

May 4, 1943.

W. E. WOODARD ET AL

2,318,040

LOCOMOTIVE CONSTRUCTION

Filed Aug. 6, 1938

11 Sheets-Sheet 1

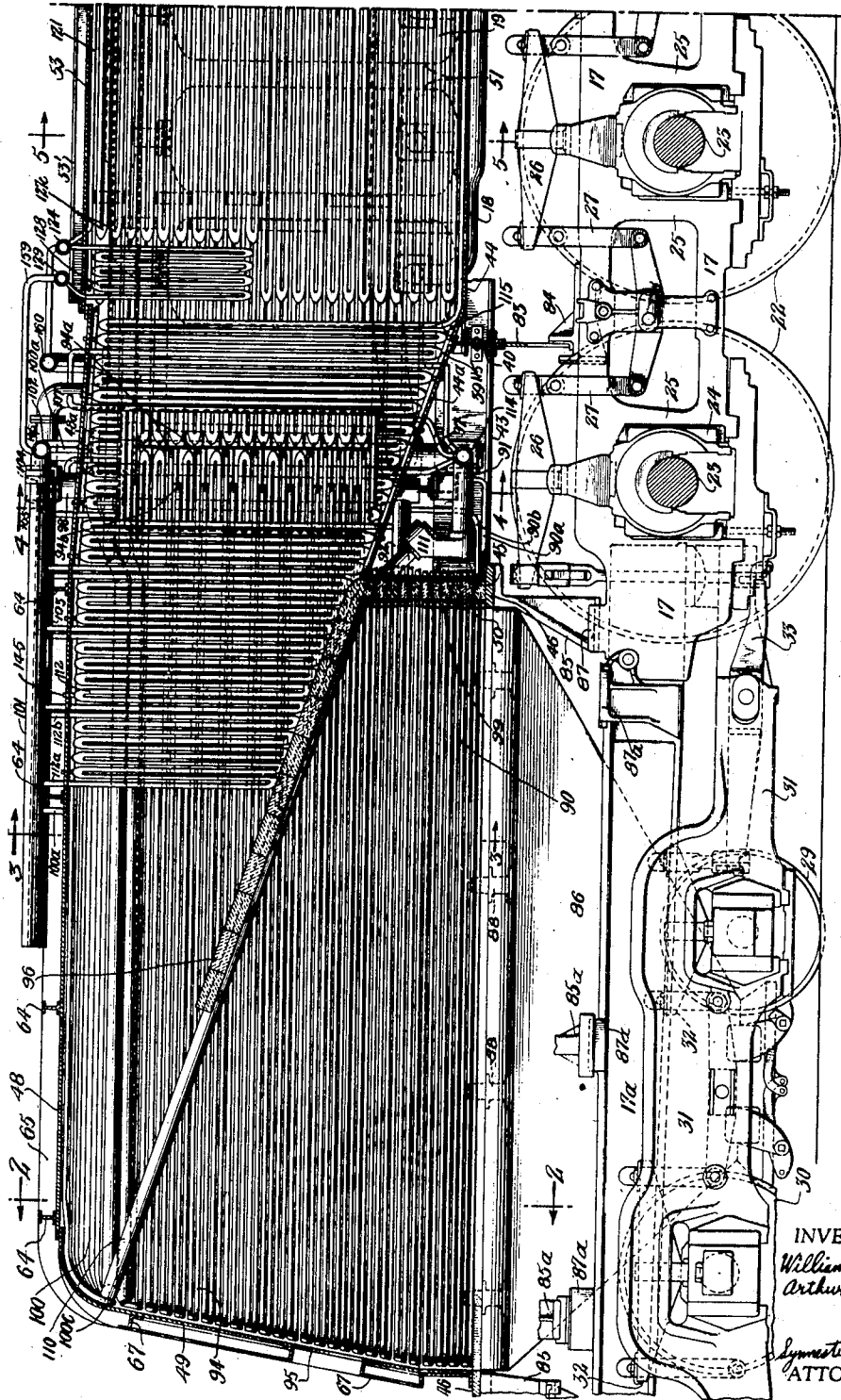


Fig. 1a.

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11 Sheets-Sheet 2

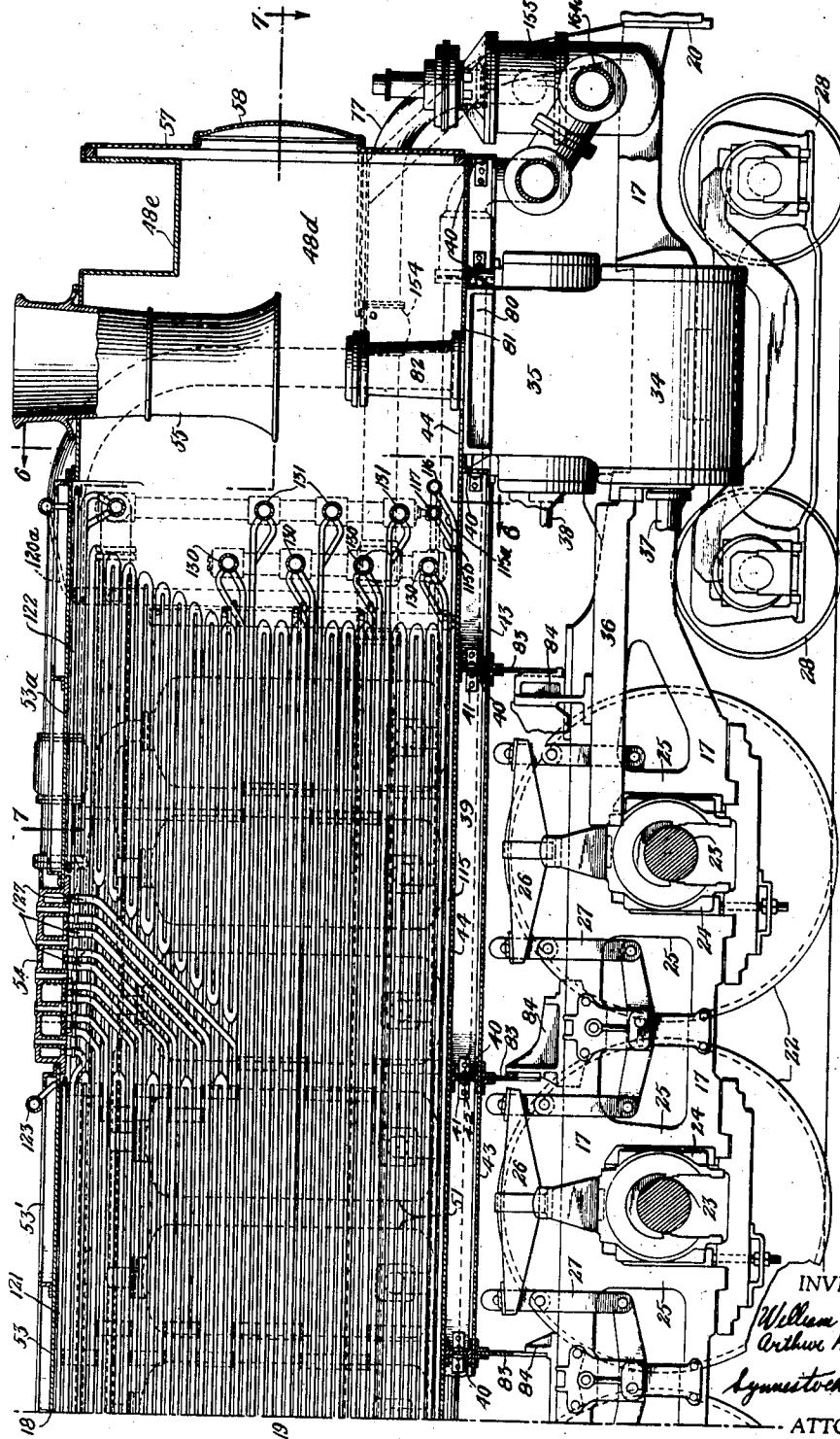


Fig. 1b.

