April 18, 1944. W. E. WOODARD ET AL 2,346,716

LOCOMOTIVE CONSTRUCTION

Original Filed Aug. 6, 1938 9 Sheets-Sheet 1

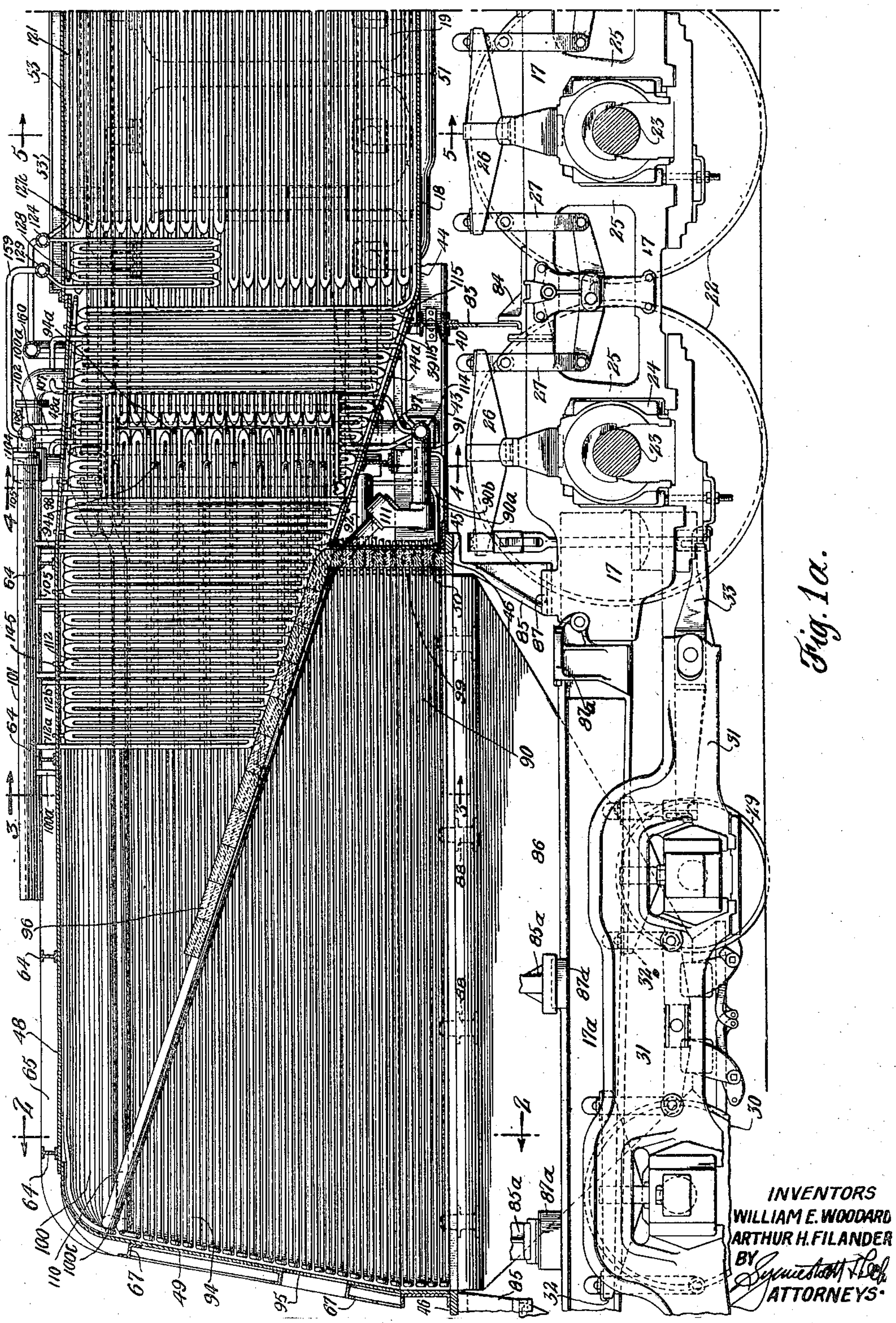

Fig. 1a.

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LOCOMOTIVE CONSTRUCTION

Original Filed Aug. 6, 1938 9 Sheets-Sheet 2

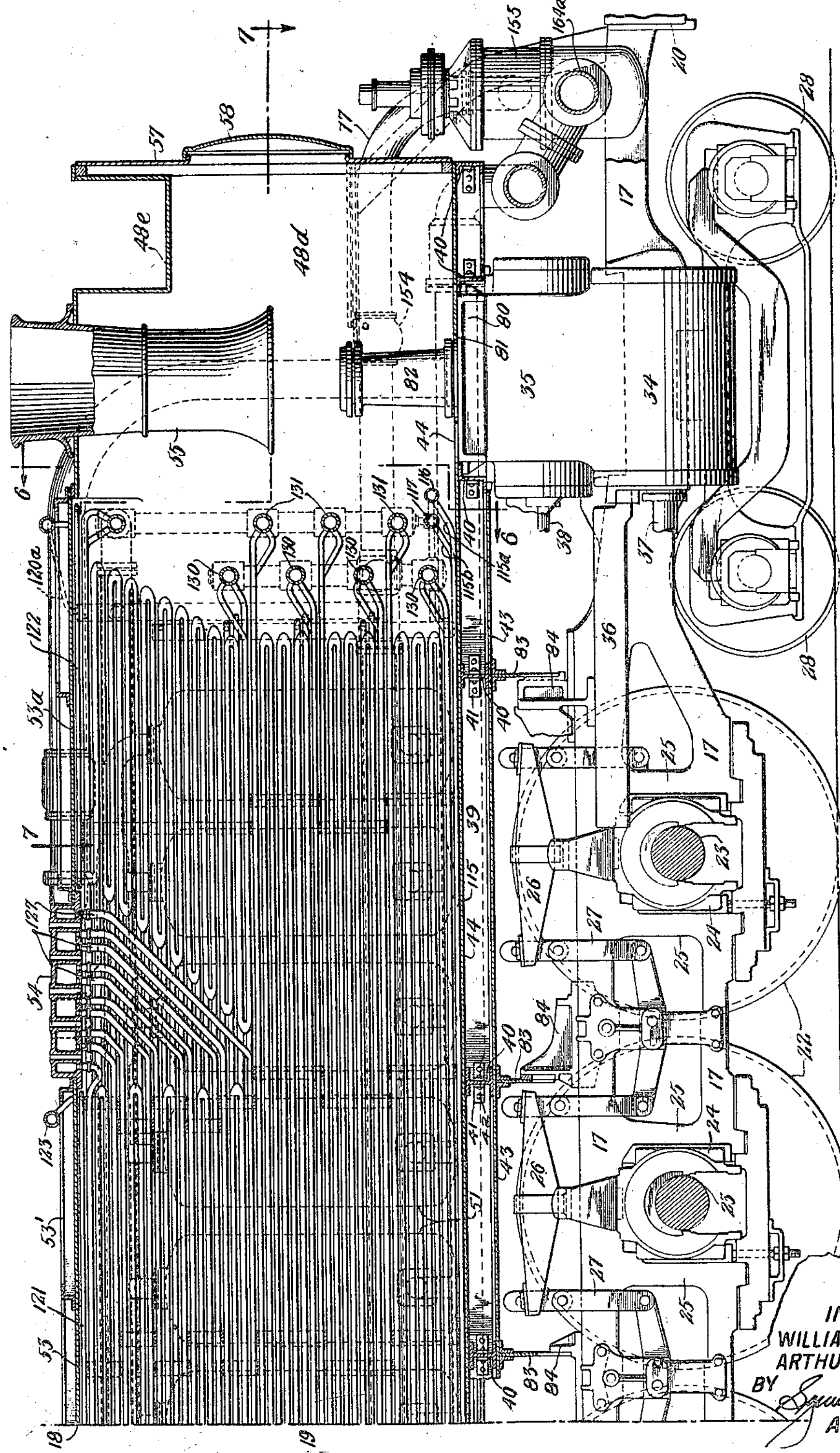

Fig. 1b.

