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P. L. CLARK.

METHOD OF OPERATING STEAM POWER PLANTS.

APPLICATION FILED JAN. 30, 1903.

NO MODEL.

Fig. 1.

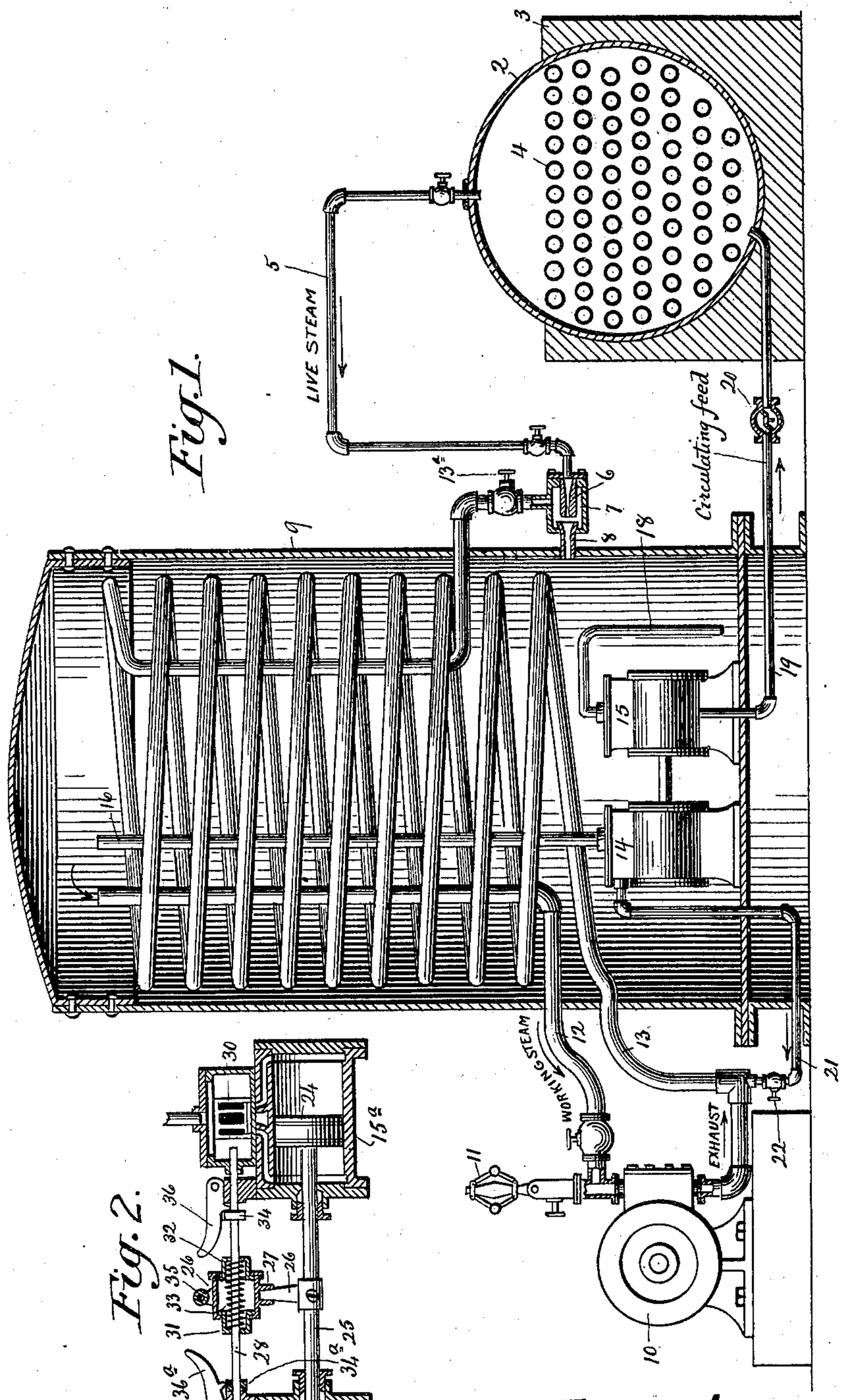

Fig. 2.

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UNITED STATES PATENT OFFICE.

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METHOD OF OPERATING STEAM-POWER PLANTS.

SPECIFICATION forming part of Letters Patent No. 736,578, dated August 18, 1903.

