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METHOD OF GENERATING HIGH TEMPERATURE VAPOR.

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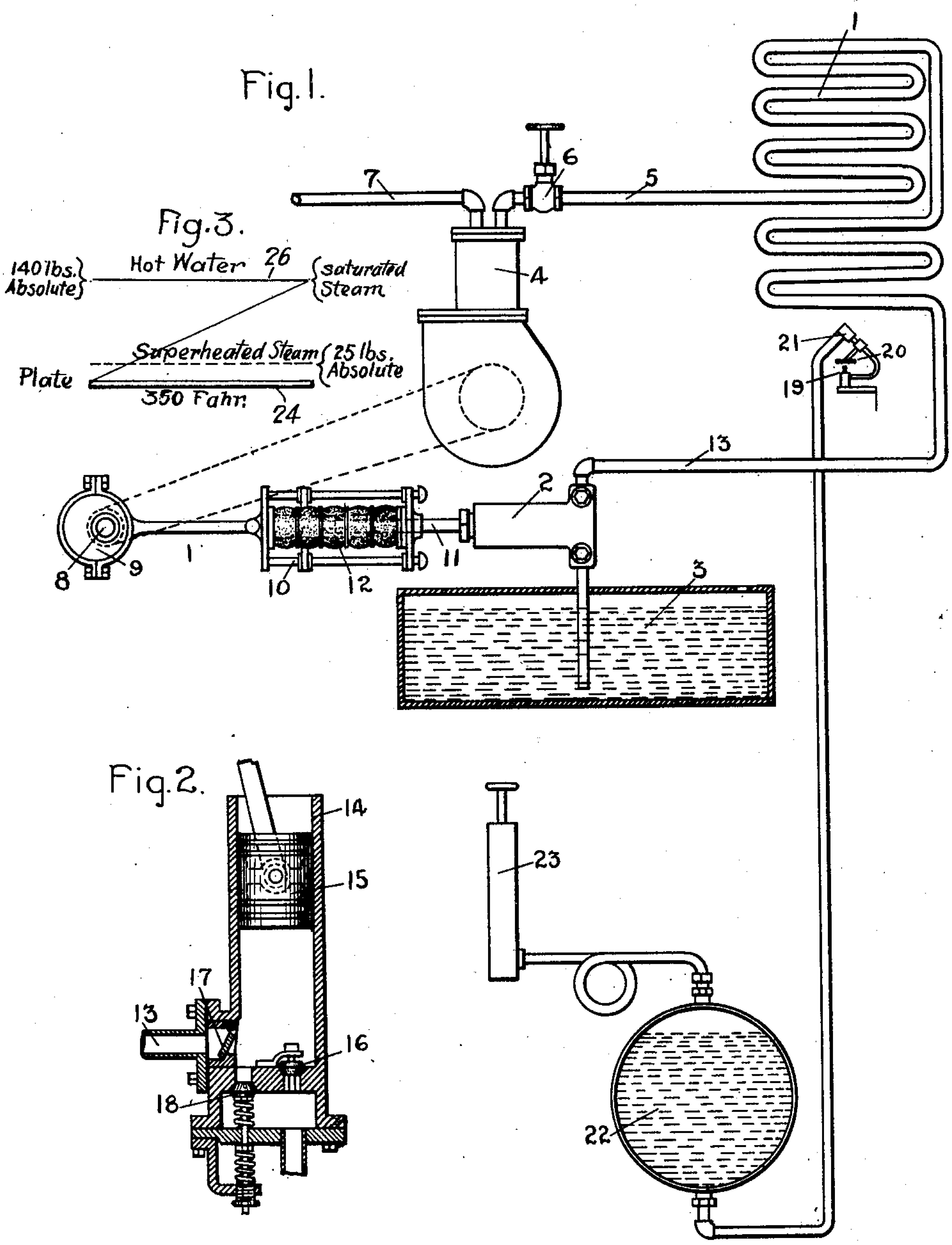

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METHOD OF GENERATING HIGH-TEMPERATURE VAPOR.

997,940. Specification of Letters Patent. Patented July 11, 1911.

