A control apparatus for selectively varying the output of a reciprocating compressor by holding open its suction valves for variable periods during the piston cycle. The apparatus includes a signal generating means for applying successive signals to a transducer which holds open the suction valves for a period proportional to the interval between signals. The signal generator has a rotating bar driven in timed proportion to crankshaft speed and first and second signal generating pickups positioned adjacent the path of the rotating bar so that passage thereby generates an output signal. The angular position of the second signal pickup is selectively varied to vary the time interval between signals and thus the time within the piston cycle that the compressor is unloaded. The angular position can be manually varied or automatically varied in response to changes in compressor output through a fluid pressure responsive actuator.

11 Claims, 3 Drawing Figures
TOP DEAD CENTER - HEAD END. (BOTTOM DEAD CENTER - CRANK END.)

CLEARANCE VOLUME GAS EXPANSION EVENT.

INCREASING TIME

COMPRESSOR DISCHARGE EVENT.

COMPRESSOR SUCTION EVENT.

SUCTION VALVE PLATES LOCKED OPEN. (MIN. LOAD)

SUCTION VALVE BACK FLOW EVENT.

MIN. LOAD.

MAX. LOAD.

TOP DEAD CENTER - CRANK END. (BOTTOM DEAD CENTER - HEAD END).

FIG - 2 -

FIG - 3 -

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This invention relates to a control apparatus for reciprocating compressors or pumps which is capable of infinitely varying the output throughout a wide range of output volumes and/or pressures.

In reciprocating compressor or pump installations, it is usually undesirable to vary the speed of the prime mover when changes in output of the compressor are desired, particularly when it is desired to completely shut off the compressor output, which would require shutting off the prime mover. Consequently, a common method of controlling compressor or pump output is the selective disabling of the suction valves of the compressor by holding them open so that subsequent strokes of the piston merely slish the fluid being acted upon back and forth in the intake manifold. In most compressor installations, the suction valves are disabled in steps, which means that one or more valves are held open, depending upon the desired output, throughout a range of full load to zero load. The step method has the disadvantage that there is a fluctuating pressure and unbalance on the prime mover and other stresses in the compressor parts plus, the fact that precise and infinitely variable changes of compressor output cannot be made.

It is an object of this invention to provide an apparatus for controlling the output of reciprocating compressors or pumps which is capable of the infinite control of output throughout the range from full load to no load and which eliminates some of the disadvantages attendant with the step type control systems. This and other advantages have been accomplished through use of an electronic control system which is used in combination with a valve unloading device which is triggered by an electrical signal to disable the suction valves of the compressor at a particular time during the compression stroke of the piston. By disabling and releasing the suction valves throughout a time range during the compression stroke of the piston, the amount of fluid being compressed or the efficiency of the piston stroke can be infinitely varied to thus vary the output of the compressor.

This is accomplished essentially through use of a signal creating timing mechanism which is mechanically driven by the compressor crankshaft in timed proportion to crank speed and which generates a pair of signals for each piston cycle. The pair of signals includes a first signal for actuating the valve disabling means and a second signal for deactuating the same. The time or interval between the successive signals within each pair determines the length of time during the compression stroke that the valve is disabled, to thus vary the compressor output. The valve disabling means itself can be mechanical, magnetic or hydraulic with an appropriate transducer for converting the actuating and deactuating signals into a force compatible valve disabling against the valve spring to hold it in open position.

Other objects and advantages of the invention will be apparent to those skilled in the art from the following detailed description of a preferred embodiment thereof, with reference being made to the accompanying drawings in which:

FIG. 1 is a schematic view of an entire compressor installation utilizing the output control device of this invention;

FIG. 2 is a cross sectional view, taken along line 2—2 of FIG. 1, of the signal generating device attached to the crankshaft of the compressor; and

FIG. 3 is a schematic diagram showing the timing relationships within one complete cycle of the compressor piston.

