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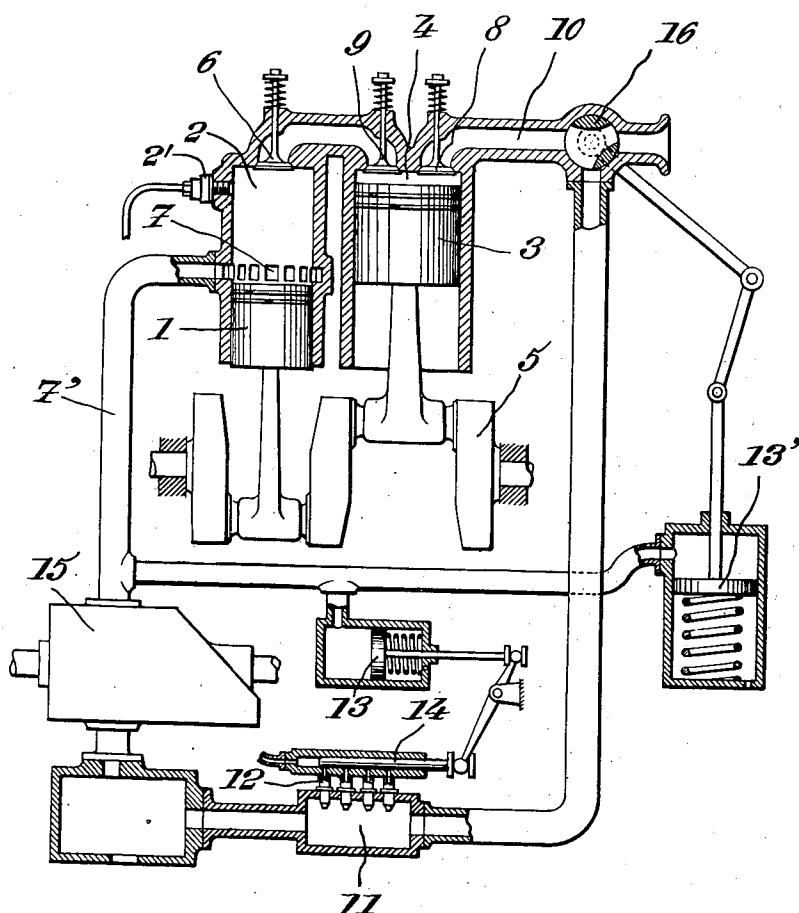
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HOT AND COMPRESSED GAS AUTOGENERATOR

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Fig. 1



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Fig. 3.

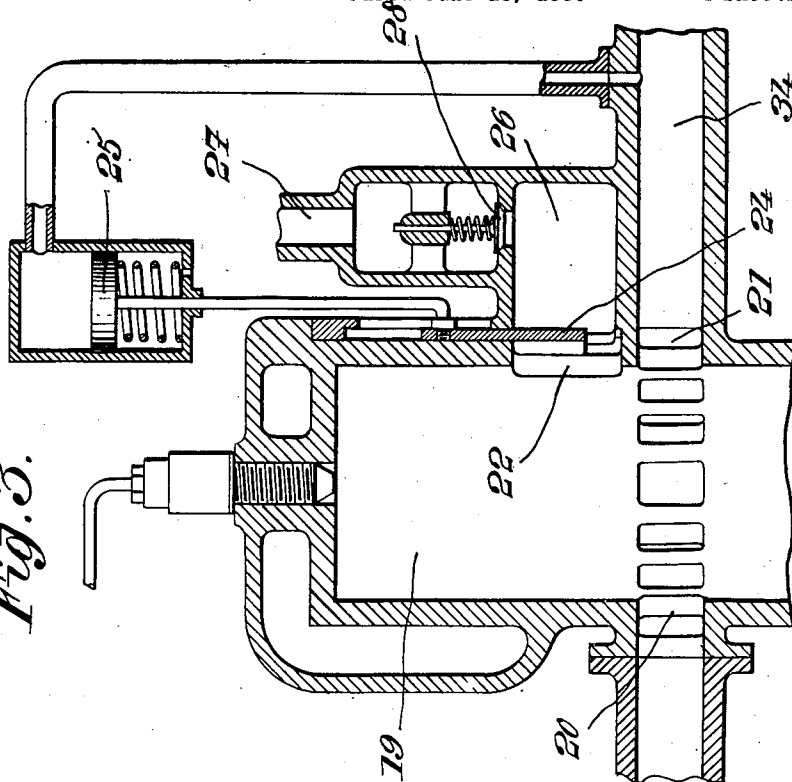
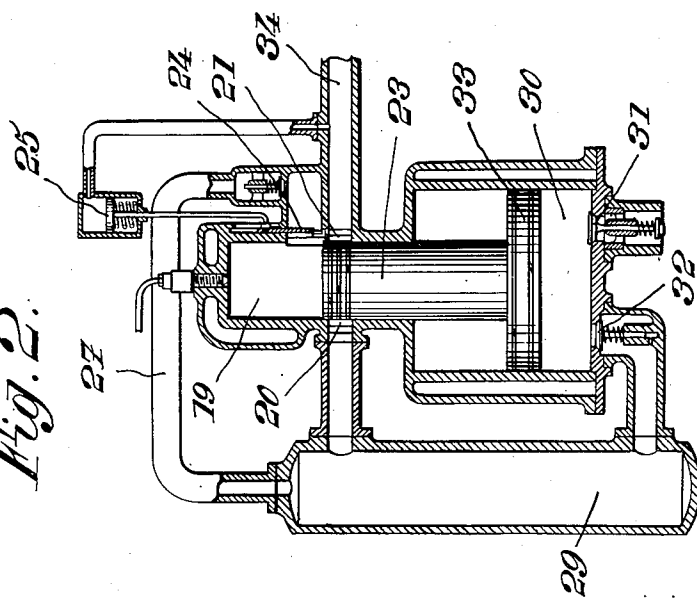


