March 31, 1931. R. R. McKNIGHT ET AL 1,798,550

AUTOMOTIVE STEAM GENERATOR

Filed April 28, 1927 4 Sheets-Sheet 1

Fig. 1

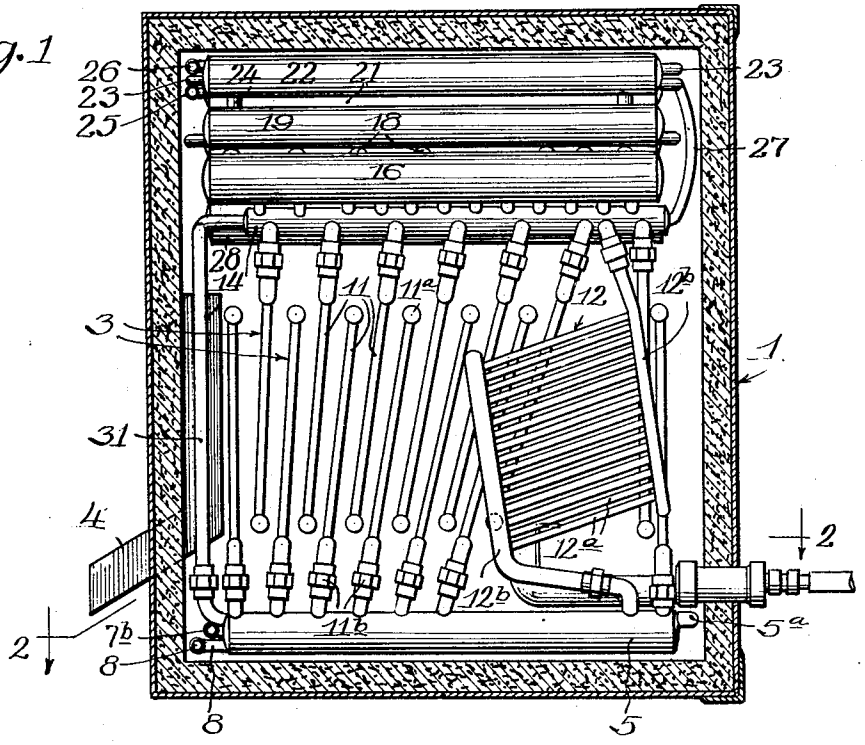
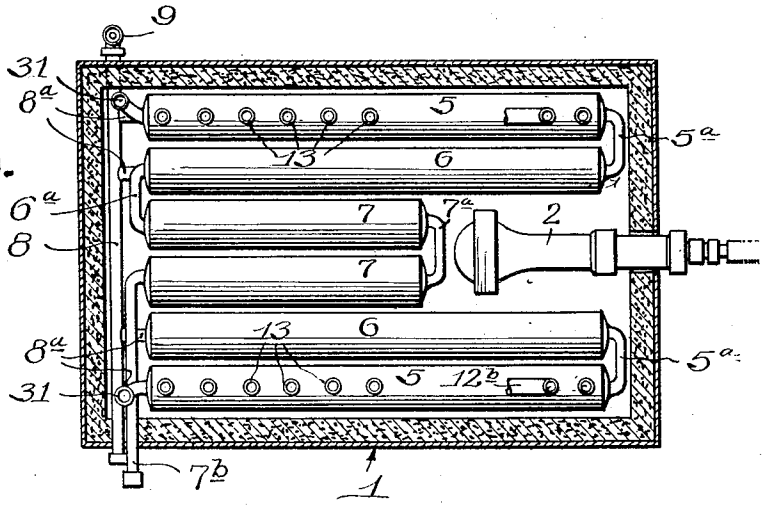


Fig 2.



Witness:
Chas. L. Koursh.

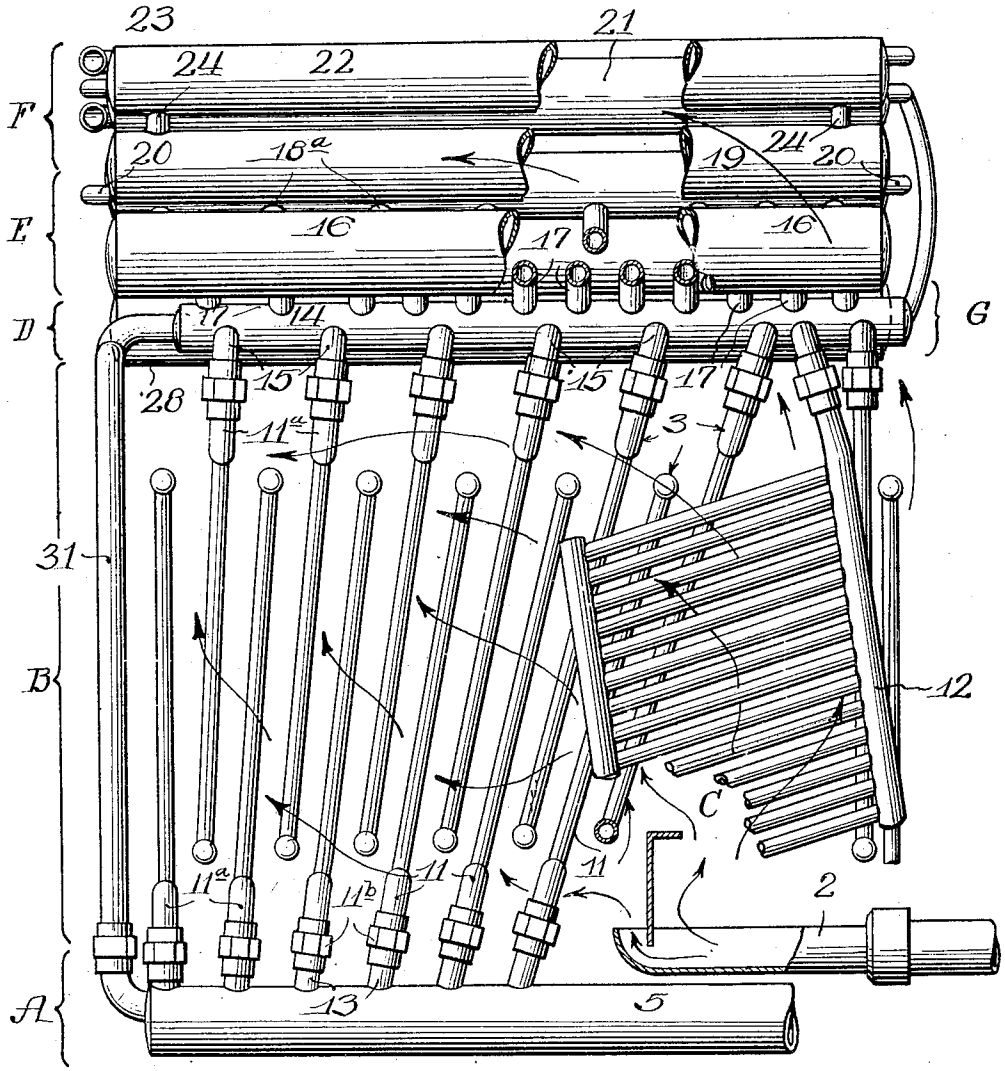
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AUTOMOTIVE STEAM GENERATOR

