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REGULATING DEVICE FOR A FREE PISTON GAS  
GENERATOR-TURBINE RECEIVER SYSTEM

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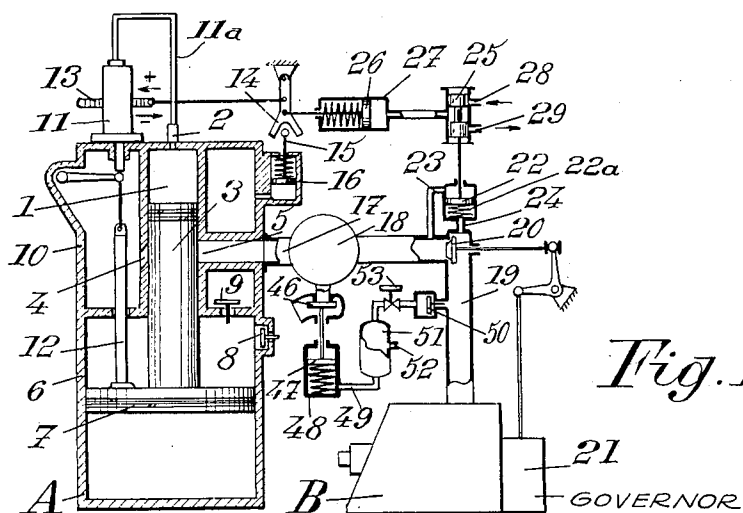


*Fig. 1.*

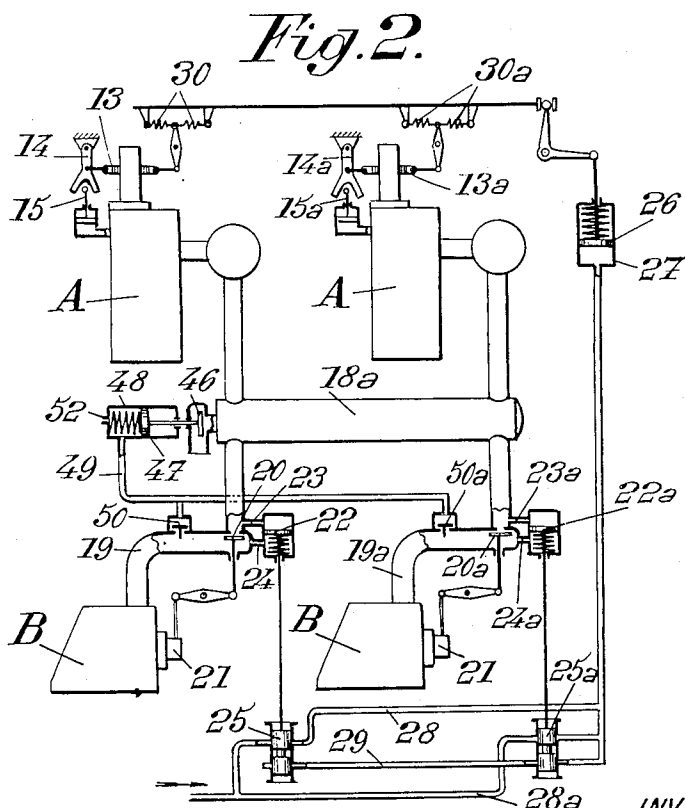


*Fig. 2.*

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## REGULATING DEVICE FOR A FREE PISTON GAS GENERATOR-TURBINE RECEIVER SYSTEM

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10 Claims. (Cl. 60—13)

The present invention is relative to improvements in regulating devices for systems including at least one machine for delivering gas under pressure and at least one receiver machine driven by said gas and it is more particularly but not exclusively concerned with systems of this kind in which the receiver machine or machines is, or are, constituted by a turbine, or turbines, and with systems in which the machine, or machines, for delivering gas under pressure is, or are, constituted by a free piston machine, or free piston machines, working either as free piston motor compressors or as free piston auto-generators.

