G. ENGEL.

BOILER.

APPLICATION FILED SEPT. 8, 1905.

948,271. Patented Feb. 1, 1910.

3 SHEETS—SHEET 1.

Fig. 1,

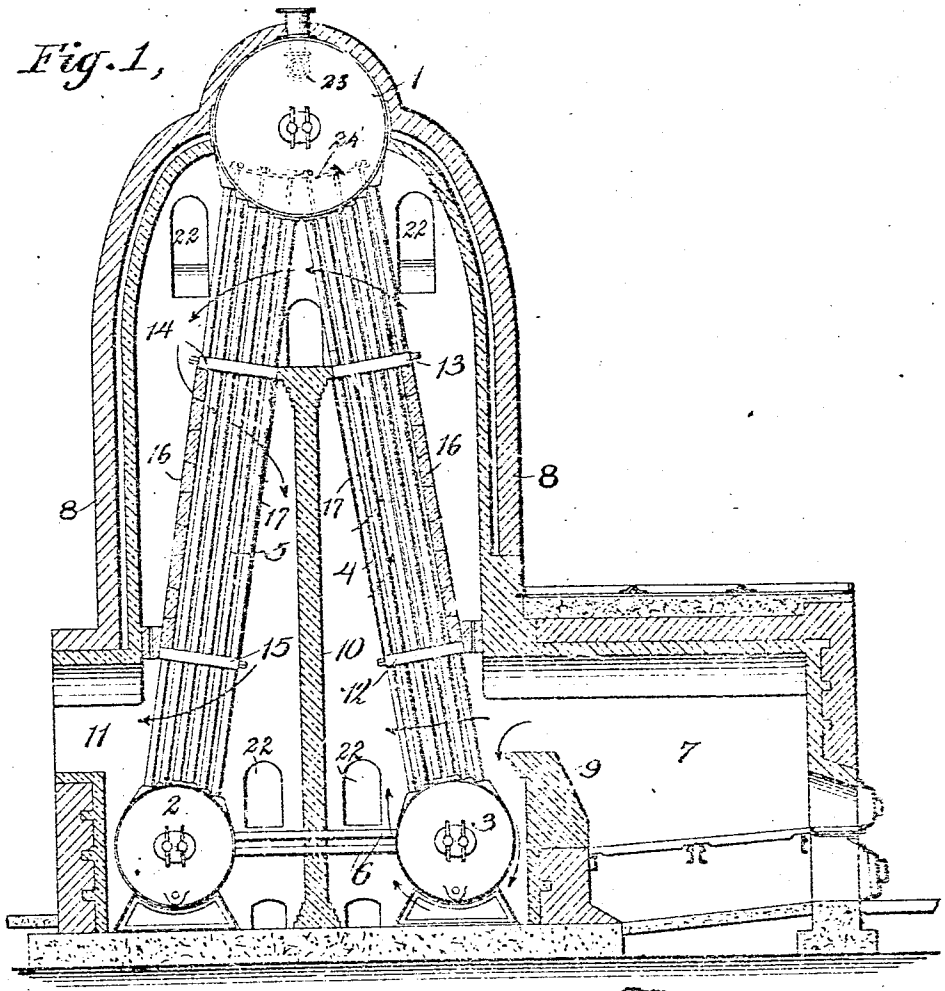
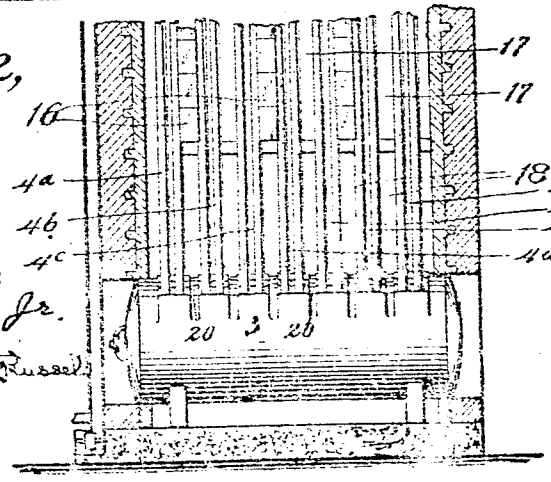


Fig. 2,



WITNESSES:

L. L. Andrews Jr.

Russell B. Russell

INVENTOR

Godfrey Engel

BY

H. M. Marble

ATTORNEY

G. ENGEL.

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3 SHEETS—SHEET 2.

