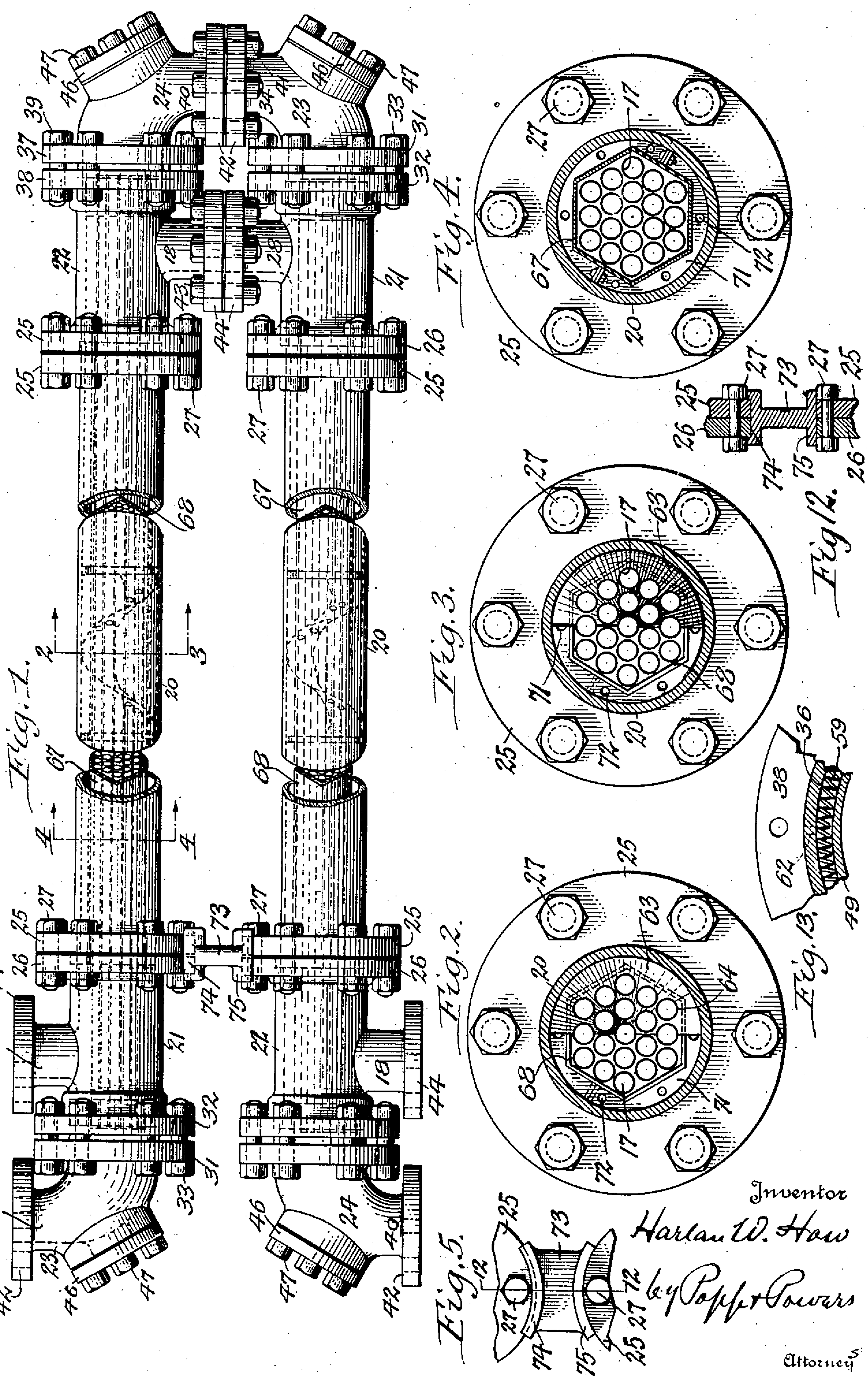
Jan. 27, 1931. H. W. HOW 1,790,151

HEAT EXCHANGER

Filed Feb. 29, 1928 2 Sheets-Sheet 1



