Oct. 18, 1960 F. BONI, JR 2,956,704

REMOVABLE TUBE SHEET CONSTRUCTION FOR HEAT EXCHANGERS

Filed May 15, 1957 3 Sheets-Sheet 1

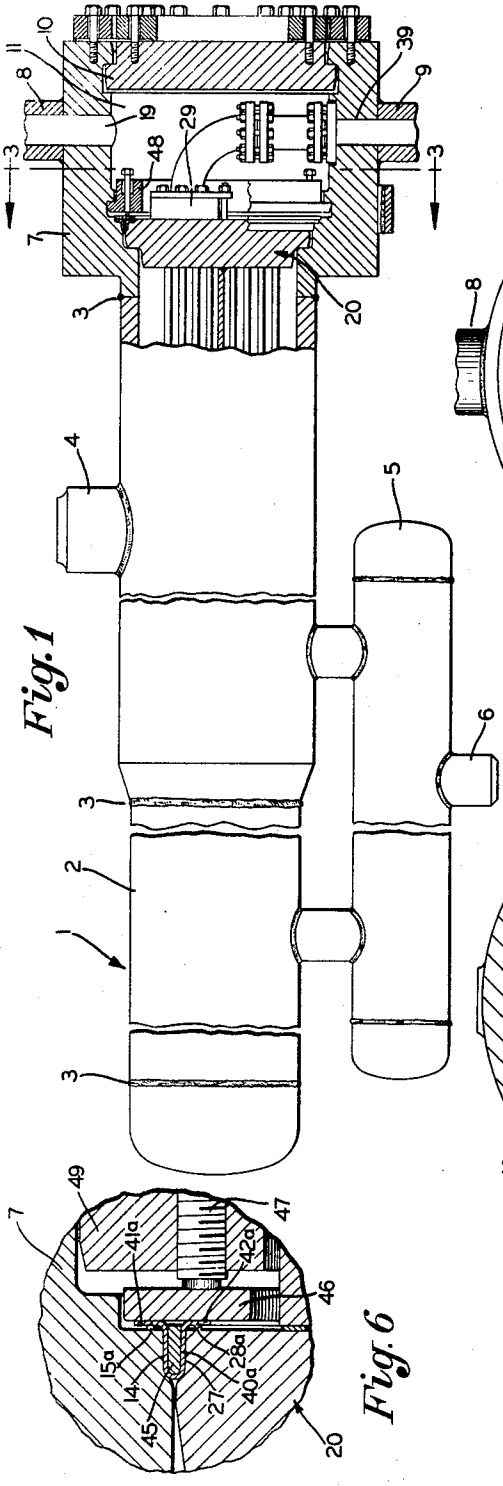


Fig. 1

