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PLANTS INCLUDING AT LEAST TWO FREE PISTON AUTO-GENERATORS INTENDED TO WORK IN GIVEN PHASE RELATION TO EACH OTHER

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Fig. 1.

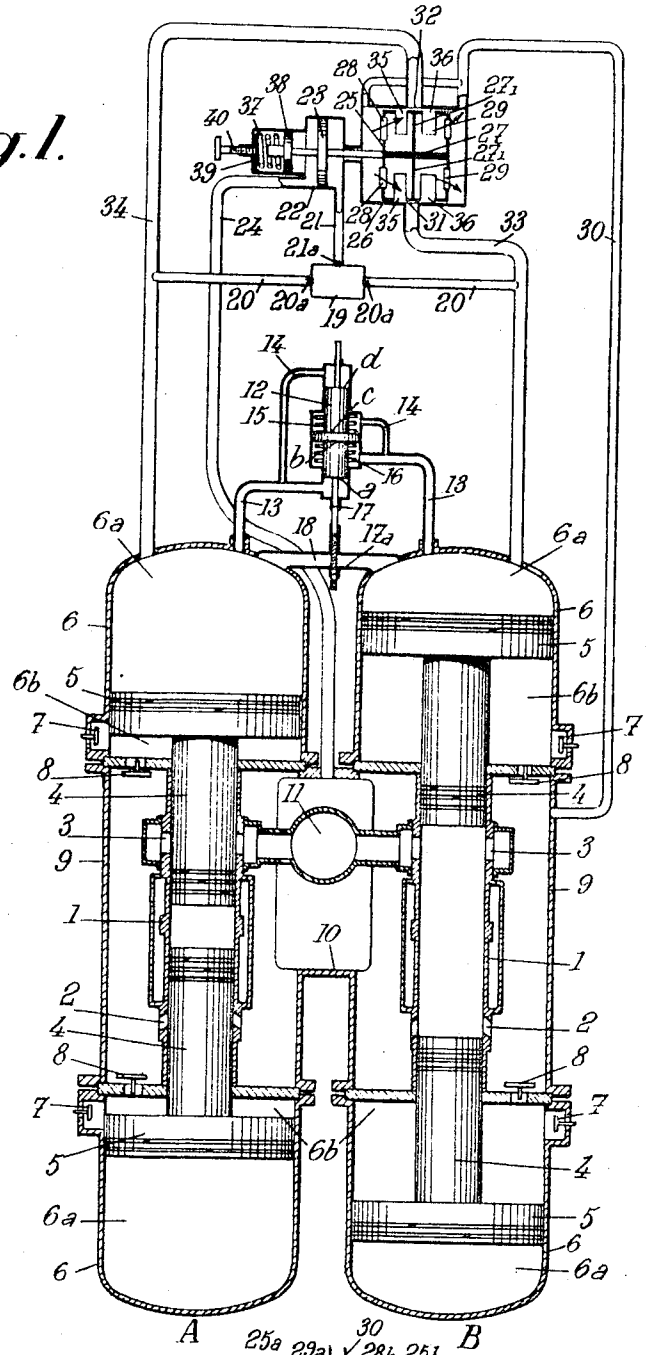
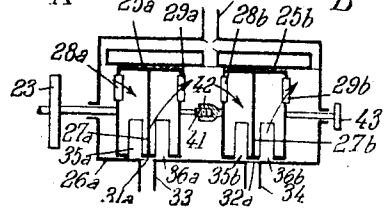


Fig. 2.



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PLANTS INCLUDING AT LEAST TWO FREE PISTON AUTO-GENERATORS INTENDED TO WORK IN GIVEN PHASE RELATION TO EACH OTHER

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6 Claims. (Cl. 123—46)

The present invention relates to a plant including at least two free piston auto-generators intended to work in predetermined phase relation respectively. The invention is more especially concerned with the case of two auto-generators having communicating casings, or even a single casing common to both of them, said two auto-generators working in phase opposition (that is to say with a phase difference of 180°) said auto-generators being hereinafter called "twin auto-generators."

Free piston auto-generators generally comprise a device, called "stabiliser," which controls the amount of air present in their return energy accumulators (cushions) in such manner as to ensure a stable operation. Such a stabiliser is generally controlled, on the one hand, by a factor which is a function of the load of the auto-generator, this factor being, as a rule, the pressure existing in the air reservoir (casing) of the auto-generator, and, on the other hand, by a pressure corresponding to a value which is characteristic of the mass of air in the cushion. This characteristic value is, for instance, either the mean of the instantaneous pressures existing in the cushion during an oscillation of the free piston of the auto-generator, or the pressure existing in the cushion for a given position of the free piston therein.