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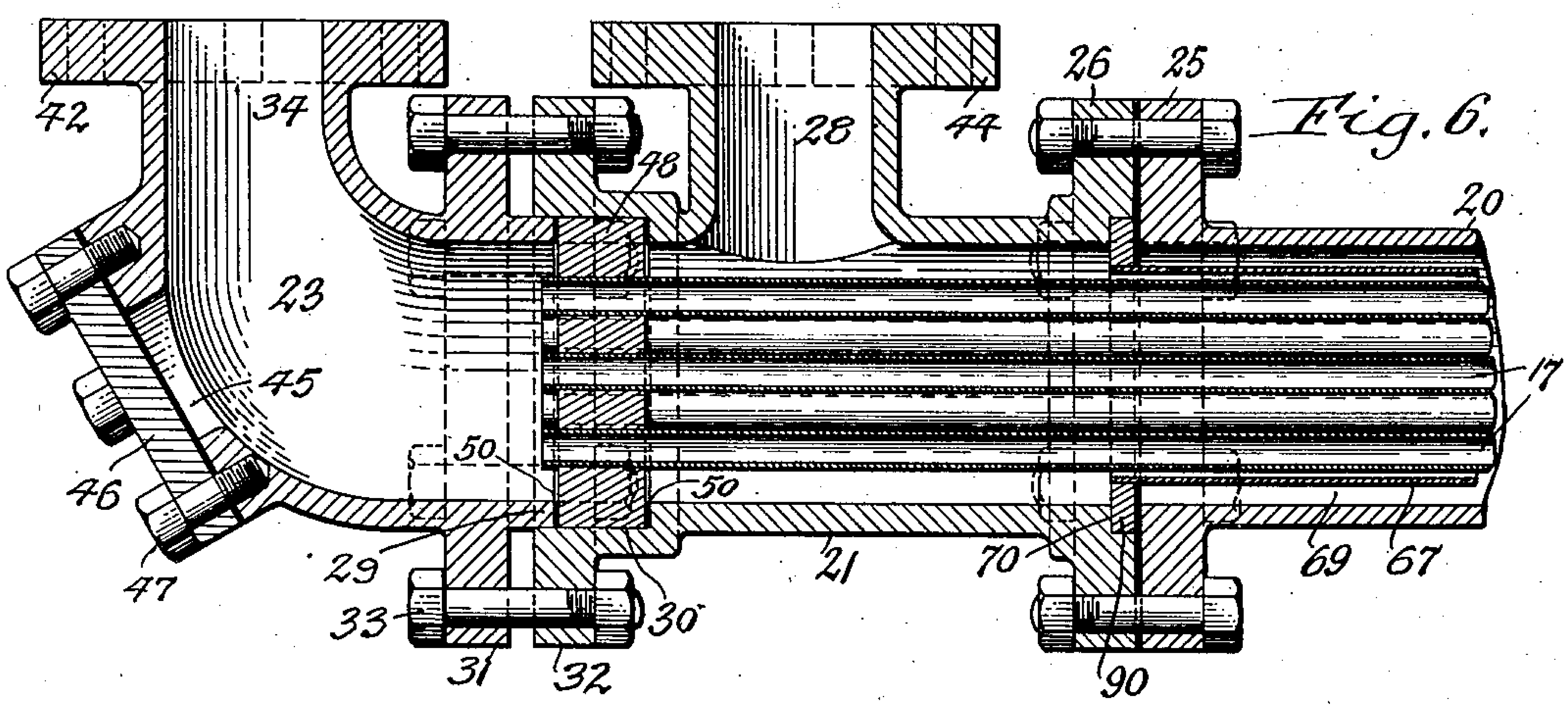
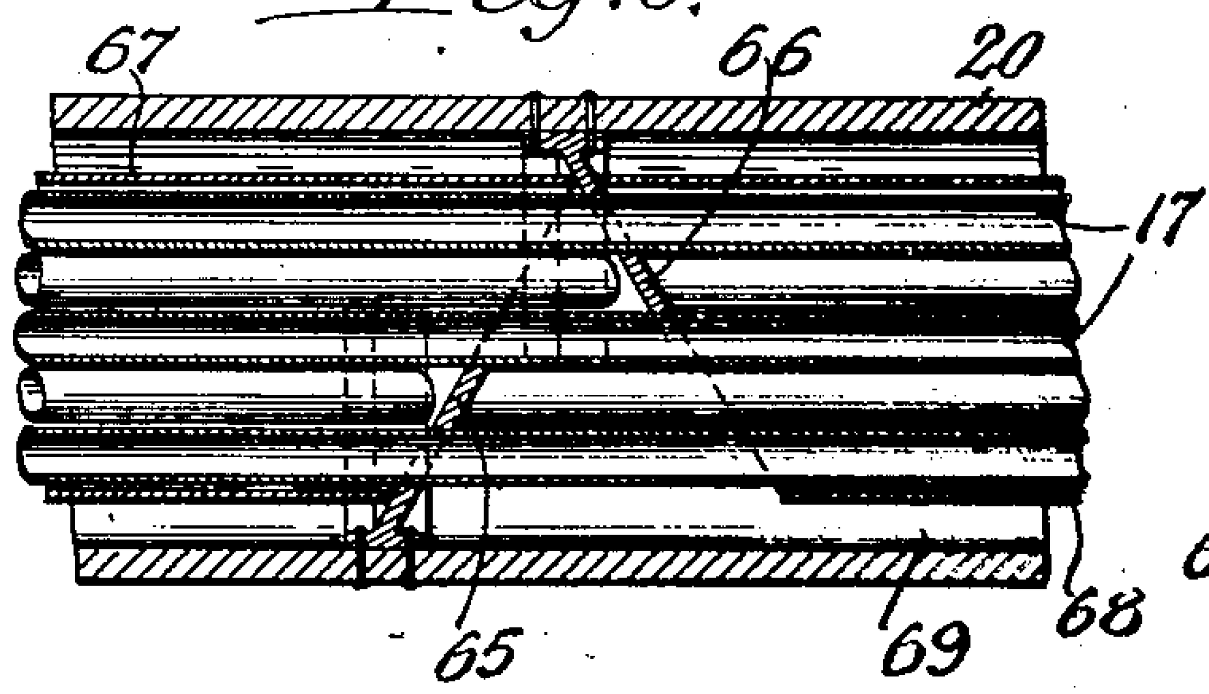