Fig. 2.



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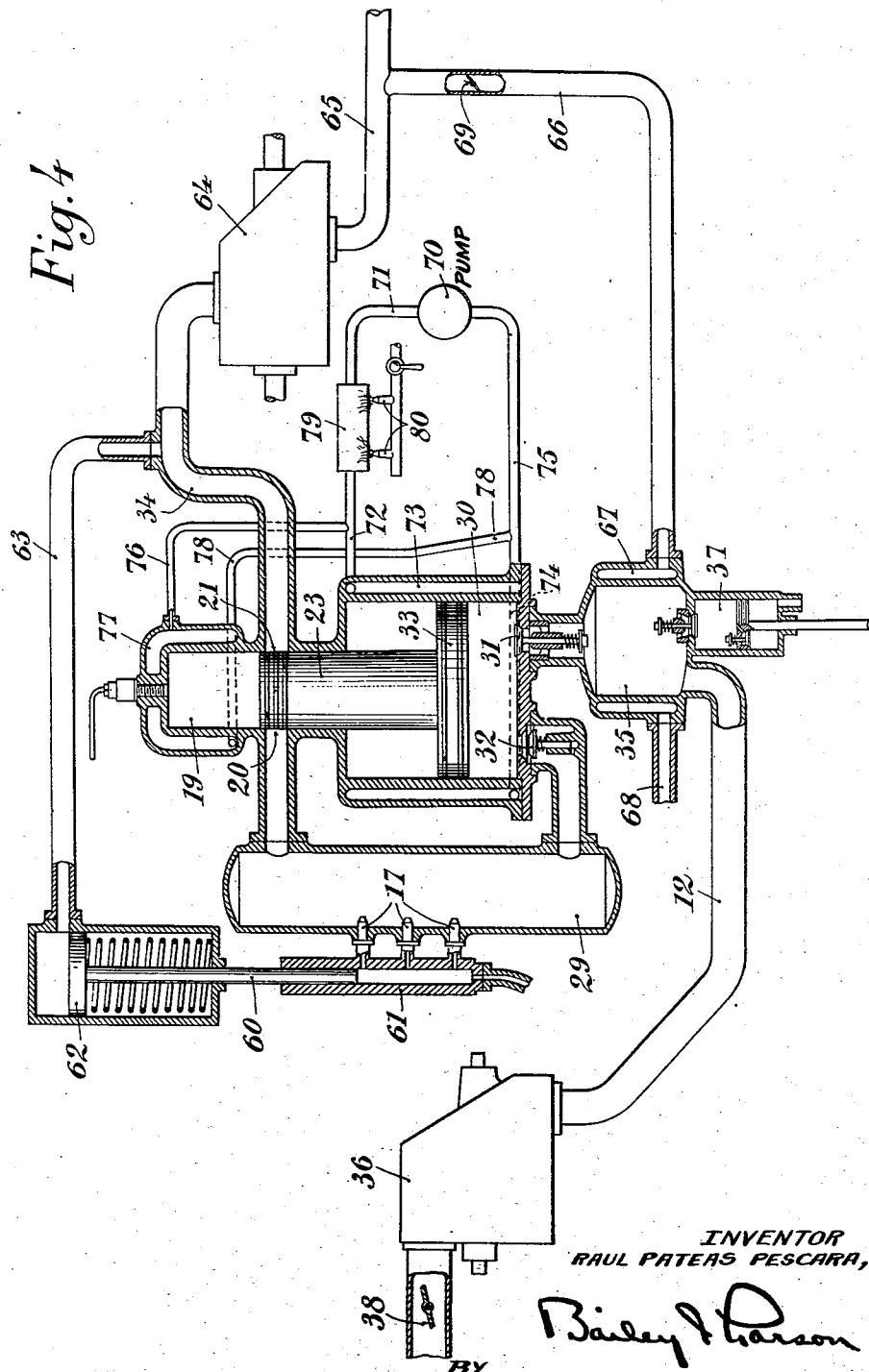
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HOT AND COMPRESSED GAS AUTOGENERATOR

