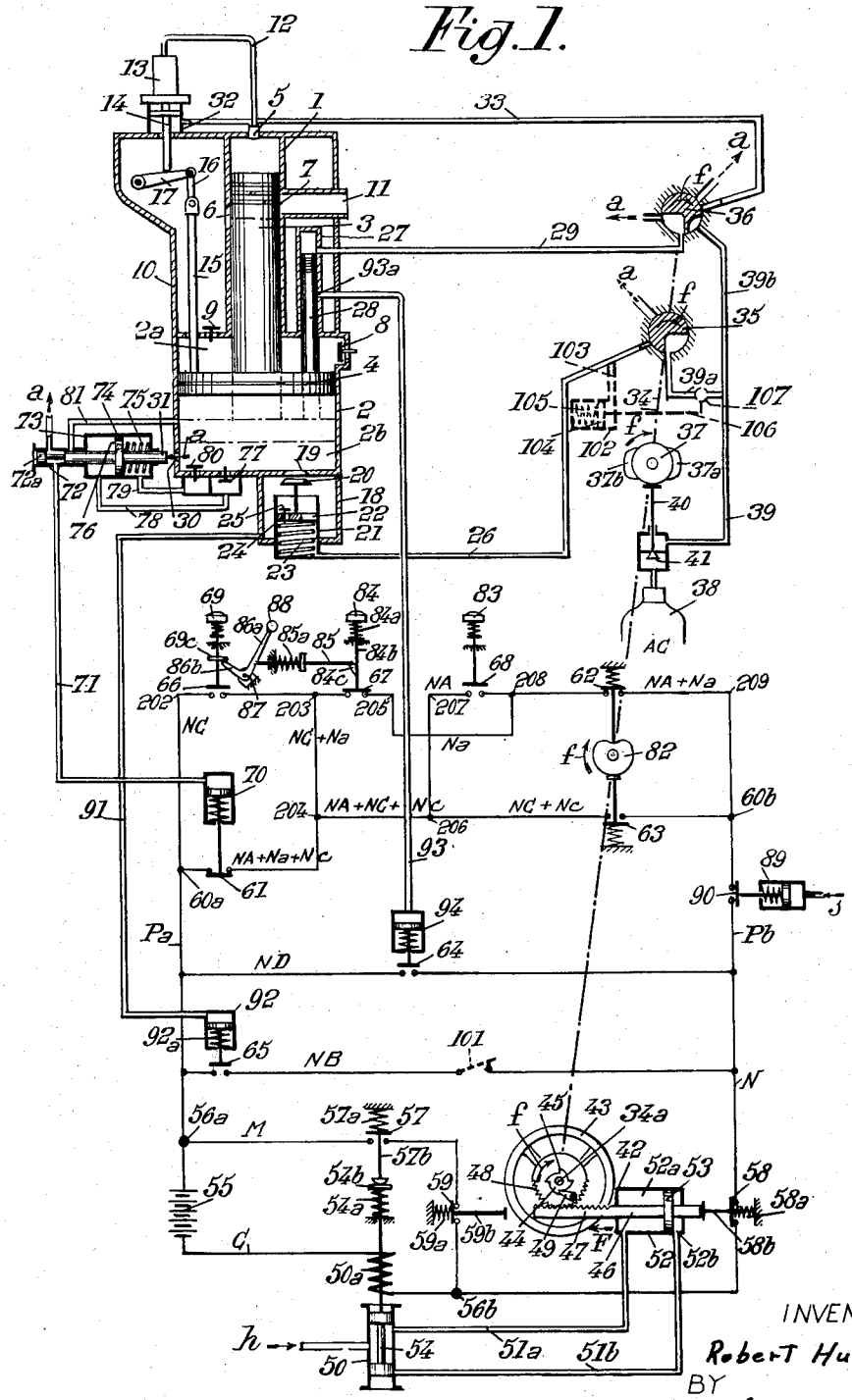
July 4, 1961 R. HUBER 2,990,680

DEVICES FOR STARTING AND STOPPING FREE PISTON MACHINES AND IN PARTICULAR FREE PISTON AUTO-GENERATORS

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Fig. 1.



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Fig. 2.

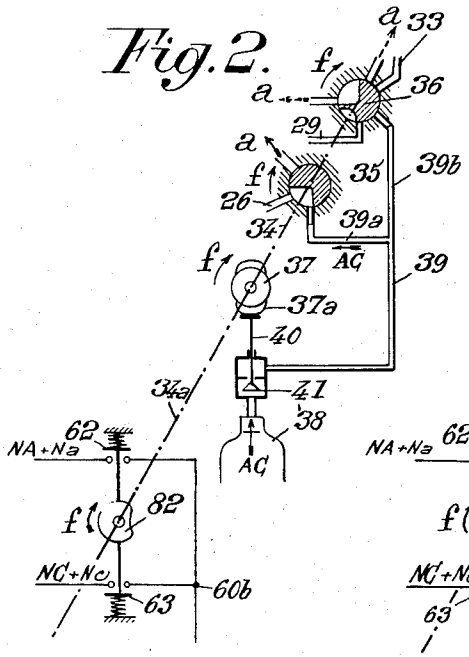


Fig. 3.

