Jan. 11, 1944. W. RAYMOND 2,339,191

ELECTRIC MULTISTEP CONTROLLER

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Fig. 1

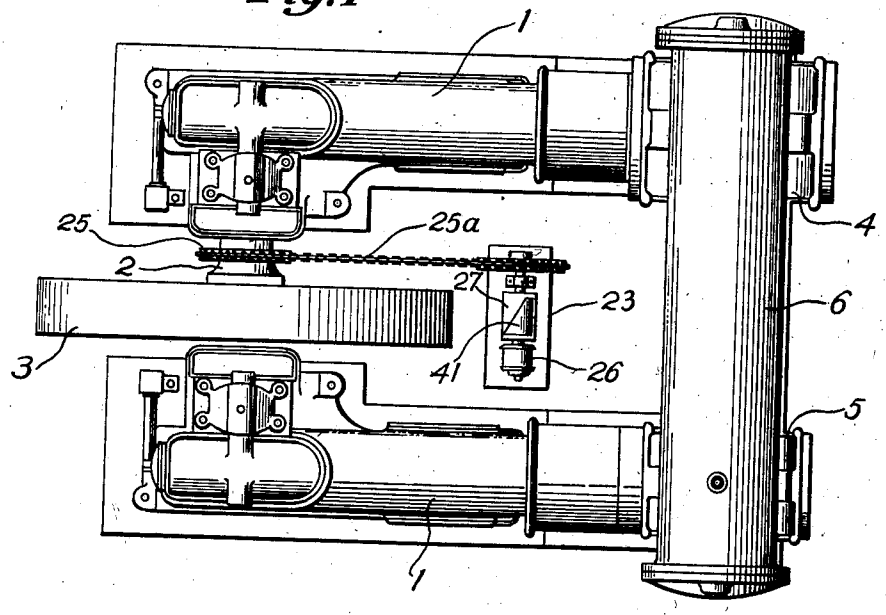
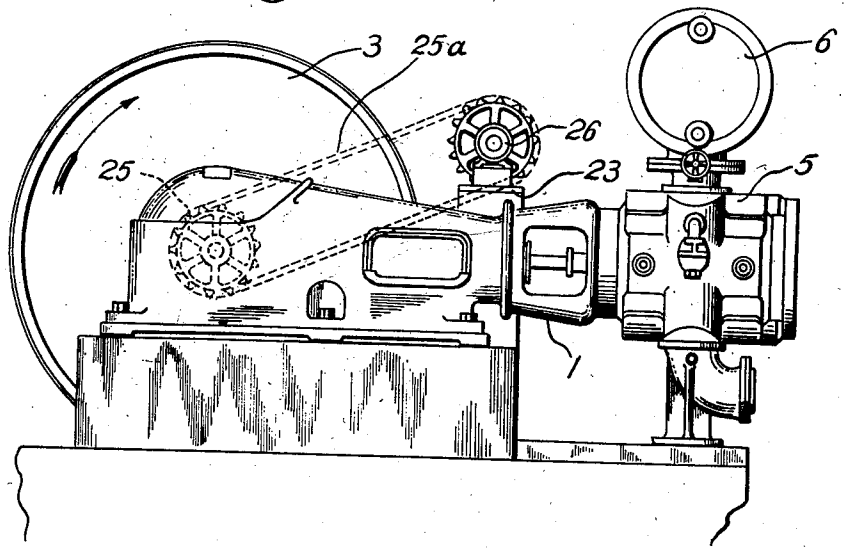