Application filed January 30, 1903. Serial No. 141,216. (No model.)

To all whom it may concern:

Be it known that I, PHILIPPE LYONS CLARK, a citizen of the United States, residing at Barnard House, Chelmsford, in the county of Essex, England, have invented a new and useful Improvement in the Method of Operating Steam-Power Plants; and I do hereby declare the following, when taken in connection with the accompanying drawings and the letters of reference marked thereon, to be a full, clear, and exact description of the same, and which said drawings constitute part of this specification, and represent, in—

Figure 1, a view, partly in vertical section and partly in elevation, of one form which an apparatus for carrying out my improved method may assume; Fig. 2, a detached broken view in vertical section, illustrating a form of pump which may be used in an apparatus for carrying out my improved method.

My improved method relates to that class of inventions designed to utilize the exhaust of steam-power systems by injecting the exhaust thereof back into some part of the power system, and it more particularly relates to that branch of the art wherein a supplementary reservoir for supplying the whole or a part of the working steam to the motor has been interposed between the generator and the motor, and wherein one function or the sole function of the generator has been to supply steam to actuate the injector.

In all prior methods of which I am aware of employing an interposed reservoir for the working steam no provision has been made for maintaining a predetermined difference of pressure between the reservoir and the generator. Without such provision there must be a congestion of mass and energy in the reservoir, whereby the pressure therein will attain a height at which injection will become impossible and the system will come to a stop. For efficient injection of this kind it is necessary to maintain a difference between the generator and reservoir pressures of at least forty-two per cent. of the generator-pressure, and such difference can only be maintained by either discharging steam out of the system from the reservoir or transferring it from the reservoir to the generator. The advance which I have made in the art is in establishing such a circulation in the entire system as will maintain a predetermined difference between the boiler and reservoir pressures at a point which will allow of the full utilization of the kinetic energy of the live steam for the purpose of injecting the exhaust-steam into the reservoir.

The fundamental principle of my invention is the utilization of the internal energy of the system to effect a constant circulation of the working fluid throughout the system, beginning and ending a cycle at the generator. The first essential requirement of this principle is to establish two distinct steam-pressures in the system and maintain a constant ratio of difference between them; second, to work the motor from the lower of the two pressures and to exhaust it into a suction and compression device delivering into a reservoir for the lower pressure; third, to actuate the suction and compression device by utilizing the kinetic energy of a jet of steam flowing at the maximum possible velocity of steam spouting against pressure; fourth, to convert the reservoir for the lower pressure into a partial condenser by constantly disturbing the relation of density, temperature, and pressure in the mass therein contained, and, fifth, to utilize the tendency to congestion of energy in said reservoir to transfer the surplus of fluid mass to the generator.

With the end in view of securing the maximum economy in the use of steam and of avoiding the objection above referred to my invention consists in a method in which provision is made for establishing and maintaining a predetermined difference in pressures between the generator and reservoir.

My invention further consists in a method of operating steam-power plants in which the circulation of the working fluid throughout the entire system is such as to maintain constant a predetermined difference between the higher and the lower pressures of the system and which predetermined difference is such as will permit the delivering for injection of live steam from the higher pressure against and into the lower pressure at the maximum velocity at which live steam can be made to flow or deliver against pressure, and the said predetermined difference of pressures being

maintained by the utilization of the lower pressure for the transference therefrom of a portion of its mass and energy to the generator.

My invention further consists in a method having certain other features, as will be hereinafter set forth, and pointed out in the claims.

In carrying out my invention various forms of apparatus may be used, dependent upon the character of the installation. It will therefore be understood that the apparatus shown and described is only illustrative in its character and that my invention is not limited to the use of such an apparatus, which may be varied in whole or in part, according to the dictation of circumstances.