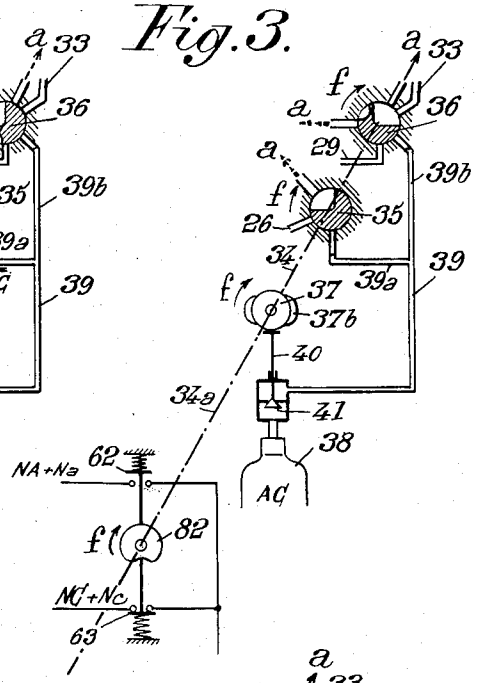
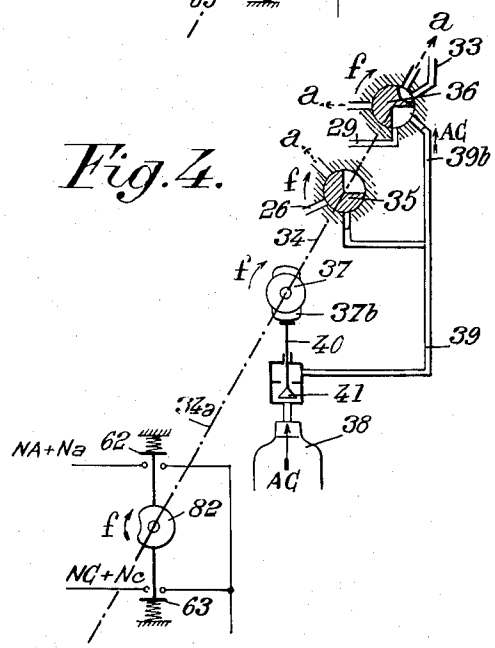


Fig. 4.



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DEVICES FOR STARTING AND STOPPING FREE PISTON MACHINES AND IN PARTICULAR FREE PISTON AUTO-GENERATORS

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6 Claims. (Cl. 60—14)

The present invention relates to devices for starting and stopping free piston machines, this invention being more especially but not exclusively concerned with such devices as applied to free piston auto-generators.

One of the objects of this invention is to obtain, successively, the stopping of the free piston machine and the automatic positioning of the piston unit thereof preparatory to a subsequent starting of the machine, respectively by means of a manual control member and by means of a control member operative by the stopping of the machine, these two control members being mounted in parallel with respect to an actuating mechanism capable, during a first step of its operation, controlled by said manual control member, of causing the machine to stop, and, during a second step, controlled by said second control member, of operating means for resetting the piston unit into position for a subsequent starting of the machine.

According to another object of this invention, in a free piston machine including a control part, for instance a shaft, controlling all the successive operations to be performed to start the engine and, when necessary, to stop it, the manual control member for starting the machine is subjected to the action of locking means operatively connected with said control part and which make said manual control member inoperative for all positions of said part other than that it occupies after the operations preparatory to starting have been performed and the control member for stopping the machine is subjected to the action of locking means operatively connected with said control part and which make said second mentioned control member inoperative for all positions of said control part other than that it occupies when the machine is running.

Other objects and features of my invention will appear more clearly from the following detailed description of an embodiment thereof, with reference to the appended drawings, given merely by way of example and in which:

FIG. 1 diagrammatically shows a free piston auto-generator made according to the present invention.

FIGS. 2, 3 and 4 show, in other relative positions, the means for controlling the starting and stopping of the auto-generator.

The auto-generator includes two coaxial cylinders 1 and 2 rigid with each other. Cylinder 1 is a power cylinder whereas cylinder 2 is both a compressor cylinder (portion 2*a* adjoining cylinder 1) and a return energy accumulator or resilient cushion (portion 2*b*). These two cylinders cooperate with two freely movable pistons rigid with each other, to wit a power piston 3 slidable in power cylinder 1 and a compressor piston 4 slidable in cylinder 2.

Power cylinder 1 is fed with fuel through an injector 5 and it is provided with inlet ports 6 and exhaust ports 7, these ports being controlled by the displacements of piston 3.

The portion 2*a* of cylinder 2 is provided with one or several air intake check valves 8 and with one or several delivery check valves 9 past which compressed air is transferred into an air reservoir 10 forming a casing which surrounds power cylinder 1.

Air is therefore sucked in through intake valve 8 during the outward strokes of pistons 3—4 under the action of the combustion of fuel in cylinder 1, and this air is compressed and delivered into reservoir 10 when pistons 3—4 move in the opposed direction under the action of the energy stored up in accumulator 2*b* during the preceding stroke.

Air compressed in reservoir 10 passes through inlet ports 6 (when they are cleared by piston 3 in the vicinity of its outer dead center position) for scavenging power cylinder 1 and feeding fresh air thereto.