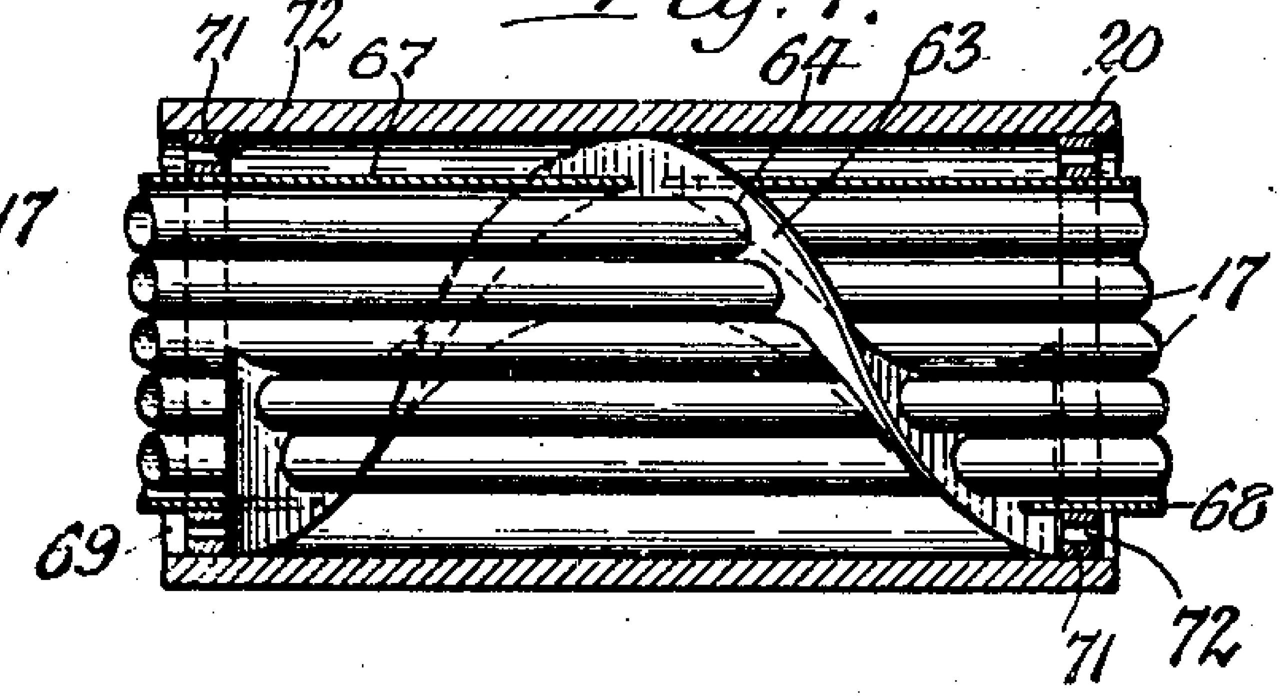
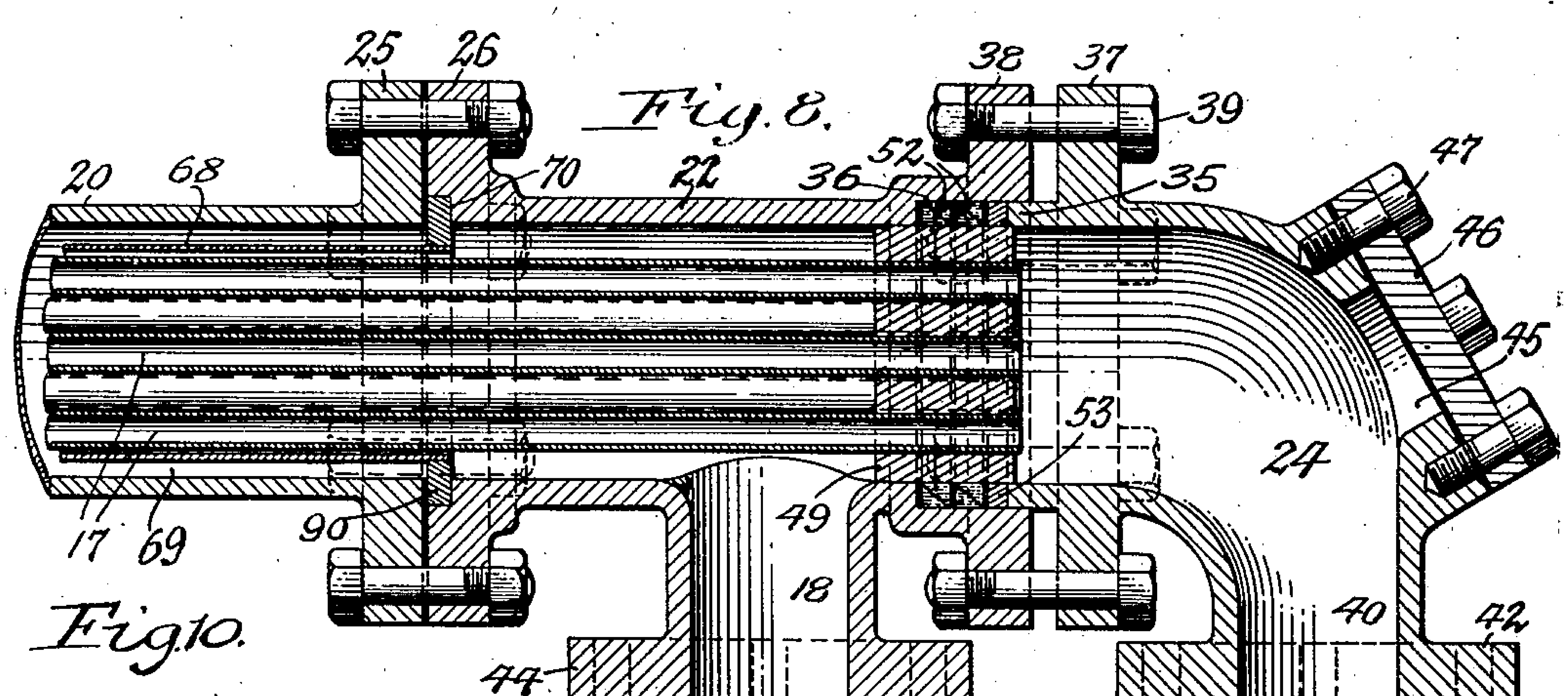
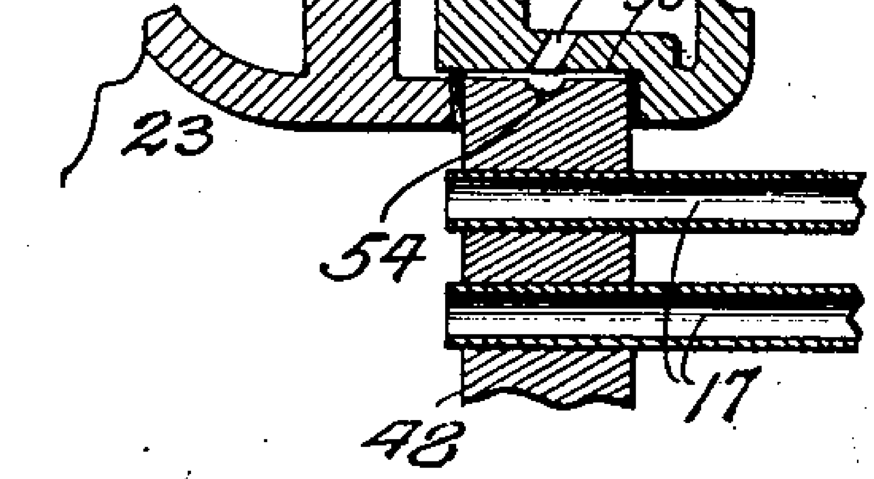
2 Sheets-Sheet 2

