No. 704,907. Patented July 15, 1902.

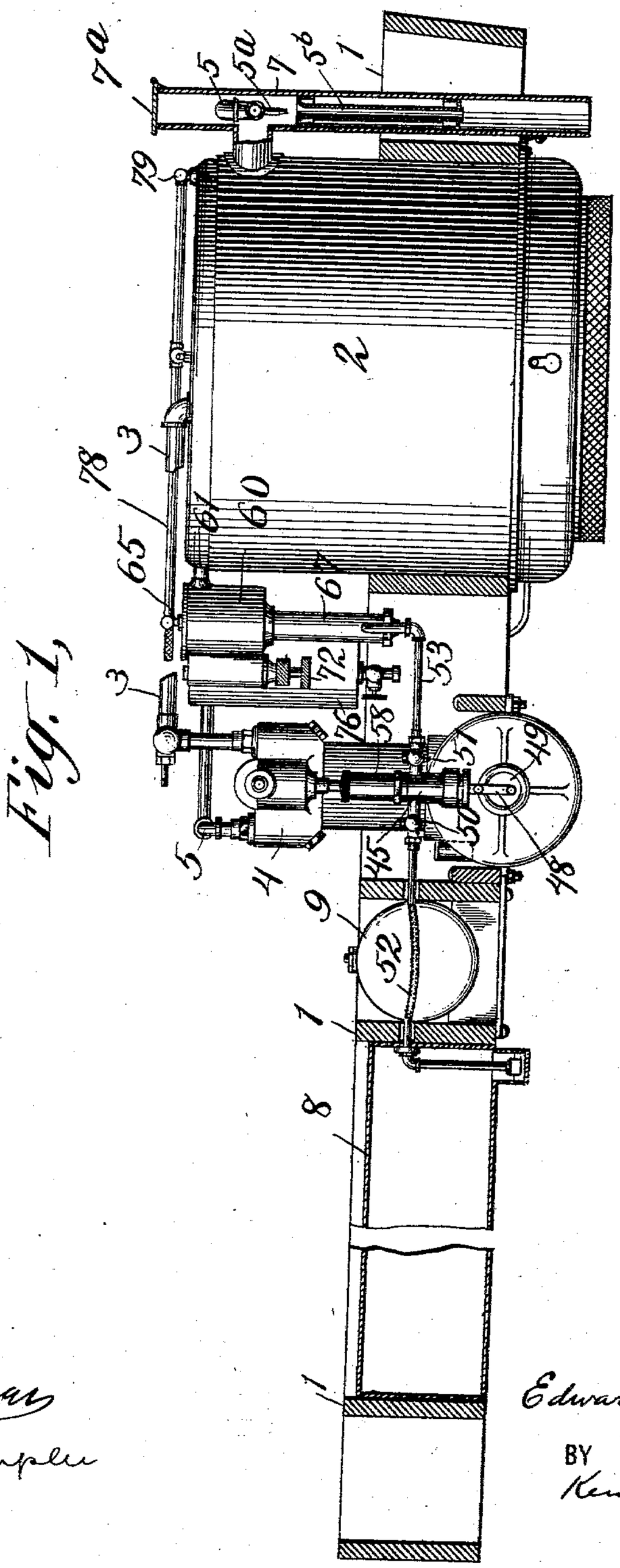
E. C. NEWCOMB.

APPARATUS FOR GENERATING STEAM OR VAPOR.

(Application filed June 7, 1901.)

(No Model.) 6 Sheets—Sheet 1.

Fig. 1.



WITNESSES:
Edwin Segar
John C. Kemplen

INVENTOR
Edward C. Newcomb
BY
Kenyon & Kenyon
ATTORNEYS

No. 704,907. Patented July 15, 1902.

E. C. NEWCOMB.

APPARATUS FOR GENERATING STEAM OR VAPOR.

(Application filed June 7, 1901.)

(No Model.) 6 Sheets—Sheet 2.

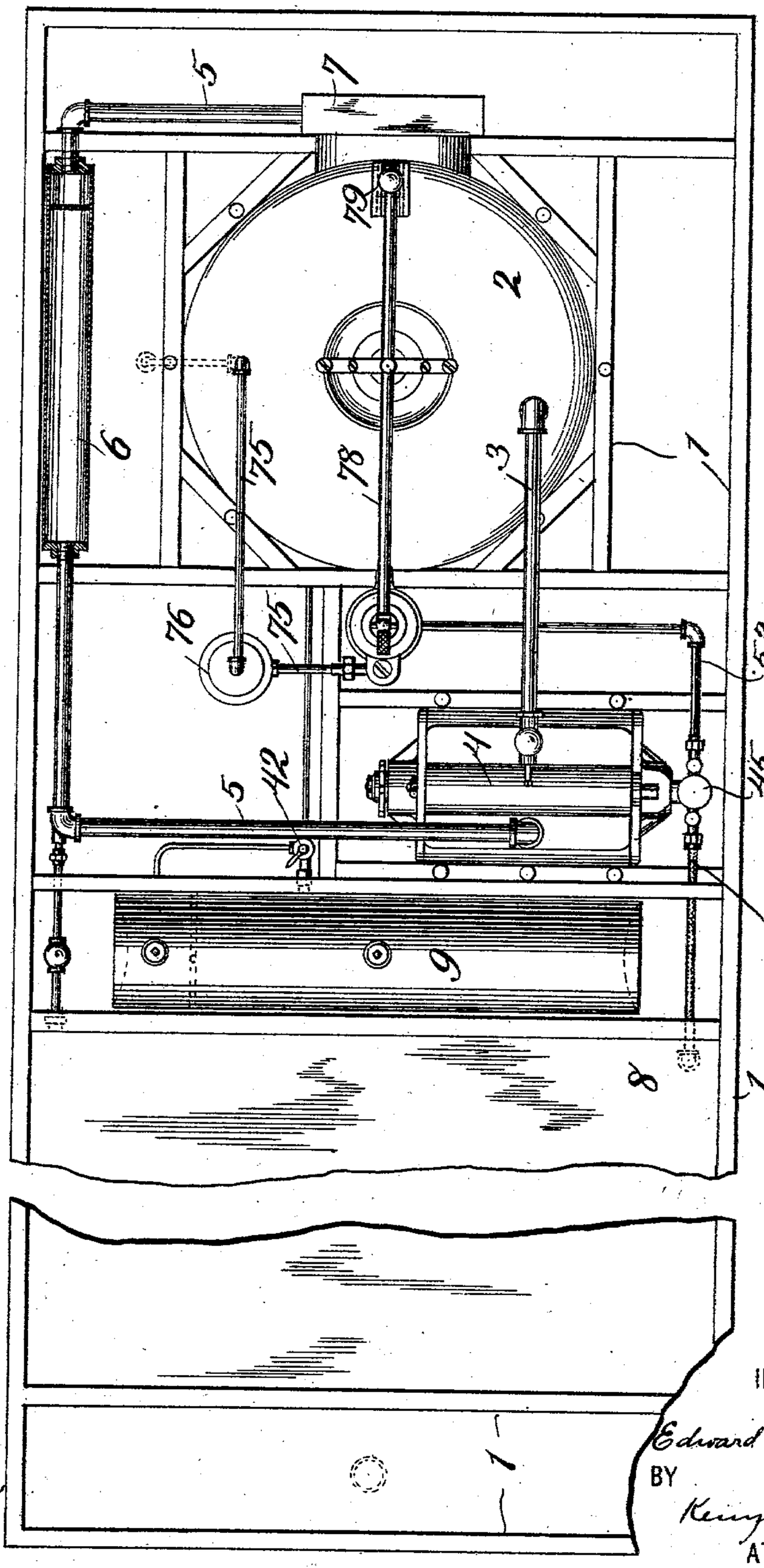


Fig. 2.

WITNESSES:
Edwin Seger
D. Kemplen

INVENTOR
Edward C. Newcomb
BY
Kenyon & Kenyon
ATTORNEYS

No. 704,907. Patented July 15, 1902.

E. C. NEWCOMB.

APPARATUS FOR GENERATING STEAM OR VAPOR.

(Application filed June 7, 1901.)

(No Model.) 6 Sheets—Sheet 3.

Fig. 3.

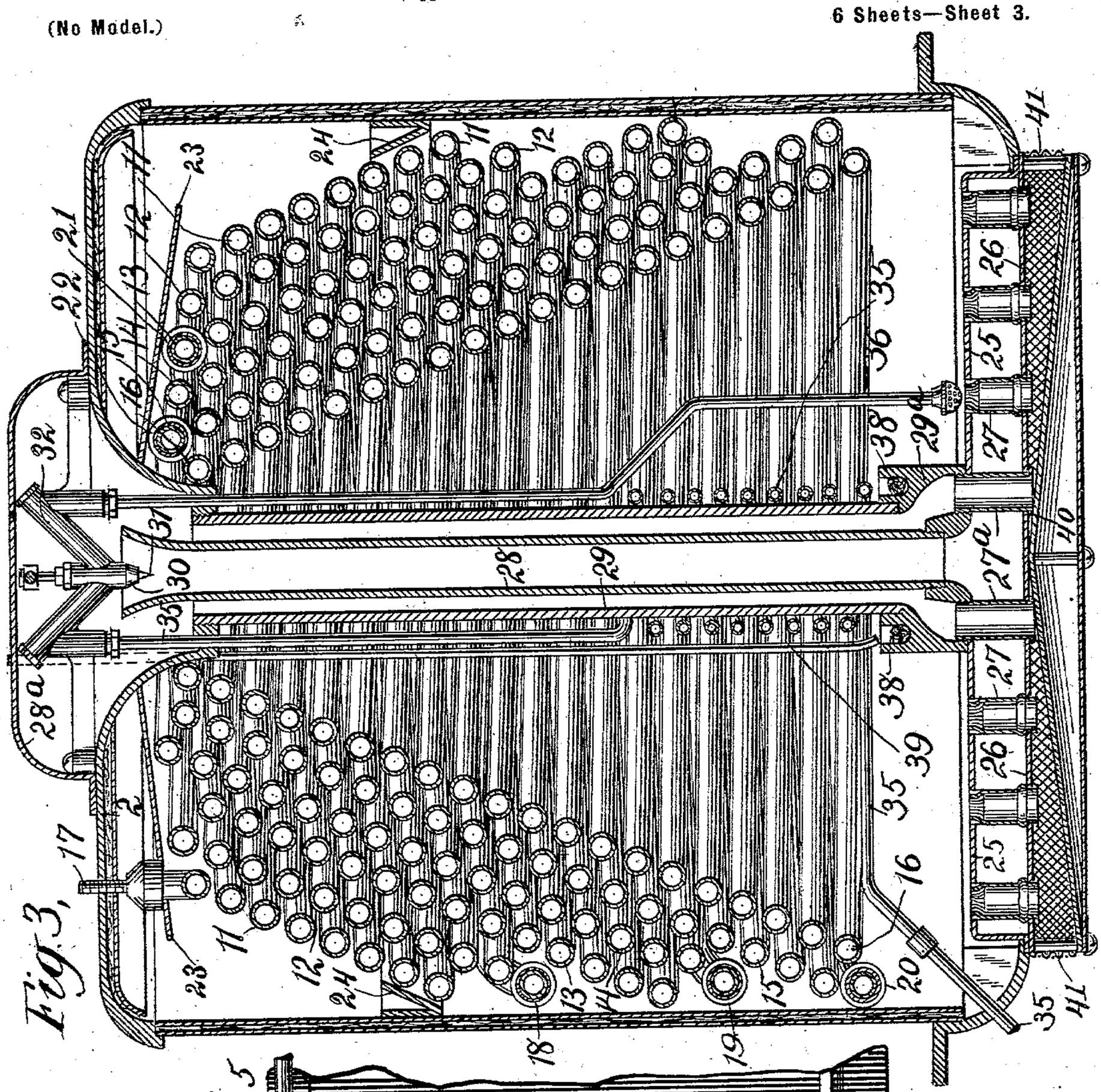
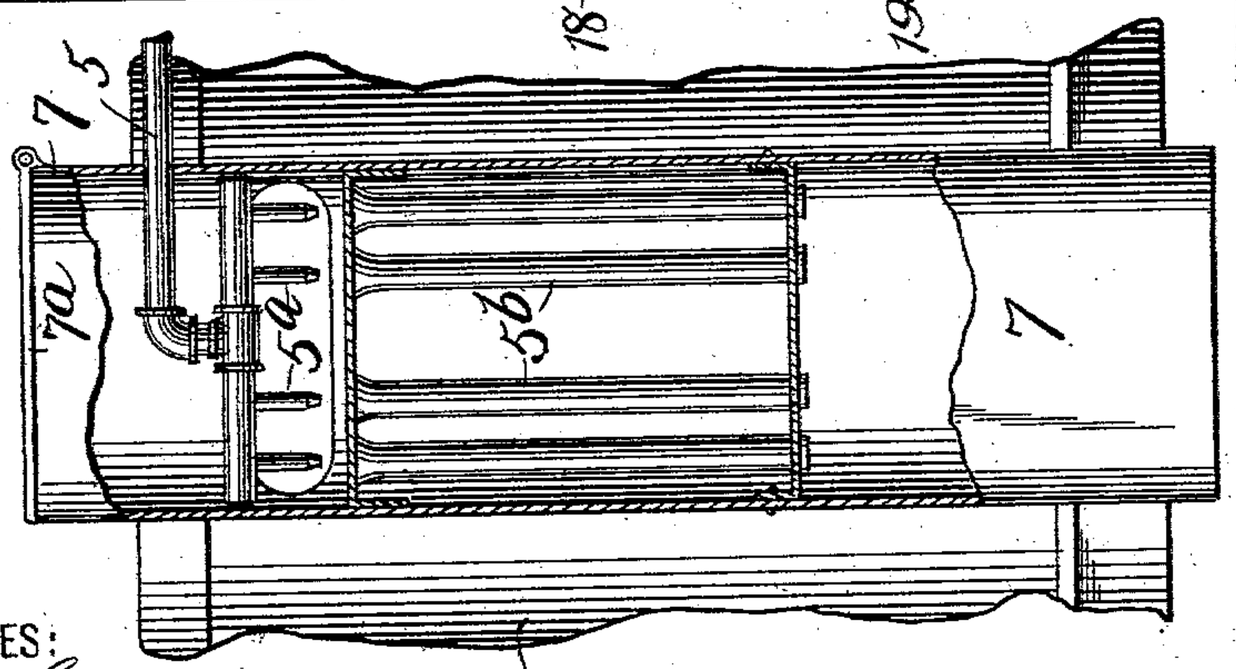


Fig. 4.



WITNESSES:

Edwin Legat

John O. Kempler

INVENTOR

Edward C. Newcomb

BY

Kenyon & Kenyon

ATTORNEYS

No. 704,907. Patented July 15, 1902.

E. C. NEWCOMB.

APPARATUS FOR GENERATING STEAM OR VAPOR.

(Application filed June 7, 1901.)

(No Model.) 6 Sheets—Sheet 4.

Fig. 6.