The exhaust ports 7 of power cylinder 1 are connected, through a conduit 11, to a receiver machine (for instance a gas turbine), the gases thus fed through conduit 11 being constituted by a mixture of compressed air (excess of the scavenging air supplied to power cylinder 1) and of combustion gases only partly expanded in power cylinder 1, this mixture being delivered through ports 7 during the period for which these ports are cleared by piston 3.

Injector 5 receives fuel through a conduit 12 from an injection pump 13. This pump includes a cylinder in which reciprocates a piston (not visible) driven by a push-piece 14 which is actuated, from the compressor piston 4, through transmission means including a bar 15, a connecting rod 16 and a lever 17.

For the sake of clarity, I have shown on the drawing an auto-generator having a single set of pistons 3—4 but, for practical purposes, auto-generators generally include two such sets of pistons mounted in opposition, the power elements 3 of these sets of pistons reciprocating in a common power cylinder 1 and the compressor elements 4 reciprocating in two cylinders 2 disposed on either side of power cylinder 1, the two sets of free pistons being connected together through conventional synchronizing means.

In order to start the auto-generator, a starting chamber 18 must first be filled with compressed air, then placed in communication, through an orifice 19 normally closed by a valve 20, with the portion 2*b* of cylinder 2, so as to push pistons 3—4 inwardly.

For this purpose, there is provided in chamber 18 a cylinder 21 in which is slidably fitted a piston 22 rigid with valve 20. Said piston 22 is urged by a spring 23 in the upward direction, where it closes valve 20. The top end of cylinder 20 opens into chamber 18; piston 22 is provided with an orifice 24 extending therethrough and in which is mounted a check valve 25 which closes orifice 24 when the pressure above piston 22 is higher than that below it. Compressed air is fed to the bottom end of cylinder 21 through a conduit 26. This inflow of compressed air has for its effect to open check valve 25 and to fill chamber 18 with compressed air, valve 20 being closed. When conduit 26 is placed in communication with the atmosphere, check valve 25 closes. The pressure existing in chamber 18 pushes piston 22 downwardly, which opens orifice 19 and causes compressed air to pass from chamber 18 into cylinder portion 2*b*.

In order to stop the auto-generator, the injection of fuel by means of pump 13 must be stopped. For this purpose, I fill with compressed air, through a conduit 33, a chamber 32 in which is slidably fitted a piston rigid with the push-piece 14 of pump 13, thus preventing said push-piece from reciprocating. Pistons 3—4 are returned to the starting position (shown in dotted lines on FIG. 1) by feeding compressed gas through a conduit 29 into a cylinder 27 in which is slidably mounted a piston 28 rigid with pistons 3—4. After pistons 3—4 have been brought into starting position, conduit 29 is brought into communication with the atmosphere. In order to facilitate the displacement of pistons 3—4 toward the starting position, the cylinder chamber 2*b* is brought into communication with the atmosphere through an orifice 30, normally

closed by a rod 31 (as explained in detailed fashion hereinafter).

Compressed air is to be fed at suitable times, respectively, to cylinders 21, 27 and 32 through conduits 26, 29 and 33. At other times, these conduits must place their cylinders in communication with the atmosphere. In order to perform these operations, I make use of a distribution system 34 including, keyed on shaft 34*a*, two rotary slide valves 35 and 36 and a cam 37. Cam 37 includes two bosses 37*a* and 37*b* which cooperate with a push-piece 40 controlling a valve 41 which, according as it is closed or opened, places a reservoir 38 of compressed air AC into or out of communication, respectively, with conduit 39. This conduit 39 includes two branches 39*a* and 39*b* which lead, respectively, to the housings of rotary valves 35 and 36. This compressed air AC may be sent, through slide valve 35 and conduit 26, to cylinder 21 and, through slide valve 36 and conduits 29 or 33, respectively, to cylinders 27 or 32. These slide valves 35 and 36 are also adapted to connect conduits 26, 29 and 33 with the atmosphere *a*.

A step by step actuating device 42 is capable of imparting to shaft 34*a* successive rotations of 90° in the direction of arrows *f* (a hand-wheel 43 being further provided to permit of performing the same operations manually, if necessary). This device 42 acts upon a ratchet-wheel 44 (having four teeth 45 at 90° to one another) fixed on shaft 34*a*.

This actuating device 42 includes a reciprocating rod 36 provided, at one end thereof, with a rack 47 meshing with a toothed wheel 48 which carries a pawl 49 adapted to cooperate with ratchet-wheel 44.

Reciprocating rod 46 is carried by a piston 53 slidable in a cylinder 52. Piston 53 devides the inside of said cylinder 52 into two chambers 52*a* and 52*b* adapted to be fed with a fluid under pressure (oil for instance) through conduits 51*a* and 51*b*, respectively. These conduits can be placed, alternately, into communication with a source *h* of said fluid by means of a slide valve 54 movable in a cylindrical casing 50.