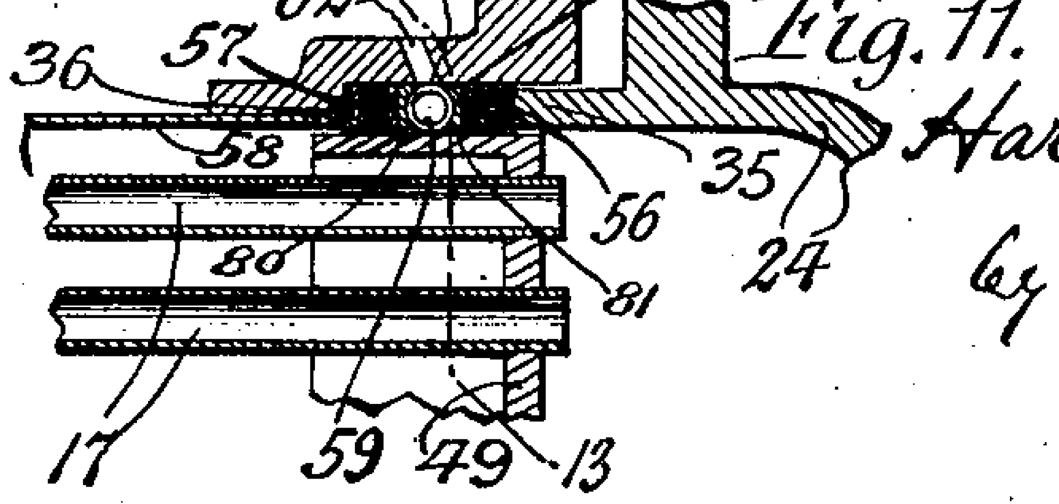












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UNITED STATES PATENT OFFICE

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HEAT EXCHANGER

Application filed February 29, 1928. Serial No. 257,830.

This invention relates to heat transfer apparatus of a tubular character whereby heat is transmitted from a vapor or steam to a cooler liquid, or the heat is transmitted from a hot liquid to a cooler liquid, one liquid flowing on the one side of the tubes and the other liquid or vapor flowing on the other side of the tubes.

The ordinary type of apparatus is designed with the requisite square feet of transmitting surface arranged in a single shell and the tubes and the heads being laid out so that the liquid flowing in the tubes makes several passes before finally emerging from the heater.

The reason for the multiple passes is to secure a total travel of tube length sufficient to heat or cool the liquid to the desired point.

One of the principal factors in the design of such apparatus is to keep the velocities of the liquids as high as possible or as high as commercially practical without too great an expense for pumping. The higher the velocity the greater the transfer of heat per unit of surface through the tubes.

For instance, when we obtain a heat transfer of say 220 degrees at a velocity of 2′ per second, we would obtain a heat transfer of approximately 500 degrees, if the speed is increased to 10′ per second. A good practical velocity is between 6′ and 8′ per second. On the above basis a heat transfer of approximately 400 degrees to 460 degrees would be obtained. This condition holds true not only with the speed of liquid but also with the speed of the steam or vapor over the tubes.

Such apparatus is used for several purposes; one is the transfer of heat from a hot liquid to a colder liquid in order to recover the heat from the hot liquid; another is the heating up of the liquid by means of vapor or steam for the purpose of heating the liquid; another is the heating of the liquid by means of vapor or steam in order to condense the vapor or steam.