Fig. 3,

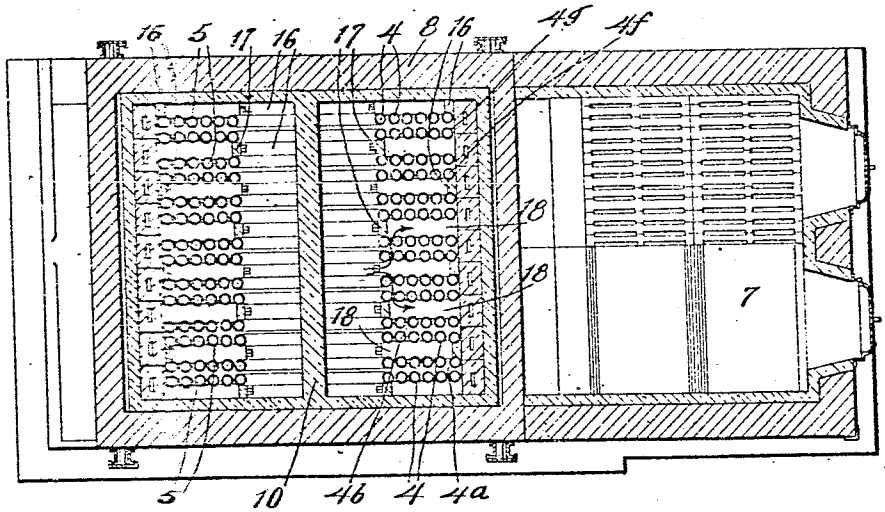


Fig. 4,

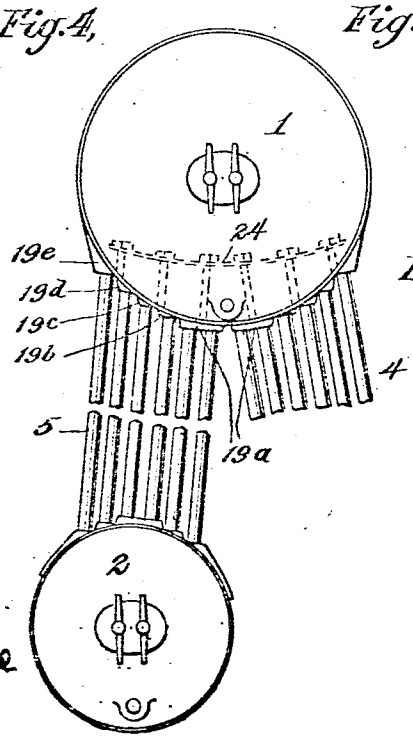


Fig. 5,

Fig. 6,

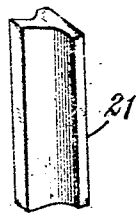
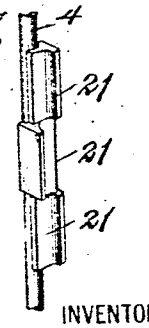


Fig. 7,



WITNESSES:

Y. S. Andrews Jr.

Russell B Russell

INVENTOR

Godfrey Engel

BY H. M. Marble

ATTORNEY

G. ENGEL.

BOILER.

APPLICATION FILED SEPT. 8, 1905

948,271. Patented Feb. 1, 1910.

3 SHEETS—SHEET 3.

Fig. 8,

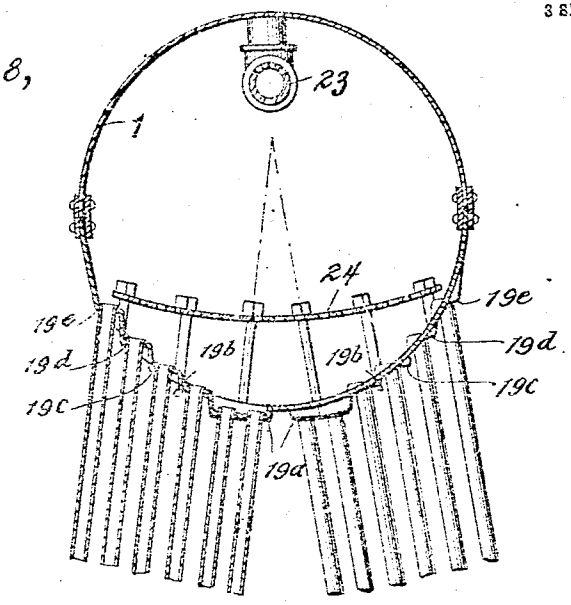


Fig. 9.

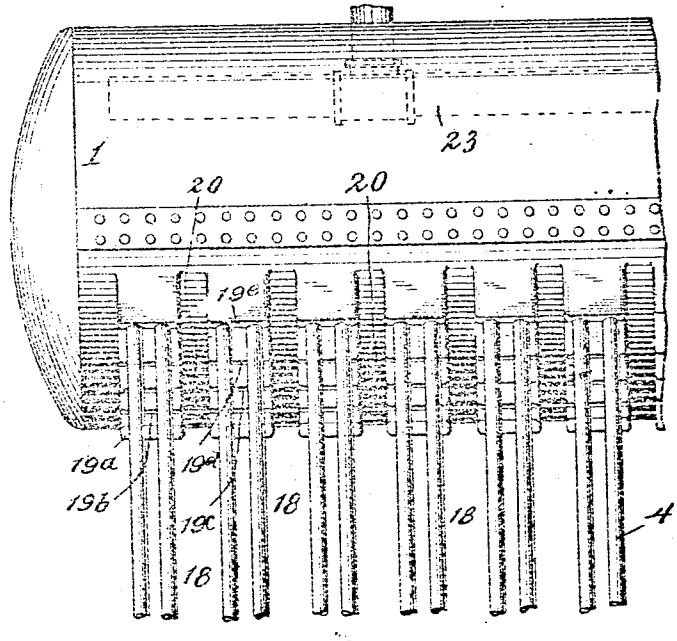
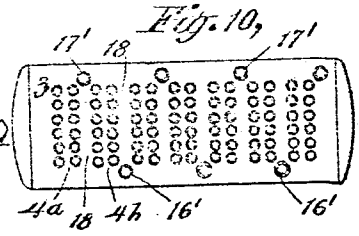


Fig. 10,



WITNESSES:

L. S. Andrews Jr.

Russell B Russell

INVENTOR

Godfrey Engel

BY H. McMath

ATTORNEY

UNITED STATES PATENT OFFICE.

GODFREY ENGEL, OF PITTSBURG, PENNSYLVANIA.

BOILER.

948,271. Specification of Letters Patent. Patented Feb. 1, 1910.

Application filed September 8, 1905. Serial No. 277,554.

To all whom it may concern:

Be it known that I, GODFREY ENGEL, a citizen of the United States, residing in Pittsburg, in the county of Allegheny and State of Pennsylvania, have invented certain new and useful Improvements in Boilers, of which the following is a specification.