Slide valve 54 can be electrically actuated by a winding 50*a* which, when excited, moves said slide valve downwardly. When winding 50*a* is not excited, a spring 54*a*, acting upon the top end 54*b* of a rod rigid with slide valve 54, holds said slide valve in its upper position (shown by FIG. 1). When slide valve 54 is in said position, shown by FIG. 1, the oil under pressure fed to chamber 52*a* brings piston 53 (together with reciprocating rod 46) into its position near the right hand end of cylinder 52, as shown by FIG. 1. When slide valve 54 is moved in the downward direction by the excitation of winding 50*a*, oil under pressure is fed to chamber 52*b* while it escapes from chamber 52*a*, which moves piston 53 and rod 46 toward the left, the total stroke of piston 53 corresponding to a 90° rotation of toothed wheel 48 and therefore of shaft 34*a*.

Winding 50*a*, which controls the position of slide valve 54, may be fed with current from a source 55 (either of direct current, as shown, or of alternating current) through a plurality of circuits all of which have in common, betwen points 56*a* and 56*b*, a circuit portion C including said source 55 and said control winding 50*a*.

One of these circuits, shown at M, includes two contactors, 57 and 59, respectively urged toward circuit closing position by springs 57*a* and 59*a*.

Contactor 57 has its rod 57*b* pushed upwardly by the end 54*b* of the rod rigid with slide valve 54 when said slide valve is in its position of rest (shown by FIG. 1) in which it is yieldingly held by spring 54*a*.

Contactor 59 includes a rod 59*b* arranged to be brought into circuit opening position by reciprocating rod 46 when the latter reaches the end of its movement toward the left.

This circuit portion M is a holding circuit which keeps control winding 50*a* fed with current from source 55 after it has been excited for a short time through another circuit, and this until contactor 59 is brought into circuit opening position by reciprocating rod 46.

Several circuits for exciting winding 50*a* can be made, in combination with circuit portion C, to send current impulses from source 55 to control winding 50*a*. All these circuits include circuit elements Pa and Pb starting respectively from points 56*a* and 56*b* (circuit element Pb includes a contactor 58 urged by a spring 58*a* toward circuit opening position but normally held in circuit closing position by rod 46, bearing, at the end of its movement toward the right, against the rod 58*b* of said contactor, as shown by FIG. 1).

These circuits for exciting control winding 50*a* include respective shunt circuit portions inserted between circuit elements P*a* and P*b*. These shunt circuit portions are:

NB; ND;

NA, starting from point 60*a*, passing at points 204, 206, 207, 208 and 209 and ending at point 60*b*;

N*a*, starting from point 60*a*, passing at points 204, 203, 205, 208 and 209 and ending at point 60*b*;

NC, starting from point 60*a*, passing at points 202, 203, 204 and 206 and ending at point 60*b*; and

N*c*, starting from point 60*a*, passing at points 204 and 206 and ending at point 60*b*.

In FIG. 1, the conductor portions common to several of these shunt circuit portions are designated by the sum of the reference characters designating said shunt circuit portions. For instance, the conductor portion between points 60*a* and 204, which is common to shunt circuit portions NA, N*a* and N*c*, is designated by

"*NA*+*Na*+*Nc*"

Several contactors are provided in said shunt circuit portions to close them in response to variations in the conditions of operation of the machine. These contactors are 61, 62, 63, 64 and 65. Manually operated switches 66, 67 and 68 are also provided to control the machine. The functions of these contactors and switches will be hereinafter described.

Stopping of the auto-generator is obtained (as it will be hereinafter described in detail) by means of push-button 69, which operates switch 66.

Resetting of the parts of the auto-generator into position for starting is achieved automatically by a control device 70 capable of operating contactor 61. This control device 70 is a piston rigid with the movable element of contactor 61 and resiliently urged upwardly by a spring which tends to bring said contactor into contact closing position. This piston 70 is slidable in a cylinder the top end of which can be fed with air under pressure through a conduit 71.

Conduit 71 can be placed by a slide valve 72 in communication either with the atmosphere *a* or with a conduit 81 leading out from the portion 2*b* of cylinder 2 of the auto-generator.

Slide valve 72 is integral with a piston 74 movable in a cylinder 73. Piston 74 is urged toward the left, in said cylinder 73, by a spring 75. The left hand portion of cylinder 73 is in communication, through a conduit 78, with a chamber adapted to communicate, under control of a check valve 77, with the portion 2*b* of cylinder 2, this check valve 77 being mounted to permit only the flow of air from chamber 2*b* toward conduit 78. The right hand portion of cylinder 73 is in communication, through a conduit 79, with a chamber adapted to communicate, under control of a check valve 80, with the portion 2*b* of cylinder 2, this check valve 2*b* being mounted to permit only the flow of air from conduit 79 toward cylinder 2.

A calibrated passage 76, of small cross-section, is provided in piston 74 so as to form a restricted communication between the two chambers of cylinder 73 into which said cylinder is divided by said piston.

Thus, when the auto-generator is running, the pressure in cylinder 73 on the left hand side of piston 74 is substantially equal to the maximum value of the cyclically varying pressure in chamber 2*b* of cylinder 2, whereas the pressure in said cylinder on the right hand side of piston 74 is substantially equal to the minimum value of this cyclically varying pressure and spring 75 is chosen such that it cannot oppose the force exerted on piston 74 by the difference between these pressures so that the rod 31 of this piston is applied against a hole 30 provided in the wall of cylinder chamber 2*b* and stops said hole, whereas conduit 71 is placed by slide valve 72 in communication with conduit 81 and therefore transmits the pressure existing in chamber 2*b* to piston 70 which keeps contactor 61 open.