The present heater is designed to provide a rapid circulation or a high velocity of the liquor both within the tubes and on the outside of the tubes.

In the ordinary type of apparatus provision is successfully made to insure a high velocity where the liquid is carried within the tubes, but where the liquid is circulated on the outside of the tubes the velocity is extremely low due to the wide spacing of the tubes, the large waste space in the large shells required, and the space between the tube banks in the heads to provide the return paths for the liquid.

Various means have been used to increase the velocity of the outside of the tubes or to direct the liquid across the tubes rather than axially or lengthwise thereof by means of baffles of sheet metal.

In some cases the inside of the shell has been filled with a sheet metal spiral running from one end to the other, with the flights closely pitched. The object of this spiral is to direct the liquid in a path at approximate right angles to the tubes, and provide a long glow path. None of these devices has succeeded in increasing the velocity of flow to the extent necessary for efficient heat transmission.

The present heater is so designed that the speed of the liquid in unit quantities is approximately the same on the outside of the tubes as it is on the inside of the tubes. This is effected by spacing the tubes very closely together and using very thick tube sheets in order to have the sheets strong enough to withstand the rolling action of the tube expander when the tubes are inserted and made tight, and the tube bundle is arranged in the form of a hexagon. Even this arrangement if used as described would still leave too much waste space to maintain the velocity at the proper point. In order to cut down this waste space, a tubular jacket or wall of hexagon shape is placed around the tube bundle.

The object of this invention is to obtain a greater heat transference for a given velocity and length of passages, also to provide for a unit construction which reduces the cost of manufacture and also permits of readily increasing the capacity of the apparatus where desired; and which permits vapors and liquids to flow with a stream line which encounters the minimum resistance and therefore effects a maximum exchange of heat for a given length of travel of the fluids which exchange heat.

In the accompanying drawings:—

Fig. 1 is a fragmentary side elevation of a heat exchanger embodying my invention.

Figs. 2 and 3 are cross sections on an enlarged scale taken on line 2—3, Fig. 1, Fig. 2 looking toward the left, and Fig. 3 toward the right of Fig. 1.

Fig. 4 is a vertical section, on an enlarged scale, taken on line 4—4, Fig. 1.

Fig. 5 is a fragmentary view showing the saddle for supporting the adjacent parts of two shells relatively to one another.

Fig. 6 is a fragmentary longitudinal section on an enlarged scale, of the left end portion of one of the units of the heat exchanger.

Fig. 7 is a similar view of the central part of this unit.

Fig. 8 is a similar view of the right end portion of this unit.

Fig. 9 is a view similar to Fig. 7 but showing a modified form of the baffle for supporting the tubes in the central part of the shell.

Figs. 10 and 11 are fragmentary longitudinal sections, showing modified forms of the joints between the tube sheets and the shell of the heat exchanger.

Fig. 12 is a vertical section taken on line 12—12, Fig. 5.

Fig. 13 is a fragmentary vertical section taken on line 13—13, Fig. 11.

Similar characters of reference indicate like parts in the several figures of the drawings:

The improvements in this heat exchanger are embodied in a single unit of the same which is so designed that a plurality of such units may be assembled for producing a heat exchanger of any desired capacity. In the preferred construction each of these units is provided with an outer tubular shell or enclosing casing consisting of a central section 20, two intermediate sections 21, 22 and two outer end sections 23, 24. The central section has preferably the form of a straight horizontal tube which is provided at its opposite ends with external coupling flanges 25. Each of the intermediate sections is provided with a straight body the inner end of which is provided with an external flange 26 which is connected by bolts 27 with the flanges 25 on the adjacent end of the central shell section, and between its ends each intermediate shell section is provided with an inner nozzle or branch, which nozzle on one intermediate section extends upwardly as shown at 28, and on the other intermediate section this nozzle extends downwardly as shown at 18 in the preferred manner of assembling the units. Each of the end sections of the shell is of elbow form and has its inner end arranged in line and connected with the outer end of one of the intermediate sections while its outer end is arranged at right angles to the inner end and forms a nozzle. The elbow shaped section 23 at the left end of the shell is provided on its inner end with a gland 29 which engages with the outer end of a rabbet 30 on the outer end of the intermediate section 21, the opposing ends of these sections being provided with external flanges, 31, 32 which are connected by bolts 33. The outer end of the left section 23 forms an outer nozzle 34 which in the present case is turned upwardly. The other end section 24 has its inner end provided with a gland 35 which engages with a rabbet 36 on the outer end of the right intermediate section 22, the opposing ends of these sections being provided with external flanges 37, 38 which are connected by bolts 39. The outer end of the right section 24 forms an outer nozzle 40 which in this case projects downwardly.

In assembling the shells of a plurality of such units these units are preferably placed one above the other to form a vertical tier but alternate units are reversed so that the downwardly turned inner and outer nozzles at one end of one unit will register with the upwardly turned inner and outer nozzles of the other unit and the corresponding nozzles of the two adjacent units communicate with each other. The shells of adjacent units are connected by bolts 41 passing through the flanges 42 on the corresponding outer nozzles and bolts 43 passing through flanges 44 on the corresponding inner nozzles of the shells, as shown in Fig. 1.

On the outer side of each end shell section the same is provided with a hole or opening 45 for inspection, cleaning or repairing, which is normally closed by a cover or plate 46 removably secured thereto by screws 47 or other suitable means.