Filed April 28, 1927 4 Sheets-Sheet 2

Fig. 3



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March 31, 1931. R. R. McKNIGHT ET AL 1,798,550

AUTOMOTIVE STEAM GENERATOR

Filed April 28, 1927 4 Sheets-Sheet 3

Fig. 5

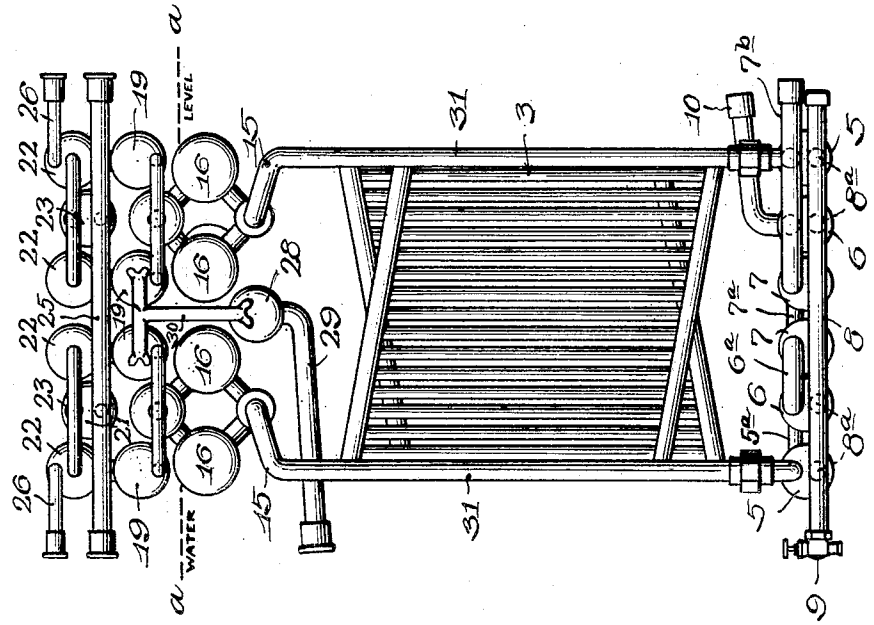
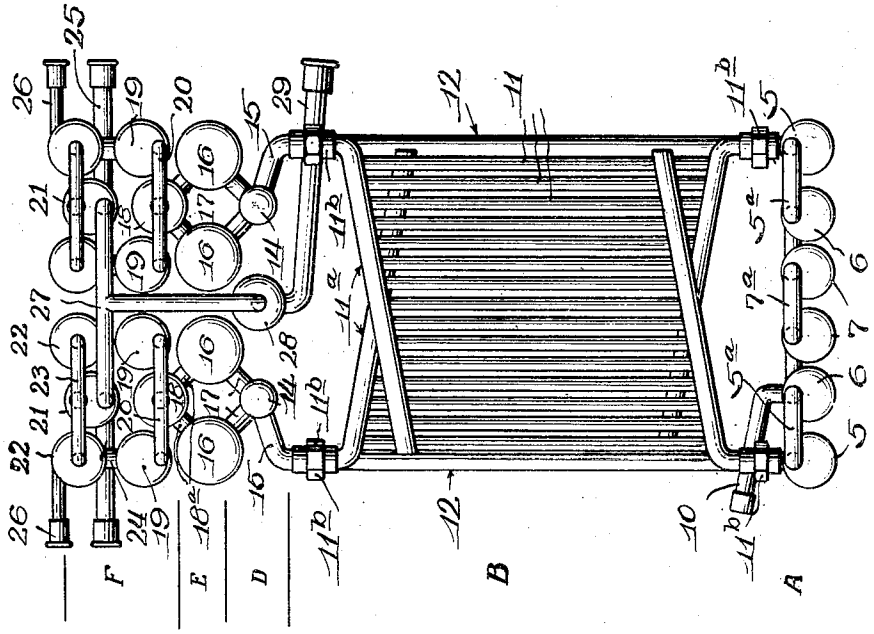


Fig. 4



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March 31, 1931. R. R. McKNIGHT ET AL 1,798,550