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To all whom it may concern:

Be it known that I, Elihu Thomson, a citizen of the United States, residing at Swampscott, in the county of Essex, State of Massachusetts, have invented certain new and useful Improvements in Methods of Generating High-Temperature Vapor, of which the following is a specification.

Steam generators have been heretofore constructed out of a coil of pipe into which water was forced by a pump or equivalent means. When operated under ordinary conditions, namely at relatively low temperatures and pressures, these operated satisfactorily, neglecting certain difficulties in maintaining tight joints; but when the temperature was first materially increased much of the water fed thereto passed through in the spheroidal state, resulting in water being entrained with the steam as it passed to the engine, and even in the production of a shell of steam lining the tube and almost completely preventing the passage of heat to the water in the boiler. In this case the pressure produced through the same was due in part to water delivered with the steam. Obviously such an arrangement is not satisfactory.

In order to obtain the advantages of superheated steam, and at the same time prevent the water from assuming the spheroidal state, boilers have been constructed with restricted water passages whereby the water was mechanically maintained in boiling contact with the metal. These are called capillary boilers and will partially overcome the difficulties mentioned, but are not commercially satisfactory because the passages become obstructed even though usual precautions are taken to remove impurities. This means that the boiler must be taken down from time to time and the passage cleared, a matter both difficult and expensive; when the boiler is made of flattened tubes this is almost impossible, because of the difficulty of inserting any clearing device into the restricted passage. When the boiler tube or passage is substantially filled with loose metallic pieces, as is sometimes done, clearing it entails the removal of all, or substantially all, of these pieces. Manifestly such constructions do not appeal to engineers in general, and where the boiler is to be used by relatively unskilled persons, its use is almost prohibitory.

I have discovered a method of operation whereby the objections above pointed out can be entirely obviated and a boiler having a water passage of substantial cross-section employed. From experiment it has been determined that water under atmospheric pressure will assume the spheroidal state when in contact with a surface heated to 350° Fah. The standard steam tables however show that water is in boiling contact with the metal of the boiler at temperatures far above that required to produce the spheroidal state in vessels exposed to atmospheric pressure.

I have determined that water in the spheroidal state or condition can be changed to one of contact by subjecting it to pressure. This pressure varies with different temperatures, gradually increasing with the increase in temperature.

The above propositions form the basis of my invention. In order to obtain a complete understanding of my invention it is well to consider the character and action of a coil boiler. It is preferably made of hard drawn steel tubing arranged in such a manner that a considerable length can be coiled into a small space. It will be found satisfactory to form the boiler in sections each of which is composed of tubes bent in any suitable manner. Water enters one end of the tube and is gradually heated up to the point of vaporization and the vapor is highly superheated thereafter as it flows toward the point of discharge. The point of vaporization varies somewhat under different conditions of service, it being nearer the inlet end of the boiler in some cases and farther away in others. The tube by preference gradually increases in temperature from the inlet to the discharge end, and the tendency for the water to enter the spheroidal state is at or near the point of vaporization. A boiler of this character can supply steam whose pressure is practically nothing, or it may be 500 or 600 pounds, or even more. This is so even though the temperature of the boiler is very high and sufficient, for example, to impart 600 degrees of superheat to the steam. This condition of affairs means that such a relation as to pressure and temperature of the steam exists that the pressure of the steam may or may not have the steam table equivalent thereof.

By my invention the evaporating and storage capacity of a coil boiler is increased so that, on demand, a very large output of steam or vapor can be furnished from the stored heat in the interior of the boiler; the boiler being kept at a relatively high temperature. It will be understood that a coil of pipe of circular bore or any other open section if heated in fire has a certain steaming capacity when water is pumped through it. If the temperature of the pipe be so high that the water passing therethrough does not enter into actual contact with the metal, or into boiling contact, but escapes therefrom by remaining in the spheroidal state, the capacity of the boiler is much diminished in spite of the temperature of the metal being high. I overcome the objection above mentioned by exerting at all times upon the water to be vaporized such a pressure as will maintain it in boiling contact with the metal, notwithstanding the fact that the metal itself may be almost or quite at a red heat.