Fig. 2



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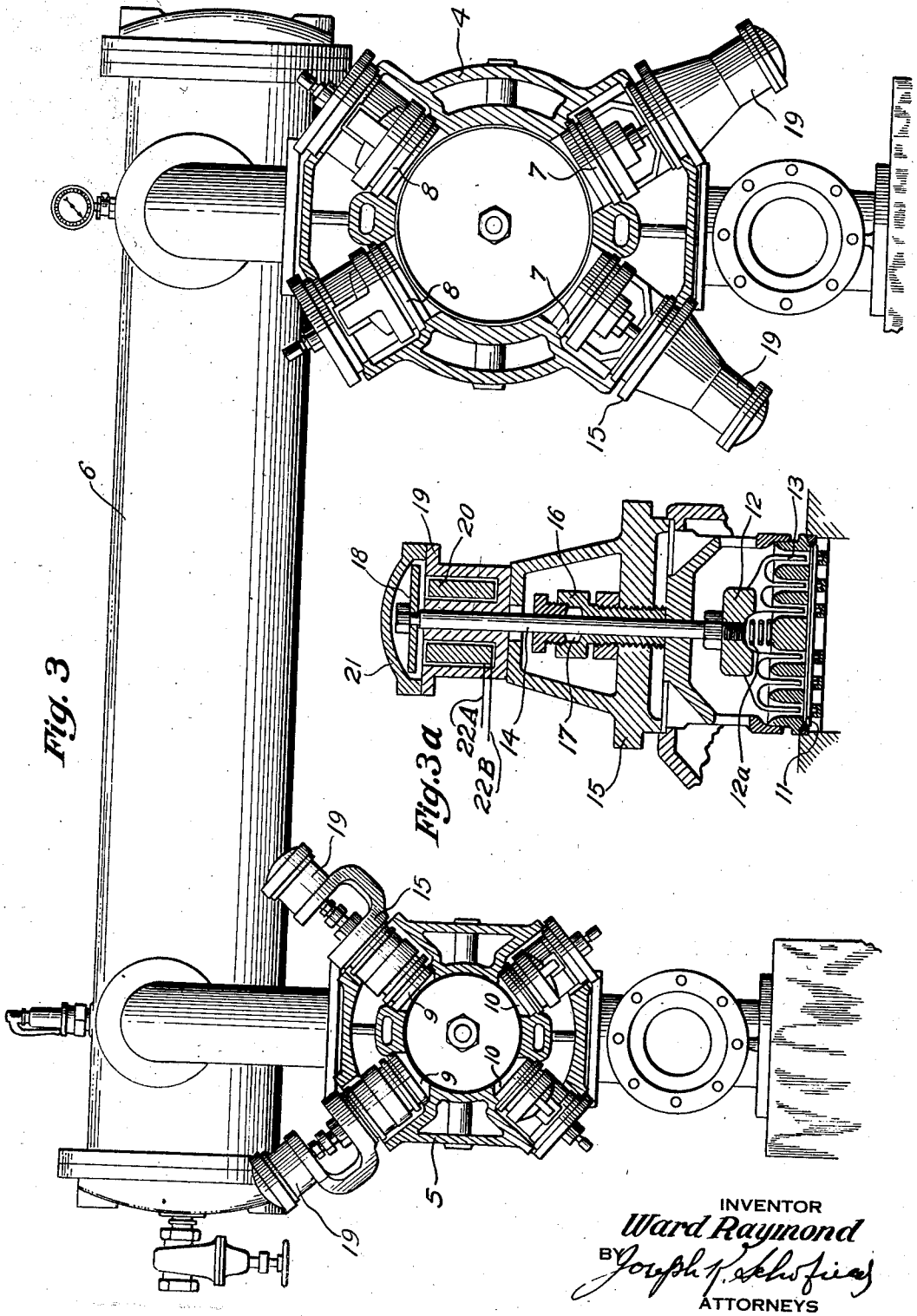


Fig. 3

Fig. 3a

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ELECTRIC MULTISTEP CONTROLLER

