March 22, 1932. W. D. LA MONT 1,850,281

HEAT EXCHANGE APPARATUS

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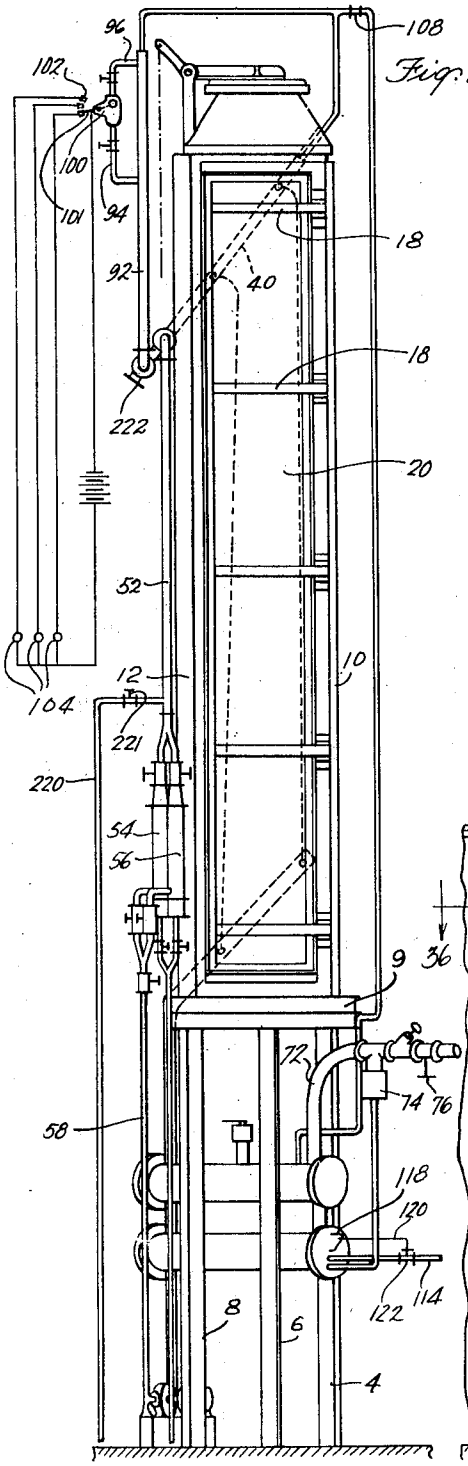


Fig. 2.

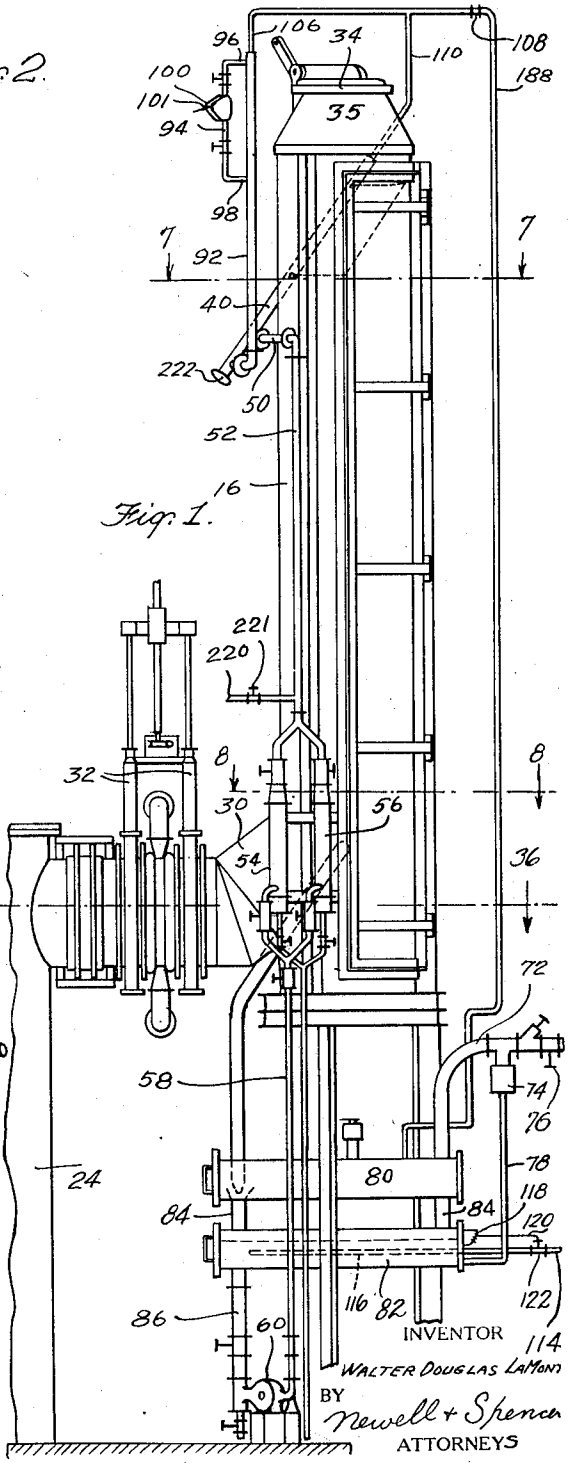


Fig. 1.

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WALTER DOUGLAS LAMONT
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HEAT EXCHANGE APPARATUS

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Fig. 3.

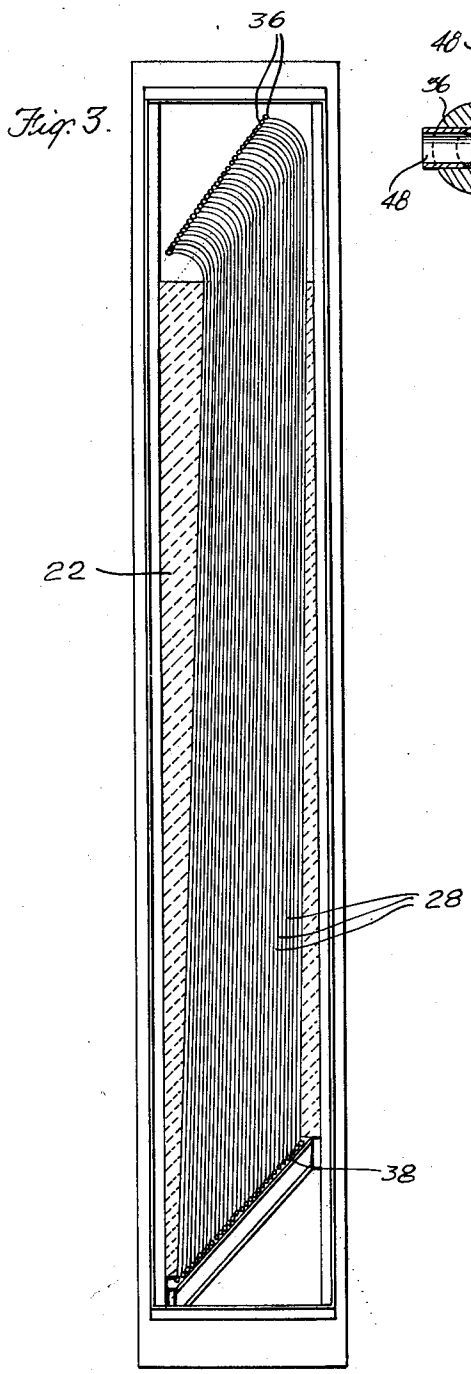
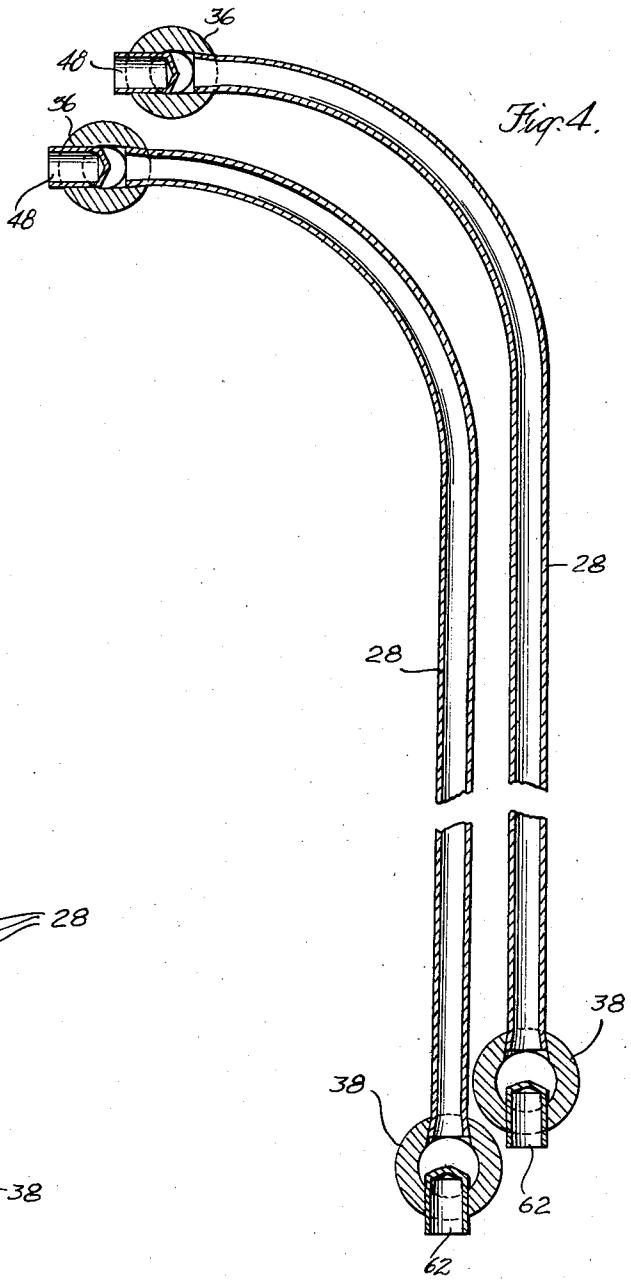


Fig. 4.



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Fig. 6.

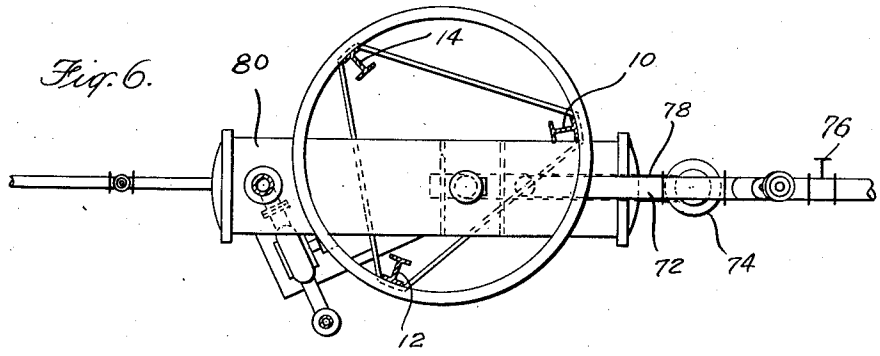


Fig. 26

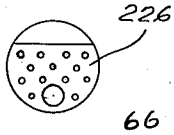


Fig. 27.

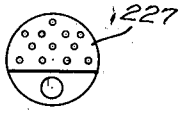


Fig. 5.

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HEAT EXCHANGE APPARATUS

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Fig. 7.

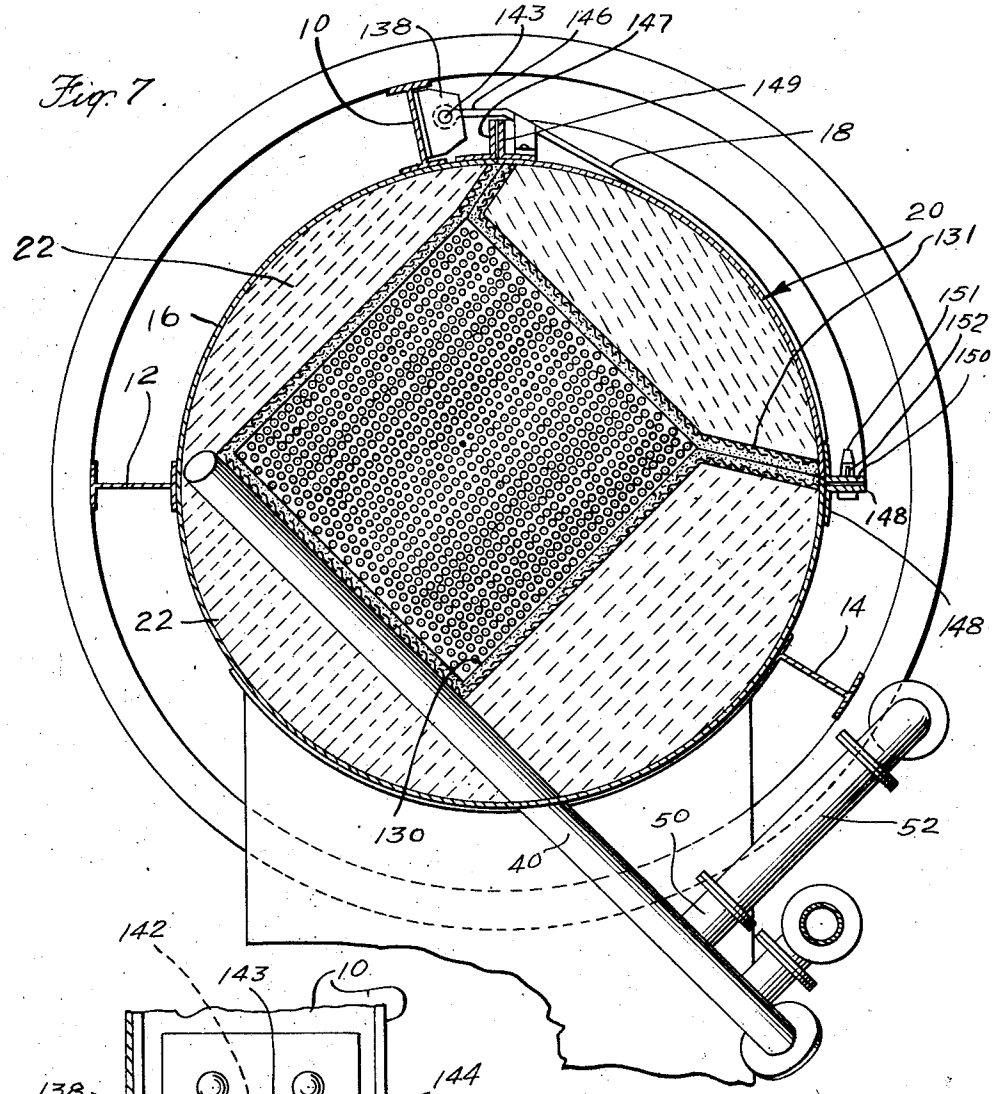
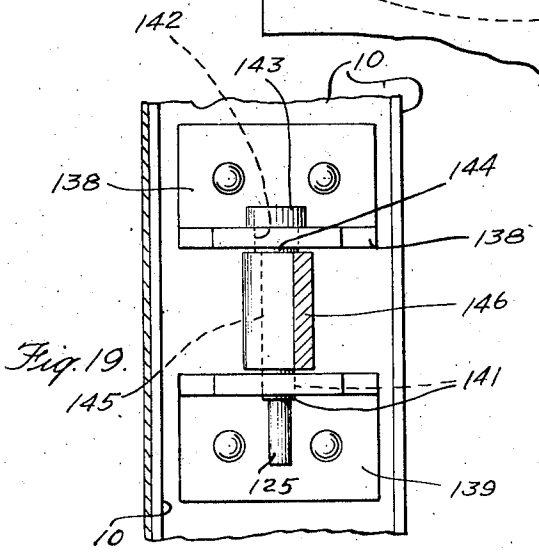


Fig. 19.