As it is known, motor compressors are machines including a power portion in the form of an internal combustion engine and a compressor portion and which deliver air under pressure to the outside, whereas auto-generators are machines which also include a power portion of the internal combustion type and a compressor portion and which deliver to the outside, through exhaust ports of the power cylinder of the power portion, a hot gaseous mixture under pressure constituted by the incompletely expanded combustion gases of this power portion and by air under pressure compressed by the compressor portion, which latter portion supplies said power cylinder with at least most of the air under pressure compressed by said power portion.

The object of my invention is to provide a system of the kind above described which is better adapted to meet the requirements of practice than those existing at this time and in particular which is such that regulation is smoother and more progressive, while adapting itself also to sudden variations of power.

According to a main feature of my invention, I provide, in the conduit which connects the gas delivering machine with the receiver machine, and upstream of the latter, an adjustable gas flow throttling device, and I control the amount of fuel fed to the gas delivering machine in accordance with the position of said throttling device to obtain a substantially constant pressure drop past said throttling device.

Other features of my invention will become apparent in the course of the following detailed description of some preferred embodiments of my invention with reference to the accompanying drawings, given merely by way of example, and in which:

Figs. 1 to 4 show each a system according to one embodiment of my invention, respectively.

The auto-generator or motor generator belonging to the system according to my invention may be provided either with a simple piston or with opposed pistons. By way of example, Fig. 1 shows, in axial section, an auto-generator including a power portion which works on a two-stroke Diesel cycle, this power portion comprising a power cylinder 1, a fuel injector 2, a power piston 3, air inlet ports 4 and exhaust ports 5.

This auto-generator further includes a compressor portion constituted by a compressor cylinder 6, a compressor piston 7 rigid with the power piston 3, an intake

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valve 8 and a delivery valve 9. These valves are mounted in the portion of compressor cylinder 6 which is located on the inner side of piston 7 and which therefore constitutes the compressor cylinder proper. On the other hand, the chamber formed in cylinder 6 which is located on the outer side of piston 7 constitutes, in the known manner, a cushion serving to store up energy supplied by the power portion during the outward stroke of parts 3-7, and to give up this energy back to said parts when they are moving inwardly, the compression of air in the compressor cylinder proper and also in the power cylinder 1 taking place during this last mentioned movement.

The air delivered during the inward stroke of the pistons through delivery valve 9 is stored up in casing 10, which surrounds the power cylinder 1 and this compressed air enters said power cylinder when the inlet ports 4 are opened by power piston 3.

Fuel injector 2 is fed through a conduit 11a from a fuel pump 11 driven by the movable elements 3-7 through a rod 12 and a link system which connects this rod with the piston of the pump. The amount of fuel which is injected into the power cylinder on every oscillation of the movable system 1-7 depends upon the position of an adjustment rack 13 the displacement of which rotates the pump piston about its axis, in a known manner. The adjustment displacements of rack 13 are limited, also in a known fashion, by a cam 14 provided with a double active surface which cooperates with an abutment 15 mounted on a piston 16 the position of which depends upon the pressure existing in casing 10, which pressure, as a matter of fact, is practically equal to the pressure with which the power gases, constituted by a mixture of incompletely expanded combustion gases and of the excess of air under pressure fed to the power cylinder, escape from the auto-generator through port 5.

The system may include one or several auto-generators each of which is designated, in the drawings, by A. The power gases from this part of the system are fed to the inlet of one or several turbines B. The system illustrated by Fig. 1 includes only one generator A and one turbine B, whereas Figs. 2, 3 and 4 show systems including each several auto-generators, for instance two, and several turbines, for instance two. However, it should be well understood that the number of generators may be different from the number of receiver turbines.

The delivery of each of the auto-generators is connected with the intake of the turbine or turbines through a conduit 17 which conveys the gases into a reservoir 18, from which said gases are fed to the turbine or turbines, through conduit or conduits 19.

In the gas circuit 17-18-19, upstream of turbine B, and preferably in conduit 19, there is provided a gas stream throttling device the position of which determines the amount of power gases fed to the turbine.

According to the main feature of my invention, the position of the fuel adjusting element 13 of the auto-generator A or of each of the auto-generators A is controlled in response to displacements of the active element of this throttling device 20, which may be constituted by a mere valve, so as to maintain, for all loads, at least during normal operation of the system, a substantially constant and relatively low pressure drop (ranging from 0.05 to 0.1 kilogram per sq. cm.) past said throttling device.