My invention relates to improvements in boilers, and particularly to improvements in water-tube boilers, all as hereinafter fully set forth and particularly pointed out in the claims.

The objects of my invention are, first, to produce a compact, efficient boiler of high capacity in proportion to size, weight, and heating surface; second, to avoid restriction of circulation, and particularly restriction of streams of mixed water and steam, to cause the generating tubes to deliver directly into a relatively large drum, affording ample space for disengagement of water from the steam, and to cause such disengagement to take place principally, and as nearly as possible entirely, in the upper drum; third, to insure thorough and rapid natural circulation of the water in the boiler, and the heating of the feed water to mean boiler temperature before it encounters the hottest portions of the boiler, and to keep covered with water all parts of the boiler which are exposed to the direct action of the furnace gases; and fourth, to prevent formation of scale in the tubes and drums and to cause all sediment to be deposited in mud drums; fifth, to insure dry steam, to avoid foaming, to prevent projection of spray into proximity to the place or places from which steam is taken off; sixth, to cause the furnace gases to circulate through the boiler in an improved manner, to equalize the circulation of the gases about and along the surface of the tubes, to cause said tubes to be exposed constantly to fresh portions of the furnace gases, avoiding dead spaces or portions of the tube to which heat is imparted indirectly rather than directly, to make the entire heating surface of the boiler highly efficient, and to provide a relatively long path for the gases, in proportion to the length of the tubes and their arrangement, permitting the grouping of the tubes in a relatively small number of banks of tubes, and permitting the use of a relatively small number of drums, while insuring efficient transfer of heat from the gases to the water and the lowering of the temperature of said gases to a relatively great degree; seventh, to obtain high furnace efficiency; eighth, to permit the use of bricks or tiles of simple and strong form for the construction of the various baffle walls and partitions, to key together the sections of the baffle walls arranged longitudinally on the tubes, and to permit the main dividing baffle wall to be vertical, and to be built of ordinary fire brick laid with close joints, so as to avoid short-circuiting of the gases, and to permit the baffles to be removed and replaced at will, and without difficulty; ninth, to make the boiler simple, compact and durable, to render stays unnecessary and avoid the use of stayed members, to permit all parts to be made of rolled steel, to obtain maximum strength with minimum weight, to make proper provision for expansion and contraction, to make all parts easy of access, to avoid the necessity of exceptional skill on the part of the attendants, and to make the boiler easy to operate, clean and maintain; and lastly, to permit forcing of the boiler and to permit the use of strong draft in the operation thereof, with high economy of operation.

One of the important objects of my present invention is to improve the drums of such boilers, and particularly the tube sheets thereof, so that while provision is made for facilitating the insertion and withdrawal of the tubes, the tendency to distortion and harmful stretching of the metal is reduced to a minimum and great economy in the metal is effected, due to the fact that the distribution of the metal in the formation of the tube seats is to a large extent in the lines of strain.

My invention is capable of being embodied in boilers of many different types, adapted for many different uses and for use with many different types of fuel. I have not attempted to illustrate all of the forms in which my improved invention may be embodied, or to illustrate all of the modifications and alternative constructions which may be employed or devised without departing from the spirit and scope of the invention, but in the accompanying drawings have illustrated one type of boiler embodying my invention, said boiler being of the stationary type. Many of the features of invention illustrated in said drawings are capable of being used in boilers of different construction, and in connection with

other features of different construction and method of operation than those herein illustrated, as will be apparent to those skilled in the art.

The particular boiler illustrated herein as embodying the features of invention hereinafter claimed, is of a novel type, comprising an upper steam and water drum and a plurality of lower drums (two, in the instance shown), said drums all connected by tubes, the arrangement illustrated in the drawings resembling the letter A, or a triangular figure. In connection with the drums and tubes thus arranged I provide a furnace or other means for supplying heating gases, and preferably, though not necesarily, I cause said heating gases to flow up along one of the main series or banks of generating tubes connecting the upper drum with the lower drum, and down along another such bank of tubes: and I may also provide means whereby the heating gases are caused to flow across, along and around substantially the entire length and surface of each of such tubes, thereby providing a relatively long path for the gases in a relatively compact and simple boiler, keeping the furnace gases at all times in contact with or in effective proximity to the heating surface of the boiler, and constantly exposing new portions of the gases to such heating surface, avoiding stagnation of the gases and indirect transmission of heat.

In the accompanying drawings, Figure 1 shows an elevation of one form of my improved boiler, the walls thereof being shown in section. Fig. 2 shows a detail side view of one of the lower drums and its tubes, and illustrates the grouping of the latter. Fig. 3 shows a horizontal section of the boiler, looking downward. Fig. 4 shows a detail end elevation of the upper and one of the lower drums, and the tubes thereof. Fig. 5 shows a longitudinal section of one of the transverse baffles. Figs. 6 and 7 are detail views of the longitudinal baffles, Fig. 6 being a perspective elevation of one of the baffle sections, detached, and Fig. 7 showing in perspective a row or wall of such sections, arranged as in practice, in connection with one of the tubes. Fig. 8 shows a vertical transverse section of the upper drum, illustrating particularly the construction thereof, the section being taken on two different planes. Fig. 9 shows a side view of such drum and its tubes. Fig. 10 shows a plan view of a lower drum and a cross-section of the tubes thereof, and illustrates the use of tubes as longitudinal baffles.