It is also known to keep the operation of the free pistons of several auto-generators either in phase or with a given phase offsetting by varying, by means of a device called "dephaser," the ratio of the respective masses of air present in the cushions of said auto-generators so as to adjust said masses when there is a perturbation in the phase relation between the auto-generators. This adjustment, corresponding to a variation of the ratio of the air masses in the respective cushions, may be obtained by transferring a portion of the air present in the cushion of the auto-generator which is leading into the cushion of the auto-generator which is lagging until the desired phase relation has been restored.

In the known plants of the kind in question which include a dephaser, each stabiliser is controlled by pressures which are characteristic only for the cushion or cushions of the auto-generator to which the stabiliser belongs. It will be understood that the action of the dephaser may then have a disturbing effect upon the respective stabilisers of the auto-generators. On the other hand, these stabilisers may interfere with the action of the dephaser.

The object of the present invention is to obviate these drawbacks.

To this effect, in a plant including at least two free piston auto-generators and a dephaser for maintaining the desired phase relation between them, the stabilisers of the respective auto-generators are controlled, on the one hand, by a factor which is a function of the load of the plant, and, on the other hand, by a factor which corresponds to the mean value of the characteristic pressures in the cushions of the auto-generators.

This permits of obtaining an adjustment of all the air masses contained in the cushions of the auto-generators instead of an individual and independent adjustment of the respective cushions of the auto-generators. This excludes

any disturbance, whether it is produced by the operation of the stabilisers during the dephasing action or by the dephasing during the operation of the stabilisers.

A preferred embodiment of the present invention will be hereinafter described with reference to the appended drawing, given merely by way of example, and in which:

FIG. 1 diagrammatically shows a plant including twin free piston auto-generators mounted in phase opposition, and a dephaser, this plant being made according to the present invention;

FIG. 2 diagrammatically shows a modification.

The plant shown by FIG. 1 comprises two free piston auto-generators A and B intended to work in phase opposition. Each of these auto-generators comprises a motor cylinder **1** provided with inlet ports **2** and exhaust ports **3**, these ports being controlled by motor pistons **4** moving in opposed directions, respectively, in motor cylinder **1**. Each of said motor pistons **4** is rigid with a compressor piston **5** slidable in a compressor cylinder **6**. Compressor piston **5** divides the corresponding cylinders into two chambers **6***a* and **6***b*. Chamber **6***a*, located on the external side of piston **5**, constitutes a return energy pneumatic accumulator, or cushion. Chamber **6***b*, located on the inner side of piston **5**, constitutes the compressor chamber proper and is provided with intake valves **7** and delivery valves **8**. These last mentioned valves control the passage of compressed air from compressor chamber **6***b* into casing **9**, which surrounds motor cylinder **1** and which constitutes a reservoir for air serving to feed and to scavenge said motor cylinder **1**. The inlet ports **2** of motor cylinder **1** communicate with said casing **9**.

The two movable sets of free pistons **4** and **5** of every auto-generator are interconnected by a synchronizing device, not shown by the drawing, made in any known manner, for instance consisting of a lever oscillating about a fixed axis and connected through rods with the two sets of pistons.

In order to have in the two cushions of a given auto-generator equal instantaneous pressures these two cushions are connected together by a conduit, not shown.

Each motor cylinder **1** is fitted with a fuel introduction device, for instance an injector, not shown, fed by means of an injection pump.

The two casings **9** of the juxtaposed auto-generators A and B communicate together through a conduit **10**.

The exhaust openings of motor cylinders **1** are connected with a common exhaust pipe **11** which leads the power gases issuing through exhaust ports **3** to a receiver machine to be driven by said gases, for instance a turbine. If the two auto-generators are in opposed phase relation, the pressure variations in exhaust pipe **11** are small.

The means serving to produce and to maintain a 180° phase relation between between auto-generators A and B are adapted, if the actual phase relation differs from the desired relation, to cause air to flow from the cushions of the auto-generator that is leading to the cushions of the auto-generator that is lagging, thus slowing down one of these auto-generators and accelerating the other until the desired phase relation is restored. Such a dephaser may include, as described in the French Patent No. 999,940, filed February 5, 1946 by Raul Pateras Pescara and the firm called Societe d'Etudes et de Participations, Eau, Gaz, Electricité, Energie, S.A.