This result may be obtained in various ways. In particular, I may either control immediately in accordance with the position of the throttling element a device for actuating the fuel adjustment element 13, or exert this controlling action indirectly in accordance with said position of the throttling element, for instance by making use of the variations of the difference between the gas

pressures upstream and downstream of the throttling element respectively. This second method is that applied in the embodiments of Figs. 1, 2 and 4, while the embodiment of Fig. 3 corresponds to the first mentioned method.

Furthermore, the throttling element itself may be controlled either by the man in charge of the system or automatically, for instance in accordance with the speed of revolution of the turbine or with another factor variable as a function of the load of this turbine.

In the plant illustrated by Fig. 1, and which includes only one auto-generator A and one turbine B, the throttling element 20 is controlled by a speed governor 21 driven by turbine B. The effect of a modification of the position of element 20 upon the fuel adjustment element 13 is such that, when, due to an increase of the speed of the turbine, the throttling passage is reduced by valve 20, adjustment element 13 is moved in such manner as to reduce the rate of injection of fuel to the auto-generator. The consequence of this is to reduce the amount and pressure of the gases delivered by the generator whereby, despite the reduction of the throttling passage area, the drop of pressure due to this throttling remains practically constant.

In the system illustrated by Fig. 1, the difference between the pressures existing upstream and downstream of the throttling element acts upon a piston 22 subjected on one side to the pressure existing upstream of element 20 and which is fed to said piston through a conduit 23, whereas the pressure existing downstream of element 20 is transmitted to the other side of piston 22 through a conduit 24. This last mentioned side of piston 22 is also subjected to the action of a spring 22a which, for a predetermined difference between the pressures existing respectively upstream and downstream of part 20, keeps piston 22 in a given position such that pilot valve 25, connected with piston 22, cuts off the inflow and outflow of a driving fluid, for instance oil under pressure, which acts upon a piston 26 of a servomotor to actuate adjustment element 13.

Slide valve 25, once moved out of its neutral position shown by Fig. 1, places the inside of cylinder 27, in which piston 26 is movable, in communication either with the oil inflow conduit 28 or with the oil outflow conduit 29, thus varying the rate of feed of fuel every time piston 22 moves in one direction or the other from its position of rest.

In the systems illustrated by Figs. 2, 3 and 4, the several auto-generators A, the regulating racks 13, 13a of which are controlled by the same device, supply power gases, through a main reservoir 18a, to several turbines B each of which is fitted, in its conduit 19, 19a, with a throttling element 20, 20a the position of which depends upon the charge of the corresponding turbine. With such an arrangement, it is advantageous to arrange the means which control the displacements of the regulating racks 13, 13a of generators A in accordance with the positions of the throttling elements in such manner that:

the fuel injection to these generators is increased as soon as the throttling element of only one turbine is moved to open substantially the passage through its conduit 19, 19a, that is to say when this turbine is insufficiently fed with gas for the load applied thereto, whereas

a reduction of the amount of fuel introduced into the various generators A takes place only when the throttling elements of all the turbines reduce the total passage to these turbines to a predetermined value for which there is a high rate of throttling.

Accordingly, in the system illustrated by Fig. 2, conduits 28, 28a which feed the driving fluid under pressure to cylinder 27 (in which the control piston 26 is fitted) are disposed in parallel so that every slide valve 25, 25a can open the corresponding conduit 28, 28a and thus cause an increase of the fuel injection to the generators when there is an increase of the load applied

to the turbine corresponding to this slide valve. On the contrary, the whole of the slide valves 25, 25a controls, for the outflow from cylinder 27 of the driving fluid under pressure, a single conduit 29 on which all the slide valves are mounted in series. Therefore, it is only when all the slide valves open simultaneously conduit 29 that a portion of the fluid under pressure acting upon piston 26 can escape through this conduit 29.

In the system of Fig. 2, the means for controlling each of the throttling elements and the means which control the respective pilot valves 25, 25a, in accordance with the position of the corresponding throttling elements are analogous to those shown in Fig. 1.