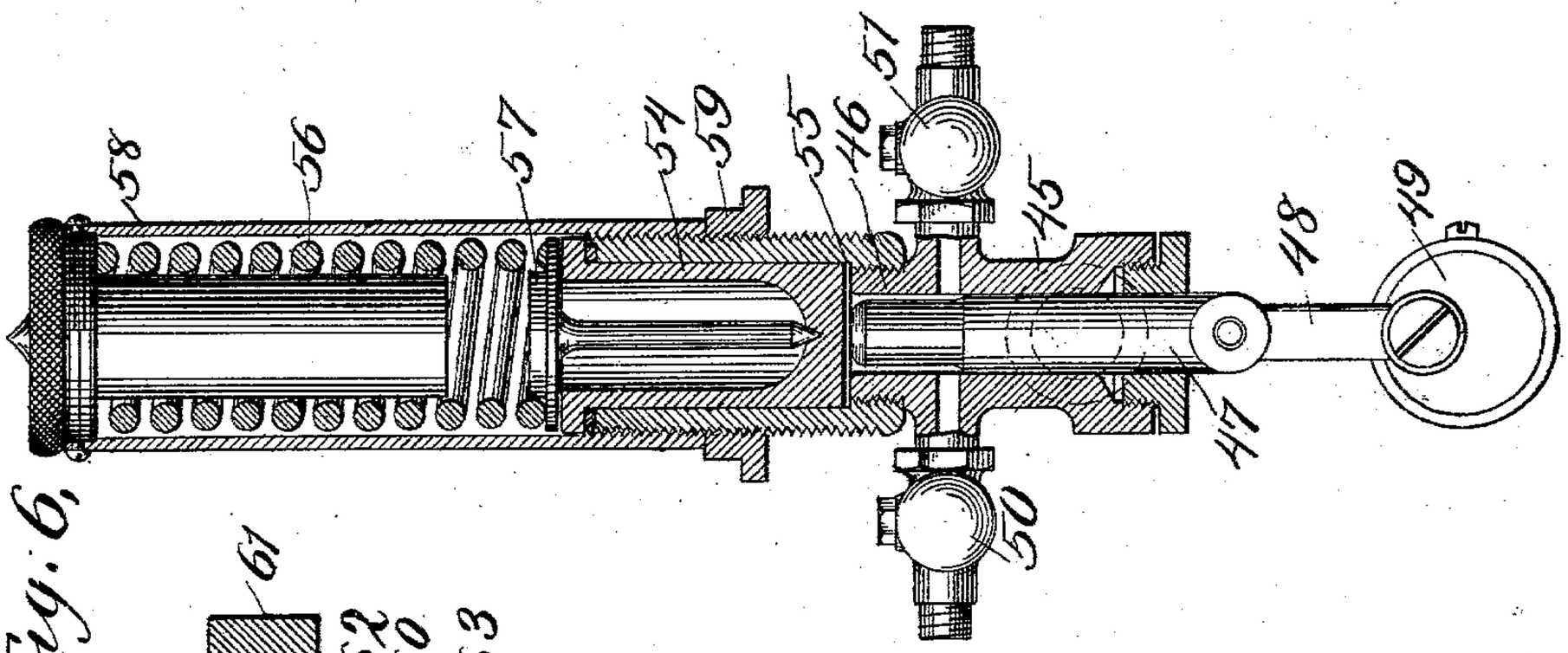


Fig. 7.

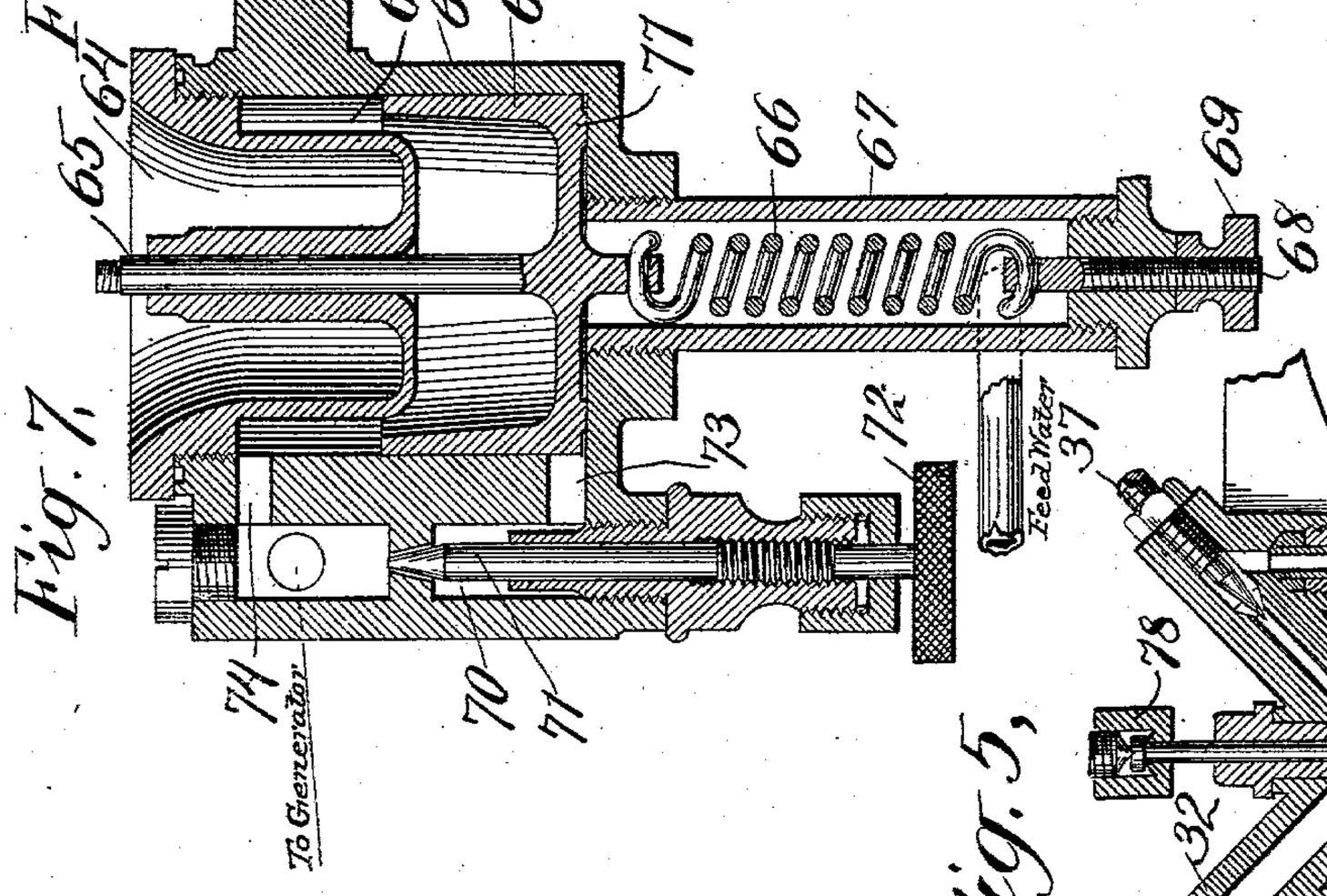
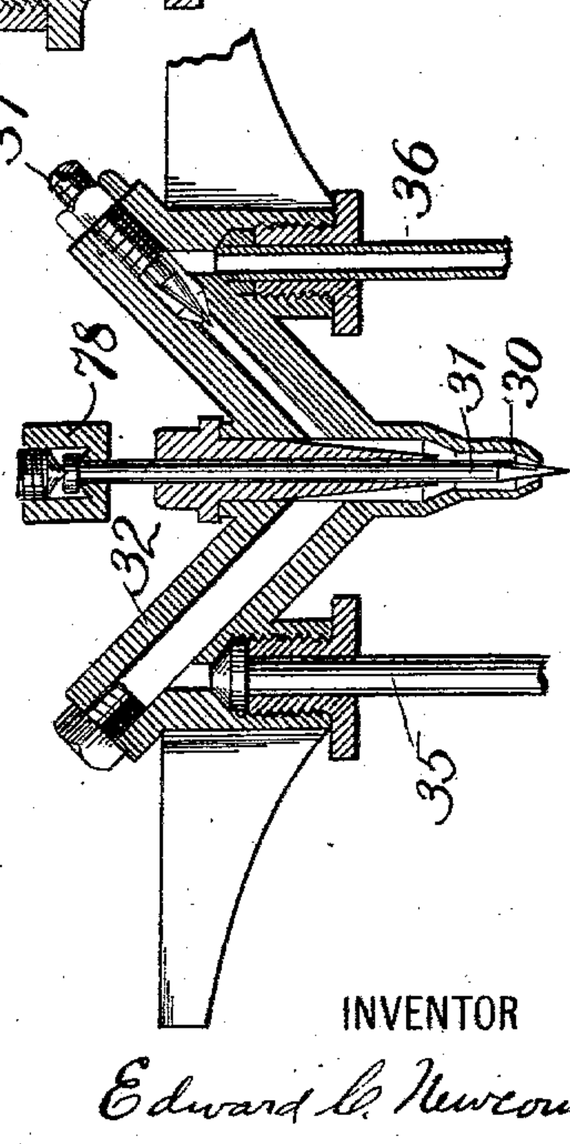


Fig. 5.



WITNESSES.

Edwin Legat

John O. Kempler

INVENTOR

Edward C. Newcomb

BY

Kenyon & Kenyon

ATTORNEYS

No. 704,907. Patented July 15, 1902.

E. C. NEWCOMB.

APPARATUS FOR GENERATING STEAM OR VAPOR.

(Application filed June 7, 1901.)

(No Model.) 6 Sheets—Sheet 5.

Fig. 10.

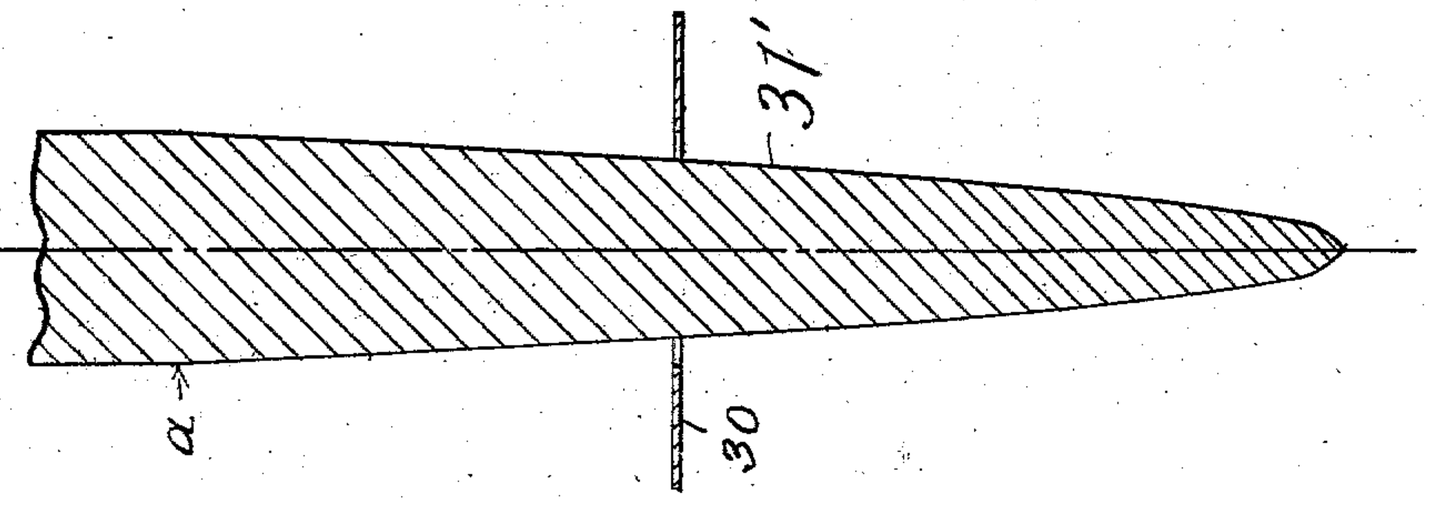


Fig. 8.

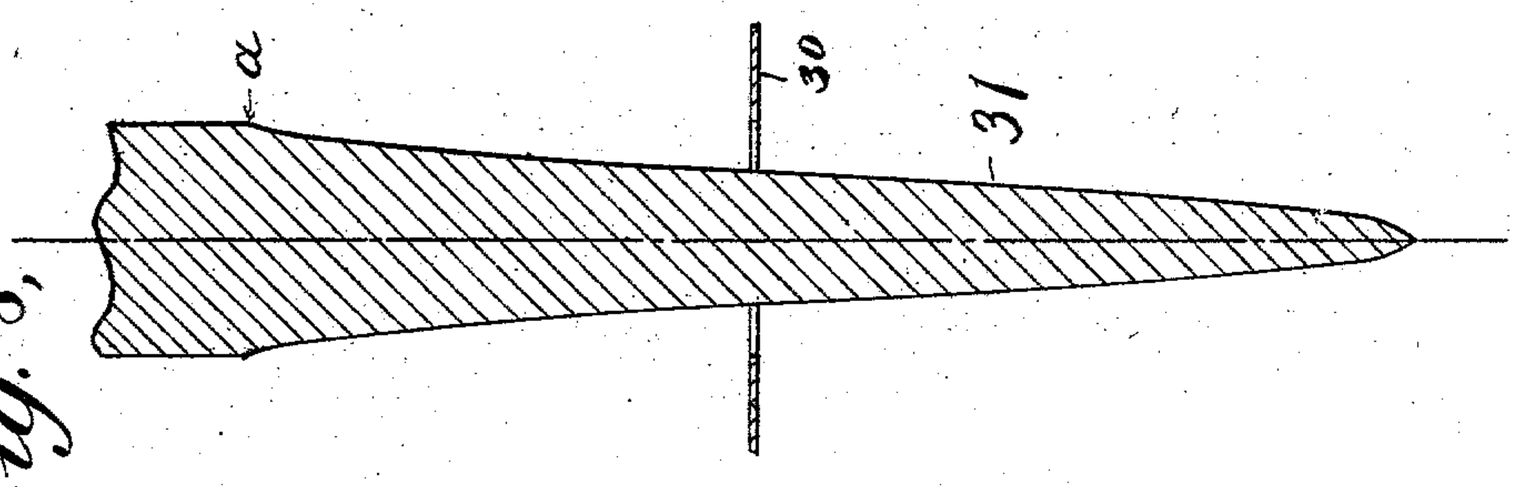
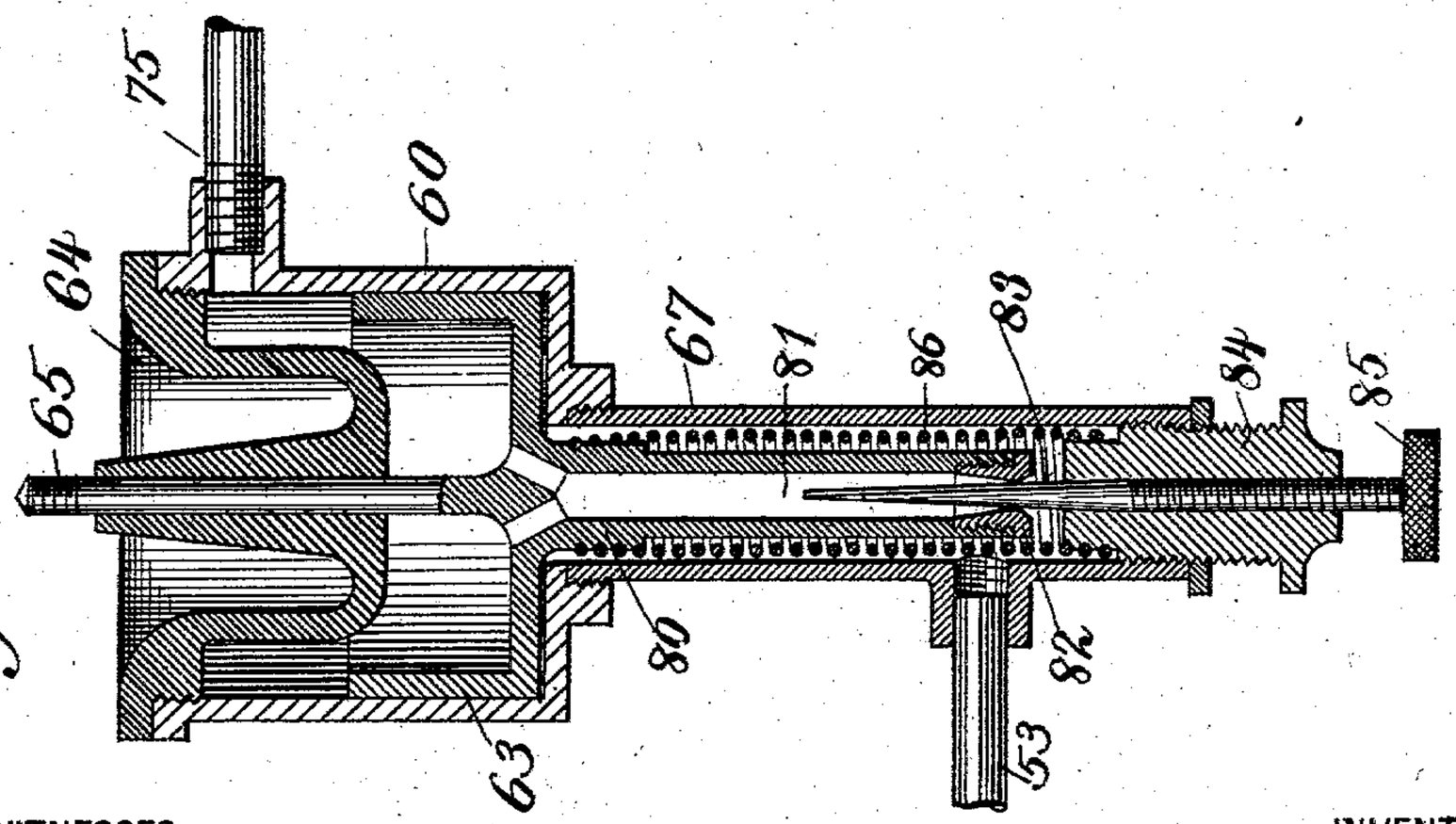


Fig. 9.



