A. HINZ.

ROTARY COMPRESSOR AND THE METHOD OF O'ERATING IT.

APPLICATION FILED JULY 21, 1911.

1,216,119.

Patented Feb. 13, 1917.

3 SHEETS—SHEET 1.

Fig. 1.

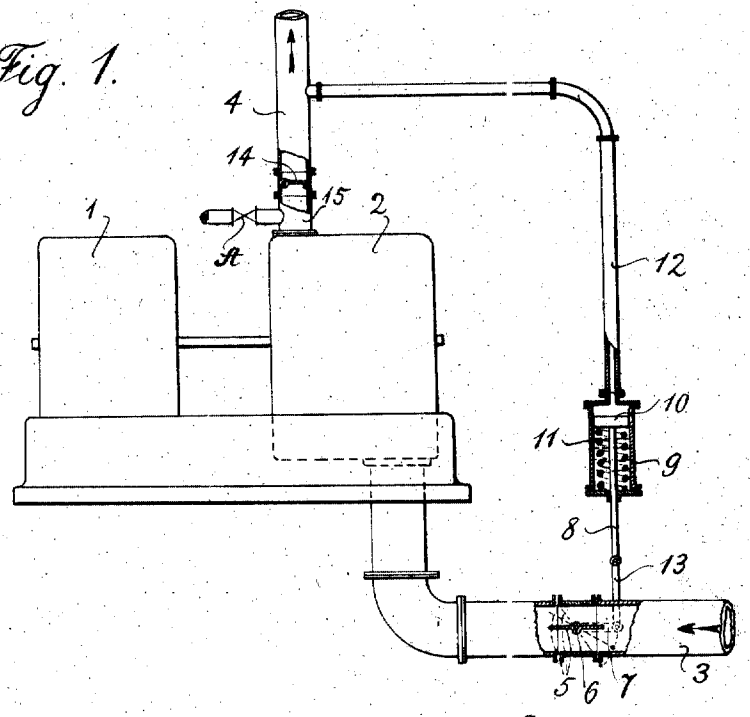
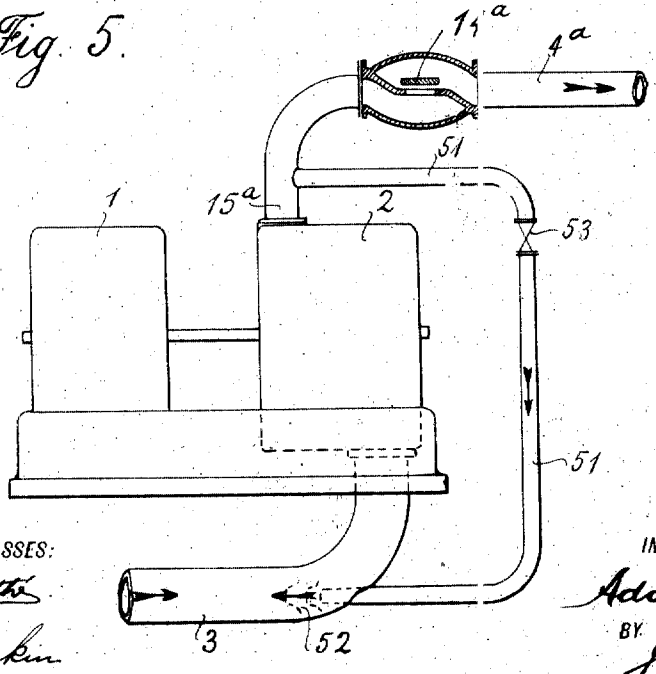


Fig. 5.



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3 SHEETS—SHEET 2.

Fig. 2.