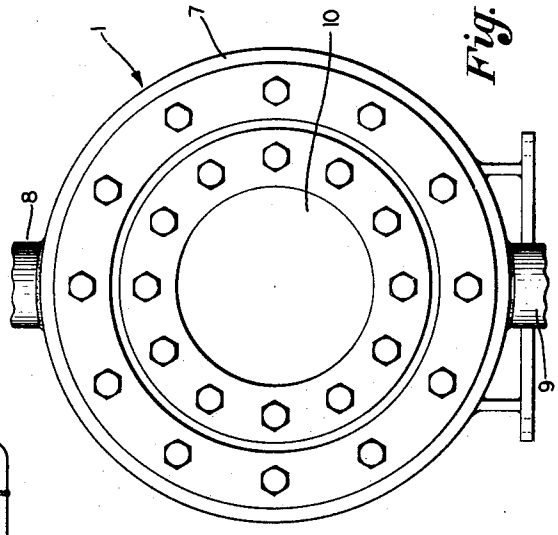


Fig. 2

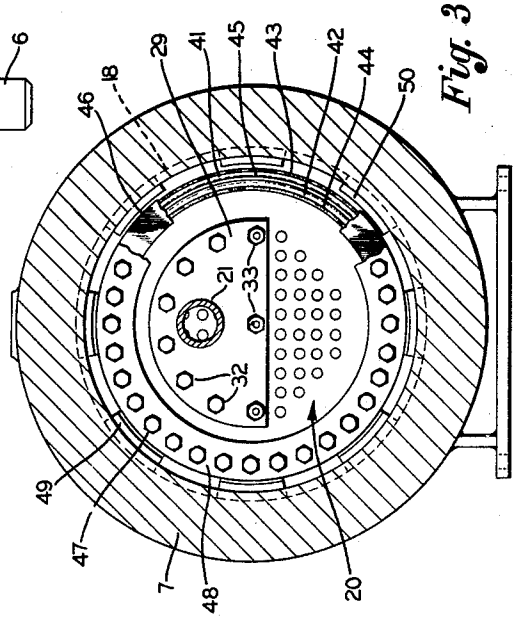


Fig. 3

Fig. 6

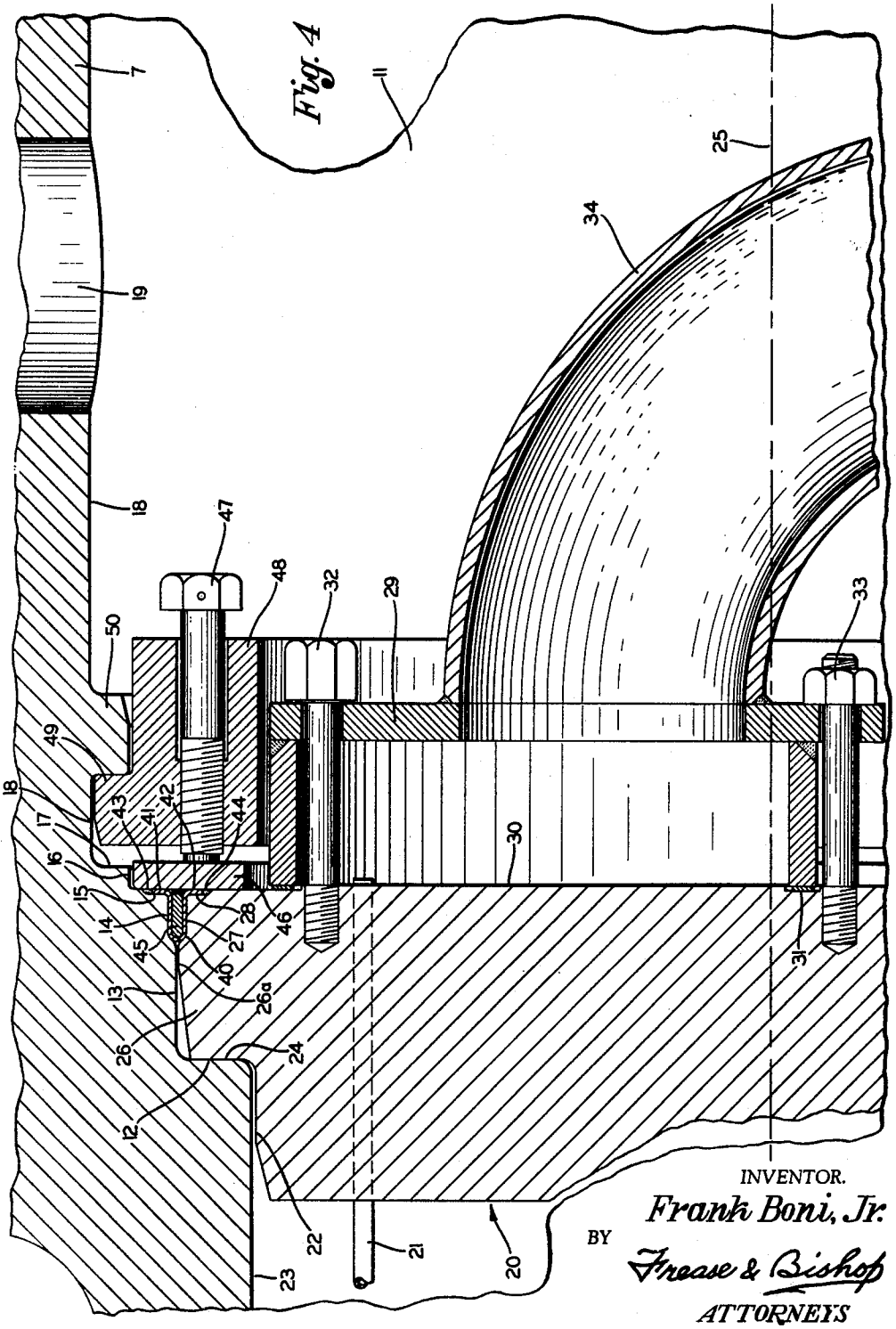
INVENTOR.
Frank Boni, Jr.
BY
Frease & Bishop
ATTORNEYS