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Fig. 4

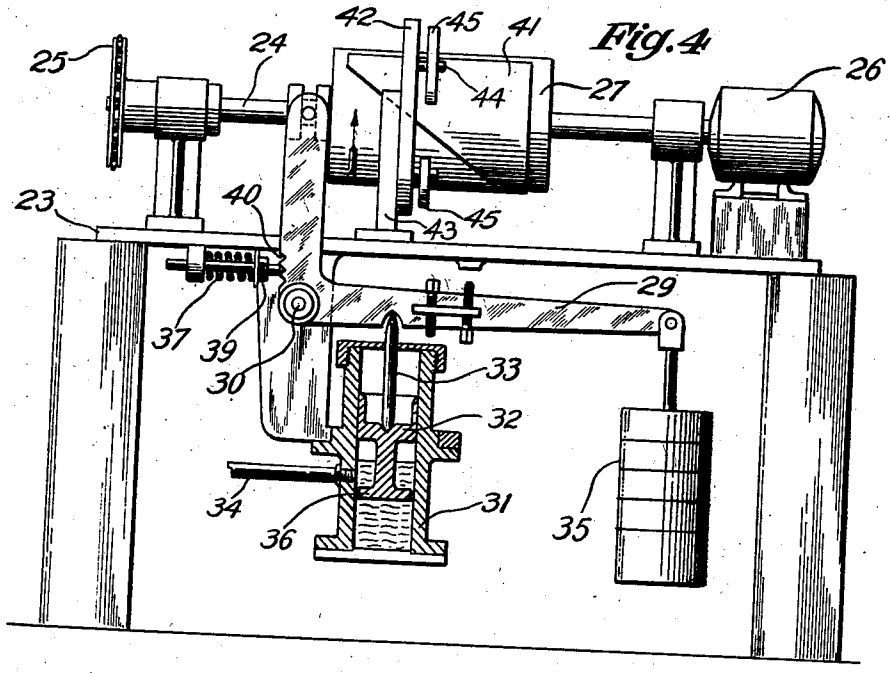
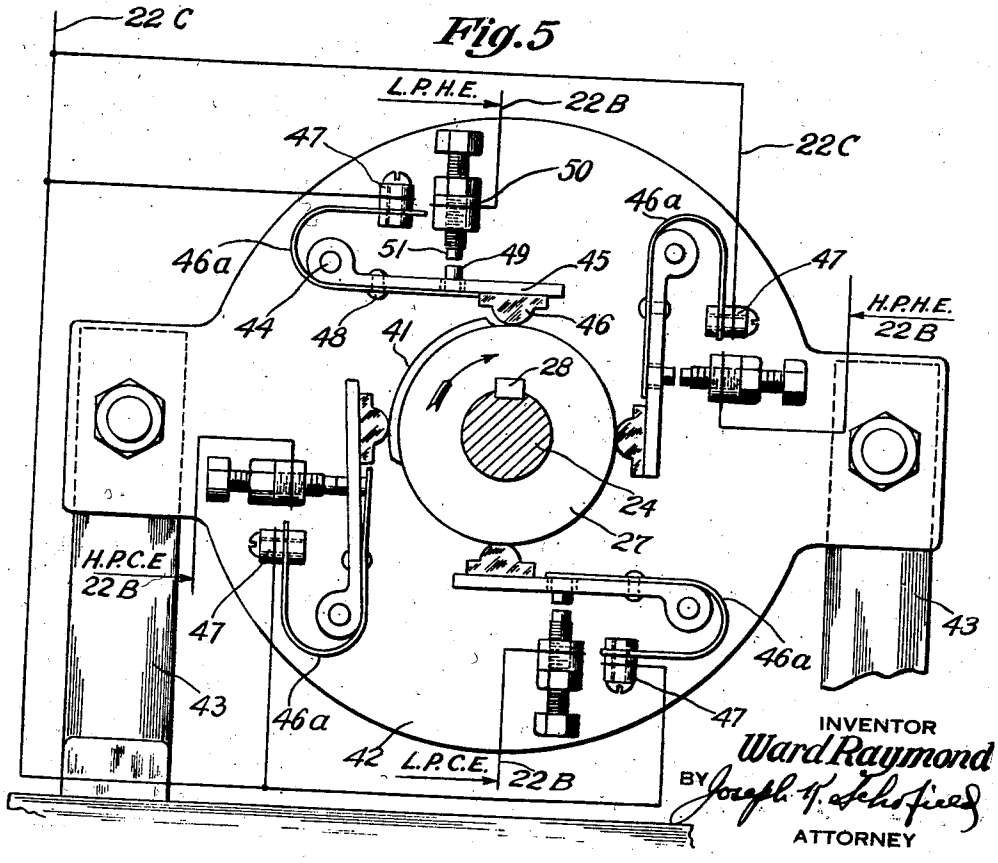