In the accompanying drawing, which diagrammatically illustrates my invention, Figure 1 shows a coil boiler and its regulating means arranged to supply steam to an engine; Fig. 2 is a sectional view of a bypass regulator for the pump; and Fig. 3 is a diagram illustrating certain of the operations.

Referring to Fig. 3, I have represented diagrammatically a plate or part of a boiler 24 which is supposed to be heated to 350° Fah. and subjected to atmospheric pressure. Water dropped thereon will immediately enter the spheroidal state. If now the water is subjected to pressure, say ten pounds gage or twenty-five pounds absolute, for example, as indicated by the line 25, the water will pass from the spheroidal condition to one of contact and hence boil. The steam tables show that the maximum pressure obtainable for saturated steam at 352.8° Fah. is 140 pounds absolute, which is indicated by the line 26. If the pressure is increased to a point above 140 pounds absolute the steam will pass into superheated water, and although the water would wet the surface of the metal the pressure would be so great as to prevent boiling. It follows from the above that the pressure within the boiler must be great enough to hold the water in contact with the metal at the point of vaporization, yet not great enough to prevent the water from boiling. In the present illustration there is a range in pressure from 25 to 140 pounds absolute between which it is safe to operate, and the steam produced will be superheated. The present illustration is given merely as a matter of convenience because the temperature at which the spheroidal state exists at atmospheric pressure can readily be determined, whereas it is difficult to make such investigations with higher pressures.

It is common practice with me to operate a coil boiler with an inlet temperature of 75° to 100° Fah. and a discharge temperature of from 700° to 1000° Fah. I have determined that the vaporization point in a coil boiler, which point may cover several feet, is continually shifting toward and away from the inlet end as the demand for steam changes. This continual shifting or surging is at times small but at other times is considerable. During the shifting there is a tendency for the column of water to break owing to the fact that steam is formed at some intermediate point therein. This is probably due to the fact that the temperature at some particular point is better adapted to form steam than the portions adjacent thereto. This further increases the surging because more or less water is entrained with the steam and as a result the point of vaporization is continually moving away from the inlet and toward the discharge end of the boiler until finally the boiler will no longer produce steam until the proper conditions are reëstablished. In other words, the boiler is "cold". Since it is some intermediate point in the boiler tube that causes the water to enter the vaporous state, which point shifts along a tube of varying temperature, it follows that the pressure on the steam must be great enough at all times to prevent the water entering the spheroidal state, yet low enough so that the water will boil. When this relation is established the boiler will operate satisfactorily.

1 represents a coil boiler of any desired construction, but preferably composed of steel tubing made in sections, and the several sections welded together. The tube may with advantage be about one hundred and forty-four feet long, and have an internal diameter of .49 of an inch. A boiler of this construction has been found to give excellent satisfaction for self-propelled vehicles of ordinary weights, but I do not wish to be construed as limiting myself to any particular sectional area for the water passage, or to any particular length of passage or tube. The lower end of the passage is connected to a water pump 2 having the usual suction and delivery valve, which pump receives its supply from the tank 3, and is capable of forcing water into the boiler under a relatively high maximum pressure, such as five hundred to six hundred pounds. The other end of the boiler tube or passage is connected to the engine 4 by the steam pipe 5. Included in the steam pipe 5 is a throttle valve 6, the open-

ing in which is preferably smaller than the opening or bore of the pipe 5, so as to have a tendency to choke back the steam and assist in maintaining the pressure within the boiler. It is not absolutely necessary to do this, for the engine itself may, when running slowly, act as a sufficient back resistance to the passage of steam, or the throttle need never be opened fully except in emergencies. It will be found desirable however to use this arrangement when the vehicle or other apparatus equipped with the system is in the hands of unskilled persons. The exhaust is conveyed away from the engine by the pipe 7.

The engine is coupled to a driving shaft 8, which, in a self-propelled vehicle, may be the axle carrying the driving wheels. It is preferable to drive the pump from the engine, since by so doing variations in speed, with the corresponding changes in steam consumption, will be compensated for. The pump can of course be driven from a separate source of power, the only requisite being that it shall at all times be capable of delivering the maximum amount of water demanded by the boiler. In other words, the pump mechanism must be so arranged that its effective delivery is great enough at all times to maintain a pressure within the boiler exceeding that at which the spheroidal state can take place regardless of the boiler temperature.