Concerning the means for connecting piston 26 and the respective regulating racks 13, 13a, said means include, for every regulating rack, resilient transmissions, such as springs 30, which prevent said connecting means from being injured when one of the regulating racks 13 is blocked in its displacements by the application of cam 14 against the abutment 15 of the corresponding auto-generator.

The arrangement of Fig. 3 corresponds substantially to that of Fig. 2 with the difference that the throttling elements 20, 20a are actuated by the man in charge of the system through hand wheels 31, 31a, respectively, and that every throttling element 20, 20a is connected with an electric switch 32, 32a, preferably through elastic means, such as a spring *r*. Switches 32, 32a are inserted in two electric circuits 33 and 34 arranged to cause an electric motor 35 to run in one direction or the other according as one or the other of these circuits is closed. Circuit 33, which, when it is closed, causes motor 35 to run in the direction which reduces the amount of fuel injected into the generators, is such that switches 32 and 32a are in series therein, so that this circuit 33 is closed only when both of the switches 32 and 32a have their movable elements moved upwardly. On the contrary, circuit 32 includes two branches 34a and 34b each inserted between the common source of current and one of said switches so that it suffices to have the movable element of one of the switches 32 and 32a moved downwardly to close this circuit 34, which then causes motor 35 to run in the direction which increases the amount of fuel injected to the generators A.

Each of these two circuits 33 and 34 further includes a safety circuit breaker 36, 37, respectively, which is opened when the rod 38, which is moved in one direction or the other by motor 35 to operate regulating racks 13, 13a, reaches either of its extreme positions. For this purpose, rod 38 carries two abutments 39, 40 between which is located the end of a lever 41 mounted pivotable about an axis 42 located between the control rods of circuit-breakers 36, 37. When rod 38 reaches either of said extreme positions, one of these abutments 39, 40 drives lever 41 in one direction or the other, which causes one of the circuit-breakers 36, 37 to be opened.

In the system, shown in Fig. 4, only one of the throttling elements 20, 20a, to wit that which exerts the lowest throttling action and therefore causes the corresponding turbine to be fed with gas at the highest pressure, determines the pressure existing on one of the sides of differential piston 22, which is common to both turbines, the other side of this piston being subjected to the pressure existing in the common reservoir 18a.

For this purpose, the conduit 24a which transmits to one of the sides of piston 22 the pressure existing at the intake of said turbine B includes two branches 43, 43a, each interposed between said conduit 24a and the intake of one of the turbines, at a point located downstream of the corresponding throttling element, each of these branches being provided with a check valve 44, 44a.

Conduit 24a is further provided with a calibrated discharge orifice 45 which makes it possible to adjust the quickness of response of the control device acting upon the regulating racks 13, 13a of auto-generators A.

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It should further be noted that, in the system of Fig. 4, the throttling element of one of the turbines is automatically controlled by the speed governor 21 of this turbine, whereas the throttling element of the other turbine is controlled manually by the operator in charge of the system, by means of a hand-wheel 31a.

According to another feature of my invention, means responsive to variations of the pressure of the power gases downstream of the throttling element or elements are provided for controlling a discharge valve mounted in a chamber, preferably reservoir 18 or 18a containing gas under pressure and located upstream of the throttling element or elements.

Said control means are arranged in such manner that they cause said discharge valve to open when the difference between the respective pressures on the upstream side and the downstream side of the throttling element or (in the case of a system including several such elements) of all the throttling elements exceeds a predetermined value corresponding to normal operation of the system.

In other words, when the throttling element or all the throttling elements exert too great a throttling effect, which means that the production of gas by the generator or generators is too high for the possibility of absorption of the turbine or of the whole of the turbines, the valve above referred to is opened to discharge into the atmosphere the excess of gas supplied by the auto-generator or generators.

In order to avoid too sudden an opening of this discharge valve, which might take place when the charge of the turbine or turbines is suddenly very much reduced, and which might produce perturbations in the adjustment of the generators and even stoppage thereof, I provide, on the pneumatic means for controlling the discharge valve, a buffer tank provided with a calibrated discharge orifice and I interpose a check valve between this tank and the intake of the turbine or turbines. Consequently, if, in the intake conduit of the turbine, due to a sudden drop of the load of this turbine, a quick drop of pressure occurs, corresponding to a practically complete closing of the throttling element, the check valve closes and prevents the buffer tank from emptying with the same speed, since this tank can empty itself to the atmosphere only through the calibrated orifice of small section.