Fig. 5



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Fig. 6

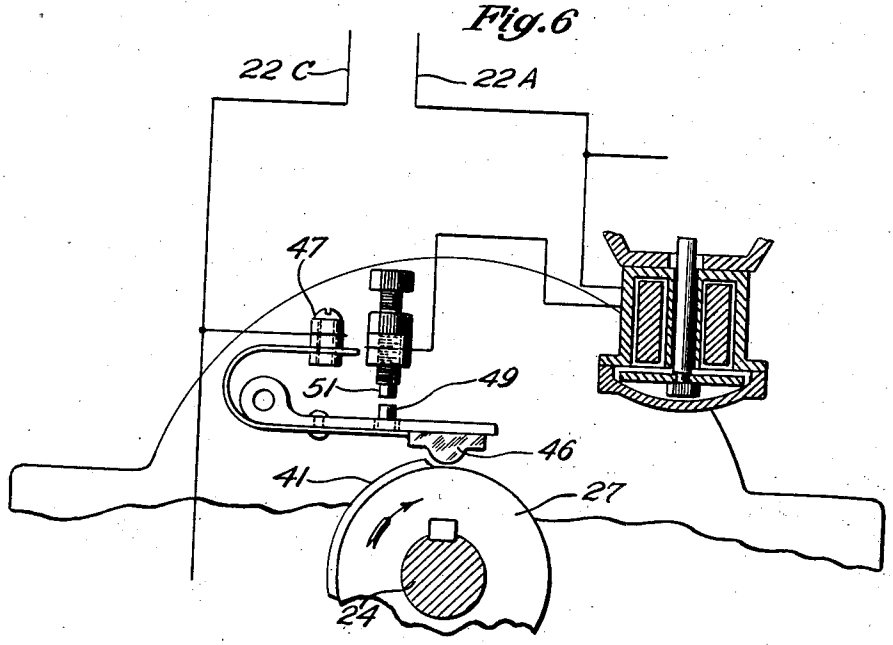
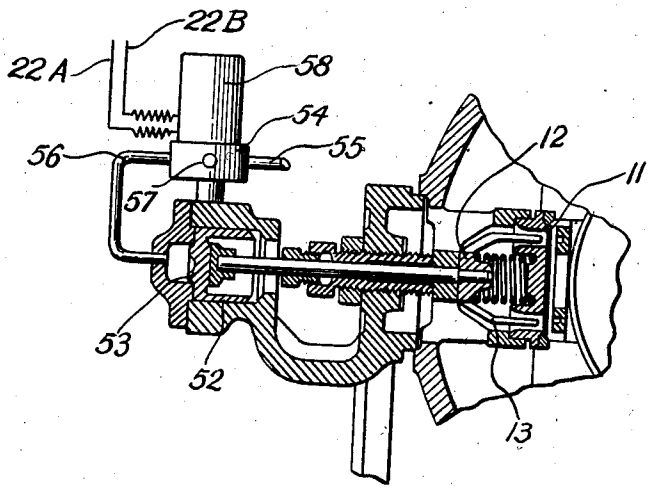


Fig. 7



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UNITED STATES PATENT OFFICE

2,339,191

ELECTRIC MULTISTEP CONTROLLER

Ward Raymond, Easton, Pa., assignor to The Pennsylvania Pump & Compressor Company, Easton, Pa., a corporation of Pennsylvania

Application February 8, 1939, Serial No. 255,194

5 Claims. (Cl. 230—26)

This invention relates to compressors and has for its primary object a novel and efficient means for unloading or controlling the output of an air or gas compressor so that the amount of air or gas delivered by the compressor may be varied to suit an intermittent or irregular demand.

Several different systems have been employed heretofore to obtain this result. In some cases the intake is closed and opened intermittently, or throttled to reduce the inflow. In other cases the inlet valves are held open, allowing the air drawn into the cylinder on the suction stroke to be discharged back into the suction instead of being compressed. Another method is to employ additional valve controlled clearance spaces or pockets communicating with a cylinder which may be cut in or out to vary the effective clearance volume and thereby control the amount of air or gas compressed.

Substantially all these plans, with the exception of throttling, which is not economical, operate in steps of comparatively large magnitude, and when the demand falls between two consecutive steps, one of the steps must be cut in and out repeatedly to meet the intermediate demand.

Still another method of control is by holding the inlet valves open for only a portion of the compression stroke, during which portion of the stroke air in the cylinder is expelled through the inlet valves. After allowing the valves to close at a point in the compression stroke, the air remaining in the cylinder after the valve closes is compressed. I am aware that this has been done, but my present invention proposes to control the output of air or gas compressors by the employment of electric devices including magnets energized for longer or shorter periods during the stroke of the piston, whereby the inlet valves are held in their open position during such portion of the compression stroke as will cause the compressor to deliver substantially the amount of air demanded of it at the moment, and to vary the period during which the valve is held open as the demand may vary.

