

March 31, 1959

E. G. BAILEY ET AL

2,879,717

STEAM POWERED LOCOMOTIVE WITH WATER TUBE STEAM GENERATOR

Filed May 13, 1954

15 Sheets-Sheet 1

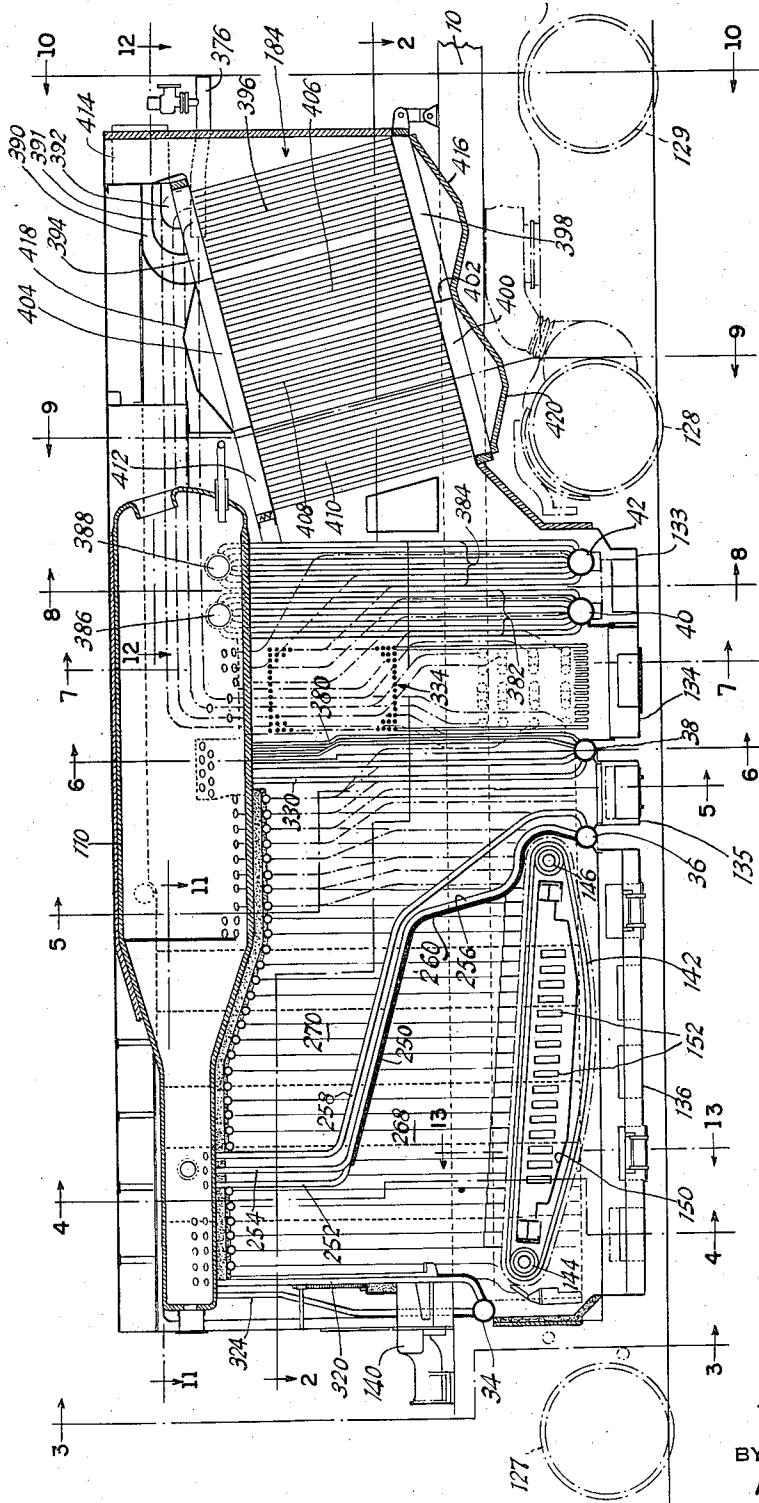


FIG. 1

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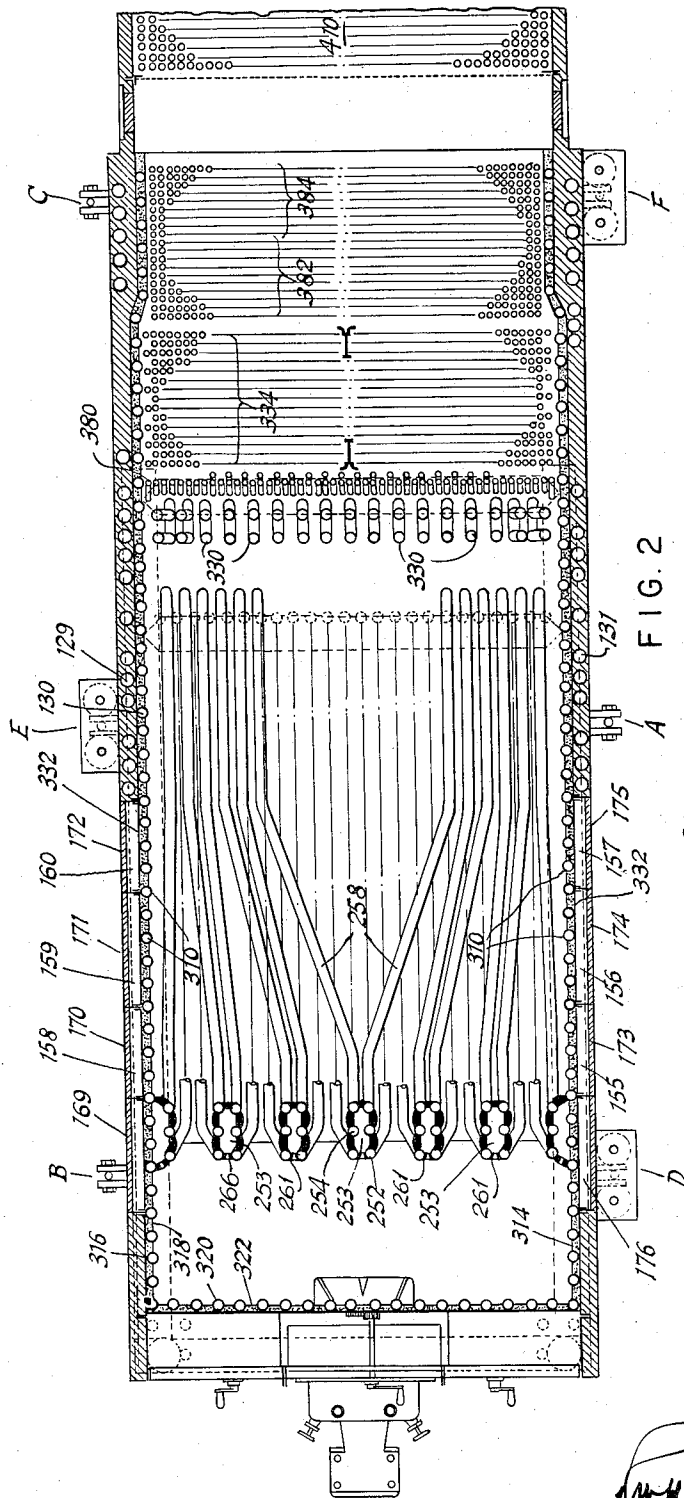


FIG. 2

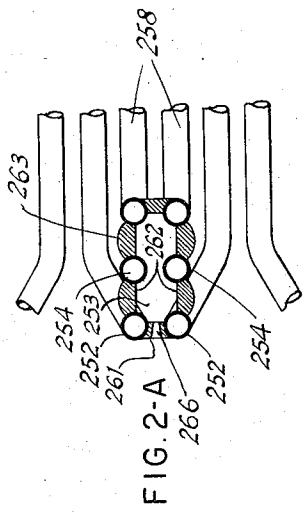


FIG. 2-A

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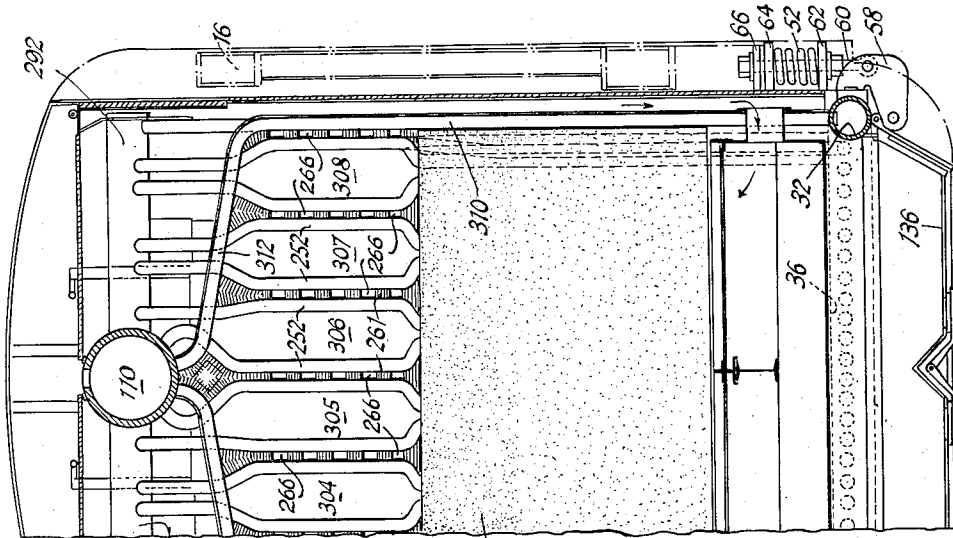