WITNESSES:

Edwin Seger

John O. Kempler

INVENTOR

Edward C. Newcomb.

BY

Kenyon & Kenyon

ATTORNEYS

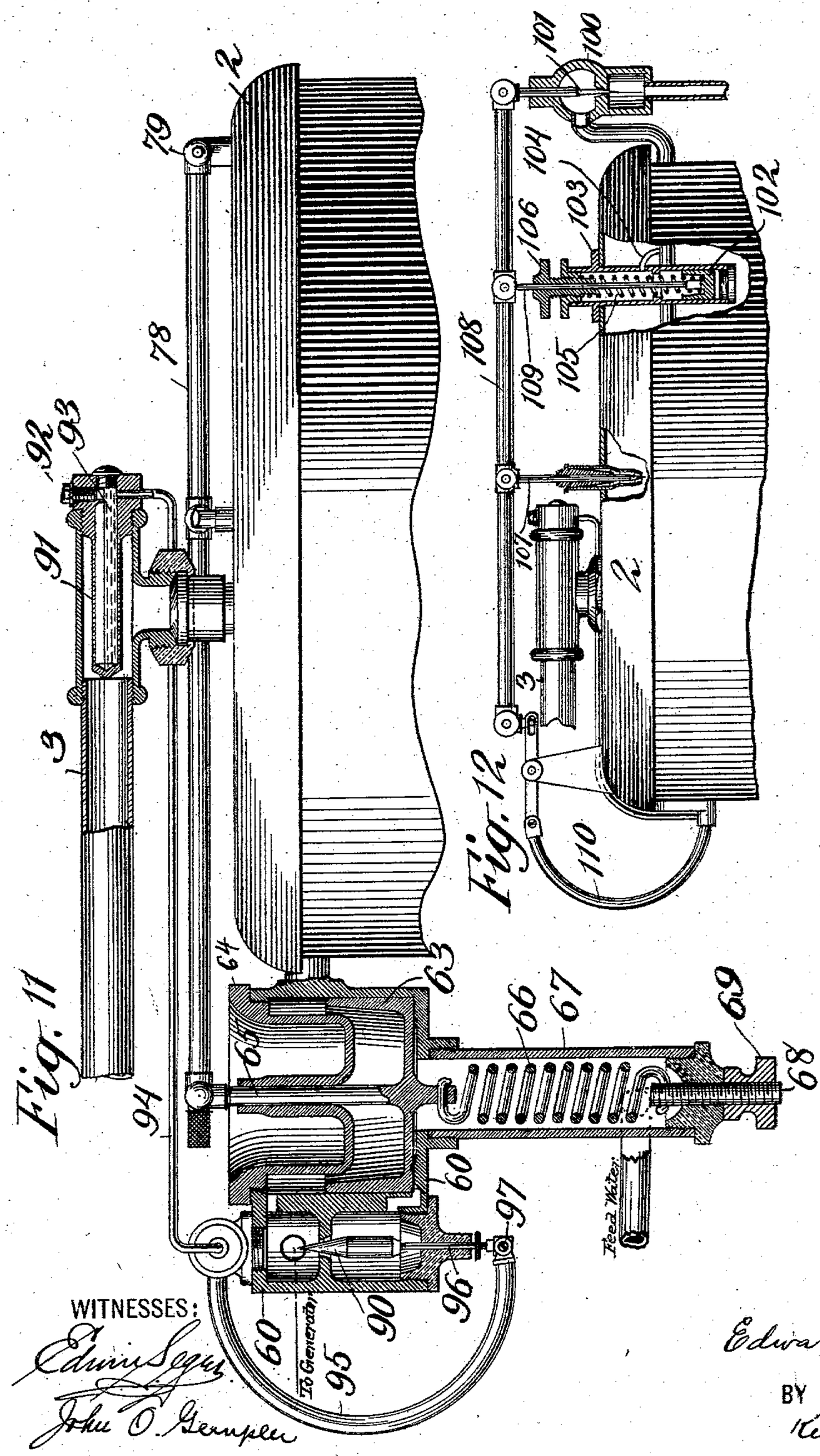
No. 704,907. Patented July 15, 1902.

E. C. NEWCOMB.

APPARATUS FOR GENERATING STEAM OR VAPOR.

(Application filed June 7, 1901.)

(No Model.) 6 Sheets—Sheet 6.



UNITED STATES PATENT OFFICE.

EDWARD C. NEWCOMB, OF JAMAICA PLAIN, MASSACHUSETTS, ASSIGNOR OF THREE-FIFTHS TO PHILIP VAN VOLKENBURGH, OF NEW YORK, N. Y.

APPARATUS FOR GENERATING STEAM OR VAPOR.

SPECIFICATION forming part of Letters Patent No. 704,907, dated July 15, 1902.

Application filed June 7, 1901. Serial No. 63,555. (No model)

To all whom it may concern:

Be it known that I, EDWARD C. NEWCOMB, a citizen of the United States, and a resident of Jamaica Plain, county of Suffolk, and State of Massachusetts, have invented a certain new and useful Apparatus for Generating Steam or Vapor, of which the following is a specification.

My invention has special reference to apparatus for generating steam or vapor, and while it has characteristics which render it particularly effective when embodied in apparatus for generating steam or other vapor and delivering it in a superheated condition the invention, as to some of its features at least, may be advantageously embodied in apparatus designed for other purposes than generating steam, such as apparatus for heating air, apparatus for heating water, or apparatus for heating other fluids for domestic or other purposes.

In order to maintain a supply of steam at a substantially uniform pressure and temperature, it has been the universal practice heretofore to utilize potentially active reserve energy in one form or another to compensate for the variations between the demand and the supply. In the ordinary steam-boiler the reserve energy is mainly supplied by the body of water in the boiler, which is maintained at the temperature and the pressure of the steam generated therefrom. When the demand for steam is below normal, this body of water absorbs the heat supplied in excess of that necessary to generate the steam being used, and when the demand for steam exceeds that generated by the source of heat the heat stored in the water supplies the deficiency. According to another type of steam-generator a supply of heat is maintained which is in excess of that necessary to generate sufficient steam to meet the maximum demand of the apparatus, and the water is supplied to the generator in limited quantities, the attempt being to generate only sufficient steam to meet the demand from time to time. In order to meet variations in the demand for steam in generators of this type without maintaining the source of heat at its maximum, a supply of heat in reserve is always maintained in practice by providing a body of suitable heat-absorbing material which acts as a reservoir of heat to supplement the normal source of heat when the demand for steam is in excess of the normal. Generators of the first type are dangerous, especially in the hands of careless or inexperienced operators, by reason of the explosive nature of the body of water therein, as when suddenly released from pressure. Generators of the second type are unreliable in operation, and they are short-lived, and when used for motive power they require engines and other apparatus of special construction, which apparatus is also short-lived and unreliable in operation. Generators of both types, moreover, require considerable experience and skill for their successful manipulation. They are also more or less inefficient as to the absorption and utilization of the heat, and they are more or less bulky and heavy and expensive to construct and maintain. It has been found impractical, furthermore, to deliver steam from the generators of either class hitherto devised at a substantially uniform degree of superheat, although in theory it is well established that for power purposes steam in a substantially uniform superheated condition is much more efficient than when in a saturated or a nearly-saturated condition.

My invention has for an object to provide an apparatus for generating steam by which the defects above referred to are practically overcome.

My invention is more particularly addressed to the provision of an apparatus whereby superheated steam or vapor may be delivered in a condition which as to temperature or pressure, or both, is substantially unvarying or which bears some other definite or predetermined relation to the demand for energy, regardless of any variations of that demand within the capacity of the apparatus, and also to the provision of an apparatus whereby a supply of such steam or vapor may be maintained without involving the use of a considerable quantity of potentially active reserve energy.

Other objects of my invention are to provide an apparatus of the character referred to which is automatic in its operation and easily controlled, also one which at the same

time is safe and reliable and efficient even in the hands of careless or inexperienced operators, also to provide an apparatus which may be put into active condition without delay and which when in action will almost instantly and with great precision adjust itself to meet the greatly-varying loads or demands upon it, and also to simplify and improve in other respects apparatus whereby the use of superheated steam is rendered practical and efficient even where only small powers are required and in situations where the demand for power varies greatly and the variations are sudden and irregular—as, for example, in the propulsion of automobiles. These and other objects will more fully appear from the following description.

My invention consists in the novel parts, elements, and features of construction, the novel combinations of parts, elements, and features of construction, and the novel improvements herein shown and described.

The accompanying drawings, which are referred to herein and form a part hereof, illustrate one embodiment of my invention, together with modifications of certain elements and features thereof, the form of apparatus shown being particularly designed for the generation of superheated steam or vapor for power purposes.

Of the drawings, Figure 1 is a side elevation, partly in section, of the apparatus as a whole. Fig. 2 is a plan view of the same. Fig. 3 is a vertical central section of the generator and the burner forming parts of the apparatus. Figs. 4 and 5 are sectional views illustrating details. Fig. 6 is a sectional view of the pump forming a part of the apparatus. Fig. 7 is a similar view of the device for automatically regulating the flow of the fuel. Fig. 8 is a diagrammatic view illustrating, on an enlarged scale, a form of valve adapted to be used with the regulator shown in Fig. 7. Fig. 9 is a sectional view illustrating another form of regulator. Fig. 10 is a diagrammatic view illustrating a form of the valve member adapted to be used with the regulator shown in Fig. 9; and Figs. 11 and 12 are elevations, partly in section, illustrating modifications of the apparatus.

Like reference-numerals refer to like parts wherever they occur throughout the several views.

In accordance with my invention the generation of thermal energy is varied in substantial unison with the variations of demand for thermal energy and in substantially the same degree with said variations.

In carrying out my invention this result is attained by varying the supplies of a fluid to be heated and an agent for heating the same in substantial unison with the variations in the demand for the thermal energy contained in the heated fluid and each according to a definite quantitative relation to said variations—that is to say, for every variation in the rate of delivery of the thermal energy contained in the heated fluid discharged from the generator there are variations produced in the respective supplies of the fluid to be heated and of the agent for heating the same, and these variations are produced in such time with relation to the variations in the demand for the thermal energy contained in the heated fluid and in such definite quantitative relations to said variations that the rate of generation of the thermal energy equals the rate of delivery thereof. For example, if an existing demand or rate of delivery of the thermal energy of the heated fluid is doubled, the supplies of the fluid to be heated and the heating agent are both so increased that double the amount of thermal energy is generated per unit of time.

Should it be desired to have the condition of the heated fluid vary as to temperature or pressure, or both, with different rates of delivery of thermal energy, the quantitative relations of the respective supplies of the fluid to be heated and the agent for heating the same to the demand for thermal energy would be so determined as to bring about this result.

Where it is desired to deliver the heated fluid in a substantially unvarying condition as to both temperature and pressure, the supplies of both the fluid to be heated and the agent for heating the same are varied in such manner that the effective supplies of both vary in substantial unison with the variations of demand for the thermal energy of the heated fluid delivered and in substantially the same degree with said variations.

As applied to an apparatus for generating steam or other vapor my invention would be embodied in an apparatus comprising a combustion-chamber, a suitable generator arranged in coöperative relation with the combustion-chamber, means for supplying a liquid to said generator, means for supplying a fuel to said combustion-chamber, and means for varying the supplies of both the liquid and the fuel in substantial unison with the variations of the demand for the thermal energy of the steam or vapor delivered by the apparatus and according to definite quantitative relations to said variations. For the sake of clearness and brevity I have herein referred to the variations of the thermal energy of the steam or vapor delivered by the apparatus per unit of time as the variations of demand for steam or vapor energy.

Preferably the means for supplying the liquid to be heated are rendered operative by variations in the condition of the fluid being heated to automatically vary the supply of the liquid in substantial unison with the variations of demand for the energy of the fluid and according to a definite quantitative relation to said variations, and the effective supply of the heating agent is so regulated that it varies in substantial unison with the variations of the flow of the fluid being heated and according to a predetermined quantitative relation to said variations. Preferably, also,

means are provided whereby the relation between the effective supply of the fuel and the effective supply of the fluid to be heated may be varied so as to control the temperature of the heated fluid, and where a very accurate or a predetermined regulation of the temperature of the heated fluid is desired means are provided for automatically controlling such relation.

The condition selected for controlling the supply of liquid to be heated should be such as that under the circumstances of its use it shall vary inversely and simultaneously or in substantial unison with the demand for the heated fluid and such as that it shall vary also in a regular way or according to a known law, so that the effective supply of the liquid may be varied in the manner described. With the type of generator herein shown and described the condition of the fluid therein as to pressure may be used for controlling the supply of liquid, or under proper circumstances the temperature may be used. The flow of the heating agent may be regulated in the manner described by variations in a condition of the fluid being heated resulting from variations in the flow of said fluid or by variations in any other condition of that fluid which varies simultaneously with the flow and according to a known law, as, under proper circumstances, the temperature or pressure.

In practice a fluid-heating agent or a heating agent which can be controlled as fluids are controlled should be used, in order that the quantity of the heat developed may be accurately regulated and quickly varied to correspond with the variations of demand for the thermal energy of the heated fluid.