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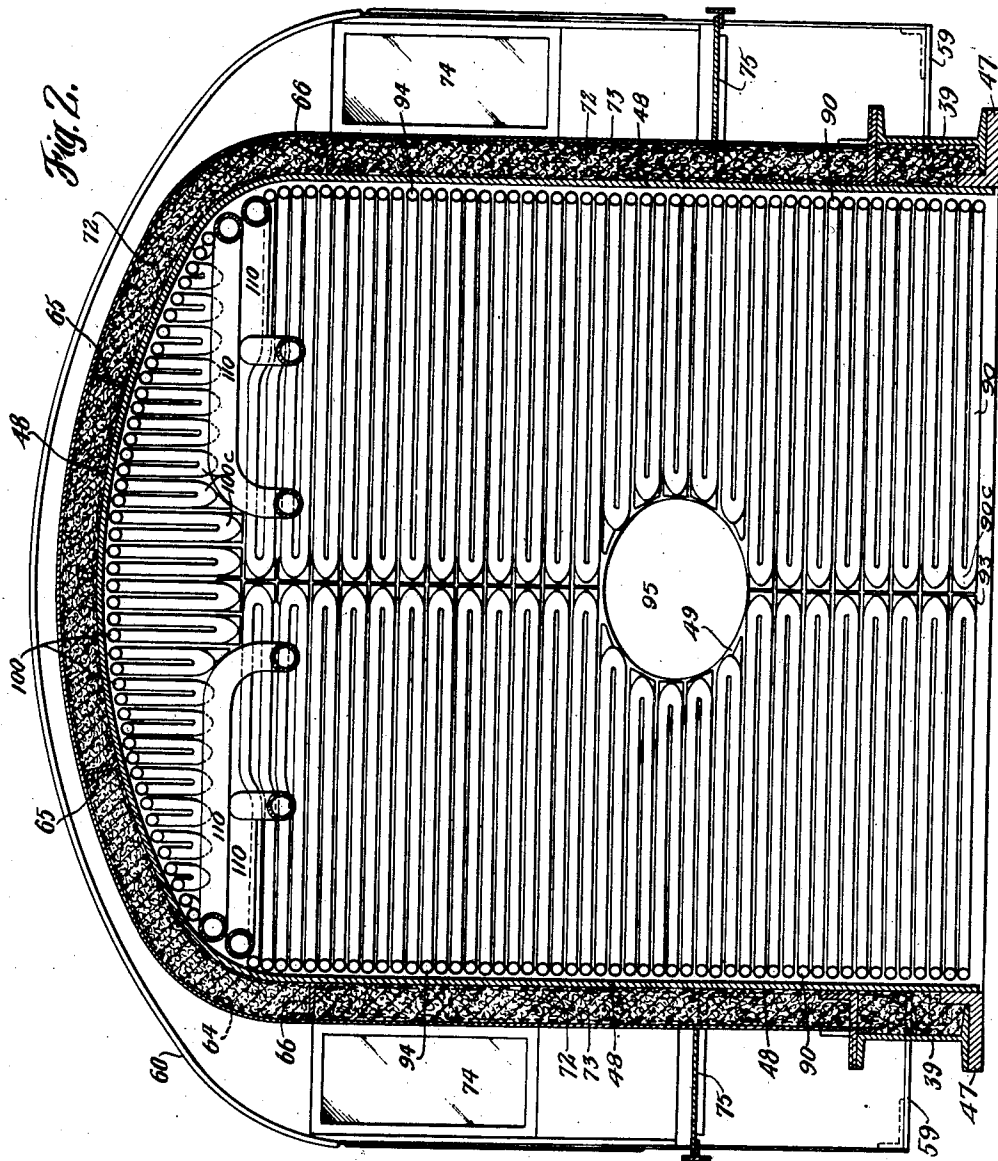
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11 Sheets-Sheet 3



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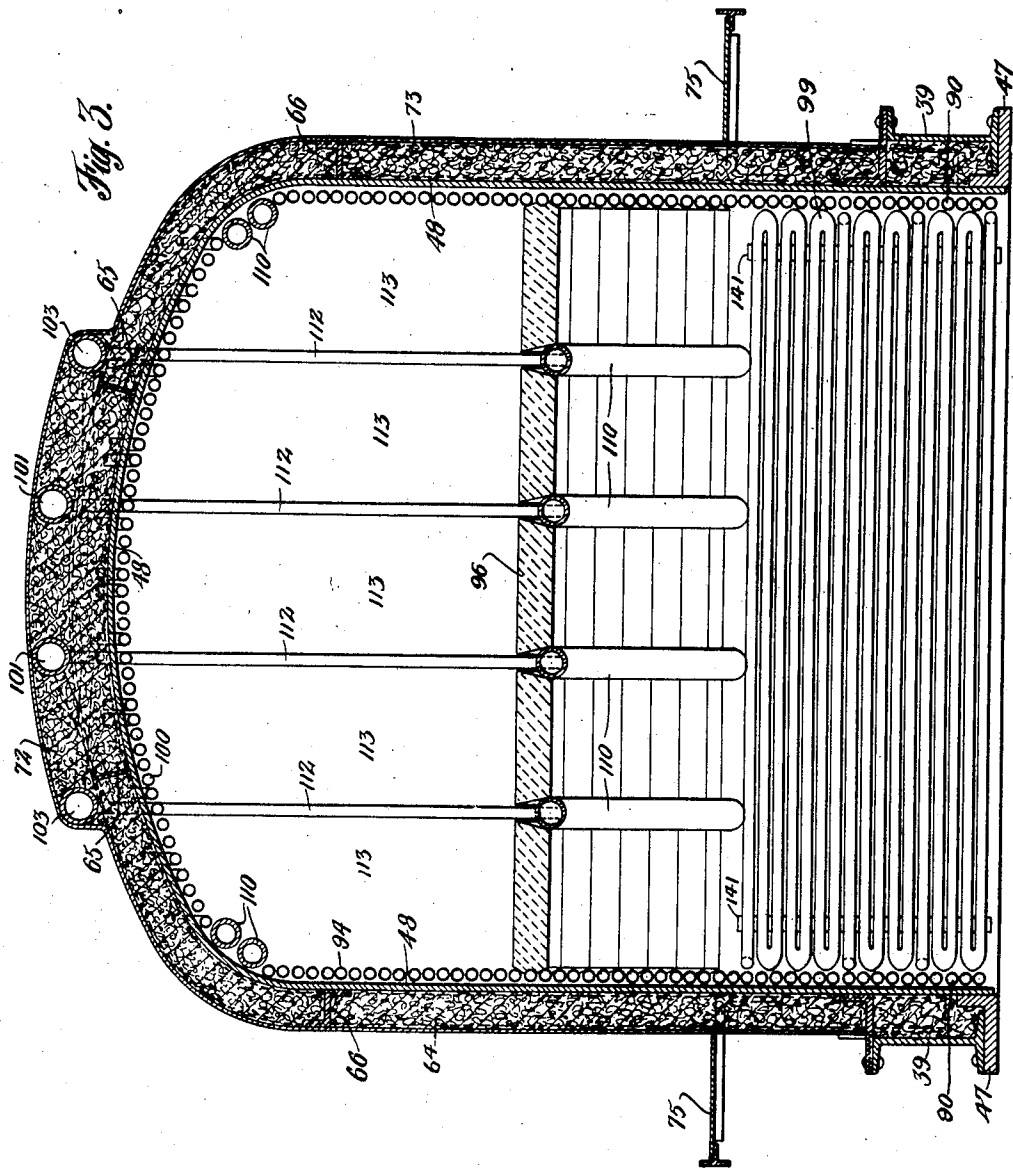
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LOCOMOTIVE CONSTRUCTION

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11 Sheets-Sheet 4



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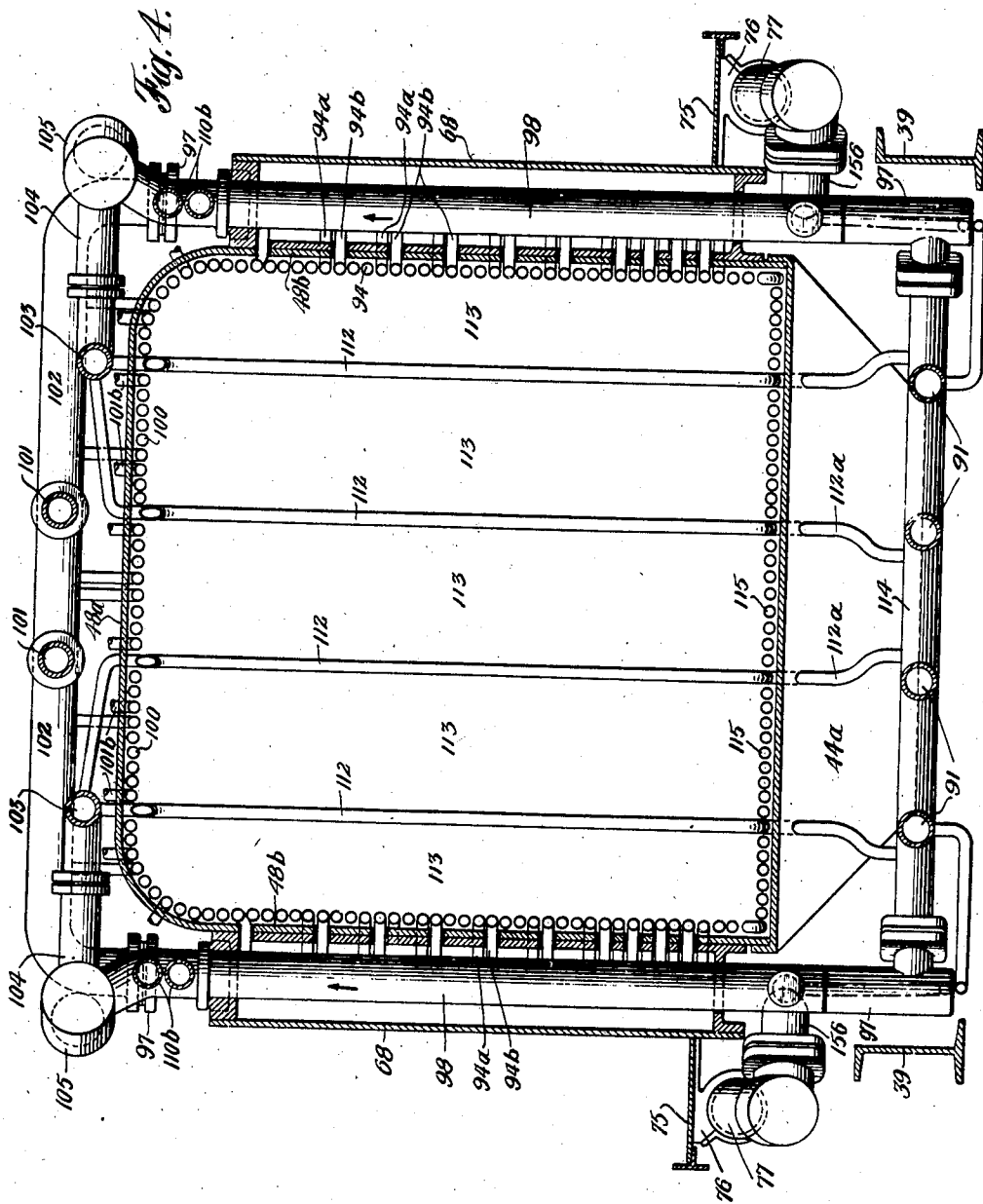
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LOCOMOTIVE CONSTRUCTION