Such a dephaser includes a floating piston **12** provided with a flange, so that said piston has, in a stepped cylinder where it moves, four surfaces *a*, *b*, *c*, *d*. Surfaces *a* and *b* are subjected to the action of the instantaneous pressures in cushions **6***a*, these pressures being transmitted to said surfaces through conduits **13** of relatively large cross section. Surfaces *c* and *d* are subjected to the action of pressures equal to the mean value of the instantaneous pressures existing in said cushions **6***a*. For this

purpose, the spaces to which said surfaces *c* and *d* belong are connected with cushions **6***a* through channels **14** of small cross section. Finally, piston **12** is subjected to the actions of two opposed springs **15** and **16** which urge the floating piston into its mean position. This floating piston **12** is connected to a slide valve **17** interposed in a conduit **18** interposed between the respective cushions **6***a* of auto-generators A and B so as to connect said cushions together when the aperture **17***a* of said slide valve is in line with conduit **18**.

The operation of this dephaser is as follows:

As long as the free pistons of the twin auto-generators maintain the desired phase opposition (180°), the amplitude of the oscillations of the system constituted by ports **12** and **17** is not sufficient to cause conduit **18** to be opened by slide value **17**. On the contrary, if the phase opposition is no longer maintained, the amplitude of the oscillations of the oscillating system increases and slide valve **17** opens conduit **18** at times such that the cushion of the leading auto-generator is partly discharged into the cushion of the lagging auto-generator until the desired 180° phase relation is restored.

In order to adapt the mass of air in cushions **6***a* to the load of the corresponding auto-generator, each generator comprises a stabiliser which increases the mass of air in the cushions thereof when the load of the corresponding auto-generator increases and which drives out air from said cushions when the load of the auto-generator decreases.

The respective stabilisers of the auto-generators are controlled by a common element which is subjected, on the one hand, to the action of the pressures existing in the common casing of the two auto-generators, and, on the other hand, to the action of a pressure corresponding to the mean value of the characteristic pressures in the cushions of the auto-generators.

In the plant of FIG. 1 the characteristic pressure of the cushions is equal to the mean of their instantaneous pressures.

This characteristic pressure is obtained in a space **19** which is connected through conduits **20** to the respective cushions **6***a* of the auto-generators. Each of these conduits **20** is provided, for instance at the place where it opens into space **19**, with a throttled portion **20***a*. Thus space **19** receives the mean pressures in cushions **6***a*. Furthermore space **19** is connected through a conduit **21** provided with a throttled portion **21***a* to one of the ends of a cylinder **22** in which is slidably mounted a piston **23**. The other end of said cylinder **22** is connected through a conduit **24** with the common casing **9** of the twin auto-generators. Therefore piston **23** is subjected on one side to the action of a pressure which is the mean value of the mean pressures existing in the cushions **6***a* of the twin auto-generators, and on the other side, to the action of the pressure existing in casing **9**. Piston **23** constitutes the common control member for both of the stabilisers of the respective auto-generators.

In the embodiment of FIG. 1, these two stabilisers comprise a single hollow slide valve **25** and a single cylinder **26** in which said slide valve **25** is movable. This slide valve is divided into two compartments by a partition **27**, one of these compartments belonging to the stabiliser of one of the auto-generators and the other to the stabiliser of the other auto-generator. Each of these compartments is divided by a wall 27_1 into two chambers one of which is provided with a check valve **28** opening toward the inside of the slide valve, whereas the other chamber is provided with a check valve **29** opening from the corresponding chamber into cylinder **26**. This cylinder **26** communicates, through a conduit **30** with the inside of casing **9** and it is provided in its side wall with two ports **31**, **32**, one of which, **31**, is connected through a conduit **33** with the air cushion **6***a* of auto-generator B, whereas the other port, **32**, is connected through conduit **34**, to the cushion **6***a* of the other auto-generator A.

Each compartment of slide valve **25** is provided with two openings, **35**, **36**. If the pressure rises in casing **9** so that piston **23** and slide valve **25** rigid therewith are moved toward the right from their neutral position (in which ports **31** and **32** are closed by the slide valve) ports **35** are placed in communication with ports **31** and **32** provided in the side wall of cylinder **26**. In this case, air may flow from casing **9**, through check valves **28**, into cushions **6***a* to increase the mass of air present therein. On the contrary, if the pressure in casing **9** decreases, piston **23** and slide valve **25** rigid therewith are moved toward the left, which places the ports **36** of the slide valve opposite the ports **31**, **32** provided in the side wall of cylindrical housing **26**. In this case a portion of the air present in cushions **6***a* may escape through check valves **29** into cylindrical housing **26** and thence into casing **9**.