AUTOMOTIVE STEAM GENERATOR

Filed April 28, 1927 4 Sheets-Sheet 4

Fig. 6

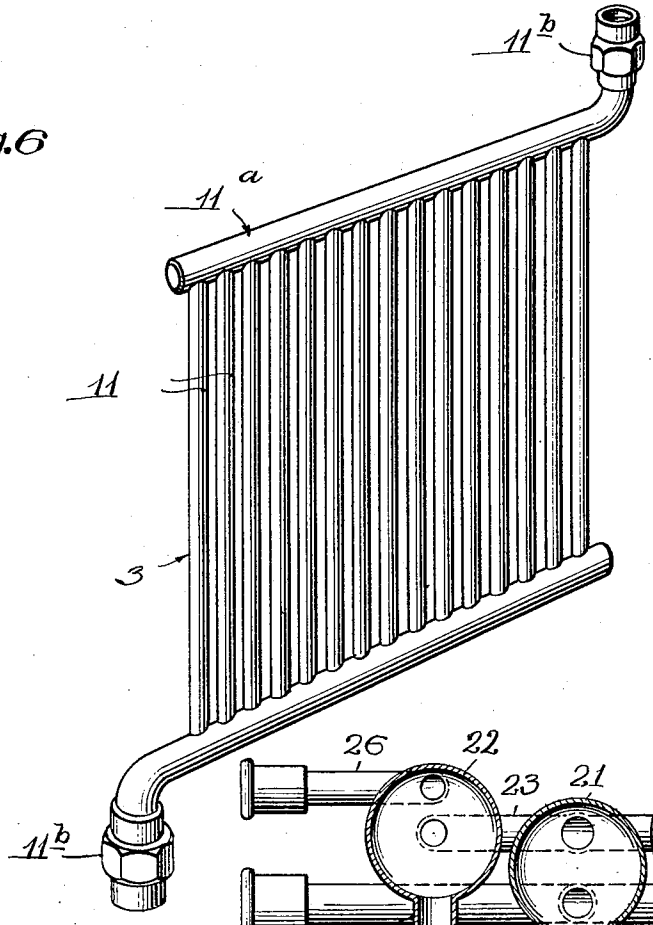
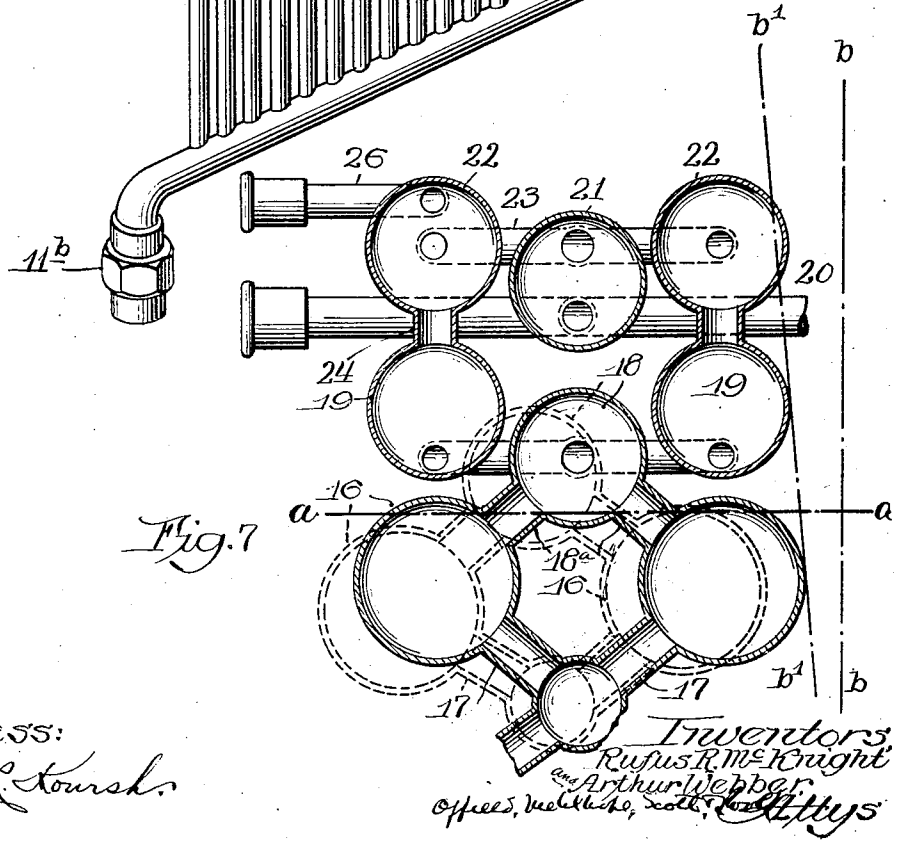


Fig. 7



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and Arthur Webber
by Offices, Mellish & Scott, Their Attys

Patented Mar. 31, 1931

1,798,550

UNITED STATES PATENT OFFICE

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AUTOMOTIVE STEAM GENERATOR

Application filed April 28, 1927. Serial No. 187,377.

This invention relates to improvements in automotive steam generators, and more particularly to boilers forming a part of a power plant for steam driven vehicles and other steam propelled means of locomotion.

The object of the invention is to provide a new and useful construction for a steam generator calculated to combine the essential and desirable features of compactness, flexibility, efficiency and rapid steam generation in a power unit suitable for the various vehicles of transportation now generally dependent upon the internal combustion motor.

The merits of the automotive steam power plant have always been recognized because of its simplicity of moving parts, its flexibility of performance and economy, as compared with the internal combustion engine, but its advantages have been outweighed by certain popular prejudices—some deserved and others not—which have limited the more extensive use of steam as motive power for locomotion, chief of which are, the interval of time required to generate steam on starting and the inability of the generator to maintain a constant steam pressure under all conditions of operation. Other objections have been found in the steam power plants heretofore designed for vehicle propulsion, such as the burning out of the tubes and imperfect water circulation due invariably to faulty construction and improper application of the principles governing steam generation and boiler construction.