FIG. 4

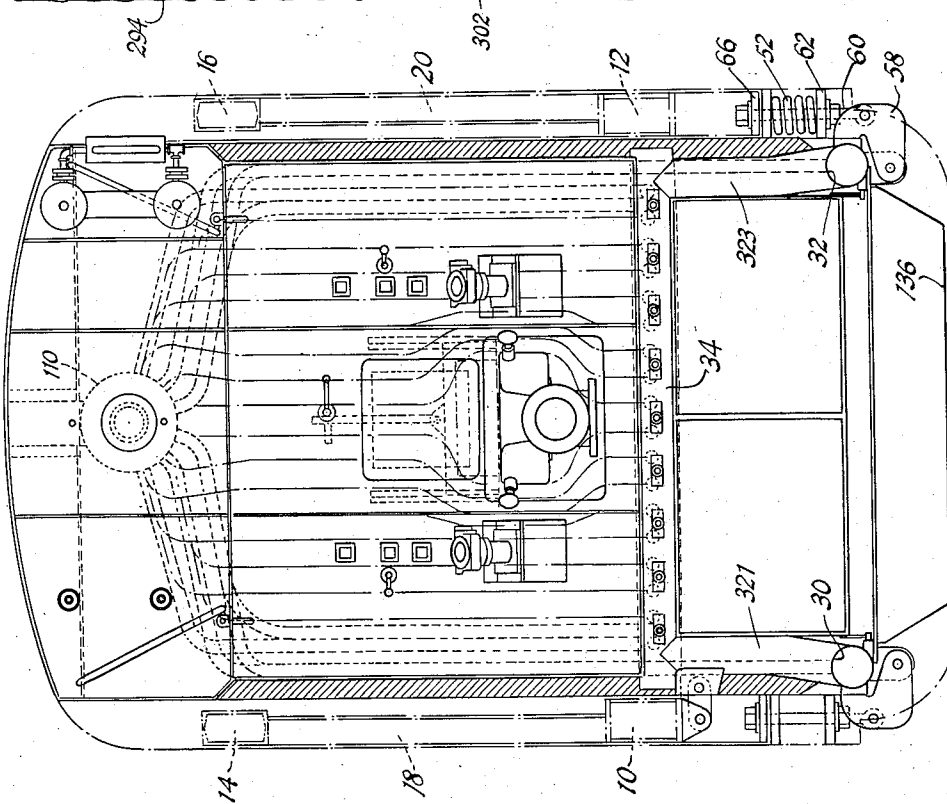


FIG. 3

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15 Sheets—Sheet 4

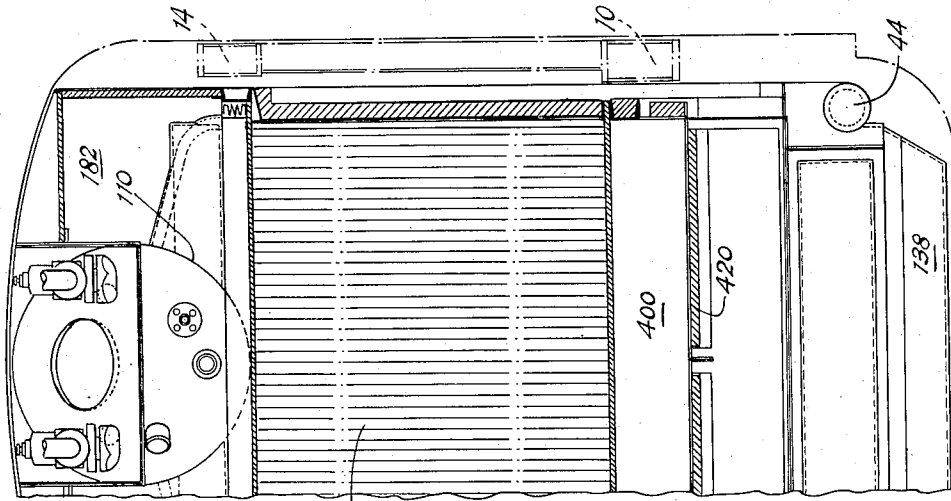


FIG. 9

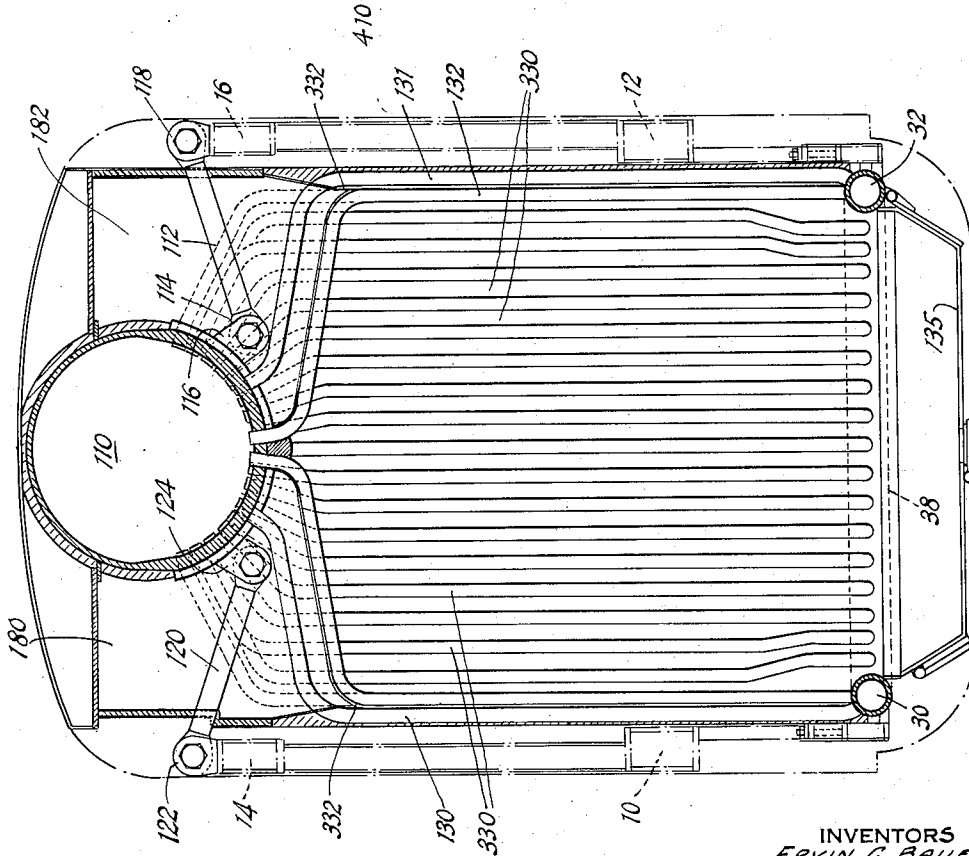


FIG. 5

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15 Sheets-Sheet 5

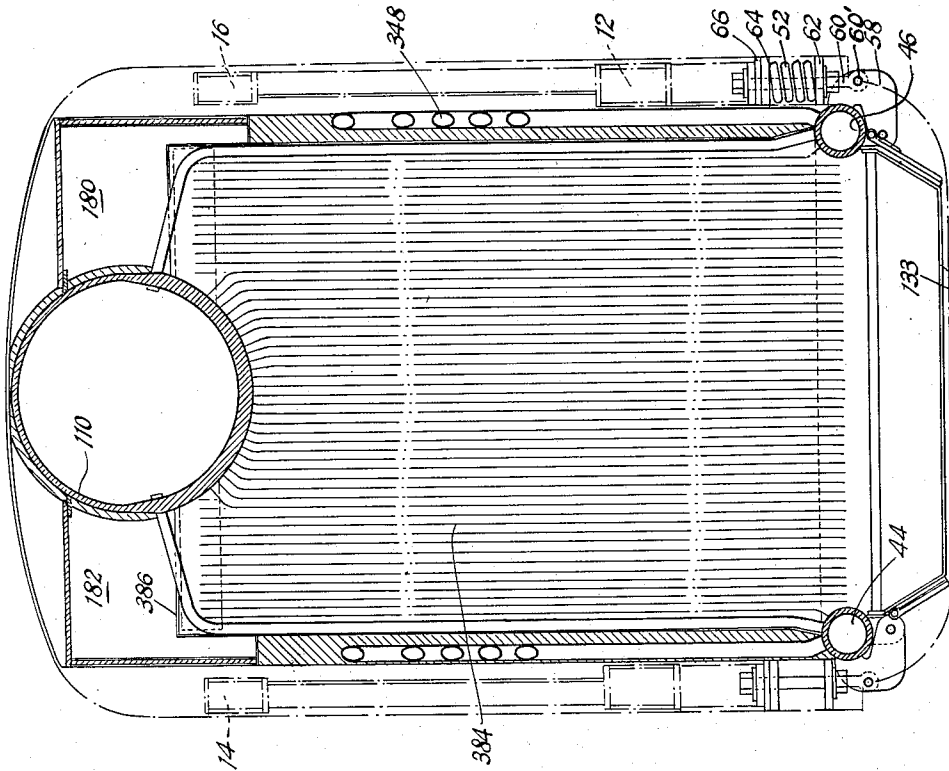


FIG. 8

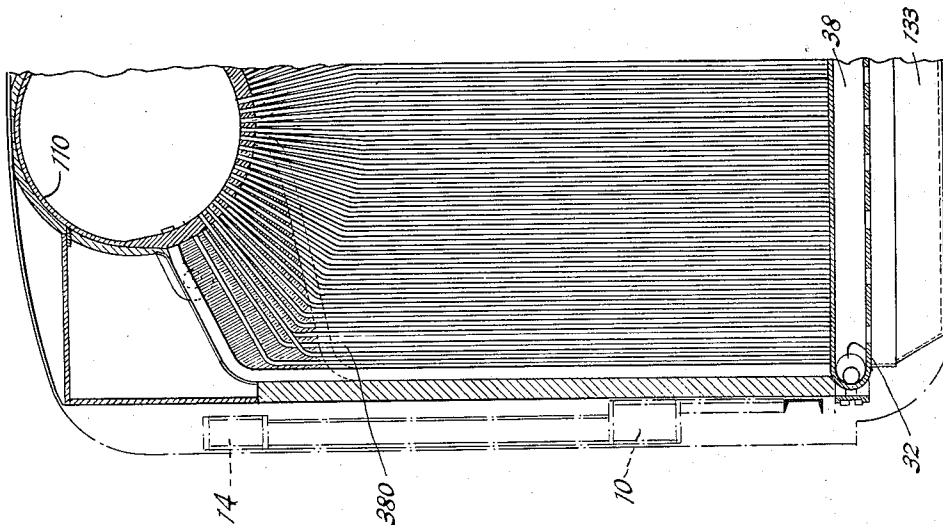


FIG. 6

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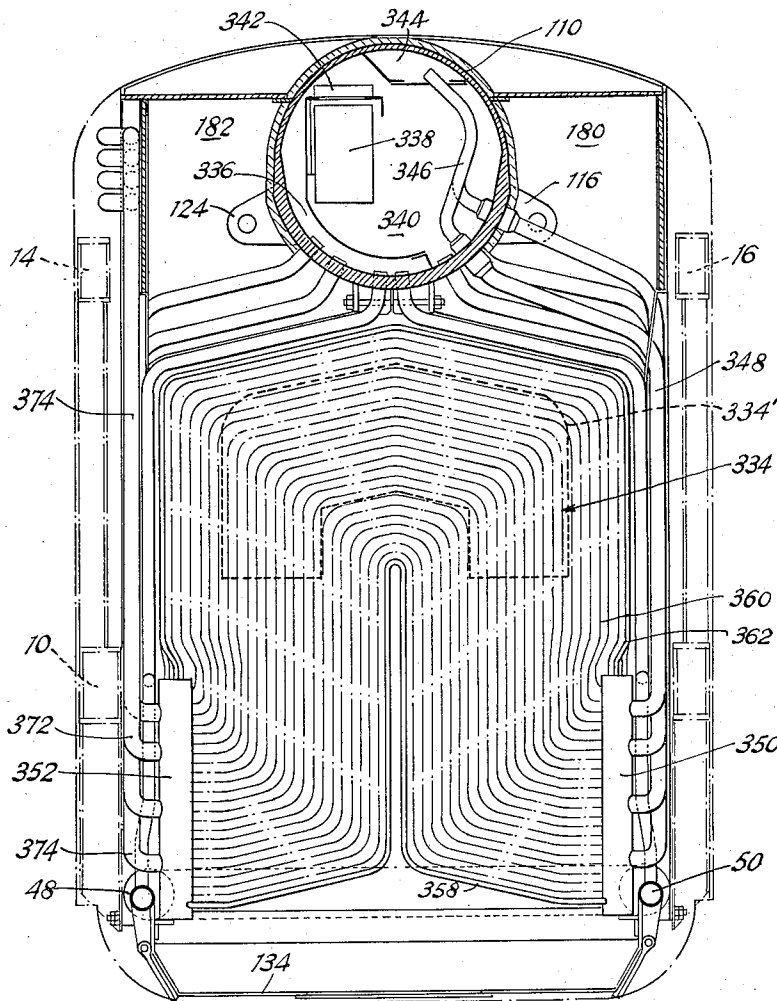