In the systems illustrated by the drawings, the discharge valve above referred to is mounted on reservoir 18 or 18a and it is designated by reference character 46. This valve is actuated by a piston 47 movable in a cylinder 48. This cylinder (Figs. 1, 2 and 3) is connected with the intake conduit 19 or 19a of the turbine (or of each of the turbines) through a conduit 49 provided with the check valve 50 or 50a located at the point where said conduit 49 opens into conduit 19 or 19a. If the volume of cylinder 48 and that of conduit 49 are sufficiently great, they may themselves constitute the above mentioned buffer tank. Otherwise, there is provided a special tank 51 inserted in conduit 49. As for the calibrated discharge orifice, designated by reference number 52, it may be provided either in tank 51 (Figs. 1, 3 and 4) or in cylinder 48 (Fig. 2).

When, due to an abnormally intensive throttling, the difference between the pressures existing in reservoir 18 or 18a and the pressure downstream of each of the throttling valves exceeds a predetermined value, valve 46 opens and a portion of the gases present in said reservoir escapes to the atmosphere. This opening is braked and made progressive as a consequence of the closing of check valve or check valves 50 because the pressure which acts on piston 47 to close valve 46 can then drop but relatively slowly since the gases escape through the small orifice 52.

I may interpose in conduit 49 a valve or cock 53 (Fig. 1). This valve is closed when the system is started so as to reduce the force which tends to close discharge valve 46 during this period and to keep a low pressure of the gases while the turbine is gathering speed. Then, a pro-

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gressive opening of cock 53 makes it possible slowly to increase the pressure of the gases.

In a general manner, while I have, in the above description, disclosed what I deem to be practical and efficient embodiments of my 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 accompanying claims.

What I claim is:

1. A system including at least one machine for supplying gas under pressure and at least one receiver machine to be driven by said gas under pressure, conduit means for connecting the outlet of said gas supplying machine with the inlet of said receiver machine, an adjustable gas throttling device in said conduit means, adjustable means for feeding fuel to said gas supplying machine, a member movable in response to the variations of the difference between the pressures in said conduit means respectively upstream and downstream of said throttling device, and servo-motor means operative by said member for controlling the adjustment of said fuel feeding means to keep the pressure drop past said throttling device small and substantially constant.

2. A system including at least one machine for supplying gas under pressure and at least one receiver machine to be driven by said gas under pressure, conduit means for connecting the outlet of said gas supplying machine with the inlet of said receiver machine, an adjustable gas throttling device in said conduit means, adjustable means for feeding fuel to said gas supplying machine, a member movable in response to the variations of the difference between the pressures in said conduit means respectively upstream and downstream of said throttling device, servo-motor means for adjusting said fuel feeding means, and means operative by said member for controlling said servo-motor means to keep the pressure drop past said throttling device small and substantially constant.

3. A system including at least two machines for supplying gas under pressure and at least two receiver machines to be driven by said gas under pressure, conduit means for connecting the outlet of each of said gas supplying machines with the inlet of one of said receiver machines respectively, an adjustable throttling device in each of said conduit means, adjustable means for feeding fuel to each of said gas supplying machines, a member movable in response to the variations of the difference between the pressures, in each of said conduit means, respectively upstream and downstream of the throttling device located therein, a single hydraulic servo-motor means for adjusting said fuel feeding means, two branch pipes in parallel for the flow of liquid under pressure to said servo-motor means, a pipe for the outflow of liquid under pressure from said servo-motor means, the flow of liquid under pressure through either of the first mentioned branch pipes causing said servo-motor means to increase the fuel feed rate and the outflow of liquid through the second mentioned pipe causing said servo-motor means to reduce the fuel feed rate, and slide valves operative by said members respectively, each of said slide valves being inserted in one of the two branch pipes and in the second mentioned pipe.