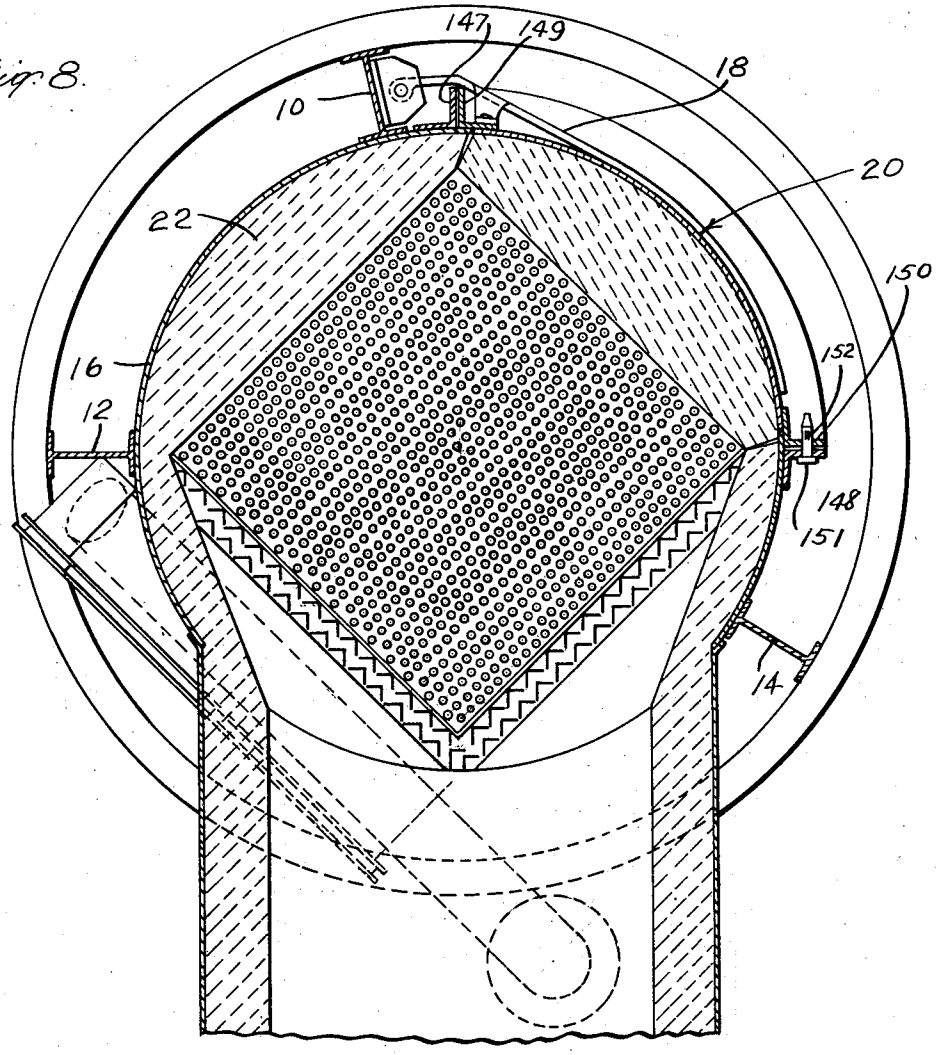
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Fig. 8.



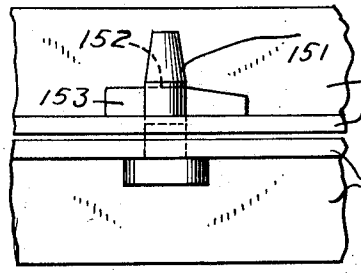


Fig. 9.

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Fig. 10.

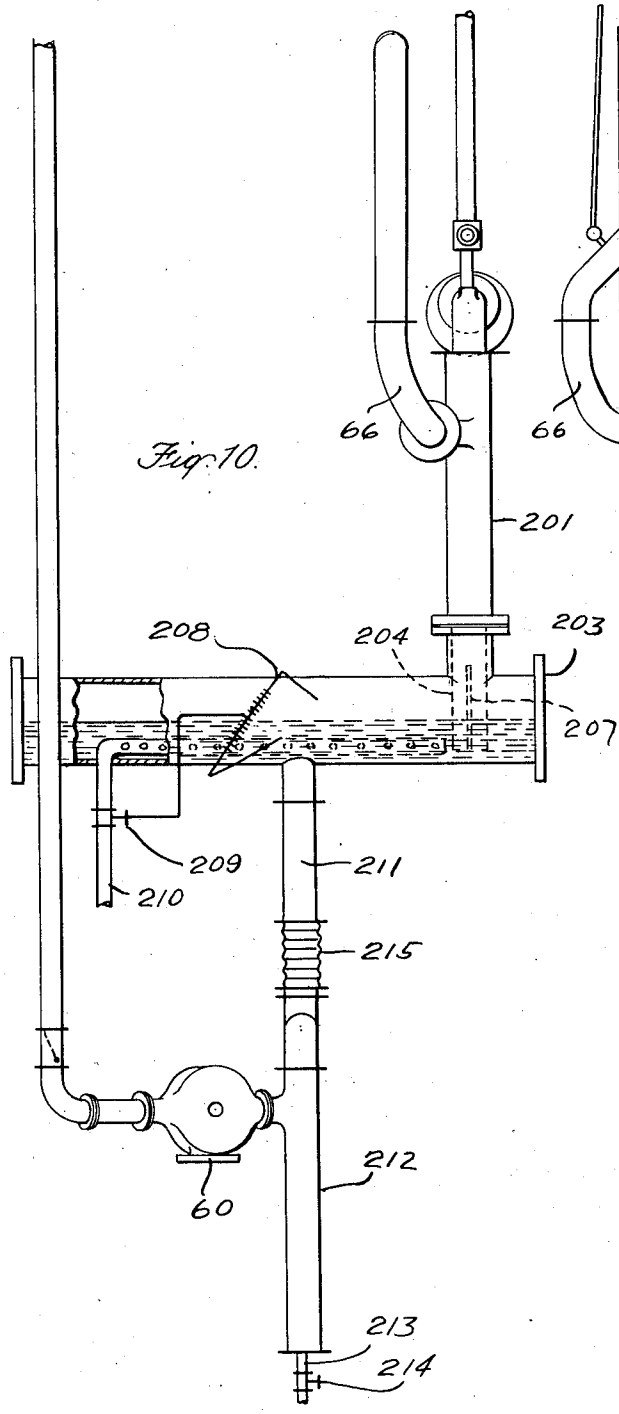
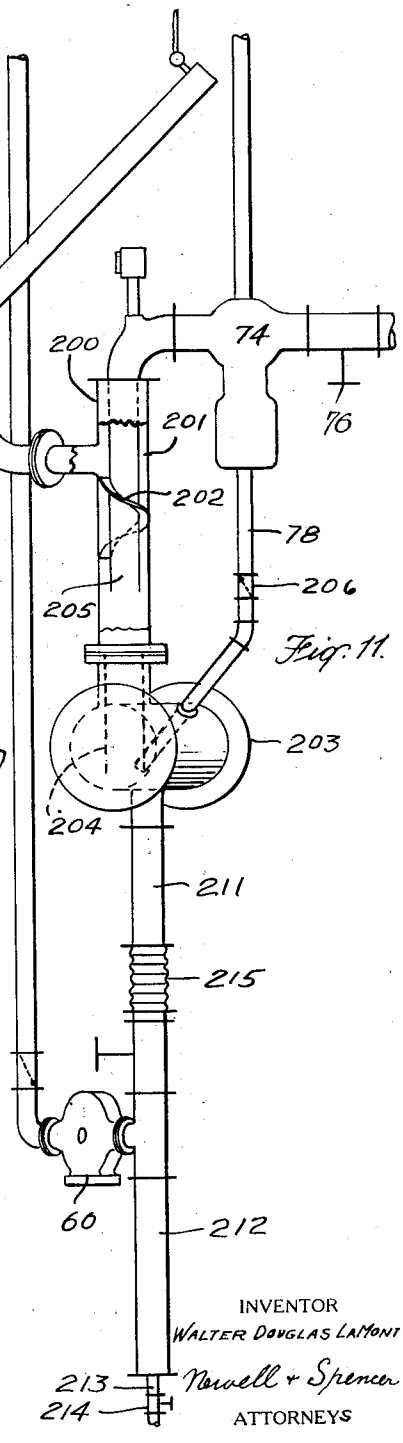


Fig. 11.



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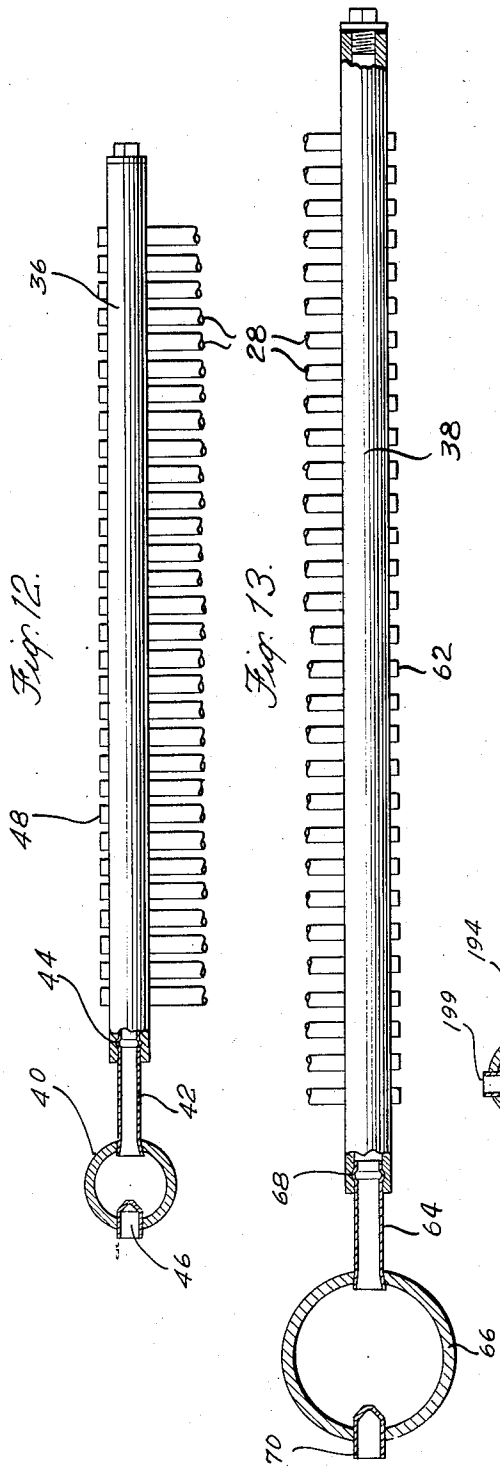


Fig. 12.

Fig. 13.

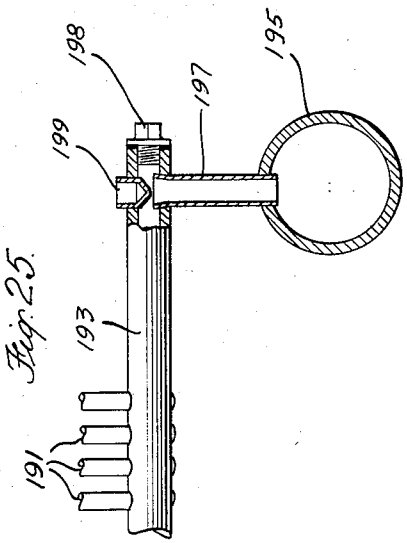


Fig. 25.

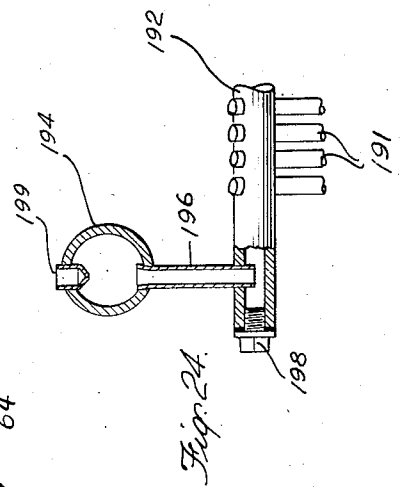


Fig. 24.