FIG. 7

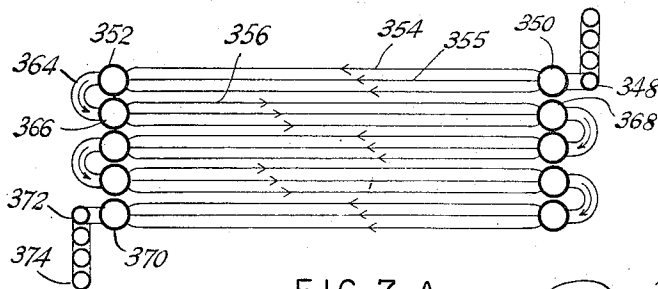


FIG. 7-A

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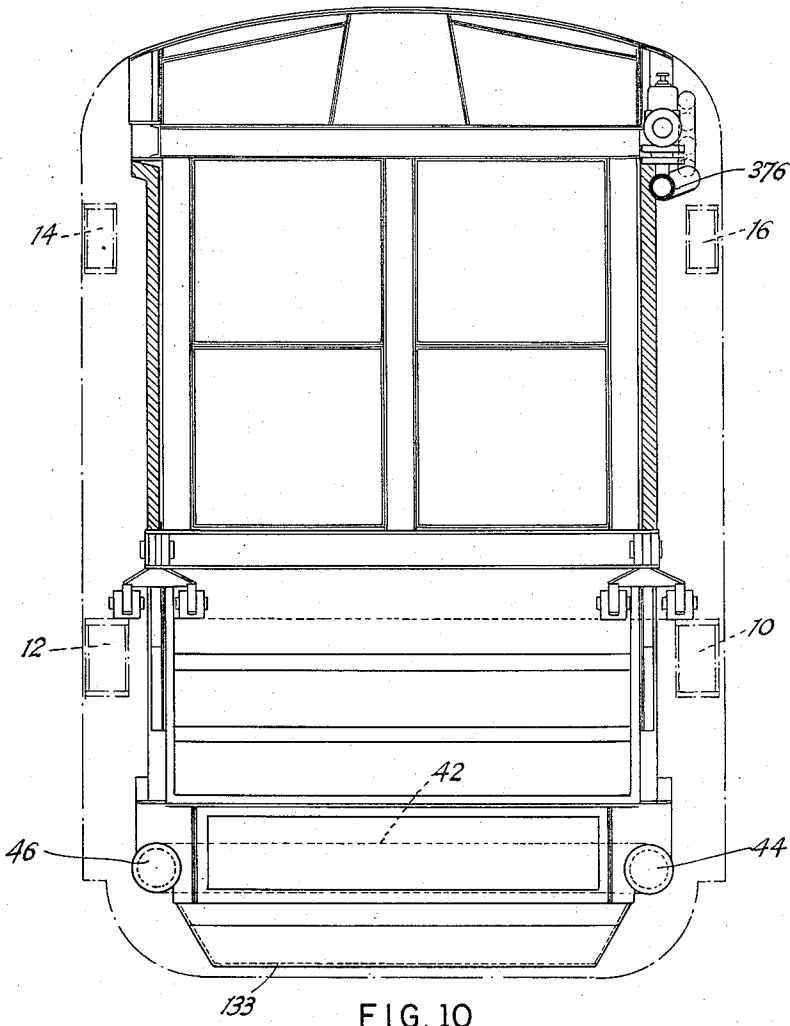
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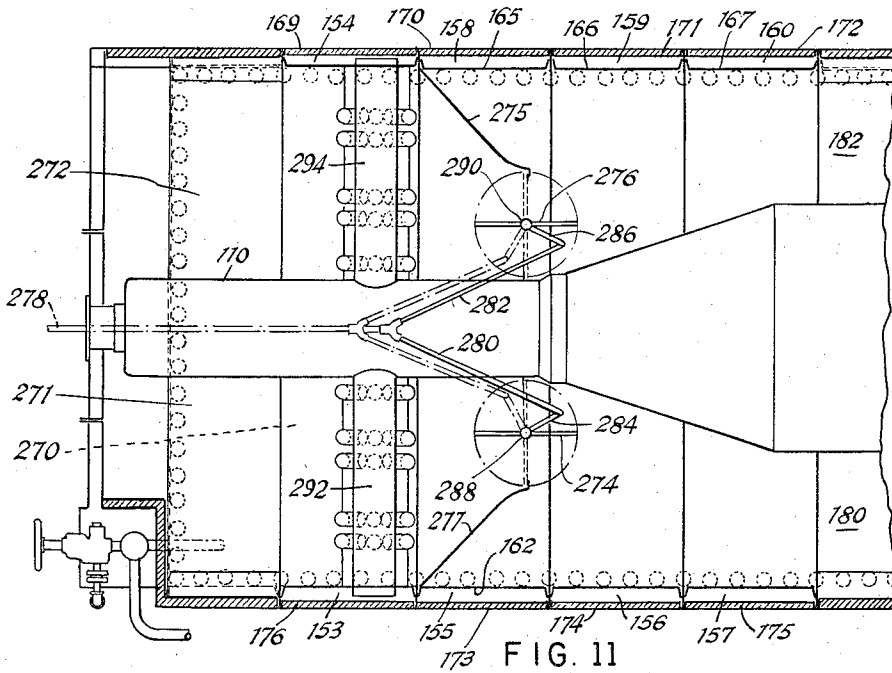


FIG. 11

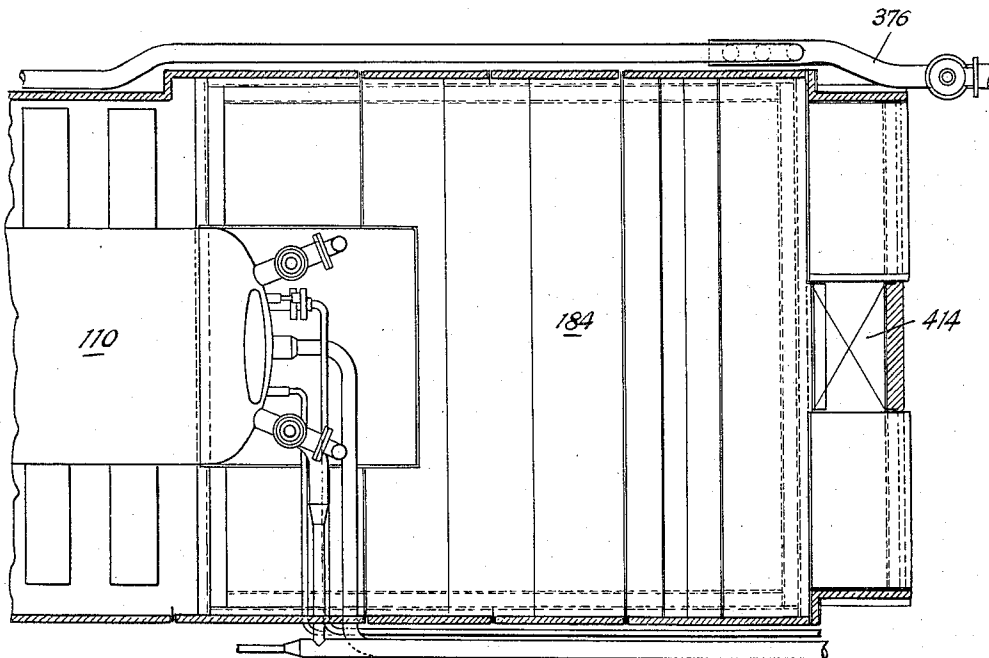


FIG. 12

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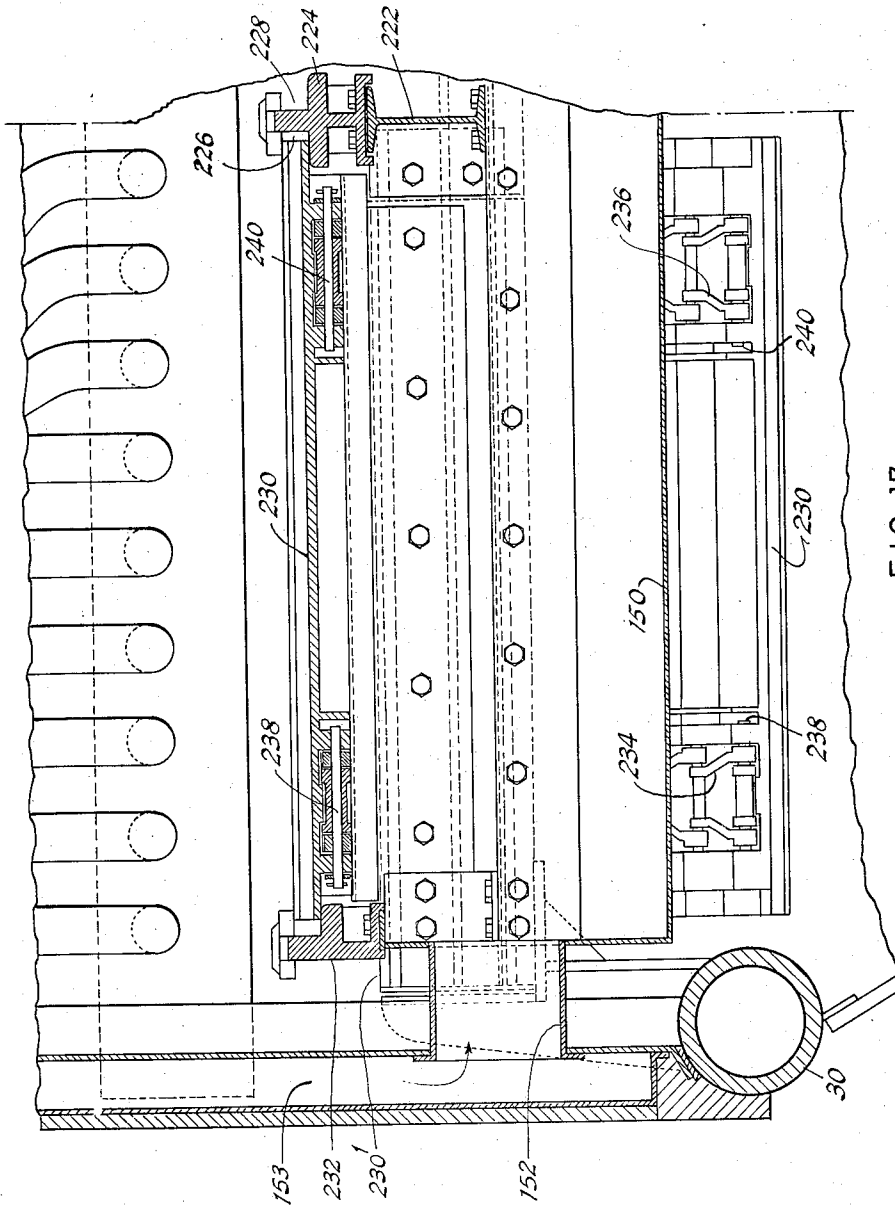


FIG. 13

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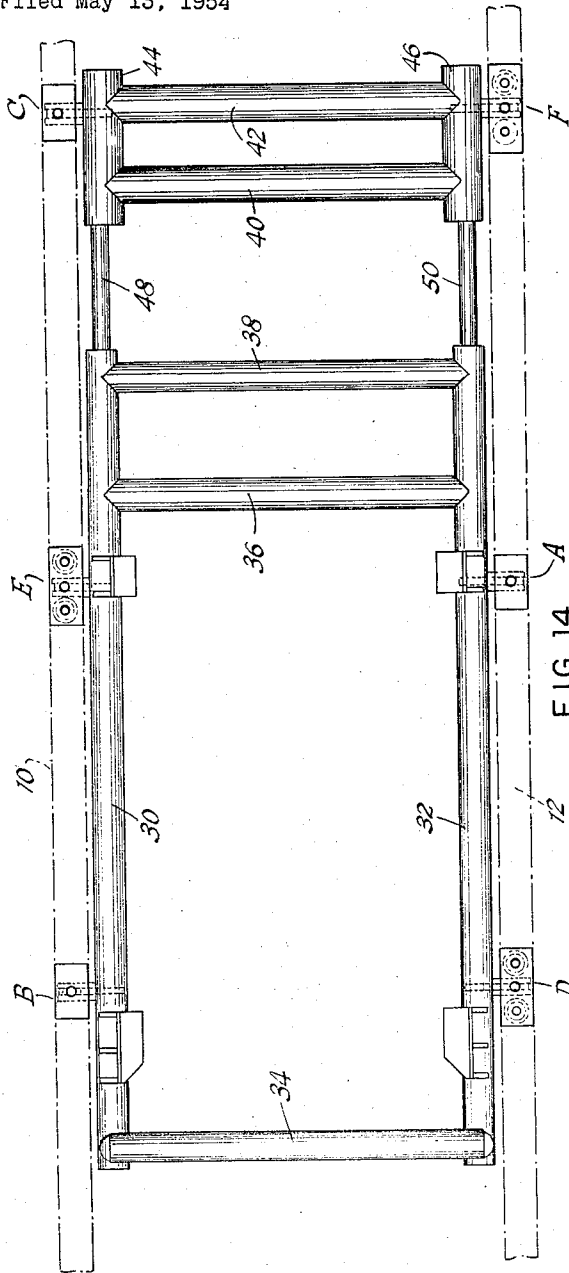


FIG. 14

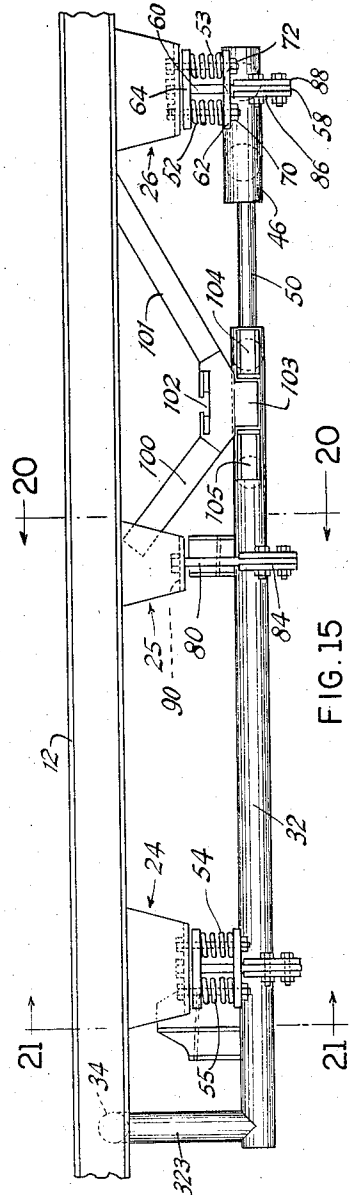


FIG. 15

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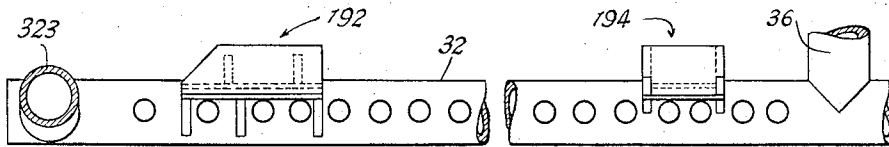


