inlet end portions of the tubes being located within this envelope and through openings in the relatively thick end wall thereof, said openings being substantially exactly the outer diameter of the tubes, so that the tubes have only a sliding fit through the openings with only a very few thousandths of an inch clearance.

A further object is to provide such an envelope having a condensate inlet in its lower wall through which condensate is forced into the envelope by steam or vapor pressure within the shell, and a condensate outlet in its upper portion for maintaining the tubes submerged in the condensate.

The above objects together with others which will be apparent from the drawings and following description, or which may be later referred to, may be attained by constructing the improved feed water heater with sub-cooling zone in the manner illustrated in the drawings and hereinafter described in detail.

In general terms the invention may be briefly described as comprising a feed water heater consisting of an upright head barrel or water box having a water inlet at its lower end and a water outlet at its upper end, a partition wall within the water box separating the inlet and outlet, a shell extending from one side of the water box and having a steam inlet therein, U-shape tubes being located within the shell and communicating at opposite ends with the water box below and above the partition therein, and an envelope extending into the shell from the lower portion of the water box and surrounding the inlet end portions of the tubes.

The envelope comprises spaced upper and lower walls and a relatively thick end wall having openings therein through which the tubes have only a sliding fit, the openings being of such size that only a very few thousandths of an inch clearance is provided between each tube and the corresponding opening, so that any steam or vapor from the shell leaking through these clearances will condense into water before it reaches the interior of the envelope, thus preventing the steam from mixing with the water.

A condensate inlet is provided in the lower wall of the envelope, through which condensate is forced into the envelope by steam or vapor pressure in the shell, and a condensate outlet is provided in the upper portion of the envelope for maintaining these portions of the tubes submerged in condensate.

A horizontal type feed water heater embodying the invention is illustrated in the accompanying drawings, in which;

FIG. 1 is a longitudinal sectional view through a feed water heater having a sub-cooling zone embodying the principles of the invention;

FIG. 2 a transverse, sectional view through the shell and the sub-cooling zone, taken on the line 2—2, FIG. 1, looking in the direction of the arrows;

FIG. 3 a transverse section through the shell and sub-cooling zone, taken on the line 3—3, FIG. 1, looking in the direction of the arrows;

FIG. 4 a transverse section through the shell, taken on the line 4—4, FIG. 1, looking in the direction of arrows;

FIG. 5 an end view of the feed water heater with the head cover removed, looking at the right hand end of the heater as viewed in FIG. 1;

FIG. 6 a view similar to FIG. 5 showing the head cover in position for locking or removing;

FIG. 7 a similar end view showing the cover in locked position; and

FIG. 8 an enlarged, fragmentary, sectional view through the thick end wall of the envelope, showing the tubes slidably located through openings therein.

Referring now more particularly to the embodiment of the invention illustrated, in which similar numerals refer to similar parts throughout, the feed water heater comprises the head barrel or water box **10** having a cold feed water inlet **11** at its lower end and a heated feed water outlet **12** at its upper end, with partition walls **13** and **14** dividing the interior of the barrel or water box into the inlet chamber **15** and outlet chamber **16**.

The outer side of the barrel or water box is adapted to be closed by the head cover **17**, provided around its periphery with the spaced lugs **18** received in the annular groove **19** of the barrel or water box, and adapted to be turned upon its axis so as to locate the lugs **18** behind the similar lugs **20** extending inwardly from the aperture **21** in the head barrel or water box **10**.

The head cover **17** and the surrounding portion of the barrel or water box **10** are provided with concentric ribs **22** and **22*a*** against which the gasket **23** and sealing ring **24** are adapted to be clamped by means of the inner and outer hoop flanges **25** and **26**, which are clamped in position by nuts **27** upon the bolts **28**.

The shell, indicated generally at **29**, extends horizontally from the other side of the barrel or water box **10**, being closed at its outer end as indicated at **30**, the open, inner end of the shell being welded to the adjacent side of the barrel or water box, as indicated at **31**. If desired, the shell may be formed or sections having the abutting ring flanges **32** thereon, clamped together with a gasket **33** therebetween, as by the bolts **34** and nuts **35**.