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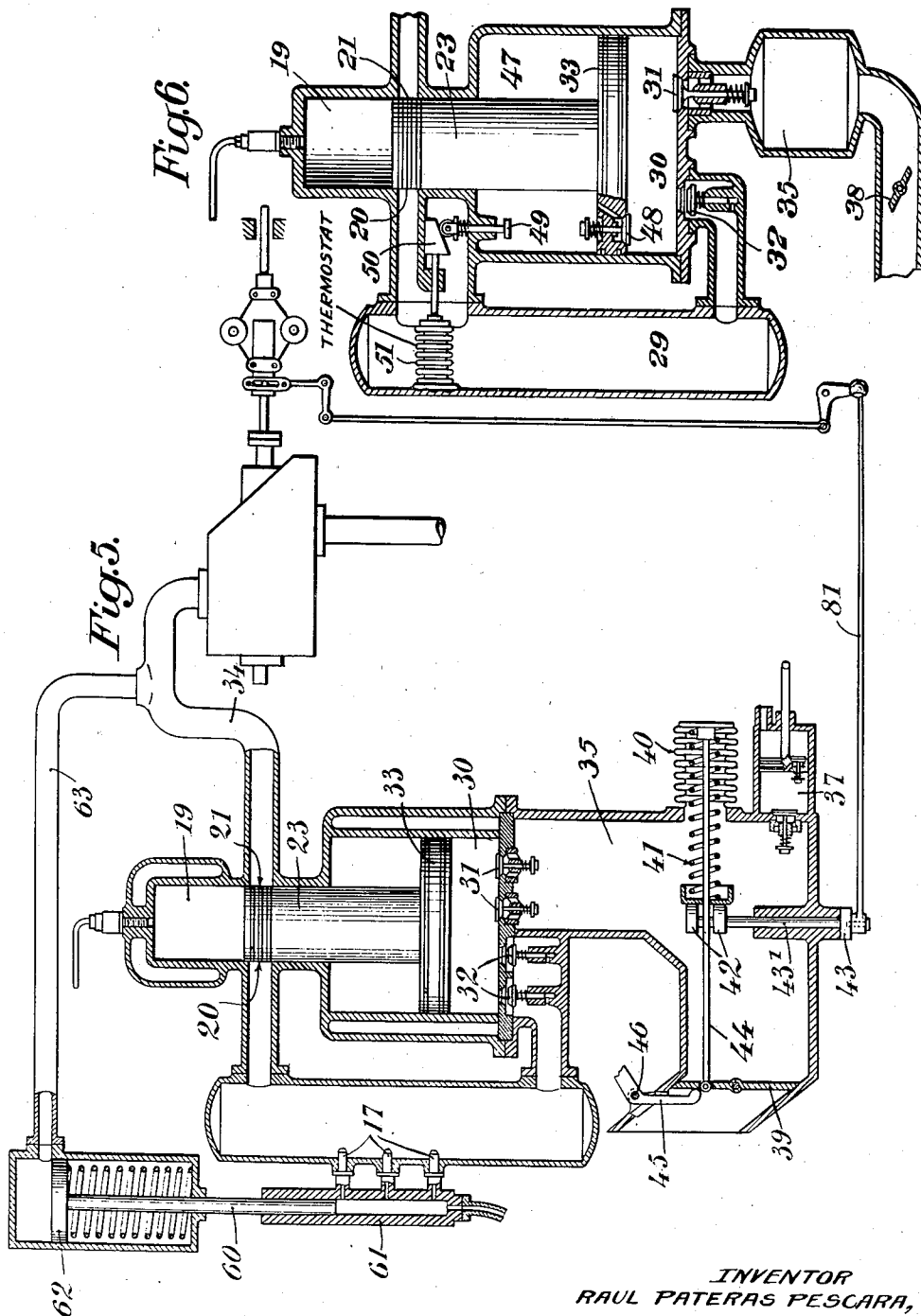
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HOT AND COMPRESSED GAS AUTOGENERATOR

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4 Sheets-Sheet 4



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HOT AND COMPRESSED GAS
AUTOGENERATOR

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11 Claims. (Cl. 60—44)

The present invention relates to hot and compressed gas auto-generators, this expression designating machines including at least one motor element, advantageously of the two-stroke type, and at least one compressor element driven by said motor element, the mechanical work of the motor being absorbed by the compressor element and the motor element being supercharged and scavenged by at least one part of the air compressed and fed by said compressor element.