Referring first to FIG. 1, a conventional horizontal compressor having a piston 10 and piston rod 11 connected to a connecting rod 12 by a cross head 13 is shown. The compressor has a crank end cylinder 14 and a head end cylinder 15, each having discharge valves 16 and 17, respectively, connected to a discharge line 18 leading to the fluid receiver. Suction valves 19 and 20 are equipped with devices, designated by reference numerals 21 and 22, which include an appropriate signal transducer for converting electrical impulses to a force necessary to hold the valve open to unload the compressor. The particular unloading device can be magnetic, hydraulic or mechanical and its specific design does not constitute a part of this invention.

The compressor is driven by a prime mover, shown as an electrical motor in this embodiment, which is operably connected by means of a drive belt 23 which turns the crankshaft 24 driving the fly wheel 25 and connecting rod 12. The signal generating device, generally indicated by reference numeral 26, is mounted adjacent the crankshaft 24 and has a rotating input shaft 27 secured for rotation to the crankshaft 24 by a coupling 28. The particular type of compressor, the source of power and other mechanical arrangements shown in FIG. 1 are used for illustration purposes only and that the output control device of this invention can be used with other types of compressors or pumps driven by other types of power sources.

Referring now to FIG. 2, the housing 29 of the signal generating device 26 is secured to the frame of the compressor by a mounting adapter 30 which supports bearings 31 for the input shaft 27. On the inboard end of the input shaft 27 is a rotating plate 32 having a ferrous metal bar 33 secured to its outer periphery. If the plate 32 were driven at half the crankshaft speed, as by a camshaft, then two bars 33 mounted on the plate 32 180° apart would be used.

An internal yoke 35 of the housing 29 supports a hub 36 having a sleeve 37 whose outer surface is provided with bearings 38 which journal a rotating sleeve 39 to which is secured an annular disc 40. The annular disc 40 has a diameter such that the rotating ferrous bar 33 on the plate 32 passes closely adjacent the outer edge of the annular disc. A bushing 40 extends within the sleeve 37 of the hub 36 and has a flanged outer end 43 secured to the rotating sleeve 39 so that axial rotation of the bushing 42 will in turn rotate the annular disc 40.

Extending out from the yoke 35 is an annular cylinder wall 44 which is closed by a head cap 45. Between the adjacent annular surfaces of the cylinder wall 44 and head cap 45 is a flexible diaphragm 46 having a central aperture through which is secured a plunger 47. The plunger 47 is secured to the diaphragm 46 between a pair of collars 48 with an end 49 of the plunger 47 extending towards an axial bore 50 in the head 45. An adjustment screw 51 is threaded into the axial bore 50 with its inner end in contact with the extending end 49 of the plunger 47 so that the axial position of the plunger 47 can be adjusted, for the purpose subsequently explained.

A coil spring 52 is compressed between the inner collar 48 on the diaphragm 46 and the adjacent facing surface of the hub 36 so that the diaphragm 46 and plunger 47 are urged to their outer, right hand position as shown in FIG. 2, against the set screw 51. On the inner end of the plunger 47 is a spiral or slotted guide groove 53 which is engaged with a like guide 54 secured to the inner surface of the bushing 42. It will now be apparent that, as the plunger 47 moves along its axis, to the left as shown in FIG. 2, that the groove 53 and engaged detent 54 will cause the bushing 42 and consequently the annular disc 40 to rotate. The plunger 47 is held in its outer position by the spring 52, as previously explained, and it is moved against the bias spring 52 by fluid pressure in the closed chamber between the head 45 and the diaphragm 46. This space is pressurized by a line 55 which is connected to a fluid pressure source as will be subsequently explained.

Finally, first electrical sensors 56a and 56b is secured on an arm 57 on the interior of the adapter 30 so that it is positioned closely adjacent the rotary path of the ferrous bar 33. Second moving electrical sensors 56a and 58 are secured to the disc 40 to rotate with the disc. As the disc 40 is rotated by movement of the diaphragm 46 and plunger 47, etc., the angular relative position between the first and second sensors 56a, 56b, 58 and 59 will be changed. This selected change in angular position or distance between sensors 56a, 56b, 58 and 59 will change the interval between said unloading signals which are used to load or unload the compressor.