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REMOVABLE TUBE SHEET CONSTRUCTION FOR HEAT EXCHANGERS

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Fig. 4



INVENTOR.
Frank Boni, Jr.
BY
Frease & Bishop
ATTORNEYS

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REMOVABLE TUBE SHEET CONSTRUCTION FOR HEAT EXCHANGERS

Filed May 15, 1957 3 Sheets-Sheet 3

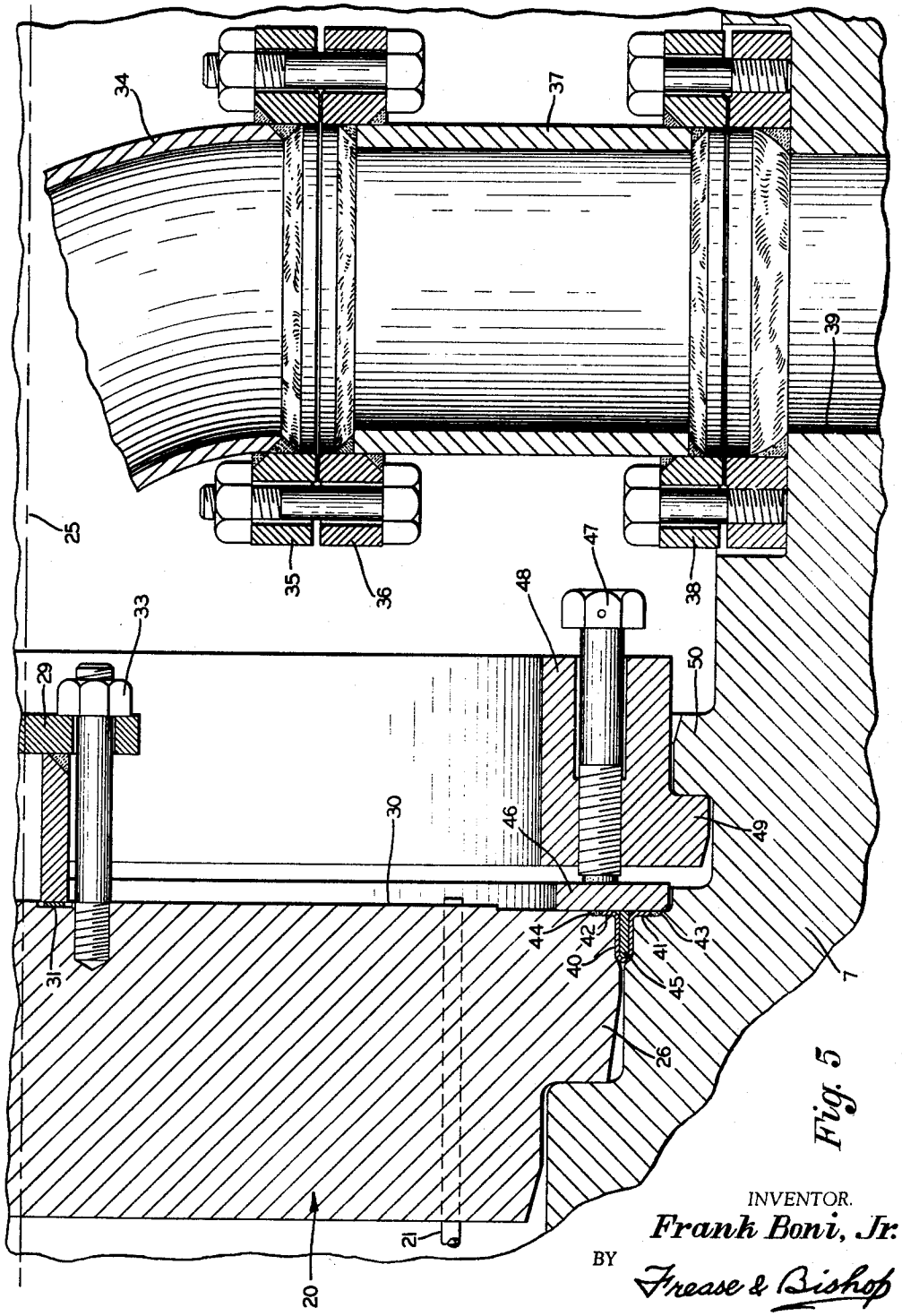


Fig. 5

INVENTOR.
Frank Boni, Jr.
BY
Frease & Bishop
ATTORNEYS

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REMOVABLE TUBE SHEET CONSTRUCTION FOR HEAT EXCHANGERS

Frank Boni, Jr., Massillon, Ohio, assignor to The Griscom-Russell Company, Massillon, Ohio, a corporation of Delaware

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6 Claims. (Cl. 220—46)

The invention relates to heat exchangers and more particularly to a removable tube sheet construction for heat exchangers.

A problem has developed in the construction of heat exchangers for high-pressure work which in some instances requires the shell member to be formed of heavy wall sections welded together. Shells constructed of welded-up zones to withstand high pressure must be heat treated for stress relief of the welded joints, and these welded joints must be accessible for X-ray inspection.

In carrying out a stress relief heat treatment the entire shell after fabrication and welding must be placed in a furnace and heated to the required temperature and for the required time, followed by the X-ray inspection. The tube bundle and tube sheet cannot be present in the shell during such stress relief heat treatment. Their presence would prevent access to the shell after heat treatment for X-ray inspection. Also, the tube sheet if integral with the shell, and the tubes which would have to be assembled prior to completely welding the shell, would be subject to oxidation if present in the shell during heat treatment. The formation of oxide scale on the tube sheet and tubes under such circumstances would lead to serious difficulties.

Although removable tube sheet constructions have been known, prior designs have involved serious difficulties in providing a satisfactory and efficient sealed joint between the tube sheet and shell or barrel walls and have required difficult machining operations to be performed and extremely close tolerances to be maintained.