The object of the present invention is to provide a generator of this type which is better adapted to meet the requirements of practice than those used up to the present time, and in particular which works in a safe and reliable manner when the whole is starting and working under low load.

According to an essential feature of the present invention, I heat, when the system is starting and working under low load, the air intended to support combustion in the motor element, either before or after the compressor element, the degree of heating being preferably automatically regulated as a function of the supercharging pressure of the motor element and in inverse relation thereto.

According to another feature of the present invention, concerning especially auto-generators of the type above referred to which work with a constant or substantially constant piston stroke and with an output pressure variable in accordance with a constant or substantially constant compression ratio by means of a preliminary expansion of the feed air of the compressor element from the pressure of the surrounding atmosphere to the variable feed pressure of this last mentioned element, this preliminary expansion is effected by means of a member adapted to receive energy, such as a turbine capable of transforming, advantageously in an isothermic manner, at least a portion of the energy released by said expansion into work.

According to still another feature of the present invention, which relates also to the case of auto-generators having a constant or substantially constant stroke of the piston and a pressure variable with a ratio of compression substantially constant by means of the variation of the feed pressure of the compressor element, I provide before the suction of said compressor element, a pre-chamber in which the pressure is kept substantially constant between two successive suction strokes.

According to still another feature of the present invention, relating to auto-generators of the

type above referred to in which the return stroke is ensured by an additional source of energy, I vary the energy of said source as a function of the temperature of the combustion supporting air.

Other features of the present invention will result from the following detailed description of some specific embodiments thereof.

Preferred embodiments of the present invention will be hereinafter described, with reference to the accompanying drawing, given merely by way of example and in which:

Fig. 1 is a diagrammatic sectional view of a plant including a compressed gas generator having a given stroke, with pre-heating of the feed air, according to the invention;

Fig. 2 diagrammatically shows, in section a compressed gas generator with free pistons, also fitted with means for pre-heating the feed air prior to its ingress into the motor cylinder;

Fig. 3 is a detail view of the auto-generator according to Fig. 2;

Fig. 4 is a diagrammatical view of a plant including a compressed gas generator with free pistons, of the variable suction type, made according to the present invention;

Fig. 5 is a sectional view of a modification of the device for adjusting the feed pressure of the compressor element which is a part of the auto-generator of Fig. 4;

Fig. 6 is a diagrammatic sectional view of a compressed gas generator with free pistons, including means for accumulating the energy for returning the pistons back into initial position, this energy being variable in an automatic manner as a function of the temperature of the air for supercharging the motor element.

In Fig. 1, I have shown a hot and compressed gas auto-generator the pistons of which have a stroke of invariable length.

In such an auto-generator, the ignition of the fuel introduced into the motor element of said generator depends essentially upon the ratio of compression existing between the feed pressure of the compressor element, on the one hand, and the final pressure of the motor element, on the other hand, and also upon the thermic state of the machine.

When use is made of an auto-generator in which the piston strokes are constant or substantially so, this ratio of pressures depends essentially upon the output pressure of said generator, this last mentioned pressure determining the discharge pressure of the compressor element and, consequently, the ratio of compression be-

tween the phases of said element, provided that the suction pressure of said element remains substantially constant. As a rule, the ratio of compression existing between the suction pressure of the compressor element and the final pressure of the motor compression ensures, under quite satisfactory conditions, the combustion of the fuel introduced into the engine cylinder when the output pressure of the auto-generator has its normal or its maximum value, and when, in addition, the machine has reached its normal thermic state.

But the temperature necessary for the ignition and the satisfactory combustion of the fuel is no longer obtained when the generator is working under low load or when the output pressure of the auto-generator is lower than its normal output pressure and chiefly during starting conditions where not only the pressures are low but also the machine is cold.

The generator shown by way of example by Fig. 1 includes a motor piston 1, working in a motor cylinder 2, having a fuel injection nozzle 21, and a compressor piston 3, working in a compressor cylinder 4, the two pistons 1 and 3 being coupled with a crank-shaft 5. The motor cylinder 2 is scavenged and fed with compressed air from the compressor cylinder 4. For this purpose, the motor and compressor cylinders are fitted with distribution means consisting, respectively, concerning motor cylinder 2, of an inlet valve 6 and exhaust ports 7, uncovered near the end of the motive stroke by piston 1 and, concerning compressor cylinder 4, of inlet valve 8 and exhaust valve 9.