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11 Sheets-Sheet 5



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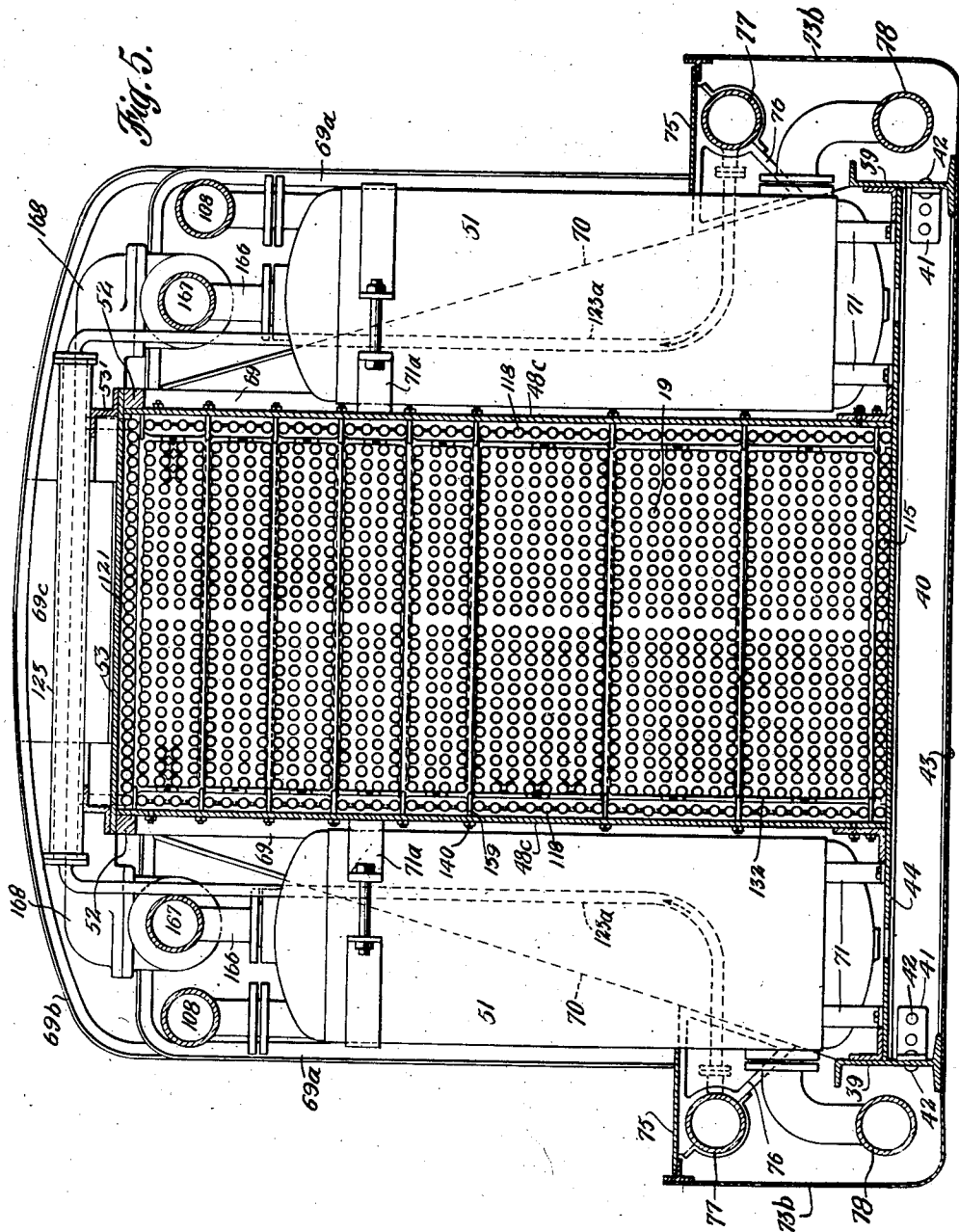
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LOCOMOTIVE CONSTRUCTION

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11 Sheets—Sheet 6



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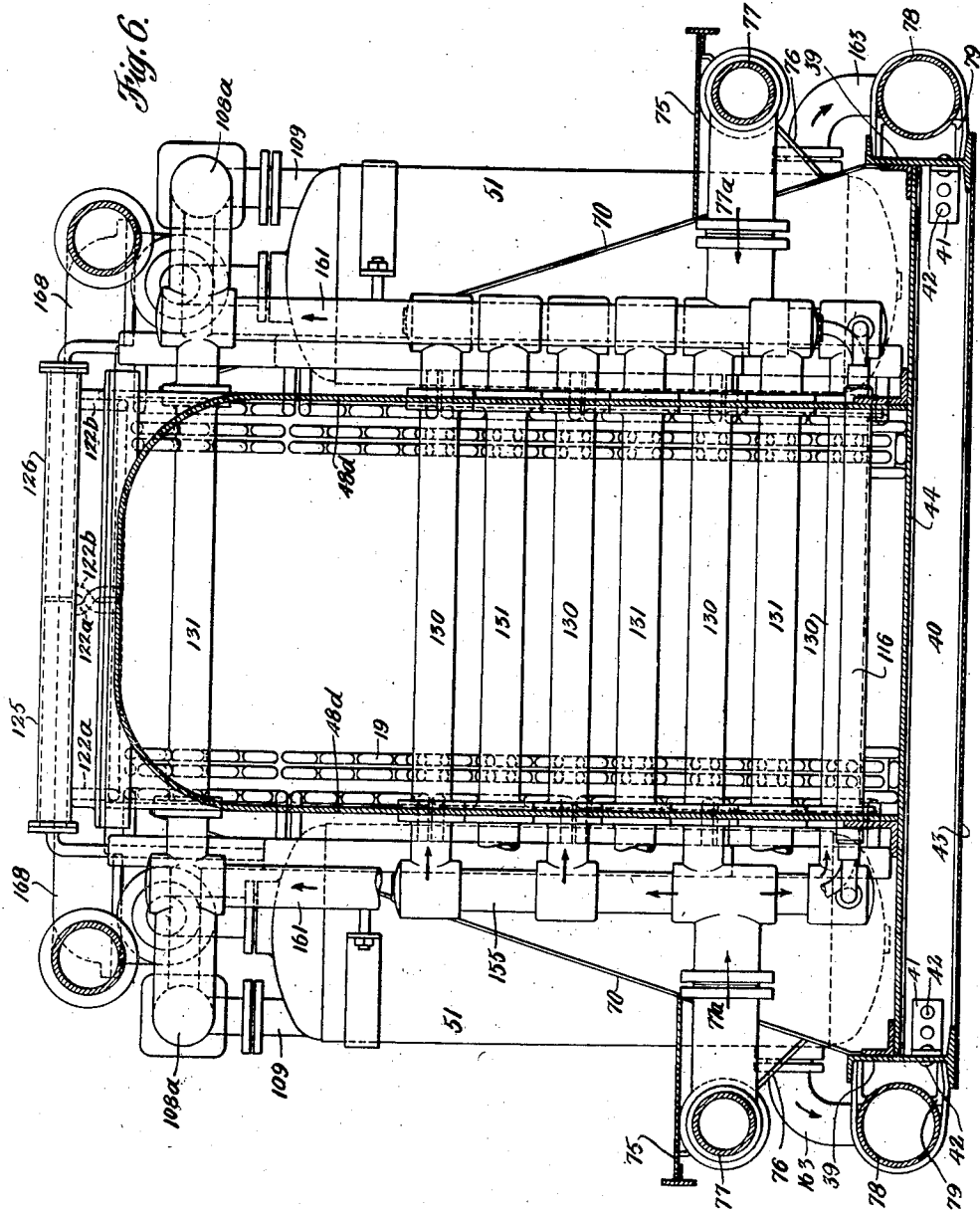
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11 Sheets-Sheet 7