The sensors 56a, 56b, 58 and 59 may be electro-magnets, permanent magnets or other inductive or capacitive devices which will register an electrical output as the ferrous bar 33
passes thereby. This coupling phenomena which is well known to those skilled in the art is used to create successive first and second output signals with the interval between the signals determining the time that the suction valves of the compressor are unlatched to thus vary the output of the compressor through an infinite variation as the angular distance is infinitely varied.

Referring again to FIG. 1, the electrical output from the sensors 56a, 56b, 58 and 59 is connected by leads 60 and 61 to an electronic signal amplifier having a DC power supply. The output of the signal amplifier is applied to the unloading device transducers which convert the electrical signals to the appropriate force for unloading the valves 21 and 22. In the illustrated system, the receiver tank pressure is applied through the pipe 55 to the chamber formed by the diaphragm 46 and head 45. In this illustrated system, the receiver pressure is used to control the signal generating device 26 so that a constant receiver pressure can be maintained. It is to be understood that the principle of this invention can be used with a manual or other programmed source of pressure signals applied to the line 55 to control the output of the compressor.

In some installations, it is advantageous to supply a known air pressure to the space on the left of the diaphragm 46 to assist or even eliminate the spring 52. This is accomplished by a pressure line 62 extending through the cylinder wall 44, as shown in FIG. 2 and a seal 63 around the plunger 47. Thus, with a known constant pressure supplied by the line 62 acting with the spring 52 or alone, the range of values of pressure in line 55 necessary to move the diaphragm 46 and plunger 47, etc. can be infinitely varied without changing the spring 52.

FIG. 3 schematically shows the time relationships for a complete cycle of the compressor, using the rotating sensors 58 and 59 in the illustrated example of a double acting compressor. In this example, one sensor controls the signal for the crank end 14 and the other for the head end 15. Taking for example only one end of the compressor, the head end 15, FIG. 3 illustrates at the 12 o'clock position the top dead center of the piston. Moving counter clockwise, the suction stroke of the piston starts at the angular position marked A and continues to bottom dead center at the 6 o'clock position marked B. The compression of the fluid starts at the position marked C while discharge starts at the position marked D. As previously explained, if the suction valves are held open some time during the interval from A through C, the compressor output will be reduced as fluid is then drawn back into the suction manifold. The minimum load on the compressor is attained by holding open the suction valves during the entire interval between A and C, while the maximum load is attained by holding them open between A and B, so that the interval between B and C is varied to obtain outputs between minimum and maximum load.

As previously explained, the length of time that the suction valves are held open, throughout an infinite range of the compressor cycle between events B and C of FIG. 3 is controlled by the length of the interval between the output signals from the first and second sensors 56a, 56b, 58 and 59. This interval between signals is in turn controlled by the angular relation of the sensors 56a and 58 or 56b and 59. It will thus be apparent that pressure changes such as from the receiving tank through the line 55 can be automatically applied to the signal generator 26 so that extremely precise control of output pressure or volume is maintained. Furthermore, with other simple pneumatic or electrical controls, a manual or programmed output cycle can be easily attained with infinite variation, without the disadvantages attendant in the prior art systems.

It should also be pointed out that the concept of this invention can be utilized with several means for varying the angular position between the sensors, such as electro-magnetic or mechanical means, for example, a direct current torque motor or a solenoid essentially the same as shown above, or any other device capable of moving the sensor 56 and 59, whereby the signal generating unit shown in FIG. 2 can be used to control a plurality of compressor cylinders by the addition of additional plates 40 and second sensing means 58, 59, etc. (not shown). It will also be apparent that the concepts of the signal control unit 26 can be used with various types of valve unloader transducers, magnetic or hydraulic, which will require various electronic means for amplifying, shaping or inverting the signals to adapt them for the particular type of transducer. Application of the principles and concepts of this invention to various types of known transducer and compressor hardware will be within the capabilities of those skilled in the art. Other variations and applications of the invention herein described can be made by those skilled in the art without departing from the spirit of the following claims.