Referring to the drawings, 1 designates the said steam and water drum; 2 and 3 designate the said mud drums; 4 and 5 designate the said banks of inclined generating tubes; 6 designates tubes connecting the mud drums 2 and 3; and 7 designates the said furnace. The drums, 2 and 3, and the tubes 4, 5 and 6 together constitute a closed circulating circuit, all within the main heating chamber formed by the brick walls 8 of the boiler setting, through which circuit the water will circulate very rapidly and freely while the boiler is in operation. In the particular construction shown the furnace, 7, is of the external type, being located in the main outside of the setting 8. This arrangement of the furnace has the advantage that combustion within the furnace is not prevented by the presence of relatively cool heating surfaces, there being no contact of the gases with the heating surface of the boiler until said gases pass the bridge wall 9. However, I do not confine myself to this location of the furnace, but may locate it otherwise as may prove convenient, effective, or otherwise desirable.

Between the two banks of tubes, 4 and 5, I provide a main dividing wall or vertical baffle, 10, supported at the bottom by the boiler foundation. This baffle wall, being vertical and of simple construction, and well supported, may be built of ordinary fire brick, laid with close joints, and so substantially impervious to the furnace gases. This wall forces the furnace gases as they enter the heating chamber to flow, in the first instance, upward along the bank of tubes 4, and then downward along the tubes 5, thus insuring a relatively long path for the furnace gases in a relatively compact heating chamber comprising a relatively small number of banks of tubes. The gases are further caused to cross tubes 4 at right angles when first entering the heating chamber, and to cross tubes 5 at right angles in passing from the heating chamber into the offtake 11. By means hereinafter described I further prolong the path of the furnace gases within said chamber and insure a very effective action of the furnace gases on the tubes 4 and 5 and on the under surface of the drum 1, which surface constitutes highly efficient heating surface. When the furnace gases first enter the heating chamber, a portion of said gases pass down, under and around the mud drum 3, and up through the spaces between tubes 6, thus making drum 3 and tubes 6 effective as heating surface.

It is well recognized that for effective transfer of heat from furnace gases to heating surface, fresh portions of the gases should be impinging on the heating surface at all times. If the gases merely flow parallel to the tubes of the boiler, there is a tendency for the portions of the gases which first impinge upon said tubes to remain in contact, or substantially in contact, therewith, until the direction of flow is changed or the ends of the tubes are reached; and such portions of the gases as do not impinge upon the mediately, while the heat of such portions

of the gases as do not impinge upon the tubes reaches the latter, if at all, only by transmission through the already-cooled bodies of gas. Furnace gases being extremely poor conductors of heat, mere parallel flow of the gases is productive of inefficiency, and is to be avoided. To avoid this defect, it has been common to cause the gases to flow as nearly as possible transversely of the tubes, the entire current of furnace gases being caused to pursue a very tortuous course, crossing and recrossing the same bank of tubes a number of times. The defects of this practice are, that considerable portions of the several tubes are practically out of the main current of furnace gases, and are practically dead, that considerable portions of the currents of furnace gases are at a considerable distance from heating surface, and are therefore ineffective, that somewhat complicated arrangements of baffles are required which for structural reasons are apt to be full of openings which permit short-circuiting of the gases, and that the sides of the tubes opposite those on which the gas currents impinge are relatively ineffective as heating surface. To avoid the characteristic defect, above pointed out, of the mere parallel flow of the gases, it is not necessary to go to the extreme of making the gases cross the tubes at right angles, or nearly so. It is sufficient to cause the gases to flow at a slight angle to the tubes, thus producing, in effect, a gradual translation of the current of gases across the tubes while said current is flowing lengthwise of the tubes; by which translation fresh portions of the furnace gases are constantly brought into contact with the surface of the tubes, the gas is prevented from "stagnating", so to speak, about said tubes, and all the benefits of transverse flow of the furnace gases are realized without considerable portions of said tubes being out of the main current, *i. e.*, "dead".

By the arrangement of transverse and longitudinal baffles, or their equivalents, employed in my boiler, I produce such a motion of translation of the currents of furnace gases with respect to the tubes while said gases are flowing along the tubes, and at the same time cause the gases to flow in and out around and between the tubes so that the heating of the tubes is equalized, all portions of the surface of the tubes subjected to such nearly-parallel currents being subjected almost equally to the action of such gases, so that practically the entire surface of each tube is utilized in the most efficient manner as heating surface. Referring now to this feature of my invention as embodied in the construction illustrated in the drawings, I provide the two banks of tubes, 4 and 5, with four transverse baffle walls 12, 13, 14 and 15, and I also provide said banks of tubes with longitudinal baffle walls, 16 and 17, (for the latter see Fig. 3) located between the transverse baffles 12 and 13, and 14 and 15, the walls 17 on the inner side of each bank of tubes, the walls 16 on the outer side of each bank. The longitudinal walls 16 and 17 are each relatively narrow, with spaces 18 between for the flow of the gases, there being a number of walls 16 and 17 for each bank of tubes, as shown particularly in Figs. 2 and 3. In practice I customarily arrange the tubes of each bank in a plurality of groups, each group comprising a plurality of rows of tubes (two rows, in the construction shown), each group separated from the adjacent groups by spaces somewhat wider than the distance between the rows comprising each group. Thus, in the arrangement shown, the tubes of bank 4 are arranged in groups 4^a, 4^b, 4^c, etc., each comprising two rows of tubes, and the tubes of bank 5 are similarly arranged. The principal reason for employing this arrangement of tubes will be pointed out hereafter; but said arrangement has the important advantage, in this connection, of greatly facilitating the use of baffles, or their equivalents, to cause the peculiar circulation of the gases between the tubes, in a direction parallel to the front of the boiler, means to produce which forms one of the principal features of my invention. The tubes being arranged in groups, as described, I employ the baffle walls 16 to close alternate spaces between groups on the outer side of the banks 4 and 5, and similarly employ walls 17 to close alternate spaces between groups on the inner side of banks 4 and 5, the intermediate spaces between groups, designated by numerals 18, being left open; but the walls 16 and 17 are not opposite, but are staggered, and so are the openings 18, as a result. The effect is that gases entering openings 18 between walls 17 of bank 4, cannot pass directly through said openings to the outside, but must flow between the tubes, in a direction parallel to the front of the boiler, to the spaces between the tubes of the adjacent groups, and to the openings 18 beyond. This flow of the gases is indicated by arrows in the drawings. By this arrangement of baffles, the entire portion of the tubes between transverse baffles 12 and 13, and 14 and 15, are surrounded by furnace gases flowing not only longitudinally, but also transversely, with respect to said tubes, in a manner to insure the highest efficiency of heating surface, and to insure substantially the same efficiency for all portions of the heating surface of said tubes exposed to such currents. At the same time, the gases flow in a relatively direct path, and through openings of ample area, so that excessive draft is not required. The tubes being very nearly vertical, ash and dust cannot collect on them,