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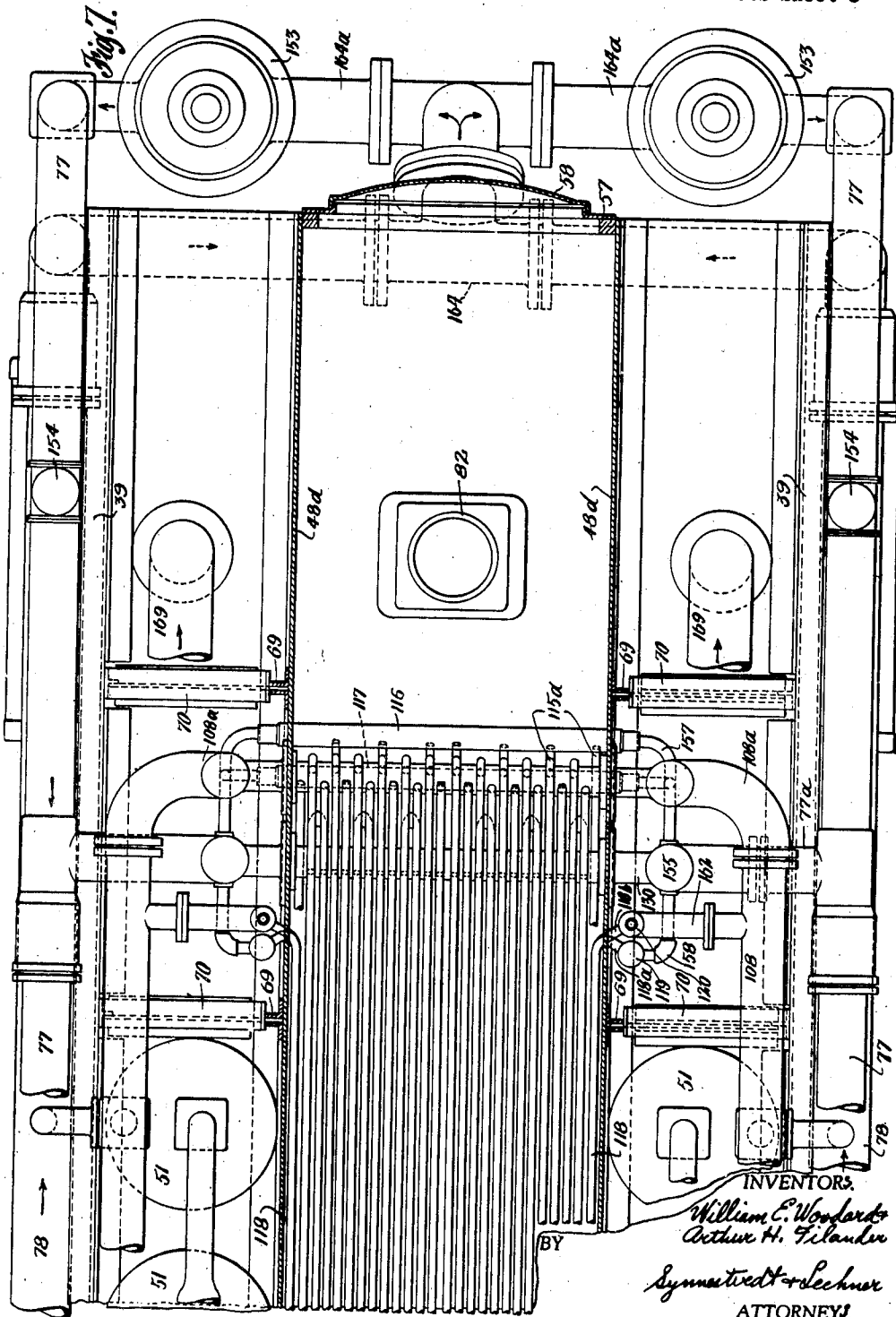
May 4, 1943.

W. E. WOODARD ET AL  
LOCOMOTIVE CONSTRUCTION

2,318,040

Filed Aug. 6, 1938

11 Sheets-Sheet 8





May 4, 1943.

W. E. WOODARD ET AL

2,318,040

LOCOMOTIVE CONSTRUCTION

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11 Sheets-Sheet 9

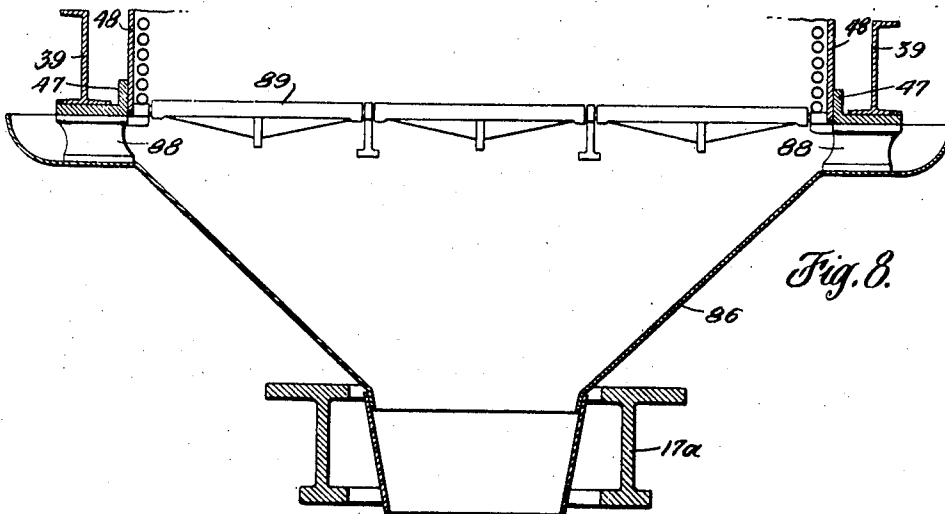


Fig. 8.

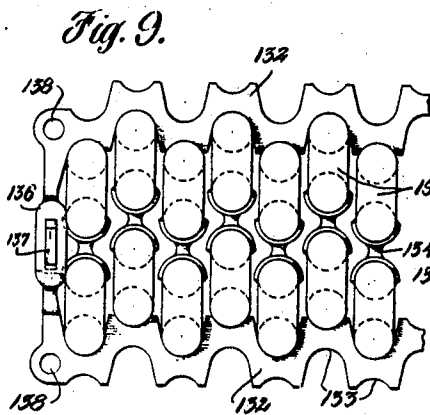


Fig. 9.

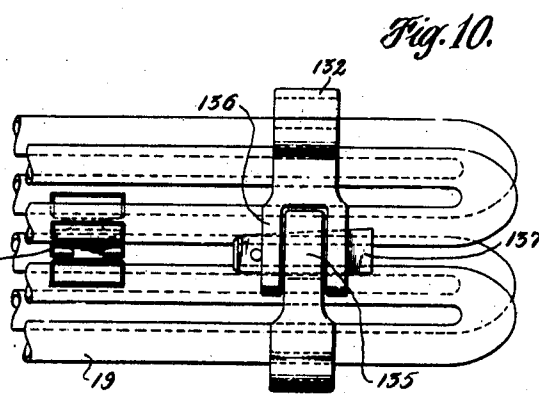


Fig. 10.

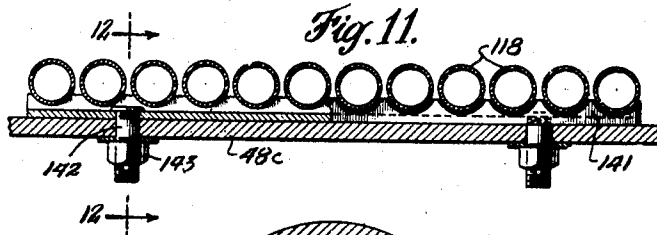


Fig. 11.

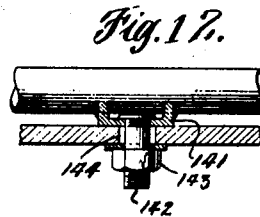


Fig. 12.

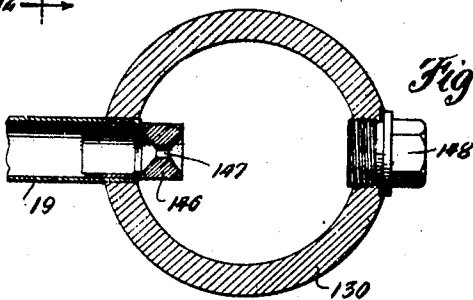


Fig. 13.