In a system of this kind designed for automobile service, the demand for steam varies suddenly and between wide limits. It may be at the maximum one moment, as when climbing a hill, and at the minimum the next moment, as in descending. This means that the amount of water delivered to the boiler must be varied from a maximum to a minimum in accordance with the variations in demand on the vaporizer, and in substantial unison with the said variations and in the same degree. As the pressure in the boiler changes, the pump pressure must be great enough to force the water into boiling contact with the walls of the tube at the point of vaporization, regardless of their temperature. In other words, an artificial relation is created and maintained between the temperature and pressure of the steam. By "artificial relation" I mean that the pressure of the steam does not of necessity have the steam table equivalent in temperature, and conversely the temperature of the steam does not of necessity have the steam table equivalent in pressure.

In Fig. 1 a variable-stroke pump is employed to assist in maintaining the proper conditions. Mounted on the axle is an eccentric 9, and this eccentric is connected by a rod with the frame 10. The piston rod 11 is connected to the frame through rubber buffers 12. When the back pressure in the water delivery pipe 13 from the pump to the boiler is below a certain predetermined amount indicating a maximum demand for vapor energy, the pump piston will work under full stroke, but just as soon as the pressure exceeds that predetermined amount, indicating that the demand for vapor is decreasing relative to the water supply, its length will be decreased by an amount proportional to the increase. In other words, there is a most intimate relation between the parts of the organization, and the amount of water delivered to the boiler increases and decreases simultaneously with the demand for vapor energy, and in substantially the same degree, but throughout all of the changes the pressure at the point of vaporization is maintained above that at which water can enter the spheroidal state, and below that which prevents the formation of steam for a given temperature. When the demand for steam is *nil*, the boiler pressure is at a maximum, and the eccentric and rod will of course continue to work so long as the shaft 8 is revolving, but the piston will remain stationary, the buffers taking up the movement. Intermediate load conditions demanding a variation in the water supply will cause the parts to assume positions between those mentioned. As previously stated, the spheroidal state of water in a boiler can be prevented by maintaining a relatively high pressure, so for this reason the pump is set by properly proportioning the buffers to maintain a water delivery which will at all times maintain a pressure great enough to prevent the spheroidal state without regard to temperature conditions under which the boiler is operating.

In Fig. 2 is shown a by-pass regulator for the pump, which may be used separately or in conjunction with the spring pump. 14 represents the cylinder, 15 the piston, 16 and 17 the suction and delivery valves, and 18 the spring-pressed by-pass valve. When the pressure in pipes 13 exceeds a certain predetermined maximum, the valve 18 opens and permits more or less water to return to the suction pipe.

Situated below the boiler is a burner adapted for hydrocarbon fuel, the one shown being intended more especially for kerosene in vapor form, and should be capable of raising the boiler to a high temperature.

19 represents the nozzle, 20 the baffle plate for the flames, and 21 the vaporizer.

Fuel for the burner is supplied from the tank 22, the latter being placed under air pressure by an air pump 23. The burner shown merely typifies a heating device; its character and the regulating means are immaterial so long as it has sufficient capacity.

The action of my invention is as follows: The burner is started into operation and water is forced into the boiler. As soon as the proper temperature and pressure are reached, steam may be admitted to the engine through the throttle 6. The engine is connected to the shaft which drives the automatic water pump, and the latter delivers water to the boiler, the automatic regulator being so adjusted and arranged that the pump can force the necessary amount of water into the boiler to hold the pressure well above the point where the spheroidal condition of the water can take place for a given boiler temperature, but not sufficiently high to prevent the formation of steam. As steam passes out of the boiler there is a tendency for the pressure to drop, and if the supply of water were momentarily discontinued a certain amount of the water contained in the boiler would quickly assume the spheroidal condition, and greatly interfere with the operation of the system; but the instant that there is the slightest decrease in steam pressure the pump forces water enough into the boiler to create the necessary steam to maintain a given pressure. It is to be assumed that the arrangement shown will supply fuel to the burner in sufficient amounts at all times to maintain the operating temperature. For ordinary working conditions the pump regulator has sufficient range to include all changes in temperature of the boiler and burner from minimum to maximum.