Arranged lengthwise in the central and intermediate sections of the shell is a bundle or group of tubes, pipes or flues 17 which are spaced apart from each other and also from the walls of the shell sections containing them and which communicate at their opposite ends with the chambers formed within the elbow shaped end sections of the shell. The most compact arrangement of the bundle of tubes which still leaves a clearance between them is best obtained by arranging each tube opposite the space between two opposing tubes so that as a whole the tubes are staggered relatively to each other and the bundle as a whole is substantially hexagonal in cross section while the bore of the shell section is cylindrical in cross section. These tubes are made of comparatively heavy stock and the opposite ends of the same pass through openings in transverse tube sheets 48, 49 which latter are made of comparatively thick stock so as to permit of securing the tubes therein and forming a tight joint therewith by expanding the ends of the tubes. One of these tube sheets is fixedly mounted on the shell and the other is mounted on the shell so as to be slidable or floating lengthwise thereon to thereby permit the tubes and shell to expand and contract independently of each other in response to variations in temperature without liability of straining, breaking or injuring any parts. In the preferred construction this is accomplished by extending the marginal part of the tube sheet 48 into the rabbet 30 and clamping the same between the bottom of this rabbet and the gland 29 so as to hold this tube sheet against movement. If desired packing rings or gaskets 50 may be arranged between the tube sheet and the rabbet 30 and gland 29 so as to form a fluid tight joint between the same. The other tube sheet 49 is free to slide lengthwise by engaging its periphery with a packing arranged in the other rabbet 36 of the shell which packing may consist of a plurality of packing rings 52 and a follower ring 53 arranged in the rabbet 36 between the bottom thereof and the gland 35, thereby forming a stuffing box which provides a leak tight joint between the tube sheet 49 and the shell and still permitting this sheet to slide in the shell.

If desired the joints between the tube sheets and the shell may be so constructed that any leakage which may occur in these joints will be conducted to the exterior of the apparatus where it will be visible to attendants and thus lead to prompt adjustment of the packings in these joints which will prevent further leakage. Means suitable for this purpose are shown in Figures 10 and 11. In Fig. 10 the periphery of the fixed tube sheet 48 is provided with an annular leakage groove 54 and the adjacent part of the rabbet 30 is provided with a vent opening 55 leading to the atmosphere. If any leakage should occur in the joint between the tube sheet 48 which would permit fluid to pass from the elbow section to the groove 54 such leakage would find its way through the vent opening 55 to the exterior when the same would be detected, and similarly any leakage of fluid from the space around the tubes to the groove 54 would be likewise conducted by the opening 55 to the exterior and consequently observed. As shown in Figs. 11 and 13, any leakage past the packing between the sliding tube sheet 49 from either side of the tube sheet escapes to the exterior of the shell through the vent opening 62, the packing being designed to permit such leakage. This packing comprises two packing rings or gaskets 56 and 57 embracing the periphery of the tube sheet and engaging the bottom and shoulder of the rabbet 36 and the end of the gland 35. Between these packing rings is arranged a pair of follower rings 80, 81 and between these follower rings is arranged an openwork ring 59 having preferably the form of a coil of wire. The openwork ring 59 is arranged opposite the vent opening 62 in the shell. Any leakage past either of the packing rings 56, 57, to the openwork ring 59 will therefore be conducted to the vent opening 62, leading to the outer atmosphere. The structure shown in Fig. 11 also shows the body 58 of the shell made of drawn tubing instead of cast metal. These leak detecting means also prevent the passage of any fluid from one side of either tube sheet to the other inasmuch as such leakage is carried to the exterior, thereby preventing mixing of the fluids on the inner and outer sides of the tubes which is very important, particularly when contamination of one of these fluids by the other must be avoided.

In using this apparatus for exchanging heat between one fluid and another, one of these fluids is passed through the inside of the tubes in one direction and the other fluid is passed through the shell on the outer side of the tubes in the opposite direction, whereby the temperature of one fluid is raised and the other lowered, assuming that the fluids were of unlike temperatures before passing through this apparatus.

When using this apparatus for raising the temperature of cold oil by means of hot oil which has just been heated during the process of treating of the same it will be assumed that the cold oil enters through the outer, upper nozzle 34 at the left side of the upper unit and that the hot oil is admitted through the lower inner nozzle 44 at the left end of the lower unit shown in Fig. 1. In such a case the cold oil would first pass from the left to the right end of the tubes in the upper unit, thence through the elbows of both units at the right ends thereof, thence through the tubes in the lower unit from the right to the left ends thereof, and thence out through the outer nozzle 40 of the left elbow of the lower unit to another unit, if the process is continued, or to some other piping or vessel if the process is completed, the number of units employed depending on the number of passes required for finishing a particular product. At the same time the hot oil enters through the inner lower nozzle 44 at the left end of the lower unit, thence through the lower shell around the tubes in the lower unit, from the left to the right end thereof, thence through the inner nozzles at the right ends of the units, thence through the shell of the upper unit and around the tubes therein from the right to the left end thereof, and thence out through the inner upper nozzle 28 at the left end of the upper unit.

The fluid by these means is caused to flow in steady stream lines through the shell and tubes, without meeting with any obstruction which would cause a sudden deflection or change of course in the direction of flow of the fluid, this being due to the fact that the elbows and nozzles at the ends of the units cause the fluid to be gradually reversed in its flow, thereby avoiding undue checking of the flow of fluid and maintaining the capacity of the heat exchanger accordingly.

One of the distinguishing features of this heat exchanger is its small diameter and extraordinary length.