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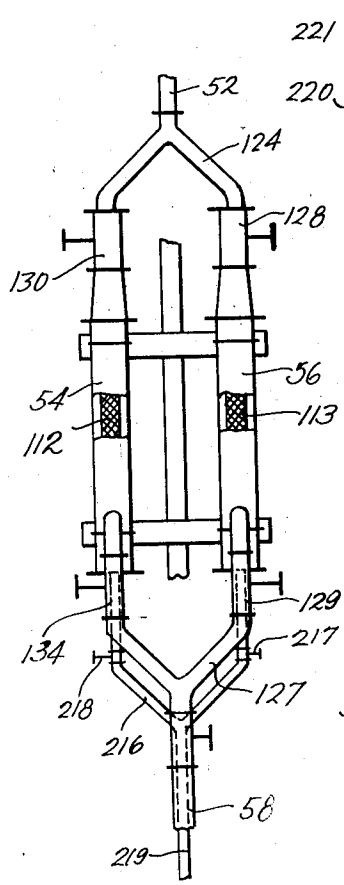


Fig. 14

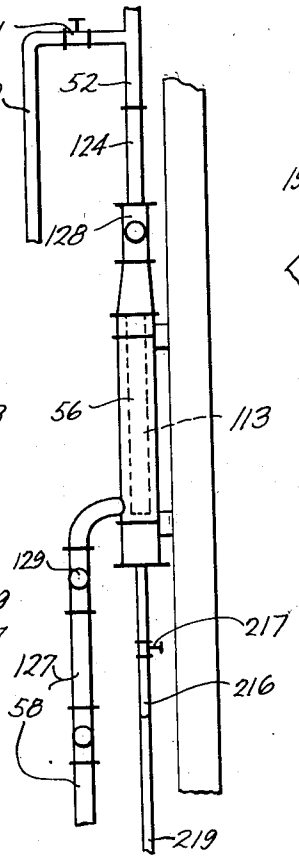
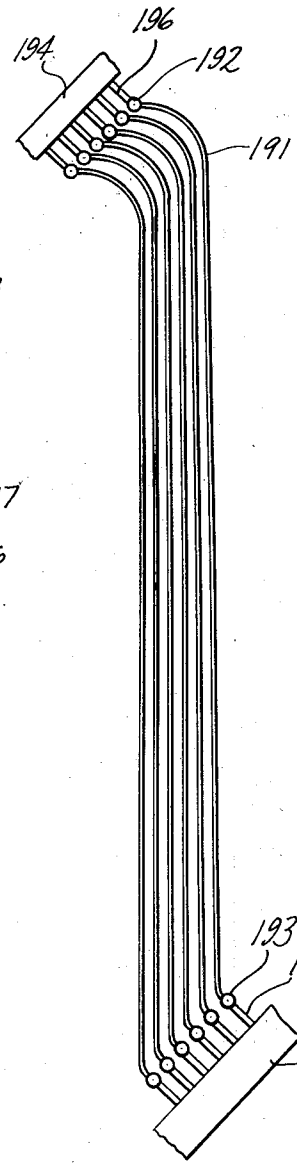


Fig. 15

Fig. 23.



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Fig. 16.

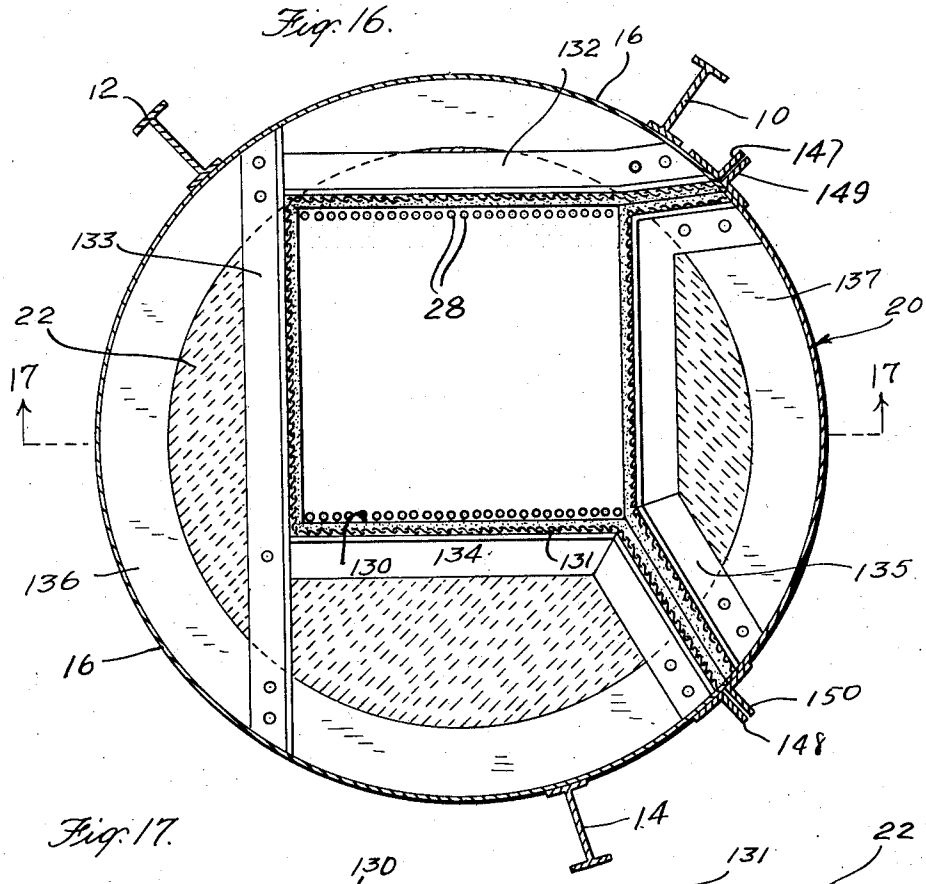
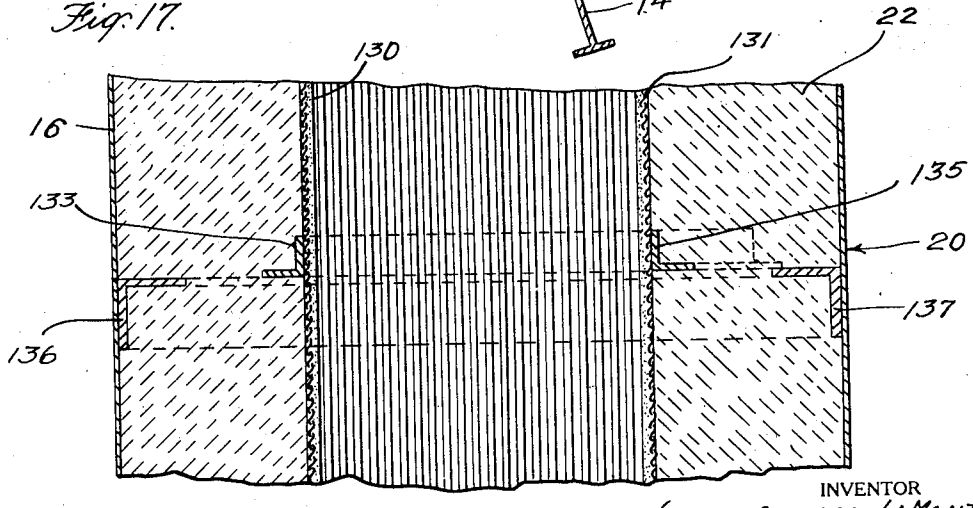


Fig. 17.



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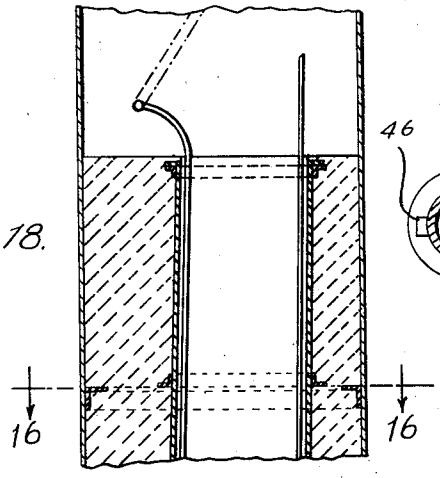
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Fig. 18.



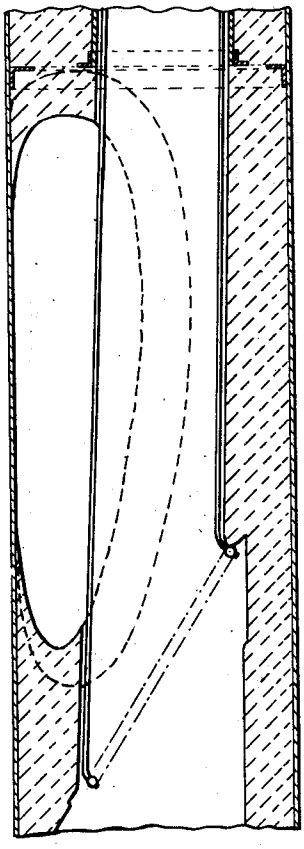


Fig. 20.

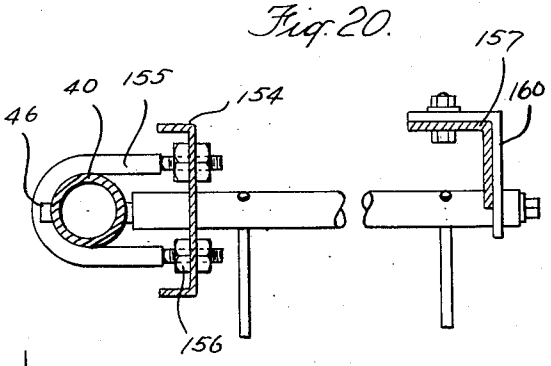
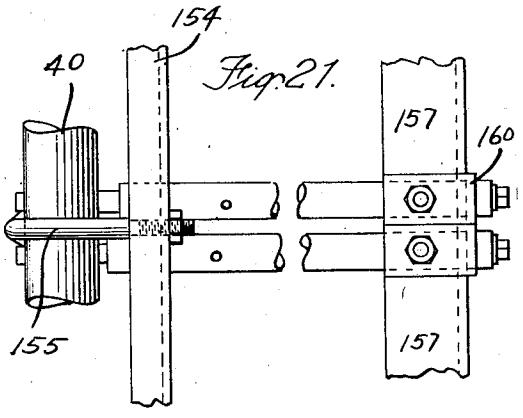


Fig. 21.



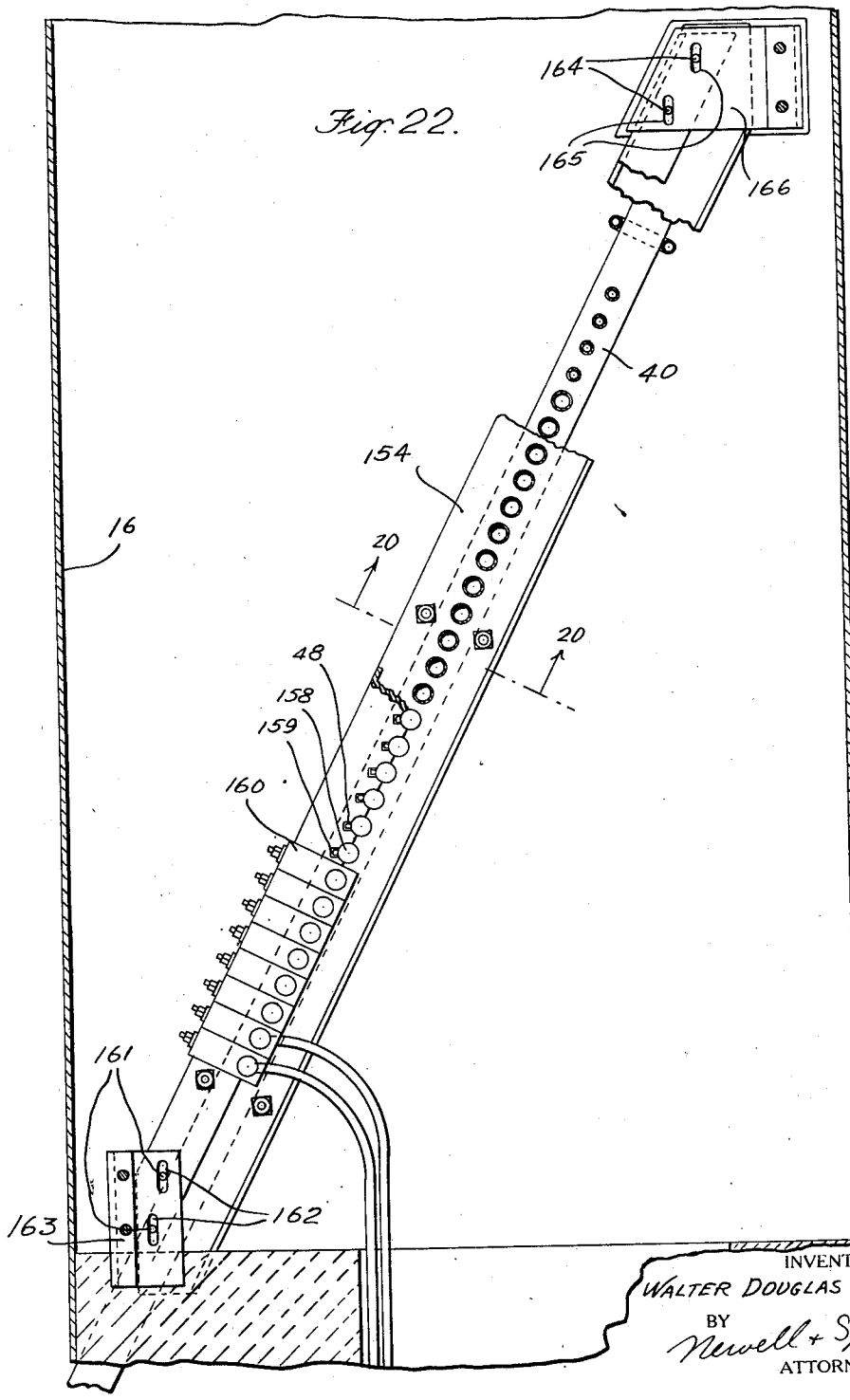
INVENTOR
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Fig. 22.



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Fig. 28.

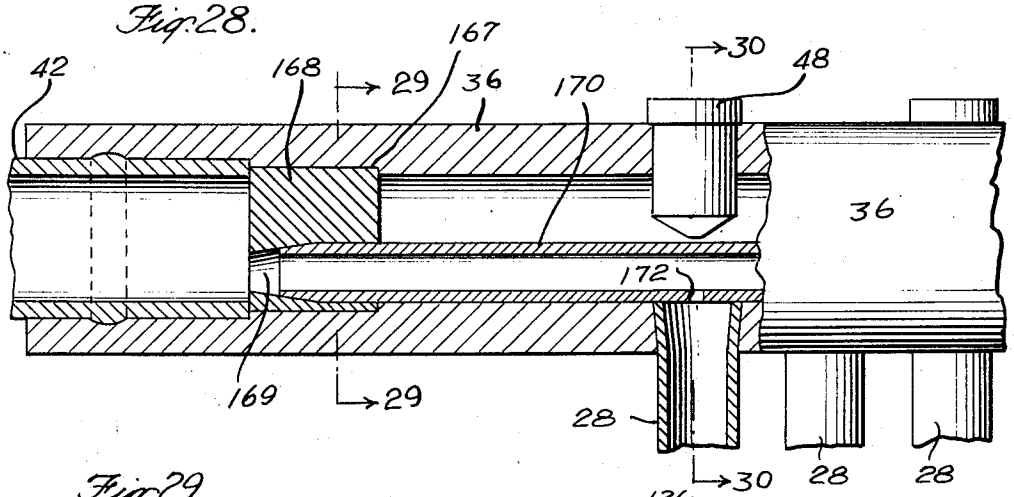


Fig. 29

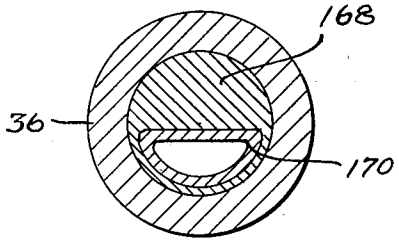
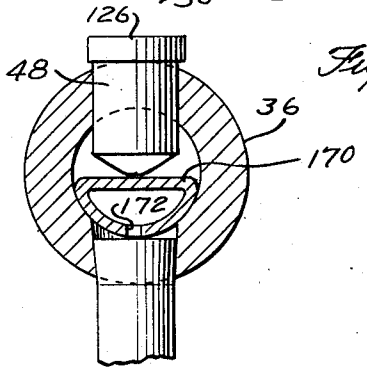


Fig. 30.



