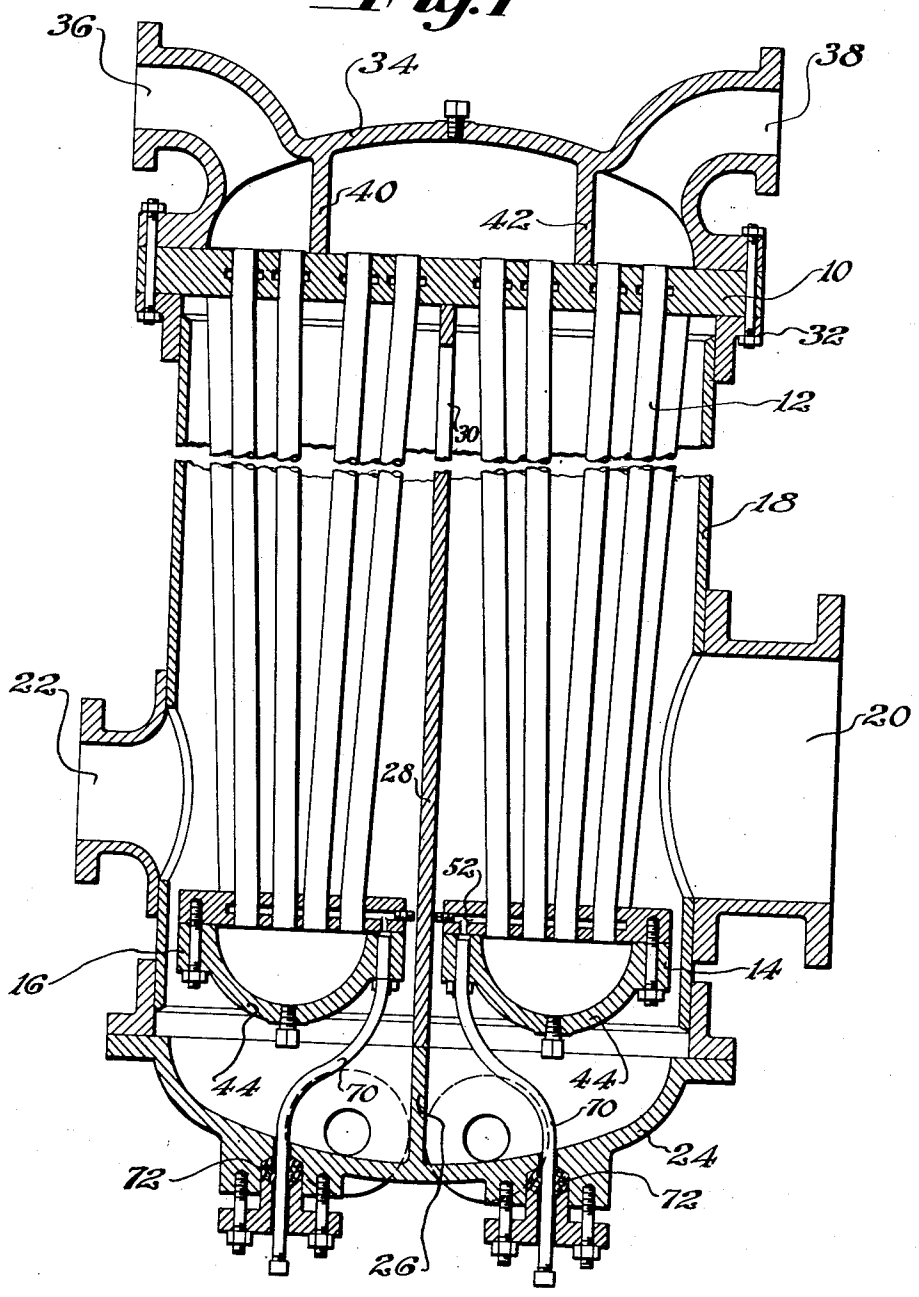
Jan. 15, 1935. F. W. CATTANACH 1,987,891