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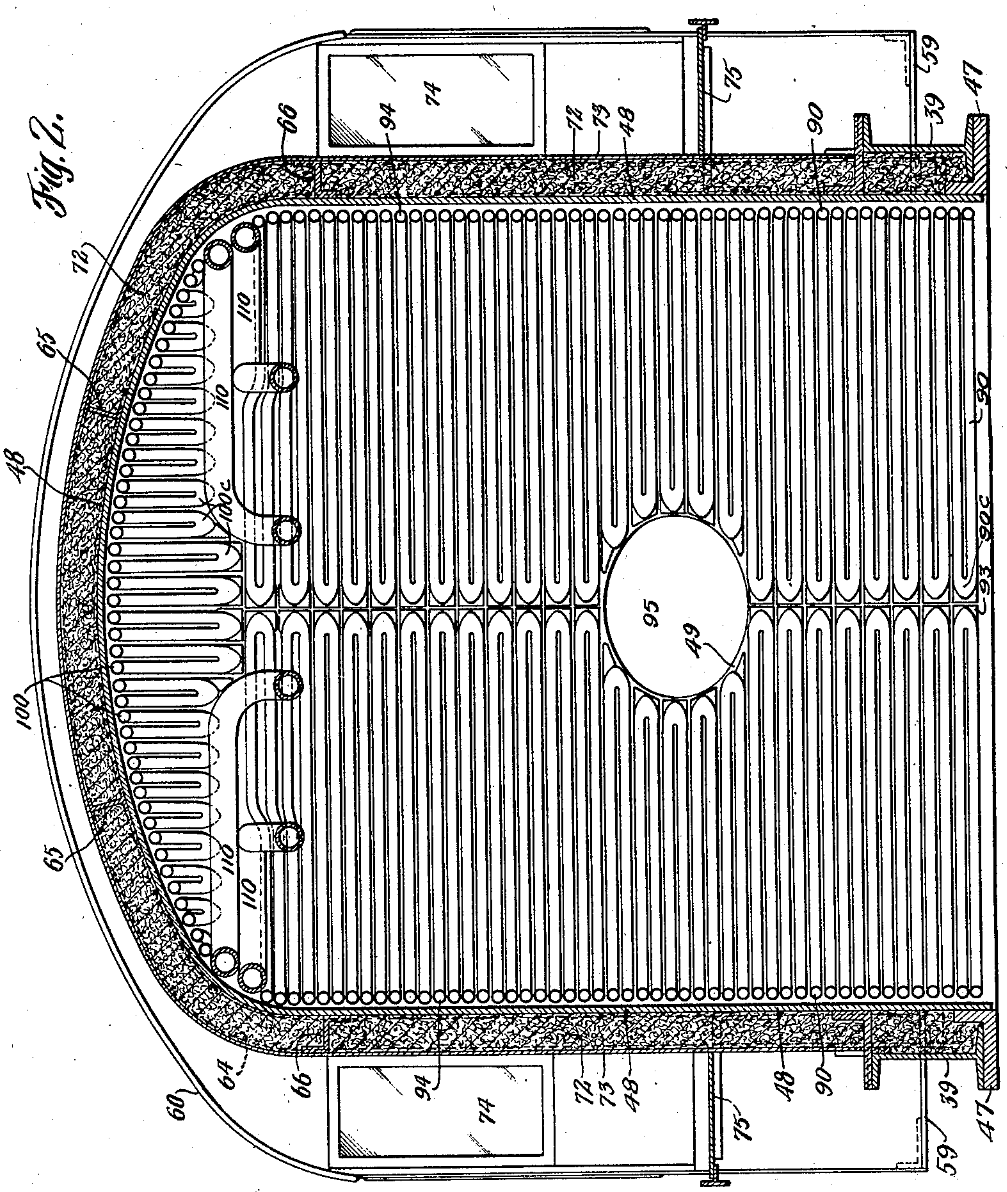
LOCOMOTIVE CONSTRUCTION

Original Filed Aug. 6, 1938 9 Sheets-Sheet 3

Fig. 2.



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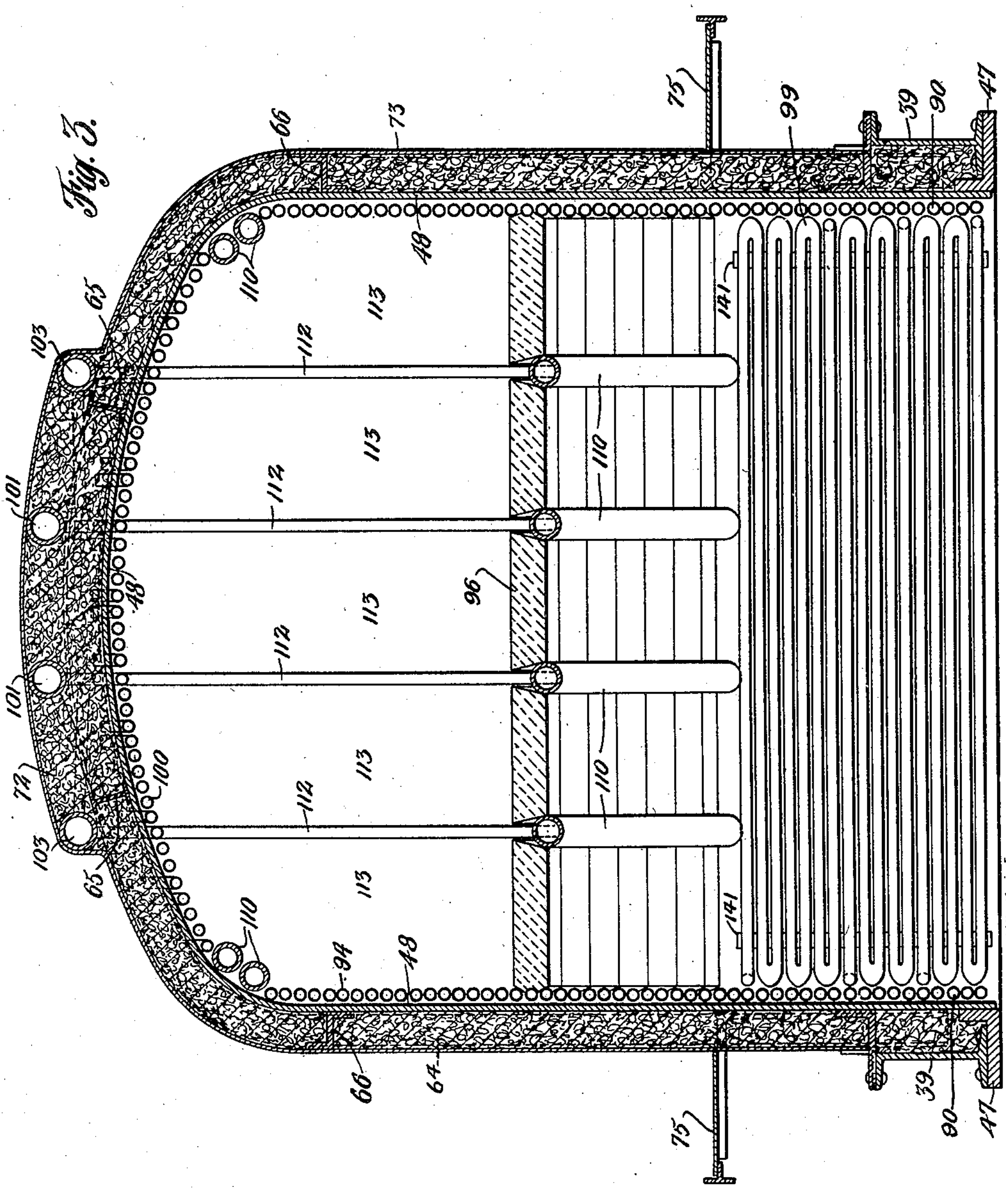
LOCOMOTIVE CONSTRUCTION

Original Filed Aug. 6, 1938 9 Sheets-Sheet 4



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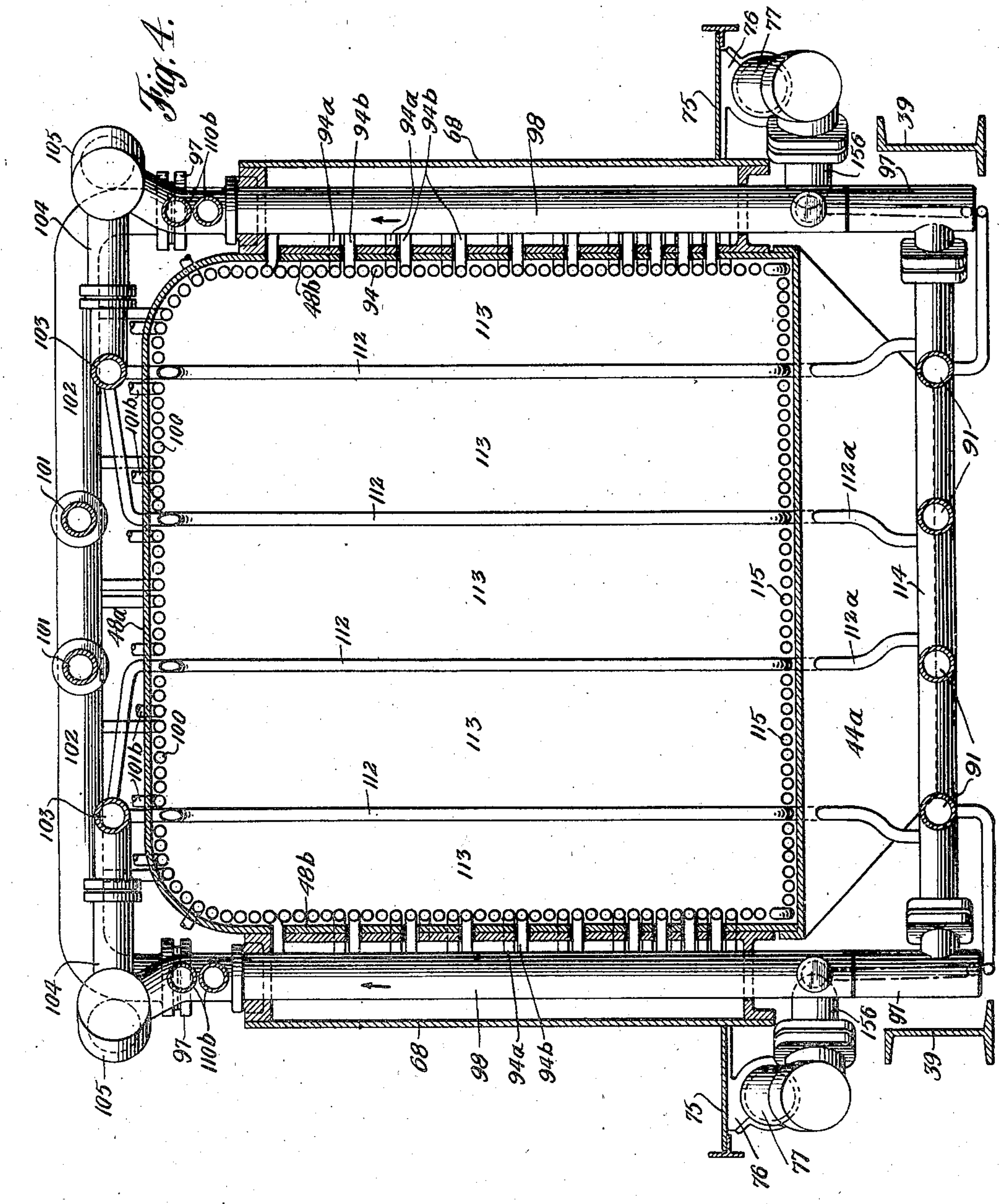
LOCOMOTIVE CONSTRUCTION

Original Filed Aug. 6, 1938 9 Sheets-Sheet 5

Fig. 4.