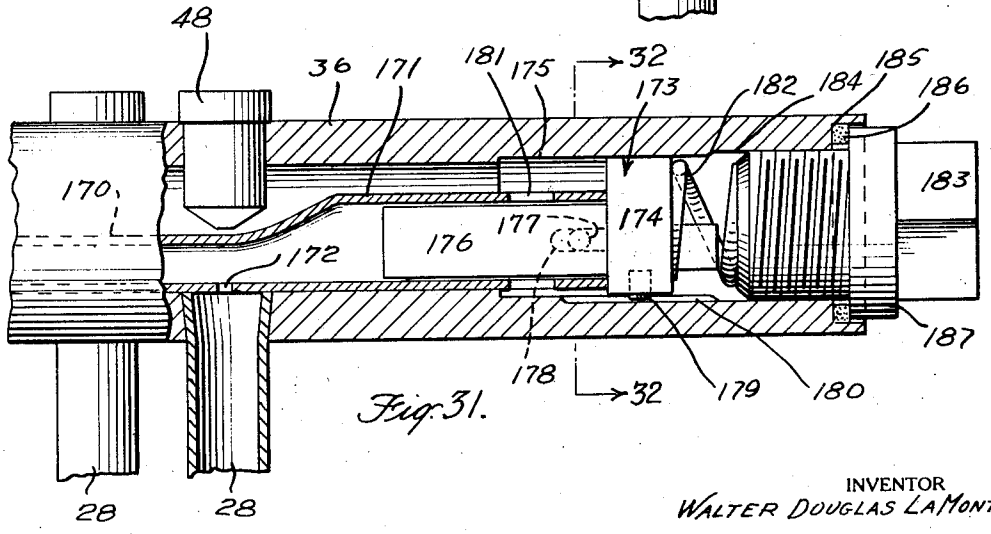


Fig. 31.

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Fig. 32.

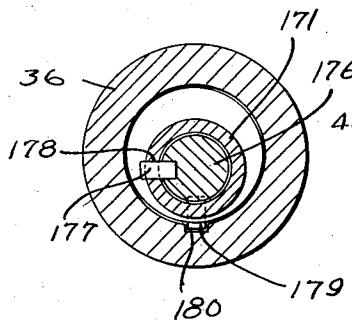


Fig. 33.

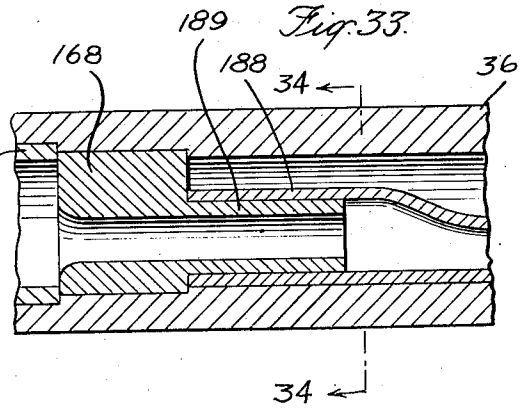


Fig. 34.

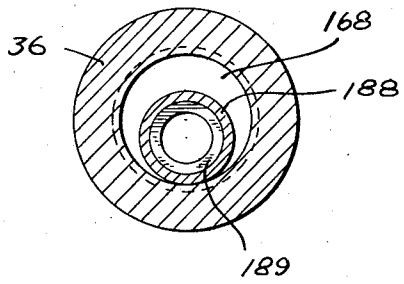
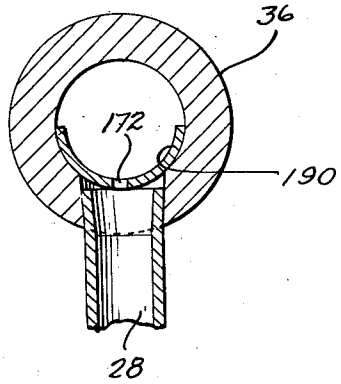


Fig. 35.



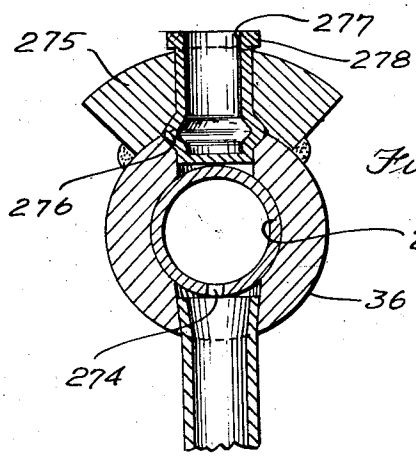


Fig. 43.

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Fig. 36.

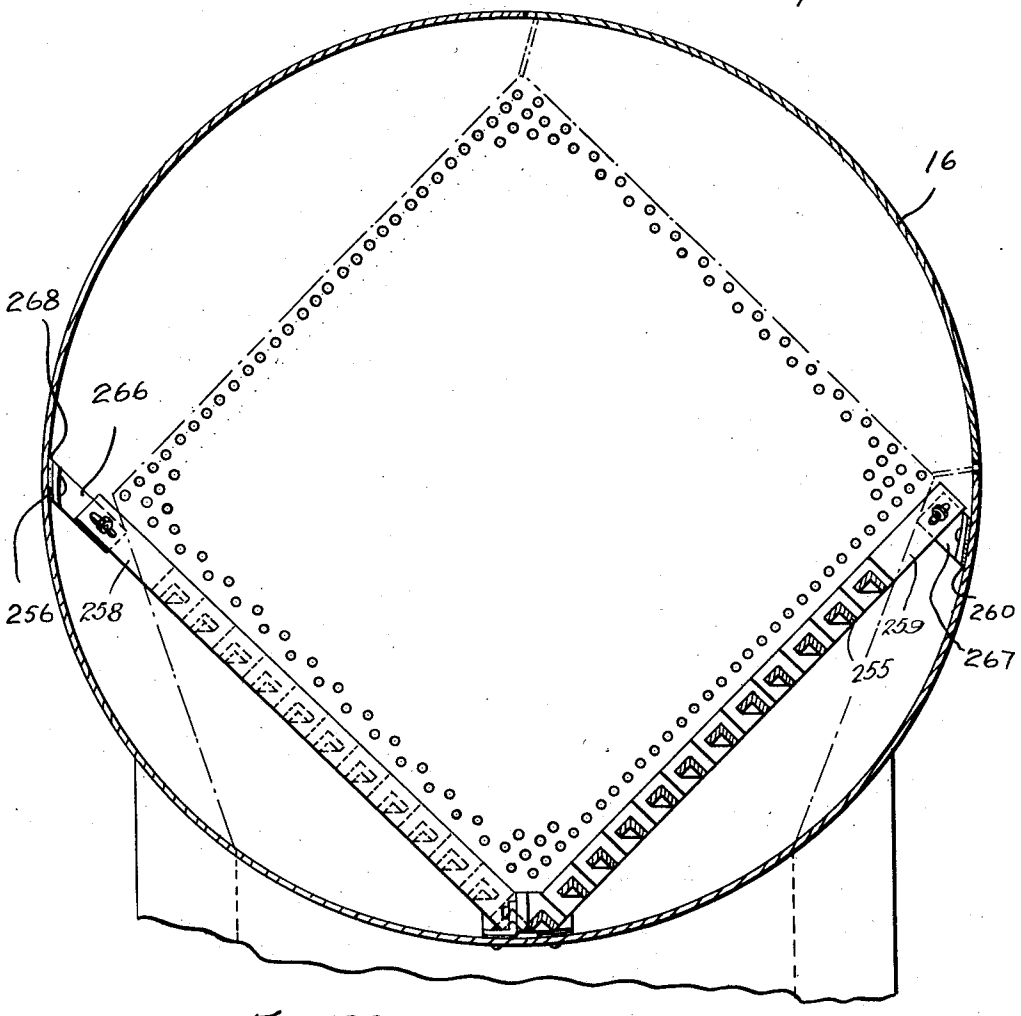
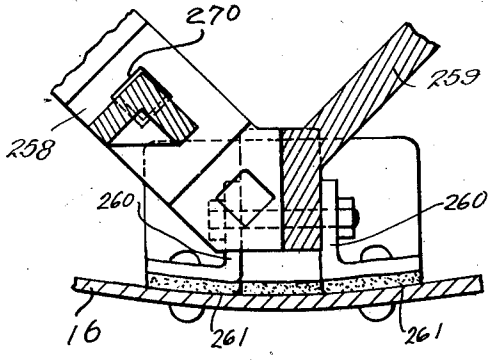


Fig. 38



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Fig. 37.

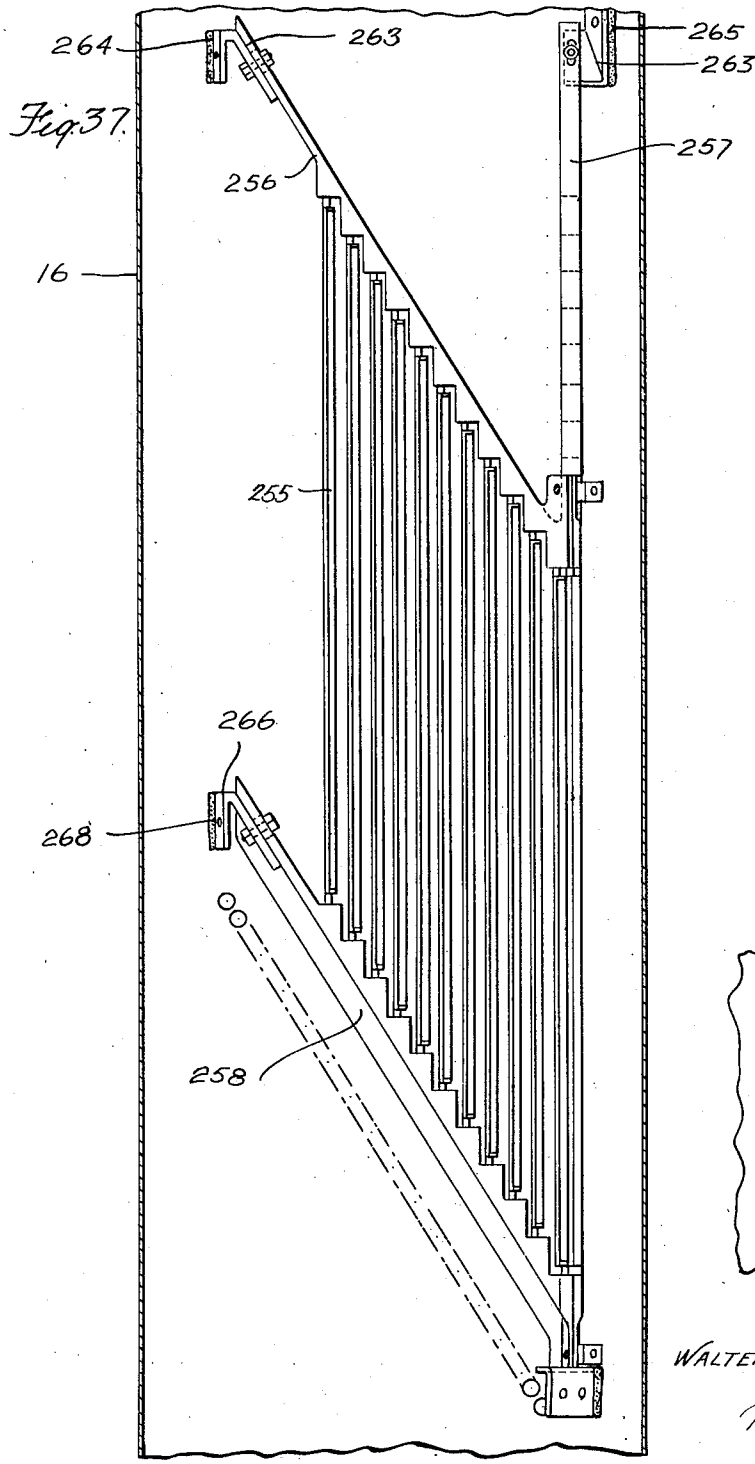
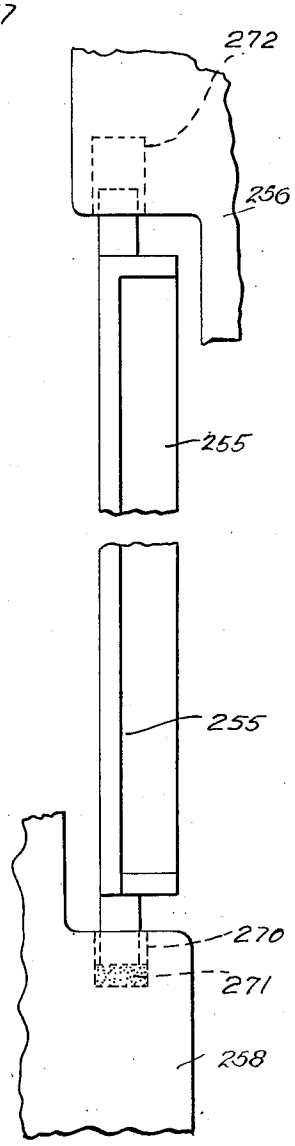


Fig. 39.