A further object, therefore, of the present invention is to provide an improved construction for steam generators for vehicle power plants, calculated to overcome and correct the difficulties which have heretofore been experienced in development and advancement of steam power in the field largely preempted by the internal combustion motor.

It has long been recognized that the essential requirements of an efficient steam boiler are, rapidity of steam generation, compactness as to space occupied, lightness of weight, efficient water circulation, and ability to maintain a working steam pressure under all conditions. In the present disclosure, one of the principal departures from the standard practice is the adoption of a semi-flash water tube type of generator as distinguished from the fire-tube type of boiler generally used. Coupled with this feature, is an improved arrangement of preheating, distributing and superheating steam drums so interconnected as to afford positive and rapid water circulation and steam generation.

A preferred embodiment of the invention is disclosed in the accompanying drawing, in which—

Figure 1 is a general view in vertical section taken longitudinally of the complete generator.

Figure 2 is a view in horizontal section taken on line 2—2 of Figure 1 to show the drums at the bottom of the generator.

Figure 3 is a view in side elevation of the generator with the housing removed.

Figure 4 is a view in front elevation of the generator with the housing removed.

Figure 5 is a view in rear elevation of the generator with the housing removed.

Figure 6 is a perspective view of one section or bank of tubes removed; and

Figure 7 is an enlarged detail view of a group of drums above the tube banks shown in section.

As already explained, the generator herein disclosed is of the water tube type, that is to say, the water is conducted through banks of tubes enclosed within an insulated housing and heated by the products of combustion of fuel oil burners or other source of heat located in a fire box at one end of said housing. Thus as shown in Figure 1, the generator consists generally of an outer casing or housing 1, preferably constructed in the form of a frame which supports walls of suitable insulating material completely enclosing the space occupied by the generator proper, which will first be briefly described by reference to sections and zones within the housing.

Extending longitudinally along the bottom of the housing 1, is a series of interconnected drums which constitute the water preheating zone A of the generator. Above the preheating zone A is the primary water heating zone B consisting of banks of water tubes 3 arranged in sections extending transversely of

the housing, these sections being generally vertical but gradually inclining from the perpendicular at the rear of the housing, to an angle of about 60° to the horizontal at the front. A triangular space forwardly of the tube sections and above the preheating drums provides the fire box C in which a burner 2 is located, there being additional tube sections in front and on the sides of the fire box as will hereinafter be described. The tube sections connect the drums of the preheating zone A with groups of interconnected drums occupying the upper portion of the housing and extending lengthwise thereof. These groups are arranged in tiers one above the other which may be designated from bottom to top by zones as follows: D, the water distributing zone; E, the zone of flash; and F, the saturated steam zone. The upper tier of drums in the saturated steam zone F connect with a single drum located above the center of the tube sections and at about the level of the distributing zone D which is the superheated steam zone G from which the steam supply to the engine (not shown) is conducted. And finally, the water distributing zone B is connected with the water preheating zone A by tubes 31 extending downwardly at the rear of the housing whereby a feedback or reflex circulation is maintained between these two zones, as will later be set forth.

The arrows in Figure 3 disclose in a general way the path of the products of combustion as they issue from the burner 2 in the fire box C. The main path of the heat is upwardly and rearwardly following a general line at right angles to the tube sections and hence the reason for their gradual approach to the perpendicular toward the rear of the housing. However, there is considerable spread of the flame at the point of combustion in all directions, and particularly upward, so that a considerable portion of the heat circulates among the drums in the upper part of the housing and thence toward the rear. All of the products of combustion converge at the rear of the housing and escape through the stack 4 (Figure 1) opening upwardly below the rear end of the upper steam drums, and passing downwardly extending through the rear wall of the housing near its bottom and thence to the atmosphere.

Having described the general arrangement of the generator, a more detailed description of its construction and design will now follow: Since the circulation of the water is upwardly, it follows that the boiler water is fed to the generator through the preheating zone A consisting of a series of drums, preferably six in number, arranged in parallel relation along the bottom of the housing. These drums are metal tubes of about two inches in diameter closed at their ends except for the short tubes which connect them together. These drums are preferably grouped in pairs, viz., an outer pair 5—5, an intermediate pair 6—6, and a central pair 7—7, there being corresponding drums of each pair on opposite sides of the center line of the generator. At the front of the generator (Figure 4) the ends of the adjacent outer and intermediate drums 5 and 6 are interconnected near their upward portion by small tubes 5*a*, and the ends of the central pair 7—7 by a similarly elevated tube 7*a*. At the rear of the generator (Fig. 5) said outer and intermediate drums 5—5, 6—6 are all connected together in parallel by a pipe or tube 8 extending across the rear ends of the drums and having branch tubes 8*a* leading to these drums near their bottoms. The end of the pipe 8 is provided with a drain and blow-off cock 9 whereby the system can be drained or sediment removed. This pipe 8 also acts to equalize the flow between the two outer pairs of drums 5 and 6. Likewise the intermediate drum 6 on the left (Fig. 5) is connected to the adjacent central drum 7 by an elevated tube 6*a* and the other central drum 7 on the right is provided at its end with an elevated branch pipe 7*b* which connects with the source of water supply and thus is the feed water inlet to the system as indicated in Fig. 2. If desired, additional drains and blow-offs may be provided for the drums where needed. Likewise a branch pipe from one of the drums 6, such as 10 (Figure 5) for the lower connection of a water gauge is also provided, it being understood that such would be provided where required.