Advantageously, slide valve **25** is subjected to the action of an adjustable spring **37** interposed between a disc **38** rigid with control piston **23** and a fixed abutment **39** the position of which may be adjusted by means of a threaded rod **40**. This threaded rod may be controlled either manually or automatically.

In view of the fact that slide valve **25**, common to both of the stabilisers, is controlled by the mean of the characteristic pressure of cushions **6***a*, this slide valve, in case of variation of the load, varies the whole of the air masses which are located in the cushions of the two auto-generators without the operation of the two stabilisers being influenced by the distribution of the total air mass between the cushions of the two auto-generators, which takes place in particular during the periods for which the dephaser works to restore the desired dephasing. The operation of this dephaser is therefore not disturbed by the operation of the stabilisers. On the other hand the effect of the dephaser has no disturbing influence upon the operation of the stabilisers.

In some cases it may be advantageous to separate the two stabilisers while having them controlled, as above stated, by a common member. This separation permits of varying their relative position so as to compensate, if need be, for the internal disymmetries which may exist between two twin auto-generators. This modification is illustrated by FIG. 2.

According to this embodiment, piston **23** controls two slide valves **25***a* and **25***b* connected together through a threaded rod **41** rigid with slide valve **25***a* and a nut **42** rigid with slide valve **25***b*. These two slide valves are movable in a common cylindrical housing **26***a* provided with ports **31***a* and **32***a* communicating with the respective cushions **6***a* of the two auto-generators. In order to vary the distance between slide valves **25***a* and **25***b* to compensate for disymmetries between the auto-generators, it suffices to rotate one of the slide valves, for instance **25***b*, with respect to the other slide valve. This rotation is effected by means of control wheel **43**. Each of the slide valves **25** and **25***b* is provided, in its end wall, with two sets of check valves **28***a*, **29***a* and **28***b*, **29***b*. Each hollow slide valve is divided by a partition **27***a*, **27***b* into two compartments. One of the sets of check valves permits air to flow from cylinder **26***a* into one of the compartments of the corresponding slide valve and the other set of check valves permits air to flow out from the other compartment of the slide valve into cylinder **26***a*. Finally each of the slide valves is provided, in its side walls, with ports **35***a*, **36***a*, and **35***b*, **36***b* located on opposite sides of the partition which divides the inside of the hollow slide valve into two compartments.

The operation of the stabiliser of FIG. 2 is analogous to that of the stabiliser illustrated by FIG. 1.

According to a modification, the two stabilisers, instead of being controlled by a single part, are each provided with its own control part, the respective control parts being placed, on the one hand, under the action of the pressure in the casing, and, on the other hand, under the action of a pressure corresponding to the mean value of

the characteristic pressures in the cushions of the auto-generators. According to another modification the control part or parts of the stabilisers is, or are, actuated not by said pressures but by forces (either electrical or hydraulic) variable in accordance with said pressures.

In a general manner, while we have in the above description disclosed what we deem to be a practical and efficient embodiment of our invention, it should be well understood that we 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 we claim is:

1. A plant which comprises, in combination, at least two free piston auto-generators, each of said auto-generators comprising a motor unit and a compressor unit, said motor unit including two motor elements, a motor piston and a motor cylinder, one movable in the other to form between them a variable volume fuel combustion chamber, said compressor unit including two compressor elements, a compressor piston and a compressor cylinder, one movable in the other, each of said compressor elements being fixed to one of said motor elements, respectively, a casing fixed with respect to said motor cylinder for feeding compressed air thereto, said compressor elements forming between them on the one hand an air compression chamber for feeding said casing with compressed air and on the other hand a closed air cushion chamber the volume of which is reduced on every increase of volume of said fuel combustion chamber, whereby expansion of said air cushion produces every return stroke of said motor piston, a conduit having one end thereof in communication with said air cushion chamber, and a stabiliser mounted to control the communication between the other end of said conduit and said casing, said stabiliser including a cylindrical housing, a hollow slide valve slidable in said casing and having a neutral position therein and check valve means carried by said slide valve arranged to open through said slide valve a unidirectional communication from said casing to said conduit when said slide valve is moved from said neutral position thereof in one direction and a unidirectional communication from said conduit to said casing when said slide valve is moved from said neutral position thereof in the other direction, means for producing a predetermined phase relation between the respective operations of said auto-generators, and means for urging the slide valve of each of said stabilisers in said first direction in response to an increase of the load of the plant and, in said second direction in response to an increase of the mean value of respective pressures characteristic of the pressures in the cushion chambers of said auto-generators, respectively.