On the contrary, when the auto-generator is at rest, the respective pressures on opposite sides of piston 74 quickly become equal, due to the communication through passage 76, and spring 75 moves piston 74 toward the left, which causes hole 30 to be opened (so that the pressure in chamber 2*b* drops to atmospheric value) and slide valve 72 to connect conduit 71 with the atmosphere (at *a*), so that contactor 61 is closed.

As soon as the auto-generator is started, the difference of pressure between the opposed faces of piston 74 is quickly established, hole 30 is closed and conduit 71 is once more placed in communication with conduit 81 through which the pressure in cylinder chamber 2*b* is transmitted to piston 70, thus opening contactor 61.

A cam 82 carried by shaft 34*a* is arranged so as to have contactor 62 closed for the position of said shaft shown by FIG. 1 and opened for the three other positions of said shaft, shown by FIGS. 2, 3 and 4. On the other hand, this cam 82 has contactor 63 closed for the position of shaft 34*a* shown by FIG. 3 and opened for the three other positions of said shaft, shown by FIGS. 1, 2 and 4.

A push-button 83 serves, when it is depressed against the action of its return spring, to close switch 68 to start the auto-generator.

Another push-button 84 serves to obtain an automatic restarting of the auto-generator when it has stopped for an accidental reason. When depressed against the action of its return spring 84*a*, this push-button 84 closes switch 67. It is locked in this depressed position by a rod 85 engaging an abutment 84*c* of its rod 84*b* and urged toward locking position by a spring 85*a*. In order to permit of releasing push-button 84 from its depressed position, a lever 86*a* is connected with rod 85 so that when the end 88 of said lever 86*a* is moved toward the left, locking rod 85 is pulled toward the left and retracted from engagement with the abutment 84*c* of push-button 84 which is thus allowed to return into its inoperative upper position.

A push-button 69 serves, when it is depressed against the action of its return spring, to close switch 66 to stop the auto-generator. Of course, when the auto-generator is thus deliberately closed, the automatic restarting push-button 84 must not be left in depressed position if it has been previously brought into this position. This is why the rod of push-button 69 carries a small plate 69*c* adapted to cooperate with a branch 86*b* of lever 86*a* so that, if push-button 84 is in depressed position, the depressing of push-button 69 automatically releases push-button 84 which is then returned by its spring 84*a* into upper position.

Contactor 65, provided in shunt circuit portion NB, is normally held open by a spring 92*a*. It can be closed by the action on a piston rigid therewith and slidable in a cylinder 92, of air under pressure transmitted through conduit 91 from starting chamber 18, when the pressure in said chamber is sufficiently high to start the auto-generator (spring 92*a* being chosen to yield under the effect of this pressure transmitted to cylinder 92).

Contactor 64, provided in shunt circuit portion ND, is normally held open by a spring acting upon a piston 94 subjected to the fluid pressure transmitted through conduit 93 from cylinder 27 when piston 28 has moved down sufficiently to clear the opening of said conduit 93.

The operation of the device which has been described is as follows:

When the auto-generator is ready for starting, the parts are in the relative positions shown by FIG. 1, pistons 3—4 being in the position shown in dotted lines.

In order to start the auto-generator, push-button 83 is depressed, closing switch 68. The electric circuit P*a*, NA, P*b*, C is closed. Winding 50*a* is excited and slide valve 54 is moved into lower position against the action of spring 54*a*, so that oil under pressure is fed to chamber 52*b*, pushing piston 53 toward the left. Rack 47 moves toward the left and causes toothed wheel 48 and shaft 34*a* to rotate through an angle of 90° in the direction of arrow *f*.

During this rotation of 90° of shaft 34*a*, to bring it from the position of FIG. 1 to that of FIG. 2, valve 41 is opened by the boss 37*a* of cam 37, which pushes back push-rod 40. Compressed air from reservoir 38 thus passes through conduit 39 into branch 39*a* and, due to the new position of slide valve 35, into conduit 26 and cylinder 21. Compressed air then flows past check valve 25 into starting chamber 18. At the same time, due to the rotation of shaft 34*a* in the direction of arrow *f* and to the displacement of rod 46 in the direction of arrow F which has produced this rotation, contactor 62 is opened (due to the rotation of cam 82) and contactor 58 is opened by its spring 58*a*, thus opening circuit P*a*, NA, P*b*, C, which besides is also opened as soon as push-button 83 is no longer depressed. But the displacement of slide valve 54 has closed contactor 57 which has brought into action the holding circuit M which is then substituted for circuit P*a*, NA, P*b*, and this as long as rod 46 has not reached its limit position toward the left (corresponding to the end of the rotation of shaft 34*a*).

When this position is reached, that is to say when shaft 34*a* has come into the position of FIG. 2, contactor 59 is opened by rod 46 and, under the action of spring 54*a*, slide valve 54 returns into the position of FIG. 1, so that oil under pressure is now fed to conduit 51*a*. Piston 53 moves toward the right until it closes contactor 58. All the switches and contactors are then in the respective positions shown on FIG. 1, with the exception of contactor 62 which remains open.