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11 Sheets-Sheet 10

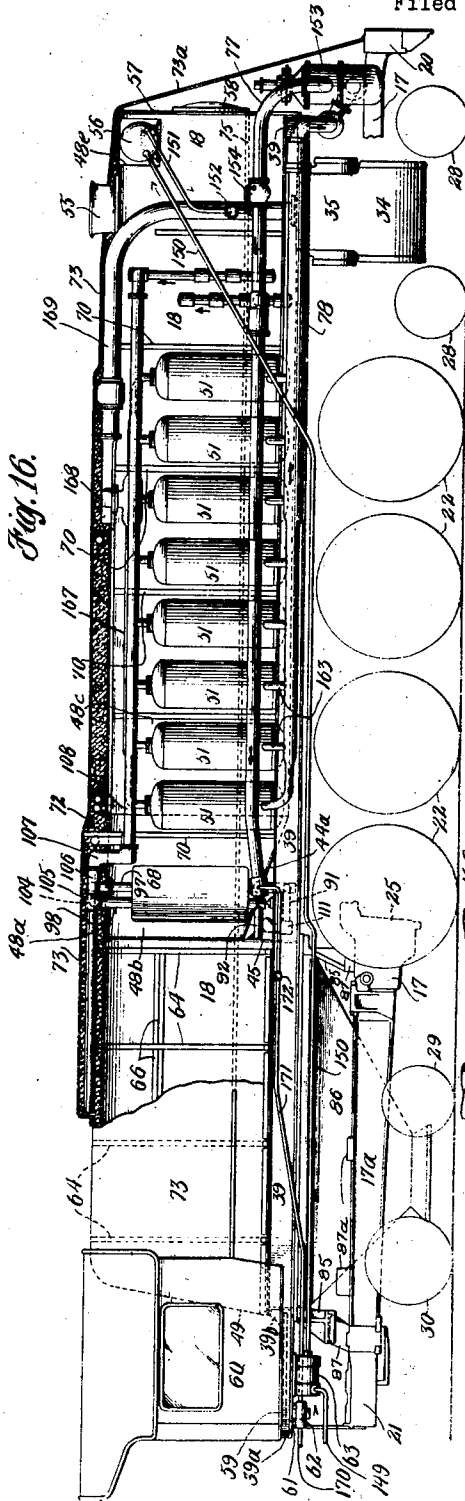
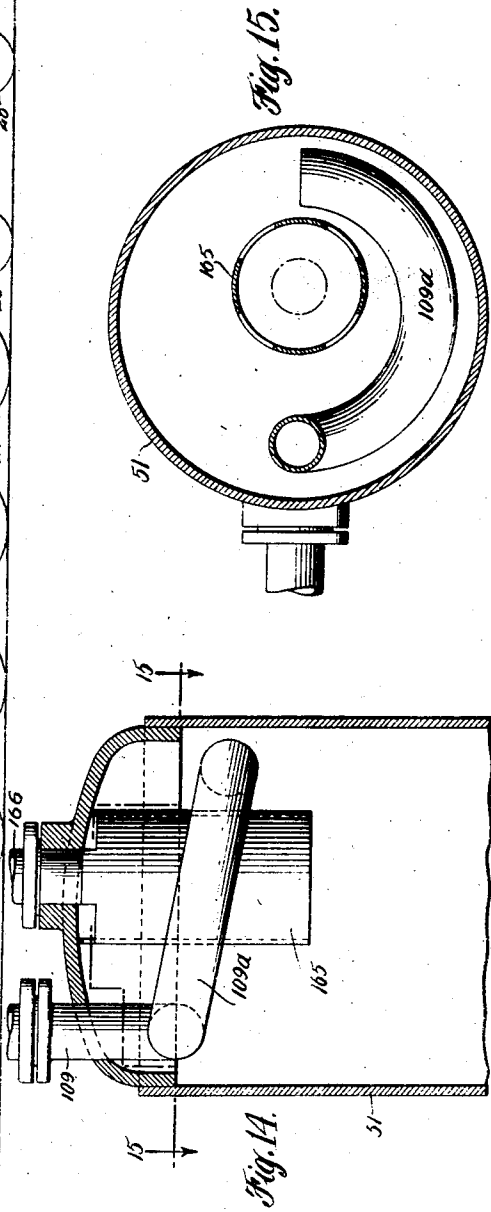


Fig. 16.



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11 Sheets-Sheet 11

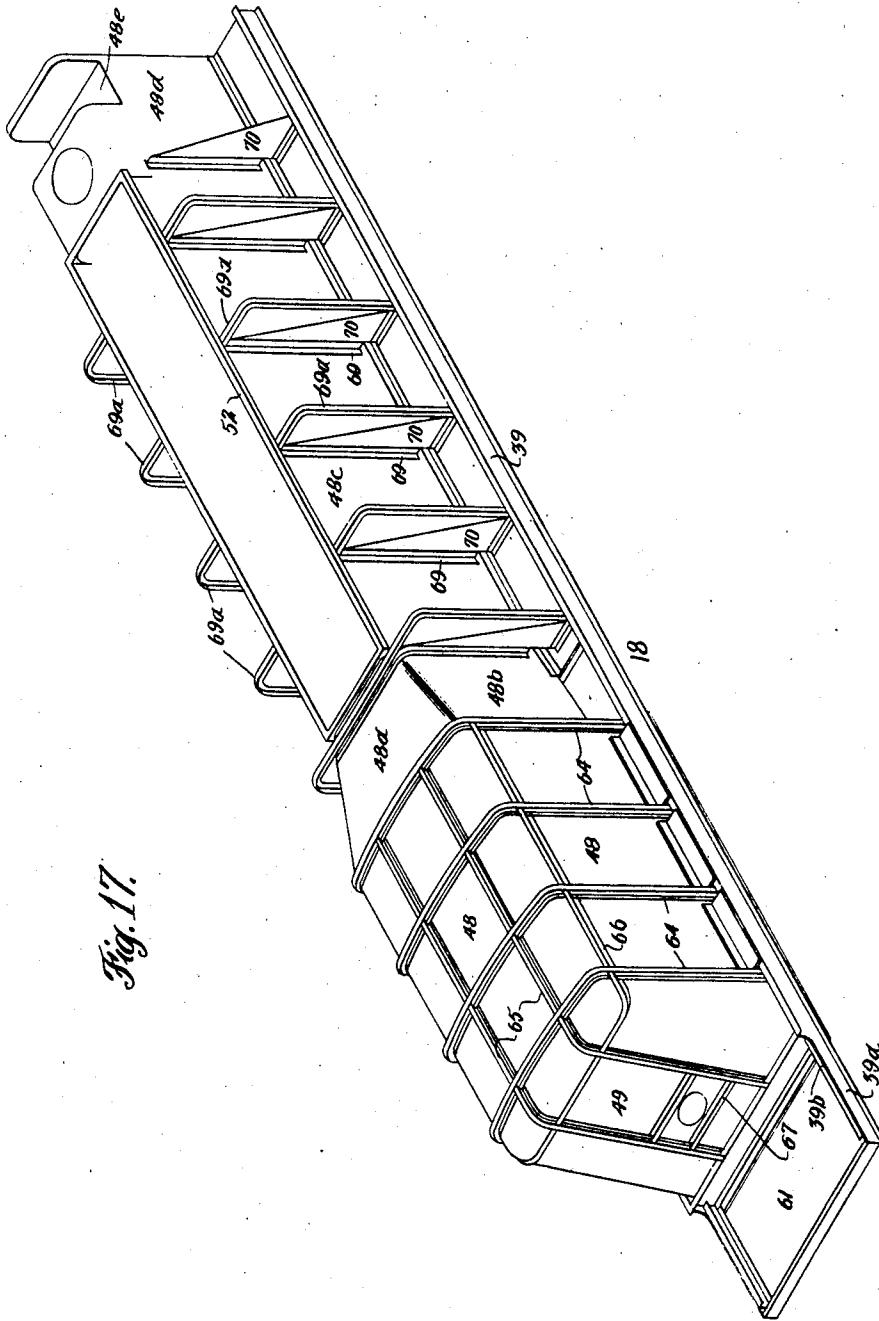


Fig. 17.

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# UNITED STATES PATENT OFFICE

2,318,040

## LOCOMOTIVE CONSTRUCTION

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Application August 6, 1938, Serial No. 223,528

38 Claims. (Cl. 105—43)

### *Field of the invention*

This invention relates to locomotive construction generally, and more particularly to the locomotive boiler and boiler shell 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, notably the frame; the invention being further related to locomotive construction adapted for incorporation of water-tubes having rapid water circulation as by forced-circulation pumps. 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 also of 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 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 design of the locomotive boiler, and particularly of the boiler shell, 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 related to increasing the safety factor in locomotive operation, particularly by an improved structural arrangement adapted for cooperation with a novel combination of boiler elements conductive to safe operation.