A steam or vapor inlet **36** is provided in the upper side of the shell, preferably at a point adjacent to the barrel or water box **10**, and an impact baffle **37** may be provided in the path of steam entering at the inlet **36** to prevent erosion of the tubes by impingement of high velocity steam or vapor.

A connection **38** is provided in the upper side of the shell for attaching a pressure gauge to indicate the steam pressure within the shell, and a relief valve may be attached to the connection **39** in the upper side of the shell for controlling the steam pressure within the shell.

If desired, a drip inlet **40** may be provided in the upper side of the shell, near the outer end thereof, an inclined impact baffle **41** being preferably located below the same, and, if desired, an air operating vent **42** may be provided in the shell.

A plurality of U-shaped tubes **43** extend longitudinally within the shell, the terminal ends thereof being supported in the stationary tube plate **44** forming one side of the barrel or water box **10**, as indicated at **45**.

As shown in FIG. 1, the inlet ends of the tube **43** communicate with the inlet chamber **15** of the head or water box, below the partition wall **13**, while the outlet ends of these tubes communicate with the outlet chamber **16**, above the partition wall **13**.

The U-shaped tubes **43** may be supported within the shell by the semi-support plates **46** and segmental support plates **47**, carried upon the tie rods **48** with spacers **49** thereon between adjacent plates, the tie rods being connected at one end to the side wall **44** of the barrel or water box and having the nuts **50** upon their other ends. A drain **51** may be provided in the lower side of the shell with means for opening the same when it is desired to lower the level of condensate within the shell.

The sub-cooling zone is in the form of an envelope, comprising the upper wall **52** extending horizontally through the shell at a point near the center thereof, the lower wall **53**, spaced above the bottom of the shell, and the end wall **54**.

The top wall **52** is welded, or otherwise rigidly connected, at one end to the adjacent side of the barrel or water box **10**, the other end thereof being welded, or otherwise attached, to the upper end of the end wall **54**.

The lower wall **53** of the envelope is spaced above the bottom of the shell and one end is connected to the lower edge of the end wall **54**, the other end terminating adjacent to the barrel or water box.

A blank-off plate **55** is welded to the underside of the bottom wall **53**, intermediate the ends thereof, and to the lower side of the shell forming a sump **56**. A drain **57** may be provided in the lower portion of the shell, between the blank-off plate **55** and the water box, and provided with means for opening the same when desired to drain condensate which may accumulate in the sump **56**.

A condensate inlet **58** is provided in the bottom wall **53** of the envelope, preferably at a point near the end wall **54**, and a condensate outlet **59** is provided in the upper portion of the envelope, preferably adjacent to the barrel or water box **10**.

A plurality of vertical baffles **60** are located transversely through the envelope, terminating at their upper and lower edges at points near the top and bottom walls **52** and **53** respectively of the envelope. These baffles are supported by tie rods **61** connected to the adjacent side wall of the barrel or water box **10** and provided with spacers **62** for holding the baffles in properly spaced position, nuts **63** upon the outer ends of the tie rods clamping the structure together.

The end wall **54** of the envelope is relatively thick as compared with conventional practice, being from 1 inch to 6 inches in thickness. Tube openings **64** in this end wall, through which the tubes **43** are located, are formed very accurately to substantially exactly the outer diameter of the tubes, so that the tubes may be slipped through these openings with only sufficient clearance to provide a sliding fit.

The wall thickness of the end wall **54** is a function of so many variables, such as steam pressure, temperature of water in tubes, clearance between tubes and holes, etc., that the exact thickness of the end wall to be used for any particular unit must be calculated. However, the end wall **54** must have sufficient thickness to prevent steam from leaking through the apertures **64** without being condensed.