The embodiment of my invention illustrated consists of an apparatus for generating superheated steam or vapor and delivering the same at a substantially predetermined pressure and at a temperature which for practical purposes is unvarying. This apparatus comprises in general a combustion-chamber, a generator arranged in coöperative relation to the combustion-chamber, means for supplying liquid to the generator, said means being constructed to automatically vary the supply of the liquid in substantial unison with the variations of demand for steam energy and in a substantially definite quantitative relation to said variations, means for supplying a fluid fuel to the combustion-chamber, and means for maintaining such a relation between the supply of the fuel and the supply of the liquid to the generator that one varies in substantial unison with the variations of the other and according to a predetermined quantitative relation to said variations. The generator is so constructed and arranged with relation to the combustion-chamber that a condition of the fluid therein varies inversely as the demand for steam or vapor varies, and that the rate of variation of that condition varies inversely with the quantity of liquid in the generator. The means for supplying liquid to the generator is constructed to supply the liquid at a predetermined pressure—to wit, the pressure at which it is desired to operate the apparatus. The means for supplying the fuel to the burner are controlled by variations in a condition of the fluid flowing to and through the generator resulting from variations in the flow of said fluid. Means are also provided for varying the predetermined relation between the supply of the liquid to be heated and the supply of the fuel, and in one form of the device means are provided for automatically varying this relation.

It is not to be understood by the term "substantial unison" that the relative variations in the supply, demand, or condition of the various fluids are strictly simultaneous. The essential in this regard is that the variations are produced promptly enough to maintain the apparatus in a practically predetermined condition. The expressions "definite quantitative relation" and "predetermined quantitative relation," as used herein, are not to be understood as necessarilyreferring to unchanging relations between the supplies or flows of the fluids and the demand for thermal energy, for that relation may be made a varying one. It is intended that this expression shall include within its scope such a relation between the supplies of the fluids as will produce practically uniform results. Where, for example, the efficiency of the apparatus varies materially with the demand, the predetermined relation between the supply of the fluid to be heated and the heating agent may be so established as to compensate for the variations in the efficiency of the apparatus and deliver the heated fluid at the desired temperature at all times.

Referring now to the drawings and in general at first to Figs. 1 and 2, 1 represents a suitable frame, upon which the various parts of the apparatus are mounted. The generator is mounted in a suitable casing 2 and is connected by a pipe 3 to a suitable motor 4, the exhaust-pipe 5, which passes to a suitable muffler 6, and from the muffler to the escape-pipe or chimney 7 of the generating-casing 2. Suitable feed-water and fuel-supply tanks are indicated at 8 and 9, respectively.

While some of the advantages of my invention may be realized by the use of various types of generators in connection with apparatus constructed in accordance with my invention, the best results can only be attained, as will hereinafter more fully appear, by the use of a generator in which the liquid is gradually heated from its point of entrance to the point where it is substantially all transformed into vapor and in which only a small quantity of liquid is maintained at the temperature of vaporization corresponding to the pressure at which the apparatus is operated. In accordance with the best embodiment of the apparatus the generator has a liquid-heat-

ing portion, a vaporizing portion, and a superheating portion. The liquid-heating portion is preferably such that the liquid is gradually heated up to the temperature of vaporization, the vaporizing portion should be such that it contains only a small quantity of the liquid to which the latent heat of vaporization is added gradually, and the superheating portion is preferably directly connected to and is adapted to form a part of the vaporizing portion. These conditions are best realized in a generator consisting of a continuous pipe or passage which forms the liquid-heating as well as the vaporizing and superheating portions of the generator and which receives the water or other liquid to be vaporized at one end and delivers the superheated steam or vapor at the other end, said pipe or passage being so arranged with relation to the source of heat that the fluid therein is gradually heated from the point of entrance to the point of exit.

As shown in the drawings, (see Fig. 3,) the generator is formed of a plurality of pipe-coils 11, 12, 13, 14, 15, and 16, which are preferably frusto-conical in form and are so arranged vertically one within the other around a combustion-chamber as to present the greatest mass or depth of heat-absorbing surface to the direct or natural path of the heated gases and products of combustion as they flow from the combustion-chamber. The coils are connected together in series, preferably by separable connections 18, 19, 20, 21, and 22, all of which, as shown, are arranged at the outer part of the mass of heat-absorbing surfaces in such a position as not to be subjected to the hottest portions of the products of combustion. The outermost coil 11 is connected at the top to the feed-water-supply pipe 17, and the innermost coil is connected to the steam-pipe 3. The outer coils thus constitute the liquid-heating portion and the inner coils the vaporizing and superheating portions of the generator. By reason of this construction the water is caused to flow gradually and uniformly from the outer coil toward the inner coil in a direction opposite to that of the flow of the products of combustion and is thus gradually and uniformly heated and the stream is prevented from breaking up, so that bodies of water as such are not driven to the inner coil or coils, as might happen if the coils were less uniformly heated, and water is prevented from flowing by gravity to the inner coil or coils, as it would if the coils were arranged one above another and directly connected. With this construction also the products of combustion are uniformly subjected to the action of successively cooler heat-absorbing surfaces, the heat being thus very perfectly absorbed. As shown, all the coils are substantially the same in diameter at their lower ends and are successively shorter from the inner one toward the outer one, so that when assembled they substantially conform to the shape of the cylindrical casing. By this arrangement, moreover, the greatest mass of the heating-surfaces is located in the upper part of the casing, directly in the path of the largest volume of the products of combustion, and all the products of combustion must pass between the turns of all the coils in succession, from the innermost coil to the outermost coil, shields 23 and 24 being provided at the top and sides of the coils, as shown, to insure this action.

While six coils are shown, it is obvious that a greater or less number may be used, if desired. There should be a sufficient number of coils, however, to form an efficient mass of heat-absorbing surfaces, and to insure a suitable temperature gradient between the successive coils. It may be observed generally, moreover, that the coils should be so connected that the water cannot flow directly from a colder portion to a much hotter portion of the heating-surfaces and that the water should be brought to the boiling-point at some part of the generator where its flow at that point is not appreciably affected by gravitation.

The casing 2 is provided near the top with a suitable outlet for the waste gases, which outlet, as shown in Figs. 1 and 4, communicates with the vertically-arranged escape-pipe or chimney 7. The chimney 7 is open at the bottom, and the exhaust-pipe 5 of the engine is terminated in the chimney with a series of downwardly-projecting nozzles 5^a, through which the exhaust-steam is ejected when the engine is running, a draft being thus created to carry away the waste gases. A tube 5^b is preferably arranged below each of the nozzles 5^a in such a manner as to increase the aspirating effect of the steam-jets, and thus improve the draft. The top of the chimney is provided with a pivoted cover 7^a, whereby the chimney may be opened to provide a free outlet for the waste gases when the apparatus is being started.

The burner for heating the generator is located below the lower turn of the inner coil 16, within and concentrically with said lower turn, so that the space inclosed by all the turns of said inner coil forms a tapering combustion-chamber of ample dimensions to permit complete combustion of the fuel and insure uniform heating of the tubes. Any suitable form of burner may be used. That shown consists of two plates 25 and 26, separated to form a chamber for the fuel mixture, said plates being connected by a multiplicity of tubes 27, which form passages for the air necessary to support combustion. As shown, each of the tubes 27 is corrugated at its upper end, so as to form between it and the edge of the opening in the plate 25 an annular series of passages to admit the fuel mixture to the combustion-chamber.

The fuel mixture is supplied to the burner by a combining-tube 28, which, as shown, passes down through the combustion-chamber and enters a burner at a central point and at

right angles to the general plane thereof. The tube 28 is shielded from the direct heat of the combustion-chamber by a tube 29, which is somewhat larger than the tube 28 and is arranged concentrically therewith, so as to form an air-chamber around the inner tube. In order that the air supplied to the combining-tube 28 may be suitably heated, the top of said tube is inclosed as by a casing 28ª, and the air-chamber formed between the tubes 28 and 29 is placed in communication with the top of the tube 28, the lower end of said air-chamber being connected to a central series of air-tubes 27ª, as shown.

The fuel is discharged into the mixing-tube by a nozzle 30, the flow through which is regulated, as hereinafter described, by a suitable valve member, as the needle 31. The nozzle 30 is formed on a suitable casing 32, which is secured in a recess centrally formed in the top of the casing 2. The fuel is supplied to the nozzle through a pipe 35, and where a liquid fuel is used the pipe 35 is passed into the combustion-chamber and, as shown, is coiled around the tube 29, so as to form a vaporizer for the fuel. A supply-tube 36 for a pilot-burner is connected with one branch of the casing 32 and extends down through the combustion-chamber to a suitable point above the burner. The supply of fuel to the pilot-burner may be regulated by a needle-valve 37 to maintain a pilot-light for the main burner. For the purpose of vaporizing the fuel in the pipe 35, as required in starting the apparatus, a suitable receptacle 38 is formed in the casing 29ª around the lower end of the tube 28, and is adapted to hold a small quantity of suitable inflammable liquid, which may be supplied through a pipe 39. A substantially uniform pressure is maintained on the supply of fuel in the tank by any suitable means, as by an air-pump. (Not shown.)

For the purpose of preventing drafts of air from extinguishing the flame or otherwise interfering with the operation of the burner the bottom thereof is inclosed in a shield which, as shown, consists of a plate 40, secured at a central point to the center of the burner and tapering downwardly and outwardly, so as to form an annular chamber which tapers from the outer edge of the burner to the center thereof. The periphery of this tapering chamber is covered by a suitable screen 41, which acts to break up any blast of air and destroy its force before it reaches the air-passages of the burner. This shield, moreover, absorbs heat radiated from the burner and serves to heat the air and evenly distribute it to the air-passages of the burner.

With a burner constructed as described the vaporized fuel is at all times, before and after it is mixed with the air, maintained at a temperature above that at which it condenses, and by reason of the fact that the air is heated before it is brought into contact with the fuel the latter does not have to be superheated to such a high degree as would otherwise be necessary to prevent condensation. Objectionable coking, either in the fuel-vaporizer or in the combining-tube, is thus obviated. By reason of this fact a comparatively heavy oil, as kerosene, may be successfully used. When a heavier oil than gasolene is used, however, it is desirable to start the burner with a more volatile fluid, as gasolene or alcohol. To this end the tank 9 is divided into two compartments, as indicated by dotted lines in Fig. 2, a smaller compartment for the more volatile fluid and a larger compartment for the less volatile fluid, the two compartments being connected to the supply-pipe by suitable branch pipes and a three-way valve 42. By reason of the fact, moreover, that the fuel is admitted to the combining-tube at a uniform pressure a uniform mixture of air and gas for all loads is secured, and by reason of the fact that the combining-tube enters the burner at a central point and at right angles to the general plane thereof a very even distribution of the fuel mixture is obtained, thus enabling the burner to be operated with a very low flame without liability of objectionable smell due to imperfect combustion or of being extinguished by gusts of wind, and without danger of "back-firing."

The means herein shown for supplying the water to the generator consist of a device which is constructed to supply the water at a predetermined pressure and to be rendered operative by variations in the pressure of the steam or vapor. While one of the forms of the device illustrated is preferred, my invention is not limited to the use of such a device, as the essential features of the invention may be carried into effect by the use of any means for supplying water to the generator, which is adapted to automatically vary the effective supply of water in a definite quantitative relation and in substantial unison with the variations of demand for steam or vapor energy.

Referring to Figs. 1, 2, and 6, 45 indicates the casing, which, as shown, is attached to one end of the motor-casing. This casing 45 is provided with a bore 46, in which a plunger 47 is fitted. The plunger 47 is connected by a link 48 to a crank 49, carried by one end of the motor-shaft. The bore 46 of the pump is provided with inlet and outlet passages in which are arranged suitable check-valves 50 and 51, respectively, the inlet-passage being connected with the feed-water tank by a pipe 52 and the outlet-passage being connected with the feed-pipe 53. A piston 54, which is preferably somewhat larger in diameter than the plunger 47, is fitted in a suitable bore 55, having free communication with the bore 46. The piston 54 is held at the inner end of its stroke by means of a compression-spring 56, which is confined between a bearing member 57, suitably seated on the piston 54, and an extension-casing 58, which is threaded on the casing 45 and held in its adjusted position by means of a lock-nut 59. The spring 56 is so adjusted that it will require a pressure equal

to the pressure which it is desired to maintain in the generator to move the piston 54. It follows from this construction that when the apparatus has been started and the pressure in the generator rises to predetermined point the piston 54 will be moved on each stroke of the pump and more or less of the water displaced by the plunger 47 will be forced into the bore 55 instead of through the check-valve 51 into the feed-pipe 53, and the amount of water forced into the bore 55 will increase as the pressure rises above the predetermined point in the generator. When the pressure in the generator rises to a sufficiently high degree, the displacement of the piston 54 will equal the displacement of the plunger 46 and no water will be forced into the generator. It will thus be seen that the water is supplied by this device to the generator at a pressure which varies between certain predetermined limits only and that the device is rendered operative by variations in the pressure of the steam or vapor to vary the effective displacement of the pump inversely and in the same degree as the pressure varies between such predetermined limits. With a generator in which the pressure during changes of demand tends to vary promptly, to the extent, at least, of the limits fixed by the device described and, inversely, with relation to the rate of delivery of steam drawn therefrom the device will act to vary the supply of water directly and in a substantially definite quantitative relation to the variations of demand for steam energy.

In accordance with my invention, broadly considered, any suitable means may be used for maintaining a predetermined relation between the supply of the fuel and the supply of liquid to the generator. With a device similar to the one above described for supplying the water to the generator the supply of the fuel may be regulated directly or indirectly by the variations in the pressure of the steam or vapor, or where the water is supplied at a substantially unvarying pressure the supply of the fuel may be regulated by variations of pressure alone or by variations in some condition of the steam, which varies directly with the pressure. In the embodiment illustrated of this feature of my invention the flow of the fuel is regulated by variations in a differential pressure resulting from variations in the flow of the feed-water to the generator. A suitable form of the flow-regulating device is illustrated in detail in Fig. 7. As shown, this device consists of a casing 60, which is attached by a lug 61 to any suitable part of the apparatus, as to the casing 2 of the generator. (See Figs. 1 and 2.) The casing is provided with a suitable bore 62, in which is fitted a piston 63. The bore 62 is closed by a head 64, through which is passed a piston-rod 65, by means of which the motion of the piston is communicated to the mechanically-coacting parts of the device. A tension-spring 66 is arranged in a casing extension 67 on the opposite side of the piston from the piston-rod 65 and is adjustably secured by means of the threaded bolt 68, which passes through the lower end of the extension 67 and is engaged by nut 69. A restricted passage 70 is formed in the casing 60 at one side of the bore 62, and in order that the area of the passage 70 may be regulated a needle-valve member 71 is threaded in the casing, as shown, and is provided with a suitable hand-wheel 72. The bore 62 at opposite sides of the piston 63 is connected with the opposite sides of the passage 70 by suitable ports 73 and 74. The feed-water pipe 53 communicates with one side of the passage 70, the opposite side of which is connected to the inlet end of the generator by pipe 75, in which a suitable air-chamber 76 is preferably interposed. The feed-pipe 53 is preferably connected to the casing extension 67, and the piston 63 is provided with a seat 77, which is adapted to contact with the end of the casing 60 and cut off communication between the extension 67 and the passage 70.