As long as shaft 34*a* is in this position, shown by FIG. 2, chamber 18 is charged with air under pressure. When the pressure necessary for starting the auto-generator has been obtained in chamber 18, it acts through conduit 91 upon the piston slidable in cylinder 92 so as to close contactor 65. As a consequence of this, circuit P*a*, NB, P*b*, C is closed. Winding 50*a* is excited and causes rack 47 to move toward the left (as above described) until shaft 34*a* has again rotated through 90° to come into the position of FIG. 3. During this rotation of shaft 34*a* from the position of FIG. 2 to that of FIG. 3, the air compressed in cylinder 21 has escaped to the atmosphere through conduit 26 placed in communication with the atmosphere by the shifting of slide valve 35 from the position of FIG. 2 to that of FIG. 3. As a consequence of this, valve 20 opens and compressed air passes from chamber 18 into cylinder chamber 2*b*, thus starting the auto-generator.

When shaft 34*a* reaches the position of FIG. 3, contactor 59 is opened by the end of rod 46, which produces the return movement of piston 53 and rod 46 as above described.

The auto-generator, the piston of which has been started by compressed air from chamber 18, quickly assumes its normal running conditions, the injection of fuel through injector 5 being adjusted by pump 13 driven

by rod 14 and cylinder 32 being in communication with the atmosphere through conduit 33.

In normal running conditions (shaft 34*a* being in the position of FIG. 3), valve 41 is closed, contactor 62 is open and contactor 63 is closed; furthermore, contactor 61 is open due to the displacement of slide valve 72 toward the right. The other contactors and switches are in the respective positions they occupy on FIG. 1. No current is flowing through winding 50*a* and the slide valve 54 is in the position shown by FIG. 1.

If it is desired to stop the auto-generator, push-button 69 is depressed, which closes contactor 66. Circuit P*a*, NC, PB, C is thus closed, exciting winding 50*a*. If the auto-generator stops accidentally, pistons 3—4 cease to reciprocate in cylinder 2 and piston 74 moves toward the left so as to come into the position shown by FIG. 1, for the reasons above stated, and contactor 61, which had been opened when the auto-generator had started running, closes. Circuit P*a*, N*c*, P*b*, C is then closed and excites winding 50*a*. The closing of either of these circuits P*a*, NC, PB, C or P*a*, N*c*, P*b*, C has for its effect to produce, as above explained, by excitation of winding 50*a*, the displacement of piston 53 in the direction of arrow F and a further rotation of shaft 34*a* through 90° into the position of FIG. 4. The projection 37*b* of cam 37 again opens valve 41. During the rotation of shaft 34*a* from the position of FIG. 3 toward that of FIG. 4, compressed air from reservoir 38 temporarily flows, through conduit 39 and branch 39*b*, into conduit 33 and causes pump 13 to stop, which cuts off the feed of fuel to cylinder 1. When shaft 34*a* has rotated through 90° to come into the position of FIG. 4, conduit 33 is again in communication with the atmosphere and compressed air is sent, past slide valve 36, from branch 39*b* into conduit 29 and, thence, into cylinder 27, which pushes piston 28 back in the downward direction and brings pistons 3—4 into the starting position shown in dotted lines. During this time, due to the opening of contactors 63 and 59, piston 53 has come back into the position shown by FIG. 1.

When pistons 3—4 reach the starting position, the compressed air in cylinder 27 is allowed to flow through conduit 93 because the opening 93*a* of this conduit has been cleared by piston 28. Air under pressure is thus fed to conduit 93, closes contactor 64, which closes circuit P*a*, ND, P*b*, C, thus causing, in the same manner as above described, a further rotation of shaft 34*a* through 90° in the direction of arrows *f*. Thus, said shaft 34*a* is returned into the position of FIG. 1, in which the auto-generator and the starting device are ready for a new starting of the auto-generator, for instance under the effect of a downward movement imparted to push-button 83.

When it is desired to obtain an automatic restarting of the auto-generator after an accidental stopping thereof, it suffices to depress push-button 84 so as to close contactor 67. In these conditions, when, after such an accidental stopping of the machine, shaft 34*a* has returned into the position shown on FIG. 1, circuit P*a*, N*a*, P*b*, C is closed, which again produces the operations which bring shaft 34*a* from the position of FIG. 1 to that of FIG. 3 which corresponds to the starting of the auto-generator. Push-button 84 is kept depressed by a rod 85 acting upon abutment 84*c*, as above explained. In view of the operation of contactor 62 under control of cam 82, push-button 84 can act only when shaft 34*a* has returned into the position of FIG. 1.

However, when it is desired to stop the auto-generator by depressing push-button 69, it is of course necessary to prevent an automatic restarting of said auto-generator and, as above explained, this is why, in this case, push-button 84 is automatically returned into inoperative position.

The free piston machine includes an oil circuit *j* diagrammatically shown on the right hand side of FIG. 1, and means should be provided in order to prevent starting of the machine when the oil pressure in this circuit is insufficient. For this purpose, a contactor 90 is provided for instance in circuit P*b* and this contactor is connected with a piston movable in a cylinder 89 in communication with circuit *j* so that when the pressure in this circuit has dropped below a predetermined value, a spring acts upon said piston so as to open contactor 90. Of course, when contactor 90 is opened, any starting of the machine is impossible.