Also, the clearance between the tubes and the holes in the end wall is a function of many variables, such as the thickness of the end wall, steam pressure, temperature of water in the tubes, etc., so that the exact clearance must be calculated.

The relation of the end wall thickness and clearance is expressed in the following formula:

$$L=Cg\sqrt{\frac{\Delta p}{(Ts-tw)}\,\frac{\rho\lambda}{z}}$$

where:

L=tube sheet thickness in inches
g=diametral clearance in inches
Ts=steam temperature in shell—° F.
tw=water temperature in tubes—° F.
Z=steam viscosity—centipoises
λ=latent heat of condensation of steam
ρ=density of steam—lbs. per cubic feet
Δp=maximum pressure difference across end plate—p.s.i.
$C\cong$constant (approximate)
=20 for horizontal zones
=40 for vertical zones
L—normally from 1½″ to 5″, but may be from 1″ to 6″
g—normally 0.008″, but may range from 0.004″ to 0.016″

In the operation of the apparatus, cold feed water or the liquid from the inlet **11** is admitted to the inlet chamber **15** of the water box and then conveyed through the tubes **43**, in which the water or other liquid is heated by steam or vapor admitted to the shell through the steam inlet **36**. The heated liquid passes from the tubes through the outlet chamber **16** of the water box to the outlet **12**.

As the steam or vapor passes from the inlet **36** back and forth around the partitions **47** and **46**, in contact with the tubes **43**, much of the heat is extracted therefrom in heating the liquid in the tubes, and the steam vapor finally condenses within the shell and collects as condensate in the bottom of the shell to about the level indicated at C in FIG. 1.

Steam or vapor pressure within the shell forces this condensate upward through the condensate inlet neck **58** into the sub-cooling envelope formed by the walls **52**, **53** and **54**, to the level of the condensate outlet **59**, thus submerging the first pass of the tubes **43** in the condensate and extracting further heat from the condensate as it passes back and forth around the baffles **60** from the inlet **58** to the outlet **59**.

Direct mixing of the steam or vapor in the shell with the condensate in the sub-cooling envelope is prevented by the thickness of the end wall **54** of the envelope, and the very slight clearance spaces between the tubes **43** and the tube-receiving openings **64** in said end wall. As these clearance spaces are only a few thousandths of an inch in width, and are of some considerable length, steam is prevented from leaking therethrough without being condensed.

However, it should be noted that these slight clearance spaces between the tubes and the tube-receiving openings are sufficient to provide only a sliding fit for the tubes within the openings, whereby tubes may be easily replaced in the event of tube failure, by slipping the defective tubes out of the openings in the thick end wall **54** and slipping new tubes therethrough.

It will be evident from the above that a simple and efficient sub-cooling zone is provided, which overcomes the difficulties and disadvantages of prior constructions, and which solves the problems involved in the use of a sub-cooling envelope, by providing for easy replaceability of tubes in the event of tube failure, and at the same time taking care of differential expansion of the tubes and envelope walls while maintaining a seal between the tubes and the tube-receiving holes in the thick end wall through which the tubes pass in order to prevent direct mixing of the steam in the shell with the condensate in the envelope.

Although the invention is illustrated and described in detail herein as embodied in a horizontal-type feed water heater sub-cooling zone, it should be understood that this is for the purpose of illustrating one embodiment only and that the invention is also applicable to vertical-type feed water heater sub-cooling zones and may be carried out therein with the same principle illustrated and described in detail herein.

In the foregoing description, certain terms have been used for brevity, clearness and understanding, but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art, because such words are used for descriptive purposes herein and are intended to be broadly construed.

Moreover, the embodiments of the improved construction illustrated and described herein are by way of example, and the scope of the present invention is not limited to the exact details of construction.

Having now described the invention or discovery, the construction, the operation, and use of preferred embodiments thereof, and the advantageous new and useful results obtained thereby; the new and useful construction and reasonable mechanical equivalents thereof obvious to those skilled in the art, are set forth in the appended claims.