4. A system including at least two machines for supplying gas under pressure and at least two receiver machines to be driven by said gas under pressure, conduit means for connecting the outlet of each of said gas supplying machines with the inlet of one of said receiver machines respectively, an adjustable gas throttling device in each of said conduit means, adjustable means for feeding fuel to each of said gas supplying machines, a member movable in response to the variations of the difference between the pressures, in each of said conduit means, respectively upstream and downstream of the throttling

device located therein, a single electric servo-motor for adjusting said fuel feeding means, two electric branch circuits in parallel leading to said motor to drive it in the direction which increases the fuel feed rate, a single electric circuit leading to said motor to drive it in the direction which reduces the fuel feed rate, and switches operative by said members respectively, each of said switches being arranged to open one branch circuit while closing the single circuit or vice versa.

5. A system including at least two machines for supplying gas under pressure and at least two receiver machines to be driven by said gas under pressure, conduit means for connecting the outlet of each of said gas supplying machines with the inlet of one of said receiver machines respectively, said conduit means including a common reservoir, an adjustable gas throttling device in each of said conduit means between said reservoir and each of said receiver machines, adjustable means for feeding fuel to each of said gas supplying machines, a single member movable in response to the variations of the difference between the pressures existing on opposite sides of said member, means for applying to one side of said member the pressure existing in said common reservoir, means for connecting both of said conduit means, downstream of said throttling means with the other side of said member, and a single servo-motor operative by said member for adjusting said fuel feeding means.

6. A system including at least one machine for supplying gas under pressure and at least one receiver machine to be driven by said gas, conduit means for connecting the outlet of said gas supplying machine with the inlet of said receiver machine, a gas throttling device in said conduit means, a discharge valve mounted on a portion of said conduit means upstream of said throttling device for the outflow of gas under pressure therefrom mounted to be urged toward open position by the gas pressure in said portion of said conduit means, a piston rigid with said discharge valve, a cylinder for said piston, and means for connecting said cylinder with the portion of said conduit means downstream of said throttling device to oppose the opening of said discharge valve for opening said discharge valve when the difference between the gas pressures respectively upstream and downstream of said throttling device exceeds a predetermined value.

7. A system according to claim 6 further including, between said cylinder and the portion of said conduit means downstream of said throttling device, a buffer tank provided with a calibrated orifice opening to the atmosphere, and a check valve between said tank and the inlet of said receiver machine mounted to prevent the flow of gas from said receiver machine toward said tank.

8. A system including at least one machine for sup-

plying gas under pressure and at least one receiver machine to be driven by said gas, conduit means for connecting the outlet of said gas supplying machine with the inlet of said receiver machine, and adjustable gas throttling device in said conduit means, adjustable means for feeding fuel to said gas supplying machine, means for adjusting said fuel feeding means in response to variations in the conditions of operation of said gas throttling device, a discharge valve mounted on said conduit means upstream of said throttling device for the outflow of gas under pressure therefrom, and means operative in response to variations of the pressure of the gas downstream of said throttling device for controlling said discharge valve to open said valve when the difference between the gas pressures respectively upstream and downstream of said throttling device exceeds a predetermined value.

9. A system including at least one machine for supplying gas under pressure and at least one receiver machine to be driven by said gas, conduit means for connecting the outlet of said gas supplying machine with the inlet of said receiver machine, an adjustable gas throttling device in said conduit means, adjustable means for feeding fuel to said gas supplying machine, means for adjusting said fuel feeding means in response to variations in the conditions of operation of said gas throttling device, a discharge valve mounted on said conduit means upstream of said throttling device for the outflow of gas under pressure therefrom, and pneumatic means between said discharge valve and the inlet of said receiver machine operative in response to variations of the pressure of the gas downstream of said throttling device for controlling said discharge valve to open said valve when the difference between the gas pressures respectively upstream and downstream of said throttling device exceeds a predetermined value.

10. A system according to claim 9 in which said pneumatic means include a buffer tank provided with a calibrated orifice opening to the atmosphere, and a check valve between said tank and the inlet of said receiver machine mounted to prevent the flow of gas from said receiver machine toward said tank.

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