According to a modification of the system above described, means may be provided to ensure an immediate starting of the machine when so desired, owing to a preliminary filling of starting chamber 18 with air under pressure, the passage of this air under pressure into the portion 2*b* of cylinder 2 taking place only when it is desired to start the auto-generator. Such an arrangement corresponds to the showing in dotted lines on FIG. 1. In this case, a switch 101 is provided in the shunt circuit portion NB.

Furthermore, a device limiting the pressure in starting chamber 18 is provided, this device including for instance a cylinder 102 (in communication, through a conduit 103, with conduit 26). A piston 104 is slidable in this cylinder 102 and it is connected, through a rod 106, with a valve 107 capable of closing conduit 39*a*. Piston 104 is subjected on one side to the pressure in conduit 103 and on the other side to the action of a spring 105 the strength of which responds to the limit pressure which must exist in chamber 18, this spring yieldingly opposing the shifting of valve 107 toward closing position.

When switch 101 is closed, the operation of the system is the same as above explained.

On the contrary, when switch 101 is open, the closing of contactor 65 no longer closes the shunt circuit portion NB. When the pressure in chamber 18 reaches the above mentioned limit value, spring 105 yields and valve 107 is closed, which stops the feed of compressed air to said chamber 18. In order to obtain an immediate starting of the machine when so desired, it suffices to close switch 101, which closes circuit NB so that cylinder 21 is placed in communication with the atmosphere and the compressed air present in chamber 18 passes into the portion 2*b* of cylinder 2, thus starting the machine. Furthermore, piston 104 is moved toward the right and reopens valve 107.

It should be well understood that the various circuits which have been shown, instead of being electric circuits, might be control circuits of any kind, such as air circuits, oil circuits, for distribution of a fluid under pressure, the switches and contactors illustrated being then replaced by valves controlled as above explained, and winding 50*a* being for instance replaced by a piston connected with slide valve 54 and subjected to the fluid pressure existing in the branch C of the circuits.

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.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In a free piston machine including a power portion of the internal combustion engine type and a compressor portion, said power portion including a power cylinder and a power piston slidably reciprocable therein and said compressor portion including a compressor cylinder in line with said power cylinder and fixed with respect thereto and a compressor piston slidably reciprocable in said compressor cylinder and rigid with said power piston, so that said two pistons form together a piston unit

freely movable with respect to said cylinders, said piston unit occupying, when the machine is to be started, an outward position with respect to said cylinders called starting position, the combination of starting means for moving said piston unit inwardly from said starting position, stopping means operatively connected with said power portion of the machine for preventing the operation thereof, resetting means operatively connected with said piston unit for bringing it into said starting position, a power driven actuating mechanism operatively connected with said stopping means and said resetting means and capable when it is energized of successively operating said two last mentioned means, a manual control means operatively connected with said mechanism for energizing it, and automatic control means operatively connected with said mechanism and responsive to variation of one operational factor of the machine for energizing said mechanism when the machine is stopped, said automatic control means being in parallel with said manual control member.

2. In a free piston machine including a power portion of the internal combustion engine type and a compressor portion, said power portion including a power cylinder and a power piston slidably reciprocable therein and said compressor portion including a compressor cylinder in line with said power cylinder and fixed with respect thereto and a compressor piston slidably reciprocable in said compressor cylinder and rigid with said power piston, so that said two pistons form together a piston unit freely movable with respect to said cylinders, said piston unit occupying, when the machine is to be started, an outward position with respect to said cylinders called starting position, the combination of starting means for moving said piston unit inwardly from said starting position, a fuel injection pump mounted to feed fuel to said power portion of the machine, stopping means operatively connected with said fuel pump for preventing the operation thereof, pneumatic means operatively connected with said piston unit for bringing it into said starting position so that the machine can be restarted by imparting a starting impulse to said piston unit from said starting position, a control device for feeding gas under pressure to said pneumatic means, a power driven actuating mechanism operatively connected with said pump stopping means and said control device and capable when it is energized of successively operating them, a manual control means operatively connected with said mechanism for energizing it, and pneumatic control means automatically responsive to the variation of pressure in a portion of said compressor cylinder caused by the stopping of the machine and operatively connected with said mechanism for energizing said mechanism when the machine is stopped, said pneumatic control means being in parallel with said pneumatic control member.

3. In a free piston machine including a power portion of the internal combustion engine type and a compressor portion, said power portion including a power cylinder and a power piston slidably reciprocable therein and said compressor portion including a compressor cylinder in line with said power cylinder and fixed with respect thereto and a compressor piston slidably reciprocable in said compressor cylinder and rigid with said power piston, so that said two pistons form together a piston unit freely movable with respect to said cylinders, said piston unit occupying, when the machine is to be started, an outward position with respect to said cylinders called starting position, said free piston machine further comprising a pneumatic bounce chamber the compression of air in which tends to move said power piston in the direction of its compression stroke, the combination of starting means for injecting compressed air into said bounce chamber to start said piston unit reciprocating, stopping means operatively connected with said power portion for preventing the operation thereof, resetting means operatively connected with said piston unit for bringing it into said starting position, a rotatable control part capable of occupying either of two permanent positions, a first one and a second one, said control part being operatively connected with the three above mentioned means so that in both of these permanent positions thereof it leaves said three means inoperative but that when rotating from said first permanent position to said second permanent position it passes through a first transitory position where it operates said starting means and that when rotating from said second permanent position back to said first permanent position it passes successively through a second transitory position where it operates said stopping means and through a third transitory position where it operates said resetting means, power means for rotating said control part capable of imparting thereto a first rotation from said first permanent position through said first transitory position to said second permanent position and a second rotation from said second permanent position through said second and third transitory positions back to said first permanent position, manual control means for operating said power means to perform said first rotation, manual control means for operating said power means to perform said second rotation, and automatic means responsive to the stopping of pressure oscillations in said bounce chamber for automatically operating said power means to perform said second rotation when said machine is stopped.