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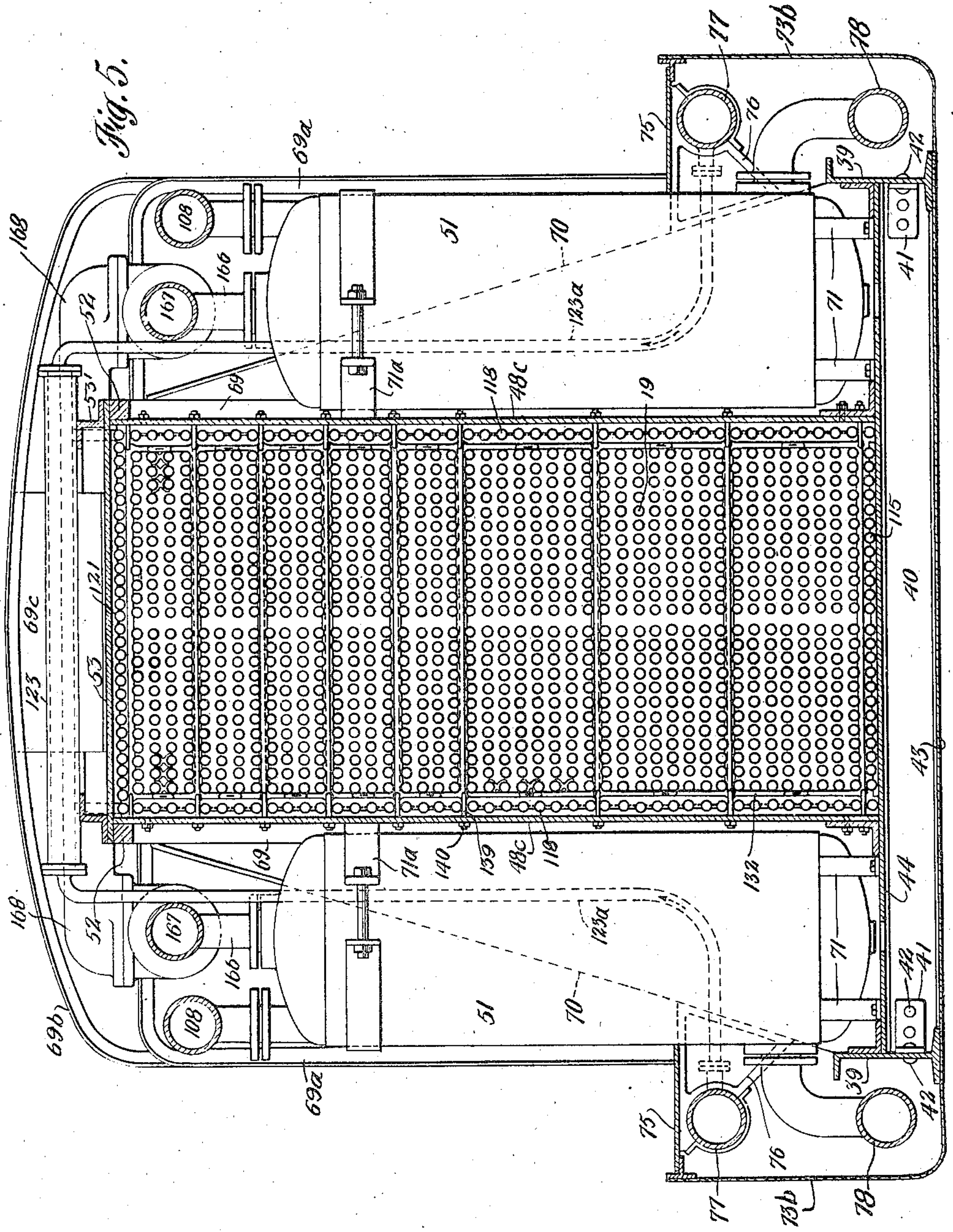
April 18, 1944. W. E. WOODARD ET AL **2,346,716**

LOCOMOTIVE CONSTRUCTION

Original Filed Aug. 6, 1938 9 Sheets-Sheet 6

Fig. 5.



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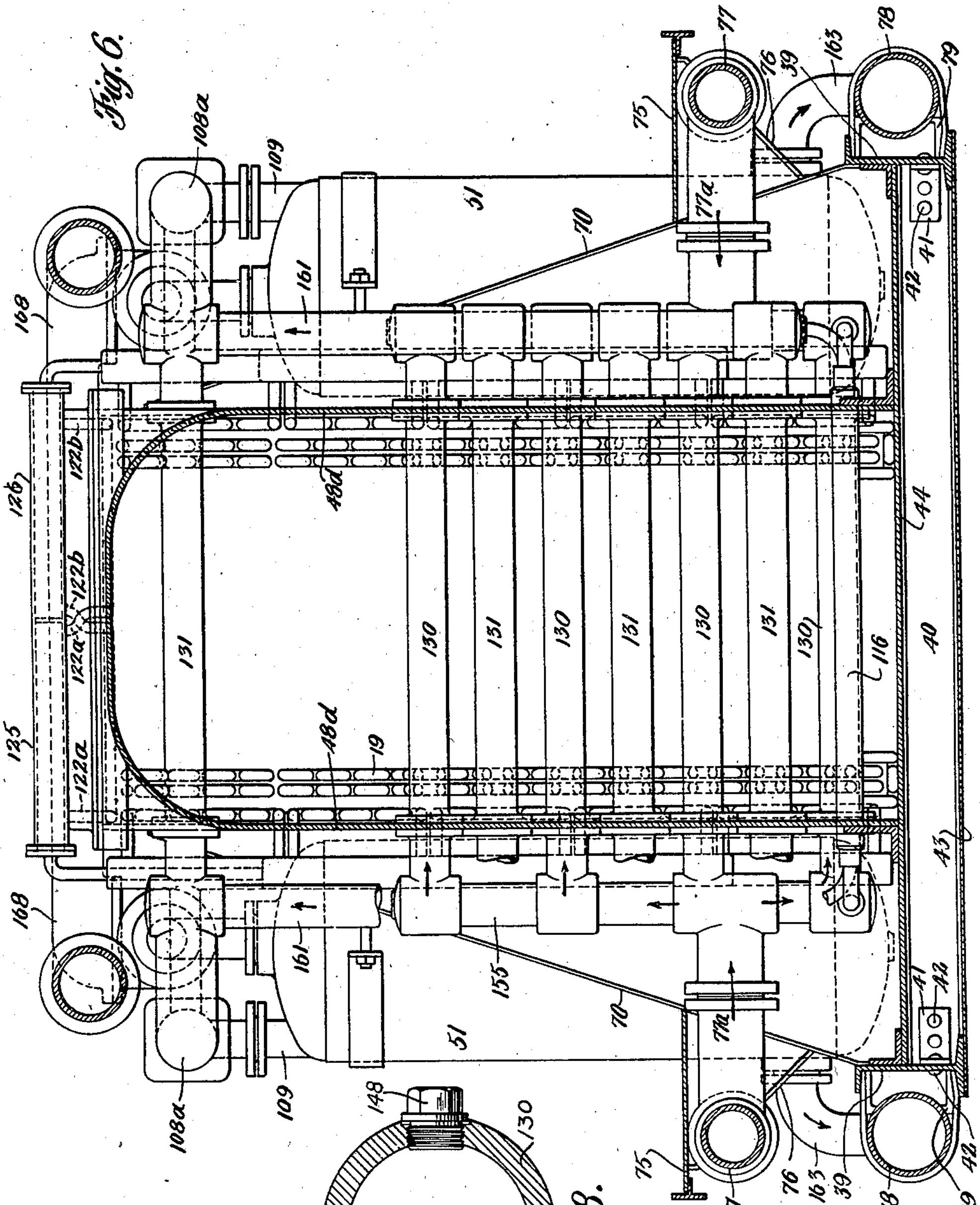

Fig. 6.

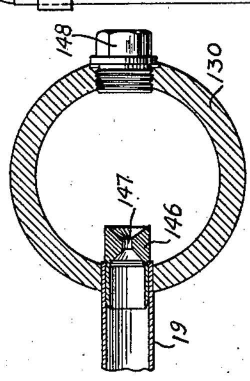

Fig. 8.