Accordingly, it is an object of the present invention to provide a new removable tube sheet construction for heat exchangers which permits welded fabrication, stress relief and X-ray inspection of the shell prior to assembly of the tube sheet and tube bundle therein.

Furthermore, it is an object of the present invention to provide a new removable tube sheet construction for heat exchangers having an adequate, complete, efficient and fluid-tight seal at the joint between the tube sheet and shell or barrel walls, further characterized in that the joint also serves as an expansion joint to accommodate radial expansion of the parts and a moderate amount of relative axial movement therebetween while maintaining an effective fluid-tight seal.

Also, it is an object of the present invention to provide a new removable tube sheet construction for heat exchangers satisfying the stated requirements and which may be fabricated without requiring close machining tolerances to be maintained in machining the various parts of the removable tube sheet and sealed joint.

Moreover, it is an object of the present invention to provide a new removable tube sheet construction for heat exchangers which enables the tube sheet and tube bundle to be fabricated and installed as a unit in the shell.

Also, it is an object of the present invention to provide a new removable tube sheet construction for heat exchangers which includes tube pass separation means assembled as a part of a tube sheet and tube bundle unit independently of the heat exchanger head.

Likewise, it is an object of the present invention to provide a new removable tube sheet construction for heat exchangers with a fluid-tight sealed joint between the tube sheet and shell or barrel walls in which the shell end load against the tube sheet is transferred to the barrel walls independently of the fluid-tight joint seal between the tube sheet and shell or barrel walls.

Also, it is an object of the present invention to provide a new removable tube sheet construction for heat exchangers with which any desired head closure construction may be used.

Finally, it is an object of the present invention to provide a new removable tube sheet construction for heat exchangers which solves existing problems in the art, eliminates prior art difficulties in the construction and manufacture of removable tube sheets for high-pressure heat exchangers, generally improves heat exchanger manufacturing procedures, and obtains the foregoing advantages and desiderata in a simple and effective manner.