Briefly, my invention employs suitable electric magnets or other electrically controlled means operating in conjunction with one or more of the inlet valves of the cylinder or cylinders, whereby the inlet valves may be held open during such period of each compression stroke of the piston as is necessary to properly reduce the output of the compressor, and then allow it to close and the air remaining in the cylinder to be compressed and discharged in the usual manner.

This electric control is obtained by means of a timer or distributer operated in synchronism with the compressor crank shaft, and in which the portion of the compression stroke of the piston during which the valve is open is varied by means under the control of the discharge pressure of the air or gas being compressed.

In the drawings and description I have shown my invention as applied to an air compressor of the duplex horizontal two-stage cross-compound type, but it will be understood that the invention is not limited to compressors of this type, as my invention may be incorporated in other standard types, it only being required that the compressor has one or more compressing cylinders of the reciprocating piston type and has inlet valves normally open during the suction and closed during the compression stroke. In its simplest form the invention would be applied to a compressor having one compressing cylinder and of the single or double-acting type.

While I herein describe my invention as applied to an air compressor, it will be understood that it is equally suitable for other gases, and I have used the term "air" in order to facilitate the description.

Referring to the drawings, Fig. 1 shows in plan a duplex two stage cross compound air or gas compressor of one of the types for which my invention is suitable.

Fig. 2 shows a side elevation of the compressor shown in Fig. 1;

Fig. 3 shows an end view of the compressor shown in Figs. 1 and 2 with the compressing cylinders in section and showing the valves and operating devices therefor. Fig. 3*a* is a detail sectional view of an intake valve and the means for holding it open;

Fig. 4 shows the timing or distributing mechanism for the valve opening means.

Fig. 5 shows a detailed view of certain parts of the timer shown in Fig. 4 upon an enlarged scale:

Fig. 6 shows diagrammatically the wiring of a suitable electric circuit; and

Fig. 7 shows an alternate mechanism for operating the valves.

In the drawings, 1 represents the main frames of the compressor, in which frames is mounted the main crank shaft 2 carrying the driving element 3 and fly wheel which may be driven by any suitable means such as a synchronous motor, belt or other means.

At the rear of the frames are the low pressure compressing cylinder 4 and high pressure cylinder 5, and above them is superimposed the inter-

cooler 6. All of the foregoing parts are or may be of the usual or standard type and will not require further description.

In Fig. 3 are shown the low pressure inlet valves 7 and discharge valves 8, as well as the high pressure inlet valves 9 and discharge valves 10 at one end of the cylinders. These valves, being of the usual disc, ring or leaf type, will not require further description. It will be understood that there are similar valves at the opposite ends of the cylinders.

As previously explained, the method of unloading this compressor consists in holding the inlet valves 7 and 9 off their seats for a greater or less portion of the compression stroke of the piston or pistons, and I will now describe one form of means for doing this. As the same description applies to both low and high pressure cylinder valves, the same descriptive numbers will be used for both.

Beneath the valve discs 11 are hubs 12 carrying lifting fingers 13 which enter the intake ports, and when moved into contact with the valve discs 11 force these discs off their seats and thereby hold them open. On the discharge stroke of the piston therefor the air or gas will not be compressed while the inlet valve is open but will be free to return into the intake. Engaging these hubs 12 are the stems 14. The stems 14 pass out through the covers 15, in fact, pass through a central bore in the setscrews 16 which retain the valve asesmblies in position. When necessary to retain pressure, or when gas is compressed, suitable packings 17 may be provided to prevent leakage through the bore in setscrew 16. At the outer end of each stem 14 is mounted a case 19 containing an electric magnet 20 shown in conventional form only. These magnets may be enclosed by the covers 21. Cases 19 and covers 21 form a complete unit of the proper materials and design to aid in the energizing and rapid de-energizing of the magnets 20, and there is a unit provided for each inlet valve.