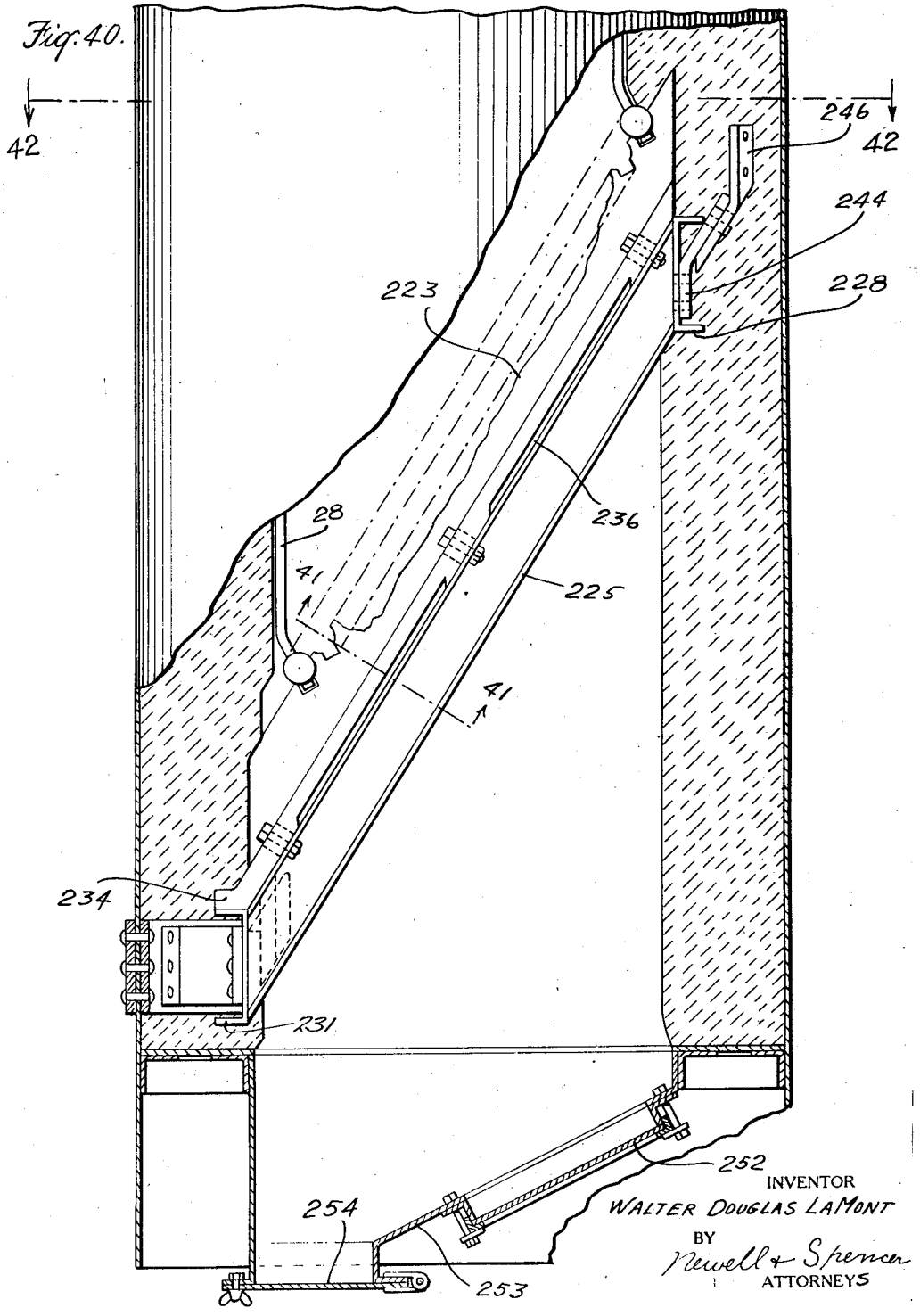
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WALTER DOUGLAS LAMONT
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Fig. 40.



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Fig. 42

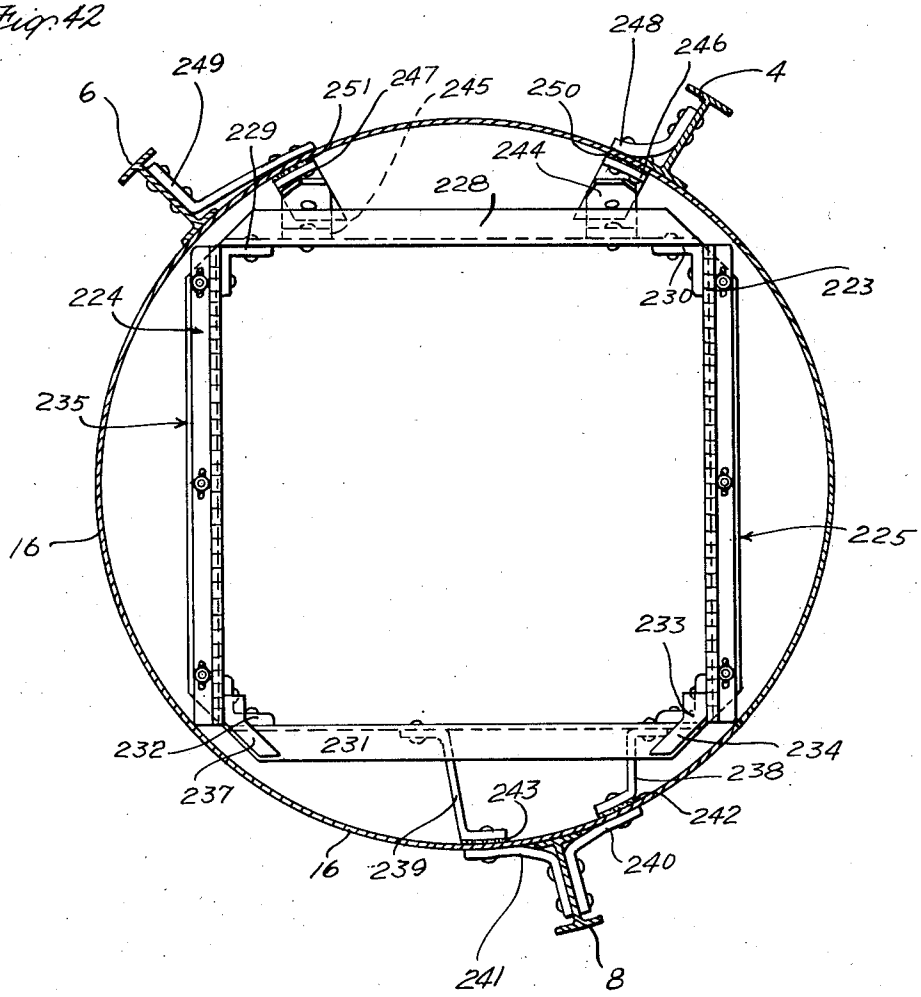


Fig. 41.

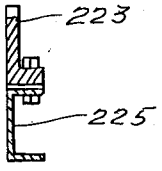
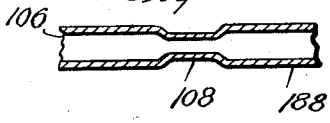


Fig. 44.



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BY
Newell & Spencer
ATTORNEYS

Patented Mar. 22, 1932 1,850,281

UNITED STATES PATENT OFFICE

WALTER DOUGLAS LA MONT, OF LARCHMONT, NEW YORK, ASSIGNOR TO LA MONT CORPORATION, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

HEAT EXCHANGE APPARATUS

Application filed October 9, 1926. Serial No. 140,665.

This invention relates to steam and other vapor generators and heat exchangers and more particularly to improved steam generators of the type described in my prior Patent No. 1,545,668, and my co-pending application, Serial No. 32,064, filed May 22, 1925. The invention also includes improvements in the combination of steam generators with various waste heat sources such as water gas generators and the like.

In my prior Patent No. 1,545,668 and in my prior application above referred to, I have described generators in which water is circulated through a number of long small diameter tubes forming a film on the inner walls thereof. In the constructions above referred to the tubes are connected to a series of headers which are then joined to one or more distributors. The connections shown are by ordinary unions and the upper and lower headers are exposed to the full heat of the hot gases. I have found that unions tend to loosen and result in leakages, particularly where they are exposed to high gas temperatures. It is one of the features of the present invention that the tubes are so arranged with respect to the gas passage that the headers are carried outside of the zone of high heat and the tubes are fastened to the headers by expanding therein, the headers themselves being connected to the distributors by nipples or short pipe lengths also fastened by expanding. In this construction the headers are subjected to a minimum of expansion and contraction as they are not exposed to the main heat of the heating gases and there are no threaded joints to become loose.

Owing to the high rate of speed with which the relatively small amounts of water flow through the tubes there is practically no tendency to scale formation as any solids precipitated are at once swept on by the rapid flow of water and steam. I have found that these solids can be removed by passing through a suitable strainer in the circuit outside of the tubes. It is thus possible to eliminate complicated treating means substituting therefor a simple screen in the water circuit. This constitutes an additional feature of the present invention.

As the amount of water in the tubes is comparatively small, it is necessary to provide for reliable means to prevent the tubes from running dry. It is one of the features of the present invention that a control device is associated with the upper distributor pipe or pipes in such a manner as to prevent water deficiency in any of the headers and also serves as a warning indicator.

In the more specific embodiment of the present invention in which the generator is associated with a source of waste heat, the present invention includes important advantages in generator structure and in the arrangement of gas travel. I have found that excellent results can be obtained by introducing the hot gases at an angle to the generating tubes at the bottom thereof, but above the lower headers and suitably arranging the inlet gas passage so as to produce an easy bend and gas entrance. The structure of the generator can be simplified and particularly the over-all height of the installation can be reduced by causing the heating gases to enter at an angle to the tubes. This is an important advantage since the best results are obtained with very long generator tubes, being from 25 to 30 feet long in the average installation.

In order to obtain high heat transfer efficiencies it is desirable to use high gas velocities and this in turn necessitates close spacing of the tubes. I have found that draft losses can be greatly minimized when the heating gases enter at an angle to the tubes by increasing the area of the face or faces of the tube bundle, which are presented to the incoming gas. In the preferred embodiment the tube bundle which may advantageously consist of a series of substantially parallel trays of tubes, is of rectangular shape and is so arranged that it presents a corner to the entering gases so that the side area of the tube bundle presented to the gas is considerably greater than the cross section of the gas passage. Similar results may be obtained by so arranging the gas passages as to cause the gas to enter the tube bundle from several directions. While the invention in its broader aspects is not limited to the entrance of the gases around an angle of the tube bundle,

I have found that this construction lends itself excellently to compact and simple generator construction and constitutes the preferred embodiment of the present invention.

Expansion of the long small tubes must be provided for and I have found that a very satisfactory structure can be produced by supporting the bottom of the tubes and permitting the upper ends to expand and contract freely, the supports for the bottom of the tubes being provided with suitable fastenings which permit limited lateral motion to compensate for unequal expansion of the tubes and the supporting structure. By supporting the tubes at their bottom ends, a heavy shell structure is avoided and the shell can be supported by light columns or may even in some cases be self-supporting. A very light and economical shell structure can be produced and it is possible as shown in the preferred embodiments of the invention, to provide for a door opening the full height of the shell so that individual trays of tubes, that is to say, an upper header, lower header and the connecting tubes, can be removed or inserted bodily, making repairs or replacements a very simple matter and greatly decreasing the labor costs. These features of door and shell construction will be described in greater detail in connection with the drawings and constitute specific features of the invention.

Preferably, the gas passage should be decreased progressively in order to compensate for the shrinkage in volume of the heating gases as they are cooled in passing over the generating tubes. The arrangement of tubes is also preferably such that they at all times fully occupy the gas passage and are uniformly distributed therein. I do not claim this proportioning of gas passage in the present invention per se apart from the other structural features as this forms the subject-matter of the co-pending application of myself and Alfred F. Ernst, Serial No. 140,099, filed October 7, 1926.

The expanded connections of the tubes into the upper headers and the upper header nipples into the distributing pipes make it necessary to cut the nipple when a tray is to be removed and of course the closing plug opposite the nipple will usually be knocked into the distributor. In order to make it possible to effect repairs without extensive dismantling, I preferably provide the upper distributor pipe with a flanged opening at the bottom, closed normally by a suitable blank flange, so that when nipples are cut off and forced into the distributor tube, they can be removed from the latter without removing it.

In my application, Serial No. 32,064, above referred to, I describe vertical steam separating chambers or pots for separating the steam and water discharged from the bottom headers. I have found that a more effective separation and a more reliable operation can be achieved by providing a plurality of horizontal steam separating chambers located below the boiler and of larger size than the pots described in my application above referred to. These separating chambers may also preferably be provided with suitable baffles and inlet pipe arrangement to enhance the efficiency of steam separation.

In its preferred embodiment, my invention also includes other structural features such as detachable supports for the upper headers and easily demountable supporting means for the upper distributor and the like. The invention also includes an improved type of expansion plug for closing expander tool openings in the various headers and distributors. Other and further features of the invention will be apparent from the following detailed description taken in connection with the drawings, in which—

Figure 1 is a side elevation of a steam generator embodying the present invention, this figure showing the generator connected to a source of waste heat such as the superheater of a gas generating set;

Figure 2 is a front elevation of the steam generator shown in Fig. 1;

Figure 3 is a vertical section through the heat chamber of the steam generator of the present invention illustrating the arrangement of the banks or trays of steam generating tubes, this view also illustrating the arrangement of the heat insulation in the heat chamber;

Figure 4 is a detail section showing the manner of the connection of the steam generating tubes to the supply and collecting headers;

Figure 5 is an elevation, on a somewhat larger scale, of the collecting pot, the steam separator, the water level control, the slow point and the circulating pump;

Figure 6 is a section on the line 6—6 of Figure 5 looking in the direction of the arrows;

Figure 7 is a section on the line 7—7 of Figure 1 showing the spacing and arrangement of the generating tubes with respect to each other at the upper end of the generator;

Figure 8 is a section on the line 8—8 of Figure 1 showing the spacing and arrangement of the tubes at the lower end of the heat chamber;

Figure 9 is a detail showing the manner of locking the door or doors of the casing in closed position;

Figure 10 is a view, substantially in front elevation, of a modified arrangement of collecting pot, steam separator, water level control and associated parts;

Figure 11 is a side elevation of the arrangement shown in Figure 10;

Figure 12 is a sectional detail showing the

manner of connecting the supply headers to the supply manifold;

Figure 13 is a sectional detail showing the manner of connecting the collecting headers to the collecting pot;

Figure 14 is an enlarged detail elevation of the strainers and the connections thereto permitting their alternate use and convenient cleaning, and

Figure 15 is a side elevation of the structure shown in Figure 14;

Figure 16 is a section along the line 16—16 of Figure 18 showing bracing of the shell;

Figure 17 is a vertical section along the line 17—17 of Figure 16;

Figure 18 is a section through the shell of a generator on a larger scale than Figure 1;

Figure 19 is a detail elevation of a door hinge;

Figure 20 is a section through the upper header supporting means;

Figure 21 is a plan view of the header supporting means shown in Figure 20;

Figure 22 is a side elevation partly broken away of the header supporting structure;

Figure 23 is an elevation showing a modified header and manifold construction;

Figures 24 and 25 are side elevations partly in section of upper headers and distributor manifold and lower headers and collector manifold respectively;

Figures 26 and 27 are detail elevations of the drum baffles shown in Figure 5;

Figure 28 is a detail elevation partly in section of a header and generating tubes showing orifice tube construction and connections with the distributor manifold;

Figures 29 and 30 are sections along the lines 29—29 and 30—30 respectively of Figure 28;

Figure 31 is an elevation partly in section of the end of a header opposite to the collector manifold showing orifice tube construction;

Figure 32 is a vertical section along the line 32—32 of Figure 31;

Figure 33 is a detailed vertical section through a modified type of header and orifice tube construction;

Figure 34 is a vertical section along the line 34—34 of Figure 33;

Figure 35 is a vertical section through another modification of header and orifice construction;

Figure 36 is a section along the line 36—36 of Figure 1, showing the construction of inlet baffles;

Figure 37 is a phantom elevation of the inlet baffles;

Figure 38 is a detail of the baffle frame fastening;

Figure 39 is a detail of a baffle on a larger scale;

Figure 40 is an elevation of the support for the generator tubes;

Figure 41 is a detailed section along the line 41—41 of Figure 40, and

Figure 42 is a horizontal section along the line 42—42 of Figure 40.