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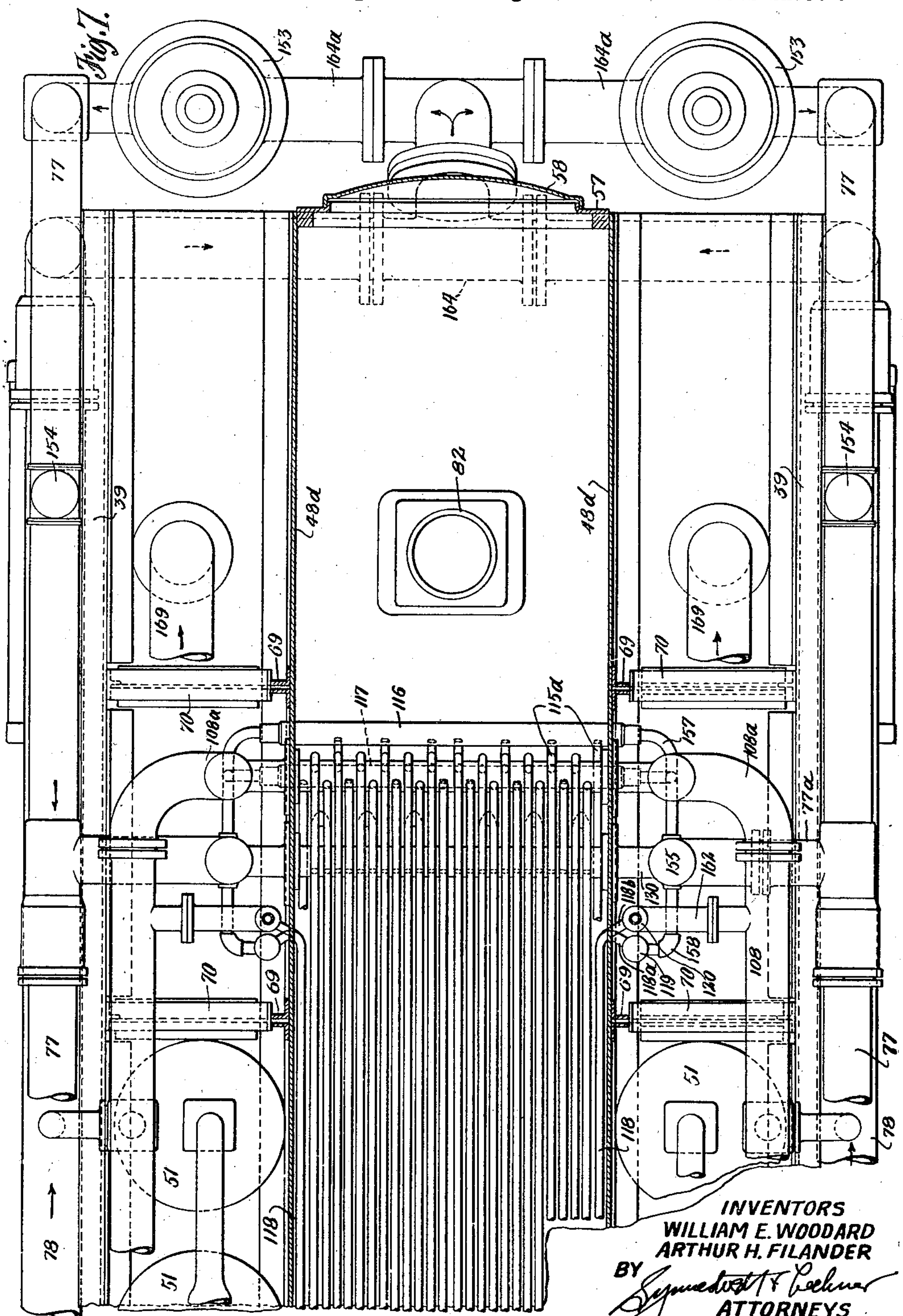

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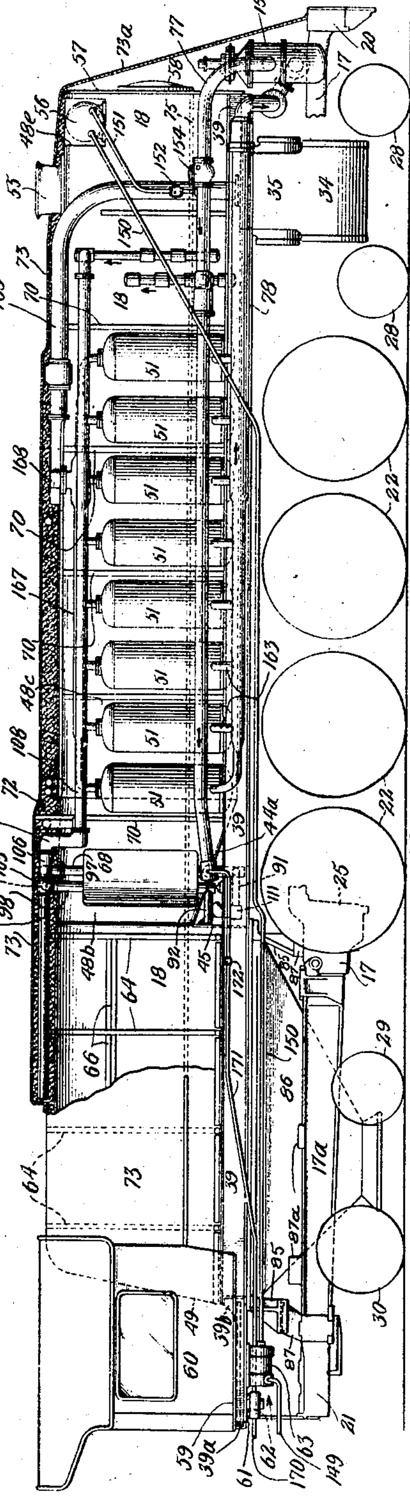

Fig. 11.

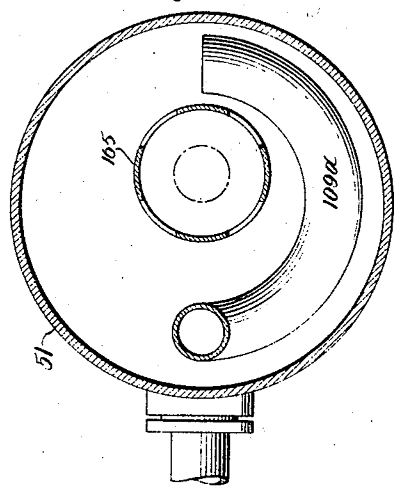

Fig. 10.

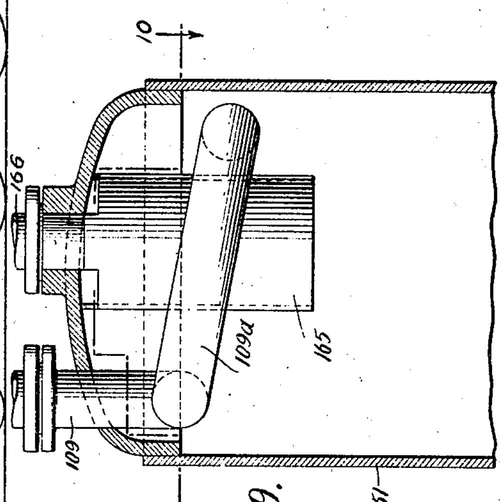

Fig. 9.

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Patented Apr. 18, 1944 2,346,716

UNITED STATES PATENT OFFICE

2,346,716

LOCOMOTIVE CONSTRUCTION

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Original application August 6, 1938, Serial No. 223,528. Divided and this application August 15, 1941, Serial No. 406,962

12 Claims. (Cl. 122—235)

Field of invention

This invention relates to locomotive construction, and more particularly to the locomotive boiler and to the cooperative relation of the steam evaporating and collecting means and the boiler shell to each other and to the remainder of the locomotive; the major aspects of the invention being related to water-tube locomotive boiler construction adapted for rapid water circulation as by forced-circulation pumps. This case is a division of our application No. 223,528, filed August 6, 1938, now Patent No. 2,318,040, granted May 4, 1943.

The nature, objects and advantages of the invention will be best understood after a brief reference to existing locomotive design.

Problems to be overcome

Heretofore it has been almost the universal practice to employ the horizontal barrel type of locomotive boiler, with flues extending longitudinally therein for the passage of the products of combustion from the fire-box to the smoke-box and thence to the stack, the fire-box walls being formed chiefly by flat water legs, stay-bolted to withstand the internal pressure; and although there has long been a need for the increase in power and economy which would result from higher pressures, it has not been feasible to employ locomotive boiler pressures of much more than 350 pounds per square inch, even with the advent of boiler plates and sheets formed from alloy steels of high tensile strength. A few attempts have been made to overcome the inherent limitations of the ordinary type of boiler, by inserting water tube evaporating units in some of the flues or in the fire-box, or by utilizing a plurality of upright water tubes in conjunction with upper and lower longitudinally-extending drums, but these modifications have not met with general acceptance, even though in essential principle the water tube boiler is theoretically capable of increased capacity for a given size and weight, and higher operating pressures.

Objects and advantages of the invention

One of the primary purposes of the present invention is to overcome the above mentioned and other problems and disadvantages of customary locomotive practice, and in general to make feasible the employment of higher boiler pressures and/or the utilization on a large scale of water tube evaporating surfaces in a locomotive boiler, whereby to secure substantial improvements in economy, efficiency and steaming capacity within given limitations of space, weight, safety, first cost and maintenance.

Another object of the invention is to provide a locomotive boiler adapted to substantially increase the volume of the combustion space and/or the gas flow area, within locomotive and fire-box structures of given outside dimensions, particularly for improvement of the efficiency of combustion and of heat transfer, whereby it may also be practically feasible to install pulverized fuel burning equipment in locomotives.

A further object of the invention is to render the locomotive boiler design more flexibly adaptable to existing limitations of proportion and size and also to the preferred design criteria of the locomotive chassis and other parts.

Still other objects of the invention are to increase the safety factor in locomotive operation, particularly by reducing the risk of the boiler running dry and also by reducing the hazard incident to boiler leaks or rupture if such should occur; to greatly increase the circulation in the boiler, and to reduce the detrimental effects of "bad water" delivered to the boiler, and thus to prolong the time between boiler clean-out periods.

In accomplishing the foregoing, the invention further contemplates the provision of improved boiler steaming and circulating means, associated with a metallic housing or structural shell, wholly or in large part formed as a substantially air-tight enclosure and support for the various other parts of the water tube boiler, said structural shell being preferably water-cooled but not subjected to the boiler pressure, the said shell preferably extending substantially throughout the length of the locomotive and arranged to enclose, in a generally longitudinally serial order, most or all of the following locomotive boiler elements: the combustion space, the main body of the evaporating elements, the superheating units, and the smoke-box space.