FIG. 17

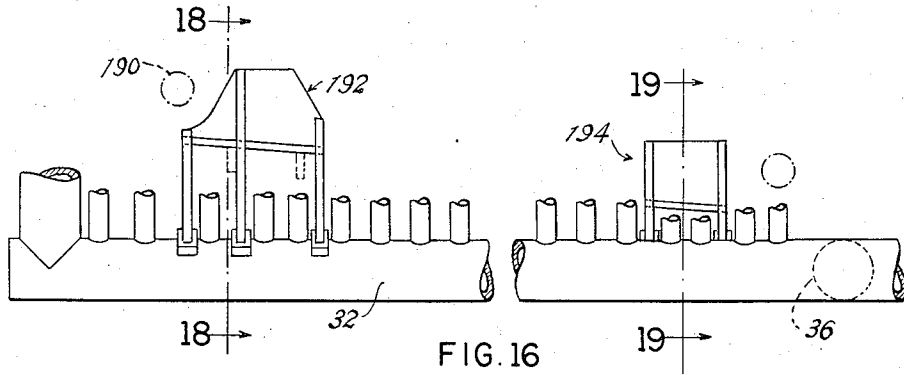


FIG. 16

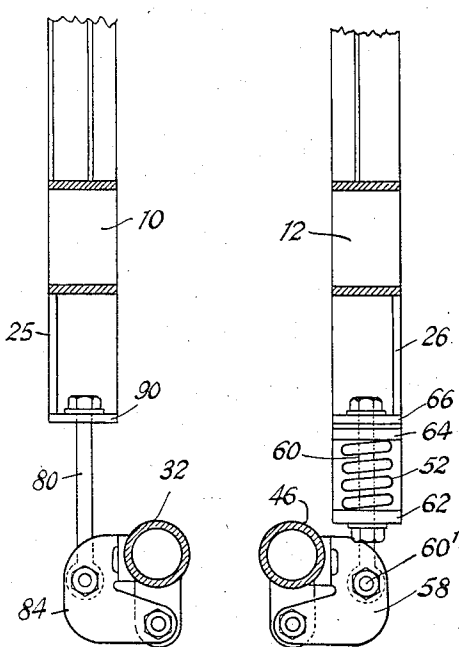


FIG. 20

FIG. 21

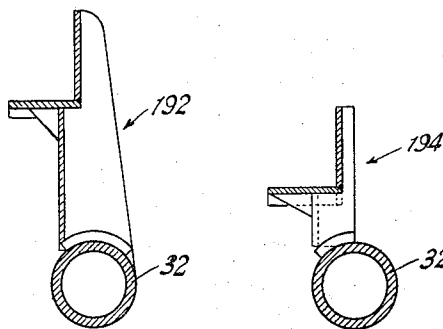


FIG. 18

FIG. 19

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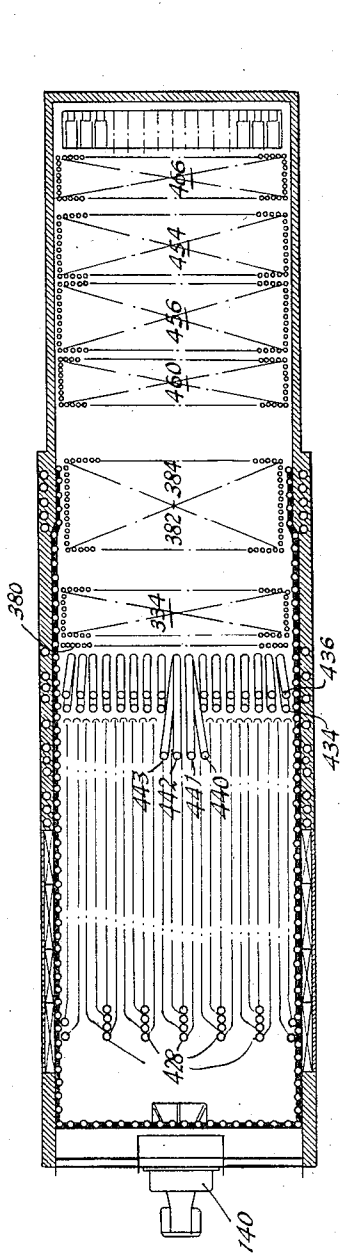


FIG. 23

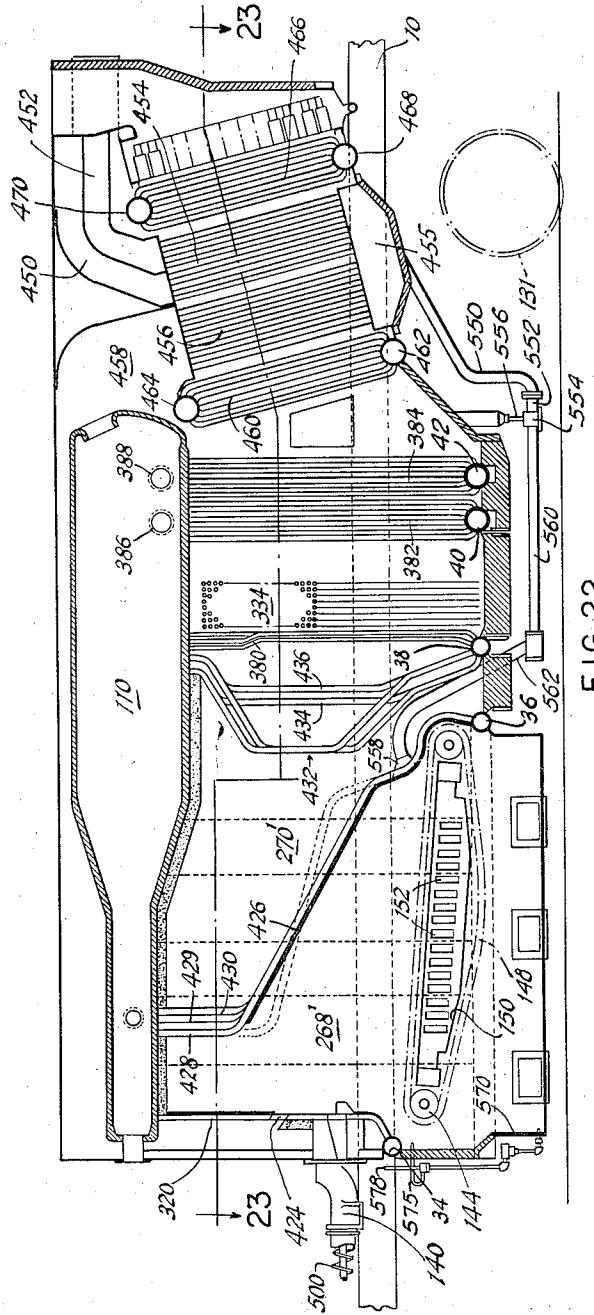


FIG. 22

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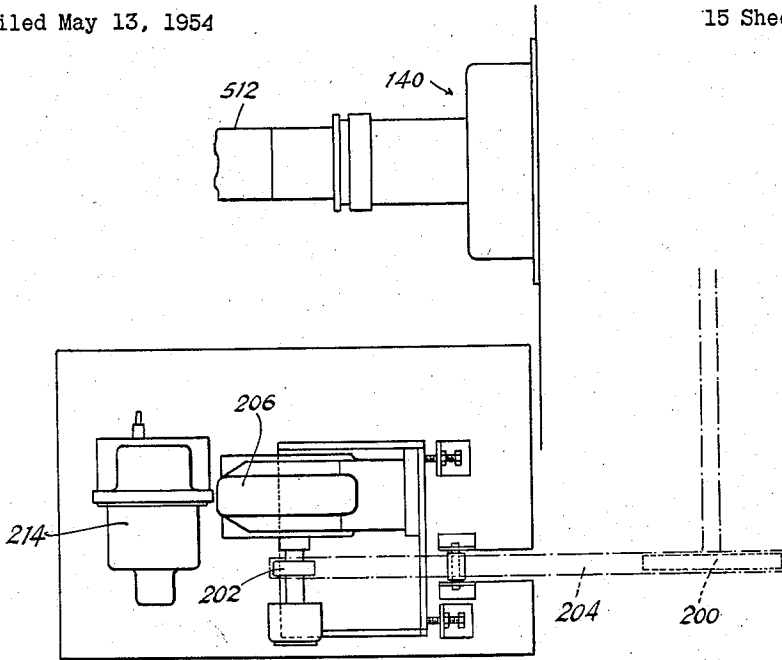


FIG. 24

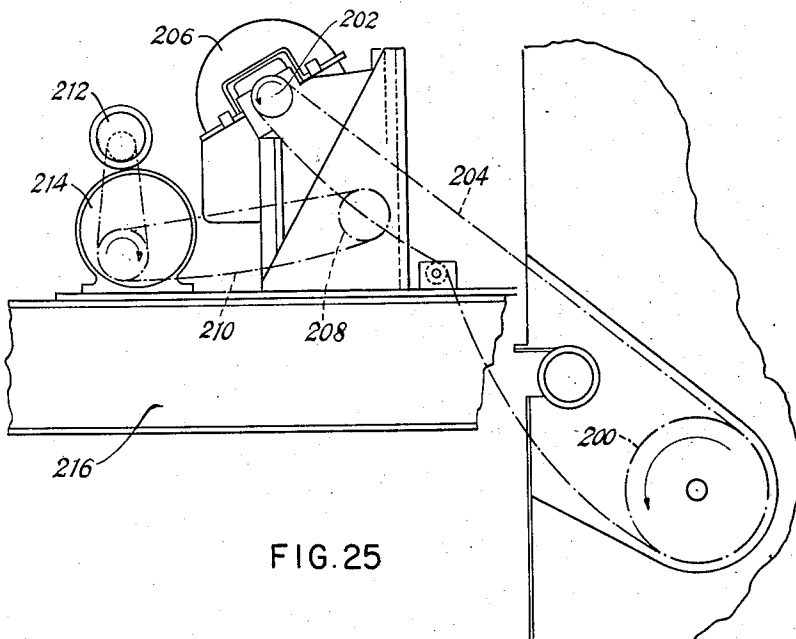


FIG. 25

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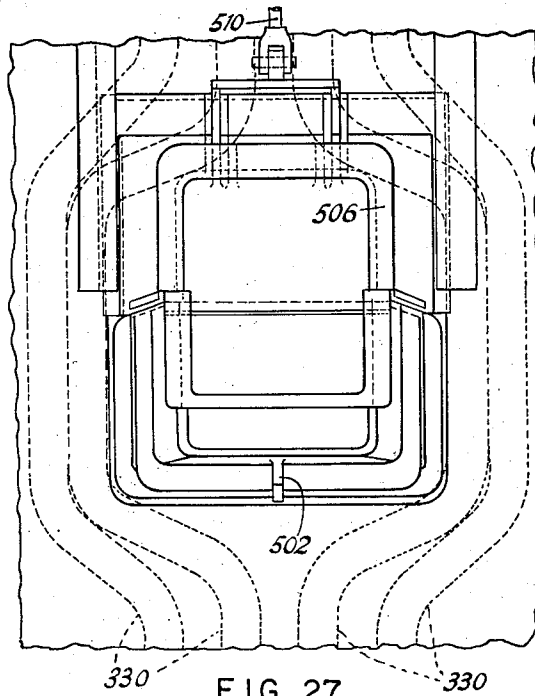