4. In a free piston machine including a power portion of the internal combustion engine type and a compressor portion, said power portion including a power cylinder and a power piston slidably reciprocable therein and said compressor portion including a compressor cylinder in line with said power cylinder and fixed with respect thereto and a compressor piston slidably reciprocable in said compressor cylinder and rigid with said power piston, so that said two pistons form together a piston unit freely movable with respect to said cylinders, said piston unit occupying, when the machine is to be started, an outward position with respect to said cylinders called starting position, said free piston machine further comprising a pneumatic bounce chamber the compression of air in which tends to move said power piston in the direction of its compression stroke, the combination of starting means for injecting compressed air into said bounce chamber to start said piston unit reciprocating, stopping means operatively connected with said power portion for preventing the operation thereof, resetting means operatively connected with said piston unit for bringing it into said starting position, a rotatable control part capable of occupying either of two permanent positions, a first one and a second one, said control part being operatively connected with the three above mentioned means so that in both of these permanent positions thereof it leaves said three means inoperative but that when rotating from said first permanent position to said second permanent position it passes through a first transitory position where it operates said starting means and that when rotating from said second permanent position back to said first permanent position it passes successively through a second transitory position where it operates said stopping means and through a third transitory position where it operates said resetting means, power means for rotating said control part capable of imparting thereto a first rotation from said first permanent position through said first transitory position to said second permanent position and a second rotation from said second permanent position through said second and third transitory positions back to said first permanent position, manual control means for operating said power means to perform said first rotation, manual control means for operating said power means to perform said second rotation, automatic means responsive to the stopping of pressure oscillations in said bounce chamber for automatically operating said power means to perform said second rotation when said machine is

stopped, means operatively connected with said control part for making said first mentioned manual control means inoperative as long as said control part is not in said first permanent position and means operatively connected with said control part for making said second mentioned manual control means and said automatic means inoperative as long as said control part is not in said second permanent position.

5. In a free piston machine including a power portion of the internal combustion engine type and a compressor portion, said power portion including a power cylinder and a power piston slidably reciprocable therein and said compressor portion including a compressor cylinder in line with said power cylinder and fixed with respect thereto and a compressor piston slidably reciprocable in said compressor cylinder and rigid with said power piston, so that said two pistons form together a piston unit freely movable with respect to said cylinders, said piston unit occupying, when the machine is to be started, an outward position with respect to said cylinders called starting position, said free piston machine further comprising a pneumatic bounce chamber the compression of air in which tends to move said power piston in the direction of its compression stroke, the combination of starting means for injecting compressed air into said bounce chamber to start said piston unit reciprocating, stopping means operatively connected with said power portion for preventing the operation thereof, resetting means operatively connected with said piston unit for bringing it into said starting position, a rotatable control part capable of occupying either of two permanent positions, a first one and a second one, said control part being operatively connected with the three above mentioned means so that in both of these permanent positions thereof it leaves said three means inoperative but that when rotating from said first permanent position to said second permanent position it passes through a first transitory position where it operates said starting means and that when rotating from said second permanent position back to said first permanent position it passes successively through a second transitory position where it operates said stopping means and through a third transitory position where it operates said resetting means, power means for rotating said control part capable of imparting thereto a first rotation from said first permanent position through said first transitory position to said second permanent position and a second rotation from said second permanent position through said second and third transitory positions back to said first permanent position, manual control means for operating said power means to perform said first rotation, manual control means for operating said power means to perform said second rotation, automatic means responsive to the stopping of pressure oscillations in said bounce chamber for automatically operating said power means to perform said second rotation when said machine is stopped, means for manually locking said first mentioned manual control means in the operative position thereof, where it operates said power means to perform said first rotation, and means operatively connected with said second mentioned manual control means for automatically returning said first mentioned manual control means into inoperative position against the action of said locking means when said second mentioned manual control means is in operative position, where it operates said power means to perform said second rotation.

6. In a free piston machine according to claim 3, said power means including a reciprocating member, fluid operated means operatively connected with said member for moving it, a valve inserted in said fluid operated means for controlling them, a winding for controlling said valve, an electric circuit connected with said winding to transmit control impulses thereto, another electric circuit connected with said winding to keep it excited after the ends of said impulses, a first contactor in the first of said circuits, a second contactor in the other of said circuits, means operatively connected with said member for opening said first contactor at the beginning of the forward movement of said member and for closing said first contactor at the end of the return movement of said member, and means operatively connected with said member for opening said second contactor at the end of the forward movement of said member and for closing it at the beginning of the return movement of said member.

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