Thus following out the circulation of the feed water through the preheating zone A (Fig. 2) the same enters the left-hand central drum 7 at the rear, thence forwardly to the right-hand central drum 7 at the front tube connection 7*a* rearwardly in this drum, thence to the adjacent intermediate drum 6 (on the right) through connecting tube 6*a* and thence to the outer right-hand drum 5 through connecting tube 5*a* at the front. The right-hand intermediate and outer drums 5 and 6 are also connected at the lower portions of their rear ends to the equalizing pipe 8 which connects with the corresponding left-hand drums 5 and 6, so that water passes through these drums which are likewise connected at their forward ends by a tube 5*a*.

The general scheme of circulation in admitting water into the boiler is therefore from rear to front and from center outwardly, although all of the water does not follow the same path. However, the ultimate discharge of the water from the preheating zone is along the outer drums 5, 5 which act as distributors or headers for the banks of tubes above and forming the main heating zone B. Before describing the tube banks, however, it is desirable at this point to note that the drums 5, 5, 6, 6 and 7, 7 are lo-

cated beneath the burner 2 and therefore below the zone of extreme heat. In other words, these drums are not subjected to direct contact with the flame but rather to the indirect heat within the housing. As a result, the heating of the water is more gradual and of equal importance is the fact that the drums 6—6 serve to afford spaces for the separating out and depositing of sediment, the accumulation of which at this point is promoted by reason of the fact that the drums 6—6 are outside of the heating tube circuit, so that during the operation of the boiler the water flow through the drums 6—6 will be gradual, which permits the undisturbed depositing of sediment at a point of relatively low temperature, so that there will be no tendency for the sediment to bake onto the surface of the drums as scale. This settling operation is facilitated by reason of the fact that each pair of adjacent drums 5 and 6 at their rear ends (see Fig. 5) are connected at a low level whereby the main area of circulatory disturbance through the drum 5 and heating tubes will be above the rear point of connection with the companion drum 6, thus affording a relatively quiet and undisturbed pool in the drum 6 for settling purposes. Incidentally the formation of scale is the chief cause for burning out of tubes in the usual type of fire-tube, water-tube or flash boilers wherein the flame is entirely below the generator and hence giving the scale an opportunity to form in the tubes in direct contact with the high temperatures, with the ultimate loss of heating effect, retardation of circulation, and finally the burning out of the tubes.

The tube banks 3 forming the heating zone B consist of a series of units or sections extending transversely or crosswise of the housing and arranged as follows: The main group of sections extend from the fire-box C to the rear of the housing, the forwardmost sections being inclined at an angle of about 60° to the vertical and in a forward direction from bottom to top, while each successive section or pair of sections gradually assumes a position more nearly vertical, the rearmost section being quite vertical, as shown in Figure 3. Figure 6 illustrates one of these tube sections which consists of a plurality of small vertical tubes 11 of about ½ inch diameter spaced relatively close together and having their ends welded into headers 11*a* of larger diameter, also parallel with each other but inclined at an angle of about 15° to the horizontal. The headers are closed at one end and at their opposite ends have connections formed by bending the headers upwardly and downwardly parallel with the tubes 11*a* and equipping them with pipe couplings or unions 11*b*. These connections, however, are at diagonally opposite sides of the section. Thus the upper header has its connection at its upper right end and extending upward, and the lower header has its connection at its lower left end and extending downwardly, as shown in Figure 6. It being understood, however, that the alternate sections stand in reversed relation to one another, so that all of the tube sections which have their upper connections on the right side will connect with an upper distributing drum 14 on that side of the generator, while all of the intervening tube sections which have their upper portions on the left side will similarly connect with a companion distributing drum 14 on the left side of the generator, as best indicated in Fig. 4; while the lower connections in each instance will be led into the outermost preheating drum 5 on the same side of the generator. The right hand preheating drum 5 shown in Fig. 4 will thus be connected through a group of tube sections with the left hand distributing drum 14, while the left hand preheating drum 5 will similarly be connected through interspersed sets of tube sections with the right hand distributing drum 14. Thus the first tube section (Figs. 3 and 4) is connected at its lower end to the left-hand drum 5 with its headers 11*a* inclined upwardly and to the right, and its upper or outlet connection at the top and on the right. The second or next tube section is just reversed with its lower connection at the right-hand drum 5 and its upper connection at the left. This arrangement continues throughout the length of the housing so that the circulation through these banks of tubes is in a general vertical direction coupled with a side to side movement in opposite directions in alternate tube banks.

As the tube sections are preferably arranged, the first and second sections are located in vertical position in front of the fire-box C and adjacent the front wall of the housing. Then comes the fire-box space which is converging from bottom to top, this convergence being due to the inclination of the tube sections just beyond the fire-box. In order to obtain the maximum of heat radiation, additional tube sections 12, 12 (Figure 3) are placed at the sides of the fire-box. These sections are similar in construction to the main tube sections but are placed so that the small tubes 12*a* extend more nearly horizontal but with an appreciable inclination and the headers 12*b* extend more nearly vertical.

The tube sections 3, as already intimated, are connected into the outermost drums 5, 5 at the bottom of the housing, the same having short branch pipes 13, spaced apart at proper distances along their top sides to take the pipe couplings 11*b* of the sections. The side sections 12, 12 are likewise connected to the drums 5, 5 near their forward ends by a somewhat similar arrangement of branch

pipes and couplings. It is noted, however, that the side tube sections have their lower and upper connections on the same side of the housing.