FIG. 27

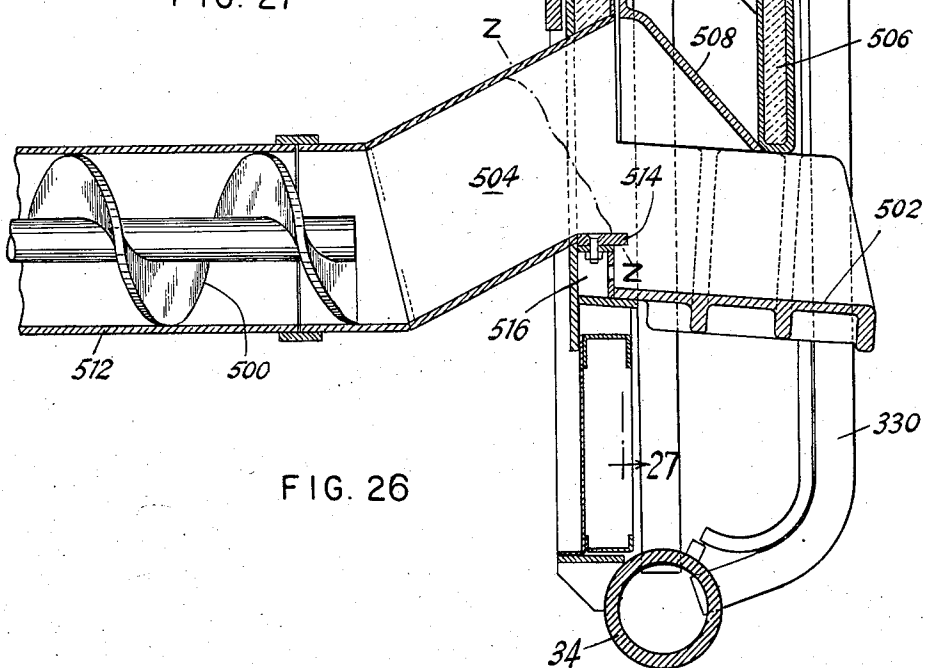


FIG. 26

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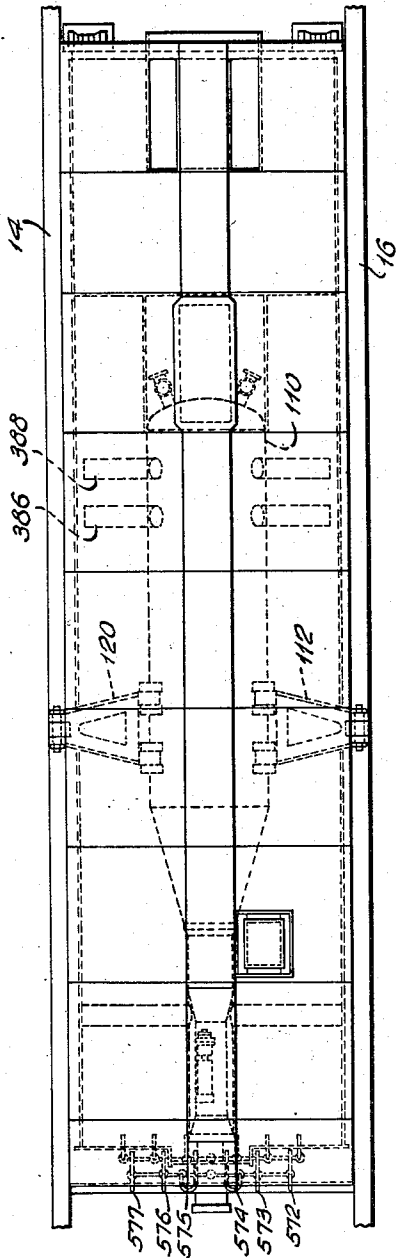


FIG. 28.

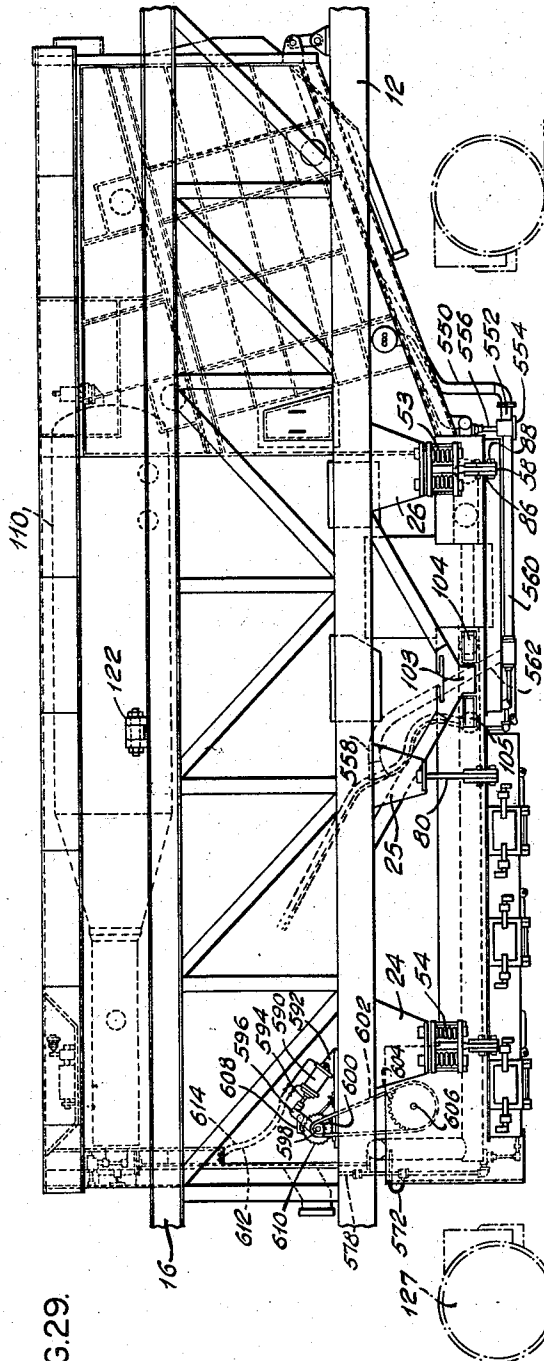


FIG. 29.

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STEAM POWERED LOCOMOTIVE WITH WATER TUBE STEAM GENERATOR

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Application May 13, 1954, Serial No. 429,612

12 Claims. (Cl. 105—37)

This invention relates to improvements in locomotives, and it is more particularly concerned with a locomotive in which a steam generator is incorporated in a novel manner to provide for the effective and reliable development of high pressure steam for driving the locomotive.

The invention more particularly involves a stoker fired water tube locomotive steam generator capable of long continued and effective use as a railway motive power unit to economically and efficiently provide a power source which will operate with a minimum of locomotive outage for maintenance or repair.

The invention is exemplified in a stoker fired single drum water tube steam generator especially combined with a locomotive frame in a steam turbine electric locomotive of high horsepower. The locomotive includes a locomotive frame and a water tube steam generator, both of which are particularly constructed and coordinated to produce a successful unitary locomotive. This coordination is such that the steam generator is maintained in operative relationship with respect to the locomotive frame under such wide changes in temperature as are involved in the firing and starting up of the steam generator from a cold condition to a high temperature operative or normal condition. Such action necessarily involves expansion of parts of the steam generator and their movement relative to the locomotive frame, and such expansion is permitted in the illustrative locomotive without imposing damaging stresses. This result is attained while at the same time eliminating or minimizing relative movement endwise of the locomotive, between the locomotive frame and the steam generator. It is also attained while minimizing or eliminating relative side sway of the steam generator with respect to the locomotive frame. Also, the steam generator is so particularly supported from the locomotive frame that the racking and twisting stresses imposed upon the locomotive frame by normal railway operation at speed have a minimum effect upon the multiplicity of pressure-tight joints or connections between the many operative parts of the water tube steam generator.

The illustrative steam generator has a capacity of the order of 50,000 lbs. of steam per hour at a pressure in excess of 600 p.s.i., and at a superheat, or final steam temperature of the order of 900° F. The illustrative steam generator includes a furnace and a convection pass which are combined within a water tube structure formed by steam generating wall tubes disposed between a large diameter upper drum, on the one hand, and bottom side wall and cross headers, on the other hand. In order that the furnace of the illustrative steam generator may be fired under pressure, the heat exchange elements are enclosed in a casing welded to the outside of the wall tubes to form a gas tight enclosure. At the bottom of the unit the enclosure is completed by ash pans suspended from the bottom headers. The drum is equipped with cyclone steam and water separators and the bottom headers of the unit are supplied with water by downcomers disposed exteriorly of gas flow. The unit

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includes a convection superheater of the inverted loop type, arranged in sections with short vertical headers connected by external return bends and disposed along the furnace walls. Next in line, as to gas flow, are upright and horizontally spaced tubes forming one or more banks of convection steam-generating tubes. A gas heated tubular air heater is disposed immediately beyond the convection steam-generating tubes and the casing closure in this zone is formed by a welded panel construction.

The illustrative unit is fired by a stoker in the operation of which, coal is fed from a bunker by a screw conveyor delivering the coal to a distributing table where steam jets distribute the coal uniformly over the grate, the latter being preferably of the forward running, continuous chain grate type. Ashes resulting from the combustion, are distributed in the ash pan constructions by a series of steam jets, preferably operated periodically by a timer. Combustion air enters the unit at the rear top, passes around the stack and part of this air turns down into the gas heated air heater with some tempering air passing forward along the top of the unit. The heated air passes forwardly along each side of the drum to the furnace roof area. From this area air is conducted to the stoker grate through side wall ducts after being suitably tempered from a superposed cold air duct. From the side wall ducts air enters a windbox built within the chain grate of the stoker by passing through a series of small rectangular ducted ports located between the wall tubes.

In the forward section of the hot air duct, in one modification of the invention, there is a pair of dampers regulating entry of the air into the over-fire section of the furnace. The hot air is not dampered and is fed downwardly into the over-fire air ducts formed by studded tubes of an arch separating a primary stage of the furnace from the secondary stage. These stud tubes are clustered and brought up through the furnace roof. A slot the entire length of the gas port permits effective jet penetration of the over-fire air into the gas stream leaving the primary stage of the furnace. After completion of combustion in the secondary stage of the furnace, the gases pass through a slag screen, a convection superheater, a bank of convection heated steam generating tubes and an air heater.

In the stoker fired steam generator of the illustrative locomotive, this invention provides a stoker particularly adapted for firing the coal fed toward the stoker by conveying means (herein exemplified as a screw conveyor) and then spread over the area of the stoker grate by jet means, such as a multiplicity of steam jets. The furnace with its enclosed stoker is advantageously adapted for pressure firing and, with this mode of operation, the invention involves, in the arrangement and construction of the coal feeding means, means for minimizing or preventing the escape of the furnace gases through the coal which is being fed to the stoker. For this purpose, the means providing the coal feeding passage is directed upwardly at a position close to the furnace fuel inlet, and over a ledge in which the high pressure jets are disposed for jetting the coal into positions over the stoker bed. The coal feeding passage at the position of this jetting means may be considered as being inclined downwardly in opposite directions. This construction causes the inlet end of the coal feeding passage to be filled up with coal along a position closer to a normal to the longitudinal axis of the passage at a position close to the jet means and close to the furnace inlet. The fact that the passage is entirely filled (over its cross section) with coal at this position has a considerable effect as a pressure seal.

The invention will be thoroughly and concisely set forth in the appended claims but for a complete understanding of the invention, its uses and advantages, re-

course should be had to the following description which refers by like reference characters, to the accompanying drawings in which a preferred embodiment, or preferred embodiments, of the invention are indicated, it being understood that the disclosure in the drawings and specification are made for the purpose of illustration only, and not for the purposes of limitation.

In the drawings:

Fig. 1 is a sectional side elevation of the illustrative locomotive including the pertinent vapor generating and superheating unit;

Fig. 2 is a plan section on the line 2—2 of Fig. 1;

Fig. 2-A is a detail horizontal section through one of the tempering fluid ducts shown on a much smaller scale in Fig. 2;

Fig. 3 is an end elevation taken at the firing end of the unit as indicated at 3—3 and its associated arrows, of Fig. 1;

Fig. 4 is a partial transverse vertical section of the planes indicated by 4—4 and its associated arrows, of Fig. 1;

Fig. 5 is a vertical section on the planes indicated by 5—5 and its associated arrows, of Fig. 1, showing the steam and water drum in vertical section, and the tubular superheater protective screen of vapor generating tubes in elevation;

Fig. 6 is a partial vertical section on the planes indicated by 6—6 and its associated arrows of Fig. 1, showing a transverse bottom header for the superheater protecting screen and indicating the bank of small diameter vapor generating screen tubes rearwardly of the bank of large diameter screen tubes of Fig. 5;

Fig. 7 is a transverse vertical section on the plane indicated by 7—7 and its associated arrows of Fig. 1, this view showing mainly the structure and arrangement of the tubular components of the superheater;

Fig. 7-A is a diagrammatic plan to show the manner in which the superheater headers are connected;

Fig. 8 is a transverse vertical section on the plane of section line 8—8 and its associated arrows of Fig. 1, this view showing the arrangement of tubes within a rearward convection section of the unit and also partially indicating the manner in which the vapor generating and superheating unit is mounted within the locomotive frame;

Fig. 9 is mainly an up-right transverse section through a part of the air heater, the position of this section being indicated by the line 9—9 and its associated arrows of Fig. 1;

Fig. 10 is an end elevation as indicated by line 10—10 and its associated arrows at the right hand end of Fig. 1;

Fig. 11 is a partial plan section as indicated by line 11—11 of Fig. 1 and its associated arrows, this view showing the air ducts on opposite sides of the steam and water drum, with dampers for controlling the flow of air from the main ducts on opposite sides of the drum to the downflow over-fire ducts formed by the upper ends of the arch tubes;

Fig. 12 is a partial plan as indicated by the line 12—12 of Fig. 1 and associated arrows, this view showing the air heater end of the unit;

Fig. 13 is a partial transverse vertical section of the endless belt of the stoker, the position of this sectional view being indicated by the line 13—13 of Fig. 1 and its associated arrows;