The magnets 20 are energized through the connections 22A and 22B in a circuit presently to be described. It will now be seen from the above description that upon the energizing of magnets 20 their armatures 18 will be drawn toward them. This movement of the armatures, acting through stems 14 and lifting fingers 13, will move the valve discs 11 away from their seats and thereby hold the valves open.

Upon opening the circuit including connections 22*a* and 22*b* and de-energizing a magnet 20 controlled thereby its armature 18 will be released through the action of spring 12A and the valve will be allowed to close.

As the magnets 20 operate individually on the inlet valves to hold them open, it will be apparent that if the inlet valves at one end of a cylinder were held open during the whole of the compressing stroke, all the air in the cylinder would be forced back through the inlet valves and no air would be compressed during that stroke. On the other hand, if the magnets 20 were de-energized at the middle of the stroke and the valves allowed to close at that point, the air remaining in the cylinder (half a cylinder full), would be compressed and forced through the discharge valves in the usual way. At whatever portion of the stroke the inlet valves at one end of a cylinder are released and close, the remaining portion of the full capacity of the compressor will be delivered.

Referring now to Figs. 4 and 5, Fig. 4 shows a distributor suitable for operating the inlet valves in the manner described. On the base 23 is mounted the shaft 24 driven in synchronism with the compresssor main shaft 2 by the sprocket 25 and chain 25A. The shaft 24, if desired, may be driven by the synchronous motor 26 electrically locked in step with the main shaft 2 when driven by a synchronous motor. It is only required that the shaft 24 revolve in uniformity and fixed angularity of rotation with shaft 2. On each shaft 24 is a drum 27 keyed thereon by key 28 but free to slide longitudinally thereon. The position of drum 27 on the shaft 24 is determined by a bell crank 29 pivoted in the bearing 30 in the base 23 and having pins on the vertical arm engaging an annular groove at one end of the drum 27. Controlling the longitudinal movement of drum 27 through bell crank 29 is the pressure cylinder 31 with the piston 32 and stem 33 bearing against the bell crank 29.

Air discharged from the compressor system is supplied through connection 34 to force the piston 32 upward, and this is balanced by the weights 35 on the horizontal arm of bell crank 29. These weights are adjusted to balance the air pressure required in the system. The piston 32 may be provided with a lower flange 36 which is submerged in oil or other fluid to act as a dashpot and dampen any suddent movement of the piston 32. The angular movement of the bell crank 29 may be limited, by any suitable means not shown.

It will now be apparent that any change in discharge pressure of the compressor system will cause movement of piston 32, and this pressure acting through bell crank 29 will cause a longitudinal movement of drum 27 along shaft 24. In order that a slight change in air pressure will not cause a complete movement of piston 32 and drum 27, I may provide the spring 37 fulcrumed against one arm of the bell crank 29 adjacent the joint 30, so that the upward movement of piston 32 will be opposed by the increasing resistance of spring 37, and a position of stability maintained at a point in its movement according to the discharge pressure. The dampening effect of this spring may be varied in two ways, first, by changing the compression of the spring through nut 39, so that the total loading of the bell crank 29 may be varied, and second, by changing the position of the fulcrum 40 on the bell crank 29 so that the amount of movement for a given increment of pressure change may be varied.

On the drum 27 is a cam 41 having its surface raised above the surface of the drum, as is clearly shown in Fig. 5. One edge of this cam is straight and lies parallel to the axis of the drum. The other edge is inclined or helical, wrapping itself a portion of the way around the drum, all as will later be explained.

Surrounding the drum 27 is the mounting block 42, preferably made of an insulating material such as fibre. This block may be mounted in fixed position upon suitable supports 43. On this mounting block 42 are mounted a series of distributing members, one for each set of valves to be controlled, four being shown in this figure, one member for the inlet valves at each end of each cylinder.

For convenience, I have shown these distributing elements of the type commonly employed in the ignition system of an automobile, as this is simple and readily understood, but I do not limit myself to this particular construction, as others,

for instance a wiping contact on the cam surface 41 acting as one terminal might be substituted. As these four distributers are alike, but one will require description.

On a stud 44 outstanding from the block 42 is hinged an arm 45 carrying the cam block 46 adapted to ride upon the surface of the drum 27. This block may preferably be of fibre or similar material. Mounted on the arm 45 is the spring 46a, the outer end of which is secured in the post 47. The spring is secured to the arm as by rivets 48, leaving a free end thereof to which is secured the contact point 49 passing through an opening in arm 45 as shown. Mounted above this contact member and adjustable in the support 50 is the adjustable contact point 51.