In order to prevent the tubes from sagging midway of their length and possibly engaging with each other when they are of considerable length and thereby reducing the efficiency of the apparatus means are provided which will support the tubes between their ends without however interfering with the flow of the fluid through the shell. As shown in Figs. 2, 3, and 7 these means consist of a helical web 63 of metal which bears with its outer edge against the central part of the bore of the central shell section and provided with a plurality of openings 64 through which the tubes pass and are thereby supported on the shell and also maintained in the proper space position relatively to each other so as to secure the maximum heat exchange effect without obstructing the passage of the fluid through the shell. Substantially the same effect is obtained by means of two brackets 65, 66 secured to the top and bottom of the central shell section but spaced apart and provided with openings for the reception of the tubes the said brackets being supported on the shell and maintained in spaced relation.

If the flow of the fluid through the shell is constantly in the same direction, these brackets may be inclined in the same direction in which the stream of fluid flows, as shown in Fig. 9, inasmuch as such inclination avoids any appreciable interference with the flow of the stream of fluid. When however the flow of the stream may occur in either direction through the shell these brackets are arranged at right angles to the axis of the shell so as to have the same baffling effect on the stream both ways.

A cylindrical form in cross section of the central and intermediate sections of the shell is the most desirable and economical on account of the greater ease and facility with which the same can be made. This form of the central and intermediate sections of the shell, however, leaves too much space between the bore of these shell sections and the periphery of the bundle of tubes to permit of maintaining a sufficiently high velocity of the fluid to secure the desired capacity. Means are therefore, provided for reducing the effective space within the shell around the tubes and bringing it into substantial conformity to the cross sectional form of the bundle of tubes. These means preferably comprise a tubular inner wall or jacket consisting of two sections 67, 68 each of which is of hexagonal form in cross section and surrounds the bundle of tubes between the central tube support and one end of the central shell section so as to form an annular dead space 69 between the periphery of each inner wall section and the adjacent part of the bore of the central shell section. At its outer end each of those inner walls is secured to a supporting ring 90 which is unprovided with openings in its rim and is seated in an annular rabbet 70 formed in the inner end of the respective intermediate shell section and clamped between the same and the adjacent ends of the central section. Adjacent to its inner end, each inner wall section is supported on the central shell section by a supporting ring 71 interposed between the periphery of this inner wall section and the bore of the central shell section. This ring is provided with a plurality of openings 72 so that fluid may enter the dead space 69 and thereby balance the pressure on the opposite sides of the contracting wall section. By making the rings 90 solid or unprovided with openings in its rim the fluid cannot flow through the dead spaces 69 but any fluid entering the same remains dormant therein. The inner ends of the two sections of the inner wall sections preferably engage against opposite sides of the helical tube supporting web, as shown in Fig. 7, thereby holding this support against lengthwise movement in the shell under the pressure of the stream of fluid without requiring the support to be fastened to the shell.

Means are provided whereby these ends of adjacent shells which are not in communication with each other are supported one upon another and maintained in spaced relation and still are free to slide lengthwise one relative to another. This is preferably accomplished by a saddle 73 interposed between the disconnected ends of two adjacent shell units which is provided at its upper end with a jaw 74 embracing the adjacent opposing flanges on the shell sections of the upper unit and a shoe 75 at its lower ends which is capable of sliding on the adjacent opposing flanges on the shell sections of the lower unit, as shown in Figs. 1, 5, and 12. It follows from this form of saddle that the disconnected ends of the shells of superposed units are free to move lengthwise independently of each other due to variations in temperature without rupturing any of the parts.

By cutting down the waste space in this heat exchanger, a very high velocity of the fluid through the space outside of the tubes is obtained and a corresponding increase in capacity. This velocity is not appreciably affected by the helical support for the tubes because it offers but little resistance to the flow.

The fact that the elbow shaped outer sections and the T-shaped intermediate sections at opposite ends of each unit are identical in construction reduces the cost of manufacture, permits replacement without difficulty; reduces the number of spare parts which have to be carried in stock, and also permits extension or enlargements of the heat exchanger to be made later on easily, readily and without disturbing or discarding any of the parts already installed.

Instead of operating this heat exchanger on the counter current principle previously described the same may also be operated by running the two fluid paths within and without the tubes in parallel.

It is also possible to run the apparatus so that one of the fluid paths of the several units may flow in parallel and the other fluid paths of the several units may be run in series. Other combinations are possible to suit the requirements of a particular installation.

In the heating of a liquid by vapor, the liquid would enter the circuit as described above for the inside of the tubes, while the vapor would enter the upper left hand inner nozzle and the condensate would leave from the lower left hand nozzle; however, this arrangement of vapor circulation is not essential as the vapors could be taken into each unit separately. The inner nozzle of the shells of adjacent units could also be separated and the lower T turned to the side to take the vapor while the condensate leaves each unit independently.

Owing to the manner of mounting the tube sheets in the shell those sheets cannot tilt and therefore, the tubes are always maintained in their proper position.

I claim as my invention:—

1. A heat exchanger comprising an outer shell provided at each end with an outer nozzle and an inner nozzle, one of which forms an inlet and the other an outlet, tube sheets arranged within the shell and each extending across the space therein between the outer and inner nozzle at one end thereof, tubes arranged in the shell and mounted at opposite ends on said tube sheets so as to communicate with said outer nozzles, a wall in the space within the shell between the inner nozzles thereof and around the adjacent parts of the tubes, and forming a dead space between said walls and the shell, and means for supporting said wall on said shell having passages which establish communication between the spaces on opposite sides of said wall, comprising a ring surrounding each end of said wall and engaging the inside of said shell, one of said rings being provided with openings.