1. A variable output control for a reciprocating compressor comprising, in combination, an unloader mechanism for holding open a suction valve of a compressor cylinder to thereby unload that cylinder and a controller for selectively actuating and deactuating said unloader mechanism relative to the position of the piston of said compressor cylinder throughout a variable range of piston positions, said controller including a coupling bar driven about an axis in timed relation to compressor speed, a first electrical sensing element fixed adjacent the path of said coupling bar and effective to generate an energizing signal when said coupling bar passes thereby, a second electrical sensing element positioned adjacent the path of said coupling bar and effective to generate a de-energizing signal when said coupling bar passes thereby, means for rotating said second sensing element about said axis to change its angular position relative to said first sensing element whereby the time interval between said energizing and de-energizing signals may be varied, and means for applying said signals to said unloader mechanism such that said energizing signal will actuate said unloader and said de-energizing signal will deactuate said unloader in timed proportion to the relative angular position between said sensing elements.

2. The compressor output control of claim 1 wherein said second electrical sensing element is secured to a disc rotatably journaled about said axis and having a range of angular rotation relative to said first sensing element such that time between successive signals generated by said rotating coupling bar will be varied in proportion to the angular distance between said first and second sensing elements.

3. The compressor output control of claim 1 wherein said advancing means for rotating said second sensing element comprises a fluid pressure responsive element operatively connected to said second sensing element and effective to advance the angular position of said second sensing element in response to fluid pressure variations upon said pressure responsive element.

4. The compressor output control of claim 3 wherein said fluid pressure responsive element is connected to the output from said compressor whereby variations in said compressor output pressure will control movement of said second sensing element.

5. The compressor output control of claim 1 wherein said advancing means for rotating said second sensing element about said axis comprises a plunger journaled for reciprocatory movement along said axis between first and second positions, means biasing said plunger towards said second position, a pressure responsive fluid diaphragm secured to said plunger and adapted to move said plunger against said bias means towards its said second position, and means coating with said plunger effective to advance the angular position of said second sensing element in proportion to movement of said plunger along said axis.

6. The compressor output control of claim 5 wherein said second sensing element is secured to a disc rotatably journaled about said axis and circumjacent said plunger, a sleeve secured within said disc circumjacent said plunger, a spiral groove on said plunger within said sleeve, and a detent on said sleeve extending into said spiral groove whereby axial movement of said plunger causes rotary movement of said sleeve, disc and sensing element as said detent moves within said spiral groove.
7. A control apparatus for varying the output of a reciprocating compressor having a reciprocating piston driven by a crankshaft and suction and discharge valves, said control apparatus including a suction valve unloader for holding open the suction valve to thereby unload the piston, and means for selectively actuating and deactuating said unloader for variable periods during the piston cycle, said means comprising a rotating signal element driven about an axis in timed relation to compressor crankshaft speed, a first signal sensor secured adjacent the path of said driven element and effective to generate a first signal as that driven element passes thereby, a second signal sensor positioned adjacent the path of said driven element and effective to generate a second signal as that driven element passes thereby, means for changing the angular position about said axis of said second sensor relative to said first sensor to thus change the time interval between said first and second signals a signal responsive transducer effective to actuate and deactuate said unloader upon receipt of said first and second signals respectively, and means for applying said first and second signals to said transducer whereby said compressor output will be varied in proportion to the time interval between said first and second signals.

8. The control apparatus of claim 7 wherein said rotating signal element is a ferrous bar and said first and second signal sensors are inductive windings.

9. The control apparatus of claim 7 wherein said means for changing the angular position of said second sensor is a fluid pressure responsive means whose position is varied in proportion to the output from said compressor and whose position variations control the angular position of said second signal sensor.

10. The control apparatus of claim 7 wherein said means for changing the angular position of said second signal sensor comprises a plunger journaled for reciprocatory movement along said axis between first and second positions, means biasing said plunger towards said second position, a pressure responsive fluid diaphragm secured to said plunger and adapted to move said plunger against said bias means towards its said second position, and means coacting with said plunger effective to advance the angular position of said second signal sensor in proportion to movement of said plunger along said axis.

11. The control apparatus of claim 10 wherein said second signal sensor is secured to a disc rotatably journaled about said axis and circumjacent said plunger, a sleeve secured within said disc circumjacent said plunger, a spiral groove on said plunger within said sleeve, and a detent on said sleeve extending into said spiral groove whereby axial movement of said plunger causes rotary movement of said sleeve, disc and sensing element as said detent moves within said spiral groove.

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