The upper or outlet connections of the tube sections are connected with a pair of distributing drums 14, 14 forming what has been termed the zone of distribution D. These drums 14, 14 are located on opposite sides of what may be considered the central vertical plane of the generator (see Fig. 4) and likewise of the vehicle in which the generator is installed. Moreover, these drums are located inwardly from the upper connections from the tube sections, and substantially midway between the same and the imaginary central vertical plane just referred to. And finally, these drums 14, 14 are the lowermost of two identical groups of drums on either side of this central plane and occupying the upper part of the housing. Branching outwardly and a little downwardly from the two distributing drums 14, 14 are series of branch pipes 15 which connect with the upper outlet connections 11*b* of the tube sections 11 on the same side of the generator. These branch pipes are spaced apart along the sides of the distributing drums at the proper distances to connect with the tube sections, as shown in Figure 3. Thus considering the circulation in a single tube section, it takes water from a preheating drum 5 on one side of the generator and discharges into the distributing drum 14 on the opposite side, and since this circulation is reversed in each alternate tube section, it will be seen that the water is continually being passed from one side to the other.

It may be mentioned at this point that the tube banks being made in sections or units, any one may be readily removed in case a tube should burst or burn out. Furthermore, since the tubes are relatively small, the volume of steam in any one is so small that should one of them burst, the amount of steam liberated would not be enough to cause any damage to the generator, or injury to persons in the vehicle.

Continuing now with the connections from the distributing drums 14, 14 it will be observed that above each and on opposite sides thereof is a pair of drums 16, 16 all of the same diameter but larger than the distributing drum. These drums form a tier of four extending across the generator, two on each side of the central plane. Each pair of drums 16, 16 is connected with its associated distributing drum 14 by a series of short pipes 17, 17 branching upwardly and outwardly along the top of each distributing drum and connected into the sides of the pairs of drums 16, 16. These connecting pipes 17 are more numerous and spaced closer together throughout the front part of the generator, gradually decreasing in number toward the rear, due to the fact that the intensity of the heat becomes less toward the rear of the generator. Between the pairs of drums 16, 16 and slightly elevated above the same, are two intermediate drums 18, 18 connected with said drums 16, 16 by rows of short connecting pipes 18*a* spaced apart throughout the length of the drums at distances and likewise decreasing in number from front to rear. Thus each pair of drums 16, 16 leads into a single drum 18, 18 of each group.

Immediately on either side of each of the drums 18, 18 is a pair of drums 19, 19 which form therewith the third tier. These pairs of drums 19, 19 are elevated slightly above the drums 18, 18 and are connected in parallel therewith by transverse horizontal tubes 20, 20, extending across the ends of each set of three drums and having connections through the end walls of each drum.

Above each of the two sets of drums 18, 19, 19 is still another group of drums forming the top tier. Each of these groups consists of a center drum 21, in vertical alignment with the distributing drums 14 and center drum 18 of the group below, and two drums 22, 22 on either side elevated slightly above the center drum. The three drums of each of these groups are also connected in parallel by horizontal tubes 23, 23 across each end.

Each of the upper groups of drums 21, 22, 22 are connected with the groups just below by short vertical pipes 24, 24 connecting the outer pair of drums 19, 22 of each group, just inwardly from each end.

Up to this point the circulation has been upwardly through the identical groups of drums on opposite sides of the central plane of the generator, that is, from each distributing drum 14 to the several sets or groups of parallelly interconnected drums immediately above, until it finally reaches the drums 21, 21 in the upper tier on each side of the generator.

It may now be stated that the normal water level in the generator is approximately at the top of the drums 16, 16 although this will be more accurately described at another point. However, it may be assumed that the generation of steam or the conversion of the water to steam takes place at about the level indicated and therefore the drums above contain steam in varying degrees of saturation until the upper tiers of drums are reached where the steam is still saturated but to a less degree than in the drums just below, this being due to the obvious fact that as the steam rises its moisture content is continually being reduced by contact with the heat through the walls of the drums. Thus it may be assumed that on reaching the upper groups 21, 22, 22 of drums, the steam is still saturated and therefore suitable for operating the water pumps and other auxiliaries of the power plant. Thus a pipe 25 extends across

the rear of the generator (Figure 5) and connects the drums 21, 21, this pipe not only having connections at each end for supplying steam to said auxiliaries but also serves as an equalizing pipe to balance the steam pressures between the separate groups of drums on the two sides of the generator. So also short pipes 26 branch off from the drums 22 in the upper tier which lead to the water gauge, safety and relief valves.

At the front of the generator and connecting the ends of the two saturated steam drums 21, 21 is a T-shaped pipe 27 (Figure 4) its main branch extending downwardly at the center of the generator and connected with the forward end of a single centrally disposed drum 28 located between the two distributing drums 14, 14 and just above the tube sections 11. This is the superheated steam drum from which the steam is drawn off through a pipe 29 leading to the engine which operates the vehicle. This superheated steam drum extends the length of the generator and is preferably supported at its rear end by a T-shaped strap 30 welded at its ends to the adjacent end of the drum and the two drums 19, 19 above. The location of the superheated steam drum 28 in the zone of the more intense heat is calculated to convert the saturated steam into superheated steam as it is drawn from the top tier of drums and from both groups on either side of the generator.

Having thus set forth the grouping of the various elements of the generator, it will be more clearly seen how the division of the same into zones is brought about. Thus the preheating of the water takes place in zone A made up of the drums 5, 6 and 7 at the bottom of the housing and below the region of intense heat from the burner 2; next the zone B of intensive water heating made up of the tube banks 3, next the zone D of conversion where the water reaches the temperature where it is converted to saturated steam, the successive stages of saturated steam in zone F and finally the uniting of both groups of drums in the superheating drum of zone G.