The invention further contemplates, especially in locomotive boilers of the water tube type: the subdivision of the evaporating surface into a plurality of units which are preferably coupled to headers or the like and are individually removable and replaceable, and more particularly the provision of a plurality of water containing boiler units of the convection and/or radiantly heated type, which are separately handleable with respect to each other and to one or more associated superheater units; the utilization of certain of said units, formed as water tubes which may have longitudinally extending external fins thereon, in closely spaced relation against the inside surfaces of the enclosing structural shell as the major or sole protection of said shell against the heat of the combustion chamber and of the hot gases passing to the smoke-box space; and the disposition of other of said units in the major portion of the space within said shell in the path of the combustion gases and/or within the region of radiant heat in the combustion zone, the tubular elements of said units being disposed either longitudinally or in vertical longitudinal planes in such manner that the fuel and flame stream and the hot gases pass generally in longitudinal parallel paths, whereby efficient heat transfer is secured and a minimum of scouring or grinding of the water tubes by the cinders occurs.

Still further, as to the boiler elements proper, the invention involves: the formation of most or all of the radiant and convection heating surface in the shape of tubes of relatively small diameter, located within said shell, to which the water is fed through headers and from which the water is taken by other heads, said headers being preferably located largely outside of said shell; the provision of a plurality of larger diameter drums which extend vertically and are located in longitudinal series outside of said shell along each side of the latter, to which drums the outlet headers deliver and from which the steam is drawn for delivery to the locomotive cylinders, preferably by way of superheater elements located within the shell; provision for rapid circulation of water in said tube units, as by means of one or more circulating pumps, there being cross-connections when a plurality of pumps are employed, in order that a complete circulation throughout the boiler be maintained even upon failure of one of the pumps; and the connection of the feed water delivery means from the tender to the tubular boiler in such manner that the feed water delivery will maintain water in all the tubes of the boiler even upon total failure of the circulating pump equipment.

Various miscellaneous objects and advantages of the invention, relative to boiler construction and operation, are: the increasing of the heating surface within given volume and weight limitations; reducing the velocity of the gases of combustion; reducing the volume and weight of water required to be maintained in the boiler, per unit of steaming capacity, to such an extent that the total weight of the locomotive in working order (exclusive of tender) may be substantially reduced below that of existing locomotives of equal capacity; eliminating conventional boiler braces, flat water-legs, stay-bolts and crown-sheets with their hazards; minimizing the swash of water in the boiler; widening the gauge limits between the high water level and low water level of the boiler; increasing the flexibility of boiler operation to respond more readily to the wide fluctuations in steam demand; providing for ready removability of superheater elements without disturbing stack and nozzle castings or steam pipes to the cylinders; lowering the center of gravity of the locomotive; and generally arranging the locomotive structure in such manner that the enclosing shell, the boiler elements associated therewith, the cab and the auxiliaries can be handled as a rigid unit, for unitary removal from and replacement upon the main frame.

There are still other objects, advantages and novel features of the present invention, both structural and operational, which will appear from the accompanying drawings of a preferred embodiment of the invention, or from the following description of said embodiment, or will be otherwise evident to those skilled in the locomotive art.

Brief description of the drawings

Figures 1*a* and 1*b* together constitute a sectional view, substantially on the longitudinal vertical mid plane, through a locomotive embodying the present invention, but with the chassis of the locomotive shown in side elevation; the main driving wheels at the near side, as well as the driving rods and valve gear, being however omitted in order to show the main frame and spring rigging more clearly (Figure 1*a* showing the rear end of the locomotive and Figure 1*b* the front end), certain parts in both these figures being broken away or only fragmentarily shown;

Figure 2 is a vertical transverse section through the fire-box of the locomotive, looking rearwardly therein, taken approximately on the line **2—2** of Figure 1*a*, but to a larger scale, and showing in elevation the locomotive cab and in section the running boards at each side and the insulation upon the outside of the fire-box, which latter are omitted from Figure 1*a*;

Figure 3 is a vertical transverse section, looking forwardly in the fire-box, taken approximately on the line **3—3** of Figure 1*a*, and drawn to the same scale as Figure 2, this view omitting any showing of the main banks of boiler tubes which are located forward of the combustion space;

Figure 4 is a similar transverse vertical section, but omitting the external insulation, taken approximately on the line **4—4** of Figure 1*a*, this figure being in the region of the secondary combustion space;

Figure 5 is a similar transverse vertical section, to the same scale as Figures 2, 3 and 4, taken through the main part of the boiler, approximately on the line **5—5** of Figure 1*a*, showing in elevation one of the water and steam drums at each side of the locomotive, this figure also omitting the insulation but illustrating certain parts of the external bracing especially adapted for the support of insulation and for the mounting of external sheathing;

Figure 6 is a similar transverse vertical section through the smoke-box of the locomotive, taken approximately on the line **6—6** of Figure 1*b*, looking rearwardly in the smoke-box toward the main portion of the boiler but showing only a few of the tubes in the main banks of boiler tubes, this figure illustrating in elevation the major water inlet and outlet headers at the front end of the boiler, but omitting certain of the bracing parts shown in Fig. 5.

Figure 7 is an irregular plan section through the smoke-box and a portion of the boiler, taken about on the line **7—7** of Figure 1*b*, but to a larger scale;

Figure 8 is a detail section through the joint between a water inlet header and one of the boiler tubes fed therefrom, and showing a suitable means for restricting the flow area of the tube inlet whereby a pressure drop between the header and the tube is assured in order to secure the proper distribution of water circulation throughout the various tube units of the boiler;

Figure 9 is a detail vertical section through the upper end of one of the water and steam drums, showing the water inlet and steam outlet connections;

Figure 10 is a plan section taken on the line

10—10 of Figure 9 and showing also the water outlet connection adjacent the bottom of the drum; and

Figure 11 is a right side elevational view of the complete locomotive (excepting the tender), showing the running gear diagrammatically, and illustrating, in section only, most of the streamline covering of the locomotive and the insulation retained thereby.

Description of structure

In this description, unless otherwise qualified by the context, the following terms will be employed in the senses here indicated: the word "locomotive" will not include a separable tender which normally carries the fuel and water supply; the term "pressure-free" means substantially free from direct subjection to the boiler pressure; the word "foundation" denotes broadly the main rigid structure or basic strength structure of the locomotive which is carried and propelled by the running gear, or denotes more specifically a main frame (that may include a cylinder casting, etc.) which largely takes the pulling and buffing stresses, together with a shell which is fixed thereto and houses the steam generating means; and the term "running-gear" comprises wheels, axles, boxes, springs, spring rigging, driving and connecting rods, valve motion work, etc.

Reference will first be made to the general views of the locomotive, Figures 1*a* and 1*b* together, and Figure 11. Considered in a general way, the locomotive comprises: a longitudinally extending main frame 17; a longitudinally extending metallic structural shell 18, which, though housing much of the boiler structure, is pressure-free and is to that extent functionally independent of the boiler, said shell preferably extending throughout most of the length of the locomotive and serving as a major element of the foundation; steam generating means which chiefly comprise a multiplicity of water tube elements housed within said shell (the main body of said tubes being indicated generally by the reference character 19 in Figure 1*b*); and running-gear, the main wheels of which are designated by the reference character 22.

The structural shell 18, which houses the evaporating means of the boiler but is substantially independent thereof as to the pressure function, forms a major element of strength of the locomotive; and, although it is preferably so constructed, and removably mounted on the frame 17, that it (the shell) with the other associated boiler parts may be handled as a unit separately from the frame 17, it may be considered structurally as an integral part of the locomotive foundation, when secured in position on the frame 17.

The base of the shell, in the embodiment shown, is formed of main longitudinal girders 39, of considerable vertical depth (as seen in most of the figures of the drawings), extending substantially throughout the length of the locomotive (as seen in Figure 11), one such girder being adjacent each side of the locomotive, and the two girders being interconnected at intervals, from the front end thereof back to adjacent the region of the secondary combustion space, by means of transverse I-beams or other structural members 40 (see Figures 1*b*, 5 and 6), the interconnection of the parts being by any suitable means such as angle members 41 and rivets 42. Throughout the same region, the longitudinal girders are interconnected by a bottom plate 43 extending all the way back to the front end of the fire-box proper, there being a plate 44 spaced above said bottom plate and extending back to the front end of the secondary combustion chamber; said plate 44 serving as the bottom wall of the passage-way for the products of combustion, in other words as the bottom wall of the metallic shell which encloses the evaporating means. In the region of the secondary combustion chamber, said plate 44 slopes upwardly, as seen at 44*a* in Figure 1*a* and Figure 4, to a juncture with the transverse vertical wall 45 at the front end of the fire-box proper.

In the region of the fire-box, the main longitudinal girders 39 are interconnected by transverse bottom braces 46 at the front and rear ends of the fire-box (as shown in Figure 1*a*), and are braced along the sides of the fire-box by heavy angle bars 47 (as seen in Figures 2 and 3).

The major part of the metallic shell is built up upon the base just described, and is preferably formed of steel sheeting. In the region of the fire-box, this steel sheeting (identified in Figures 2 and 3 by the reference character 48) extends upwardly from the base member 47 at one side, completely across the crown of the fire-box space, and down on the other side to the base member 47, the rear of the fire-box enclosure being completed by a back plate 49 (Figures 1*a* and 2). In the region of the secondary combustion chamber, the top wall of the shell slopes slightly downwardly and forwardly (as shown at 48*a* in Figure 1*a*), and the side walls 48*b* (Figure 4) slop toward each other in the forward direction, to merge with the side walls 48*c* of that portion of the shell which encloses the major banks of boiler tubes (see Figure 5).