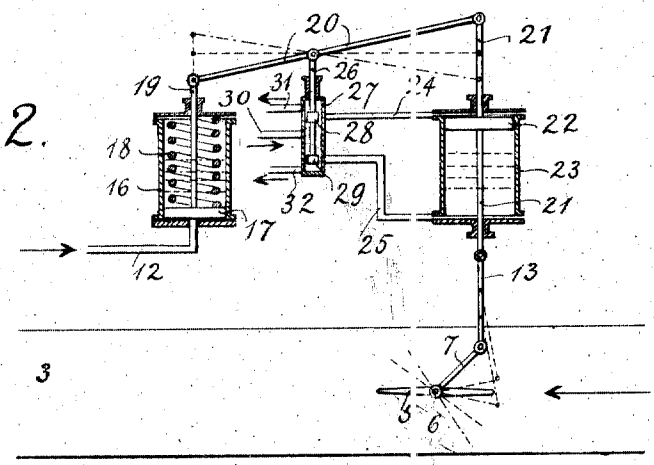


Fig. 3.

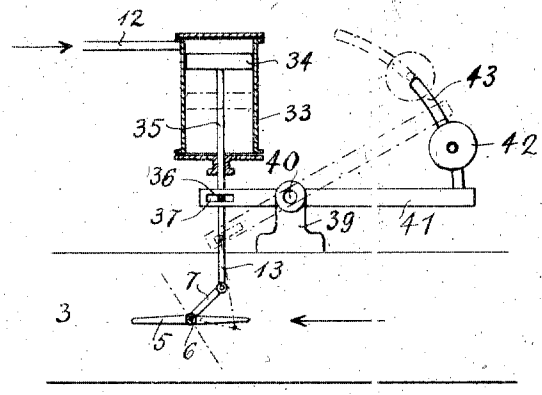
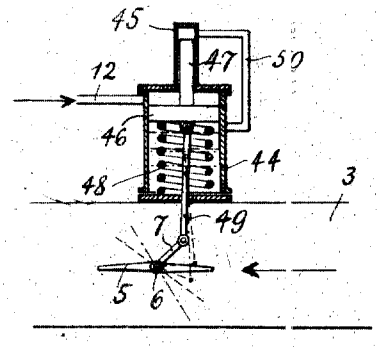


Fig. 4.



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3 SHEETS—SHEET 3.