HEAT EXCHANGE APPARATUS

Filed June 9, 1934 2 Sheets-Sheet 1

Fig. 1



Witness

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Fig. 2

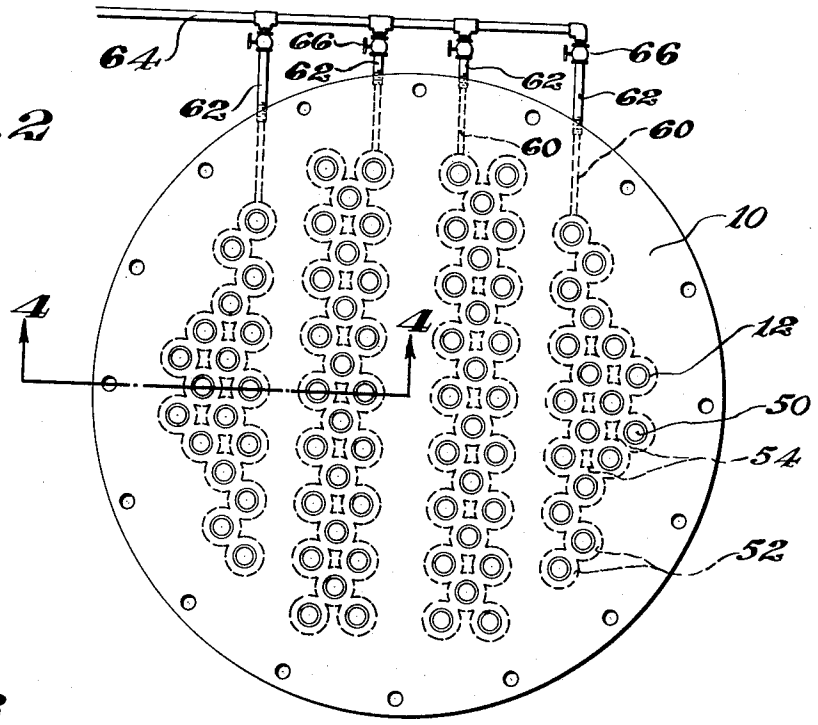
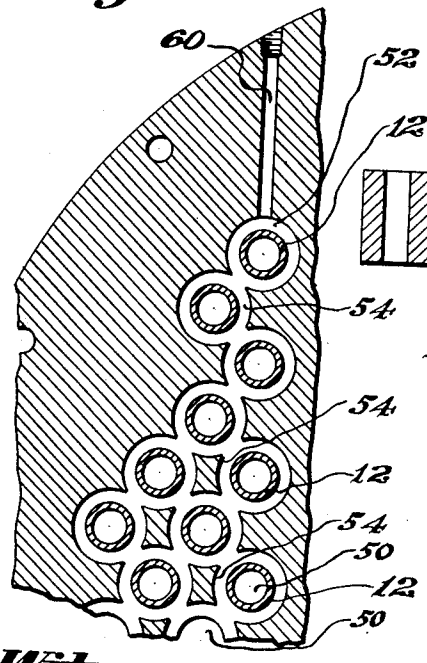


Fig. 3



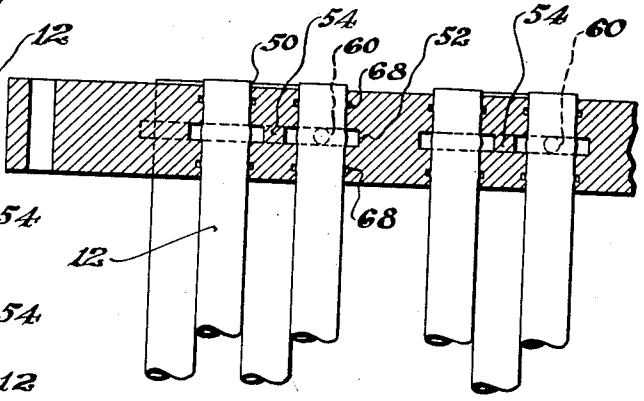


Fig. 4

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Patented Jan. 15, 1935

1,987,891

UNITED STATES PATENT OFFICE

1,987,891

HEAT EXCHANGE APPARATUS

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Application June 9, 1934, Serial No. 729,851