Boilers operating in accordance with my invention are in service daily on automobiles where the inlet end of the tube has a low temperature, 75° to 100° Fah. being a fair average, the discharge end of the tube being heated to from 700° to 1000° Fah. As commonly operated the discharge end of the tubes shows a dull red, and the steam has a temperature of about 800° Fah. For commercial running conditions the gage pressure on the inlet or water end of the boiler can with advantage be about 400 pounds and that between the throttle valve and the engine 325 to 350 pounds. For testing the boilers and engines a somewhat lower pressure can be used. A record test shows that the engine gave 5.63 horse power at a gage pressure of 195 pounds while the boiler was working at 200 pounds. In this case the relative temperatures of the receiving and discharge ends of the boiler were about the same as those above stated. The water consumed per horse power hour was 22.55 pounds. The boiler referred to had about 140′ of steel tubing of .49″ bore.

If the relation between pressures and temperatures referred to above is observed, the boiler will deliver steam superheated to a high degree and the water is prevented from entering the spheroidal state.

I do not wish to be understood as limiting myself to the above specific pressures, because they can be departed from without affecting my invention.

I have found in actual practice with vehicles equipped with my invention that so long as the pressure on the water end of the boiler is maintained, the boiler will work satisfactorily, and the steam delivered thereby will be superheated, it being assumed of course that the burner has sufficient capacity. As soon however as the pressure of the boiler falls, due to a defect in the pump or too free delivery of steam for any other reason, the temperature of the boiler remaining substantially the same, water will pass through the boiler in the spheroidal state and enter the engine, thereby conclusively showing that the spheroidal state can be prevented by maintaining a sufficiently high pressure. When the water in the boiler assumes the spheroidal state from the causes described, the tendency is for hot water to pass directly through the boiler, protected by a thin body or shell of steam from the boiler tubes, so that even a very hot boiler will supply wet steam or even hot water to the engine. With such conditions the engine works at low efficiency thus increasing the demand for steam and cooling the boiler, until finally the boiler cools down and the carriage stops. When the water assumes the spheroidal state, a carriage which otherwise discharges little or no visible steam, as for example a carriage in which the escaping steam is mingled with the products of combustion from the burner, will even with a hot boiler give forth great clouds of steam and will even discharge quantities of water from the exhaust.

In accordance with the provisions of the patent statutes, I have described the principle of operation of my invention, together with the apparatus which I now consider to represent the best embodiment thereof; but I desire to have it understood that the apparatus shown is only illustrative, and that the invention can be carried out by other means.

What I claim as new and desire to secure by Letters Patent of the United States is,

1. The method of generating high temperature vapor in a vaporizer having a conduit of relatively unrestricted bore, which consists in heating the conduit externally to such a high temperature as would cause the contained liquid to enter the spheroidal state at atmospheric pressure, partly filling the conduit with liquid to be vaporized, supplying amounts of liquid to the conduit equivalent to the vapor withdrawn, and maintaining a pressure within the conduit which is great enough to cause the contained liquid to be maintained in boiling

contact with the wall of the conduit without however preventing the formation of vapor.

2. The method of generating high temperature vapor in a conduit having a relatively unrestricted bore, which consists in externally heating the wall of the conduit to a temperature greater than that necessary to cause the contained fluid to enter the spheroidal state at substantially atmospheric pressure, continuously supplying liquid in amounts corresponding to the equivalent in vapor withdrawn, which liquid is gradually heated in flowing from the inlet to the region of vaporization, maintaining a pressure within the conduit great enough to prevent the liquid from entering the spheroidal state, and superheating the vapor from the said region of vaporization to the outlet.

In witness whereof I have hereunto set my hand this 14th day of November, 1901.

ELIHU THOMSON.

Witnesses:

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