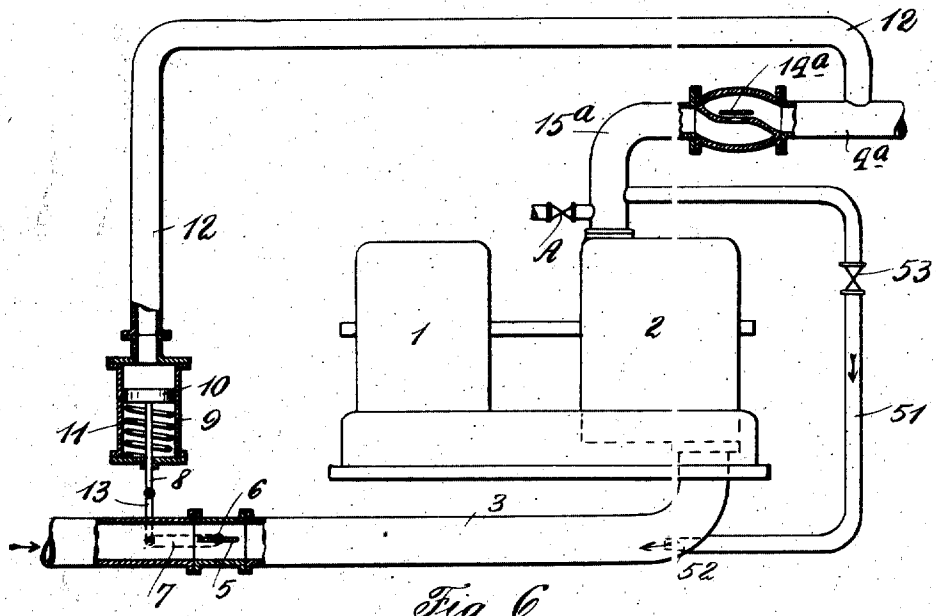


Fig. 6

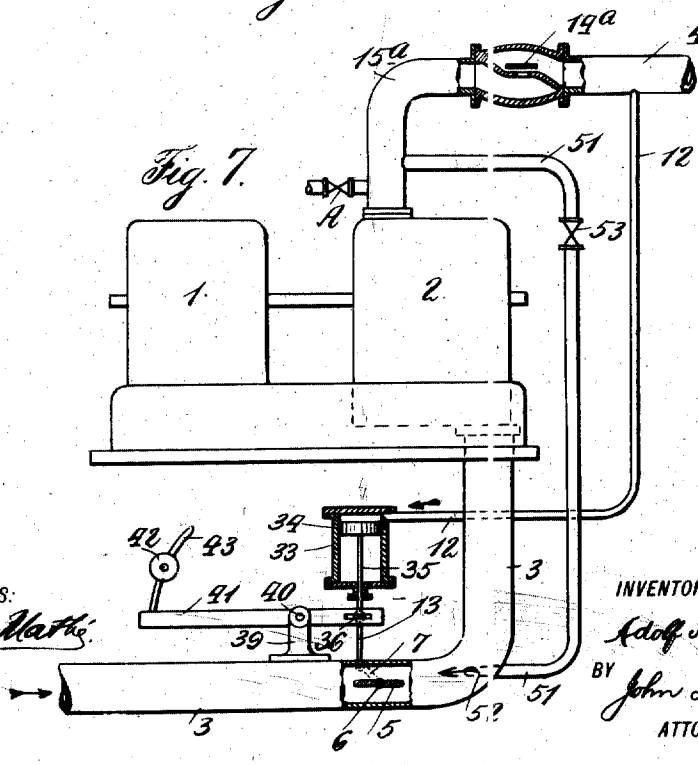


Fig. 7.

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ROTARY COMPRESSOR AND THE METHOD OF OPERATING IT.

1,216,119. Specification of Letters Patent. Patented Feb. 13, 1917.

Application filed July 21, 1911. Serial No. 639,741.

To all whom it may concern:

Be it known that I, ADOLF HINZ, a subject of the German Emperor, and resident of Frankfort-on-the-Main, Germany, have invented certain new and useful Improvements in Rotary Compressors and the Methods of Operating Them, of which the following is a specification.

Rotary compressors, as now constructed, are inferior to reciprocating piston compressors in this respect that in the case of a temporarily low consumption of gas or air the output of the compressor cannot be adjusted to the momentary consumption. Reducing the output of the compressor by diminishing the suction effect by means of a throttling device, is an expedient available only down to a certain limit, the critical output at which the air or gas within the compressor is subject to vibrations which interfere with its proper operation. It was therefore necessary hitherto, in the event of a low consumption, to operate the compressor under too great a load and to allow the excess of compressed air to escape unused.

In order to reduce this loss of energy, I have devised a method of operation according to which, in case of a consumption lower than the normal output of the compressor, the latter will be disconnected temporarily from the pressure pipe, from the time that pressure in said pipe exceeds the allowable minimum pressure (that is to say, the pressure at which the operation of the compressor becomes jerky or subject to vibrations) until the pressure has fallen again to said minimum pressure or to an intermediate pressure. During the times the compressor is disconnected from the pressure conduit, the suction effect is reduced so as to diminish as far as possible, the output of the compressor and the energy required for its operation. During these times of interrupted connection, the air required for consumption is taken from the amount of air stored in the various parts of the pressure conduit. Owing to the reduction of the suction effect during the periods of interruption, according to my method of adapting the operation of a rotary compressor to the consumption of air, the energy required for the operation of the compressor during such periods is materially smaller than that required when working under a full load, since the energy is almost in direct ratio to the suction effect.

It will therefore be understood that my improved method of operation involves two distinct steps or periods: during the first period the compressor delivers more air than required for consumption and thus the pressure within the pressure conduit will increase gradually; during the second period the compressor is disconnected entirely from the pressure conduit, so that the pressure in said conduit will be reduced by the consumption, and furthermore during this second period the energy required to operate the compressor is reduced as far as possible, by diminishing the suction effect.