and therefore the transmission of heat is not interfered with by deposits of such substances.

Instead of employing baffle walls 16 and 17, as above described, I may employ generating tubes 16′ and 17′, as shown in Fig. 10, said tubes taking the place of baffle walls and serving in effect as baffles, while at the same time also constituting very effective heating surface. Such tubes are intended to be included within the terms "baffles" and "baffle walls" as used herein and in the claims. Such tubes, when used, will connect the drums, constituting in fact parts of banks 4 and 5.

The primary reason why I prefer to arrange the tubes of banks 4 and 5 in groups, as shown, is to facilitate tubing and retubing of the boiler, and to permit the ready removal of any tube when desired. In this connection I commonly employ drums 1, 2 and 3 having tube-sheets of peculiar construction, so that to remove any tube, when it has been freed at one end from the upper drum, for example, its end so freed may be moved slightly to one side, into one of the spaces between groups of tubes, and then the tube may be lifted slightly, so as to unstep it at the bottom, after which it may be removed through one of the spaces 18 between groups of tubes. One construction of tube sheet which I may employ for this purpose is illustrated in Figs. 8 and 9. By pressing or otherwise, I form a plurality of directly connected steps, 19^a, 19^b, etc., the faces of which steps are substantially perpendicular to the rows of tubes. Each such step is usually of such width (longitudinally of the drum) that it will take tubes of all of the rows of the tube group to which it corresponds, and it may be of sufficient length (transversely of the drum) to take more than one tube of each row. This is true, in the construction shown, of steps 19^a. The first two or three steps from each row, (counting from the middle) as 19^a and 19^b, are commonly raised somewhat beyond the cylindrical surface of the drum, so that between them there are spaces or grooves 20 of such depth that when the end of a tube has been freed from its hole in such drum it may be moved over opposite such space or groove 20 (which spaces or grooves correspond to the wide spaces 18 between the groups of tubes) and may then be moved longitudinally into such space or groove to permit freeing of the other end of the tube from the drum to which it is connected. It is not necessary, however, to raise completely from the surface of the drum the steps which are well up or down on the side of the drum (as for example, steps 19^c, 19^d, and 19^e), as the tubes seated in such steps may be sprung outward, as well as to one side so as to permit them to be moved longitudinally enough to free their outer ends. Consequently the steps 19^c, 19^d, and 19^e are formed by pressing the metal partly in and partly out from the true cylindrical curvature, as shown in Fig. 8, which shows sections on two planes, the left side showing a section through one series of steps, the right side showing a section through one of the intervening spaces or grooves 20 between two series of steps. The steps of each series are directly connected, one to another, the extreme opposite edges of each step being on opposite sides of the mean curvature of the drum, which mean curvature is maintained between said series. Furthermore, the general slope of each series of steps conforms to the mean curvature of the drum, and the use of man-holes is rendered unnecessary.

The sides of the raised steps 19^a and 19^b form ribs which materially stiffen the drum. In the construction shown, the faces of the steps 19^a of drum 1 are of a curvature approximating arcs of circles struck from the points of intersection of the mean axes of the tubes entering such surfaces, said surfaces being, therefore, approximately perpendicular to the tubes entering them. However I do not limit myself to giving such surfaces any precise curvature, or to giving them any curvature at all.

The transverse baffles 12, 13, 14 and 15 are composed of bars such as illustrated in Fig. 5, adapted to be inserted between the tubes edgewise, *i. e.*, with their sides of greater width vertical, and then to be turned. These baffles are held in place by the pressure of the tubes against them, said tubes being sprung apart, slightly, when inserting the baffles, so that when the tubes are released the baffles will be held by spring action of the tubes. Preferably, the edges of the transverse baffles are grooved or corrugated, so as to surround partly the tubes adjacent to them.

Another feature of my invention resides in the construction of the baffle walls 16 and 17; and this feature is illustrated particularly in Figs. 6 and 7. Said walls are composed of sections 21 of fire-clay or other suitable material, said sections being each wider at one end than at the other, the narrow end of each section adapted to be inserted between the tubes, the wider end being too wide for such insertion. The upper and lower faces of the sections are also inclined or beveled, the narrow end of each section being higher than the wide end. In setting up these sections, alternate sections (vertically) are inserted from opposite sides of the tubes, the beveled surfaces matching so that the wall thus formed is parallel with the tubes, and fits closely thereto. The sections then key each other, so that they may not be displaced accidentally. It will be

noted that the form of the sections by which this highly desirable keying together is secured, is a very simple one, and that the sections may be made very easily.

Suitable doors 22 are provided to afford access to the heating chamber at a number of points. It will be noted that all parts of the boiler are very accessible. The hand may be placed on any tube or baffle of the boiler, and in case of breaking of the baffles, new ones may be put in at any time. Tubes may be taken out and replaced without difficulty. The construction of the boiler is such that there is ample opportunity for expansion and contraction without straining the parts. No stayed surfaces are required.