Figure 43 is a vertical section through another modified header and orifice tube. Fig. 44 is a detail.

The steam generator of the present invention being of comparatively light construction and containing only a comparatively small quantity of water at any one time, requires only a comparatively light framework for its support, and in the illustrated embodiment of the invention, the supporting framework comprises a ring 2 of channel section 1 supported upon legs 4, 6 and 8 of I section. Supported upon the ring 2 is a second ring 9 having attached to its inner face or web vertical supports or columns 10, 12, 14 of I section. The column 10, preferably extending almost to the upper end of the casing 16, furnishes support for the hinges 18 of the door 20. It is not essential for the other two columns 12 and 14 to extend as far up the casing 16 as the column 10 and they may extend only about half way up said casing.

The casing 16 comprises a cylindrical steel shell, open in one quadrant to expose all of the trays or banks of generating tubes and to permit the ready removal of any bank or tray, this opening being closed by the door 20 hereinabove referred to. The casing 16 constitutes merely a covering for the steam generator, the parts of the generator proper being supported upon the framework hereinabove described and therefore the casing 16 can be of comparatively light construction, since, with the exception of the valve at its upper end, to be hereinafter described, its supports substantially none of the operating parts connected with the generator. The casing 16 is preferably lined throughout part of its length with heat insulation 22, this insulation extending throughout the hottest part of the path of travel of the heating gases.

The inner surface of the insulation is provided with a lining of reinforced refractory material 130, which may preferably consist of a refractory cement reinforced with a wire mesh or metal lath 131. This lining is clearly shown in Figures 16, 17 and 18. The inner lining and insulation is preferably braced at suitable intervals by angles 132, 133, 134 and 135 (Figures 16, 17 and 18). The metal shell itself is braced with a circumferential angle 136 having a door portion 137, and the ends of the angles 132, 133, 134 and 135 are fastened to this ring and serve as additional braces for the metal shell as well as reinforcing the insulation 22 and the refractory lining 130. The angles 132 and 133 are substantially straight and form with the shell 16 braced segments. The angles 134 and 135 are not straight and serve to define the door and door seat. The arrangement of bracing illus-

trated in Figures 16 to 18 gives excellent results in practice but any other suitable bracing arrangement may be used. Other shapes of bracing or reinforcement may also be used wherever desirable and in some cases it may even be desirable to combine the bracing effect of the angles 132, 133, 134 and 136 which may be achieved by a suitably shaped plate or web so as to form a solid metal plate partially surrounding the tube space. Similarly the angles 135 and 137 may be combined in a single door supporting plate. When a heavy shell 16 and 20 is used in conjunction with closely spaced graces it is possible in some constructions to dispense altogether with the supporting columns 10, 12 and 14. In many constructions, however, I find that a lighter shell with columns is preferable.

In order to effect a tight closure of the door it is desirable to provide for a certain amount of play in the hinges to compensate for slight inaccuracies in alignment which are apt to occur due to the great height of the door. Any suitable hinge construction can be used but I prefer to use a flexible pin hinge joint, such as is illustrated in Figure 19. Upper and lower hinged plates 138 and 139 are fastened to the column 10 at suitable intervals and are provided with openings. The opening in the upper plate is of greater diameter than the opening in the lower plate but is concentric therewith. A pin 142 having a head 143 is provided with a shoulder 144 and a shank portion 145. This shank portion is of smaller diameter than the opening in the upper plate 141 but is of a diameter to snugly fit the eye 146 of hinge 18. The lower portion of the shank indicated at 141, Figure 19, also fits snugly in the opening in the lower plate. This pin also has a tip 125 which is smaller than the opening in the lower plate. When, however, the door is closed if difficulties arise owing to warping, the pin 142 can be raised so that the shank portion 145 passes into the opening in the plate 138 and out of the opening in the plate 139 leaving the tip 125 in the latter. This gives a little play to the pin and thus permits a tight closure of the door.

Angle irons 147 and 148 extend vertically on the shell adjacent to the door portion and corresponding angles 149 and 150 on the door portion register therewith. The angles 148 and 150 are provided with openings at suitable intervals through which extend tapered pins 151 provided with slots 152 through which tapered wedges 153 are forced to lock the door in place (see Figure 9). Slight vertical misalignments of the angles are corrected by the taper of the pin 151 which forces the holes into perfect register and the two angles 148 and 150 are tightly pressed together by the wedging action of the wedge 153, so that a firm and rigid closure is effected, while at the same time it is not necessary to make the shell and door construction of undue exactness and rigidity. The taper pin and wedge are of course, only one means of effecting a tight closure and other analogous means may of course be employed. Where the misalignment of the holes is considerable, a long pin having a suitable taper throughout its length may be used, the size of the hole being sufficient to prevent overlapping and premature wedging.

The source of heat may be any waste heat source such, for example, as the superheater 24 of a gas generating set, and in the illustrated embodiment of the invention the heat from this source is shown as introduced into the heat chamber 26 of the generator at such a point that the heat will first strike the generating tubes 28 substantially at their lower portions.

As herein shown, the connection between the superheater 24 and heat chamber 26 comprises a pipe 30, inclined at its point of junction with the casing 16 so that the gases from the superheater 24 are directed upward as they enter the chamber 26, the admission of the gases to the chamber 26 being controlled by a valve 32, preferably of the duplex steam sealed construction more fully described in my copending application Serial No. 99,243, filed April 2, 1926. There is preferably also provided a clapper valve 34 carried upon the frusto-conical part 35 of the upper end of the casing 16 when the generator is associated with a gas generating set or other intermittently operated apparatus which may produce explosive gases during the periods when it is shut off from connection with the heat chamber of the steam generator, it being preferable to have the heat chamber 26 filled with inerts during such periods.

The steam generating tubes of the illustrated embodiment of my invention, like those of the steam generator shown in my copending application Serial No. 32,064, filed May 22, 1925, are preferably comparatively long, thin-walled tubes of small diameter, spaced apart comparatively small distances and connected in groups to headers at their upper and lower ends. In the illustrated embodiment of the invention, the tubes 28 are shown as expanded at their upper ends into distributing headers 36, the tubes being preferably curved near their upper ends and arranged to enter the headers 36 substantially on the horizontal diameter of these headers. At their lower ends these tubes are shown as expanded into collecting headers 38, which they preferably enter substantially on the vertical diameters of these headers. The curvature of the upper ends of the tubes permits the headers 36 to be located somewhat out of the line of the direct travel of the heating gases, thus avoiding unnecessary expansion and contraction of the joints between the tubes and the headers and of the joints be-

tween the headers and the distributor manifold 40 hereinafter to be more fully described. Unnecessary expansion and contraction of the joints between the tubes 28 and the lower headers 38 is avoided by directing the gases entering the chamber 26 from the pipe 30 against the tubes 28 slightly above the points of junction of the tubes 28 with the headers 38.

As shown in Figure 12 of the drawings, the headers 36 are connected to the water supply manifold 40 by short pieces of connecting tubing 42, each of which is expanded into the manifold 40 at one end and at its other end is expanded into the header 36 filling an annular groove 44 therein, an opening in the manifold 40 closed by a plug 46 providing for insertion of the expanding tool to expand the annular joint 44 as well as the connection between the tube 42 and the manifold 40. Similarly, openings in the headers 36, closed by plugs 48, permit the expansion of the upper ends of the tubes 28 into the tube-receiving openings in the header 36.

The headers are mounted in supports as shown in Figures 20, 21 and 22. These supports consist in a channel 154 extending parallel to the manifold 40 and supporting the latter by means of a series of U bolts 155 fastened by nuts 156. The channel 154 is provided with perforations registering with the holes in the manifold and of sufficient size to permit the passage of headers therethrough. Parallel to the channel is an angle iron 157 having one side cut out with openings 158 to permit the passage of the headers thereunder. The tongues of metal between the openings extend only down approximately to the center line of the headers and the openings are provided with suitably arranged slots 159 to permit passage of the plugs 48 which project above the headers. The generator is assembled by sliding in the trays causing the headers to pass through the openings in the channel 154, the nipples projecting into the holes in the manifold 40. The nipples are then expanded and the holes for the expander tools closed with plugs 46 (Figure 12). Perforated L plates 160 are then slipped over the opposite ends of the headers and bolted tight to the angle 157, thereby drawing the headers firmly against the openings 158 as shown in Figures 20 and 22.

In order to permit the upper ends of the tubes to expand vertically the channel 154 and angle 157 are mounted so as to permit vertical movement but prevent lateral movement. This may be effected by any suitable structure but I prefer to use the method shown in Figure 22 wherein the angle 157 is provided with two pins 161 at either end registering with slots 162 in plates 163 attached to the shell framework. In a similar manner the channel 154 is provided with plates 166 which are firmly attached to the shell framework and are provided with slots 165. The slots are vertical and permit a limited vertical movement while preventing lateral movement. In some cases it may be desirable to provide for limited lateral movement as well as for vertical movement. This may be effected, for example, by placing the slots at a suitable angle or by making the slots of a width suitably in excess of the diameter of the pin. Any other suitable construction may be used.

In order to produce films on the inner walls of the generator tubes it is desirable to introduce the water in the form of jets and I prefer to effect this by means of orifice or jet tubes or channels as shown in Figures 28 to 35 inclusive. In the construction shown in Figures 28 to 32, the end of the header 36 which is connected to the nipple 42 is provided with a counter-bore 167 into which a plug 168 is driven. This plug is provided with a tapered D-shaped opening 169 as shown in Figures 28 and 29. An orifice tube 170 which may advantageously be of non-corrodible material, such as bronze, and which possesses at the far end a circular cross section 171 of smaller diameter than the header (Figure 31), while having a D-shaped cross section throughout the remainder of its length (Figures 29 and 30), is inserted into the header and forced to fit tightly into the plug 168 (Figures 28 and 29). The fit should be tight enough to prevent leakage but loose enough to permit ready removal. The tube 170 is provided with orifices 172 which register with the generating tubes. The circular end of the orifice tube is closed by a plug 173 having an enlarged portion 174 fitting in a counterbore 175 at the end of the header and a reduced portion 176 fitting into the orifice tube. The portion 176 is provided with a pin 177 registering with a slot 178 in the orifice tube and the enlarged portion 174 is provided with a projection or pin 179 which slides in a groove 180 in the counter-bore of the header. These two pins and their co-operating slots and grooves fix the radial alignment of the plug 173 and the orifice tube and assure that the orifices at all times register with the generating tubes. The circular end of the orifice tube is also preferably provided with two holes 181 which permit a hooked tool into the end of the tube in order to readily remove the same for cleaning or for any repair.

The plug 173 is kept in position by the spring 182 compressed by the screw plug 183 which screws into a threaded counter-bore 184 at the extreme end of the header. The end of the header is also provided with a recessed shoulder 185 carrying a gasket 186 which is engaged by a flange or shoulder 187 on the plug and serves as a watertight closure for the end of the header.

The tapering opening 169 in the plug 168

serves as a stop for the orifice tube and thus assures longitudinal alignment of the orifices with the generating tubes. This alignment may, however, be obtained by other means such as pins projecting into the opening 169 or pins on the orifice tube engaging the face of the plug 168 or any other suitable stops. When such a positive stop is used it is not necessary to make the opening 169 tapered and a straight opening is advantageous in certain constructions owing to its greater ease of production. A positive stop operating on the plug 174 may, of course, also be used instead of a stop which engages the plug 168.

The closure plugs 46, 48, 62 and 70 are of a novel design. Instead of providing a plug with a square face which is difficult to expand satisfactorily into a small tube, I have found that if the plug is formed by drilling out a metal blank or by roughing out the inner bore and finish drilling so that the end wall is in the form of a frustrum of a cone the expander tool can obtain a satisfactory grip and there is sufficient metal inside the header to produce a tight closure and lock by expansion. Preferably the outer wall of the closed end of the plug is also finished to be parallel with the inner walls, although this is not essential to the operation of the plug. The thinner walls thus produced, however, make expansion easier, as the metal thickness is less and its stiffness is correspondingly reduced. The plug is also preferably provided with a shoulder 126 at its upper end so that if necessary, it can be driven into its hole and automatically stops at a predetermined depth necessary to provide sufficient metal within the header tube to effect satisfactory closure and locking on expansion. While it should be understood that other types of closure plugs may be used, this novel type of plug constitutes a specific feature of novelty of the present invention.

Instead of using an orifice tube which possesses a circular cross section at one end and a D-shaped cross section throughout the remainder of its length it is advantageous in certain cases to use a small diameter orifice tube which has circular cross section at both ends and a D-shaped cross section in the center. Such a tube resembles the type described above except that the end toward the nipple connection of the header is also rounded as shown in Figures 33 and 34. This rounded section 188 may be fitted into a round opening in the end plug 168 in a manner similar to the construction shown in Figures 28 to 32 but I find that it is advantageous for many purposes to provide the plug 168 with a hollow nipple 189 extending into the circular end of the orifice tube. While this construction somewhat decreases the passage cross section through the plug 168 it has the advantage that a watertight joint between the plug and the orifice tube can be produced which is not as tight a fit as is necessary when the orifice tube projects into an opening in the plug, for the reason that the nipple acts as an injector and the pressure of the water is not directed against the joint as in the construction shown in Figure 28. The particular construction used must be determined in each case by the exigencies of the particular installation. Owing to the fact that clearance between the circular end 188 of the orifice tube and the upper part of the header is less than the corresponding clearance between the D-shaped portion of the orifice tube and the header (compare Figure 30 with Figure 34), there is not as much space for the closure plugs to project into the tube and it is therefore frequently necessary to use square cut plugs or a large header may be used.