These and other objects and advantages apparent to those skilled in the art from the following description and claims, may be obtained, the stated results achieved, and the described difficulties overcome by the products, parts, elements, arrangements, constructions, combinations and subcombinations which comprise the present invention, the nature of which is set forth in the following general statement, a preferred embodiment of which—illustrative of the best mode in which applicant has contemplated applying the principles—is set forth in the following description and shown in the drawings, and which are particularly and distinctly pointed out and set forth in the appended claims forming part hereof.

The nature of the improvements in removable tube sheet construction for heat exchangers of the present invention may be stated in general terms as including an integral shell, a head barrel wall connected with the shell forming a head chamber, an annular shoulder formed in the shell or barrel walls within the chamber, a removable tube sheet having an annular shoulder formed circumferentially thereof intermediate the shell and head side faces of the tube sheet and seated in axial abutment with said barrel wall shoulder, a flanged U-shaped sealing ring, the ring flanges being welded or otherwise sealed to the tube sheet and barrel wall to form a fluid-tight sealed joint between the tube sheet and barrel wall, the U-portion of the ring extending circumferentially between mating surfaces of the tube sheet and barrel wall and forming an annular recess within the U which opens outwardly toward the head chamber, an annular seal-seating ring in said recess; a back-up ring engaging the barrel wall, tube sheet, and sealing ring; a locking ring removably engaging the barrel wall, bolt means carried by the locking ring adjustably engaging the back-up ring, removable tube pass separation chamber means carried by the tube sheet, inlet and outlet connections for the head chamber, removable connections between the outlet and tube pass separation chamber means within the head chamber, and head closure means for the head.

By way of example, an embodiment of the present invention is illustrated in the accompanying drawings in which:

Figure 1 is a side elevation, with certain parts in section, of a heat exchanger provided with the improved removable tube sheet construction;

Fig. 2 is an end view looking toward the head of the heat exchanger shown in Fig. 1;

Fig. 3 is a transverse sectional view taken on the line 3—3, Fig. 1;

Fig. 4 is an enlarged fragmentary sectional view show-

ing one portion of the improved removable tube sheet construction;

Fig. 5 is a view similar to Fig. 4 showing another portion of the improved removable tube sheet construction; and

Fig. 6 is a view similar to a portion of Fig. 4 showing a modified form of construction.

Similar numerals refer to similar parts throughout the various figures of the drawings.

A heat exchanger is indicated generally at 1 in Fig. 1 and may, for example, be designed for 2,500 p.s.i. shell side pressure and 3,200 p.s.i. tube side pressure with shell side operating temperatures up to, say, 1000° F. and tube side temperatures of upwards of 750° F.

The heat exchanger 1 includes shell walls 2 formed of metal wall sections welded together by a number of welds 3, a shell inlet connection 4 and a manifolded shell outlet 5 having an outlet connection 6. A head barrel wall 7 is integrally connected by one of the welds 3 with the shell 2 and is provided with a tube inlet connection 8 and a tube outlet connection 9; and the head 7 may be closed by head closure plate 10 secured to the head barrel wall 7 in any suitable or usual manner and forming with the head barrel wall 7 a head chamber 11.

The shell 2 and head barrel wall 7, together with the inlet and outlet connections therefor, after fabrication, may be heat treated as a unit in a suitable furnace for stress relief of the welded joints 3. These joints may thereafter be inspected for soundness in any suitable manner including X-ray inspection internally of the shell 2.

In accordance with the present invention, in order to permit such shell weld stress relief and inspection, the tube sheet and tube bundle and connected parts may be assembled or removed as a unit. Thus, referring more particularly to Figs. 4 and 5, an annular shoulder 12 may be formed in the barrel wall providing an enlarged circumferential recess having a cylindrical inner surface 13 terminating adjacent its open or head end in a further cylindrical enlargement 14. At the end of enlargement 14, the barrel wall is formed with another shoulder 15 and a further enlargement 16. The enlargement 16 terminates in a third shoulder 17 extending outward to the main circumferential inner surface 18 of the head chamber 11. The barrel wall 7 is formed with a head inlet opening 19 which connects with the inlet connector 8.

The tube sheet generally indicated at 20 has tubes 21 connected thereto in the usual manner. Only one tube is shown in each of Figs. 4 and 5 for the sake of clarity.