In the operation of my boiler, the products of combustion from the combustion chamber 7 divide, part of them passing directly across the bank of tubes 4, while another part of said gases passes down under drum 3, up across tubes 6, joining the first branch of the stream. Said gases then pass through the openings 18 between baffles 17 of tubes 4, between, around, and upward along the said tubes, passing out through openings 18 between baffles 16. The gases also pass through the spaces between the tubes of each group, which openings are not closed by baffles, either longitudinal or transverse. The peculiar circulation of the furnace gases thereby produced insures the uniform heating of the tubes, in the most efficient manner, new portions of the furnace gases being brought constantly into contact with the tubes. The gases then cross tubes 4 and 5 transversely, above baffles 13 and 14, and below drum 1, which drum is thereby exposed to the heating action of said gases, its lower surface constituting effective heating surface. The gases then pass between the baffles of tubes 5 and circulate between, around and along the same in the same manner as with tubes 4, but passing in the opposite direction; and finally said gases pass across tubes 5, below baffle 15, into the off-take 11.

The gases will be materially cooler when they encounter tubes 5 than when they encountered tubes 4, and therefore there will be very rapid circulation of water from drum 1 downward through tubes 5 to drum 2, thence through tubes 6 to drum 3, and thence upward through tubes 4 to drum 1, insuring high capacity of the boiler in proportion to size and heating surface. The tubes 4 discharge directly, through unobstructed openings, into drum 1, and therefore the disengagement of the steam from the water will take place almost entirely in drum 1, where there is ample room for such disengagement. In boilers in which the flow of the water from the tubes to the drum is restricted, disengagement of steam from the water sometimes occurs to a great extent in the tubes themselves; and this may result in burning of the tubes. Such burning is impossible in my boiler, however, so long as a proper water level is maintained; and while it is desirable that the water level shall always be above the bottom of drum 1, it is known that such level may fall considerably below the bottom of the drum, the action within tubes 4 being sufficient to keep the surfaces of said tube and the surface of the lower portion of the drum wet, even when the water level is below the bottom of drum 1.

I commonly introduce the feed water into drum 1, in proximity to the mouths of tubes 5, and cause it to mix with the water flowing down through said tubes into drum 2. In this way the water will be heated thoroughly to mean boiler temperature, before it encounters the tubes 4, and the sediment which the feed water may carry will be deposited in drums 2 and 3—the most of it in drum 2 under normal conditions.

To insure dry steam, and keep the water level the same in all parts of the drum 1, I commonly take the steam off through a dry-pipe 23, perforated on top. In practice I have found that if steam be taken off at a few points only, the water level is much higher below the points at which the steam is taken off than at other points. The dry-pipe, extending substantially from one end of the drum to the other, obviates this.

To prevent projection of water from tubes 4 upward into the steam space of drum 1, I may provide perforated plates 24 above the mouths of said tubes.

Because of the efficient circulation of water in my boiler, and the very efficient circulation of the furnace gases along and around the tubes and other heating surface, the boiler may be operated, with high efficiency, with very strong draft, and thus may be forced far beyond what, according to ordinary methods of rating, would be considered its normal capacity. This fact, and the ability of the boiler to operate without injury even when the water level falls far below the normal level, especially adapts the boiler for use where the demand varies suddenly through wide limits.

It will be noted that my construction of tube sheet enables me to use straight tubes, which in the construction of boilers of this character is a matter of very great economic value.

I claim as my invention:—

1. In a boiler, the combination with a circulating system comprising a plurality of drums, upper and lower, and a plurality of connecting banks of generating tubes arranged for circulation of water between said upper and lower drums, of means for directing heating gases along said tubes comprising separate passages, each inclosing one of said banks of tubes connecting the

upper and lower drums, and arranged substantially longitudinally with respect to said tubes, said passages connected in series, and a transverse baffle within the first of such passages, extending across tubes therein.

2. In a boiler, the combination with a circulating system comprising a plurality of drums, upper and lower, and a plurality of connecting banks of generating tubes arranged for circulation of water between said upper and lower drums, of means for directing heating gases along said tubes comprising separate passages, each inclosing one of said banks of tubes connecting the upper and lower drums, and arranged substantially longitudinally with respect to said tubes, said passages connected in series, and transverse baffles in said passages, one of said baffles in the first such passage and extending across tubes therein.

3. In a boiler, the combination with an upper and a plurality of lower drums, tubes connecting said upper drum with each of said lower drums, and other tubes connecting the sides of said lower drums, said drums and tubes together constituting substantially a closed geometrical figure, of a dividing wall separating the banks of tubes connecting the upper drum with the lower drums, and transverse baffles extending from the top of said wall transversely across said banks of tubes.

4. In a boiler, the combination with an upper and two lower drums, tubes connecting said upper drum with each of said lower drums, and other tubes connecting the sides of said lower drums, said drums and tubes together constituting substantially a closed geometrical figure, of a dividing wall separating the banks of tubes connecting the upper drum with the lower drums, means for supplying heating gases, connected to the space on one side of such wall, and transverse baffles extending across the banks of tubes on the side at which such gases enter, one such baffle located above such point of entry, the other at a higher point.

5. In a boiler, the combination of an upper and a plurality of lower drums, series of tubes connecting said upper drum with each of said lower drums, other series of tubes connecting the sides of said lower drums, and means for directing heating gases between and against said series of tubes comprising a dividing partition and transverse and longitudinal baffles.