Instead of the closed orifice tube which I prefer to use I may, of course, use an open channel which is shown at 190 in Figure 35. This construction does not reduce materially the cross section of the header through which water is to flow but it is open to the disadvantage that it is somewhat more difficult to center and maintain in alignment. There is also a greater tendency for the thin channel to bend and to permit excessive steam leakage from the generator tubes into the header or from one generator tube to another. It is an advantage of the D-shaped orifice tube shown in Figures 28 to 34 inclusive, that it is sufficiently stiff to seal off the generator tubes from the header to a satisfactory extent. The relative advantages and disadvantages of the two types of jet construction will determine the best type to use under any given conditions.

A further modification of header and orifice tube construction is shown in Figure 43. In this modification the header 36 is provided with an orifice tube 273 fitting the inner bore of the header and being provided with jet orifices 274. A curved strip of metal 275 is welded on the top of the header and is provided with drilled holes registering with the expander tool holes of the header. These holes are preferably drilled before the metal is welded onto the header and should be countersunk either on the outside of the header or on the inside of the curved strip or in both places, as is shown in the illustration at 276. A straight cylindrical plug 277 provided with a shoulder 278 is forced into the hole with its lower face flush with or recessed from the inner wall of the header. This plug is then expanded into the annular space 276 and thus provides for a tight lock. In some cases where the header construction is thin it may be desirable to curve the outer surface of the plug end to conform with the curve of the inner bore of the header so that it is not necessary to recess the plug. Instead of the annular space produced by coun-

tersinking the holes in the metal strip and in the header an annular space may be formed in any other suitable way and in some cases it may be desirable to provide for a plurality of annular spaces in order to produce still more effective locking.

The construction shown in Figure 43 possesses the marked advantage that the orifice tube completely fills the header and possesses an inner bore having a cross sectional area not greatly less than that of the header itself, whereas in the D-shaped orifice tubes shown in Figures 28 to 34 inclusive, the cross sectional area of the tube is very much less than that of the inner bore of the header. It is thus possible to use very much smaller headers which is of advantage in reducing draft losses since with closely spaced tubes large headers leave but little room for the heating gases to pass between them, whereas smaller headers leave considerably larger passages and thereby reduce draft losses to a marked extent.

Instead of welding the strip onto the header, any other suitable method of fastening may be used and the shape of the strip may be varied.

Other types of jet arrangement such as described in my co-pending application, Serial No. 32,064, filed May 22, 1925, above referred to, may also be used and are included in the novel combinations of the present invention, although I do not claim such constructions per se in this application.

It will be noted that the manifold 40 is so inclined that the headers 36 may be arranged in stepped relation to each other, thus permitting a closer spacing of the tubes at their upper ends than would be readily possible with either a vertical or horizontal arrangement of the manifold. It will also be noted that the spacing of the tubes is less at their upper ends than at their lower ends, for a purpose to be hereinafter set forth.

The inclined manifold 40 is preferably located outside the heat chamber, as shown in Figure 1, and near its lower end is provided with a lateral branch 50 to which is connected a pipe 52 by which water is supplied to the manifold 40, the pipe 52 at its lower end being connected to a pair of strainers 54 and 56, hereinafter to be more fully described, these strainers in turn being connected through a pipe 58 to the pump or other circulating means 60 by which the water in the generator is circulated through the generating tubes.

The receiving headers 38, like the supply headers 36, are provided with openings closed by plugs 62 through which the tubes 28 may be expanded into the tube-receiving openings in the headers and these headers 38 at their ends, as shown more fully in Figure 13, are connected by short pieces of tubing 64 to a collecting manifold 66, the pieces of tubing 64 being expanded at one end into a countersunk opening in the collecting manifold 66 and, at their junction with the headers 38, being each expanded into the header, filling annular grooves 68 therein, openings in the collecting manifold 66 closed by plugs 70 permitting the insertion of expanding tools for expanding the nipple 64 both into the header and into the manifold 66.

In the embodiment shown in Figures 1, 2, 5 and 6, the manifold 66 is connected to a horizontal drum 80 which in turn is provided with a steam outlet 72 provided with suitable control valves 76. The pipe is also provided with a steam separator 74 which in the modification shown in Figures 5 and 6 connects with the drum 80 through the pipe 78. In the modification in Figures 1 and 2, the drum 80 is connected to a drum 82 situated below it by two pipes 84. In the modification the steam separator drain pipe also leads to the drum 82. A water level is maintained in the drum 82 by means of the water level control 118 which operates on a valve 122 in the feed line 114. From the lower water drum 82 a pipe 86 leads to the suction of the pump 60. A thorough mixing of the feed water and circulating water is effected in the two drums as the feed water pipe communicates with a perforated pipe 116 in the drum 82 extending lengthwise of the drum a suitable distance. In Figures 5 and 6, of course, the pipe 116 extends through the single drum 80.

The modification shown in Figures 5 and 6 differs from that illustrated in Figures 1 and 2 in that a single drum 80 of somewhat larger size takes the place of the two drums 80 and 82. The steam pipe 72 leads to the steam space some distance from the inlet of the collector manifold 66 and a plurality of perforated baffles are preferably used to prevent surging of water in the drum. These baffles are illustrated at 226 and 227 respectively (Figures 26 and 27). Preferably the steam separator drain pipe 78 is extended in the drum beyond the baffle 226. In the illustrated embodiment two baffles are used, one placed in the upper portion of the drum and the other in the lower. The upper and lower arrangement of baffles will depend on the dimensions of the drum and on the conditions under which the installation is to be used. In some cases the single baffle may be sufficient and in others it may be desirable to use a suitably larger number than two. The baffles may all be located in the lower or upper portions of the drum or may be distributed as illustrated.

A somewhat different arrangement for steam separation is illustrated in Figures 10 and 11. In this modification the collecting manifold 66 passes into the exterior chamber 201 of a separator 200. The steam and water passes down the annular space, a rotary or whirling motion being imparted by the spiral vane 202 and the water passing down

into the drum 203 through the pipe 204 which extends below the water level. Steam is separated in the central portion of the whirling mixture of water and steam and passes up through the steam pipe 205 into the steam separator 74 which drains into the drum 203 through the drain pipe 78 provided with the check valve 206. Any steam carried into the drum 203 by the water or released therein enters the pipe 204 through the slot 207 extending for a considerable distance above the water level and passes up with the main quantity of steam. An alternative method for freeing steam from the drum consists in a vent from the steam space of the drum to the steam main preferably entering the latter before the steam separator.

The level of water in the drum 203 may advantageously be maintained by the water level control 208 operating a valve 209 on the feed water pipe 210. In order to effect a thorough mixing of feed water and circulated water the feed pipe 210 preferably extends for a considerable distance in the water space of the drum and may advantageously be provided with perforations.

From the water space of the drum 203 the water flows down to the pump 60 through the pipe 211, a sediment trap 212, with a blow-down pipe 213 and blow-down valve 214 connecting with the pipe 211. Strains produced by unequal expansion or contraction of the piping can be taken up by the expansion joints 215. Similar expansion joints may, of course, also be used in the construction shown in Figures 1, 2, 5 and 6, and in general such standard fittings and accessories will be employed as are dictated by the conditions of any particular installation. The drawings are for the most part somewhat diagrammatic in nature and do not include all of the accessories which are ordinarily associated with steam generators but it should be understood that such accessories will be used whenever and wherever they may be desirable.

Instead of arranging the upper and lower headers so that they may be joined to their respective manifold by nipples or short pieces of pipe extending from the ends of the headers, it is desirable in some constructions to connect the headers to their manifolds by means of short pieces of pipes or nipples which enter the headers at right angles to their bores. This construction is shown in Figures 23 to 25. Figure 23 illustrates the construction diagrammatically, showing a series of trays having generator tubes 191, upper headers 192, lower headers 193, an upper manifold 194 and a lower collector 195. Short pieces of pipe or nipples 196 connecting the headers 192 with the manifold 194 and similar nipples or short pieces of pipe 197 connecting the headers 193 to the collector 195. This construction necessitates closing the ends of the headers by suitable plugs 198 and it is also necessary to provide either the manifolds or the headers with expander tool holes which must be closed by the plugs 199. In Figure 24, the manifold 194 is shown as provided with the expander hole whereas in Figure 25, the header 193 is so arranged. The arrangement is purely a matter of convenience in any installation.

It should be noted in Figure 23 that the tubes 191 are bent not only at their upper ends but also at their lower ends. In the preferred gas passage construction of the present invention it is usually not necessary to curve the lower tubes in order to bring the headers out of the path of hottest gases. It is, however, frequently desirable to curve some or all of the lower tubes in order to permit a predetermined spacing of the tubes even when using relatively large headers. Either straight or curved tubes may be used or some of the trays may be provided with tubes curved at the bottom and others with straight tubes. The choice of arrangement will be determined in every case by the structural shape of the generator as a whole.

The generator of the present invention, like that shown in my copending application, Serial No. 32,064, filed May 22, 1925, hereinabove referred to, is designed to operate with a comparatively small quantity of water in the generator at any one time and with this water constantly in circulation, the pump 60 being preferably designed to effect a continuous circulation of the water up through the pipe 58, through the strainer 54 or 56, through the pipes 50 and 52, manifold 40, headers 36, generating tubes 28, headers 38, collecting manifold 66, chamber 80, second chamber 82 and pipe 86, back to the pump.

When it is desired to operate the generator as a film or semi-film generator the jet orifices 172 are so proportioned in size to the diameter of the tubes and the water head upon them that the amount of water projected into each tube will be greater than the generating capacity of the tube but considerably less than the amount to fill the tube, whereby the water, by the action of adhesion and cohesion, will flow down the inner surface of each tube in the form of a comparatively thin film leaving the center of the tube free to receive the steam generated by the contact of the film with the heated wall of the tube.

The amount of water in the generating tubes is comparatively small and it is, therefore, desirable to assure a constant flow of water. The total amount of water in the circuit both external to the tubes and in the tubes themselves is, of course, controlled by the water control 118 operating on the feed. It is, however, desirable to assure even and sufficient flow into the top of the elements by a device which responds quickly to the actual

rate of flow into the headers. For this purpose, a standpipe 92 is connected to the bottom of the manifold 40 and is provided with valved branch pipes 96 and 98 connected by an indicator pipe 94 which operates an indicator and control mechanism 100. This mechanism may advantageously move a brush 101 over electrical contacts 102 so that signal lights 104 will be lighted to indicate the condition of water level in the standpipe. Other suitable control devices may also be operated and their nature and arrangement will depend on the conditions under which the generator is to be operated.

The standpipe 92 is connected to a pipe 106 at its upper end, from which a branch pipe 110 connects with the upper end of the manifold 40. Surges of water and steam or air pocketing are thus prevented or minimized and the registration of the water pressure in the standpipe 92 is made more uniform. It is also desirable in order to prevent surges to connect the pipe 106 to the steam-space of the drum 80 which is effected by the pipe 188 provided with a restriction orifice 108, Figure 44, which prevents excessive flow.

The rapid flow of water through the generating tubes prevents the formation of scale, as any solids precipitated are carried down by the scouring action of the water and steam and the thorough mixture of feed and unevaporated water in the drum 82 results in a far-reaching precipitation of solids which are then circulated by the pump 60 to the strainers and are there removed.

The strainer construction is shown in detail in Figures 14 and 15 and includes a Y pipe 127 connecting with the pump delivery pipe 58. Valves 129 and 134 are placed in the two legs of the Y respectively, which legs pass into the external annular space in the strainers 54 and 56 respectively. Thence all the water passes into the wire mesh cylinders 112 and 113 having closed lower ends, and up through a Y 124 provided with valves 128 and 130 in the legs. The stem of the Y unites with the pipe 52 which carries the water into the manifold 40. By closing the valves 128 and 129, the water is made to pass through the screen 54 whereas by closing the valves 130 and 134 and opening the valves 128 and 129, the water can be caused to flow through the screen 56.

The bottoms of the strainer 54 and 56 are connected to a Y 216 provided with valves 217 and 218 in the legs. The Y unites to form a blow-down pipe 219. The valves 217 and 218 are normally closed, but when it is desired to clean out the screens, they may be opened and effect a blow-down of the screens in order to remove the solids retained thereby. Thus, for example, if screen 112 is to be blown down valve 134 is closed and valve 218 is opened. The steam pressure in the generator then blows water down through the pipe 52 and screen 112 and out through the Y 216 and pipe 219, carrying with it the solids retained by the screen. The valves 128 and 129 may be open if desired or they may be closed. When they are permitted to remain open, the volume of water blown down is, of course, increased by the water flowing through the strainer 56. A similar suitable operation of the valves 217 and 129 can be used to effect blowing down of the screen 112.

Sometimes when the generator is shut down, scale may form in the manifold 40 or in the headers 36 and will, of course, be blown into the pipe 52, accumulating in the screens. This accumulation may be removed by removing one of the screen cylinders and by blowing down, but I prefer to provide a blow-down branch pipe 220 provided with a valve 221 and leading from the pipe 52 just above the Y 124.

When it becomes necessary to remove trays, it is usually necessary to cut the nipple connections to the manifold 40 and drive in the corresponding plugs 46 which fall into the manifold 40. In order to remove such plugs from the manifold without dismantling the latter, its lower end is flanged and open, the opening being normally closed by a blind flange 222. When plugs or other solids fall into the manifold, they can be removed by simply removing the blind flange 222 and permitting them to fall out of the open end. It is thus possible to effect repairs and to remove undesired solids from the manifold 40 with a minimum of labor and without any dismantling. Of course, any other suitable design of closure such as a screw plug or the like may be used.