It will be seen that the entire upper area of the piston 63 less the area of the piston-rod 65 is at all times subjected to the pressure in the generator and that the entire lower area of the piston 63 when it is out of contact with the casing 60 is subjected to a pressure equal to that of the generator plus an amount sufficient to overcome the resistance offered by the passage 70. The tension of the spring 66 is so adjusted that when the piston 63 is at the lower limit or zero-point of its stroke the force of the spring will equal the force exerted by the pressure in the generator upon an area equal to that of the piston-rod 65. It follows from this construction and arrangement that when the pump is started the piston 63 will be lifted from its seat and a flow of water from the pump to the generator will take place. The restricted passage 70 will then give rise to a difference in pressure on opposite sides of the piston 63, which will cause it to move, and with the spring 66 connected and adjusted as described the distance of the piston 63 from the zero-point will be directly proportional to this difference in pressure. As the velocity of a fluid through a passage varies as the square root of the difference in pressure on opposite sides of the passage it will be seen that the distance of the piston 63 from the zero-point will vary directly as the square of the velocity of the fluid flowing through the passage 70 and for any adjustment of the area of that passage directly as the square of the volume of the flow through said passage. The movement of the piston 63 is communicated to the member 31 of the fuel-regulating valve by lever 78, which, as shown, is fulcrumed at one end to a suitable support 79 on the casing 2 and is pivoted at the opposite end to the piston-rod 65, the needle 31 being connected to the lever at an intermediate point. The pressure on the fuel-supply being uniform, the fuel-

valve should be so constructed that the effective opening therethrough will vary with the square root of the distance moved thereby as measured from the closed position in order that the volume of the flow of the fuel may vary directly with the volume of the flow of the feed-water to the generator and in the same degree. In Fig. 8 is diagrammatically illustrated a valve member shaped to produce this result. Assuming that the orifice of the nozzle 30 presents a thin circular edge, as indicated in this figure, the valve should have a circular cross-section which decreases in diameter from the base of the valve toward the apex, the law of the decrease in diameter being expressed by the formula $d=\sqrt{1-m}$, in which d is the diameter of the valve at any point and m is the corresponding distance from the base or zero-point a of the opening of the valve. As, however, the controlling forces actuating this form of regulator are slight for small loads, the error of friction of the moving parts for such loads is great. To obviate this difficulty, I prefer in practice to use a regulator in which the proportional movement of the piston for small loads is greater than it is in the regulator just described. For instance, the regulator may be so constructed that the movement of the piston will be directly proportional to the flow of water to the generator. Such a regulator is shown in detail in Fig. 9. In accordance with this construction the piston 63 is provided with an extension 80, which passes down into the casing extension 67. In this form of regulator the side passage 70 and valve member 71 are dispensed with and in place thereof the piston extension 80 is provided with a restricted passage 81, which communicates at its upper end with the upper side of the piston 63 and is terminated at its lower end in a valve-seat 82. A valve member 83 for varying the area of the passage 81 is threaded into the head 84 of the extension 67 and is provided with a hand-wheel 85, whereby it may be readjusted. A tension-spring 86 is secured at its upper end to the upper end of the piston extensions 80 and at its lower end to the head 84, which head is threaded into the lower end of the casing 67 and may be adjusted therein for the purpose of adjusting the tension of the spring 86. The upper and lower sides of the piston 63 are placed in communication with the generator and the feed-pump, respectively, and the tension of the spring 86 is so adjusted as to equal the pressure acting on the piston-rod 65, as before. If now the valve member 83 is so formed and adjusted that the effective opening between it and the seat 82 is proportional to the square root of the extent of movement of the piston, the volume of the flow through the passage 81 will be directly proportional to the extent of the movement of the piston. This will be apparent when it is observed that with a spring connected and adjusted as described the difference in pressure at opposite sides of the restricted passage will be directly proportional to the distance of the piston from the zero-point; that the velocity of the fluid flowing through the restricted passage will be proportional to the square root of the difference in pressure at opposite sides thereof, and consequently to the square root of the extent of the movement of the piston also, and that the volume of the flow through the restricted passage will equal the velocity of the fluid multiplied by the area of the opening. Thus it will be seen that the volume of the flow will vary as the square of the square root of the movement of the piston or directly as that movement itself. To secure this result, therefore, the proper form for the valve member 83 is the same as that of the valve member 31′ used in connection with the regulator previously described. The supply of fuel being under uniform pressure, a proper form of the member 31′ of the fuel-valve to be used in connection with this form of regulator to cause the flow of fuel to vary in the same degree as the flow of water varies is that of a paraboloid or such as that produced by the revolution around its axis of a parabolic curve, the general formula of which is $y=2\,p\,x$. Such a form of valve member is diagrammatically illustrated in Fig. 10. It will be noted that while the area of the opening of the restricted passage 81 varies greatly in proportion to the movement of the regulator the flow through the said passage is directly proportional to the movement of the piston, and the area of the opening in the fuel-valve is directly proportional to the movement thereof. With this form of regulator, therefore, the control of the fluids for small flows as well as for large ones can easily be made very accurate.

It will be seen from the above that the form of regulator and the form of the valves used for controlling the flow of water through the regulator and for controlling the flow of the fuel may be greatly varied without departing from the principles of my invention. It may be further observed, however, in connection with the form of regulator last described that for every form of valve for controlling the flow of one fluid a corresponding valve should be provided for controlling the flow of the other fluid, having regard to the movement of the valves and to the pressures or the variations in pressure of the fluids flowing through them. It is to be observed also that the piston in either regulator constitutes a motor for operating the fuel-valve and that the motor is operated by variations in a condition of the fluid flowing through the generator resulting from or coincident with the variations in the flow of said fluid. Where the water is supplied to the generator under a substantially uniform pressure, it is to be noted, moreover, that the motor is, in effect, operated directly with the variations of the pressure in the generator. While in each instance the needle member is moved with re-

lation to its seat, it is obvious that this relation may be reversed, if desired. The regulation of the fuel by a valve member coöperating with the nozzle of the burner is regarded as an important feature of my invention, as by this arrangement not only is a more perfect regulation of the fuel secured, due to the fact that a uniform difference of pressure is maintained on opposite sides of the valves, but the supply of air to the burner is accurately maintained in the proper proportion to the supply of fuel irrespective of the variations of the flow of the fuel within the working capacity of the apparatus, as the velocity of the fuel being constant the quantity of the air entrained thereby will tend to vary directly with the volume or mass of the fuel.

Where the efficiency of the apparatus varies with the variations in the demand for steam energy, the shape of the fuel-valve needle in either form of regulator or of the valve member 83 in the second form may be suitably varied to compensate for the variations in the efficiency of the apparatus or to maintain the effective supplies of the liquid and fuel in the desired quantitative relation to the demand for steam or vapor energy.

In order that the steam generated by the apparatus may be delivered at various predetermined degrees of superheat, it is necessary that the ratio between the flow of the fuel and the flow of the water to the generator may be varied and accurately adjusted. The reason for this is that the quantity of heat necessary to superheat the steam is very small as compared with the quantity of heat necessary to transform the water into steam. If, therefore, the exact proportions between the fuel and the water are not obtained and maintained irrespective of variations in the demand, the steam will either have little or no superheat or will be so highly superheated as to injure the apparatus. The regulation of the ratio may be accomplished in any suitable way. In the regulator shown in Fig. 7 the ratio between the flow of the fuel and the flow of the water may be perfectly regulated by varying the opening of the restricted passage 70, as by adjusting the valve 71. In the form of the regulator shown in Fig. 9 the relation between the flows of the fluids may be changed by means of the valve member 83, but the ratio will be approximately correct for small adjustments only. In either form of regulator the ratio may be perfectly regulated by changing the leverage between the piston and the fuel-valve, as by shifting the fulcrum 79 toward or away from the valve 31. The fulcrum 79 is to this end adjustably mounted on the top of the casing 2, as indicated.

With the apparatus constructed as thus far described slight variations in the temperature of the steam delivered by the apparatus are apt to occur, due to inaccuracies in the construction or to variations in the efficiency of the apparatus at various loads. Where it is desired, therefore, to deliver the steam at a very uniform temperature, means should be provided for automatically varying the ratio between the flow of the water and the flow of the fuel in accordance with the variations in the temperature of the steam as it issues from the generator. This may be accomplished in various ways. A suitable way of accomplishing this result is illustrated in Fig. 11. As here shown, the needle-valve 90, which regulates the by-pass of a regulator of the form shown in Fig. 7, is automatically controlled by a thermostat, which is rendered operative by variations in the temperature of the steam. In accordance with the construction shown a suitable receptacle 91, capable of withstanding great internal pressure and having walls which are adapted to rapidly transmit heat to the interior of the receptacle, is so located in the steam-pipe as to be impinged upon by the steam flowing therethrough. This receptacle is partially filled with a fluid which vaporizes at a temperature considerably below that at which it is desired to deliver the steam, so that when the liquid is heated to the temperature of the steam a portion of it will be vaporized and create a very high pressure in the receptacle. The receptacle is provided with an opening through which the liquid may be admitted, said opening being hermetically closed by a screw-plug 92. For the purpose of preventing the receptacle 91 from being completely filled the mouth of the opening is extended for a suitable distance into the receptacle, as indicated at 93. The interior of the receptacle is connected by a suitable pipe 94 with any desired form of motor device adapted to operate the valve member 90, which regulates the area of the restricted passage of the regulator. An ordinary Bourdon tube 95 is preferably employed for this purpose on account of its accuracy and reliability in operation. As shown, the Bourdon tube 95 is constructed in the form of a half-circle, one end of which is fixed to the top of casing 63 in line with the axis of valve 90, the other end being free and connected to the valve below the casing by means of a stem 96 and a pivot 97. It will be seen that as the pressure varies in the receptacle 91 the valve 90 will be so operated as to vary the opening therethrough directly as said pressure varies. It follows from this construction that when the temperature of the steam flowing from the generator rises beyond a predetermined temperature the passage through the valve 90 will be enlarged, thereby reducing the difference in pressure on the opposite sides of the piston 63 and permitting the same to move under the influence of the spring in such a direction as to decrease the flow through the fuel-valve carried by the lever 78. The ratio between the flows of the water and the fuel will thus be increased and will continue to increase until the relative flow of water is increased to the point re-

quired to deliver the steam at the desired lower temperature. On the other hand, it will be seen that if for any reason the temperature of the steam should drop below the predetermined degree the ratio between the flows of the water and the fuel will be decreased until the flow of water is cut down to the point required to deliver the steam at the desired higher temperature. The predetermined degree of superheat may be adjusted by varying the position of the valve member with relation to the Bourdon tube, as by screwing the stem 96 into or out of the pivot-block 97. It is to be noted that this auxiliary thermostatic regulator should not be used when the apparatus is subjected to sudden variations, for the reason that the temperature of the superheated steam varies directly with the rapidity of its flow past the superheating-surfaces and independently of the heat supplied by the burner during the variations in the flow of the steam. This thermostatic regulator, therefore, will not operate in substantial unison with the variations of demand when the variations are sudden.

In Fig. 12 a different form of regulator and a different method of applying the thermostat are illustrated. In accordance with the construction here shown the water is supplied to the generator through a casing 100, having a restricted passage the opening through which may be varied by a needle member 101. The movement of the member 101 is controlled by means of a piston 102, which is fitted in a casing 103 and exposed on its upper side to the full pressure in the generator, as through a pipe 104. The movement of the piston in the opposite direction is controlled by a tension-spring 105, which is connected at one end to the piston and at the opposite end to an adjusting-plug 106, threaded into the upper end of the casing 103. The piston 102 is connected to the member 101 and to the stem 107 of a suitable valve for controlling the flow of the fuel by a lever 108, which is pivoted at one end to the member 101 and fulcrumed at the opposite end and connected at intermediate points to the stem of a suitable valve for controlling the flow of the fuel and to a stem 109, carried by the piston 102. The needles 101 and 107 being given a suitable relative form it will be seen that as the pressure in the generator varies the said needles will be so moved as to vary the flows of the water and the fuel and to maintain a predetermined relation between the effective flows of said fluids. By mounting the fulcrum of the lever 108 on a thermostatic device 110, such that variations in the temperature of the steam will change the relation between needles 101 and 107 in such a way as to decrease the flow of fuel relatively to that of the water when the temperature increases, and vice versa when the temperature decreases, it will be seen that any desired relation between the effective supplies of the two fluids and between those supplies and the variations of demand for steam energy will be automatically maintained.

The operation of the various mechanical features of the apparatus shown having been described in connection with the construction thereof, it only remains to point out how the different parts of the apparatus coöperate to produce the desired results.

In the generator shown and described the inflowing liquid is gradually heated and only a small portion of it is maintained at the temperature of vaporization. It results from this that when a flow of steam or vapor is created or when an existing flow is increased the pressure immediately begins to fall and the liquid which is at the temperature of vaporization corresponding to the higher pressure immediately begins to vaporize and also to fall in temperature corresponding to the temperature of vaporization of the vapor at the reduced pressure. This process continues until the supplies of liquid and heat are increased by the action of the regulating devices to correspond to the new flow or demand. When the flow of steam or vapor is thus created or increased, the sudden development of vapor within this small portion of liquid due to the drop in pressure projects a portion of it in the form of a spray toward the delivery-orifice and to such a distance along the tube as to render effective a sufficient area of heating-surface to supply the demand for steam, and if the generator is sufficiently heated the vapor will pass the saturation-point and become superheated. If less steam is drawn from the generator, the rate of vaporization and the flow of the fluid will not be so great and the spray will not be projected so far along the tube and more superheating-surface will be available; but this is as it should be, as the capacity of vapor to absorb heat from a given surface varies directly with the rate of the flow of the vapor past the surface.

As the quantity of the liquid which is maintained at the temperature of vaporization is small, the point in the vaporizer where the liquid is changed into spray is sharply defined, and as the mixed spray and steam cannot absorb heat from a surface as readily as the unmixed liquid a considerably-greater difference in temperature must exist between the spray and the metal than between the water and the metal, and as the spray and water have the same temperature at this point there must be a marked increase in the temperature potential of the metal. A similar but less sharply defined condition must exist at the transition-point of steam to superheated steam. When the liquid in the form of spray is projected farther along the vaporizing portion of the generator, due to an increase in the demand upon the vapor, the hotter portions of the metal are brought promptly into action to momentarily supply the increase in the demand and to prevent such a sudden drop in the temperature and

pressure as would temporarily destroy the proper relation between the supply and demand. On the other hand, the vaporizing portion of the generator should be gradually heated in such manner that when the water is projected along the tube by an increase of demand it will not enter the spheroidal state, for if this happens too great a quantity of water will be projected into the vaporizing portion of the generator before the rate of generation of steam is increased to the proper degree, then when the metal becomes sufficiently cooled the water will come in contact therewith and be so suddenly vaporized as to abnormally increase the pressure and prevent the proper coaction of the parts. When a decrease in the demand occurs, the spray which has been projected along the vaporizing portion of the generator and is suspended in the vapor contained therein will be more rapidly precipitated upon the hotter metal and cause a prompt rise in temperature and pressure, and this process will continue until the supplies of liquid and heat are decreased by the action of the regulating devices to correspond to the new demand. Thus prompt and active forces are developed that can be made and are made by the apparatus described to accurately control the flow of the fluids. In order that these forces may be uniformly and reliably developed, as required to secure an even and efficient performance of the apparatus, the incoming liquid should be kept in a substantially unbroken column until the temperature of vaporization is reached. To insure this, the generator should be so proportioned that the point of vaporization will always occur at a part of the vaporizer where the flow of the liquid at that point is not appreciably affected by gravity—as, for instance, at some point in the coil numbered 14 of the generator shown.