In accomplishing the foregoing, the invention further contemplates the provision of 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, and at least in large part constituting the foundation or basic strength structure of the locomotive, but preferably in conjunction with the main frame of the locomotive chassis, so as to serve as the basic strength structure of the locomotive at least with respect to the vertical and transverse stresses, 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 locomotives of the water tube boiler type: the sub-division 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 ex-

ternal 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 in vertical longitudinal planes, for example by arranging the tubular elements themselves to extend longitudinally, 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, the invention contemplates the formation of one or more parts, preferably the top or roof portion, of the structural shell as removable cover plaster or lids, on the inner faces of which are disposed certain of said boiler units, for unitary removal with said cover plates, substantially the remainder of the tubular units being arranged as separately handleable bundles which can be removed from inside the shell through the openings covered by said plates.

More specifically, the invention contemplates the provision of a metallic structural shell enclosing the tubular boiler, said shell being formed of steel sheets, with the bottom wall or deck mounted upon a supporting base which may conveniently be formed substantially flat from one end to the other and which is rigidly secured at one end to the cylinder saddle or casting and from thence to the other end is interconnected at intervals to the main frame of the locomotive by waist-sheets or bearers accommodating relative longitudinal expansion and contraction between said shell and said main frame; the base of the shell being desirably made up of longitudinal and transverse structural shapes, such as I-beams, L's and Z-bars, and the side and top walls of the shell being rigidly braced by externally disposed inverted U-shaped members extending upwardly from the base at one side, thence across the top, and downwardly to the base at the other side, triangular or other diagonal braces being located at intervals along the sides thereof; the deck or base of said shell further being extended laterally beyond the side walls of the shell, at least in the region forwardly of the fire-box zone and there serving as supports for a plurality of steam-releasing drums, at the outer sides of which ample clearance is left for running-boards; and in the preferred arrangement the invention also involves a rearward extension of the longitudinal framing members of the base of said shell to form an integral support for the locomotive cab and for auxiliaries such as stoker mechanism, injectors, water pump, and the like, and further involves a forward extension of said base at least to the front of the smoke-box.

Still further, 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 headers, 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; and provision for rapid circulation of water in said tube units, as by means of one or more circulating pumps.

Various miscellaneous objects and advantages of the invention 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; improving the application and retention of insulating lagging; providing alternatively for the use of light-weight insulation such as metal-foil; simplifying the streamlining of the locomotive; increasing the range of vision from the cab; lowering the center of gravity of the locomotive; making possible a re-arrangement of the chassis and particularly of the main frame thereof in a way to secure a more direct longitudinal transmission of pull and buffing stresses; enlarging the space for and improving the disposition of the ashpan mechanism; 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 1a and 1b 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 1a showing the rear end of the locomotive and Figure 1b 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 1a, 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 1a;

Figure 3 is a vertical transverse section, looking forwardly in the fire-box, taken approximately on the line 3—3 of Figure 1a, 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 1a, 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 1a, 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 1b, 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 1b, but to a larger scale;

Figure 8 is a fragmentary transverse sectional detail of the ashpan and fuel-supporting grate, showing the relation thereof to the cradle or rear extension of the main frame and to the fire-box structure of the locomotive;

Figure 9 is a fragmentary end elevational view of a typical bank of boiler tubes and tube-supporting and clamping means such as employed in the boiler of the present invention, but illustrating a staggered arrangement of adjacent tube units as a modification of the straight row arrangement shown in Figures 5 and 6;

Figure 10 is a fragmentary enlarged side elevational view of the structure of Figure 9, viewed from the left of that figure;

Figure 11 is a sectional detail through one of the walls of the structural casing or shell for the boiler, showing the closely spaced water wall tubes of the boiler positioned in juxtaposition to the inner face of said shell, and illustrating the means of securing said tubes to the shell;

Figure 12 is a fragmentary section on the line 12—12 of Figure 11, illustrating the means for accommodating relative longitudinal expansion and contraction between the shell and the adjacent tubes;

Figure 13 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 through the various tube units of the boiler;

Figure 14 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 15 is a plan section taken on the line 15—15 of Figure 14 and showing also the water outlet connection adjacent the bottom of the drum;

Figure 16 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; and

Figure 17 is an isometric view of the pressure-free structural shell of the present invention, with cover-plates, etc., omitted.

#### *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 1a and 1b together, and Figure 16. Considered in a general way, the preferred embodiment of the locomotive of the present invention 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 1b); and running-gear, the main wheels of which are designated by the reference character 22.

The main frame 17 extends to the front end of the locomotive and there carries the transverse pilot beam 20, cylinders 34 and valve chests 35, and has a rearward extension or cradle 17a which incorporates a pocket structure 21 for the usual drawbar and buffer. The running-gear comprises a plurality of main driving wheels 22 having their axles 23 journaled in driving boxes 24 which are vertically movable in the pedestal jaws 25; springs and spring rigging 26 and 27; a front or pilot truck comprising wheels 28; a rear or trailer truck comprising wheels 29 and 30 mounted in a truck frame 31, the wheels of said truck being desirably equalized with the main drivers as by the springs 32 and equalizer bars 33; crosshead guides 36, piston rods 37 with associated driving rods (not shown) coupled to the wheels, and valve motion mechanism (not shown) coupled to the valve stems 38.

The structural shell 18 (separately illustrated

in Fig. 17), 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 said shell or housing may be formed of parts welded together, or in part formed as castings secured together in various ways, or may conveniently be fabricated (as herein shown) of steel sheets suitably secured together and reinforced or braced by various structural members, such as girders, I-beams, angle bars, Z-bars and the like.

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 16), 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 1b, 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 44a in Figure 1a 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 1a), 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 1a and 2). In the region of the secondary combustion chamber, the top wall of the shell slopes slightly downwardly and forwardly (as shown at 48a in Figures 1a and 17), and the side walls 48b (Figures 4 and 17) slope toward each other in the forward direction, to merge with the side walls 48c of that portion of the shell which encloses the major banks of boiler tubes (see Figures 5 and 17).

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 1a). From thence

forwardly, throughout the region of the secondary combustion chamber, i. e., throughout the extent of the sloping bottom wall 44a (Figure 1a), 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 48c of the shell is relatively closer, as shown in Figure 5. This not only results in a progressive reduction in the cross-sectional area of the passage for the products of combustion, as the latter are cooled during their progress from the fire-box to the smoke-box, but also 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 16 and in the sectional views of Figures 5, 6 and 7, and shown in dotted lines in Figures 1a and 1b.

In the region of the major part of the boiler, just described, the side walls 48c, 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 Figures 5 and 17; and in this region the roof or top wall is made up of a removable cover plate 53 (see also Figures 1a and 1b), a removable superheater header 54 (see Figure 1b) and a second removable cover plate 53a (see Figure 1b).

From about the plane of the line 6—6 of Figure 1b forwardly to the front end of the smoke-box, the side walls 48d (see Figures 6 and 17) 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 48e (see Figure 1b) to receive any suitable feed water heater 56 (see Figure 16). The front end of the smoke-box may be closed by a plate 57 and a removable cover 58.

Turning again to the rear end of the shell, as seen in Figures 16 and 17, it will be observed that the main longitudinal girders 39 are continued rearwardly of the rear fire-box wall 49, as shown at 39a, the same being cut down in height, as indicated at 39b; this extension of the girders being utilized to support the cab deck 59 and thus the cab itself 60. In this same region a bottom plate 61 may interconnect the side girder extensions 39a and serve to support various auxiliaries such as stoker mechanism (not shown), injector 62 and feed water pump 63.

The structural shell is completed by the following parts: in the region of the fire-box (as seen in Figures 1a, 2, 3, 16 and 17) 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 4, are reinforced by the header boxes 68, shown in Figures 4 and 16 (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, 16 and 17). Additional flanges 69a may extend outwardly from the side walls and down to the base (Figures 5 and 17); while the cover plates 53 and 53a, which are flanged at 53', may also carry arched flanges 69b by means of vertical trans-

verse 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 convenient sub-divided space for applying layers or slabs of any of the standard available insulating materials, such as magnesia lagging, or more preferably a mass of crumpled aluminum foil indicated at 72 in Figures 2, 3, and 16; 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; and it will be seen from Figure 16 that the said external sheathing 73 can be applied in such manner as to substantially streamline the external contours of the locomotive, 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).

The bracing and stiffening members cooperate with the jacket or sheathing in serving to protect and hold in place the insulating material, which, in the case of the aluminum foil mentioned, or the equivalent is very light and must be protected against compression. With ordinary locomotives, the use of very light insulations or laggings, such as metal-foil, requires special framing to protect the same, and the weight of such framing largely offsets the saving in weight of the lagging itself. By our improved arrangement, on the other hand, provision is made for supporting, retaining and protecting the light and fragile insulation employed, without adding any weight to the shell structure. On a good sized locomotive, this arrangement effects a weight saving of approximately 4000 pounds as compared with the use of the ordinary magnesia block lagging.