It will now be seen that as the drum 27 revolves and as long as the cam blocks 46 ride upon the surface of the drum 27, the circuit between contacts 49 and 51 will be open, but during rotation of the drum when the cam 41 member comes beneath a block 46, it will be lifted, and with proper adjustment of contact 51 the circuit will be closed. The contact 49, being mounted on the free end of spring 46, provides a firm closing of the contacts, regardless of slight irregularities in the movement of the arm 45. This is shown in the case of the one cam block in contact with the cam.

The function of these four distributing elements is to supply current to the circuits for the electric magnets 20 and to energize and de-energize them in the proper order and at the proper time during the stroke of the pistons.

These four distributing elements are therefore wired in electrical connection with the magnets on the four sets of inlet valves in the order marked. That is, the distributer marked 22B—LPHE is wired in connection with the magnets on the inlet valves in the head end of the low pressure cylinder, the distributer marked 22B—LPCE is wired to the magnets in the crank end of the low pressure cylinder. The other two distributers are similarly wired to the valves in the ends of the high pressure cylinder.

The wiring circuits are completed as shown in Fig. 6 by connecting the several terminals 47 by connections 22C to one common lead, and the terminals 22A from the magnets 20 to another common lead, these two in turn being connected to a suitable source of current.

Referring again to Figs. 4 and 5 showing the distributing mechanism for the cross compound compressor selected for illustration, it will be seen that the four distributers are spaced equally around the drum 27, those for the opposite ends of each cylinder being on the opposite sides and the others at 90 degrees to them. Therefore, the action of any distributer upon the valves it controls will be duplicated by the other distributers on the valves they control.

To explain the operation, we will assume the drum 27 to be in about the position shown in Figs. 4 and 5. In this position that portion of the cam 41 directly beneath the cam blocks 46 extends approximately 90 degrees around the drum 27, or one quarter of the revolution. Now, with the drum so placed that slightly before the end of the suction stroke on the head end of the low pressure cylinder, the leading edge of cam 41 passes beneath the cam block 46 for that distributer, the arm 45 will be lifted, closing the contacts 49 and 51. This in turn energizes the magnets 20 on that end of the cylinder, bringing the lifting fingers 13 against the valves to hold them open.

As the suction stroke is not yet completed, the valves will be open and the lifting fingers coming up against them will hold them open as the remainder of the suction stroke is completed and as the compression stroke begins. With the valves held open, the air in the cylinder will be expelled back into the intake instead of being compressed. As the piston moves forward expelling the air, the drum 27 rotates and at about mid stroke (with the drum 27 in the position shown in Fig. 4) the trailing edge of the cam 41 passes from beneath the com block 46, opening the contacts 49 and 51.

The opening of this circuit immediately de-energizes the magnets 20 controlled thereby allowing the solenoid 18 to release and permit spring 12a to move the hub 12 and valve engaging fingers 13 away from the valves. The valves being now free close and the air remaining in the cylinder is compressed and discharged in the usual manner. In like manner the cam 41 as it rotates will control in the proper order the other sets of valves in the other ends of the cylinders.

In the illustration above we assumed the compressor operating at about half capacity. We will now assume the compressor starting up from rest, or with little or no pressure in the system. In such a case, the air piston 32 in cylinder 31 would be at its lowest point and the drum 27 at its extreme position to the right. In this position the narrowest portion of cam 41 passes beneath the cam blocks 46, reducing to a minimum the time during which the valves are held open, or the drum 27 may be arranged to pass sufficiently far to the right for the end of the cam 41 to pass beyond the line of the cam blocks. In that case the magnets would not be energized at all, and the inlet valves would be free to function in their usual manner delivering the full capacity of the compressor.

As the pressure in the system rises to that at which the control functions, the piston 32 rises, moving the drum 27 to the left as seen in Fig. 4. At first, as the narrow end of the cam 41 engages the cam blocks 46, the magnets will be energized but a short time, simply holding the valves open while the piston is passing through the end of the stroke and then allowing them to close. In this condition the compressor will be delivering substantially its full capacity.