In carrying out my invention as herein shown I employ a boiler comprising a shell 2, set in a bed 3 and containing tubes 4, all of any approved construction. This boiler I shall hereinafter for convenience refer to as a "generator." From this generator a live-steam pipe 5 leads to the high-pressure nozzle 6 of a suction and compression device, which also comprises a suction-chamber 7 and a compressing and mixing nozzle 8. This device has the general form and chararteristics of an ordinary ejector or injector, and for convenience I shall hereinafter refer to it as an "injector." The said nozzle 8 is connected with and delivers into a supplementary reservoir 9 for the working steam which is interposed between the generator and the steam-power engine 10, which may also be of any approved construction, dependent, again, upon the circumstances of use. In the claims I shall refer to the said reservoir 9 as an "inclosed space" and to the engine 10 as a "motor." This engine is furnished with an ordinary governor 11 and is supplied with a working steam-feed pipe 12, leading to it from the reservoir. This pipe extends upward toward the top of the reservoir, so as to take the steam therefrom where it is driest. The exhaust-steam from the engine is led from the exhaust-port of the engine into the exhaust-pipe 13, the main portion of which is coiled within the reservoir and which is connected at its other end with the suction-chamber 7 of the injector already described. This pipe is furnished with an exhaust-valve 13^a and constitutes a heater for the exhaust-steam, and will be hereinafter referred to as the "heater."

Within the lower end of the reservoir I locate a pump comprising a steam-cylinder 14 and a delivery-cylinder 15. The said steam-cylinder 14 is supplied with steam by a vertically-arranged supply-pipe 16, extending upward nearly to the top of the reservoir, where it takes steam. The said delivery-cylinder 15 is furnished with a supply-pipe 18, arranged to take its supply at or near the bottom of the reservoir. A delivery-pipe 19 leads from the cylinder to the generator at a point below the water-level thereof and is furnished with a back-pressure valve 20. This delivery-pipe constitutes what may be called the "circulating" feed-pipe between the reservoir and the generator. An exhaust-pipe 21 leads from the steam-cylinder 14 of the pump to the main exhaust-pipe 13 already mentioned and is furnished with a valve 22. The steam-cylinder 14 and the delivery-cylinder 15 together with their connections may be taken as conventional representations of the pump, the internal construction of which may or may not correspond to the construction shown in section by Fig. 2, which represents such a pump as may be used in this situation, though it must be understood that I do not limit myself to this construction or any special form of pump in the prosecution of my improved process. The piston 23 and the piston 24 are attached to the opposite ends of a piston-rod 25, furnished with an arm 26, carrying a sleeve 27, sliding upon the valve-rod 28, at the opposite ends of which the valves 29 and 30 are located. The said sleeve 27 is furnished at its opposite ends with smaller sliding sleeves 31 and 32, flanged at their inner ends and adapted to slide within the sleeve 27. These smaller sleeves are normally held at the limit of their outward movement by means of a compression-spring 33, located partly within the sleeve 27 and partly within them. When the piston-rod 25 moves from left to right, the sliding sleeve 32 engages with a collar 34, mounted upon the valve-rod, and is pushed inward into the sleeve 27, whereby the spring 33 is compressed. As the valve-rod is moved to the right an antifriction-roller 35, carried by the said arm 26, rides under and lifts the trigger-dog 36, engaging with the collar 34, until the dog is cleared from the collar, at which time the force of the spring moves the valve-rod 28 from left to right and operates the valves 29 and 30. At the same time the dog 36^a falls into position behind the collar 34^a. Now when the piston-rod 25 moves from right to left the sleeve 31 engages with the collar 34^a and is pressed inward into the sleeve 27 and the spring 33 placed under compression. As the valve-rod is moved to the left the antifriction-roller 35 engages with the trigger-dog 36^a and lifts the same so as to release the collar 34^a, at which time the power of the spring 33 moves the valve-rod from right to left and reverses the valves 29 and 30.

It will be seen from the foregoing that the cylinders 14^a and 15^a of the pump are both in the nature of the steam-cylinders of an ordinary slide-valve engine and that the valves 29 and 30 are operated by a trigger-gear set to trip at the end of a full stroke of the pistons, thus doing away with any cut-off or possibility of expansion of the motive fluid. The head against which the pump is designed to work is a positive constant element. The pressure to be utilized upon both pistons of the pump must be a positive pressure throughout the entire stroke of the pump and the capacity of the pump must be equal to an instant and constant transference of enough of the fluid-mass from the reservoir to the generator to maintain the predetermined differ-