The delivery of air or gas is interrupted as soon as the suction effect or suction pressure has been reduced by about $\frac{1}{10}$ of an atmosphere. If however in carrying out my method the pressure at the suction end is reduced in the well-known manner, by means of a throttling device which after disconnecting the compressor from the delivery conduit is brought immediately into the position in which the compressor can be run idle with the least expenditure of energy, the pressure at the suction end may be reduced to $\frac{1}{10}$ of an atmosphere (absolute measure) and even less. In this case the compressor while running idle will require only about $\frac{1}{10}$ of the normal operating power.

With this mode of operation, the load on the compressor will vary as it is run alternately under full load and idle, and according to my invention the load fluctuations thus arising may be minimized by closing the throttle gradually until the point corresponding to the critical output is reached, and then bringing the throttle into the proper position for the most economical idle running of the compressor. The reason for this is found in the fact that when throttling gradually by small amounts, say $\frac{1}{100}$ of an atmosphere, to the point at which the compressor begins to vibrate or labor, the

output may be diminished without interrupting delivery from the compressor, since owing to the reduction of the output the compression ratio will increase notwithstanding the relatively low pressure of the air at the suction end.

My improved method may be carried out automatically, that is to say, with an automatic change from one of the above-described operation periods to the other at the proper time. For this purpose, a check valve or like device is provided in the delivery conduit and the throttle arranged in the suction conduit is placed under the influence of the pressure in the delivery conduit on one hand, and on the other hand under the influence of a spring or other opposing force which acts more powerfully during the open position of the throttle than during its closed position. With such an arrangement, the existence of maximum pressure in the delivery conduit will close the throttle automatically, so as to reduce the pressure at the suction end. Now it is well known that in a rotary compressor, other factors remaining unchanged, the compression ratio, that is to say, the ratio between the final pressure of the compressed air and the pressure at the suction end, is approximately constant. Therefore, the above-mentioned reduction of pressure at the suction end will automatically and simultaneously reduce the final pressure obtained in the compressor, to a point where such pressure will be below that prevailing at the time in the delivery conduit. Consequently, air will begin to flow from the delivery conduit back into the compressor, thus causing the check valve in the delivery conduit to close automatically. This disconnects the compressor from the delivery conduit. The throttle is not opened again until the pressure in the delivery conduit has fallen an amount equal to the difference between the maximum pressure and the opposing force.

Another way of reducing the pressure at the suction end according to my invention consists in utilizing the excess of air. For this purpose, after the pressure within the delivery conduit has risen above the minimum pressure, a portion of the air delivered by the compressor is thrown by an injector or like apparatus against the air which is on its way to the compressor, and after the compressor has been disconnected from the delivery conduit, the entire amount of air delivered is thus directed against the suction current. When a check valve is provided in the delivery conduit, the returning of a portion of the air from the delivery end to the suction end, as indicated, will reduce the pressure at the suction end sufficiently to cause an automatic closing of said valve so as to disconnect the compressor from the delivery conduit. When at a later stage the entire amount of air is returned to the suction end, as described, a further material reduction of pressure takes place at the suction end and in the compressor, up to the check valve, thus again reducing the power required for operating the compressor during the time it is disconnected from the delivery conduit. In this mode of carrying out my invention, the regulation may be controlled not only by the pressure prevailing in the delivery conduit but by the output of the compressor. Furthermore, since the air returned from the pressure end of the compressor to the suction end is warm so that warm air is supplied to the compressor, the friction at the rotors of the compressor is diminished, this resulting in a further reduction of the power required to run the compressor during the time it is disconnected from the delivery conduit.

It is difficult to obtain as considerable a reduction of the pressure at the suction end when employing only the above-indicated injector action as with a throttling arrangement in the suction conduit. If therefore it is desired to secure the advantages of the injector action and at the same time to obtain a great reduction of pressure at the suction end, it is advisable to use both devices jointly, that is, the injector and the throttle.