Fig. 14 is a diagrammatic plan showing the relationship of the header construction at the lower part of the vapor generating and superheating unit to the main side frame members of the locomotive frame;

Fig. 15 is a partial side elevation showing the header construction at the bottom of the vapor generating and superheating unit, and the manner in which that header construction is related to the locomotive frame;

Fig. 16 is a partial side elevation showing the structure and arrangement of a side bottom header and the

vapor generating furnace wall tubes leading upwardly from one side of the stoker, this view also showing the pedestal for the transverse stoker bearing support beam at the front end of the stoker and the pedestal for the transverse stoker bearing support beam at the rear end of the stoker;

Fig. 17 is a plan of the structure indicated in Fig. 16;

Fig. 18 is a detail view in the nature of a transverse vertical section at the position indicated by line 13—13 of Fig. 16 and its associated arrows, this view showing the pedestal support for the front or ash-discharge end of the endless belt of the stoker;

Fig. 19 is a detail view of the pedestal support for the rear or fuel-receiving end of the endless belt of the stoker mechanism, taken as indicated by the line 19—19 of Fig. 16 and its associated arrows;

Fig. 20 is partly a vertical section and partly an elevation of one of the central non-springing supports for the vapor generating and superheating unit from the locomotive frame, the position and character of this view being indicated by the line 20—20 and its associated arrows, of Fig. 15, the support or hangers of this type being provided at A, B and C of Fig. 14;

Fig. 21 is partly a vertical section and partly an elevation showing the spring mounting of the vapor generating unit at positions near its furnace end, similar spring mountings being also provided at the opposite end of the unit as indicated in Fig. 15, mountings or hangers of this type being provided at positions D, E and F of Fig. 14;

Fig. 22 is a longitudinal sectional elevation of a modified vapor generating and superheating unit in which the over-fire arch construction and the superheater screen construction, and an air heater, are modified, relative to the construction of those components indicated in Fig. 1;

Fig. 23 is a plan as indicated by the line 23—23 of Fig. 22 and its associated arrows;

Fig. 24 is a fragmentary plan showing the drive mechanism of the endless belt of the stoker;

Fig. 25 is a view in the nature of a side elevation of the stoker drive mechanism indicated in Fig. 24;

Fig. 26 is a vertical section through the steam jet coal feeder 140 which is generally shown in Fig. 1 of the drawings, the disclosure of this figure indicating the relationship of the screw conveyor for feeding the coal to the steam jet introduction means;

Fig. 27 is a vertical section showing the relationship of the inner front door to the front wall of the furnace and to the main fuel entry passage. This view is taken on the line 27—27 of Fig. 26;

Fig. 28 is a partial plan of the locomotive vapor generators, showing particularly the triangular links associating the upper drum and the locomotive frame;

Fig. 29 is a partial side elevation indicating the manner of associating the drum, and the locomotive frame, and showing the ash pan jet system and the cinder return system.

The setting of the illustrative vapor generating and superheating unit is generally rectangular in plan so that the unit may be pendently supported within the rectangular frame of the locomotive, the lower main side beams of the locomotive frame being indicated at 10 and 12 in such figures as 1, 3 and 22. Similar longitudinally extending upper locomotive frame beams are indicated at 14 and 16 in Fig. 3, the upper and lower longitudinal beams being rigidly united by upwardly extending side frame members as diagrammatically indicated at 18 and 20 in Fig. 3. Rigidly fixed to the lower main beams 10 and 12, at opposite sides of the locomotive, are downwardly extending frame members such as indicated at 24—26 in Fig. 15. These downwardly extending frame members support, in a pendent manner, the lower frame of the vapor generating and superheating unit indicated by numerals 30, 32, 34, 40, 42, 44 and 46 in Fig. 14. This frame includes the lower longitudinally extending headers 30 and 32 having the transverse header 34 welded thereto

and having smaller parallel headers 36 and 38 welded to the main headers 30 and 32 just forwardly of the superheater. This frame of the vapor generating and superheating unit also includes the transverse headers 40 and 42 welded to the smaller longitudinally disposed side headers 44 and 46, as indicated in Fig. 14. All of these header components of the lower part of the vapor generating and superheating units are rigidly united in a unitary fluid flow system by the connecting conduits 48 and 50.

Referring again to the Figs. 14 and 15, the rigid frame of the vapor generating unit has a three point non-springing support at the positions A, B and C of Fig. 14. At the remaining support positions D, E and F there are pendent pivotal supports each including pairs of coil springs such as 52—55 of Fig. 15. The nature of these spring supports is also indicated in such figures as Figs. 3, 4, 8 and 21. At the lower right hand part of Fig. 8, the header 46 is shown as having secured thereto two parallel and spaced intermediate upright plates 58 which have pivoted thereto the eye bolt 60, the pivot being indicated at 60'. This bolt extends upwardly through a bottom bridge plate 62, then through upper bridge plate 64 and then through a horizontal flange 66 integral with the lower portion of the support 26. On opposite sides of the eyebolt 60 the compression coil springs 52 and 53 (Fig. 15) are arranged between the bridge plates 62 and 64 and are anchored in their operative relationships by the auxiliary bolts 70 and 72 which connect the flange 66 and the plate 62. Such a construction is provided at each of the locations D, E and F of Fig. 14. At positions A, B and C there are pendent supports each including an eyebolt 80 disposed between and pivotally secured to side plates 82 and 84 which are secured to the header 32 in the same manner as the plates 86 and 88 of the spring mounted constructions at positions D, E and F. The upper end of the bolt 80 is secured through the horizontal flange 90 of the pendent auxiliary support 25.

Relative endwise movement of the steam generating unit and the locomotive frame is prevented by such constructions as that indicated at 100—105 in Fig. 15. This construction includes the downwardly convergent struts 100 and 101 preferably welded to the locomotive frame at their upper ends and secured at their lower ends to the centerpiece 102 which has a downwardly extending guide member or lug 103 disposed between and in sliding contact with the spaced lugs or guide members 104 and 105. The latter are fixed relative to the header 32 so as to form guideways for the lug 103. The arrangement of these elements is such that there may be relative vertical movements between the locomotive frame and the steam generating unit, within the limits of the previously described spring mountings, but there may be no substantial endwise relative movements.

As will be subsequently described in detail, the steam generating unit with its lower frame and upper longitudinal drum connected to the lower header frame by a multiplicity of vapor generating tubes, forms a fairly rigid unit. Also, for high pressure steam generation the illustrative unit is of considerable weight. One of the heaviest components of the vapor generating unit is the elevated upper drum, extending longitudinally of the locomotive frame. It is, consequently, of considerable importance that any substantial relative endwise movement of the drum and the locomotive frame be prevented, and to this end, the drum (Fig. 5) is secured to the frame by constructions similar to that described immediately above and consisting of the elements 100—105. For instance, on the right hand side of the drum as shown in Fig. 5, there are two heavy rods 112 arranged in rigid V-shaped formation, in plan, similar to the arrangement of the elements 100—101. On this side of the drum, these elements are rigidly joined at their adjacent ends near the drum to a junction piece 114. This element 114 is pivoted to heavy plates 116 fixed to the drum, and the widely spaced outer

ends of the divergent elements are separately pivoted to frame plates or brackets 118 secured to the upper locomotive frame beam 16. There is a similar construction connecting the other side of the drum with the opposite locomotive beam 14, this other construction involving heavy rods 120, the pivot plates 122 secured to the beam 14, and the pivot plates 124 secured to drum 110. The above described drum and locomotive frame connections also act to prevent lateral swaying of the drum relative to the frame.

The locomotive frame while permitting free expansion of the drum and tubes vertically relative to the locomotive frame is supported upon railway trucks including the drivers 127—129 and associated truck frames, each axle for a pair of drivers being driven by an electric motor connected to the output of an electric generator driven by a steam turbine. The latter receives steam from the superheater of the illustrative unit.

The illustrative steam generating unit includes a stoker fired water tube boiler having, for example, a capacity of about 50,000 pounds per hour at a pressure of the order of 600 p.s.i. and including a superheater designed to deliver steam at a temperature of the order of 900° F. The furnace and the convection section of the unit are bounded by water tube constructions including upright vapor generating tubes, such as 130 and 132 (Fig. 5) directly exposed to the furnace heat and connecting the lower side wall headers 30 and 32 with the upper steam and water drum 110. Exterially of some of the tubes 130 and 132 and out of contact with the furnace gases are downcomer wall tubes 129 and 131. Steel casing sections are welded to the outside of the wall tubes to provide a gas tight enclosure, and this enclosure is completed, at the bottom of the unit, by ash pans 133—136 suspended from the bottom headers. As indicated in Fig. 14, the unit includes a number of cross headers 34, 36, 38, 40 and 42 connected to the side wall headers and having other vapor generating tubes connected thereto and connected to the upper drum in the manners indicated. The upper drum is equipped with effective steam and water separators, and the downcomers leading from the water space of the drum to the lower headers, supply water to the bottom headers.

The unit is equipped with a convection superheater of the inverted loop type as indicated in Fig. 7 of the drawings, the superheater tubes being arranged in sections with short upright headers at the sides of the unit, connected to the ends of the inverted loops and interconnected by external return bends, as indicated in Fig. 7-A.

The illustrative unit is coal fired, with a steam jet feeder 140 (Fig. 1), distributing coal uniformly over the grate formed by the upper run of the endless belt 142 of the stoker. This endless belt moves around front drive and guide sprockets 144 and rear guide pulleys 146. The lower run 148 of this endless belt, or chain grate, is spaced substantially below its upper run to provide space for a windbox 150 having rectangular passages 152 along its opposite walls for communication with the heated air ducts 153 and 155—160 formed, as indicated in Fig. 11, between the casing plates such as 162 and 167 and the outer casing sections 169—176. The upper ends of these upright ducts communicate with heated air ducts 180 and 182 (Figs. 5, 7, 8 and 11) extending longitudinally of the unit on the opposite sides of the drum 110 from the air heater 184 to the front or firing end of the unit.

The guide sprockets 144 for the stoker are mounted on the stoker driving shaft 190 (Fig. 16) which has appropriate bearings supported by the illustrative footings 192 (Fig. 16) secured to the opposite lower headers 32 and 30. The rear guide pulleys for the stoker chain grate are supported by footings or pedestal constructions 194 preferably welded to the headers 32 and 30 near their rearward ends. The stoker chain grate is

driven from the shaft 190 by driving element 200 which is preferably a sprocket wheel connected to the driving sprocket 202 by a chain belt 204 (Fig. 24 and Fig. 25). The sprocket 202 is the driven element of a gear box or speed reducer 206 which has its driving element 208 connected by a belt 210 to a driving mechanism including a motor 212 and an interposed speed reducer 214. The driving mechanism for the stoker is preferably mounted on a frame 216 which may be appropriately secured to the generator frame.

Fig. 13 shows a part of the chain grate stoker construction on an enlarged scale. Here, the windbox 150 is shown in communication with the heated air ducts such as 153 through passages 152. This figure also shows the main central support for the stoker, as consisting of I-beam 222. To the upper flange of this beam is bolted the central grate support rail 224 having opposite guide ways 226 and 228 for the grate bars 230 of the stoker. A similar construction is provided at the sides of the stoker, including a support 230' and a side support rail 232 for the stoker grate bars. The latter are connected by links 234 and 236, pivotally related by the pins 238 and 240.

The upper run of the stoker grate moves very slowly toward the steam jet coal feeder 140 as the latter distributes coal over the stoker grate by jet action directed toward the stoker arch generally indicated at 250. This arch is supported by steam generating tubes included in the fluid circulation system by reason of the connection of their lower ends with the cross header 36, and by reason of the connection of their upper ends to the drum 110. Some of these tubes, 252 and 254, have vertically inclined lower sections 256 and adjoining horizontally inclined sections of tubes 258 arranged in wall alignment and provided with radially extended studs welded thereto, the studs and the forward sides of the tubes being covered by a high temperature refractory material 260. Above the upper end of the arch 250, the tubes 252 and 254 are associated with the tubes 258 to form the ducts 253, indicated in Fig. 2. In this arrangement, the pertinent parts of these tubes have their intertube spaces filled with refractory material as indicated at 260 and 263, the refractory fillers 262 having openings 266 therein to provide for jets of a tempering fluid, such as steam or over-fire air, for mixing with the products of combustion leaving the primary furnace chamber 268 and passing to the secondary furnace chamber 270, above the arch. The tempering fluid issuing in these jets is divided and swept back over the tubes by the oncoming gases, thus cooling them and preventing slag from forming on the tubes.