ence in pressures. Any construction of the pump or arrangement of the valves or gear which would admit of the expansion of the actuating fluid in the cylinders would militate against the action of the pump and destroy its efficiency. The ratio of the cylinders must be such that the pump can only work against the desired head when the full pressure in the reservoir is exerted in both cylinders and so that it will then work with sufficient speed to maintain the head constant. Each stroke of the pump must increase the pressure against which it is working and reduces the pressure which is actuating it. Under these conditions there cannot be expansion in the cylinders, and either water or steam can be forced into the generator. The pistons 14^a and 15^a are proportioned to deliver either water or steam, or both, into and against the pressure in the generator whenever any excess of energy in the reservoir causes a tendency to reduce the difference desired to be maintained between the pressure within the generator and the reservoir. In other words, the function of the pump is to maintain a given difference in pressure between the reservoir and the generator, which is the characteristic feature of my improved method. The excess of energy in the reservoir instead of reducing the head by increasing the pressure therein actuates the pump and transfers enough fluid mass and energy to the generator to maintain the normal or predetermined difference of pressure representing the equilibrium of the apparatus. This function of the pump might, of course, be performed by some forms of steam-traps which are, in effect, pumps, though not commonly so designated.

Having now described one form of apparatus capable of carrying out my improved method, I will proceed to describe the operation thereof.

In the first place it must be understood that whatever the form of the apparatus it will be constructed with reference to maintaining a constant ratio of difference of pressure in the generator and reservoir by circulating a portion of the fluid mass and energy from the generator to the reservoir and from the reservoir back to the generator. Unless such difference of pressure is maintained congestion will follow, injection will stop, and the necessary circulation of the system will come to an end. Steam is made in the generator and the reservoir loaded to the pressure at which the engine is to be worked by delivering the steam from the generator through the injector into the reservoir. The engine exhaust-valve 13^a is now opened and the engine started in the usual way. After actuating the piston of the engine 10 the steam passes into the exhaust-pipe 13 and is heated in its passage through the coil of the pipe by the steam surrounding the same in the reservoir. This heated exhaust-steam is then drawn into and enters the suction-chamber 7 of the injector, where it meets the jet of live steam on its way from the generator to the reservoir. It is "picked up," so to speak, by this jet of live steam and compressed and commingled therewith in the compressing and mixing nozzle 8, from which it is delivered into the reservoir. The fluid mass in the reservoir will now be increased by the incoming live steam from the generator; but the ratio of volume and energy of this steam to the volume and energy of the exhaust-steam from the engine is such that the energy and temperature in the reservoir are not increased in the same ratio as the mass, and therefore the natural relation of density, pressure, and temperature having been disturbed condensation takes place in the reservoir until the natural relation of saturated steam in contact with its water again prevails. The total energy of the mass is now slightly increased as well as the volume of water, and the volume of steam is correspondingly decreased. It may be here remarked that the combination of reservoir, pump, and generator is of the nature of a cylinder having a piston loaded to maintain a constant pressure in the cylinder, the reservoir representing the cylinder in which a constant pressure is to be maintained, the pressure in the generator representing the load, and the pistons of the pump representing the loaded piston. The areas of the pistons of the pump being proportioned to work against a certain maximum head and that head being the difference which it is desired to maintain between the pressures of the generator and reservoir, any tendency to a reduction of such head by a lowering of the generator-pressure or by raising of the reservoir-pressure is instantly counteracted by the action of the pump in transferring enough energy from the lower pressure of the reservoir to the higher pressure of the generator to maintain the desired difference between them. With this explanation it will be understood that a part of the surplus energy in the reservoir will in this phase of the cycle actuate the pump instead of increasing the pressure within the reservoir. In the actuation of the pump the steam-cylinder thereof is exhausted through the engine exhaust-pipe and coil to the injector, while the surplus mass, whether in the form of water or steam, or both, is forced back into the generator, carrying with it the surplus energy, and thereby completing the cycle and maintaining the equilibrium of the apparatus.

It will be seen from the foregoing description that my method provides for such a constant circulation of the working fluid through the entire system as will maintain constant a predetermined difference beginning and ending the cycle with the generator and making good at the furnace-fire such energy as shall have been converted to external work or otherwise extracted from the system during the cycle.