Thus the shell is widest in the region of the fire-box, i. e., from the rear end up to the transverse fire brick wall 50 (Figure 1*a*). From thence forwardly, throughout the region of the secondary combustion chamber, i. e., throughout the extent of the sloping bottom wall 44*a* (Figure 1*a*), the side walls progressively come closer together (as indicated at 48b in Figure 4); and throughout the region from the front of the secondary combustion chamber forwardly to the smoke-box, the spacing between the side walls 48*c* of the shell is relatively closer, as shown in Figure 5. This provides the necessary space exteriorly of the shell, at each side, for the row of water and steam drums 51, shown in full lines in Figure 11 and in the sectional views of Figures 5, 6 and 7, and shown in dotted lines in Figures 1*a* and 1*b*.

In the region of the major part of the boiler, just described, the side walls 48*c*, instead of being continuous with the top wall (as in the fire-box) terminate at their upper ends and are there reinforced by suitable members such as the bar stock 52 seen in Figure 5; and in this region the roof or top wall is made up of a removable cover plate 53 (see also Figures 1*a* and 1*b*), a removable superheater header 54 (see Figure 1*b*) and a second removable cover plate 53*a* (see Figure 1*b*).

From about the plane of the line 6—6 of Figure 1*b* forwardly to the front end of the smoke-box, the side walls 48*d* (see Figure 6) are again continuous with the top wall, as in the case of the fire-box wall structure 48; the top of the smoke-box shell being, however, depressed forwardly of the stack 55, to form a recess 48*e* (see Figure 1*b*) to receive any suitable feed water heater 56 (see Figure 11). The front end of the smoke-box may be closed by a plate 57 and a removable cover 58.

The structural shell is completed by the following parts: in the region of the fire-box (as seen in Figures 1a, 2, 3, and 11) there are I-beams 64 at intervals, extending circumferentially upon the outside of the shell 48; and longitudinal I-beams and Z-bars 65 and 66 interbracing the same. Similar bracing structure 67 is located at the back sheet 49. In the region of the secondary combustion chamber, the forwardly converging side walls 48b, seen in Figure 5, are reinforced by the header boxes 68, shown in Figures 4 and 11 (later to be described in detail, with reference to the boiler elements). In the main boiler region, forward of the secondary combustion chamber, the side walls 48c are braced by vertical flange members 69 and flanged triangular bracing sheets 70 (see Figures 5, 6, 7 and 11). Additional flanges 69a may extend outwardly from the side walls and down to the base (Figure 5); while the cover plates 53 and 53a, which are flanged at 53', may also carry arched flanges 69b by means of vertical transverse sheets 69c. In addition, the steam and water collecting and storage means, preferably in the form of the vertical drums 51 as herein shown, serve to add to the strength and stiffness of the shell, by being mounted rigidly, as by the base brackets 71, upon the lateral extensions of the base of the shell, and by being secured firmly to the side walls of the shell, as at 71a.

The various external bracing and stiffening members of the shell, just described, serve two further functions: First, they provide a space for applying insulating materials, such as crumpled aluminum foil indicated at 72 in Figures 2, 3 and 11; and second, they provide a means of support and of fastening for the thin external metallic wrapper or covering 73 which is placed over the insulation. The latter metallic covering or sheath can be readily supported, for example upon the transverse inverted U-shaped I-beam braces 64 at the fire-box zone, by the flanging 69b on the cover plates, by the flanges 69a projecting from the side walls, and even by the outer sides of the steam drums 51 themselves, such sheathing if desired being merged with a sloping streamline nose portion 73a which may be secured to the bumper beam 20. Similarly, the piping beneath the running boards 75 may be suitably insulated and enclosed by suitable sheathing 73b (Figure 5). It will be observed from Fig. 11 that the nose sheath 73a encloses various parts, including the pumps 153, but the latter are still free from subjection to the excessive heat of the products of combustion, as they are located outside of the shell 18.

By comparing the several cross sectional views (Figures 2 to 6 inclusive) it will be seen that when looking forward from the cab windows 74, the engineer and fireman have a clear vision ahead.

It will also be seen that the available space at each side is such as to accommodate extra-wide running boards 75, which may be thus extended, at substantially uniform width, in a straight line from the front of the cab to the front end of the locomotive. These running boards are conveniently mounted upon the flanges of the triangular brace plates 70, by means of any suitable brackets 76 (see Figure 5), which also serve to support the main water delivery pipes 77 of the boiler circulating system; these pipes, together with the main water return pipes 78 from the drums 51, being conveniently located in the space beneath the running boards, the return pipes 78 being mounted by any suitable brackets 79 upon the main longitudinal girders 39 of the base of the shell (see Figure 6).

Features of the boiler

Referring now to the steam evaporating means, it will be observed that the shell structure 48 in the region of the fire-box is lined with a multiplicity of water tubes of relatively small diameter.

The side walls of the primary combustion space, from the bottom thereof up to the top of the front refractory wall 50, are covered by tubes 90, which, as seen in Fig. 1a, have their inlet and outlet ends extending out through the vertical metallic wall 45. Most of these tube ends are broken off, in the drawing, to show the header structure more clearly, but the inlet and outlet connections for one of the bottom tube units are shown at 90a and 90b, which are respectively coupled to the header members 91 and 92. Each such tube unit 90 runs rearwardly along the side wall of the fire-box (as seen in Figures 1a and 3) then transversely, half-way across the back wall of the fire-box (as seen in Figure 2), where it doubles back upon itself at 90c and returns to the front end of the box. Obviously, a tube unit may include one or more such return passes, or sinuous bends. At the point of the bends, as well as elsewhere if necessary, fins 93 are provided, in order not to leave too large an area of the structural shell unprotected from the direct heat of the products of combustion.

The remaining tubes lining the side walls of the fire-box, i. e., those lying above the level of the transverse brick wall, designated herein as tubes 94, are similarly disposed with reference to the side and back walls of the fire-box (as is seen in Figure 2), the transverse pass thereof being shortened, however, to accommodate the fire door opening 95. The front ends of these side-wall tubes extend into what may be termed a secondary combustion chamber (above the forward part of the brick arch 96) to a region just ahead of the section line 4—4 on Figure 1a, in which region their inlet ends 94a extend out through the side walls 48b of the shell (see Figure 4) for connection to the vertical delivery headers 97 (see Figures 1a and 11). The outlet ends 94b of said tubes similarly extend laterally through the shell and are connected to the vertical return headers 98, one at each side of the secondary combustion chamber. Some of these tubes 94 have return bends both at their front and at their rear ends, and may be provided with fins similar to those hereinbefore mentioned.

The front wall of the fire-box, i. e., up to the top of the transverse brick wall 50, is lined with water tube units 99 (see Figure 3), which have their inlet and outlet ends extending through the wall 45, with connections (not shown) coupling them up to the aforementioned headers 91 and 92.

The roof of the fire-box is lined with tube units 100 (see Figures 1a and 3) which at their rear ends are bent downwardly (as seen in Figures 1a and 2) and there have return bends 100c, as shown. Their inlet ends 100a are variously coupled to longitudinal headers 101 or the connected cross-header 102 which (as seen in Figure 4) is coupled to the upper ends of the vertical delivery headers 97. The outlet ends 100b are coupled to the longitudinal return headers 103 or to the laterally extending return headers 104. The transverse return headers 104 are connected into main junction members 105 (see Figures 1a, 4 and 11) which also receive the discharge from the upright return headers 98, said junction members 105 being connected through the pipes and elbows 106 and 107 to the main return line 108 delivering through branches 109 to the steam releasing drums 51.

Referring again to the fire-box, the arch tubes 110 are coupled at their lower (forward) ends to the delivery headers 91 by means of specially angled headers 111. At the upper rear portion of the fire-box these arch tubes 110 bend laterally (as seen in Figures 1a and 2) and thence extend forwardly along the side walls of the fire-box near the top thereof, and pass out through the shell and have their discharge ends 110b coupled to the vertical receiving headers 98 (see Figure 4).

Above the arch, and extending forwardly to the front of the secondary combustion chamber (i. e., to a point about mid-way between the section lines 4—4 and 5—5 of Figure 1a), are four series of upstanding tube units 112, providing five lanes or paths 113 for the products of combustion (see Figures 3 and 4). Some of these tube units have their inlet and outlet ends 112a, 112b coupled respectively to the longitudinal delivery and discharge headers 101 and 103, in the manner shown in Figures 1a, 3 and 4. Others have their inlet ends coupled to the transverse delivery header 114 and their outlet ends coupled to the longitudinal discharge headers 92, located below the sloping bottom sheet 44a beneath the secondary combustion chamber. The rows of tube units 112 are disposed substantially in vertical alignment with the arch tubes, and add materially to the evaporating surface in the secondary combustion chamber. It will be observed that in Figure 1a some of these tubes have been broken away to show the side wall tubes. It may here be mentioned that the two header boxes 68 are primarily a means of strengthening the side walls of the shell in the region of the secondary combustion chamber, where said shell has a multiplicity of apertures to permit the connections from the fire-box tubes to pass therethrough. The boxes 68 also form closures against air leakage where the tubes pass through the shell. These header boxes may be made as castings or of any other suitable rigid construction.

The bottom, sloping, wall 44a of the secondary combustion chamber is covered by a series of tube units 115, which are actually the rear ends of the floor tubes extending throughout the major portion of the length of the shell. These tubes, as seen in Figure 1b, have their inlet ends 115a (see Figures 1b and 7) coupled to a cross inlet header 116, and their outlet ends 115b coupled to a cross header 117.

The side walls 48c of the major part of the shell structure (as seen in Figure 5) are protected by finned tubes 118, which extend from adjacent the smoke-box back to the region of the secondary combustion chamber, whereat they have return bends in juxtaposition to the return bends of the side wall tubes of the fire-box (as seen in Figure 1a). The side wall tubes have their inlet ends 118a coupled to vertical headers 119 (as seen in Figure 7), and their discharge ends 118b coupled to vertical headers 120.