I claim:

1. In a heat exchanger of the horizontal shell and tube type in which fluid passing through the tubes is heated by vapor supplied to the shell and condensed therein, walls forming a sub-cooling compartment within the shell surrounding the coldest portion of the first pass tubes, inlet means for the flow of condensate from the shell into the sub-cooling compartment in response to vapor pressure in the shell, condensate outlet means communicating with the sub-cooling compartment, the sub-cooling compartment walls including a relatively thick end wall through which the first pass tubes extend from the sub-cooling compartment into the shell, said thick end wall being from 1 inch to 6 inches in thickness and having tube-receiving openings formed therein of a diameter from 0.004″ to 0.016″ greater than the outer tube diameter thereby providing only a sliding fit for the tubes through said openings and an annular clearance space from 0.002″ to 0.008″ thick between the openings and the tubes throughout the thickness of said relatively thick end wall, whereby vapor leaking from the shell through said annular clearance space condenses within said clearance space by contact with the surfaces of the cold first pass tube portions located within said thick end wall and surrounded by said annular clearance space so that the condensed vapor within said annular clearance space provides a seal between the tubes and openings within said thick end wall.

2. In a heat exchanger of the horizontal shell and tube type in which fluid passing through the tubes is heated

by vapor supplied to the shell and condensed therein, walls forming a sub-cooling compartment within the shell surrounding the coldest portion of the first pass tubes, inlet means for the flow of condensate from the shell into the sub-cooling compartment in response to vapor pressure in the shell, condensate outlet means communicating with the sub-cooling compartment, the sub-cooling compartment walls including a relatively thick end wall through which the first pass tubes extend from the sub-cooling compartment into the shell, said thick end wall being no less than 1 inch in thickness and having tube-receiving openings formed therein of a diameter substantially exactly the outer diameter of the tubes thereby providing only a sliding fit for the tubes through said openings and an annular clearance space not greater than 0.008" thick between the openings and the tubes throughout the thickness of said relatively thick end wall, whereby vapor leaking from the shell through said annular clearance space condenses within said clearance space by contact with the surfaces of the cold first pass tube portions located within said thick end wall and surrounded by said annular clearance space so that the condensed vapor within said annular clearance space provides a seal between the tubes and openings within said thick end wall.

3. In a heat exchanger of the horizontal shell and tube type in which fluid passing through the tubes is heated by vapor supplied to the shell and condensed therein, walls forming a sub-cooling compartment within the shell surrounding the coldest portion of the first pass tubes, inlet means for the flow of condensate from the shell into the sub-cooling compartment in response to vapor pressure in the shell, condensate outlet means communicating with the sub-cooling compartment, the sub-cooling compartment walls including end wall means no less than 1 inch in thickness, through which the first pass tubes extend from the sub-cooling compartment into the shell, there being tube-receiving opening means formed in said end wall means of a diameter no more than 0.016" greater than the outer tube diameter thereby providing only a sliding fit for the tubes through said opening means, said end wall means having a shell side surface and a sub-cooling compartment side surface, whereby vapor is condensed between said shell and compartment surfaces as it leaks from the shell along the tubes and within the opening means through said end wall means.

4. The heat exchanger construction defined in claim 3, in which the end wall means has a thickness of up to 6 inches between the shell and compartment surfaces thereof, whereby vapor leaking from the shell through the tube-receiving opening means and along the tubes condenses between said shell and compartment surfaces, thereby providing said means for condensing vapor between said shell and compartment surfaces.