The upright tempering fluid ducts 253 indicated in Fig. 2 have their upper ends in communication with air chambers 271 and 272 (Fig. 11) disposed in opposite sides of the drum 110 and in regulated communication with the air ducts 180 and 182 by dampers 274 and 276 which are arranged to be controlled by a control rod 278 which has links 280 and 282 connected to crank arms 284 and 286 fixed to the damper pintles 288 and 290. The dampers are disposed in orifices formed by wall means including the baffles 275 and 277. This figure also includes an indication of the horizontal header elements 292 and 294 extending from opposite sides of the front portion of the drum 110 and having the upper ends of some of the tubes 252, 254 and 256 connected thereto.

The primary furnace of the illustrative unit, is disposed between the stoker grate and the arch 250, and between the furnace side walls. For enhancing the durability and long life of the primary furnace and for promoting high temperature in the primary furnace chamber, the vapor generating tubes outlining the walls and front surfaces of this chamber are lined with high temperature non-metallic refractory material. The stoker sides of the arch tubes 252 and 254 have a stud tube

and (ceramic) refractory stratum 302. This construction of the pertinent arch section is of a known stud tube and refractory combination (i.e., E. G. Bailey Patents 2,239,662 and 1,999,984) with the refractory covering the tubes and metallic studs welded to the tubes. Fig. 4 indicates the gas flow passages 304-308 between the over-fire air ducts 253 which have been previously described, and which are particularly shown in Figs. 2 and 2-A. The side walls of the primary furnace chamber include parts of the vapor generating riser tubes 310 leading upwardly from the header 32 and having upper roof sections 312 connected to the drum 110 centrally of the unit. These wall tubes are arranged in wall-forming alignment and are preferably provided, on their furnace sides, with a refractory covering or furnace lining. This furnace lining is of refractory block construction just above the grate but above that, it is preferably of a stud tube and refractory construction 314 similar to that above referred to. A similar construction exists at the opposite side of the primary furnace chamber, with the tubes 316 (Fig. 2) covered with the stud tube and refractory construction 318. Similar stud tube and refractory construction is disposed across the front wall of the primary furnace chamber, in which there are spaced wall tubes 320 with the tubes covered by, and the spaces between the tubes filled by the pertinent stud tube and refractory construction 322 except over furnace areas at the upper parts of the furnace. These tubes have their lower ends connected to the header 34 which has downwardly extending end sections 321 and 323 (Fig. 3) connected to the side headers 30 and 32.

The header 34 is supplied with water or other vaporizable liquid by downcomers 324 extending from the drum 110 to the header 34, as indicated in Fig. 1. The side walls of the secondary furnace chamber 270 are also lined with partial stud tubes which are upward continuations of the wall tubes of the primary furnace chamber. The structure and arrangement of the side walls of the secondary furnace chamber is further indicated in Fig. 5 which shows the widely spaced upright vapor generating tubes 330 of the outer screen. This screen consists of two transverse rows of tubes leading upwardly from the header 38 to the drum 110.

The primary and secondary furnace chambers (or primary and secondary furnace stages), as well as all of the remaining gas conducting sections of the illustrative unit, are made gas tight by the securement of flat metallic sections or panels, such as 332, to the outer surfaces of the vapor generating tubes or other wall tubes. Similar panels are also secured to the roof sections of the vapor generating tubes and other fluid heating tubes, and the edges of adjoining panels are sealed or joined by welding.

The screen formed by tubes 330, and their associated screen tubes are provided for the purpose of preventing substantial accumulations of slag deposits upon the tubes of the superheater 334. The screen tubes, some of which will be later more specifically described, operate to so lower the temperature of slag particles suspended in the furnace gases that those particles are not in a sticky condition when they contact the superheater tubes.

The steam to be passed to the superheater is separated in the drum 110 from steam and water mixtures entering the mixture inlet chamber 336 from the steam generating wall tubes of the unit. The mixtures pass from the inlet chamber 336 through a series of cyclone steam and water separators 338 (Fig. 7), such as disclosed in the Rowand Patent 2,289,970, the separated water passing downwardly from the cyclones into a water space 340 and the separated steam passing upwardly through the auxiliary separators 342 to the steam outlet chamber 344. From this chamber the steam passes through a plurality of circulators 346 downwardly along the side of the unit, as indicated at 348 in Fig. 7, to a superheater inlet header 350. This inlet header is con-

ected to a similarly constructed header 352, at the opposite side of the unit, by platens 354—356 of nested and inverted U-tubes the arrangement and structure of which is more clearly indicated in Fig. 7. There are a large number of such tubes in each platen, the successive tubes having their central U-tube sections gradually increasing as to the spacing of the legs of the U-tubes, from the center of the gas pass outwardly toward the sides of the unit. The innermost U-tube in Fig. 7 is indicated at 358 and the outermost U-tubes connected to the sides of the headers are indicated at 360. Outwardly of these latter tubes are others such as 362 which are connected to the tops of opposite headers such as 350 and 352, these outermost tubes being so contoured that they follow the boundary surfaces of the superheater gass pass, such boundaries being defined by the steam generating wall tubes.

Steam discharging from the platens 354—356 into the header 352, then passes through the connectors 364 to an adjacent and parallel header 366 connected to an opposite header 368 by platens similar to 354—356. This arrangement is continued, as diagrammatically indicated, in Fig. 7-A, to the outlet header 370 from which a plurality of steam supply tubes, such as 372 and 374 extend upwardly along the left hand side of the unit, as indicated in Fig. 7, and then rearwardly to the steam line 376 for connection to a steam turbine or other prime mover.

Disposed transversely of and intermediate gas flow over the superheater is an upright inverted U-shaped baffle 334 for so affecting gas flow as to cause suspended cinders or other solids to be carried beyond the superheater to a disposal zone.

Between the superheater 334 and the widely spaced screen tubes 330 is a fine screen, such as indicated in Fig. 6. The tubes 380 of this screen are of much smaller diameter than the tubes 330 and they are more closely spaced, as indicated in Fig. 6, in order to afford adequate superheater protection against the accumulation upon the superheater tubes of deposits of slag particles. As indicated in Fig. 1, the tubes 380 of the fine screen have their lower ends connected to the header 38. Their upper ends, as indicated in Fig. 6, are directly connected with the water space of the drum 110.

Rearwardly of the superheater 334, in the direction of gas flow, are two banks 382 and 384 of fluid heating or steam generating tubes, the spacing and arrangement of which are indicated in Figs. 1 and 8. These tubes directly connect the lower headers 40 and 42 to header sections 386 and 388, extending laterally from the sides of the drum 110 as indicated in Fig. 8. Some of these tubes toward the central section of the tube banks, are directly connected to the drum as also indicated at the top of Fig. 8.

The heating gases, after flowing across the banks of tubes 382 and 384, pass over the tubes of the multiple pass air heater 184. This air heater has the air inlets 390—392 directing the incoming air to an inlet chamber 394. This inlet chamber is connected by the spaced tubes 396 to a lower inlet chamber 398 separated from an adjoining chamber 400 by a diaphragm 402. The left hand section of the intermediate air chamber 398 is connected to the rearward section of an upper intermediate chamber 404 by a bank of tubes 406, similar to the bank of tubes 396. Air flows upwardly from the left hand section of the lower chamber 398 through the tubes of the bank 406 to the rearward portion of the chamber 404, then forwardly in that chamber to its left hand section, and thence downwardly through the bank of tubes 408 to the right hand portion of the chamber 400. The air flows to the left in the chamber 400 and then upwardly through the bank of tubes 410 to the outlet chamber 412. The air then flows to the air ducts 180—182 leading toward the front end of the unit, and thence to the air inlet openings 152 of the stoker.

Additional turning space for the air passing from the first air pass through the bank of tubes 396, is afforded by wall means such as indicated at 416. Similar wall means 418 affords increased turning space for the air exiting from a bank of tubes 406 and turning into the banks of tubes 408 of the three air passes. At the air outlet of the latter, additional turning space is likewise provided by wall means 420.

As indicated in Fig. 1, the gases enter the air heater directly from the banks of tubes 382 and 384 and pass in a single pass over and around the air heating tubes to the flue 414, and thence to a stack, or induced draft fan.

Figs. 22 and 23 of the drawing disclose a modification of the Fig. 1 steam generator, the modification having several distinctions over the previously described unit. One distinction is the manner in which the over-fire air is introduced. In the Figs. 22 and 23 unit, the over-fire air is introduced through openings 424 in the front wall adjacent the steam jet coal feeder 140, the stoker arch 426 having its forward end higher than that of the arch 250 for accommodating the modified introduction of over-fire air. It will also be noted that the incline of the stoker arch 426 is greater than that of the arch 250.

Above the top of the arch 426 the upper parts 428—430 of the stoker arch tubes are arranged as platens, as clearly indicated in Fig. 23.

Another distinction involved in the unit shown in Figs. 22 and 23 pertains to the construction of the primary slag screen, indicated at 432. The upright vapor generating tubes of this slag screen, like those in the Fig. 1 unit, connect the lower header 38 to the drum 110, but the two main rows of tubes 434 and 436 of this slag screen are spaced at a greater distance from the secondary slag screen 380. Additionally, the central parts of the middle tubes 440—443 (Fig. 23) of the row of tubes 434—436 are bent out of their row formation for access purposes, as well as for the purpose of reducing gas flow resistance and promoting uniform gas flow distribution relative to the opposite sides of a median vertical plane through the secondary furnace.

The Fig. 22 unit has a two-pass air heater in which the air enters the channels 450 and 452, passes through the upright tubes to a turning space, or turning chamber 455. Thence, the air passes through the tubes of the rear bank of air heater tubes 456 to the chamber 458 from which the air flows forwardly through passages extending along both sides of the drum 110. Between the boiler tube bank 384 and the air heater is a supplementary boiler tank of tubes 460 connecting the lower header 462 to the upper header 464. Each header is appropriately connected into the main circulatory system of the generator.

Rearwardly of the air heater bank of tubes 454 is a bank of tubes 466 constituting an economizer. These two tubes connect the lower header 468 with the upper header 470, the latter of which is appropriately connected with the water space of the drum 110. The header 468 is suitably connected with a source of vaporizable liquid.

In other respects the steam generating unit of Fig. 22 and Fig. 23 is similar to the Fig. 1 unit previously described. Like the first described unit, the Fig. 1 modification is of the single gas pass type, arranged for the firing of bituminous coal by spreader stoker. Like the first described unit, the modified unit has a longitudinally disposed steam and water drum at the upper portion of the unit, the drum extending over the stoker fired furnace and over the convection steam generating tube banks. Coal is fired in a primary furnace at one end of the unit, and the products of combustion pass therefrom through a screen of tube platens 428 to a secondary furnace and then through banks of tubes constituting, in sequence, a convection steam superheater, a bank of steam generating tubes, and a tubular air heater. The walls and roof of the furnace part of the unit, and the following convection

pass are defined by wall cooling and vapor generating tubes arranged to receive a supply of water from a system or framework of lower headers, as in the Fig. 1 unit.

The primary furnace 268' is separated from the secondary furnace 270' by the stoker arch 426, and the stoker arch, together with the walls of the primary furnace, like the similar parts of the Fig. 1 unit, are of stud tube and refractory construction. The furnace is arranged to operate under pressure within a gas tight casing, with the sheet metal components of the casing welded directly to the tubes. Like the Fig. 1 unit, the bottom of the unit is provided with ash pans extending from one side to the other of the unit. Downcomer tubes are arranged to connect the water space of the drum and the lower headers, the downcomers being positioned where they are not directly subject to the heat of the products of combustion. Like the Fig. 1 unit, the large diameter section of the drum 110 is provided with cyclone steam and water separators delivering high quality steam to the superheater. The superheater is of the same construction as that illustrated in Fig. 7.

Like the Fig. 1 unit, the Fig. 22 unit has its primary furnace fired by a steam jet coal feeder which distributes coal over a rearwardly moving continuous chain grate 148 which extends rearwardly under the inclined stoker arch.

The manner of introducing the over-fire air in the Fig. 22 unit, in combination with the modified and more steeply inclined stoker arch construction, permits a greater percentage of the gases to pass over the fuel trajectory. This combination also permits the addition of over-fire air under the arch and nearer the fuel bed, without interference with the fuel trajectory. It also promotes effective ash drainage from the top of the arch in the secondary furnace, and facilitates optimum expansion of the gases as they approach the convection surfaces.