As the pressure continues to rise, the drum 27 will be removed further to the left. This will cause wider and wider portions of the cam 41 to pass beneath the cam blocks 46, thereby lengthening the period during which the magnets 20 are energized and the inlet valves held open. Finally, as the maximum pressure is reached and the drum is at the extreme left where the cam 41 extends half way around the drum, the valves will be held open during substantially the entire compression stroke and no air will be compressed. The extreme right hand end of the cam 41 may be extended entirely around the drum so that when the drum is in its extreme left hand position the contacts 49 and 51 will be kept continuously closed and the valves held continuously open.

The regulation of the compressor output is not, therefore, in steps or increments of appreciable amounts, but consists of the gradual reduction or increase at all times determined or measured by the particular demand for air at the time as indicated by a slight rise or fall of discharge pressure in the system.

In Fig. 4 I have for convenience shown the element controlling the movement and position of drum 27 as an air cylinder under the influence of the discharge pressure of the air in the system and operating through the bell crank 29, but it is obvious that any equivalent demand controlled motor may be employed.

It may happen at times that for some reason, as for instance, the size of the inlet valves, that they can not be readily operated directly by magnets. In Fig. 7 I have shown an alternate method for moving the valve holding member 12 whereby a small electrically controlled valve supplies air for the motive power. In Fig. 7 the magnet case 19 is replaced by the cylinder 52 containing the power piston 53. In close proximity to this cylinder is an electrically controlled air valve 54, preferably of the solenoid type, having the air inlet 55, outlet 56 and exhaust 57. The outlet 56 is connected to cylinder 52.

When the circuit 22A—22B is energized, the solenoid within casing 58 will open the air valve and supply air under pressure to piston 52 to operate the valves 11, as before described. Upon opening the circuit, the air in cylinder 52 will be exhausted through exhaust 57 and the valves 11 will be released.

In the foregoing description, four distributing elements are shown as required for a two-cylinder, double-acting compressor, but it is obvious that for a double-acting, single cylinder but two elements would be required, and for a single cylinder compressing in one direction only one element would be necessary. In the case of a compressor with more cylinders, the corresponding increased number of elements would be required.

I claim:

1. A regulator for compressors comprising in combination, a cylinder having a piston movable therein and inlet and discharge valves at the opposite ends thereof, members movable to positions to render one of said sets of valves inoperative, electro-magnetic means controlling said members, and a distributer operating in synchronism with said compressor to alternately energize and de-energize said electro-magnetic means, a cam on said distributer, and pressure operated means to vary the position of said cam to vary the period said electro-magnetic means are energized and said valve held inoperative during the stroke of the piston.

2. A regulator for compressors comprising in combination, a cylinder having a piston movable therein and inlet and discharge valves at the opposite ends thereof, members movable to positions to render one of said sets of valves inoperative, electro-magnetic means controlling said members, a rotating distributer operating in synchronism with said compressor to alternately energize and de-energize said electro-magnetic means, a cam on said distributer having a variable width, and pressure operated means to vary the position of said cam to vary the period said electro-magnetic means are energized and said valves held inoperative during the stroke of the piston.

3. A regulator for compressors comprising in combination, a cylinder having a piston movable therein and inlet and discharge valves at the opposite ends thereof, members movable to positions to render the inlet valves inoperative at each end of said cylinder, electro-magnetic means controlling said members, a rotating distributer operating in synchronism with said compressor and having contacts adapted to be opened and closed in circuits for said electro-magnetic means, a cam on said distributer having a variable width, and pressure operated means to vary the portion of said cam effective to close said contacts and vary the time said valves are held open during the stroke of the piston.

4. A compressor regulator comprising in combination, a cam rotated in timed relation with the compressor, pressure actuated means to move said cam axially, electric circuits having contacts opened and closed by rotation of said cam, electro-magnets energized when said contacts are closed, and unloading means operated by said electro-magnets.

5. A compressor regulator comprising in combination, a cam rotated in timed relation with the compressor, said cam having a raised portion of gradually increasing width extending axially along its cylindrical surface, pressure actuated means to move said cam axially, electric circuits having contacts opened and closed by rotation of said cam, electro-magnets energized when said contacts are closed, and unloading means operated by said electro-magnets.

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