5. In a heat exchanger of the shell and tube type in which fluid passing through the tubes is heated by vapor supplied to the shell and condensed therein, walls forming a sub-cooling compartment within the shell surrounding the coldest portion of the first pass tubes, inlet means for the flow of condensate from the shell into the sub-cooling compartment in response to vapor pressure in the shell, condensate outlet means communicating with the sub-cooling compartment, the sub-cooling compartment walls including a relatively thick end wall through which the first pass tubes extend from the sub-cooling compartment into the shell, said thick end wall having tube-receiving openings formed therein of a diameter providing only a sliding fit for the tubes through said openings and an annular diametral clearance space between the openings and the tubes throughout the thickness of said relatively thick end wall, said end wall thickness and diametral clearance being related in accordance with the following formula:

$$L=Cg\sqrt{\frac{\Delta p}{(Ts-tw)}\frac{\rho\lambda}{z}}$$

L=tube sheet thickness in inches
g=diametral clearance in inches
Ts=vapor temperature in shell—° F.
tw=water temperature in tubes—° F.
z=vapor viscosity—centipoise
λ=latent heat of condensation of vapor
ρ=density of vapor—lbs. per cubic foot
Δp=maximum pressure difference across end wall—p.s.i.
$c\cong 20$ (approximately) for horizontal sub-cooling zone
$=40$ (approximately) for vertical sub-cooling zone

whereby vapor leaking from the shell through said annular clearance space condenses within said clearance space by contact with the surfaces of the cold first pass tube portions located within said thick end wall and surrounded by said annular clearance space so that the condensed vapor within said annular clearance space provides a seal between the tubes and openings within said thick end wall.

6. In a heat exchanger of the horizontal shell and tube type in which fluid passing through the tubes is heated by vapor supplied to the shell and condensed therein, walls forming a sub-cooling compartment within the shell surrounding the coldest portion of the first pass tubes, inlet means for the flow of condensate from the shell into the sub-cooling compartment in response to vapor pressure in the shell, condensate outlet means communicating with the sub-cooling compartment, the sub-cooling compartment walls including a relatively thick end wall through which the first pass tubes extend from the sub-cooling compartment into the shell, said thick end wall having tube-receiving openings formed therein of a diameter providing only a sliding fit for the tubes through said openings and an annular diametral clearance space between the openings and the tubes throughout the thickness of said relatively thick end wall, said end wall thickness and diametral clearance being related in accordance with the following formula:

$$L=Cg\sqrt{\frac{\Delta p}{(Ts-tw)}\frac{\rho\lambda}{z}}$$

L=tube sheet thickness in inches
g=diametral clearance in inches
Ts=vapor temperature in shell—° F.
tw=water temperature in tubes—° F.
z=vapor viscosity—centipoise
λ=latent heat of condensation of vapor
ρ=density of vapor—lbs. per cubic foot
Δp=maximum pressure difference across end wall—p.s.i.
$C\cong 20$ (approximately) for horizontal sub-cooling zone

whereby vapor leaking from the shell through said annular clearance space condenses within said clearance space by contact with the surfaces of the cold first pass tube portions located within said thick end wall and surrounded by said annular clearance space so that the condensed vapor within said annular clearance space provides a seal between the tubes and openings within said thick and wall.

7. In a heat exchanger of the shell and tube type in which fluid passing through the tubes is heated by vapor supplied to the shell and condensed therein, walls forming a sub-cooling compartment within the shell surrounding the coldest portion of the first pass tubes, inlet means for the flow of condensate from the shell into the sub-cooling compartment in response to vapor pressure in the shell, condensate outlet means communicating with the sub-cooling compartment, the sub-cooling compartment walls including a relatively thick end wall through which the first pass tubes extend from the sub-cooling compartment into the shell, said thick end wall having tube-receiving openings formed therein of a diameter providing only a sliding fit for the tubes through said openings and an annular diametral clearance space between the openings and the tubes throughout the thickness of said relatively thick end wall, said end wall thickness and diametral

clearance being related in accordance with the following formula:

$$L = Cg\sqrt{\frac{\Delta p}{(Ts - tw)}\,\frac{\rho\lambda}{z}}$$

L=tube sheet thickness in inches
g=diametral clearance from 0.004" to 0.016"
Ts=vapor temperature in shell—° F.
tw=water temperature in tubes—° F.
z=vapor viscosity—centipoise
λ=latent heat of condensation of vapor
ρ=density of vapor—lbs. per cubic foot
Δp=maximum pressure difference across end wall—p.s.i.
$C \cong 20$ (approximately) for horizontal sub-cooling zone
=40 (approximately) for vertical sub-cooling zone

whereby vapor leaking from the shell through said annular clearance space condenses within said clearance space by contact with the surfaces of the cold first pass tube portions located within said thick end wall and surrounded by said annular clearance space so that the condensed vapor within said annular clearance space provides a seal between the tubes and openings within said thick end wall.