14 Claims. (Cl. 257—223)

The present invention relates to tubular heat exchangers, and is more particularly concerned with improvements in apparatus of this character where it is desired to prevent intercommunication through leakage of different fluids employed in the apparatus, and to detect any leakage which may occur about the tube joints.

The purpose and object of the invention is to provide in heat exchange apparatus of the tubular type, especially where subjected to substantial pressure differential at opposite sides of the tubes, means for insuring against leakage within the apparatus and intermingling of different fluids, coupled with provision for detecting and segregating any leakage which may occur in the region of the tube joints.

With this and other objects in view, a feature of the invention contemplates the provision of an integral tube sheet into which the ends of the tubes are rolled or otherwise secured, the tube sheet being of adequate thickness to withstand the pressure differential imposed thereon. This tube sheet is provided intermediate its opposite faces and surrounding the tube ends passing therethrough with a series of intercommunicating annular recesses which form in effect a continuous cavity communicating preferably to atmosphere or to a region of lower pressure than that to which the tube sheet is subjected at opposite sides. Any leakage in the region of the tube joint occurring at either side of this median cavity seeps into the cavity because of the lower pressure, and is directed from this point outwardly. If the tube sheet is of sufficient size to have connected thereto more than one group of tubes and if so desired, the continuous cavity surrounding each individual group of tubes may be segregated and hermetically sealed-off from adjacent cavities to permit the region of leakage to be identified and segregated, and enable the re-rolling or repair to be confined to the proper group of tubes.

By virtue of this construction and the formation of a continuous cavity through the series of intercommunicating annular recesses, the integral tube sheet is provided with spaced and integral pillars adjoining and between the cavities, which structurally support the sheet and afford the same measurable resistance to shearing stress as would be present with a tube sheet of the same thickness not so provided with a median cavity.

In the accompanying drawings illustrating the preferred form of the invention, Fig. 1 represents a section in elevation of a heat exchanger embodying the features of the invention; Fig. 2 is a plan view of the fixed tube sheet illustrating the method of segregating leakage from each tube group; Fig. 3 is an enlarged section through the tube sheet illustrating the method of forming the annular and intercommunicating recesses; and Fig. 4 is a section on the line 4—4 of Fig. 2, showing the method of routing or channeling the tube sheet for the provision of the continuous cavity.

The apparatus shown in the illustrated embodiment of the invention, more particularly Fig. 1, is in the general form of a heat exchanger for oil refining purposes in which the hot oil vapor is admitted about the exterior of the tubes and is cooled by fluid flowing through the interior of the tubes. It is desirable and important that contamination of the fluids by intermixture be avoided, and as the pressure differential to which the tubular system is sometimes subjected may be substantial, this problem of leakage and contamination of fluid becomes a matter of importance.

In the form of the invention illustrated, a fixed tube sheet 10 serves for supporting heat exchange tubing 12, which may be arranged in a series of groups as indicated more particularly in Figs. 1 and 2. These tubes depend downwardly from the tube sheet, and are connected at their lower ends to floating heads 14 and 16 in the usual manner. The space surrounding the tubes may be enclosed by a shell 18, provided with inlet and outlet vapor nozzles 20 and 22. The vapor space is closed at the bottom by a detachable cover member 24, which provides for the reception and collection of condensate in two separated portions divided by a partition 26. The vapor space is also divided into two vapor passes by a partition 28 aligned with the member 26. Vapor entering through the nozzle 20 passes upwardly about the tube bank through the opening 30, thence downwardly and outwardly through the nozzle 22. The enclosing shell 18 is bolted to the tube sheet 10 through a flange 32, and the tube sheet is in turn surmounted by a member 34 which provides for the passage of cooling fluid through the interior of the tubular system. The cooling fluid may enter at 36 and exhaust at 38, being directed in several passes through the interior of the tubes by intermediate partitions 40 and 42. At the opposite ends of the tubes the cooling fluid flow is reversed by chambers formed within the floating head covers 44.