The supporting structure for the lower headers is shown in Figures 40, 41 and 42, and consists in angle irons 223 and 224 which are bolted to channels 225 and 235, the portions adjacent to the bolt holes being in the form of bosses, so that when bolted together a space is enclosed between the angles and the channels, which space is filled with insulation 236 (Figure 40). There is thus metallic contact only at the bolts and for a small area surrounding them. The upper faces of the angles are suitably cut out so as to support the headers. Two headers are shown in place in Figure 40, and the other headers are, of course, arranged in the same manner but have been omitted for the sake of clearness. The tubes shown in Figure 40 are bent at their lower ends where they enter the lower headers but they may, of course, also be straight at their bottoms. The channels 225 and 235 are connected at their upper ends to a beam 228 by means of angle plates 229 and 230.

9. In a similar manner the lower ends of the channels are fastened to a beam 231 through angle plates 232 and 233. The angles 223 and 224 also bear at their lower ends directly on the beam 231, being provid-

ed with suitable feet 234 and 237 respectively. The beam 231 is fastened to the column 8 by means of the two plates 238 and 239, and 240 and 241. The plates 240 and 241 are riveted directly to the web of the column 8 and extend along the shell 16. The plates 238 and 239 in turn being fastened to the plates 240 and 241 by long rivets passing through the shell 16 and insulating plates 242 and 243 are interposed so that the only conduction of heat from the plates 238 and 239 to the plates 240 and 241 is through the rivets themselves.

The upper beam 228 is provided with two plates 244 and 245 which register with plates 246 and 247 which are in turn fastened through the shell to plates 248 and 249. Insulating plates 250 and 251 are interposed between the plates 246 and 248 and the shell 16. The only conduction of heat therefore from the plates 246 and 247 to the plates 248 and 249 and the shell is through the actual rivets or other fastening means. The fastening between the plates 244 and 246, and 245 and 247 is by means of pins fitting in slots, permitting limited motion to compensate for expansions and constractions of the channels 225 and 235.

An additional safeguard against explosion is provided in the explosion panel 252 which is fastened over an opening in the bottom plate 253 of the shell. A second opening, closed by the hinged plate 254, forms a dust pocket.

It will be seen that the generator is thoroughly insulated and losses by radiation from the shell or other portions of the structure are reduced to a minimum. Not only is thick insulation provided around the actual gas space but all the metallic members exposed to the hot gases are fastened to the shell or to columns by means of fastenings which have a heat insulator interposed in the leakage path so that leakage takes place only through very small sections of metal such as the fastening rivets or bolts as described, for example, in connection with the frame for the lower header shown in Figure 42.

The shape of the generator space is largely determined by the tray construction of tubes which renders a rectangular space structurally the most simple, although it is possible by using different numbers of tubes in different trays to produce roughly circular or other shapes. I have found, however, that the rectangle is the simplest and preferably should be arranged in the form of a square, as shown in the drawings. This presents two notable advantages. In the first place the circular shell which is the cheapest and strongest type available and which is subject to the least distortion in cases of explosions or excessive stresses, must be separated from the generator space by adequate thickness of insulation. The square can be placed in a circular shell of smaller size than can any other rectangular shape of equal area. A smaller shell is thus made possible and adequate insulation is provided. At the same time the perimeter of the square space generating surface is a minimum for a rectangular shape of given area and there is accordingly a smaller area of hot surface to radiate through the insulation. An additional saving in heat and cost is effected by reason of the smaller circular shell which can be used with a square generator passage and which, of course, presents a smaller surface for heat radiation. While a square tube bundle surrounded by a circular shell constitutes the preferred embodiment of the invention, it should be clearly understood that the invention is not limited thereto, and any shape of tube bundle and shell may be used wherever the conditions of the particular installation demand.

An additional advantage of the preferred square shape of the tube bundles lies in the fact that since the perimeter is a minimum, the surface friction opposing gas flow is also reduced which, in turn, reduces draft losses.

The gases from the superheater passing through the pipe 30 strike the square tube bundle at one of its corners. This permits the gases to enter the tube bundle from two sides of the square and practically doubles the entrance area. The friction in changing the direction of the gases is thereby minimized and undue draft losses are avoided. I have found that by placing an angle of the bundle facing the gas flow, this result can be most simply and easily brought about, but, of course, the gas can be caused to enter a plurality of sides of the tube bundle by a suitable arrangement of the gas passage and for some purposes such a construction may be more advantageous.

The gases from many waste heat sources contain considerable amounts of dust or of carbon particles which might tend to clog up the gas passages and to abrade the tubes. The illustrated embodiment of my invention is therefore provided with means for preventing the greater part of the dust from directly impinging on the lower portions of the tubes and for this purpose I prefer to use angles arranged vertically and acting as baffles. This construction is shown in Figures 36 to 39. The angles 255 are mounted in two inclined upper beams 256 and 257 forming a V and in a similar manner rest in two inclined lower beams 258 and 259 which also unite to form a V. The front edges of the beams are bolted to angle plates 260 which are in turn riveted to the shell 16. Plates of insulating material 261 are interposed between the shell and the plates 260 in order to minimize losses due to heat conduction. The upper ends of the beams 256 and 257 slide on plates 262 and 263 which are riveted to the shell 16, insulating plates 264 and 265 being interposed between the shell and the

plates. The connection between the beams and the plates is preferably by a bolt and slot so that the beams can move longitudinally to a limited degree in order to compensate for expansion and contraction. In a similar manner the lower beams 258 and 259 are slidably fastened to plates 266 and 267 which are riveted to the shell 16, insulating plates 268 and 269 being interposed to minimize heat conduction. The beams 258 and 259 are provided with recesses 270 into which the lower ends of the baffles 255 project, resting on insulating plate 271. Similar recesses 272 are provided in the upper beams 256 and 257 into which the upper ends of the baffles fit. The depth of the recesses 272 is such that the baffles can be raised sufficiently to clear the recesses 270 and therefore any baffle can be removed without dismantling either beam or the adjacent baffles, which greatly reduces labor costs in repairs or replacements. The provision of removable baffles constitutes one of the specific features of my invention.

The invention has been described in connection with a steam generator and preferably a steam generator of the film tube type. It should be understood, of course, that the amount of water entering the tubes can be increased by increasing the size of the orifices or by omitting the orifice tubes altogether until the tubes are substantially filled with water during operation. The advantages of a film on the tubes are clearly set out in my prior Patent No. 1,545,668 referred to above and in my prior application, Serial No. 32,964, and this constitutes the preferred embodiment of the invention but does not limit its scope since many, if not most of the structural features and devices of the present invention can be used advantageously with generators in which the tubes are operated as full tubes. Indeed, it is sometimes difficult to draw a sharp line between a generator operated as a film tube generator and one operated as a full tube generator. As the amount of water increases the tubes may be full for a portion of their length and the water present in the form of a film for the remainder. The advantages of the present invention, of course, apply also to the full tube generators which are included in the broader aspects of the invention.

The arrangement of the tube bundle so as to present an angle to the gas flow and thereby effect an easy entrance is not limited in its utility to generators of the type described, using either full tubes or film tubes with positive circulation and, on the contrary, is generally applicable to any tubular generators in which a bundle of small bore closely spaced tubes is used and where the problem of draft losses arises. This feature of the invention accordingly, is of broad applicability to various types of tubular generators.

Some of the features of the present invention are of particular advantage in connection with heat exchange apparatus which is used to actually generate steam but many of the novel features can advantageously be used in connection with heat exchange apparatus where little or no steam is generated and where water or other types of fluids are heated. Here again, there is no sharp line between a steam generator and a water heater as the generation of steam depends on the amount of heat absorbed in proportion to the mass of water and many of the novel features of the present invention can be applied to apparatus where water or other types of fluids are heated without substantial generation of steam or other vapors. In its more specific aspects, however, the invention is particularly directed to vapor generators and especially steam generators and these constitute the preferred embodiments of the invention.

In the illustrated embodiment of the invention, the lower tube headers are shown as supported at their two ends only. This is satisfactory where the length of header is not excessive but in many cases, particularly with long headers, it is desirable to provide supporting means in the center. These means may be of any suitable design either permanently fixed or removable. Where the supporting means are removable it is sometimes desirable to provide a plurality so that one may be removed to give access to the tube headers without complete loss of central support.

In the illustrated embodiment the gas passage reduction is effected by spacing the tubes of each more closely in the upper header than in the lower header and also by inclining the trays at different angles so that the parallel upper headers are brought closer together than the lower headers. This constitutes the most effective manner of reducing the gas passage which is always kept square and uniformly filled with tubes. For some purposes, however, it may be desirable to use only one of these methods and the invention is not limited to the use of both simultaneously.

What is claimed as new is:

1. A steam generator comprising in combination a plurality of long small cross-section generating elements, means for injecting water into the tops of said elements in excess of the amount of water capable of being evaporated by passage throughout, means for discharging steam and water from the lower ends of said elements, means for separating the steam and water discharged, and means associated with said injection means for continuously indicating the condition of the water flow to said elements.

2. A steam generator comprising in combination a plurality of trays of generating tubes expanded at their ends into pluralities

of headers, distributing and collecting piping connected to the headers by expanded connections, plugs in said piping opposite the expanded connections, said piping having an inclined portion adjacent the headers of the trays provided at its lower end with a closable opening and being connected at a point thereon above said opening to a branch conduit, said opening providing, without removal of the piping, for removal of solids, such as said plugs, which are forced into said piping.

3. In a steam generator of the type described, generating elements consisting in a plurality of trays of long small bore tubes connected to headers substantially at right angles thereto, said headers being parallel and in the same plane and being provided at one end with nipples, a supporting framework for said upper headers comprising in combination a channel frame inclined along the plane of the headers and provided with perforations adapted to permit passage of the nipples and header ends therethrough, an inclined distributing pipe extending lengthwise of the channel and provided with perforations registering with the channel perforations, said nipples being expanded into the perforations of the distributing pipe, an angle parallel to said channel extending along the opposite ends of the headers, and having its edge cut so as to fit over the upper semicircumference of the headers being cut so as to permit passage of the header thereunder, the header ends extending beyond and under said angles and perforated detachable L-plates attached to said angle and fastening over said header ends, whereby any tray may be removed or inserted by making or breaking the expanded joint in the distributing pipe and by removal of the corresponding L-plate without requiring the removal or disturbance of any tray.

4. A plurality of generating tubes forming a substantially rectangular generating space, a generator shell surrounding said space and consisting in a circular external metal shell, insulation filling the space between the said shell and the generating space, an opening door in said shell extending the full length of one side of the generating space and having its insulation associated therewith to form a unit, and cross braces extending parallel and along the generating space to the shell, two of said braces being substantially straight and defining with the external shell segments, the other two being bent at one corner of the space and serving to define the door unit, and circumferential bracing means attached to the inner wall of the metal shell at a plurality of levels.

5. A generator according to claim 4, in which the generator space is surrounded by a heat and abrasion resistant reinforced refractory cement lining, said lining extending from the adjacent corner of the generator space to the door opening and conforming to the cross braces defining therewith the heat passage and serving with the metal shell as a bracing wall for the heat insulating material thereon.

6. The combination with a steam generator having steam generating elements in the form of relatively long tubes, of a shell surrounding the tubes and provided with a door opening extending the full length of the tubes, insulation between the shell and the tubes forming a passage for the heating gases along the tubes, and means for maintaining the gas passage in alignment comprising a plurality of columns supporting the shell, said columns being so arranged that at least one of the columns is adjacent to the door opening.

7. The combination with a steam generator having steam generating elements in the form of relatively long tubes, of a shell surrounding the tubes and provided with a door opening extending the full length of the tubes, insulation between the shell and the tubes forming a passage for the heating gases along the tubes, and means for maintaining the gas passage in alignment comprising a plurality of columns supporting the shell and transverse braces arranged at intervals and bracing the shell and supporting said insulation.

8. In combination with a steam generator having steam generating elements in the form of relatively long, small-diameter tubes, insulation enclosing the tubes and forming a gas passage along which the heating gases are adapted to be conducted at high velocity, the inner face of said insulation being provided with heat and abrasion resistant lining immediately surrounding the gas passage, and transverse braces arranged at intervals for supporting the insulation and bracing said lining and shell.

9. A steam generator comprising a casing enclosing a space of long length relative to the cross section thereof, a plurality of parallel trays of relatively long, small bore generating tubes mounted within said casing and extending lengthwise of said space, means supporting said trays but permitting removal thereof by a motion transverse to the length of the casing and substantially in the plane of the tray, an opening door in said casing extending the full length of the trays and arranged with respect thereto so that when opened any tray may be removed without dismantling the casing and without affecting any other tray, said casing consisting in an external metal shell provided with insulation filling the space between the metal and the tubes, the insulation associated with the door portion of the casing being movable as a unit therewith.

10. Heat exchange apparatus comprising

a shell enclosing a gas passage tapered lengthwise of said shell, tubular heat exchange elements mounted lengthwise in said passage, tubular headers to which sets of the tubular elements are connected to form trays having a header at each end of the passage, each tray being removable as a unit and having the elements more closely spaced in the header which is at the smaller end of the tapered passage than in the header at the larger end of the passage.

11. Heat exchanger according to claim 10 in which the spacing between the trays is less at that end of the passage at which the tubes are more closely spaced in the headers than the spacing between the trays at the other end of the passage.

12. A steam generator comprising a generator shell having an opening through which hot gases are admitted at one side of the shell, said shell enclosing a central gas passage, steam generating tubes arranged in sets across the gas passage, the tubes extending along the passage and being connected at their ends to headers, the headers near the gas inlet end being arranged in stepped formation but out of contact with the gases flowing from the opening across the generating tubes whereby said flow is directed along the length of the tubes.

13. The combination with a steam generator having generating elements in the form of relatively long tubes of small diameter, upper and lower headers connecting the ends of the tubes, a support for the tubes at the bottom on which the lower headers rest, means including a support for the upper headers arranged to maintain a spaced relation therebetween and which serves to brace the tubes at the top against substantially lateral motion while leaving them free for movement lengthwise of the tubes.

14. A steam generator comprising a group of steam generating tubes arranged closely together and extending in the same general direction, a plurality of headers at one end of the group and each connected to the ends of a set of the tubes, a plurality of headers at the other end of the group and each connected to the ends of a set of tubes, a support for the headers at one end of the group arranged to prevent lengthwise motion of the tubes at that end, and means including a support for the headers at the other end of the group which serves to brace the tubes against substantial lateral motion while leaving them free to expand lengthwise.

Signed at New York, New York, this 9th day of October, 1926.

WALTER DOUGLAS LA MONT.

CERTIFICATE OF CORRECTION.

Patent No. 1,850,281. March 22, 1932.

WALTER DOUGLAS LA MONT.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 5, line 130, for "tapering" read tapered; page 11, line 36, for the number "32,964" read 32,064; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 12th day of July, A. D. 1932.

M. J. Moore,
Acting Commissioner of Patents.

(Seal)