The tube sheet 20 has reduced end portion 22 extending into the main cylindrical portion 23 of the connected shell and barrel walls and the tube sheet 20 is provided with a shoulder 24 intermediate the shell and head faces of the tube sheet and lying in a plane extending normal to the center line or axis of the shell indicated by dot-dash line 25. When the tube sheet is assembled in the heat exchanger, the shoulder 24 axially abuts the barrel wall shoulder 12.

The shoulder 24 is formed by a flange 26 on the tube sheet 20, and flange 26 has an outer circumferential surface 26*a* telescoped within the barrel wall inner surface 13. The tube sheet flange 26 is formed with a circumferentially-extending generally cylindrical recess 27 having a cross-sectional shape similar to the shape of the enlarged cylindrical recess 14 in the barrel wall 7; and tube sheet recess 27 terminates in a shoulder 28.

The tubes 21 preferably are U-tubes and the tube 21 illustrated in Fig. 4 may be the outlet end of one particular tube. Tube pass separation may be accomplished by seating a D-shaped (Fig. 3) tube pass housing member 29 against the head face 30 of tube sheet 20. A sealing gasket is provided at 31 and seating bolts 32 and 33 hold the housing 29 in place. The housing 29 may have an outlet elbow 34 integrally connected therewith and provided with a flange 35 for flanged coupling connection with the flange 36 of an outlet pipe 37. The lower end of pipe 37 is connected by flange coupling 38 with the barrel wall 7 in communication with an outlet opening 39 which extends to the head outlet connection 9.

Thus, tube fluid may enter the head chamber 11 through inlet connection 8 and inlet opening 19 and fill the head chamber 11, from whence it passes through tubes 21, the inlet end of one of which is illustrated in Fig. 5, and through the tubes 21 to within the pass separation housing 29, then through elbow 34 and outlet pipe 37 to outlet opening 39 and outlet connection 9. The pressure of the tube inlet fluid within head chamber 11 assists in maintaining the pass separation housing 29 seated against gasket 31.

The joint between the tube sheet 20 and barrel wall 7 is sealed in fluid-tight manner by a flanged U-shaped sealing ring 40, the U-portion of which extends circumferentially between the mating surfaces of the recesses 14 and 27, respectively, in the barrel wall 7 and tube sheet 20. The flanges 41 and 42 of the U-shaped sealing ring 40 are seated against the shoulders 15 and 28, respectively formed in the barrel wall 7 and tube sheet 20, and are welded at 43 and 44, respectively, to the barrel wall 7 and tube sheet 20.

This flanged U-shaped sealing ring 40 welded to the barrel wall 7 and tube sheet 20 thus forms an effective diaphragm-like liquid-tight seal for the joint between the tube sheet 20 and shell 2. At the same time, because the flanged U-shaped sealing ring 40 is formed of relatively light gauge metal which may be readily removed, it is possible to readily remove the tube sheet 20 in case it becomes necessary to gain access to the shell or tubes for repairs.

As shown, the walls of the U-portion of the sealing ring 40 form an annular recess within the U which opens outwardly toward the head chamber. An annular seal-seating ring 45 is seated in this recess to hold the light gauge walls of the U-portion of the sealing ring 40 in mating engagement with recesses 14 and 27, respectively, formed in the barrel wall 7 and tube sheet 20.

In accordance with the invention, a back-up ring 46 is located in engagement with the head surface of the tube sheet 20, the head barrel wall 7 within enlargement 16, and the outer surfaces of the flanges 41 and 42 of the sealing ring 40. The back-up ring 46 is adjustably pressed into seated position by compression screws 47 carried by a locking ring 48 having circumferentially-spaced radially-extending lugs 49 which engage similar lugs 50 extending inwardly of the barrel wall 7. The lugs 49 and 50 thus form a typical bayonet joint connection between the barrel wall 7 and locking ring 48.

In this manner the tube sheet shoulder 24 is seated against the barrel wall shoulder 12, and the shell end load imparted to the tube sheet 20 is carried directly to the barrel wall through the tube sheet 20, back-up ring 46, compression screws 47, locking ring 48 and lugs 49 and 50. Accordingly the fluid-tight seal between the tube sheet 20 and barrel wall 7 is relieved of any shell end load.