8. In a heat exchanger of the shell and tube type in which fluid passing through the tubes is heated by vapor supplied to the shell and condensed therein, walls forming a sub-cooling compartment within the shell surrounding the coldest portion of the first pass tubes, inlet means for the flow of condensate from the shell into the sub-cooling compartment in response to vapor pressure in the shell, condensate outlet means communicating with the sub-cooling compartment, the sub-cooling compartment walls including a relatively thick end wall through which the first pass tubes extend from the sub-cooling compartment into the shell, said thick end wall being from 1 inch to 6 inches in thickness and having tube-receiving openings formed therein of a diameter from 0.004" to 0.016" greater than the outer tube diameter thereby providing only a sliding fit for the tubes through said openings and an annular clearance space from 0.002" to 0.008" thick between the openings and the tubes throughout the thickness of said relatively thick end wall, whereby vapor leaking from the shell through said annular clearance space condenses within said clearance space by contact with the surfaces of the cold first pass tube portions located within said thick end wall and surrounded by said annular clearance space so that the condensed vapor within said annular clearance space provides a seal between the tubes and openings within said thick end wall.

9. In a heat exchanger of the shell and tube type in which fluid passing through the tubes is heated by vapor supplied to the shell and condensed therein, walls forming a sub-cooling compartment within the shell surrounding the coldest portion of the first pass tubes, inlet means for the flow of condensate from the shell into the sub-cooling compartment in response to vapor pressure in the shell, condensate outlet means communicating with the sub-cooling compartment, the sub-cooling compartment walls including a relatively thick end wall through which the first pass tubes extend from the sub-cooling compartment into the shell, said thick end wall being no less than 1 inch in thickness and having tube-receiving openings formed therein of a diameter substantially exactly the outer diameter of the tubes thereby providing only a sliding fit for the tubes through said openings and an annular clearance space not greater than 0.008" thick between the openings and the tubes throughout the thickness of said relatively thick end wall, whereby vapor leaking from the shell through said annular clearance space condenses within said clearance space by contact with the surfaces of the cold first pass tube portions located within said thick end wall and surrounded by said annular clearance space so that the condensed vapor within said annular clearance space provides a seal between the tubes and openings within said thick end wall.

10. In a heat exchanger of the shell and tube type in which fluid passing through the tubes is heated by vapor supplied to the shell and condensed therein, walls forming a sub-cooling compartment within the shell surrounding the coldest portion of the first pass tubes, inlet means for the flow of condensate from the shell into the sub-cooling compartment in response to vapor pressure in the shell, condensate outlet means communicating with the sub-cooling compartment, the sub-cooling compartment walls including end wall means no less than 1 inch in thickness, through which the first pass tubes extend from the sub-cooling compartment into the shell, there being tube-receiving opening means formed in said end wall means of a diameter no more than 0.016" greater than the outer tube diameter thereby providing only a sliding fit for the tubes through said opening means, said end wall means having a shell side surface and a sub-cooling compartment side surface, whereby vapor is condensed between said shell and compartment surfaces as it leaks from the shell along the tubes and within the opening means through said end wall means.

11. The heat exchanger construction defined in claim 10, in which the end wall means has a thickness of up to 6 inches between the shell and compartment surfaces thereof, whereby vapor leaking from the shell through the tube-receiving opening means and along the tubes condenses between said shell and compartment surfaces, thereby providing said means for condensing vapor between said shell and compartment surfaces.

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