An important feature yet to be disclosed is the provision of the continual feeding back of a portion of the water from the distributing drums 14, 14 to the preheating drum by what has been termed a "reflex" action. This is accomplished by connecting the rear ends of each distributing drum 14, 14 with the rear end of each of the outer preheating drums 5, 5 on the same side of the generator, with pipes 31, 31 extending vertically at the rear of the housing. By virtue of these feed back pipes, there is set up a secondary circulation from the preheating drums 5, 5 upwardly through the tube banks to the distributing drums 14, 14 and thence back to the preheating drums 5, 5 through the pipes 31, 31, thus diverting a portion of the water which otherwise would continue into the drums above. There are several advantages in this so-called reflex action. First, the feeding back of the water at high temperature into the preheating zone manifestly aids in bringing the feed water up to temperature in a shorter period of time, inasmuch as the water so fed back enters the outer drums 5, 5 and mingles with the water about to enter the tube banks. The tendency, therefore, is to retard the withdrawal from the other preheating drums in which the water is relatively cooler, thereby increasing the period of preheating. Secondly, the temperature of the water delivered to the tube banks is higher than it would otherwise be, thus tending to equalize the temperature above and below the zone of greatest effective heat. And finally, by the reflex action the water at high temperature is returned and delivered to the tube banks at the rear of the generator where the effective heat is somewhat less than at the front and hence uniformity of temperature is maintained from front to rear as well as above and below the tube banks.

Attention has also been directed to the grouping of the drums in the upper portion of the housing and more especially to the division of these drums into identical groups on opposite sides of the central plane of the generator. There are several reasons for this arrangement. The use of a plurality of relatively small drums connected together is considered to better automotive practice than a single large drum or header, first, because the smaller drums are capable of withstanding high steam pressure with relatively thin walls and hence it is possible to use steel tubing throughout rather than heavy cast metal in order to secure the thickness required in a larger drum to hold the same pressures. Furthermore, the storage of steam in a multiplicity of drums materially increases the factor of safety owing to the fact that the failure of one small drum would be far less serious than the bursting or burning out of a single large drum or reservoir. And finally, the multiplicity of drums and connecting tubes greatly increases the effective heating area and hence gives the generator greater efficiency and steaming capacity. This advantage is manifest from the very nature of the design which allows for complete circulation of the heat in and about the nest of tubes and drums in the upper part of the housing.

Lastly, will be discussed the reasons for duplication of groups of drums on opposite sides of the generator. This feature of design has to do especially with the conditions of operation of the vehicle in which the generator is installed, whether it be a road vehicle, a power boat or even an aeroplane. Assuming in any case that the generator is posi-

tioned longitudinally of the vehicle, there will be more or less tilting or rolling from side to side. For instance, an automobile is continually rolling from side to side due to unevenness of the pavement, or will lean to one side in travelling along a crowned pavement. As a result, the water in the generator in seeking its level will manifestly flow from the high to the low side with the angular movement of the vehicle. The effect would be apparent if a single large drum were used in place of the multiplicity of the drums above the tube banks, namely, the inertia of the relatively large volume of water would set up a violent agitation with marked variations in the level of the water on opposite sides of the generator. However, by distributing the water into a plurality of drums extending transversely of the generator, the tilting or rolling of the vehicle has relatively small effect on the general water level, since it directly effects only the drums on one side of the generator. So too, by the grouping of the drums on opposite sides of the longitudinal axis of the rolling or tilting movement, the effect of the movement is minimized since the lowering of the water level on the high side is confined to the drums on the same side of the axis, and hence the actual displacement of the water is relatively small. This feature is illustrated in Figure 7 which shows the group of drums on one side of the generator. If the normal water level is assumed to be represented by line *a*—*a* passing through the bottom of the drum 18 and *b*—*b* represents the vertical axis of the generator it will be seen that if the vehicle tilts until the vertical axis assumes the position *b'*—*b'* that the displacement of the drums adjacent the water level would be at the same angle as indicated by the dotted line positions. But this displacement is not sufficient to effect any considerable transfer of water from the higher or right hand drum to the lower drum, whereas if all of the drums 16 were connected across the generator, the one on the high side would be emptied and the one on the low side would overflow into the drums above. Thus by the separate grouping of the drums those on opposite sides of the center of each group function independently of the other in the generation of the steam, although they are balanced or equalized so that the load will be evenly distributed under all conditions of operation.

Although we have disclosed and illustrated a preferred embodiment of the invention, it will be understood that it may be variously modified without departing from the spirit of the invention, as set forth in the appended claims.

We claim as our invention:

1. In a steam generator, the combination of a housing, water preheating drums at the bottom of said housing arranged on opposite sides of the longitudinal center plane, a plurality of upright tube sections extending transversely of said housing and spaced apart substantially throughout the length thereof, and drums above said tube sections and extending on opposite sides of the longitudinal center plane, each tube section being connected at its lower end with a preheating drum on one side of the center plane, and at its upper end with the upper drum on the opposite side of the center plane, the spacing of the tube sections in the front portion of the housing being increased to provide a fire-box located within the zone of said tube sections, and the tube sections immediately to the rear of the fire-box space standing in planes obliquely disposed with their tops lying forwardly of the vertical, and succeeding tube sections toward the rear progressively approaching the vertical plane, and a tube section on each side of the fire-box space standing in a substantially longitudinal plane to furnish a side inclosure for the fire-box space.

2. In a steam generator, the combination of a housing, water preheating drums at the bottom of said housing arranged on opposite sides of the longitudinal center plane, and drums above said preheating drums and extending on opposite sides of the longitudinal center plane, a plurality of tube sections, each comprising substantially vertically extending tubes, and substantially horizontally extending means connecting upper and lower sets of ends of said tubes, one of said horizontal means being connected with a preheating drum on one side of the center plane, and the opposite horizontal means with an upper drum on the opposite side of the center plane, and the alternate tube sections alternating in respect to the sides to which their horizontal means are connected, the spacing of the tube sections in the front portion of the housing being increased to provide a fire-box located within the zone of said tube sections, and the tube sections immediately to the rear of the fire-box space standing in planes obliquely disposed with their tops lying forwardly of the vertical, and succeeding tube sections toward the rear progressively approaching the vertical plane, and a tube section on each side of the fire-box space standing in a substantially longitudinal plane to furnish a side inclosure for the fire-box space.