The particular construction and shape of the sealing ring 40, the seal-seating ring 45, and the seating of the ring 40 in recesses 14 and 27 and the welding of the flanges at 43 and 44, respectively, to the barrel wall 7 and tube sheet 20 have a number of important advantages. First, the welded joints 43 and 44 are relieved of any stress incident to slight relative movement between the parts due to the shell end loading or to expansion and contraction incident to temperature changes. Second, the sealing ring 40 acts as an expansion joint in that it can accommodate radial expansion and contraction and differentials in such expansion and contraction in the barrel wall 7 and tube sheet 20. Third, the sealing ring 40 can accommodate a moderate amount of relative axial movement incident to expansion and contraction of the barrel wall 7 and tube sheet 20. Fourth, close tolerances

need not be maintained in machining the various surfaces of the tube sheet **20** and barrel wall **7** because large tolerances can be compensated for by adjustment of the compression screws **47**.

The modified construction shown in Fig. 6 is identical with that shown in Figs. 1 to 5 excepting for the manner in which the U-shaped sealing ring **40***a* is sealed in a fluid-tight manner with the tube sheet **20** and barrel wall 7. The U-portion of the flanged U-shaped sealing ring **40***a* extends circumferentially between the mating surfaces of recesses **14** and **27**, formed, respectively, in the barrel wall **7** and tube sheet **20**. The flanges **41***a* and **42***a* of the U-shaped sealing ring **40***a*, however, are seated against annular ribs **15***a* and **28***a*, respectively, formed in the barrel wall **7** and tube sheet **20** adjacent the recesses **14** and **27**, to form a fluid-tight joint therebetween. This seating of the flanges **41***a* and **42***a* against ribs **15***a* and **28***a* is accomplished by the pressure of back-up ring **46** which is adjustably pressed into sealing position by compression screws **47**.

As shown, the walls of the U-portion of the sealing ring **40***a* are maintained against collapse by the annular seal-seating ring **45** which holds the light gauge walls of the U-portion of the sealing ring **40***a* in mating engagement with the recesses **14** and **27**, respectively, formed in the barrel wall **7** and tube sheet **20**.

Again, the particular construction and shape of the sealing ring **40***a*, the seal-seating ring **45**, the seating of the ring **40***a* in recesses **14** and **27**, and the liquid-tight seal between the flanges **41***a* and **42***a*, respectively, and the barrel wall rib **15***a* and tube sheet rib **28***a* have the same advantages as in the construction shown in Fig. 1. First, the liquid-tight sealed joints are relieved of any stress incident to slight relative movement between the parts due to the shell end loading or to expansion and contraction incident to temperature changes. Second, the sealing ring **40***a* acts as an expansion joint in that it can accommodate radial expansion and contraction and differentials in such expansion and contraction in the barrel wall **7** and tube sheet **20**. Third, the sealing ring **40***a* can accommodate a moderate amount of relative axial movement incident to expansion and contraction of the barrel wall **7** and tube sheet **20**. Fourth, close tolerances need not be maintained in machining the various surfaces of the tube sheet **20** and barrel wall **7** because large tolerances can be compensated for by adjustment of the compression screws **47**.

Accordingly, the improved removable tube sheet construction of the present invention permits welded fabrication, stress relief and X-ray inspection of the shell prior to assembly of the tube sheet and tube bundle therein; provides an adequate, complete, efficient and fluid-tight seal at the joint between the tube sheet and shell; provides a joint which functions as an expansion joint to accommodate radial expansion and a moderate amount of relative axial movement between the barrel wall and tube sheet; provides a construction which may be fabricated without requiring close machining tolerances to be maintained; provides a construction in which tube pass separation means may be incorporated as a part of a tube sheet and tube bundle unit independently of the heat exchanger head; and provides a construction solving existing problems in the art, eliminating prior art difficulties and achieving the described advantages in a simple and effective manner.

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

Having now described the invention, the manufacture and use of a preferred embodiment thereof, and the advantageous, new and useful results obtained thereby, the new and useful products, parts, elements, arrangements, constructions, combinations and sub-combinations, and reasonable mechanical equivalents thereof obvious to those skilled in the art, are set forth in the appended claims.