This construction typifies what may be con-

sidered as an inverted type of heat exchanger, and the present invention may be equally well embodied in a heat exchanger with the fixed tube sheet located at the bottom and the tubes projecting upwardly therefrom, or any system in which the tubes project horizontally from a vertical tube sheet, as is common in the art.

Intercommunication between the liquid and vapor space is precluded in the present invention without sacrifice of strength of the tube sheet by providing the tube sheet, as shown clearly in Figs. 2 to 4, with a series of annular recesses each surrounding the opening through which the tube passes, and each being of sufficient diameter to communicate with the next adjacent recess. As indicated more particularly in Figs. 3 and 4, the tube 12 is received in one of a series of openings 50 passing through the tube sheet to opposite sides. Surrounding this opening approximately midway between opposite faces of the tube sheet is an annular recess 52. This recess is of sufficient diameter to break into and communicate with the next adjoining recess 52 surrounding the adjacent tube. A series of these recesses would form a continuous cavity, somewhat as shown in Fig. 3, depending obviously upon the arrangement of the tubes. This cavity would be interspersed with integral pillars 54 adjoining opposite sides of the tube sheet and serving to strengthen and reinforce the tube sheet. The cavity at the point nearest the edge of the tube sheet communicates with a vent passage 60, which in turn, as indicated more particularly in Fig. 2, may be connected with a vent pipe 62. If the cavities are separated to segregate individual groups of tubes, then a series of vent pipes 62 may be caused to communicate with a single vent 64, each of the separate branch vents being valved at 66 to permit closure of the vents and segregation of the region of leakage in the event that this occurs. The tube ends may be expanded by rolling into the annular grooves 68 provided for this purpose, in a manner which will be obvious to those skilled in the art.

With this construction, leakage occurring from either side of the tube sheet or from within the tube outwardly will be diverted into the mid cavity and thence outwardly through the vents because of the lower pressure therein. Not only will the provision of this mid cavity prevent intercommunication between the two fluids due to leakage, but it serves in addition as an automatic detector of such leakage. Through the provision, furthermore, of separate cavities confined to each tube group, or a portion of a tube group, the leakage region may be confined in any desired degree, depending upon the number of cavities which are employed and the area and extent of each tube group so segregated.

As will be evident, although the fixed tube sheet may be vented outwardly as shown, the floating tube sheets or heads 14, if provided with similar leakage cavities 52, should be vented outwardly through the apparatus, and due to their construction and capacity for movement with expansion and contraction of the tubes, this is best accomplished through the provision in each case of an individual vent pipe 70, which may pass from the head downwardly through the cover member 24 provided with a stuffing box 72, the vent permitting the relief of leakage outside of the apparatus, and also permitting relative movements of the floating head with respect to the fixed shell.

The present form of construction lends itself admirably to commercial methods of production. After drilling the tube sheet in the usual manner for the reception of the tube ends, an expanding tool is inserted in each of the drilled openings and in a manner usual with this class of apparatus is rotated to cut the annular recess 52. Obviously the location, the depth and the diameter of the recess may all be controlled according to the necessities of the occasion. No showing of the expanding tool is made, as this class of apparatus is common and well known to those skilled in the art.