With a generator constructed and heated as herein described the quantity of liquid therein will for a given ratio between the supplies of liquid and fuel remain practically fixed irrespective of any variation in the demand for steam or vapor within the capacity of the apparatus. This will be obvious when it is noted that should the quantity of liquid in the generator for any reason be greater than the quantity normal to a given ratio the vaporizing portion of the generator will be immersed in an abnormally hot region and the temperature potential of the metal will be abnormally high. This will result in the maintenance of a higher average of pressure than normal, as will clearly appear by a consideration of the effect of changes in demand. For example, the drop in pressure due to an increase of demand will be less in degree than normal and less prompt than normal, and the increase in pressure due to a decrease of demand will be greater in degree and more prompt. It follows that by reason of their coöperation with the generator the regulating devices will cause less fluid to be supplied to the generator than is taken therefrom while there is too much liquid in the generator. On the other hand, should the quantity of liquid in the generator be less than the quantity normal to a given ratio the vaporizing portion of the generator will be immersed in a cooler region, and the temperature potential of the metal will be below normal. On an increase of demand, therefore, the drop in pressure will be greater in degree and more prompt than normal and the increase in pressure due to the decrease of demand will be less in degree and less prompt. In other words, the average pressure will be less than normal. Consequently the supply of liquid to the generator will be greater than normal and will so continue until a condition of equilibrium is attained. It will thus be seen that the rate of variation in the controlling condition of the fluid in the generator varies inversely as the quantity of liquid in the generator varies, the tendency being to normally maintain such a quantity of liquid in the generator as will cause the regulating devices to vary the supply of liquid to the same extent weight for weight that the demand for steam or vapor varies. It is clear, therefore, that so long as a proper predetermined relation is maintained between the effective supplies of liquid and fuel and so long as the supplies of both fluids are varied in unison with the variations of demand the internal condition of the generator remains substantially fixed, and the steam or vapor is delivered at a practically unvarying temperature and pressure, and this irrespective of any variations of demand within the capacity of the apparatus, and also that the capacity of the apparatus is only limited by the capacity of the liquid and fuel supplying devices and the quantity of heat that may be rendered effective in the combustion-chamber and still maintain a substantially uniform distribution of the heat throughout the generator.

It will be obvious that the quantity of liquid in the generator will vary with variations in the ratio which is maintained between the supplies of liquid and fuel, the point of vaporization always being located in a region of the generator the temperature of which closely approximates the temperature of vaporization corresponding to the pressure at which the apparatus is operated.

As before indicated, the point where superheating begins automatically adjusts itself for varying loads to maintain the proper proportion between the vaporizing and superheating surfaces, the reason being that the efficiency of the vaporizing-surface varies inversely as the flow of fluid past it, whereas the efficiency of the superheated surface varies in the same direction as the flow of fluid past it varies. Where the correlation between the vaporizing and superheated portions of the generator is not such as to produce the desired uniformity in the temperature of the

superheated steam at various loads and where the variations in the load are not too sudden, the thermostatic regulator may be used. Where, however, the load varies suddenly through a wide range, the thermostatic regulator will so interfere with the action of the pressure-regulator as to make the use of the former impractical.

It is to be observed that the difference in temperature between the metal and the fluid in the vaporizing portion of the generator must not be excessive, as it usually is, for instance, in the flasher or the so-called "semi-flasher" type of generator, for in this case the water which is projected into the vaporizing portion of the generator upon an increase in the load would eventually be so rapidly evaporated that the temperature and the pressure would increase rather than decrease, or at least it would not decrease in such relation to the load as to cause substantial unison between the operation of the regulating mechanism and the variations of demand and bring about the remedial effect in time to keep the apparatus in a practically operative condition.

While the generator has been referred to herein as having three portions—to wit, a liquid-heating portion, a liquid-vaporizing portion, and a superheating portion—it is to be understood that in the form of generator herein shown the points of division between these parts are conditional, the division between the liquid-heating portion and the vaporizing portion being located at the point where the water has reached the temperature of vaporization and the division between the vaporizing and superheating portions being located at the point where all the latent heat of vaporization has been absorbed and superheating commences. While the point of division between the first two portions is substantially fixed for all loads at a given ratio between the supplies of the two fluids, it varies more or less, depending upon the proportions and arrangement of the generator relative to the burner for every variation in the ratio, and the point of division between the vaporizing and superheating portions varies for every change in load, as well as for changes in the ratio. The fact that the points of division between these portions of the generator vary in the manner described is immaterial, however, so long as they are kept within the proper limits and so long as the vaporizing portion contains such a small quantity of liquid as is adapted to bring about the prompt changes in pressure required to operate the regulating devices when changes in the load occur, as before explained.

It will be observed that as a very small portion of the generator shown and described and of the water in the generator are maintained at a high temperature there is but little potentially-active reserve energy in the apparatus, and consequently the defects which are necessarily associated with the use of such reserve energy are avoided.

I regard the construction of generator shown as a very important feature of my invention, as, aside from the fact that the use of an objectionable amount of reserve energy is avoided, it has numerous other advantages, among which the following may be mentioned: The heating-surfaces are arranged at right angles to the flow of the products of combustion and are so disposed as to thoroughly break up the currents and absorb the greatest possible amount of the heat contained therein. A large combustion-chamber is provided of a form which allows of a large burner area and permits the burner to operate at full load without bringing the flame in contact with the heating-surfaces, thus insuring complete combustion at all times without producing objectionable smell and without loss of energy. The combustion-chamber is entirely inclosed within the cooled surfaces of the generator, so that little jacketing is required and great efficiency is secured. The quantity of liquid in the generator is self-adjusting. The liquid is uniformly and gradually heated, and the liquid column is kept intact by gravity, so that the liquid is prevented from flowing onto the highly-heated surfaces and entering the spheroidal state when the apparatus is rendered inactive. The generator, moreover, is compact and simple and cheap in construction and has great strength, it being practically impossible to rupture it by internal pressure. It is free to expand under the influence of the heat, and none of the joints are exposed to the direct action of the flame.

One of the chief advantages of my invention resides in its ability to deliver the steam in a uniformly-superheated condition and at any desired degree of superheat notwithstanding great and sudden variations in the demand for steam, thus enabling great economy in steam consumption to be realized in a simple single-expansion engine. The apparatus is, moreover, automatic in its operation and reliably so. It is safe even in the hands of inexperienced or careless operators and is not subject to injury, as by overheating, and it is simple and cheap in construction and occupies a small space in proportion to its power.

My invention in its broader aspects is not limited to the particular construction shown nor to the particular construction by which it may be carried into effect, as many changes other than those herein suggested may be made in such construction without departing from the main principles of my invention and without sacrificing its chief advantages.

The methods of generating steam or of heating fluids herein described and carried out by the apparatus herein shown and described are not claimed herein, as the same forms the subject-matter of another applica-

tion pending simultaneously herewith. The generator and the burner herein shown and described, moreover, form the subject-matter of separate applications pending simultaneously herewith.

Having thus described my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in definite quantitative relations to said variations.

2. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in definite quantitative relations to said variations of demand.

3. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator at a substantially predetermined pressure, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition as to pressure of the fluid being heated for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in definite quantitative relations to said variations of demand.

4. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially definite quantitative relations to said variations.

5. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated, for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially definite quantitative relations to said variations.

6. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator at a substantially predetermined pressure, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition as to pressure of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially definite quantitative relations to said variations of demand.

7. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations.

8. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations.

9. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, means for supplying a liquid to the generator at a substantially predetermined pressure, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition as to pressure of the fluid being heated for varying the supplies of both the liquid and the fuel in substantial unison with the variations of de-

mand for steam or vapor energy and in substantially the same degree with said variations of demand.

10. In an apparatus for generating superheated steam or vapor and delivering the same in a substantially unvarying condition as to the energy thereof, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations.

11. In an apparatus for generating superheated steam or vapor and delivering the same in a substantially unvarying condition as to the energy thereof, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations.

12. In an apparatus for generating superheated steam or vapor and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, means for supplying a liquid to the generator at a substantially predetermined pressure, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition as to pressure of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations of demand.

13. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations, and means for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

14. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being rendered operative by variations in the condition of the fluid being heated to automatically vary the effective supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations of demand, and means for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

15. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying fuel to the combustion-chamber, means for supplying a liquid to the generator at a substantially predetermined pressure, said means being rendered operative by variations in the condition as to pressure of the fluid being heated to automatically vary the effective supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations of demand, and means for maintaining a predetermined quantitative relation between the supplies of the liquid and the fuel.

16. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations, and means for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

17. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being rendered operative by variations in the condition of the fluid being heated to automatically vary the effective supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations of demand, and means for maintaining

a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

18. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator at a substantially predetermined pressure, said means being rendered operative by variations in the condition as to pressure of the fluid being heated to automatically vary the effective supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations of demand, and means for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

19. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply of liquid in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations, and means rendered operative by variations in the condition of the fluid being heated for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

20. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply of liquid in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations, and means rendered operative by variations in a condition of the fluid flowing through the generator resulting from variations in the flow of said fluid for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

21. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply of liquid in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations and means rendered operative by variations in the condition as to pressure of the fluid being heated for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

22. In an apparatus for generating superheated steam or vapor and delivering the same in a substantially unvarying condition as to the energy thereof, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations, and means for regulating the supply of the fuel in such manner that the effective supply of the fuel varies in substantial unison with the variations of supply of the liquid and in substantially the same degree with said variations of supply.

23. In an apparatus for generating superheated steam or vapor and delivering the same in a substantially unvarying condition as to the energy thereof, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations, and means rendered operative by variations in the condition of the fluid being heated for regulating the supply of the fuel in such manner that the effective supply of the fuel varies in substantial unison with the variations of supply of the liquid and in substantially the same degree with said variations of supply.

24. In an apparatus for generating superheated steam or vapor and delivering the same in a substantially unvarying condition as to the energy thereof, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations, and means rendered operative by variations in the condition of the fluid flowing through the generator resulting from variations in the flow of said fluid for regulating the supply of the fuel in such manner that the effective supply of the fuel varies in substantial unison with the variations of the flow of fluid through the generator and in

substantially the same degree with said variations of flow.

25. In an apparatus for generating superheated steam or vapor and delivering the same in a substantially unvarying condition as to the energy thereof, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations, and means rendered operative by variations in the differential pressure resulting from variations in the flow of the fluid through the generator for regulating the supply of the fuel in such manner that the effective supply of the fuel varies in substantial unison with the variations of the flow of fluid through the generator and in substantially the same degree with said variations of flow.

26. In an apparatus for generating superheated steam or vapor and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator at a substantially predetermined pressure, said means being rendered operative by variations in the condition as to pressure of the fluid being heated to automatically vary the supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations of demand, and means rendered operative by variations in the condition as to pressure of the fluid being heated for regulating the supply of the fuel in such manner that the effective supply of fuel varies in substantial unison with the variations of supply of the liquid and in substantially the same degree with said variations of supply.

27. In an apparatus for generating superheated steam or vapor and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator at a substantially predetermined pressure, said means being rendered operative by variations in the condition as to pressure of the fluid being heated to automatically vary the supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations of demand, and means rendered operative by variations in a differential pressure resulting from variations in the flow of the fluid through the generator for regulating the supply of the fuel in such manner that the effective supply of the fuel varies in substantial unison with the variations of the flow of fluid through the generator and in substantially the same degree with said variations of flow.

28. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations, means tending to maintain a substantially predetermined quantitative relation between the supplies of the liquid and the fuel, and means for varying the relation between said supplies.

29. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations, and means rendered operative by variations in the condition of the fluid being heated for regulating the supply of the fuel in a manner tending to vary the supply of the fuel in substantial unison with the variations of supply of the liquid and according to a substantially predetermined quantitative relation to said variations of supply, and means for varying the relation between said supplies.

30. In an apparatus for generating steam or vapor and delivering the same at a substantially unvarying temperature, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations, means tending to maintain a substantially predetermined quantitative relation between the supplies of the liquid and the fuel, and means rendered operative by variations in the temperature of the steam or vapor for varying the relation between said supplies.

31. In an apparatus for generating steam or vapor and delivering the same at a substantially unvarying temperature, the combina-

tion with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations, and means rendered operative by variations in a condition of the fluid flowing through the generator resulting from variations in the flow of said fluid for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel, and means rendered operative by variations in the temperature of the steam or vapor for varying the relation between said supplies.

32. In an apparatus for generating steam or vapor and delivering the same at a substantially unvarying temperature, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations, means tending to maintain a substantially predetermined quantitative relation between the supplies of the liquid and the fuel, and means including a saturated vapor-tension thermostat operated by variations in the temperature of the steam or vapor for varying the relation between said supplies.

33. In an apparatus for generating steam or vapor and delivering the same at a substantially unvarying temperature, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator, said means being constructed to automatically vary the supply in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations, and means rendered operative by variations in a condition of the fluid flowing through the generator resulting from variations in the flow of said fluid for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel, and means including a saturated vapor-tension thermostat operated by variations in the temperature of the steam or vapor for varying the relation between said supplies.

34. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator at a substantially predetermined pressure, said means being rendered operative by variations in the condition as to pressure of the fluid being heated to automatically vary the effective supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations of demand, means tending to maintain a substantially predetermined quantitative relation between the supplies of the liquid and the fuel, and means rendered operative by variations in the temperature of the steam or vapor for varying the relation between said supplies.

35. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator at a substantially predetermined pressure, said means being rendered operative by variations in the condition as to pressure of the fluid being heated to automatically vary the effective supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations of demand, means tending to maintain a substantially predetermined quantitative relation between the supplies of the liquid and the fuel, and means including a saturated vapor-tension thermostat operated by variations in the temperature of the steam or vapor for varying the relation between said supplies.

36. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator at a substantially predetermined pressure, said means being rendered operative by variations in the condition as to pressure of the fluid being heated to automatically vary the effective supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations of demand, means rendered operative by variations in a condition of the fluid flowing through the generator resulting from variations in the flow of said fluid for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel, and means rendered op-

erative by variations in the temperature of the steam or vapor for varying the relation between said supplies.

37. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fuel to the combustion-chamber, means for supplying a liquid to the generator at a substantially predetermined pressure, said means being rendered operative by variations in the condition as to pressure of the fluid being heated to automatically vary the effective supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations of demand, means rendered operative by variations in a condition of the fluid flowing through the generator resulting from variations in the flow of said fluid for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel, and means including a saturated vapor-tension thermostat operated by variations in the temperature of the steam or vapor for varying the relation between said supplies.

38. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in substantially definite quantitative relations to said variations, said generator being of a type in which only a small quantity of the liquid is maintained at the temperature of vaporization.

39. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in substantially definite quantitative relations to said variations, said generator being of a type in which only a small quantity of the liquid is maintained at the temperature of vaporization.

40. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations, said generator being of a type in which only a small portion of the liquid is maintained at the temperature of vaporization.

41. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations, said generator being of a type in which only a small portion of the liquid is maintained at the temperature of vaporization.

42. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and at substantially the same degree with said variations and in substantially predetermined quantitative relations to said variations, said generator being of a type in which only a small portion of the liquid is maintained at the temperature of vaporization.

43. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to the energy thereof, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations, said generator being of a type in which only a small portion of the liquid is maintained at the temperature of vaporization.

44. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to the temperature and pressure thereof, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, means for supplying a liquid to the generator, means for supplying a fuel to the

combustion-chamber, and means rendered operative by the variations in the condition of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations of demand, said generator being of a type in which only a small portion of the liquid is maintained at the temperature of vaporization.

45. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in substantially definite quantitative relations to said variations of demand, said generator being so constructed and arranged with relation to the combustion-chamber that the rate of variation of the controlling condition of the fluid therein varies inversely as the quantity of liquid therein varies.

46. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially definite quantitative relations with said variations of demand, said generator being so constructed and arranged with relation to the combustion-chamber that the rate of variation of the controlling condition of the fluid therein varies inversely as the quantity of liquid therein varies.

47. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to the energy thereof, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means rendered operative by the variations in the condition of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations, said generator being so constructed and arranged with relation to the combustion-chamber that the rate of variation of the controlling condition of the fluid therein varies inversely as the quantity of liquid therein varies.

48. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to the temperature and pressure thereof, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, means for supplying a liquid to the generator at a substantially predetermined pressure, means for supplying a fuel to the combustion-chamber, and means rendered operative by the variations in the condition of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations of demand, said generator being so constructed and arranged with relation to the combustion-chamber that the rate of variation of the controlling condition of the fluid therein varies inversely as the quantity of liquid therein varies.

49. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator so constructed and arranged with relation to the combustion-chamber that different portions of the generator are heated by the products of combustion to different temperatures, means for supplying a liquid to a cooler portion of the generator, means for supplying fuel to the combustion-chamber, and means for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in substantially definite quantitative relations to said variations.

50. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator so constructed and arranged with relation to the combustion-chamber that different portions of the generator are heated by the products of combustion to different temperatures, means for supplying a liquid to a cooler portion of the generator, means for supplying fuel to the combustion-chamber, and means for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially definite quantitative relations to said variations.

51. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator so constructed and arranged with relation to the combustion-chamber that different portions of the generator are heated by the products of combustion to different temperatures, means for sup-

plying a liquid to a cooler portion of the generator, means for supplying fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in substantially definite quantitative relations to said variations.

52. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator consisting of a plurality of pipe-coils connected together in series and located one within another around the combustion-chamber, means for supplying a liquid to the outer coil, means for supplying a fuel to the combustion-chamber, and means for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in substantially definite quantitative relations to said variations.

53. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator consisting of a plurality of pipe-coils connected together in series and located one within another around the combustion-chamber, of means for supplying a liquid to an outer coil, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially definite quantitative relations to said variations.

54. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a generator consisting of a plurality of pipe-coils connected together in series and located one within another around the combustion-chamber, means for supplying a liquid to the outer coil, means for supplying a fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations of demand.

55. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a generator consisting of a plurality of pipe-coils connected together in series and located one within another around the combustion-chamber, means for supplying liquid to an outer coil at a substantially predetermined pressure, said means being rendered operative by variations in the condition of the fluid being heated to automatically vary the supply of the liquid in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations of demand, means for supplying a fuel to the combustion-chamber and means rendered operative by variations in the condition of the fluid being heated for maintaining a substantially predetermined quantitative relation between the supplies of the liquid and the fuel.

56. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator consisting of a plurality of pipe-coils located one within another around the combustion-chamber, of means for supplying a liquid to an outer coil, means for supplying a fuel to the combustion-chamber, and means for automatically varying the effective supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in substantially definite quantitative relations to said variations, said coils being so connected in series that the liquid is gradually heated and vaporized and is brought to the temperature of vaporization at a point where its flow is not appreciably affected by gravity.

57. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, means for supplying a liquid to the generator, means for supplying a fuel to the combustion-chamber, and means for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations, said generator having a vaporizing portion adapted to receive a small quantity of the liquid and vaporize it gradually.

58. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, said generator having a liquid-heating portion adapted to gradually heat the liquid to the temperature of vaporization, means for supplying the liquid to said generator, means for supplying a fuel to the combustion-chamber, and means for automatically varying the effective supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in a substantially predetermined quantitative relation to said variations.

59. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, means for supplying a liquid to the generator, means for supplying a fuel to the combustion-

chamber, and means for automatically varying the supplies of the liquid and the fuel in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations, said generator having a liquid-heating portion in which the liquid is gradually heated to the temperature of vaporization, a vaporizing portion adapted to receive a small quantity of the liquid and vaporize it gradually and a superheating portion directly connected to and forming an extension of said vaporizing portion.

60. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fluid fuel to the combustion-chamber, means tending to maintain a substantially predetermined quantitative relation between the flow of the fuel and the flow of the fluid through the generator, and means for automatically varying the relation between the flows of said fluids.

61. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for maintaining a substantially predetermined quantitative relation between the flow of the fuel and the flow of the fluid through the generator, and means for automatically varying the relation between the flows of said fluids.

62. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fluid fuel to the combustion-chamber, means rendered operative by variations in a condition of the fluid flowing through the generator resulting from variations in said flow for regulating the flow of the fuel in such manner that the flow of the fuel varies in substantially the same degree and in substantial unison with the variations of the flow of fluid through the generator, and means acting on the flow of one of said fluids for varying the ratio between the flows of said fluids.

63. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fluid fuel to the combustion-chamber, means rendered operative by variations in the pressure of the fluid flowing through the generator for regulating the flow of the fuel in such manner that the flow of the fuel varies in substantially the same degree and in substantial unison with the variations of the flow of fluid through the generator, and means acting on the flow of one of said fluids for varying the ratio between the flows of said fluids.

64. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to the temperature thereof, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator, means for supplying a fluid fuel to the combustion-chamber, means rendered operative by variations in a condition of the fluid flowing through the generator resulting from variations in said flow for regulating the flow of the fuel in such manner that the flow of the fuel varies in substantially the same degree and in substantial unison with the variations of the flow of the fluid through the generator, and means acting on the flow of one of said fluids and rendered operative by variations in the temperature of the steam or vapor for varying the ratio between the flows of said fluids.

65. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to the temperature and pressure thereof, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator at a substantially predetermined pressure, means for supplying a fluid fuel to the combustion-chamber, means rendered operative by variations in the pressure of the steam or vapor for regulating the flow of the fuel in such manner that the flow of the fuel varies in substantially the same degree and in substantial unison with the variations of the flow of fluid through the generator, and means acting on the flow of one of said fluids and rendered operative by variations in the temperature of the steam or vapor for varying the ratio between the flows of said fluids.

66. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to the temperature and pressure thereof, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator at a substantially predetermined pressure, means for supplying a fluid fuel to the combustion-chamber, means rendered operative by variations in a condition of the fluid flowing through the generator resulting from variations in said flow for regulating the flow of the fuel in such manner that the flow of the fuel varies in substantially the same degree and in substantial unison with the variations of the flow of the fluid through the generator, and means acting on the flow of the liquid to the generator and rendered op-

erative by variations in the temperature of the steam or vapor for varying the ratio between the flows of said fluids.

67. In an apparatus for heating fluids, the combination with a fluid-receptacle, of means for supplying a fluid to be heated to said receptacle, said means being constructed to vary the supply of the fluid in substantial unison with the variations of demand for fluid energy and in a definite quantitative relation to said variations, means for supplying a fluid-heating agent to said receptacle, means for maintaining a predetermined quantitative relation between the flow of the heating agent and the flow of fluid through the receptacle, and means for automatically varying the ratio between the flows of said fluids.

68. In an apparatus for heating fluids, the combination with a fluid-receptacle, of means for supplying a fluid to said receptacle, said means being rendered operative by variations in a condition of the fluid being heated to vary the supply of the fluid in substantial unison with the variations of demand for fluid energy and in a substantially definite quantitative relation to said variations, means for supplying a fluid-heating agent to said receptacle, means for regulating the flow of the heating agent by variations in the condition of the fluid being heated in such manner as to maintain a predetermined quantitative relation between the flow of the heating agent and the flow of the fluid through the receptacle, and means for automatically varying the ratio between the flows of said fluids.

69. In an apparatus for heating a fluid and delivering the same at a substantially unvarying temperature, the combination with a fluid-receptacle, of means for supplying the fluid to be heated to said receptacle, said means being rendered operative by variations in the condition of the fluid being heated to vary the supply of the fluid in substantial unison and in a substantially definite quantitative relation to said variations, means for supplying a fluid-heating agent to said receptacle, means for regulating the flow of the heating agent by variations in the condition of the fluid flowing through the receptacle resulting from variations in said flow for maintaining a substantially predetermined quantitative relation between the flows of said fluids and means rendered operative by variations in the temperature of the heated fluid for varying the relation between the flows of said fluids.

70. In an apparatus for heating a fluid, the combination with a fluid-receptacle, of means for supplying the fluid to be heated to said receptacle, means for supplying a fluid-heating agent to said receptacle, means for maintaining a predetermined relation between the flows of said fluids, and means whereby the relation between the flows of said fluids may be varied.

71. In an apparatus for heating a fluid, the combination with a fluid-receptacle, of means for supplying a fluid to be heated to said receptacle, means for supplying a fluid-heating agent to said receptacle, means rendered operative by variations in one condition of the fluid being heated for maintaining a predetermined relation between the flows of said fluids, and means rendered operative by variations in another condition of the fluid being heated for varying the relation between the flows of said fluids.

72. In an apparatus for heating a fluid, the combination with a fluid-receptacle, of means for supplying a fluid to be heated to said receptacle, means for supplying a fluid-heating agent to said receptacle, means rendered operative by variations in the condition of the fluid being heated for regulating the flow of the heating agent in such manner as to maintain a predetermined quantitative relation between the flow of the heating agent and the flow of the fluid through the receptacle, and means for automatically varying the ratio between the flows of said fluids.

73. In an apparatus for heating a fluid, the combination with a fluid-receptacle, of means for supplying the fluid to be heated to said receptacle, means for supplying a fluid-heating agent to said receptacle, means rendered operative by variations in a condition of the fluid flowing through the receptacle resulting from variations in the flow of said fluid for maintaining a predetermined quantitative relation between the flow of the heating agent and the flow of fluid through the receptacle, and means rendered operative by variations in the condition of the fluid for varying the ratio between the flows of said fluids.

74. In a device for maintaining a predetermined quantitative relation between the flows of two fluids, the combination with a motor constructed to be rendered operative by variations in a condition of one fluid resulting from variations in the flow thereof, of means operated by said motor for controlling the flow of the other fluid, and means acting on the flow of one of said fluids for so controlling the operation of said device that the relation between the flows of said fluids may be varied.

75. In a device for maintaining a predetermined quantitative relation between the flows of two fluids, the combination with a conduit for conveying one fluid, said conduit having a restricted passage, of a motor operated by the variations in pressure resulting from variations in the flow of fluid through said restricted passage, means operated by said motor for controlling the flow of the other fluid, and means whereby the relation between the flows of the fluids may be varied.

76. In a device for maintaining a predetermined quantitative relation between the flows of two fluids, the combination with a conduit for conveying one fluid, said conduit having a restricted passage, of a motor operated by the variations in pressure resulting from variations in the flow of fluid through said restricted passage, means operated by said mo-

tor for controlling the flow of the other fluid, and means for regulating the size of said restricted passage whereby the predetermined relation between the flows of the fluids may be varied.

77. In a device for maintaining a predetermined quantitative relation between the flows of two fluids, the combination with a motor constructed to be rendered operative by variations in a condition of one fluid resulting from variations in the flow of said fluid, of a valve for controlling the flow of the other fluid, and connections between the motor and one member of said valve, the members of said valves being so shaped with relation to their relative movement that the flow of one fluid varies in the same degree and in substantial unison with the variations of the flow of the other fluid.

78. In a device for maintaining a predetermined quantitative relation between the flows of two fluids, the combination with conduits for conveying said fluids, one of said conduits having a restricted passage, of a motor communicating with the conduit having the restricted passage and at opposite sides of the restricted passage, a spring for moving said motor in one direction, a valve rendered operative by said motor for varying the size of the restricted passage and a valve rendered operative by said motor for controlling the flow of fluid through the other conduit, said valves being so shaped and proportioned as to maintain a predetermined quantitative relation between the flows of the fluids.

79. In a device for maintaining a predetermined quantitative relation between the flows of two fluids, the combination with two conduits for conveying said fluids, one of said conduits having a restricted passage, of a motor communicating with the conduit having the restricted passage and at opposite sides of the restricted passage, a spring for moving said motor in one direction, a valve rendered operative by said motor for varying the size of the restricted passage, a valve rendered operative by said motor for controlling the flow of fluid through the other conduit, said valves being so relatively shaped and proportioned as to maintain a predetermined quantitative relation between the flows of the fluids, and means for varying the relation between the flows of the fluids at will.

80. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fluid fuel to the combustion-chamber, means for supplying water to the generator, said means being rendered operative by variations in the condition of the fluid being heated to automatically vary the effective supply of the water in substantial unison with the variations of demand for steam energy and in a substantially definite quantitative relation to said variations of demand, and means rendered operative by variations in the condition of the fluid flowing through the generator resulting from variations in the flow of said fluid for regulating the flow of fuel in such manner as to maintain a substantially predetermined quantitative relation between the flow of the fuel and the flow of the fluid through the generator.

81. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, of means for supplying a fluid fuel to the combustion-chamber, means for supplying water to the generator, said means being rendered operative by variations in the condition of the fluid being heated to automatically vary the effective supply of the water in substantial unison with the variations of demand for steam energy and in a substantially definite quantitative relation to said variations of demand, and means rendered operative by variations in the condition of the fluid flowing through the generator resulting from variations in the flow of said fluid for regulating the flow of fuel in such manner as to maintain a substantially predetermined quantitative relation between the flow of the fuel and the flow of the fluid through the generator, and means for varying the relation between the flows of said fluids.

82. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a suitable generator arranged in coöperative relation with the same, means for supplying a fluid fuel to the combustion-chamber, means for supplying water to the generator, said means being constructed to automatically vary the supply of water in substantial unison with the variations of demand for steam energy and in a substantially definite quantitative relation to said variations, means rendered operative by variations in one condition of the fluid being heated for maintaining a substantially predetermined quantitative relation between the flow of the fuel and the flow of the fluid through the generator, and means rendered operative by another condition of the fluid being heated for varying the relation between the said flows.

83. In an apparatus for generating superheated steam and delivering the same at a substantially uniform temperature, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying water to the generator, means for supplying fluid fuel to the combustion-chamber, means rendered operative by variations in one condition of the fluid being heated for maintaining a substantially predetermined quantitative relation between the flow of the fuel and the flow of the fluid through the generator, and means rendered operative by another

condition of the fluid being heated for automatically varying the relation between the flows of said fluids.

84. In an apparatus for generating superheated steam and delivering the same at a substantially uniform temperature, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying water to the generator, means for supplying a fluid fuel to the combustion-chamber, means rendered operative by variations in one condition of the fluid being heated for maintaining a substantially predetermined quantitative relation between the flow of the fuel and the flow of fluid through the generator, and means rendered operative by variations in another condition of the fluid being heated and acting upon the supply of the water to the generator to vary the relation between the flows of said fluids.

85. In an apparatus for generating superheated steam, the combination with a combustion-chamber and generator having a single continuous passage so arranged with relation to the combustion-chamber that different portions of it are subjected to the action of products of combustion of different temperatures, means for supplying water to a cooler portion of the generator, means for supplying a fluid fuel to the combustion-chamber, and means for automatically varying the supplies of both the water and the fuel in substantial unison with the variations of demand for steam energy and in substantially definite quantitative relations to said variations.

86. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a generator having a single continuous passage so arranged with relation to the combustion-chamber that different portions of it are subjected to the action of products of combustion of different temperatures, means for supplying water to a cooler portion of the generator, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying the supplies of both the water and the fuel in substantial unison with the variations of demand for steam energy and in substantially definite quantitative relations to said variations.

87. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a generator having a single continuous passage so arranged with relation to the combustion-chamber that different portions of it are subjected to the action of products of combustion of different temperatures, of means for supplying water to a cooler portion of the generator at a substantially predetermined pressure, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the condition as to pressure of the fluid being heated for automatically varying the supplies of both the water and the fuel in substantial unison with the variations of demand for steam energy and in substantially definite quantitative relations to said variations.

88. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a generator having a single continuous passage so arranged with relation to the combustion-chamber that different portions of it are subjected to the action of products of combustion of different temperatures, means for supplying water to the generator, said means being constructed to automatically vary the supply of water in substantial unison with the variations of demand for steam energy and in a definite quantitative relation to said variations, means for supplying a fluid fuel to the combustion-chamber and means for maintaining a predetermined quantitative relation between the flow of the fuel and the flow of fluid through the generator.

89. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a generator having a single continuous passage so arranged with relation to the combustion-chamber that different portions of it are subjected to the action of products of combustion of different temperatures, means for supplying water to a cooler portion of the generator, said means being rendered operative by variations in the condition of the fluid being heated for automatically varying the supply of water in substantially the same degree and in substantial unison with the variations of demand for steam energy, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for maintaining a predetermined quantitative relation between the flow of the fuel and the flow of fluid through the generator.

90. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a generator having a single continuous passage so arranged with relation to the combustion-chamber that different portions of it are subjected to the action of products of combustion of different temperatures, means for supplying water to a cooler portion of the generator, said means being rendered operative by variations in the condition of the fluid being heated for automatically varying the supply of water in substantially the same degree and in substantial unison with the variations of demand for steam energy, means for supplying a fluid fuel to the combustion-chamber, means rendered operative by variations in a condition of the fluid flowing through the generator resulting from variations in the flow of said fluid for maintaining a predetermined quantitative relation between the flow of the fuel and the flow of fluid through the generator.

91. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a generator having a sin-

gle continuous passage so arranged with relation to the combustion-chamber that different portions of it are subjected to the action of products of combustion of different temperatures, means for supplying water to a cooler portion of the generator at a substantially unvarying pressure, said means being rendered operative by variations in the condition as to pressure of the fluid being heated to automatically vary the supply of the liquid in substantially the same degree and in substantial unison with the variations of demand for steam energy, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in a differential pressure resulting from variations in the flow of fluid through the generator for maintaining a substantially predetermined quantitative relation between the flow of the fuel and the flow of fluid through the generator.

92. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a generator arranged in cooperative relation with the same, of means for supplying water to the generator at a substantially predetermined pressure, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the pressure of the fluid being heated for automatically varying the supplies of both the water and the fuel in substantial unison with the variations of demand for steam energy and in substantially definite quantitative relations to said variations, said generator being of a type in which only a small quantity of the liquid is maintained at the temperature of vaporization.

93. In an apparatus for generating superheated steam and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying water to the generator at a substantially predetermined pressure, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the pressure of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam energy and in substantially the same degree with said variations, said generator being of a type in which only a small quantity of the water is maintained at the temperature of vaporization.

94. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a generator arranged in cooperative relation with the same, of means for supplying a liquid to the generator at a substantially predetermined pressure, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the pressure of the fluid being heated for automatically varying the supplies of both the liquid and the fuel in substantial unison with the variations of demand for steam energy and in substantially definite quantitative relations to said variations of demand, said generator being so constructed and arranged with relation to the combustion-chamber that the rate of variation of the controlling condition of the fluid therein varies inversely as the quantity of water therein varies.

95. In an apparatus for generating superheated steam and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying water to the generator at a substantially predetermined pressure, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the pressure of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary in substantial unison with the variations of demand for steam energy and in substantially the same degree with said variations of demand, said generator being so constructed and arranged with relation to the combustion-chamber that the rate of variation of the controlling condition of the fluid therein varies inversely as the quantity of liquid therein varies.

96. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a generator consisting of a plurality of pipe-coils connected together in series and located one within another around the combustion-chamber, of means for supplying water to an outer coil at a substantially predetermined pressure, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the pressure of the fluid being heated for automatically varying the supplies of both the water and the fuel in substantial unison with the variations of demand for steam energy and in substantially definite quantitative relations to said variations of demand.

97. In an apparatus for generating superheated steam and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a generator consisting of a plurality of pipe-coils connected together in series and located one within another around the combustion-chamber, of means for supplying water to an outer coil at a substantially predetermined pressure, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the pressure of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the liquid and the fuel vary

in substantial unison with the variations of demand for steam energy and in substantially the same degree with said variations of demand.

98. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a generator consisting of a plurality of pipe-coils connected together in series and located one within another around the combustion-chamber, means for supplying water to the outer coil at a substantially predetermined pressure, said means being rendered operative by variations in the pressure of the fluid being heated to automatically vary the supply of the water in substantial unison with the variations of demand for steam energy and in substantially the same degree with said variations of demand, means for supplying fuel to the combustion-chamber, and means rendered operative by variations in a condition of the fluid flowing through the generator resulting from variations in the flow of said fluid for maintaining a substantially predetermined quantitative relation between the flow of the fuel and the flow of the fluid through the generator.

99. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a generator consisting of a plurality of pipe-coils located one within another around the combustion-chamber, means for supplying water to an outer coil, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying the supplies of both the water and the fuel in substantial unison with the variations of demand for steam energy and in substantially definite quantitative relations to said variations of demand, said coils being so connected in series that the liquid is gradually heated and vaporized and is brought to the temperature of vaporization at a point where its flow is not appreciably affected by gravity.

100. In an apparatus for generating superheated steam and delivering the same in a substantially unvarying condition as to the energy thereof, the combination with a combustion-chamber and a generator consisting of a plurality of pipe-coils located one within another around the combustion-chamber, means for supplying water to an outer coil, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the water and the fuel vary in substantial unison with the variations of demand for steam energy and in substantially the same degree with said variations, said coils being so connected in series that the liquid is gradually heated and vaporized and is brought to the temperature of vaporization at a point where its flow is not appreciably affected by gravity.

101. In an apparatus for generating superheated steam and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a generator consisting of a plurality of pipe-coils located one within another around the combustion-chamber, of means for supplying water to the outer coil at a substantially predetermined pressure, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the pressure of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the water and the fuel vary in substantial unison with the variations of demand for steam energy and in substantially the same degree with said variations of demand, said coils being so connected in series that the liquid is gradually heated and vaporized and is brought to the temperature of vaporization at a point where its flow is not appreciably affected by gravity.

102. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, means for supplying water to the generator, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the condition of the fluid being heated for automatically varying the supplies of the liquid and the fuel in substantial unison with the variations of demand for steam energy and in substantially predetermined quantitative relations to said variations of demand, said generator having a water-heating portion in which the water is gradually heated to the temperature of vaporization, a vaporizing portion adapted to receive a small quantity of the water and vaporize it gradually, and a superheating portion directly connected to and forming an extension of said vaporizing portion.

103. In an apparatus for generating superheated steam, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, means for supplying water to the generator, means for supplying a fluid fuel to the combustion-chamber, means rendered operative by variations in the condition of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the water and the fuel vary in substantial unison with the variations of demand for steam energy and in substantially the same degree with said variations, said generator having a water-heating portion in which the water is gradually heated to the temperature of vaporization, a vaporizing portion adapted to receive a small quantity of the liquid and vaporize it gradually, and a superheating portion directly connected to and forming an extension of said vaporizing portion.

104. In an apparatus for generating superheated steam and delivering it in a substan-

tially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, means for supplying water to the generator at a substantially uniform pressure, means for supplying a fluid fuel to the combustion-chamber, and means rendered operative by variations in the pressure of the fluid being heated for automatically varying said supplies in such manner that the effective supplies of both the water and the fuel vary in substantial unison with the variations of demand for steam energy and in substantially the same degree with said variations, said generator having a heating portion in which the water is gradually heated to the temperature of vaporization, a vaporizing portion adapted to receive a small quantity of the water and vaporize it gradually and a superheating portion directly connected to and forming an extension of said vaporizing portion.

105. In an apparatus for generating superheated steam and delivering the same at a substantially unvarying temperature, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying water to the generator, means for supplying a fluid fuel to the combustion-chamber, means tending to maintain a substantially predetermined quantitative relation between the flow of the fuel and the flow of fluid through the generator, and means for automatically varying the relation between the flows of said fluids, said generator being of a type in which only a small quantitity of the water is maintained at the temperature of vaporization.

106. In an apparatus for generating superheated steam and delivering the same at a substantially unvarying temperature, the combination with a combustion-chamber and a generator arranged in coöperative relation to the same, means for supplying water to the generator, means for supplying a fluid fuel to the combustion-chamber, means rendered operative by variations in the condition of the fluid being heated for maintaining a substantially predetermined quantitative relation between the flow of the fuel and the flow of the fluid through the generator, and means for automatically varying the relation between the flows of said fluids.

107. In an apparatus for generating superheated steam and delivering the same at a substantially unvarying temperature, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying water to the generator, means for supplying a fluid fuel to the combustion-chamber, means rendered operative by variations in one condition of the fluid being heated for maintaining a substantially predetermined quantitative relation between the flow of the fuel and the flow of the fluid through the generator, and means rendered operative by variations in another condition of the fluid being heated for automatically varying the relation between the flows of said fluids.

108. In an apparatus for generating superheated steam and delivering the same at a substantially unvarying temperature, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying water to the generator, means for supplying a fluid fuel to the combustion-chamber, means rendered operative by variations in a condition of the fluid flowing through the generator resulting from variations in the flow of said fluid for maintaining a substantially predetermined quantitative relation between the flow of the fuel and the flow of fluid through the generator, and means rendered operative by variations in the temperature of the superheated steam for automatically varying the relation between the flows of said fluids.

109. In an apparatus for generating steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying liquid to the generator, means for supplying a fluid fuel to the combustion-chamber at a substantially predetermined pressure, a nozzle for delivering the fuel to the combustion-chamber and means acting on the flow of the fuel at the nozzle for so regulating said flow that the flow of fuel varies in substantial unison with the variations of the flow of fluid through the generator and according to a substantially predetermined quantitative relation to said variations.

110. In an apparatus for generating steam or vapor, the combination with a generator and a burner arranged in coöperative relation with the same, of means for supplying liquid to the generator, means for supplying a fluid fuel to the combustion-chamber at a predetermined pressure, a nozzle for delivering the fuel to the combustion-chamber, and means rendered operative by variations in the fluid being heated and acting on the flow of fuel at the nozzle for so regulating said flow that it varies in substantial unison with the variations of the flow of fluid through the generator and according to a substantially predetermined quantitative relation to said variations.

111. In an apparatus for generating superheated steam or vapor, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying liquid to the said generator, said means being constructed to automatically vary the supply of liquid in substantial unison with the variations of demand for steam or vapor energy and in a substantially definite quantitative relation to said variations, means for supplying a fluid fuel to the combustion-chamber at a predetermined pressure, a nozzle for delivering fuel to the combustion-chamber, and means controlled by variations in the condition of the fluid be-

ing heated and acting on the flow of the fuel at the nozzle for so regulating said flow as to maintain a substantially predetermined quantitative relation between the flow of the fuel and the flow of the fluid through the generator.

112. In an apparatus for generating steam or vapor and delivering the same in a substantially unvarying condition as to temperature and pressure, the combination with a combustion-chamber and a generator arranged in coöperative relation with the same, of means for supplying a liquid to the generator at a substantially predetermined pressure, said means being rendered operative by variations in the condition of the fluid being heated for automatically varying the supply of fuel in substantial unison with the variations of demand for steam or vapor energy and in substantially the same degree with said variations of demand, means for supplying a fluid fuel to the combustion-chamber at a predetermined pressure, a nozzle for delivering the fuel to the combustion-chamber, and means controlled by variations in a condition of the fluid flowing through the generator resulting from variations in the flow of said fluid and acting on the flow of fuel at the nozzle for so regulating the flow of fuel as to maintain a substantially predetermined quantitative relation between the flow of fuel and the flow of fluid through the generator.

113. In an apparatus for superheating steam, the combination with a superheater, of means for supplying steam to the superheater, means for supplying a fluid-heating agent for heating the superheater, and means for automatically varying the effective supply of the heating agent in substantial unison with the variations of demand for superheated steam and in a substantially predetermined quantitative relation to said variations of demand.

114. In an apparatus for superheating steam, the combination with a superheater, of means for supplying steam to the superheater, means for supplying a fluid-heating agent for heating the superheater, and means rendered operative by variations in the condition of the fluid flowing through the superheater for automatically varying the effective supply of the heating agent in substantial unison with the variations in demand of superheated steam and in a substantially predetermined quantitative relation to said variations of demand.

115. In an apparatus for superheating steam, the combination with a superheater, of means for supplying steam to the superheater, means supplying a fluid-heating agent for heating the superheater, and means rendered operative by variations in a condition of the fluid flowing through the superheater resulting from variations in said flow for automatically varying the effective supply of the heating agent in substantial unison with the variations of demand for superheated steam and in a substantially predetermined quantitative relation to said variations of demand.

116. In an apparatus for superheating steam, the combination with a superheater, of means for supplying steam to the superheater, means for supplying a fluid-heating agent for heating the superheater, and means for automatically varying the effective supply of the heating agent in the same degree and in substantial unison with the variations of demand for superheated steam.

117. In an apparatus for superheating steam, the combination with a superheater, of means for supplying steam to the superheater, means for supplying a fluid-heating agent for heating the superheater, and means rendered operative by variations in one condition of the fluid flowing through the superheater for automatically varying the effective supply of the heating agent in a substantially predetermined quantitative relation with and in substantial unison with the variations of demand for superheated steam, and means rendered operative by another condition of the said fluid for varying the relation between the supply of the heating agent and the demand for steam.

118. In an apparatus for superheating steam, the combination with a superheater, of means for supplying steam to the superheater, means for supplying a fluid-heating agent for heating the superheater, and means for automatically varying the effective supply of the heating agent in substantial unison with the variations of demand for superheated steam and in a substantially predetermined quantitative relation to said variations, and means rendered operative by variations of the temperature of the superheated steam for varying the relation between the supply of the heating agent and the demand for steam.

119. In an apparatus for superheating steam, the combination with a superheater, of means for supplying steam to the superheater, means for supplying the fluid-heating agent for heating the superheater, and means rendered operative by variations in a condition of the fluid flowing through the superheater resulting from variations in said flow for automatically varying the effective supply of the heating agent in substantial unison with the variations of demand for superheated steam and in a substantially predetermined quantitative relation to said variations of demand, and means rendered operative by variations of the temperature of the superheated steam for varying the relation between the supply of the heating agent and the demand for steam.

120. In an apparatus for superheating steam, the combination with a superheater, the effective heating-surface of which is automatically varied inversely and in substantial unison with the variations of demand for superheated steam, means for supplying a fluid-heating agent for heating the superheater,

and means for automatically varying the effective supply of the heating agent in substantial unison with the variations of demand for superheated steam and in a substantially predetermined quantitative relation to said variations of demand.

121. In an apparatus for superheating steam, the combination with a superheater, the effective heating-surface of which is automatically varied inversely and in substantial unison with the variations of demand for superheated steam, means for supplying a fluid-heating agent for heating the superheater, and means for automatically varying the effective supply of the heating agent in substantially the same degree and in substantial unison with the variations of demand for superheated steam.

122. In an apparatus for superheating steam, the combination with a superheater, the effective heating-surface of which is automatically varied inversely and in substantial unison with the variations of demand for superheated steam, means for supplying a fluid-heating agent for heating the superheater, means rendered operative by variations in the condition of the fluid flowing through the superheater for automatically varying the effective supply of the heating agent in substantial unison with the variations of demand for superheated steam and in a substantially predetermined quantitative relation to said variations of demand, and means rendered operative by variations in the temperature of the superheated steam for varying the relation between the supply of the heating agent and the demand for superheated steam.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

EDWARD C. NEWCOMB.

Witnesses:
JOSEPH H. FREEMAN,
EDWIN SEGER.