The lower the temperature of the exhaust-steam when brought into contact in the in-

jector with the live steam the less the efficiency of the injector. Hence before delivering the steam to the injector I raise its temperature. I provide for this in the apparatus shown by forming the exhaust-steam pipe into a large coil located within the reservoir. In passing through this coil the exhaust-steam is raised to the temperature of the reservoir, or the temperature of the exhaust-steam may be increased in some other way—as, for instance, in a heater located in the furnace or flue of the generator. This heater for the exhaust-steam may either revivify or superheat the same, dependent upon the amount of saturation and the temperature of the heater. Therefore in the sense in which I use the word "heater" I intend to cover superheating as well as heating. The efficiency of the injector may also be increased by superheating the injection-steam, thereby increasing the efficiency of the injector to the extent of the superheat without increasing the weight of steam used. The weight of high-pressure steam for injection should transfer to the reservoir only sufficient energy to make good the heat units converted into work by the engine and by the pump, returned to the generator by the pump, and lost by radiation, &c. Condensation in the reservoir will then constantly equal the weight of steam passing from the generator to the reservoir and will be as constantly returned to the generator. With a greater weight of steam used for injection the condensation will be incomplete and some steam will require to be pumped thence to the generator.

Where excessive fluctuations of load and speed are to be provided for, I may connect a number of small injectors to a common exhaust-chamber and automatically increase or diminish the number of jets in use, as required.

It is not essential that all of the energy shall be conserved by my method, which is valuable in proportion as the energy conserved thereby exceeds that expended thereon.

As stated at the outset of this description, the apparatus herein shown and described has been chosen for convenience of disclosing my improved method, which may be employed by the use of apparatus of a great variety of forms. As herein sugested also, the method itself may be varied without losing its essential and novel character. Thus instead of operating the steam-cylinder 14 of the pump by steam taken from the reservoir through the pipe 16 I may take the steam required directly from the generator instead of from the reservoir. The arrangement of a pipe for this purpose is too obvious to require illustration. I would therefore have it understood that I do not limit myself to the steps and apparatus herein set forth, but hold myself at liberty to make such departures therefrom as fairly fall within the spirit and scope of my invention.

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

1. A method of operating a steam-power system which consists in generating live steam, conducting a portion of the said live steam to an inclosed space, operating a motor by the pressure of the steam therein, injecting the exhaust from the motor to the inclosed space by means of the live steam, returning a portion of the mixed live and exhaust steam and water of condensation of the inclosed space to the live-steam generator and maintaining a predetermined difference of pressure between the live steam in the generator and the mixture of live and exhaust steam in the inclosed space.

2. A method of operating a steam-power system which consists in generating live steam, conducting it to an inclosed space, operating a motor by the pressure of steam in the said inclosed space, injecting the exhaust from the motor into the inclosed space by means of the kinetic energy of the live steam and utilizing the fluid-pressure of the system to circulate from the inclosed space to the live-steam generator such portion of the mixed live steam, exhaust-steam and water of condensation of the inclosed space as will maintain constant a predetermined difference between the pressure in the live-steam generator and in the inclosed space, and predetermining that difference at a point which permits of delivering the live steam from the generator, for injection, into the inclosed space at the maximum velocity at which live steam can be made to flow against pressure.

3. A method of operating a steam-power system consisting in generating live steam, conducting a portion of it to an inclosed space, operating a motor by the pressure of the steam in the said inclosed space, heating the exhaust from the motor, injecting the heated exhaust from the motor into the inclosed space by means of the kinetic energy of the live steam and utilizing the fluid-pressure of the system to circulate from the inclosed space to the live-steam generator such portion of the mixed live and exhaust steam and water of condensation of the inclosed space as will maintain constant a predetermined difference between the pressure in the live-steam generator and in the inclosed space, and predetermining that difference at a point which permits of delivering the live steam from the generator, for injection, into the inclosed space at the maximum velocity at which live steam can be made to flow against pressure.

4. A method of operating a steam-power system which consists in generating and superheating live steam, conducting the superheated live steam to an inclosed space, operating a motor by pressure of the steam in the said inclosed space, injecting the exhaust from the motor to the inclosed space by means of the kinetic energy of the live steam and utilizing the fluid-pressure of the system to transfer from the inclosed space to the live-

steam generator such portion of the mixed live and exhaust steam and water of condensation of the inclosed space as will maintain constant a predetermined difference between the pressure in the live-steam generator and in the inclosed space, and predetermining that difference at a point which permits of delivering the live steam from the generator, for injection, into the inclosed space at the maximum velocity at which live steam can be made to flow against pressure.

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