Figs. 26 and 27 show the detailed construction at the furnace fuel inlet, this construction including the relationships of the coal feeding screw 500, the distributor table to which coal is fed, and the passage 504 leading from the coal screw to the table. These views also illustrate the means whereby the movement of the inner door 506 may be controlled by a fluid pressure cylinder 510 to close the opening through which the interior of the furnace may be viewed. It is to be particularly noted, in this construction, that the coal is fed through the cylindrical tube 512 to a tubular element forming the upwardly inclined passage 504 directing the fuel upwardly to and over the ledge 514 which covers the jet chamber 516 from which high pressure fluid jets operate upon the coal falling over the ledge to direct the coal to various positions within the furnace. This upwardly inclined passage, in conjunction with the operation of the coal screw, causes this passage to be filled with coal the surface of which is disposed generally in a plane ZZ transverse to the longitudinal axis of that inclined passage 504. This filling of the passage with coal as a result of this inclined construction, tends to prevent the escape of the superatmospheric gases within the furnace.

The illustrated vapor generating unit has a cinder return system by which the high pressure air supplied to the air heater from a forced draft fan is utilized for the impelling force to cause a flow of cinders from the lower part of the convection section to the primary furnace chamber 268' of Fig. 22. The inclined pipe 550 directs air at superatmospheric pressure from the chamber 455 downwardly to a venturi chamber 552 where the jet of air from this chamber passes into the cinder jet chamber 554 which laterally receives cinders through the vertical pipe 556. This pipe has at its upper end a funnel-like structure open at its top to the gas pass space between the bank of tubes 384 and the air heater. Cinders collecting in this space pass downwardly through pipe 556 and into the jet chamber 554. From that chamber the impelling air current causes the cinders to pass through the horizontal pipe 560 to a position adjacent the header 38, and

thence through an upwardly inclined branch pipe 562 the outlet of which is in communication with the primary combustion chamber 268', as indicated in the drawing. Thus the accumulation of cinders at the lower part of the convection section is reduced and secondary over-fire air with cinders in suspension is delivered to the primary combustion chamber.

To distribute the ash in the ash pan 136, the front wall 570 has extending therethrough into the ash pan 136 a series of ash pan jet pipes 572-577 supplied with steam from the drum 10 by the pipes 578. Thus undesirable accumulations of ash at the discharge end of the stoker are prevented.

Figure 28 shows the structure of the triangular links 112 and 120 and their relationship to the drum 110 and the upper longitudinal main frame locomotive members 14 and 16.

Figure 29 further indicates the relationship of the vapor generator drum and the locomotive frame members, and it also shows a ratchet drive for the stoker. This stoker drive includes pivoted fluid pressure cylinder 590 having its lower part supported on the fixed base 592. Its piston rod 594 is pivoted at the upper end of an oscillating lever 596. The lower end of this lever is pivoted upon the sprocket shaft 598 on which there is fixed a sprocket 600 connected by a sprocket chain 602 to a much larger sprocket 604 fixed upon the stoker drive shaft 606. The crank arm or lever 596 has a pawl 608 pivoted thereon so as to coact with the toothed wheel 610 to complete the ratchet drive for the stoker. The fluid pressure cylinder 590 is supplied with a fluid under pressure through the lines 612 and 614. The operation of the air cylinder is preferably controlled through a regulating valve chamber positioned intermediately relative to the lines 612 and 614, and the fluid pressure cylinder 590.

Whereas, in compliance with the pertinent sections of the revised statutes, the invention has been described with reference to the details of a preferred embodiment, it is to be realized that the invention is susceptible of use without all of these details, provided exactly as described. The invention is rather of a scope commensurate to the scope of the subjoined claims.

What is claimed is:

1. In a vapor generating and superheating unit, an elevated vapor and liquid separating drum; means forming a furnace, an upright tubular furnace screen, a convection superheater, upright tubes forming a convection vapor generating section and convection air heater arranged in that sequence longitudinally of the drum and at elevations beneath the drum; means including furnace walls and forming a horizontally directed gas pass for said superheater and vapor generating section beneath the drum; said gas pass being formed in part by vapor generating wall tubes; a plurality of lower headers at the sides and ends of the unit rigidly joined to present a rectangular lower header frame with the combined headers connected to the lower ends of wall tubes; the furnace including a chain grate stoker with a refractory covered stoker arch including vapor generating tubes connecting at least one of the headers with the drum; said refractory arch extending at a horizontal inclination over a major part of the stoker to separate a lower primary combustion chamber from an upper secondary combustion chamber for horizontal gas flow to said gas pass; and means for supplying combustion air for the burning of fuel within the furnace; said air supplying means including over-fire air supply devices and under-fire air supply means.

2. In a locomotive steam generating and superheating unit; an elevated steam and water drum extending longitudinally of at least a major part of the unit; a system of longitudinal and transverse lower headers disposed near the bottom of the unit and rigidly connected to form a lower frame of the generator; wall means forming an enclosure for a furnace at one end of the unit and for a horizontal flow gas pass leading therefrom, said wall

means including vapor generating wall tubes connecting the drum with the headers; the furnace including a chain grate stoker and an overlying forwardly and upwardly inclined stoker arch separating a primary furnace directly above the stoker from a secondary furnace above and beyond the primary furnace, said stoker also including a steam jet coal feeder; the stoker arch including vapor generating tubes covered with refractory upon the stoker side and connecting at least one of said headers to the drum with the upper parts of these vapor generating tubes forming a slag screen across the flow of gases from the primary furnace to the secondary furnace; a convection superheater including upright tubes disposed across the flow of gases beyond the secondary furnace, and a convection boiler tube section connecting some of the headers with said drum and disposed rearwardly of the superheater.

3. In a steam generator of the character described, a furnace, a stoker for firing the furnace of said unit, steam generating tubes and refractory material forming a stoker arch for the furnace and separating a primary furnace stage from a secondary furnace stage, said arch tubes having extensions forming a screen extending across gas flow from the primary furnace stage to the secondary furnace stage, a bank of convection tubes subject to furnace gas flow beyond the secondary furnace stage, convection superheater subject to the furnace gas flow beyond the said convection bank of steam generating tubes, a convection economizer, a convection air heater, and a combined secondary air delivery means and cinder collecting and returning means operating to normally inject secondary air and cinders into the furnace at a position above the stoker, said cinders being collected from the bases of the convection components of the unit and conveyed to the furnace by a stream of secondary air.

4. The combination of claim 3 further characterized by the disposition of the air heater adjacent the end of said unit opposite the stoker, a roof for the unit, said roof combining with the parts of the drum to form main air ducts leading along opposite sides of the drum from the air heater toward the furnace and the stoker, means directing the air from said main air ducts to the furnace, and air flow regulators disposed at opposite sides of the drum near the exits of the main air ducts regulating the flow of air to the furnace.

5. In a steam driven locomotive, a locomotive frame including a rigidly connecting upper and lower frame members presenting a rectangular frame with rectangular openings therein, a water tube steam generator including a long upper steam and water drum disposed between the upper parts of the locomotive frame, the water tube steam generator also forming a unit having a rigid rectangular lower frame made up of transverse and longitudinal headers rigidly united and connected by upright steam generating tubes with said drum to form a steam generating and superheating unit, said unit being disposed within the rectangular frame of the locomotive with the frame of the unit suspended at an elevation lower than the rectangular lower part of the locomotive frame, three-point non-springing pivoted suspension support means secured at their upper ends to the locomotive frame and secured at their lower ends to the unit frames, springing supports disposed in a three-point support arrangement alternating with the positions of the three-points of the first mentioned three-point support and secured at the upper ends to the locomotive frame and at the lower ends to the unit frame to restrain upward movements of said steam generating unit relative to said locomotive frame, all of said suspension means constituting a bottom support for the unit, and a plurality of anti-sway bars or rods pivotally connecting the upper side members of the locomotive frame and the drum.

6. In a steam generating and superheating unit; an elevated steam and water drum extending longitudinally

of at least a major part of the unit; a system of longitudinal and transverse lower headers disposed near the bottom of the unit and rigidly connected to form a lower frame of the generator; wall means forming an enclosure for a furnace at one end of the unit and for a horizontal flow gas pass leading therefrom, said wall means including vapor generating wall tubes connecting the drum with the headers; the furnace including a moving grate and an overlying forwardly and upwardly inclined arch separating a primary furnace directly above the moving grate from a secondary furnace above and beyond the primary furnace; the arch including vapor generating tubes covered with refractory upon the stoker side and connecting at least one of said headers to the drum with the upper parts of these vapor generating tubes forming a slag screen between the primary and secondary furnaces; means for introducing solid ash containing fuel into said furnace including an upwardly inclined conveyor having an upwardly directed portion exposed to the gas space of said furnace, a convection superheater including upright tubes disposed across the flow of gases beyond the secondary furnace, and a convection boiler tube section connecting some of the headers with said drum and disposed rearwardly of the superheater.

7. In a steam generating and superheating unit; an elevated steam and water drum extending longitudinally of at least a major part of the unit; a system of longitudinal and transverse lower headers disposed near the bottom of the unit and rigidly connected to form a lower frame of the generator; wall means forming an enclosure for a furnace at one end of the unit and for a horizontal flow gas pass leading therefrom, said wall means including vapor generating wall tubes connecting the drum with the headers; the furnace including a moving grate and an overlying forwardly and upwardly inclined arch separating a primary furnace from a secondary furnace above and beyond the primary furnace, a fluid jet coal feeder positioned above said grate, an upwardly inclined screw conveyor for delivering coal to said jet feeder, said arch including vapor generating tubes covered with refractory upon the stoker side and connecting at least one of said headers to the drum with the upper parts of these vapor generating tubes forming a slag screen across the flow of gases from the primary furnace to the secondary furnace; a convection superheater including upright tubes disposed across the flow of gases beyond the secondary furnace, and a convection boiler tube section connecting some of the headers with said drum and disposed rearwardly of the superheater.

8. In a steam generating and superheating unit; an elevated steam and water drum extending longitudinally of at least a major part of the unit; a system of longitudinal and transverse lower headers disposed near the bottom of the unit and rigidly connected to form a lower frame of the unit; wall means forming an enclosure for a furnace at one end of the unit and for a horizontal flow gas pass leading therefrom, said wall means including vapor generating wall tubes connecting the drum with the headers; a moving grate positioned in the lower portion of said furnace, an overlying forwardly and upwardly inclined arch separating a primary furnace directly above the moving grate from a secondary furnace above and beyond the primary furnace, a steam jet coal feeder positioned above said grate; the furnace arch including vapor generating tubes covered with refractory upon the primary furnace side and connecting at least one of said headers to the drum with the upper parts of the vapor generating tubes forming a slag screen across the flow of gases from the primary furnace to the secondary furnace; means for tempering the gases entering said slag screen, a convection superheater including upright tubes disposed across the flow of gases beyond the secondary furnace, and a convection boiler tube section connecting

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some of the headers with said drum and disposed rearwardly of the superheater.

9. In a steam powered locomotive, a rectangular box-like locomotive frame including upper and lower main longitudinal frame members, a water tube steam generating and superheating unit disposed within said frame, said unit including an upper drum and a lower header frame, means including pendent supports for constituting bottom supports for said unit from the lower frame members, spring members positioned between said unit and at least some of said pendent supports to facilitate restricted upward movements of said steam generating and superheating unit relative to said locomotive frame, means pivotally connecting the drum with opposite upper frame members to minimize side sway of the unit relative to the frame, and means preventing any substantial endwise relative movements of the unit and the locomotive frame including arms attached to said locomotive frame and movable in guides attached to said headers.

10. In a steam powered locomotive, a substantially rectangular locomotive frame, said locomotive frame having upper and lower longitudinally extending main beams, locomotive trucks including drivers supporting the frame, a water tube steam generator including longitudinally disposed lower side headers and transversely extending lower headers rigidly connecting the side headers, a longitudinally extending steam and water drum disposed at the upper part of the locomotive and between the upper main beams of the locomotive frame, and steam generating tubes connecting the lower side headers with said drum, with certain of the steam generating tubes delineating the walls of a furnace; pivotally connected non-springing supports connecting the lower main beams of the locomotive frame with the lower side headers of said frame of the steam generator in a three-point pendent support arrangement with two of the points of support on one side of the locomotive and one on the other side and intermediate the first two supports lengthwise of the locomotive; and a three-point support arrangement of pivotally connected pendent springing supports connecting the

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lower main beams of the locomotive frame with the lower side headers of said frame of the steam generator to facilitate restricted upward movements of said steam generating unit relative to said locomotive frame, each springing support being located transversely of a non-springing support on the opposite lower side header.

11. The combination of claim 10, further characterized by downwardly converging anti-sway bars pivotally connecting the upper main beams of the locomotive frame with the steam and water drum.

12. A combination of claim 10, further characterized by means for preventing endwise movement of the steam generator relative to the locomotive frame while permitting limited relative vertical movement of the steam generator and the locomotive frame, said means including a structure fixed to the locomotive frame and including convergent struts and a guide member fixed relative thereto, said guide member being received in a guideway formed by other members fixed to the steam generator frame.

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