2. A heat exchanger comprising an outer shell having an inner and an outer nozzle at each end, a tube sheet within the shell at each end between the respective inner and outer nozzles, tubes arranged lengthwise in the shell and supported at opposite ends on the tube sheets and communicating with said outer nozzles, a support for said tubes between the ends thereof, and an inner wall consisting of sections arranged within the shell around the tubes and abutting against said support.

3. A heat exchanger comprising an outer shell having an inner and an outer nozzle at each end, a tube sheet within the shell at each end between the respective inner and outer nozzles, tubes arranged lengthwise in the shell and supported at opposite ends on the tube sheets and communicating with said outer nozzles, a support for said tubes between the ends thereof, an inner wall consisting of sections arranged within the shell around the tubes and abutting against said support, said support having parts arranged at an angle to the axis of the shell.

4. A heat exchanger comprising an outer shell having an inner and an outer nozzle at each end, a tube sheet within the shell at each end between the respective inner and outer nozzles, tubes arranged lengthwise in the shell and supported at opposite ends on the tube sheets and communicating with said outer nozzles, a support for said tubes between the ends thereof, and an inner wall consisting of sections arranged within the shell around the tubes and abutting against said support, said support having the form of a helical web and provided with openings through which said tubes pass.

5. A heat exchanger comprising an outer shell having an inner and an outer nozzle at each end, a tube sheet within the shell at each end between the respective inner and outer nozzles, tubes arranged lengthwise in the shell and supported at opposite ends on the tube sheets and communicating with said outer nozzles, a support for said tubes between the ends thereof, an inner wall consisting of sections arranged within the shell around the tubes and abutting against said support, and rings supporting said wall sections on the inner side of said shell.

6. A heat exchanger comprising a shell having a tubular central section, two intermediate sections arranged at opposite ends of the central section and each having an inner nozzle, and two outer sections arranged at the outer ends of said intermediate sections and each having an outer nozzle, tube sheets arranged in the shell adjacent to the joints between said outer and intermediate shell sections, tubes arranged within the shell and mounted on said sheets, a tubular inner wall arranged within the shell and around said tubes, and supporting rings which carry said inner walls and which are secured in the joints between the outer ends of said central shell section and the inner ends of said intermediate shell sections.

7. A heat exchanger comprising a plurality of shells each of which is provided at its opposite ends with outer nozzles which project from opposite sides of the shell and with inner nozzles which project in opposite directions from the shell, the outer and inner nozzles at the corresponding ends of two shells communicating with each other, tube sheets arranged in each shell between the inner and outer nozzles thereof, tubes arranged in each shell and mounted at opposite ends on the sheets therein, said shells being provided, adjacent to their ends, with peripheral flanges, and a saddle which is interposed between the opposite disconnected ends of adjacent shells and which interlocks at one edge with the flanges of one shell and slides on the flanges of the other shell.

8. A heat exchanger comprising a plurality of shells each composed of a central section, intermediate sections secured to the ends of said central section and having laterally extending nozzles and elbows secured to the ends of said intermediate sections, the elbow and nozzle at one end of each shell projecting in the opposite direction from the nozzle and elbow at the opposite end of said shell and all substantially an equal distance from the center of the shell, means for connecting the nozzles at the corresponding ends of the shells, means for connecting the adjacent elbows of the shells, tube sheets arranged in the shells between said nozzles and elbows, at least one of said tube sheets being held in place in the joint between the elbow and the intermediate section at the corresponding end of the shell, and tubes arranged in said shells and mounted at their ends in said tube sheets.

9. A heat exchanger comprising a plurality of shells each of which is provided at its opposite ends with outer nozzles which project from opposite sides of said shell and with inner nozzles which project in opposite directions from said shell, the outer and inner nozzles at the corresponding ends of two shells communicating with each other, tube sheets arranged in each shell between the inner and outer nozzles thereof, tubes arranged in each shell and mounted at opposite ends in the sheets therein, a saddle which is interposed between the opposite disconnected ends of adjacent shells and means for removably connecting said saddle with each shell.

10. A heat exchanger comprising a shell having an inner and an outer nozzle at each end, a tube sheet arranged at each end of the shell and fitted with its periphery adjacent the bore of said shell, tubes arranged in said shell and mounted on the tube sheets and communicating with the outer nozzles, said shell being provided with at least one vent passage leading from the joint between at least one tube sheet and shell to the atmosphere and a packing at said joint comprising a central annular open work ring and annular packings on opposite sides of said ring and embracing the tube sheet.

11. A heat exchanger comprising a shell having an inner and an outer nozzle at each end, a tube sheet arranged at each end of the shell and fitted with its periphery adjacent the bore of said shell, one of said tube sheets being fixed and the other slidable longitudinally in said bore, said shell being provided with an internal rabbet around said slidable tube sheet, tubes arranged in said shell and mounted on said tube sheets and communicating with the outer nozzles, said shell being provided with a vent passage leading from said rabbet to the atmosphere, said rabbet also containing a packing comprising a central annular helical spring, a metal ring on each side of said spring, and packing rings on the outer sides of said metal rings, the elements forming said packing embracing said slidable tube sheet and preventing leakage thereby.

In testimony whereof I affix my signature.

HARLAN W. HOW.