The roof tubes, for the main body of the boiler, are divided into two general groups, i. e., tubes 121 on the inner face of the cover plate 53, and tubes 122 on the inner face of the cover plate 53a (as seen in Figures 1a, 1b and 5). The tubes 121 have their inlet ends coupled to a cross header 123 and their outlet ends coupled to the cross header 124. The tubes 122 have their inlet ends 122a coupled to a header 125 extending half-way across the top of the shell (see Figure 6) and their outlet ends 122b coupled to a similar cross header 126.

The roof is completed by a superheater header structure 54, the superheater elements 127 extending from the region 54 (Figure 1b) to the region just forward of the secondary combustion chamber (Figure 1a), the rear return bends 127c of the superheater elements being shielded by a series of short vertical water tube units 128 having their inlet ends coupled to the cross header 129 and their outlet ends to the cross header 124.

The main bulk of the convection surface of the steam generating means is composed of the tube bundles generally indicated at 19 in Figure 1b and in Figure 5. The tubes in these bundles are coupled up to the various cross delivery headers 130 and the cross discharge headers 131 (see Figures 1b, 6 and 7); it being here noted that Figures 1a, 1b, 5 and 7 are the only figures showing the full banks of these tubes. The said main banks of tubes 19 are omitted entirely from Figures 3 and 4 in order not to confuse the same, since the tube banks are actually located ahead of the planes on which Figures 3 and 4 are taken. Only a few of the tubes 19 are shown in Figure 6, but it will be understood that all of the front ends of said tubes would be seen in elevation when looking in the direction of that figure.

It will be observed that, for the most part, straight longitudinal paths are provided for the passage of the products of combustion from the fire-box to the smoke-box, thus reducing to a minimum the scouring of the tubes by the cinders. Even in the fire-box itself, the tubes which line the walls thereof are substantially parallel with the path of the fuel and flame stream.

Various tube fastening means may be employed to secure the tubes against vibration. Several such are described and claimed in divisional application Serial No. 456,010, filed August 25, 1942.

It will now further be observed that the tubes are disposed primarily for convenience of installation and removal, and for ease of making external connections to the internally housed tubes, rather than to facilitate natural circulation. In fact, with the sinuous tubes herein employed, effective natural circulation would be impossible. For this reason, and others hereinafter to be referred to, we have provided a forced-feed water circulation, from the delivery headers to the tube units, and thence returning through the discharge headers. This mechanism will be described later. In order, however, to assure a suitable pressure head between the delivery headers and the tube units, restrictions can be placed in the inlet ends of the tubes, as shown in Figure 8.

As typical of the tube units generally, the tube 19 where it enters the delivery header 130, is provided with a plug member 146 having a restricted orifice 147, so as to assure the necessary pressure drop. Elements 146 having orifices 147 of differing sizes can be employed in different tubes, in order to secure the desired distribution of the circulation; and if tests indicate the need for changes in circulation an orifice of one size may be substituted for one of another size. The external plug 148 provides a means for access to the tube end, for initially securing the tube in the header, and for other purposes including access to the restriction elements 146.

It should be noted that although the shell is lined with only a single layer of tubes, double or closely staggered arrangements of wall lining tubes may be employed.

The boiler circulation

Turning now to the circulation of the boiler, which is indicated generally by arrows, it will be seen from Figure 11 that the feed water from the source of supply (such as the tender) is normally taken by way of the pipe 149, by means of pump 63, which delivers the feed water through the pipe 150 to the feed water heater 56 (the details of which need not be herein shown, as any suitable feed water heater may be employed), and from the feed water heater the pipe 151 delivers through check valve 152 into the discharge line 77 from one of the circulating pumps 153. The two lines 77 are the main water delivery lines from the pumps, and each has a check valve 154 to prevent return flow through the particular pump in the event said pump should fail. The check valves 154 also retain the water in the tube coils above the water level in the drums 51.

The two delivery lines 77 are cross-connected by the branches 77*a*, the vertical headers or pipes 155 and the crossheaders 130 (Figure 6); also by the upwardly extending pipes 123*a* and crossheader 123 (Figure 5) and the pipes 157 and cross header 116 (Figure 7). Adjacent the rear of the boiler they are further cross-connected by way of the lateral pipes 156, vertical pipes or headers 97 and crossheaders 102 and 114 (Figure 4). The water delivery system includes various other branch pipes and connections, such as 158 (Figure 7), 159 (Figure 1*a*), and 120*a* (Figure 1*b*). It will be evident that all of the tube units, hereinbefore described in detail, are fed from this main system.

The discharge from the various steam generating tube units is collected by the discharge connections heretofore also described, and passes into the main longitudinal pipes 108 above the steam drums, at the outer sides thereof. At the rear, the two main longitudinal discharge lines 108 are coupled by suitable crossheaders 160 and 124 (Fig. 1*a*), and adjacent the front by means of the elbows 108*a*, the vertical pipes or headers 161, and the crossheaders 131 (Fig. 6). Other discharge connections into this line are shown at 162 (Fig. 7). From the main discharge lines 108, the branch lines 109 deliver into the collecting and storage drums 51, preferably tangentially, by means of the curved pipes 109*a* seen in Figures 9 and 10.

From the bottoms of the drums, branch pipes 163 deliver water into the main return lines 78 which go to the intake side of the pumps, by way of the cross-connection 164 (Fig. 7) and the two branches 164*a*.

The steam is released within the drums, and passes out through the traps 165 (Figs. 9 and 10) to the steam branch pipes 166, which in turn deliver into the main longitudinal steam pipe or manifold 167. The said manifold, at each side of the locomotive, delivers through a steam header 168 into the superheater header 54. After passing through the superheater units, the superheated steam is delivered from the superheater header through the steam pipe 169 to the valve chests (there being any suitable throttle valve, not shown, in the superheater header, in accordance with standard practice).

It should be understood that the pumps, which may be of any suitable available type, are so chosen that they circulate the water preferably several times as fast as evaporation takes place, for example, a circulation of eight times the evaporation. If each pump is of a maximum capacity equal to about three-quarters of the total desired circulating capacity, they can be normally operated together at about two-thirds of maximum rating. In the event that one pump should fail, the other could still give ample circulation, and even if the remaining pump was in such a condition of wear that it could only pump a fraction of the intended 8 to 1 circulation, it would prevent burning out of the boiler.

It is further desirable that the pumps should develop a pressure sufficiently above the normal boiler pressure that a pressure drop through the orifices between the water inlet headers and the steam generating tubes will always exist. (As an example, but not by way of limitation, a differential of about 35–40 lbs. may be employed). In this way, the tubes are maintained substantially full of water, and the steam is released largely in the drums, which, standing vertically, give considerable leeway for fluctuation of the water level therein, without risk of the boiler running dry since there is a forced circulation through the tubes regardless of the water level in the drums.

In the event of total pump failure, circulation can still be effected by means of the injector 62, taking water through the line 170, and delivering by way of pipe 171 and check valve 172 into the main feed line 77, preferably adjacent the back end thereof, but in any event at a point such that the other check valves 152 and 154 will prevent feed water from the injector going back to the pumps or to the feed water heater.

Typical example of general results secured by the construction herein disclosed

For purposes of comparison, let us consider for the moment a typical locomotive of ordinary firetube boiler construction, say of the 4-8-4 type, having a weight of about 477,000 pounds (exclusive of tender), operating at 300 pounds boiler pressure, having a grate area of 100 square feet, a fire-box volume of about 600 cubic feet, a heating surface of about 5500 square feet, a minimum gas passage flow area of about 1400 square inches, and rated at about 80,000 pounds of steam per hour. In such a locomotive, the complete steam generating plant, i. e., fire-box and boiler barrel with water and steam therein, tubes, flues, superheater, smoke-box, steam pipes, lagging and jacket, weighs about 184,000 pounds.

A locomotive constructed according to the present disclosure, in external proportions similar to the ordinary locomotive just referred to, and within the same clearance and weight limitations, and having the same grate area, would have about 800 cubic feet of fire-box volume, about 6300 square feet of heating surface, and about 1600 square inches minimum cross sectional area of the gas passage, and even if operated at the same boiler pressure (300 pounds) would produce close to 100,000 pounds of steam per hour, in addition to which there would be a reduction in the velocity of the products of combustion, reducing cinder scouring, and improved combustion.

Viewed in another way, the comparative locomotive of the present disclosure, if made to have a steaming capacity similar to the typical ordinary locomotive, will weigh less, for example, about 453,000 pounds as against about 477,000 pounds (still assuming the same boiler pressure). This is due to the fact that the evaporating and collecting means of the present disclosure weigh much less and contain substantially less water. Still greater improvement can be made by using boiler pressures of 700, 800 or 900 pounds, which can be employed in practice with this type of boiler without a substantial increase in weight of the steam generating parts and the shell enclosing them.

The collecting drums in the present example may be designed to hold about one-tenth the weight of water evaporated per hour, i. e., in this example, a drum storage capacity of about 8000 pounds even though the drums are of relatively small diameter (and can therefore be made of relatively light weight), but since they stand upright the water level can vary through about 30 inches of height. In the ordinary locomotive just referred to, when working at full capacity and no feed water is being pumped into the boiler, the water level will recede from the maximum water level down to the lowest gauge cock (which is the minimum safe water level) in about 5½ minutes, the maximum and minimum gauge limits being only about 6 or 7 inches apart, compared with about 30 inches in the present case. Even if the capacity of the drums of the instant case provides only the same time interval (i. e., 5½ minutes) between maximum and minimum permissible water levels, much less accuracy in reading the gauges is required.