6. In a boiler the combination of an upper and two lower drums, two series of tubes connecting said upper drum with each of said lower drums, another series of tubes connecting the sides of said lower drums, means for supplying heating gases, and means directing such gases between and against said last-mentioned series of tubes and along said two first-mentioned series of tubes comprising a dividing wall and baffles extending transversely across said two first-mentioned series of tubes, one such baffle located immediately above the point of entry of the heating gases.

7. A boiler comprising an upper drum and a plurality of lower drums and separate banks of tubes connecting said upper drum with each of said lower drums, in combination with means directing heating gases in alternately opposite directions along said banks of tubes, comprising separate passages for said banks of tubes and transverse baffles therein, one of said baffles within the first of said passages, the flow of said gases being upward along one of such banks and downward along the next.

8. A boiler comprising an upper drum and a plurality of lower drums and separate banks of tubes connecting said upper drum with each of said lower drums, in combination with means directing heating gases in alternately opposite directions along said banks of tubes comprising separate passages for said banks of tubes having staggered longitudinal baffles with openings between.

9. A boiler comprising an upper and two lower drums and two banks of tubes each connecting said upper drum to one of said lower drums, in combination with means directing heating gases upward along one of said banks of tubes and downward along another bank thereof comprising a dividing wall and transverse and longitudinal baffles, the latter staggered with openings between.

10. A boiler comprising a plurality of drums, upper and lower, a plurality of banks of tubes connecting said upper and lower drums, means forming separate longitudinal passages for each of said banks of tubes comprising a dividing partition and side walls, said passages connected in series, a furnace discharging heated gases across one such bank of tubes toward said dividing wall, and a transverse baffle crossing such bank of tubes immediately above the point of impinging of such gases thereon.

11. A boiler comprising an upper and two lower drums and two banks of tubes each connecting said upper drum to one of said lower drums, in combination with a furnace, a partition separating said banks of tubes for directing gases from said furnace upward along one of said banks of tubes and downward along another bank thereof, and transverse baffles crossing said banks of tubes near the top of said partition and below said upper drum.

12. A boiler comprising an upper and two lower drums and banks of tubes connecting said upper drum to each of said lower drums, in combination with a furnace, a heating chamber inclosing said tubes and having a dividing baffle wall, and transverse baffles

crossing said tubes near the top of said wall and below said upper drum, and other transverse baffles crossing said tubes at lower points.

13. A boiler comprising an upper and two lower drums and banks of tubes connecting said upper drum to each of said lower drums, in combination with a heating chamber, inclosing said tubes, and having a dividing baffle wall, transverse baffles in said chamber crossing said tubes, and longitudinal baffles on opposite sides of said banks of tubes having staggered openings, and means for supplying heating gases.

14. A boiler comprising an upper and two lower drums and banks of tubes connecting said upper drum to each of said lower drums, in combination with a heating chamber inclosing said tubes and having a dividing baffle wall, means for admitting heating gases to one side of said wall, transverse baffles on each side of said wall crossing said tubes, near the top of said wall and below the upper drum, other transverse baffles crossing said tubes at lower points, and longitudinal baffles between the transverse baffles having staggered openings.

15. A boiler comprising an upper and two lower drums and two banks of tubes each connecting said upper drum to one of said lower drums, in combination with a heating chamber including said tubes and having a dividing baffle wall between said banks of tubes and a source of supply of heating gases on one side of said dividing wall and means for the escape of such gases on the other side of said wall, and transverse baffles for the first of said banks of tubes causing the heating gases to flow across and along the tubes.

16. A boiler comprising an upper and two lower drums and two banks of tubes each connecting said upper drum to one of said lower drums, in combination with a heating chamber inclosing said tubes and having a dividing baffle wall between said banks of tubes and a source of supply of heating gases on one side of said dividing wall and means for the escape of such gases on the other side of said wall, and transverse and longitudinal baffles causing said gases to flow across, along and around said tubes.

17. A boiler comprising an upper and two lower drums and two banks of tubes each connecting said upper drum to one of said lower drums, in combination with a heating chamber inclosing said tubes and having a dividing baffle wall and a source of supply of heating gases on one side of said dividing wall, and means for the escape of such gases on the other side of said wall, and transverse and longitudinal baffles causing said gases to flow across, along and around said tubes.

18. A boiler comprising an upper and two lower drums and two banks of tubes each connecting said upper drum to one of said lower drums, in combination with a heating chamber inclosing said tubes and having a dividing baffle wall and a source of supply of heating gases on one side of said dividing wall, and means for the escape of such gases on the other side of said wall, and two transverse baffles for each said bank of tubes, one located near the lower end thereof and the other near the other end thereof.

19. A boiler comprising an upper and two lower drums and two banks of tubes each connecting said upper drum to one of said lower drums, in combination with a heating chamber inclosing said tubes and having a dividing baffle wall and a source of supply of heating gases on one side of said dividing wall and means for the escape of such gases on the other side of said wall, transverse baffles for one or both of said banks of tubes located one near the lower end thereof and another near the upper end thereof, and longitudinal baffles between said transverse baffles.

20. In a boiler, the combination with a series of generating tubes, and a heating chamber inclosing the same having means for supplying heating gases and an off-take, of longitudinal baffles for said series of tubes, located on opposite sides of said series, staggered openings between said baffles being provided for the flow of heating gases across the tubes.

21. In a boiler, the combination with a series of generating tubes, and a heating chamber inclosing the same having means for supplying heating gases and an off-take, of longitudinal and transverse baffles for said series of tubes, the longitudinal baffles located on opposite sides of said series, staggered openings between said longitudinal baffles being provided for the flow of the heating gases along and across said tubes.

22. A boiler comprising two drums, series of tubes connecting the same, and a heating chamber inclosing said series of tubes and having means for supplying heating gases and an off-take, in combination with longitudinal baffles located on opposite sides of said series of tubes, staggered openings between said baffles being provided for the flow of heating gases across said tubes.