By comparing the several cross sectional views (Figures 2 to 6 inclusive) it will be seen that with the progressive narrowing of the shell walls from the point adjacent the front of the fire-box (Figure 2) forwardly, space is provided at each side of the various parts, such as the header boxes 68 (Figure 4) and the collecting drums 51 (Figures 5 and 6); the overall transverse dimension of these various parts forward of the firebox being just within the overall transverse dimension of the outer sheathing 73. Thus, when looking forward from the cab windows 74, the engineer and fireman have a clear view 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).

The main base of the structural shell can be made flat and disposed horizontally from one end to the other, for ease and rigidity of attachment to the main frame structure. Thus, referring to Figures 1a, 1b and 16, said base is rigidly (but removably) secured, as by any suitable bolts (not shown) to the saddle structure 80 which may be cast integrally with the cylinders and valve chests, said saddle structure being formed with a rectangular flat top having suitable reinforcing and mounting flanges and brackets, as shown. The bottom plate 44 of the shell proper rests upon and is secured to the top of the saddle and is apertured at 81 to accommodate the upstanding exhaust nozzle 82. It will be obvious that this form of cylinder saddle is easier to manufacture and easier to align with the shell than is the case with the ordinary cylindrical boiler barrel and arcuate saddle.

Rearwardly of the cylinders, at intervals along the main frame, we provide a series of inter-braces or connections between the shell and the frame, which are rigid in a transverse vertical plane but allow for relative longitudinal expansion and contraction between the shell and the main frame. These supports may take the form of waist sheets 83 secured to the bottom of the shell base, in alignment with the cross-members 40, said waist sheets being secured to suitable brackets 84 mounted fast on the main frame. In the region of the firebox, the main frame 17 and its extension 17a are inter-braced with the structural shell, by any suitable bearer members 85 which are preferably rigidly secured to the transverse bracing structure 46, 46, at the base of the firebox, in front of and to the rear of the ashpan 86, and which rest on pads or other points of support 87 on the frame 17 and cradle 17a, at which points the bearers 85 have freedom for relative sliding in a longitudinal direction to accommodate expansion and contraction of the shell. Thus the vertical and transverse stiffness of the locomotive foundation is chiefly provided by the pressure-free shell which encloses the evaporating means of the boiler. Similar supports 85a, 87a, (fragmentarily shown) are provided for the mounting of stoker and grate mechanism.

It should now be observed that since there are no flat water legs in the firebox, and no inner crown sheet, the available space for combustion, extending practically the full height of the boiler, is so substantial (within the usual outside clearance limitations) that it is not necessary to provide the usual downwardly and forwardly sloping side edges at the firebox, and in view of this the bottom of the firebox can be positioned substantially in the same plane with the bottom of the remainder of the shell which extends forwardly therefrom. In this way, a larger space for the ashpan is provided, and the slope of the ashpan can be made steeper. Additionally, as shown in Figure 1a, the main frame extension 17a can be placed in substantially the same horizontal plane as the forward part of the main frame, so



that there is practically a direct horizontal transmission of the longitudinal pulling and buffing stresses. The ashpan 86 may be mounted on the cradle or it may be secured to the longitudinal base members 47 of the firebox by any suitable brackets 88 (as shown in Figure 8. The grate structure 89 may take any desired form, or any other suitable fuel burning means may be provided, which will effect a burning of the fuel in the combustion zone so that the tubes in the firebox will be subjected to radiant heat.

Referring now to the steam evaporating means, it will be observed that the shell structure 48 in the region of the firebox 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 firebox (as seen in Figures 1a and 3) then transversely, half-way across the back wall of the firebox, (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 firebox, 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 firebox (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 87 (see Figures 1a and 16). 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 firebox, 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 firebox 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 16) 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 firebox, 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 firebox these arch tubes 110 bend laterally (as seen in Figures 1a and 2) and thence extend forwardly along the side walls of the firebox 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 firebox 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 the 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 115c 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 smokebox 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 firebox (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 firebox to the smokebox, thus reducing to a minimum the scouring of the tubes by the cinders. Even in the firebox itself, the tubes which line the walls thereof are substantially parallel with the path of the fuel and flame stream.

It is important that the tubes be held as against vibration, kept in their proper spacing, and arranged for convenient removal and replacement as unitary bundles. Suitable apparatus for accomplishing these purposes is indicated fragmentarily in Figure 5, and in detail in Figures 9 to 12 inclusive.

Although the tubes in Figures 9 and 10 are shown in staggered relation, it will be understood that the tube clamps 132 shown therein may readily be configured with their curved tube seats 133 either in staggered relation or in straight rows as indicated in Figure 5. A plurality of tube units, or a plurality of passes of the same tube unit, are positioned in superimposed relation by means of the double-ended saddle members 134, which may if desired be welded to the adjacent tubes. Any suitable number of the tube units are then clamped together between two of the members 132, which have complementary tongues and forks 135, 136, apertured to receive a wedging key 137. At the corners of the assembled bundle, the clamping members 132 have holes 138, adapted to be engaged by hooked bolts 139 (see Fig. 5) which pass through the walls of the shell and are there secured as by nuts 140.

A suitable fastening for the wall and roof tubes (for example the tubes 118 of Figure 5) is shown in Figures 11 and 12, wherein it will be seen that saddle strips 141 extend at right angles to the

axes of the tubes, the tubes being welded in said saddles. Stud 142 pass out through the wall 48c of the shell, and are secured as by suitable nuts 143. In order to allow for relative longitudinal expansion between the tubes and the shell structure, holes 144 through which the studs pass may be made elongated in the direction of the tube length, as shown in Figure 12. An additional means of securing the tubes, particularly where they extend in a direction perpendicular to the length of the shell, will be seen in Figure 1a, wherein the bent ends of the tube units are provided with integral lugs or studs 145, secured in the shell.

Features of the tube securing means above-described are claimed in our copending divisional application 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 13.

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. The plug 148 provides a means for access to the tube end, for initially securing the tube in the header.

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.

Turning now to the circulation of the boiler, which is indicated generally by arrows, it will be seen from Figure 16 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 77a, the vertical headers or pipes 155 and the crossheaders 130 (Figure 6); also by the upwardly extending pipes 123a and crossheader 123 (Figure 5) and the pipes 157 and crossheader 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 1a), and 120a (Figure 1b).

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. 1a), and adjacent the front by means of the elbows 108a, 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 delivery into the collecting and storage drums 51, preferably tangentially, by means of the curved pipes 109a seen in Figures 14 and 15.

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 164a.

The steam is released within the drums, and passes out through the traps 165 (Figs. 14 and 15) 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 headers and the 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.

Features of boiler construction and of the above-described circulating system are claimed in our divisional case, Serial No. 406,962, filed August 15, 1941.

*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 fire-tube 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 firebox 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., a 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 firebox 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

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9

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 arrangement herein disclosed 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 locomotive construction, a pressure-free structural shell extending lengthwise of the locomotive and chiefly defining the gas passage area and forming the major stiffening element of the locomotive foundation, steam evaporating means housed within said shell and comprising a multiplicity of water tubes, said tubes being arranged in bundles rigidly secured to said shell as against dislodgment therefrom, but with freedom for expansion and contraction relative thereto, and tube spacing means holding the various tubes rigidly as against vibration due to operation of the locomotive.

2. In locomotive construction, a pressure-free structural shell extending lengthwise of the locomotive and chiefly defining the gas passage area and forming the major stiffening element of the locomotive foundation, said shell including a rigid base structure extending rearwardly to form a cab support.

3. In locomotive construction, a pressure-free structural shell extending lengthwise of the locomotive and chiefly defining the gas passage area and forming the major stiffening element of the locomotive foundation, said shell including a rigid base structure which, throughout a substantial portion of the length of the shell, extends laterally beyond the sides of the shell proper, and steam and water drums carried on said lateral extensions of the base.

4. In locomotive construction, a pressure-free structural shell extending lengthwise of the locomotive and chiefly defining the gas passage area and forming the major stiffening element of the locomotive foundation, said shell including a rigid base structure which, throughout a substantial portion of the length of the shell, extends laterally beyond the sides of the shell proper, and steam and water drums carried on said lateral extensions of the base and rigidly secured thereto and to the side walls of the shell proper.

5. In a fuel-burning steam locomotive, the combination of a pressure-free foundation structure formed to define in large part a firebox and a unitary passageway extending longitudinally therefrom for carrying off the products of combustion, steam generating tubes lining the inside

of said foundation structure and positioned to protect the same from the heat of the products of combustion, said structure being of substantially inherent stiffness throughout most of its length but being of reduced dimension and thus reduced inherent stiffness adjacent the juncture of the firebox portion and the portion forming a longitudinal passageway, and header means coupled to said tubes and secured to the structure to stiffen the same at said region.