It should also be pointed out that the present arrangement results in substantial flexibility in design, and permits a lowering of the center of gravity of the locomotive (since there is no crown sheet and no large volume of water to be maintained above such a crown sheet), and the use of a plurality of small drums also permits variation in the design with respect to longitudinal location of the center of gravity, which is desirable in producing a locomotive of good tracking qualities, i. e., one which will not oscillate excessively about a vertical axis when running on tangent track. The arrangement also minimizes the swash of water.

Although the present invention substantially reduces the likelihood of the boiler running dry, it should further be noted that if one or more tube elements should run dry, the danger resulting therefrom is materially less than the dangers in ordinary locomotives.

How the various other objects and advantages referred to in the beginning of the specification are secured will be evident without further elaboration. It should also be understood that in carrying out the broad principles of the invention, many variations in detail may be made, and further that any proportions, numerical values, and the like, stated herein, are for purposes of illustration only and are not intended as limitations.

We claim:

1. In steam locomotive construction, a pressure-free shell extending lengthwise of the locomotive and forming a passage for a heating medium in its traverse from the zone of combustion to an outlet zone, a multiplicity of steam generating units of a plurality of different configurations housed within said shell in different positions for substantially differing subjection to the heating medium, steam and water collecting means, water circulating pump means located out of the direct path of the heating medium, parallel water delivery lines from the pump means to said units, discharge lines from said units to said collecting means, parallel water return lines from said collecting means to said pump means, a steam take-off system from said collecting means, and means for assuring adequacy of the pump circulation in all said units regardless of the differences mentioned.

2. In steam locomotive construction, a pressure-free shell extending lengthwise of the locomotive and forming a passage for a heating medium in its traverse from the zone of combustion to an outlet zone, a multiplicity of steam generating units comprising forced circulation water tubes of a plurality of different configurations housed within said shell in different positions for substantially differing subjection to the heating medium, steam and water collecting drums, water circulating pump means located out of the direct path of the heating medium, parallel water delivery lines from the pump means to said units, discharge lines from said units to said collecting means, parallel water return lines from said collecting means to said pump means, a steam take-off system from said collecting means, means for assuring adequacy of the pump circulation in all said units regardless of the differences mentioned, in which construction some of said units constitute the high point of the locomotive boiler, and check valve means are provided in the water delivery system from the pump means to the generating units adapted to prevent drop in water level in said units.

3. In steam locomotive construction, a pressure-free shell extending lengthwise of the locomotive and forming a passage for a heating medium in its traverse from the zone of combustion to an outlet zone, a multiplicity of steam generating units of a plurality of different configurations housed within said shell in different positions for substantially differing subjection to the heating medium, steam and water collecting means, water circulating pump means located out of the direct path of the heating medium, water delivery lines from the pump means to said units, discharge lines from said units to said collecting means, water return lines from said collecting means to said pump means, a steam take-off system from said collecting means, and means for assuring adequacy of the pump circulation in all said units regardless of the differences mentioned, in which construction means are provided for taking feed water from a source of supply and having a normally open feed connection into a water delivery line between the pump means and the generating units.

4. In steam locomotive construction, a pressure-free shell extending lengthwise of the locomotive and forming a passage for a heating medium in its traverse from the zone of combustion to an outlet zone, a multiplicity of steam generating units of a plurality of different configurations housed within said shell in different positions for substantially differing subjection to the heating medium, steam and water collecting means, water circulating pump means located out of the direct path of the heating medium, water delivery lines from the pump means to said units, discharge lines from said units to said collecting means, water return lines from said collecting means to said pump means, a steam take-off system from said collecting means, and means for assuring adequacy of the pump circulation in all said units regardless of the differences mentioned, in which construction the water delivery and wa-

ter return lines each comprise a plurality of main conduits in parallel, there being cross-connections between the parallel conduits of each set.

5. In steam locomotive construction, a pressure-free shell extending lengthwise of the locomotive and forming a passage for a heating medium in its traverse from the zone of combustion to an outlet zone, a multiplicity of steam generating units of a plurality of different configurations housed within said shell in different positions for substantially differing subjection to the heating medium, steam and water collecting means, water circulating pump means located out of the direct path of the heating medium, water delivery lines from the pump means to said units, discharge lines from said units to said collecting means, water return lines from said collecting means to said pump means, a steam take-off system from said collecting means, and means for assuring adequacy of the pump circulation in all said units regardless of the differences mentioned, in which construction the steam and water collecting means are disposed at each side of the locomotive.

6. In steam locomotive construction, a pressure-free shell extending lengthwise of the locomotive and forming a passage for a heating medium in its traverse from the zone of combustion to an outlet zone, a multiplicity of steam generating units of a plurality of different configurations housed within said shell in different positions for substantially differing subjection to the heating medium, steam and water collecting means, water circulating pump means located out of the direct path of the heating medium, water delivery lines from the pump means to said units, discharge lines from said units to said collecting means, water return lines from said collecting means to said pump means, a steam take-off system from said collecting means, and means for assuring adequacy of the pump circulation in all said units regardless of the differences mentioned, in which construction the steam and water collecting means are constituted by drums located at each side of the locomotive.

7. In steam locomotive construction, a pressure-free shell extending lengthwise of the locomotive and forming a passage for a heating medium in its traverse from the zone of combustion to an outlet zone, a multiplicity of steam generating units of a plurality of different configurations housed within said shell in different positions for substantially differing subjection to the heating medium, steam and water collecting means, water circulating pump means located out of the direct path of the heating medium, water delivery lines from the pump means to said units, discharge lines from said units to said collecting means, water return lines from said collecting means to said pump means, a steam take-off system from said collecting means, and means for assuring adequacy of the pump circulation in all said units regardless of the differences mentioned, in which construction the steam and water collecting means are constituted by a longitudinally extending series of drums located at each side of the locomotive, the drums of each row being connected in parallel to the discharge lines, return lines and take-off system.

8. In steam locomotive construction, a pressure-free shell extending lengthwise of the locomotive and forming a passage for a heating medium in its traverse from the zone of combustion to an outlet zone, a multiplicity of steam generating units of a plurality of different configurations housed within said shell in different positions for substantially differing subjection to the heating medium, steam and water collecting means, water circulating pump means located out of the direct path of the heating medium, water delivery lines from the pump means to said units, discharge lines from said units to said collecting means, water return lines from said collecting means to said pump means, a steam take-off system from said collecting means, and means for assuring adequacy of the pump circulation in all said units regardless of the differences mentioned, in which construction the water delivery and water return systems each comprise main conduits disposed at each side of the locomotive, and headers lying substantially in transverse planes are provided to connect said main conduits to various of the steam generating units.

9. In steam locomotive construction, a pressure-free shell extending lengthwise of the locomotive and forming a passage for a heating medium in its traverse from the zone of combustion to an outlet zone, a multiplicity of steam generating units of a plurality of different configurations housed within said shell in different positions for substantially differing subjection to the heating medium, steam and water collecting means, water circulating pump means located out of the direct path of the heating medium, water delivery lines from the pump means to said units, discharge lines from said units to said collecting means, water return lines from said collecting means to said pump means, a steam take-off system from said collecting means, and means for assuring adequacy of the pump circulation in all said units regardless of the differences mentioned, in which construction means are provided for taking feed water from a source of supply and having a normally open feed connection into a water delivery line between the pump means and the generating units, and means for preventing back flow through the feed water line.

10. In steam locomotive construction, a pressure-free shell extending lengthwise of the locomotive and forming a passage for a heating medium in its traverse from the zone of combustion to an outlet zone, a multiplicity of steam generating units of a plurality of different configurations housed within said shell in different positions for substantially differing subjection to the heating medium, steam and water collecting means, water circulating pump means located out of the direct path of the heating medium, water delivery lines from the pump means to said units, discharge lines from said units to said collecting means, water return lines from said collecting means to said pump means, a steam take-off system from said collecting means, and means for assuring adequacy of the pump circulation in all said units regardless of the differences mentioned, in which construction the water delivery and water return lines each comprise a plurality of main conduits in parallel, there being cross-connections between the parallel conduits of each set, and wherein the pump means comprise a plurality of pumps each delivering to a main delivery conduit and receiving from a main return conduit, whereby, in conjunction with the cross-connections, the operation of a single one of the pumps will circulate water through all the essential elements of the system.

11. In steam locomotive construction, a pressure-free shell extending lengthwise of the locomotive and forming a passage for a heating medium in its traverse from the zone of combustion

to an outlet zone, a multiplicity of steam generating units of a plurality of different configurations housed within said shell in different positions for substantially differing subjection to the heating medium, steam and water collecting means, water circulating pump means located out of the direct path of the heating medium, water delivery lines from the pump means to said units, discharge lines from said units to said collecting means, water return lines from said collecting means to said pump means, a steam take-off system from said collecting means, and means for assuring adequacy of the pump circulation in all said units regardless of the differences mentioned, in which construction the water delivery and water return systems each comprise main conduits disposed at each side of the locomotive, the main conduits of each set being connected in parallel, and headers lying substantially in transverse planes are provided to connect said main conduits to various of the steam generating units.

12. In steam locomotive construction, a pressure-free shell extending lengthwise of the locomotive and forming a passage for a heating medium in its traverse from the zone of combustion to an outlet zone, a multiplicity of steam generating units of a plurality of different configurations housed within said shell in different positions for substantially differing subjection to the heating medium, steam and water collecting means, water circulating pump means located out of the direct path of the heating medium, water delivery lines from the pump means to said units, discharge lines from said units to said collecting means, water return lines from said collecting means to said pump means, a steam take-off system from said collecting means, and means for assuring adequacy of the pump circulation in all said units regardless of the differences mentioned, in which construction the water delivery and water return systems each comprise main conduits disposed at each side of the locomotive, the main conduits of each set being connected in parallel, and headers lying substantially in transverse planes are provided to connect said main conduits to various of the steam generating units, the headers being utilized as cross-connections between the parallel conduits.

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