23. A boiler comprising two drums, series of tubes connecting the same, and a heating chamber inclosing said series of tubes and having means for supplying heating gases and an off-take, in combination with longitudinal and transverse baffles for said series of tubes, the former located on opposite sides of the series, staggered openings between said longitudinal baffles being provided for the flow of heating gases along and across said tubes.

24. A boiler comprising an upper and two lower drums, and two banks of tubes each connecting said upper drum to one of said

lower drums, in combination with a heating chamber inclosing said banks of tubes, and having a dividing baffle wall between said banks of tubes and means for supplying heating gases on one side of said wall and an off-take on the other side thereof, and transverse and longitudinal baffles for each bank of tubes, staggered openings between said longitudinal baffles being provided for the flow of heating gases along and across said tubes.

25. A boiler comprising an upper and two lower drums, and two banks of tubes each connecting said upper drum to one of said lower drums, in combination with a heating chamber inclosing said banks of tubes, having a dividing baffle wall between said banks of tubes and an off-take on one side thereof, a furnace outside of said chamber connected thereto on the other side of said wall, and upper and lower transverse baffles and longitudinal baffles for each bank of tubes, staggered openings between said longitudinal baffles being provided for the flow of heating gases along and across said tubes.

26. A boiler comprising an upper and two lower drums, and two banks of tubes each connecting said upper drum to one of said lower drums, in combination with a heating chamber inclosing said banks of tubes and having a dividing baffle wall between said banks of tubes, upper and lower transverse baffles and longitudinal baffles for each bank of tubes, staggered openings between said longitudinal baffles being provided, said heating chamber having on one side of said dividing wall an inlet for heating gases located below the lower transverse baffle on that side, and having on the other side of said wall an off-take located below the lower transverse baffle on that side, said chamber having also a passage above said upper transverse baffles connecting the two sides of said chamber.

27. In a boiler, a tube sheet of curved configuration, having series of continuous steps, and unstepped plain surfaces intervening between each of said series, a section taken through said series of steps intersecting at the treads and risers thereof a projected section of the curved sheet taken between any two of said series of steps.

28. A boiler-drum having its tube-engaging sheet curved in conformity to the remainder of the drum, and having in its surface a plurality of series of steps, for the reception of the boiler-tubes, all the steps of each series being directly connected, one to another, the extreme opposite edges of each step being on opposite sides of the mean curvature of the drum, which mean curvature is maintained between said series to form transverse spaces for facilitating the insertion and withdrawal of the tubes.

29. A boiler-drum having its tube-engaging sheet curved and formed in its surface with a plurality of series of steps, for the reception of the boiler-tubes, said series of steps being separated by transverse spaces which facilitate the insertion and withdrawal of the tubes, the general slope of each series of steps conforming to the curvature of the tube sheet at said transverse spaces, and the extreme opposite edges of each step being on opposite sides of such curvature.

30. A boiler-drum having its tube-engaging sheet curved in conformity to the remaining portion of the drum, and having in its surface a plurality of series of steps, for the reception of the boiler-tubes, the general slope of each series of steps conforming to the cylindrical portions of the drum intervening between said series of steps, said intervening portions facilitating the insertion and withdrawal of the tubes.

31. In a water tube boiler, a plain drum having separate tube landings formed therein, in parallel rows, and so arranged as to leave sufficient space between the adjacent transverse rows for the insertion or withdrawal of the tubes from either side of a row without the use of manholes, as described.

32. In a water tube boiler, a plain drum having parallel rows of separate circular tube landings formed partially above and partially below the drum face, and so arranged as to leave sufficient space between the adjacent transverse rows for the insertion or withdrawal of the tubes from either side of a row without the use of manholes, as described.

33. In a boiler, the combination with a series of tubes arranged in groups, each comprising a plurality of rows, the spaces between groups being wider than the spaces between adjacent tubes of a group, of longitudinal baffles located on opposite sides of said series of tubes and obstructing alternate spaces between groups, but leaving open the intermediate spaces between groups, such open spaces on opposite sides of the series being staggered.

34. In a boiler, the combination with a series of tubes arranged in groups, each comprising a plurality of rows, the spaces between groups being wider than the spaces between adjacent tubes of a group, of longitudinal and transverse baffles for said tubes, the longitudinal baffles being located between the transverse baffles and on opposite sides of said series of tubes, and obstructing alternate spaces between groups, but leaving open the intermediate spaces between groups, such open spaces on opposite sides of the series of tubes being staggered, and a heating chamber inclosing said tubes and

provided with means directing heating gases toward the openings between longitudinal baffles on one side of the series of tubes.

35. In a boiler, the combination with a series of tubes arranged in groups each comprising a plurality of rows, the spaces between groups being wider than the space between adjacent tubes of a group, of transverse baffles located in such spaces between groups, the spaces between rows being open.

36. In a boiler, the combination with parallel tubes, of one or more baffles arranged between and transversely of said tubes, and held in place by spring-action of said tubes fitting tightly thereagainst.

37. In a boiler, the combination with parallel rows of tubes, of one or more baffles arranged between and transversely thereof and grooved or corrugated on sides adjacent to said tubes, said baffles fitting tightly against the adjacent tubes and held in place by spring action of said tubes.

38. In a boiler, the combination with a plurality of tubes, of a baffle-wall comprising sections narrower at one end than at the other, the narrower ends of said sections longer than the wider ends thereof, said sections arranged in series with their wide and narrow faces alternately on opposite sides of said tubes.

In testimony whereof I hereunto affix my signature, in the presence of two witnesses.

GODFREY ENGEL.

Witnesses:
H. M. Marble,
K. P. McElroy.