2. A plant which comprises, in combination, at least two free piston auto-generators, each of said auto-generators comprising a motor unit and a compressor unit, said motor unit including two motor elements, a motor piston and a motor cylinder, one movable in the other to form between them a variable volume fuel combustion chamber, said compressor unit including two compressor elements, a compressor piston and a compressor cylinder, one movable in the other, each of said compressor elements being fixed to one of said motor elements, respectively, a casing fixed with respect to said motor cylinder for feeding compressed air thereto, said compressor elements forming between them on the one hand an air compression chamber for feeding said casing with compressed air and on the other hand a closed air cushion chamber the volume of which is reduced on every increase of volume of said fuel combustion chamber, whereby expansion of said air cushion produces every return stroke of said motor piston, a conduit having one end thereof in communication with said air cushion chamber, and a stabiliser mounted to control the communication between the other end of said conduit and said casing, said stabiliser including a cylindrical housing, a hollow slide valve slidable in said casing and having a neutral position therein and check valve means carried by said slide valve arranged to open through said slide valve a unidirectional communication from said casing to said conduit when said slide valve is moved from said neutral position thereof in one direction and a unidirectional communication from said conduit to said casing when said slide valve is moved from said neutral position thereof in the other direction, means for producing a predetermined phase relation between the respective operations of said auto-generators, and means for urging the slide valves of said stabilisers in said first direction in response to an increase of the pressure in said casings, and in said second direction in response to an increase of the mean values of the instantaneous pressures existing in the cushion chambers of said auto-generators, respectively.

3. A plant which comprises, in combination, at least two free piston auto-generators, each of said auto-generators comprising a motor unit and a compressor unit, said motor unit including two motor elements, a motor piston and a motor cylinder, one movable in the other to form between them a variable volume fuel combustion chamber, said compressor unit including two compressor elements, a compressor piston and a compressor cylinder, one movable in the other, each of said compressor elements being fixed to one of said motor elements, respectively, a casing fixed with respect to said motor cylinder for feeding compressed air thereto, said compressor elements forming between them on the one hand an air compression chamber for feeding said casing with compressed air and on the other hand a closed air cushion chamber the volume of which is reduced on every increase of volume of said fuel combustion chamber, whereby expansion of said air cushion produces every return stroke of said motor piston, a conduit having one end thereof in communication with said air cushion chamber, and a stabiliser mounted to control the communication between the other end of said conduit and said casing, said stabiliser including a cylindrical housing, a hollow slide valve slidable in said casing and having a neutral position therein and check valve means carried by said slide valve arranged to open through said slide valve a unidirectional communication from said casing to said conduit when said slide valve is moved from said neutral position thereof to one direction and a unidirectional communication from said conduit to said casing when said slide valve is moved from said neutral position thereof in the other direction, means for producing a predetermined phase relation between the respective operations of said auto-generators, and a single member for urging the slide valves of both of said stabilisers in said first direction in response to an increase of the load of said plant, and in said second direction in response to an increase of the mean value of respective pressures characteristic of the pressures in the cushion chambers of said auto-generators, respectively.

4. A plant according to claim 3 wherein said stabilisers comprise a common cylinder and, fitting slidably in said last mentioned cylinder, a hollow slide valve operatively connected with said member, a longitudinal partition for dividing said slide valve into two compartments, a wall for dividing each of said compartments into two portions, check valves carried by one end wall of said slide valve opening toward the inside of one of said compartment, portions check valve means carried by the other wall of said slide valve opening toward the outside of the other of said compartment portions.

5. A plant according to claim 3 wherein said stabilisers comprise a common cylinder and, fitting slidably in said last mentioned cylinder, two coaxial hollow slide valves belonging respectively to said stabilisers, further com-

prising means for adjusting the positions of said slide valves with respect to each other.

6. A plant according to claim 3 wherein said stabilisers comprise a common cylinder and, fitting slidably in said last mentioned cylinder, two coaxial hollow slide valves belonging respectively to said stabilisers, further comprising nut and screw means for adjusting the positions of said slide valves with respect to each other.

No references cited.

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