6. In a fuel-burning steam locomotive, the combination of a pressure-free foundation shell structure formed to define in large part the passageway for the products of combustion and having a face thereof formed with a closable aperture, tube units within said structural shell positioned for access through said aperture, and removable closure means for said aperture at least in part constituted by header means for said tube units.

7. In a fuel-burning steam locomotive, the combination of a pressure-free foundation shell structure formed to define in large part the passageway for the products of combustion, circulating tube units carried by said shell internally thereof and adapted to protect the same from the heat of the products of combustion, said units lying largely in vertical longitudinal planes, header means positioned chiefly externally of said shell in transverse planes, and external connections from said units to said header means.

8. In locomotive construction of the character described, a pressure-free metallic structural shell largely defining an enclosed gas passageway extending from adjacent one end of the locomotive to adjacent the other, and embodying substantial reinforcement against buckling, whereby it forms at least a major strength element of the locomotive foundation essential to the vertical stiffness thereof and is adapted for the firm support of boiler structure.

9. In locomotive construction of the character described, a pressure-free metallic structural shell largely defining an enclosed gas passageway extending from adjacent one end of the locomotive to adjacent the other, and embodying substantial reinforcement against buckling, whereby it forms at least a major strength element of the locomotive foundation essential to the vertical stiffness thereof and is adapted for the firm support of boiler structure, and boiler structure largely housed in said shell and secured thereto to receive its chief support therefrom.

10. In locomotive construction of the character described, a pressure-free metallic structural shell largely defining an enclosed gas passageway extending from adjacent one end of the locomotive to adjacent the other, and embodying substantial reinforcement against buckling, whereby it forms at least a major strength element of the locomotive foundation essential to the vertical stiffness thereof and is adapted for the firm support of boiler structure, and boiler structure largely housed in said shell and secured thereto to receive its chief support therefrom and comprising water-cooled elements positioned to provide the main protection for most of said shell against the heat of the products of combustion.

11. A construction according to claim 9, wherein the boiler structure is so disposed with reference to said shell as to facilitate the making of connections and to accommodate relative expansion and contraction rather than to promote thermal circulation in the boiler, and means are provided

for positively effecting a circulation of water through said boiler structure.

12. A construction according to claim 9, wherein the boiler structure is so disposed with reference to said shell as to facilitate the making of connections and to accommodate relative expansion and contraction rather than to promote thermal circulation in the boiler, and means are provided for positively effecting a circulation of water through said boiler structure at a rate substantially in excess of the steaming capacity of the boiler.

13. A construction according to claim 9, wherein said boiler structure is formed chiefly of tube coils secured to the walls of said shell by means which minimize relative vibration but accommodate substantial tube expansion and contraction relative to the shell.

14. A construction according to claim 9, wherein said boiler structure comprises a multiplicity of water tubes which are arranged in separately handleable bundles mounted within and supported by said shell for independent removal and replacement.

15. A construction according to claim 9, wherein the boiler structure comprises steam evaporating means within the shell, and steam and water collecting and storage means coupled to said evaporating means but positioned largely outside of said shell.

16. A construction according to claim 9, wherein steam drum means are located outside of said shell and have fluid connections with the boiler structure therein.

17. A construction according to claim 9, wherein the housed boiler structure comprises a longitudinally extending series of water tube units, and in which there is a longitudinally extending series of steam drums disposed exteriorly of said shell, with means connecting said units to said drums.

18. A construction according to claim 9, wherein the housed boiler structure comprises a longitudinally extending series of water tube units, and wherein there is provided a longitudinally extending series of vertical water and steam drums disposed exteriorly of said shell, with means connecting said units to said drums.

19. A construction according to claim 10, wherein said water-cooled elements comprise a multiplicity of closely spaced water tubes closely positioned against the inner faces of the walls of said shell, whereby any need of intermediate brick insulation is eliminated.

20. In locomotive construction of the character described, a pressure-free metallic structural shell largely defining an enclosed gas passageway extending from adjacent one end of the locomotive to adjacent the other, and embodying substantial reinforcement against buckling, whereby it forms at least a major strength element of the locomotive foundation essential to the vertical stiffness thereof and is adapted for the firm support of boiler structure, and boiler structure largely housed in said shell and secured thereto to receive its chief support therefrom and comprising a multiplicity of water tubes including tube units disposed to form a lining for said shell.

21. A construction according to claim 20, wherein a plurality of tube units have independent water delivery headers, and means are provided for effecting a positive forced circulation of water from said headers through said tubes.

22. A construction according to claim 20,

wherein a plurality of tube units have independent water delivery headers, and means are provided for effecting a positive forced circulation of water from said headers through said tubes, and further including means for effecting a substantial pressure drop in said tubes as compared with said headers whereby to assure ample distribution of water into all of said tubes.

23. A construction according to claim 20, wherein the structural shell is protected from the heat of combustion by the lining tubes, and in turn forms a firm support for an insulating covering which is disposed upon the outside of said shell to minimize heat losses.

24. In locomotive construction, a boiler comprising a longitudinally-extending substantially air-tight pressure-free metallic structural shell constituting a major strength element of the locomotive foundation, formed to define in large part the passageway for the products of combustion from adjacent one end of the locomotive to adjacent the other end, a multiplicity of water tubes housed within said shell in position to be subjected to the heat of the products of combustion including shell lining tubes directly protecting said shell and having no appreciable water-free space, and steam collecting means having steam and water connections to said tubes and configured to accommodate substantial variations in water level while the water-filled condition of said lining tubes is maintained.

25. A construction according to claim 24, wherein the steam collecting means are positioned exteriorly of the shell.

26. A construction according to claim 24, having means for maintaining water circulation at a positive pressure head in the tubes.

27. A construction according to claim 24, wherein the steam collecting means comprise a plurality of elongated upright steam-and-water drums.

28. A construction according to claim 8, wherein a pulling and buffing frame is also provided as an element of the locomotive foundation, said shell being secured to said frame rigidly with respect to vertical and transverse stresses but with freedom for longitudinal expansion and contraction relative to said frame.

29. A construction according to claim 8, wherein the structural shell is of substantially larger cross-sectional area at one end than at the other, and at the larger end is shaped to define the side and top walls of the locomotive combustion space and at the opposite end is shaped to define a smokebox, there being external bracing means for the shell which are of greater transverse extension at the regions of lesser cross-sectional area of said shell, and vice versa.

30. A construction according to claim 8, wherein the structural shell is of substantially larger cross-sectional area at one end than at the other, and at the larger end is shaped to define the side and top walls of the locomotive combustion space, the portion of smaller cross-sectional area being narrowed laterally to accommodate steam collecting means exteriorly thereof.

31. A construction according to claim 8, wherein the structural shell has a heavily reinforced base structure with means for securing the same to a locomotive frame.

32. A construction according to claim 8, wherein said shell includes a rigid base structure having means for mounting and supporting locomotive auxiliaries.

33. A construction according to claim 8, where-

2,318,040

11

in said shell includes a rigid base structure which, throughout a substantial portion of the length of the shell, extends laterally beyond the sides of the shell proper.

34. A construction according to claim 8, wherein the shell reinforcement is in the form of a series of external bracing members.

35. A construction according to claim 8, wherein the shell reinforcement is in the form of a series of external bracing members configured to receive insulation and to firmly support the same.

36. A construction according to claim 8, wherein the shell reinforcement is in the form of a series of external bracing members configured to support an outside sheath in position to form an approximately streamlined contour.

37. In a fuel-burning steam-powered locomotive, a longitudinally-extending main frame, a longitudinally - extending pressure - free shell mounted thereon and formed to define in large part the gas passageway from the region of fuel-burning to the region of discharge of the prod-

ucts of combustion, main steam generating means, for powering the locomotive, housed within said shell and comprising a lining of water tubes adjacent most of the inner wall surface of said shell in position to dispense with intermediate brick lining and configured to constitute the essential protection of the shell against the heat of the products of combustion, and means accommodating relative expansion and contraction between shell and main frame and between shell and water tubes, whereby all combinations of appreciably differing thermal expansion conditions between shell and main frame and tubes are relieved.

38. A construction according to claim 37, wherein the mounting of the shell on the main frame comprises interconnecting means between them whereby they constitute a structural unit as to generally transverse, including lateral and vertical loads imposed thereon.

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105-43

CERTIFICATE OF CORRECTION.

Patent No. 2,318,040.

May 4, 1943.

WILLIAM E. WOODARD, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, second column, line 20, for "conductive" read --conductive--; page 3, first column, line 73, for "through" read --throughout--; page 5, first column, line 60, for "side of" read --side for--; page 6, first column, line 6, after "Figure 8" and before the period insert a closing parenthesis; line 53, for "headers 87" read --headers 97--; page 8, first column, line 16, for "delivery" read --deliver--; and second column, line 19, before "fire-box" strike out "a"; page 9, second column, line 69, claim 11, for "according" read --according--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the the case in the Patent Office.

Signed and sealed this 15th day of June, A. D. 1943.

(Seal)

Henry Van Arsdale,  
Acting Commissioner of Patents.