According to the present invention, the suction conduit 10 of the compressor element is placed in communication with a chamber 11 in which fuel introduced through burners 12 can be burned.

Preferably, the amount of fuel burned in preheating chamber 11 is caused to depend upon the one of the working pressures of the generator, for instance the exhaust pressure of the motor cylinder 2. In order to obtain this adjustment, it is possible, as shown by the drawing, to couple, with a piston 13 on which said output pressure is caused to act, the adjustment member, such as a slide-valve 14 which permits, according to its position, therefore according to the pressure existing in the conduit 7' through which the motive gases are fed, of feeding a variable number of burners.

When starting the system, when the supercharge pressure is minimum and when the machine is cold, the maximum pre-heating of the air that is sucked in is ensured so as thus to obtain, at the end of the compression stroke of piston 1, a temperature such that the combustion supporting air introduced together with the fuel, for instance by means of an injector, is quickly and fully burned. As the output pressure of the auto-generator increases, the number of burners in service decreases and when the machine is working with full load it can suck in atmospheric air without any preheating.

In the device illustrated by Fig. 1, I have provided still other means for obtaining the preheating of the air sucked in by the compressor when the generator, after having been started, works under a load lower than the normal load. These last mentioned means can act simultaneously with said burners, or they may be substituted for said burners once the starting of the machine is obtained.

These last mentioned means mix with the

atmospheric air sucked in by the compressor cylinder a variable amount of exhaust gas issuing from the receiving machine, such as turbine 15, fed by the motor gases escaping from motor cylinder 2, and this, for instance, through the automatic operation of a two-way cock 16 coupled with a member sensitive to one of the working pressures of the machine, such as a piston 13' on which the discharge pressure of the generator acts in such manner that, when the pressure increases, the ratio of the weight of exhaust gas in the sucked in air decreases.

It is thus possible, by varying the preheating effect in accordance with the discharge pressure of the generator, to ensure its operation for all working pressures and in particular during the starting period.

According to an advantageous embodiment of the invention, it is, for instance, possible, to dimension the clearance space of the motor cylinder with comparison with the volume thereof in such manner that, for a supercharging pressure corresponding to the maximum load, for instance for a supercharging pressure of 4 kilograms per square centimeter, the final motor-compression pressure is that which corresponds with the best possible efficiency. This final pressure being, for instance 55 kilograms per square centimeter. Now, when the load is low (for instance with a supercharging pressure of 1.5 kilogram per square centimeter) the final compression pressure is only 27 kilograms per square centimeter, but a preheating of the sucked in air of 50° permits of reaching, at the end of the motor compression, a temperature of 550° C., sufficient for ensuring ignition of the fuel.

In the example of Fig. 1, the air is preheated before passing through the compressor cylinder, but in many cases it is preferable to heat this air after it has passed through the compressor cylinder and such an arrangement is shown by Fig. 4. In this case, the burners 17 are arranged in the wall of the intermediate reservoir 29. In this arrangement, said burners are controlled in an automatic manner, as a function of the output pressure of the auto-generator.

The means for pre-heating the combustion supporting air, shown by Fig. 1, can also be applied to the case of generators having free pistons, the lower end of the stroke of which is either fixed or variable. In the first case, it is as well the reduction of the ratio of the suction pressure (supposed to be substantially constant) of the compressor element, on the one hand, and the final pressure of the motor compression, on the other hand, as the cold state of the machine at the time of its starting, which necessitate the preheating of the combustion supporting air, whereas, in the second case (lower end of the stroke variable as a function of the discharge pressure) it is only the cold state of the machine during the starting period which constitutes the reason for the pre-heating of the combustion supporting air. It is therefore necessary differently to adjust, in these two cases respectively, the amount of heat introduced into the combustion supporting air.

Figs. 2 and 3 show an embodiment of the invention which has all the advantages above indicated and also other advantages which will be hereinafter more fully set forth.

It is known that, in existing auto-generators, the ratio of the weight of the fuel and of the weight of combustion supporting air increases when the load decreases due to the considerable

excess of scavenging air to be compressed for low values of the load. Likewise, the considerable excess of scavenging air decreases, in a manner which is sometimes very disturbing, the temperature of the motor gases escaping from the motor cylinder.

These drawbacks of known generators, which therefore involve a low efficiency, are avoided by making use of a generator as shown by Figs. 2 and 3.

In this arrangement, I withdraw, at low values of the load, a portion of the gases produced by the motor cylinder of the generator for mixing it with the scavenging air of said motor cylinder.