Aside from the very definite advantage which resides in the detection of leakage during the use and operation of the apparatus, the present form of construction is highly desirable from the point of view that the tube joints representing that portion of the apparatus most likely to failure can be adequately tested prior to installation by introducing into the leakage cavity from without a pressure which may, if so desired, be many times that which the joint will encounter in actual practice. For example, apparatus built to withstand pressure differentials on the order of 300 lbs. might readily be tested without danger through an applied pressure in the leakage cavity approximating 2,000 to 3,000 lbs., or many times in excess of the pressure normally encountered. This is due to the fact that the tube sheet itself is adequately reinforced against distortion and bulging by the integral pillars, and the tubes themselves due to the small area in contact with the cavities are supported against collapse with these high testing pressures. Furthermore, the fact that each of the individual leakage cavities is hermetically sealed except through the small vent opening, permits the introduction of these high testing pressures with a minimum of expense and inconvenience. It will be readily seen by those skilled in the art that if the tube joints are subjected to hydraulic pressure, the amount of water required to be introduced into the leakage cavity is very small as compared with the volume of water required and the time necessary if the entire tubular system is to be filled and adequately tested in this manner, which in fact, constitutes the orthodox method for testing this type of apparatus for usage.

Aside from all this, the method of testing possible through the utilization of the leakage cavity is far superior to any test possible of accomplishment by ordinary methods for the following reason. It will be evident that in the testing particularly of high pressure apparatus where the tube sheet is of substantial thickness to withstand the pressure strain, a hydraulic test at best can merely indicate the proper sealing of the tube ends within the sheet adjacent one end, and if it develops that any tube or group of tubes have been merely rolled into the tube sheet and hydraulically sealed at the lower end of the sheet, for example, which not uncommonly occurs, the test utterly fails to show or in any fashion indicate that the seal is inadequate throughout the thickness of the tube sheet. On the contrary, by inserting the test pressure mid-way between opposite faces of the tube sheet, any inadequacy in the securing and sealing of the tube end into the sheet at either side of the median leakage cavity will be instantly detected, permitting a re-rolling of the

tube ends wherever leakage has occurred before the apparatus is placed in use.

It will be evident, furthermore, that with this method of testing the adequacy of the tube joint, detection of leakage may be readily observed due to the carrying out of the test upon merely the tube sheet or head with the tubes connected thereto, and with the enclosing shell and detachable cover member or other appurtenances removed.

By testing the tube joint at an intermediate point with the tube sheet and connected tubes fully exposed to the view of the workman, leakage from either side of any tube joint may be immediately detected and the joint re-rolled sufficiently to prevent leakage. The advantage of this method of operation must be obvious to those skilled in the art, as it insures that tight joints shall not be over-rolled, and that each joint, if it leaks, shall be rolled only sufficiently to insure tightness. In the ordinary practice where testing is carried out with the cover members sealed in place and leakage occurs, it can only be overcome by first removing the cover members and other appurtenances to expose the tube ends, and thereafter re-rolling an entire group or series of joints. Subsequently the apparatus must be assembled and again tested, and if further leaks occur the operation as described repeated until finally all joints are tight. It is a certainty that even with the greatest care and skill this method of testing will cause over-rolling of certain joints, and the degree to which this occurs is obviously dependent upon the number of re-rollings required in order to make the imperfect joints tight. In any event, this method of testing makes impossible a series of tube joints of uniform holding characteristics, whereas with the present method the confinement of leakage not only to the exact tube joint but to the area of the tube joint, simplifies and makes possible not only the correction of the leakage factor, but a resultant uniformity due to the rolling of each joint and all joints only sufficiently to insure tightness.

What is claimed is:

1. A heat exchanger of the tubular type comprising an integral tube sheet, a plurality of tube ends passing through the sheet and secured thereto, means for directing dissimilar fluids about the interior and exterior of the tube series, and a leakage cavity surrounding the tube ends within the sheet, the pressure within the cavity being less than the pressures at opposite sides of the tubes.

2. A heat exchanger of the tubular type comprising an integral tube sheet, a plurality of tube ends passing through the sheet and secured thereto, means for directing dissimilar fluids about the interior and exterior of the tube series, a comparatively shallow leakage cavity located within the integral tube sheet approximately midway between opposite surfaces and surrounding the tube ends, the leakage cavity being interspersed with integral pillars for the support of the tube sheet therethrough, and means for venting fluid from the leakage cavity.