I claim:

1. Removable tube sheet construction for heat exchangers including an integral shell, a head barrel wall connected with the shell forming a head chamber, an annular shoulder formed in the barrel wall within the chamber, a tube sheet having a circumferentially-arranged, radially-extending flange adjacent the head side of the tube sheet and forming an annular shoulder located intermediate the shell and head side faces of the tube sheet, said tube sheet shoulder facing the shell side of the tube sheet and being seated in axial abutment with said barrel shoulder, the radially-extending flange having an outer circumferential surface facing the head barrel wall, fluid-tight joint-sealing means between the tube sheet circumferential surface and barrel wall; said joint-sealing means including a flexible diaphragm member having circumferentially-arranged radially-extending flange means and circumferentially-arranged axially-extending portions connecting the flange means, at least one of said circumferential surface and said head barrel wall having a circumferentially-extending generally cylindrical recess opening into the head chamber, said axially-extending portions being telescoped in the cylindrical recess between the tube sheet flange and the barrel wall, and said sealing flange means being sealed in fluid-tight relation with the tube sheet and barrel wall; a back-up ring engaging the tube sheet, joint-sealing means and barrel wall; and adjustable locking means removably engaging the barrel wall and back-up ring for pressure seating the tube sheet shoulder against the barrel wall shoulder.

2. Removable tube sheet construction as defined in claim 1, in which the sealing flange means is sealed in fluid-tight relation with the tube sheet and barrel wall by welded joints between the sealing flange means and the tube sheet and barrel wall.

3. Removable tube sheet construction for heat exchangers including an integral shell, a head barrel wall connected with the shell forming a head chamber, an annular shoulder formed in the barrel wall within the chamber, a tube sheet having a circumferentially-arranged radially-extending flange adjacent the head side of the tube sheet and forming an annular shoulder located intermediate the shell and head side faces of the tube sheet, said tube sheet shoulder facing the shell side of the tube sheet and being seated in axial abutment with said barrel shoulder, the tube sheet flange having an outer circumferential surface facing the head barrel wall, fluid-tight joint-sealing means between the tube sheet circumferential surface and barrel wall, at least one of said circumferential surface and head barrel wall having a circumferentially-extending generally cylindrical recess opening in said head side face, said joint-sealing means including a ring-like member circumferentially sealed in fluid-tight relation respectively with the tube sheet and barrel wall at radially spaced circumferential zones, said ring-like member including angularly related portions between the spaced seals in said cylindrical recess permitting relative axial and radial movement of the tube sheet and barrel wall without stressing the seals; and adjustable locking means operatively and removably engaging the barrel wall, joint-sealing means and tube sheet for pressure seating the tube sheet shoulder against the barrel wall shoulder.

4. Removable tube sheet construction for heat exchangers including an integral shell, a head barrel wall connected with the shell forming a head chamber, an annular shoulder formed in the barrel wall within the chamber, a tube sheet having a circumferentially-arranged, radially-

extending flange adjacent the head side of the tube sheet and forming an annular shoulder located intermediate the shell and head side faces of the tube sheet, said tube sheet shoulder facing the shell side of the tube sheet and being seated in axial abutment with said barrel shoulder, there being a tubular barrel wall portion having an inner surface circumferentially surrounding said tube sheet flange, the tube sheet flange having an outer circumferential surface telescoped within and facing said inner barrel wall surface, there being annular recesses formed opposite each other respectively in said inner surface of the barrel wall and in said outer tube sheet flange surface, a U-shaped sealing ring, integral circumferential flanges at the open end of said U, said integral flanges being welded to the tube sheet and barrel wall to form a fluid-tight sealed joint between the tube sheet and barrel wall, the U-portion of the ring being located in said barrel wall and tube sheet recesses, and adjustable locking means removably engaging the barrel wall, sealing ring and tube sheet for pressure seating the tube sheet shoulder against the barrel wall shoulder.

5. Removable tube sheet construction as defined in claim 4 in which the adjustable locking means includes a back-up ring engaging the tube sheet, U-shaped sealing ring and barrel wall; a locking ring removably engaging the barrel wall; and adjustable bolts carried by the locking ring removably engaging said back-up ring.

6. Removable tube sheet construction as defined in claim 5 in which an annular seal-seating ring is located in the U-portion of the sealing ring holding the U-portions of the U-shaped sealing ring in mating engagement with the barrel wall and tube sheet annular recesses.

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