3. In a steam generator, the combination of a housing, water preheating drums at the bottom of said housing arranged on opposite sides of the longitudinal center plane, a plurality of upright tube sections extending transversely of said housing and spaced apart substantially throughout the length thereof, and a distributing drum on each side of the longitudinal center plane and above the tube sections, the tube sections being ar-

ranged to have their lower ends alternately connecting with the preheating drums on opposite sides of the center plane and their upper ends alternately connected with the diagonally opposed distributing drum on the opposite side of the center plane, two groups of inter-connected upper drums, one group being connected with each of the distributing drums, and a single drum for delivering superheated steam connected with both groups of upper drums.

4. In a steam generator, the combination of a housing, water preheating drums at the bottom of said housing arranged on opposite sides of the longitudinal center plane, a plurality of upright tube sections extending transversely of said housing and spaced apart substantially throughout the length thereof, and a distributing drum on each side of the longitudinal plane and above the tube sections, the tube sections being arranged to have their lower ends alternately connecting with preheating drums on opposite sides of the center plane and their upper ends alternately connected with the diagonally opposed distributing drum on the opposite side of the center plane, two groups of inter-connected upper drums, one group being connected with each of the distributing drums, and a single drum for delivering superheated steam connected with both groups of upper drums, said last named drum being located below the groups of upper drums and immediately above the center of the tube sections.

5. In a steam generator, the combination of a housing, water preheating drums at the bottom of said housing arranged on opposite sides of the longitudinal center plane, a plurality of upright tube sections extending transversely of said housing and spaced apart substantially throughout the length thereof, and drums above said tube sections, and a distributing drum on each side of the longitudinal center plane and above the tube sections, the tube sections being arranged to have their lower ends alternately connecting with the preheating drums on opposite sides of the center plane and their upper ends alternately connected with the diagonally opposed distributing drum on the opposite side of the center plane, two groups of interconnected upper drums, one group being connected with each of the distributing drums, and a single drum for delivering superheated steam connected with both groups of upper drums, the spacing of the tube sections near the front of the housing being increased to afford a fire-box, and the tube sections to the rear of said fire-box space standing in obliquely overlying planes with respect to the vertical, and progressively approaching the vertical plane from front to rear, and a longitudinally extending tube section on each side of the fire-box space, each of said tube sections being connected at its lower and upper ends respectively to the preheating drum and the distributing drum on the same side of the center plane.

6. In a steam generator, the combination of a housing, water preheating drums at the bottom of said housing arranged on opposite sides of the longitudinal center plane, a plurality of upright tube sections extending transversely of said housing and spaced apart substantially throughout the length thereof, and drums above said tube sections, and a distributing drum on each side of the longitudinal plane and above the tube sections, the tube sections being arranged to have their lower ends alternately connecting with preheating drums on opposite sides of the center plane and their upper ends alternately connected with the diagonally opposed distributing drum on the opposite side of the center plane, two groups of interconnected upper drums, one group being connected with each of the distributing drums, and a single drum for delivering superheated steam connected with both groups of upper drums, said last named drum being located below the groups of upper drums and immediately above the center of the tube sections, the spacing of the tube sections near the front of the housing being increased to afford a fire-box, and the tube sections to the rear of said fire-box space standing in obliquely overlying planes with respect to the vertical, and progressively approaching the vertical plane from front to rear, and a longitudinally extending tube section on each side of the fire-box space, each of said tube sections being connected at its lower and upper ends respectively to the preheating drum and the distributing drum on the same side of the center plane.

7. In a steam generator, the combination of a housing, two groups of water preheating drums at the bottom of said housing arranged one group on each side of the longitudinal center plane, a plurality of upright tube sections extending transversely of said housing and spaced apart substantially throughout the length thereof, groups of drums above said tube sections and extending one group on each side of the longitudinal center plane, each tube being connected at its lower end with the outermost of a group of preheating drums on one side of the center plane and at its upper end with an upper drum of the group on the opposite side of the center plane, means for admitting water into one of the preheating drums, connections between all of the preheating drums for admitting water from one to another, said connections including a low level connection between constituent members of each group of preheating drums adapted to maintain a relatively quiet pool in one of the preheating drums of each group for the purpose of permitting a deposit

of sediment therein, and heating means located above the preheating drums for maintaining the latter in a relatively cool condition.

8. In a steam generator, the combination with a housing, of water preheating drums at the bottom of said housing arranged on opposite sides of the longitudinal center plane, and drums above said preheating drums extending on opposite sides of said longitudinal center plane; a plurality of tube sections, each comprising a plurality of vertically extending tubes extending across the fire box space, and upper and lower horizontal means connecting upper and lower sets of ends of said vertically extending tubes, the horizontally extending means for the lower set of ends being connected with a pre-heating drum on one side of the center plane and the horizontally extending means for the upper set of means being connected with an upper drum on the opposite side of the center plane, the spacing of the tube sections in the front portion of the housing at their upper ends being increased to provide a fire box located within the zone of the vertically extending tubes.

9. A vapor generator comprising spaced banks of tubes, mud drums, a feed water drum disposed between and communicating with said mud drums, said mud and feed water drums extending longitudinally beneath said banks of tubes and spaced therefrom and cooperating therewith in defining the combustion chamber, and conduit means connecting said mud drums with said banks of tubes to complete a circuit through said banks of tubes and mud drums.

Signed at Chicago, Illinois, this 25th day of April 1927.

RUFUS R. McKNIGHT.
ARTHUR WEBBER.