3. A tube sheet for tubular heat exchange apparatus comprising a series of openings passing therethrough for the reception of tube ends, and an annular recess formed about each opening, the annular recesses intercommunicating to provide a leakage space in the tube sheet between opposite faces.

4. A head for tubular heat exchangers comprising a plate of substantial thickness, openings passing through the plate for the reception of tube ends, an annular recess about each opening approximately midway between opposite faces of the plate, and adjacent recesses intercommunicating to provide virtually a continuous leakage cavity.

5. A head for tubular heat exchangers comprising a plate of substantial thickness, openings extending through the plate for the reception of tube ends, each opening being surrounded by an annular recess between its ends, adjacent recesses intercommunicating to provide a continuous cavity, and each opening being provided at opposite sides of the recesses with a shallow, annular cavity into which tube ends may be expanded at opposite sides of the leakage cavity.

6. A head for tubular heat exchangers comprising a metallic plate, a series of tube-receiving openings extending through the plate in spaced relationship, an annular recess surrounding each opening between opposite faces of the plate, the annular recesses intercommunicating to provide a continuous leakage cavity, and integral pillars remaining in the plate between the annular recesses after formation thereof.

7. A tubular heat exchanger comprising a head, a plurality of tubes secured to the head, means for conducting fluid both interiorly and exteriorly of the tubes, and means located within the head for providing more than one leakage area from the tubes and for separating each lakeage area from the other.

8. A tubular heat exchanger comprising a head, a plurality of tubes secured to the head, means for conducting fluid both interiorly and exteriorly of the tubes, means located within the head for providing more than one leakage area from the tubes, and means for separately venting each leakage area to isolate the group in which leakage occurs.

9. A tubular heat exchanger comprising a head, groups of tubes connected to the head, a leakage cavity formed in the head and surrounding each group of tubes, the leakage cavities being independent of one another, and means for separately venting each leakage cavity.

10. A tubular heat exchanger comprising heat exchange tubing, means for fixedly supporting the tubing at one end, a head connected to the tube at the opposite end to provide for expansion and contraction of the tubing, a leakage cavity provided in the head about the tube ends, a closure surrounding the tubing and head, and a vent connected to the head and extending outwardly through the closure to permit discharge of leakage without the apparatus.

11. A heat exchanger of the tubular type comprising a fixed tube sheet, tube ends connected to the sheet and passing therethrough, a floating head connected to the opposite ends of the tubes, a leakage cavity surrounding the tube ends in the fixed tube sheet between opposite surfaces and a similar leakage cavity surrounding the tube ends in the floating head, a closure surrounding the tubes and head and providing a fluid space exteriorly of the tubes, and means for venting both leakage cavities without the closure.

12. A head for tubular heat exchangers comprising a plate to which tubes are adapted to be secured, openings in the plate for the reception

of the tube ends, the openings being uniformly and regularly disposed with respect to one another, a circular recess surrounding each opening intermediate opposite faces of the plate, the recesses being of sufficient diameter to intersect and intercommunicate for the formation of a continuous leakage cavity interspersed at regular intervals with integral pillars connecting opposite faces of the tube sheet throughout the cavity.

13. Heat exchange apparatus of the tubular type comprising a tube sheet, tubes passing through the sheet and sealed into the sheet throughout measurably the region of contact, and means for applying test pressure to the tube joint intermediate opposite faces of the sheet.

14. A heat exchanger of the tubular type comprising a tube sheet, tubes projecting through the sheet and secured thereto throughout the thickness of the sheet, a chamber within the sheet and intermediate opposite faces communicating with the tubes intermediate the region of contact with the sheet, and means for introducing into the chamber a substantial test pressure which is directed upon the tube joint at opposite sides of the chamber to detect imperfect sealing of the tube and throughout the thickness of the tube sheet.

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