This is why I provide, for instance, in the wall of motor cylinder 19, provided with inlet apertures 20 and outlet apertures 21, a supplementary aperture 22 serving to the exhaust and so located that this last mentioned aperture is uncovered by the motor piston 23, belonging, in the embodiment of Figs. 2 and 3 to a free piston, before the latter uncovers the ordinary exhaust apertures 21. The aperture 22 is provided with a regulating member 24, for instance a slide-valve, which is connected with a regulating piston 25 responsive to the variations of discharge pressure of the motor cylinder of the auto-generator, for example. I provide behind slide valve 24 a chamber 26 connected through conduit 27 (which contains a check valve 28) with the intermediate reservoir 29 of the auto-generator. This reservoir 29 is fed through the compressor element of the generator, which element is constituted, in the embodiment shown by Figs. 2 and 3, by a compressor cylinder 30 fitted with inlet and discharge valves 31, 32, respectively, and by a compressor piston 33, which is also a part of the free piston of the machine.

The pre-heating of the combustion supporting air which is present in reservoir 29 by means of motor gases withdrawn from the motor cylinder has for its effect that the temperature, necessary for the ignition of the fuel fed into the motor cylinder, is already reached owing to the fact that the return stroke is shorter, for the motor piston, than when there is no pre-heating of the combustion supporting air. Owing to this shortening of the return stroke of the free piston, I obtain a reduction of the amount of air sucked in into the compressor cylinder, therefore a reduction of the compression work to be performed in the compressor cylinder, and, consequently, an improvement of the power per unit of mass of the generator and a rise of the temperature of the motor gas escaping through conduit 34. Furthermore, the fact that I mix with the combustion supporting air a certain amount of combustion gas improves the conditions of combustion in the motor cylinder.

The step of withdrawing, as above described, a portion of the combustion gases is applicable as well to machines having a variable piston stroke as to machines having a fixed piston stroke.

Fig. 4 shows an auto-generator of the free piston type in which means are provided for varying, during the starting period and for low values of the load of the machine, the feed pressure of the compressor cylinder, whereby the ratio of said feed pressure on the one hand and the final pressure of compression in the motor, on the other hand, remains substantially constant. In such a machine, the pre-heating of the combustion supporting air according to the invention is exclusively intended to compensate for the loss of heat, especially through the walls of the machine,

which occurs when the machine has not yet reached these normal thermic conditions, and especially during the starting period.

According to the invention, cooling of the combustion supporting air can be avoided either by pre-heating the combustion supporting air by means of burners 17, arranged as above explained on intermediate reservoir 20, and controlled by rod 60 sliding in conduit 61 and connected to piston 62 acted on through pipe 63 by the outlet pressure in pipe 34. Cooling of the combustion supporting air can also be avoided by circulating, in the water jacket 77 of the motor cylinder and/or in the water jacket 73 of the compressor cylinder, a hot fluid, such as hot water. This water may be heated in reservoir 79 connected in the cooling circuit by burners 80. Pump 70 through conduit 71 feeds this hot water through reservoir 79 and the cooling system; namely, through pipe 72 to jacket 73 with return through pipe 75 to the pump 70 and reservoir 79; and by branch pipe 76 to jacket 77 with return through pipe 78 to pipe 75.

I may also preheat the feed air by causing it to circulate in a heated pre-chamber 35, the heating of said chamber being obtained for instance by means of a jacket 67 through which circulates a hot fluid, which may be constituted by at least a portion of the exhaust gases. For example, an outlet 34 may feed a turbine 64 having exhaust outlet 65. Part of the exhaust gas from outlet 65 passes through pipe 66 controlled by valve 69 to jacket 67 of chamber 35, and heats the air in the chamber discharging through pipe 68.

In the case of machines as shown by Fig. 4, the condition of maintaining the compression ratio in the compressor and in the motor at a constant value makes it necessary, when working with reduced loads, to feed the compressor in depression, that is to say with a feed pressure lower than atmospheric pressure. For this purpose, the compressor is fed, not directly from the atmosphere, but from vessels 35 in which there is a certain degree of vacuum.

This method of regulation by variation of the feed pressure generally involves a considerable reduction of the efficiency, especially when working with small loads, which reduction of efficiency is chiefly due to the fact that the preliminary wire-drawing of the feed air absorbs a considerable amount of work.

According to the invention, at least a portion of this work is recovered by transforming into mechanical energy at least a portion of the energy brought into play by the preliminary drop of pressure.

For this purpose, I interpose, before the suction chamber, a turbine 36 in which the sucked in air expands substantially either according to an adiabatic line (if, in this case, care is taken to compensate for the correlative drop of the temperature by a heating of the feed air) or according to an isothermic line, the preheating then taking place in the turbine itself.

During the starting period, chamber 35 is to be brought to a pressure lower than atmospheric pressure, for instance by means of a vacuum pump 37. When working, the depression in chamber 35 may be regulated by acting on the feed of the turbine, for instance by means of a valve 38.

In any case, and whatever be the member employed for placing chamber 35 under vacuum, the expansion of the feed air, whether it produces an external work or not, must not lower the tem-

perature substantially below the temperature of the surrounding atmosphere, and this whatever be the degree of vacuum.

According to a modification of the generator shown by Fig. 4, I cause the depression or vacuum in pre-chamber 35 to be substantially held between two successive suction strokes of the compressor piston. This modification is shown by Fig. 5, in which the element, which produces the drop of pressure in the sucked in air, is constituted for instance by a valve 39 with alternating control means such that it opens by the desired amount only during the time of suction of the compressor element 30.

For this purpose, it is possible to control valve 39, as shown by Fig. 5, through the very pressure existing in chamber 35 for instance, as shown, by means of a deformable box 40, subjected, in addition to the opposing actions of the external pressure and of the pressure of chamber 35, to the action of a spring 41 the tension of which is adjustable, for instance by means of a cam 42. This cam 42 is actuated by means of a lever 43, controlled for example automatically by the governor of the turbine, so as thus to vary the pressure in chamber 35. As shown, turbine 64 drives a shaft on which is mounted a governor 84, which through bell crank lever 85, rod 83, bell crank lever 82 and rod 81 turns lever 43 rigid on shaft 43¹ of cams 42. Valve 39 is connected to box 40 by means of a rod 44. Advantageously, I further provide locking means 45 varied by a hinge pivot 46 and adapted to permit of locking the register in its closing position.

The device shown by Fig. 5 works in the following manner:

Valve 39 remains closed as long as there exists inside chamber 35 a pressure higher than that determined by the position of cam 42. Only when the pressure in chamber 35 drops below the pressure determined by cam 42 does the atmospheric pressure, acting on the bottom of deformable box 40, produce the opening of valve 39 against the action of spring 41.

Generally, before starting the machine, I produce, by means of pump 37, on the inside of chamber 35, a suction corresponding to the position of cam 42. After the starting of the machine, the suction in the compressor element produces the opening of the inlet valves 31 in such manner that the pressure of chamber 35 drops slightly below the pressure determined by the position of cam 42. It follows that valve 39 opens so as to keep in chamber 35, during the suction, the desired degree of vacuum. The suction finished, valve 39 closes at least partly in such manner that the suction in chamber 35 is practically maintained until the next suction stroke takes place. The compressor element therefore sucks in from a chamber in which there is always a predetermined degree of vacuum, this degree being variable and adjustable by means of cam 42 as a function of the speed, and therefore of the load of the turbine.

Before starting, while the suction is being created by means of pump 37, valve 39 is kept in the closed position by means of locking device 45.

Finally, Fig. 6 shows another modification of the auto-generator illustrated by Fig. 4. According to this embodiment, instead of preheating the combustion supporting air or simultaneously with this preheating, I act, as a function of at least one of the temperatures of the machine, for instance the temperature of the combustion supporting air in intermediate reservoir 29, on the

return energy accumulated in a pneumatic energy accumulator 47, which maintains a reduced pressure on the rear face of the piston, thus ensuring the return of free piston 23, 33 to its inner stroke end. Supposing, for instance, as shown by said Fig. 6, that the pneumatic energy accumulator 47 is disposed in the compressor cylinder and limited by the non-active face of the compressor piston 33, so as to act by suction during the return stroke of the piston system, it is possible to vary the energy of this cushion and, consequently, the energy which ensures the return of said system, as a function of the temperature, by placing chambers 30 and 47 in communication, for instance through a valve 48 the opening and/or the closing of which depends upon the temperature existing in reservoir 29. For this purpose, it is, for instance, possible to open valve 48, close to the inward end of the stroke, by contact against an abutment 49 the position of which depends upon the temperature of reservoir 29. For instance, this abutment 49 is subjected to the action of a sliding cam 50 connected with a thermostat 51 arranged in reservoir 29. With such a device, if the temperature rises, valve 48 is opened earlier and closed later and, consequently, the energy stored up in accumulator 47 decreases.

The communication, opened, for each cycle, at the end of the suction stroke of the compressor cylinder, between chambers 30 and 47 further has for its effect to render the feed pressure of energy accumulator 47 proportional to the variable pressures of the generator.

Anyway, whatever be the particular embodiment that is chosen, I always obtain an auto-generator in which ignition and quick and complete combustion of the fuel are obtained in a reliable manner, as well when working with full load as when working with small loads and during the starting period.

In a general manner, while I have, in the above description, disclosed what I deem to be practical and efficient embodiments of the present invention, it should be well understood that I do not wish to be limited thereto as there might be changes made in the arrangement, disposition, and form of the parts without departing from the principle of the present invention as comprehended within the scope of the appended claims.

What I claim is:

1. A hot and compressed gas auto generator which comprises, in combination, at least one motor element and at least one compressor element driven by said motor element each having a variable output pressure, means for interconnecting said two elements so that the mechanical work of the motor element is absorbed by the compressor element, said motor element having gas outlet means, means for feeding through said motor element to said gas outlet at least a part of the air fed by said compressor element for scavenging and supercharging said motor element to support combustion therein, means for preheating the combustion supporting air fed to said motor element, and means responsive to variations in the pressure of gas in the auto-generator for controlling said last mentioned means automatically to decrease the preheating as such pressure increases.

2. A generator according to claim 1 in which said preheating means include at least one means for burning fuel in combustion supporting air on its way toward said compressor element.

3. A generator according to claim 1 in which said preheating means include a plurality of

burners for burning fuel in combustion supporting air on its way toward said compressor element, and means responsive to changes in a gas pressure which varies in accordance with the value of the load of the generator for controlling the number of burners in action.

4. A generator of the type described, which comprises, in combination, at least one motor element and at least one compressor element driven by said motor element each having a variable output pressure, means for interconnecting said two elements so that the mechanical work of said motor element is absorbed by said compressor element, means for feeding through said motor element to said gas outlet at least a part of the air fed by said compressor element for scavenging and supercharging said motor element to support combustion therein, means for mixing at least a part of the combustion gases with the combustion supporting air of the motor element on its way toward said motor element, when starting said generator or operating it with a small load, and means responsive to variations of the pressure of gas in the auto-generator for controlling said last mentioned means automatically to reduce the amount of combustion gases so mixed as the pressure increases.

5. A system according to claim 4 further including a receiver machine operated by said generator, the combustion gases introduced into the combustion supporting air on its way toward said motor element coming from said receiver machine.

6. In combination, a hot and compressed gas generator including at least one motor element and at least one compressor element driven by said motor element each having a variable output pressure, means for interconnecting said two elements so that the mechanical work of the motor element is absorbed by the compressor element, said motor element having gas outlet means, means for feeding through said motor element to said gas outlet at least a part of the air fed by said compressor element for scavenging and supercharging said motor element to support combustion therein, a receiver machine fed by said generator, an intake conduit for said compressor element, means to conduct exhaust gases from said receiving machine to said intake conduit, valve means in said conduit responsive to variations of the output pressure of said auto-generator for controlling the flow to said compressor element of the exhaust gases from said receiver machine, and means operative by said valve means for simultaneously controlling, in opposed relation a direct communication between the intake conduit of the compressor element and the atmosphere.

7. A generator plant according to claim 6 having means for heating the combustion supporting air fed to motor element including burners mounted across the path of the exhaust gases from the receiver machine toward the intake conduit of said compressor element, and means operative in response to the output pressure of said

generator for controlling the amount of fuel supplied to said burners.

8. A generator of the type described, which comprises, in combination, at least one motor element and at least one compressor element driven by said motor element each having a variable output pressure, means for interconnecting said two elements so that the mechanical work of said motor element is absorbed by said compressor element, said motor element having gas outlet means, means for feeding through said motor element to said gas outlet at least a part of the air fed by said compressor element for scavenging and supercharging said motor element to support combustion therein, means for withdrawing at least a part of the combustion gases of said motor element and mixing them with the combustion supporting air under pressure for said motor element, and means to render said last mentioned means operative only during the starting period and when the generator is working with small load.

9. A hot and compressed gas auto-generator which comprises, in combination, at least one motor element and at least one compressor element driven by said motor element each having a variable output pressure, means for interconnecting said two elements so that the mechanical work of the motor element is absorbed by the compressor element, said motor element having gas outlet means, means for feeding through said motor element to said gas outlet at least a part of the air fed by said compressor element for scavenging and supercharging said motor element to support combustion therein, energy receiving means for subjecting the air sucked in by said compressor element to a preliminary expansion and means responsive to variations in the output pressure to control said means to vary the degree of such expansion upon variations in the output pressure.

10. A hot and compressed gas auto-generator which comprises, in combination, at least one motor element and at least one compressor element driven by said motor element each having a variable output pressure, means for interconnecting said two elements so that the mechanical work of the motor element is absorbed by the compressor element, said motor element having gas outlet means, means for feeding through said motor element to said gas outlet at least a part of the air fed by said compressor element for scavenging and supercharging said motor element to support combustion therein, means for subjecting the air sucked in by said compressor element to a preliminary expansion, and a pre-chamber interposed between said expansion means and said compressor element adapted to keep the expansion pressure at a substantially constant value.

11. A generator according to claim 10 further including an auxiliary pump connected with said prechamber for producing a given suction therein before the starting of the machine.

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