In the foregoing I have assumed a construction in which the disconnection of the compressor from the delivery conduit is the result of the reduction of pressure at the suction end, which causes a check valve to close. It will be understood, however, that the disconnection may be effected in any other suitable manner, as for instance, by the manual closing of a valve or cut-off slide, or by means of an auxiliary motor entering into action when the maximum pressure is attained. After the connection has been interrupted at the delivery end, the pressure may be reduced at the suction end so as to reduce the power required for operating the compressor.

The novel features of my invention are defined in the appended claims.

Seven typical examples of compressors embodying my invention are illustrated in the accompanying drawings, in which Figure 1 is an elevation, with parts in section, showing in diagrammatic fashion an arrangement in which the pressure of the compressed fluid is utilized to govern the operation automatically; Fig. 2 is a fragmentary sectional view illustrating a regulator construction differing slightly from that shown in Fig. 1; Figs. 3 and 4 are sectional views representing two further constructions of regulators; Fig. 5 illustrates diagrammatically a form of my invention in which the

compressed fluid is returned to the suction end; Fig. 6 shows diagrammatically a structure combining the features of Figs. 1 and 5; and Fig. 7 is a diagrammatic representation of a structure combining the features of Figs. 1, 3, and 5.

According to the construction shown in Fig. 1, the rotary compressor 2 (of any suitable type), driven by a suitable motor 1, receives its supply of air or other fluid to be compressed, through the suction pipe 3 and delivers such fluid in a compressed condition through the outlet 15 into the delivery conduit 4 from which the compressed air is led or distributed to the place of consumption. In the suction pipe 3 is located a throttle valve 5 pivoted to the pipe by means of a rock shaft 6. Upon this shaft is secured an arm 7 connected by a link 13 with the rod 8 of a piston 10 movable in the cylinder 9. A pipe 12 connects the upper end of the cylinder 9 with the delivery conduit 4, so that the piston 10 is exposed on one side to the air pressure prevailing at that time in the delivery conduit. A suitable force, constituted in the present case by the tension of a coiled spring 11, acts against the other side of the piston and therefore in opposition to the pressure exerted on the upper face of the piston. The tension of the spring is preferably adjustable, as by providing a screw connection between the piston 10 and its rod 8.

A suitable check device, such as a check valve 14, is interposed between the outlet 15 and the delivery conduit 4.

The tension of the spring 11 is adjusted to a point where it will balance the air pressure exerted against the upper face of the piston 10 when the consumption of air and the output of the compressor are normal. In this case the throttle valve 5 is in the open position indicated by solid lines.

When the consumption of air is smaller than the normal output of the compressor 2, the latter forces into the delivery conduit 4 a greater amount of air than is used. The resulting clogging causes the pressure in the delivery conduit 4 (including the piping connected therewith) to rise above the normal pressure. This in turn will gradually force down the piston 10 and move the throttle valve 5 so as to reduce the effective cross section of the suction pipe 3. Under these conditions, the output of the compressor is diminished slightly, so that such output will adjust itself to a diminished consumption, provided the decrease is slight. This will continue until the so-called critical output is reached, which as a rule amounts to about $\frac{3}{4}$ of the normal output. When the output has fallen to the critical point, the throttle 5 will be in the intermediate position indicated by the dotted line in Fig. 1.

When however the consumption of air falls below the critical output, the continued increase of pressure in the delivery conduit 4 will cause the throttle valve 5 to assume the extreme position indicated by the dot-and-dash line. This position reduces the pressure at the suction end by about $\frac{1}{10}$ of an atmosphere, and the pressure at the outlet 15 of the compressor will fall below that prevailing in the delivery conduit. The check valve 14 will therefore close automatically, interrupting the communication between the compressor and the delivery conduit 4. The reduced amount of air then still delivered by the compressor is allowed to escape through an outlet A.

While the compressor is cut off from the delivery conduit, the compressed air required at the places of consumption is taken from the amount stored or contained in the delivery conduit 4, so that the pressure within said conduit is reduced. When the reduction has proceeded to an extent corresponding to the friction of the piston 10 in the cylinder 9 and to the friction at the pivot joints of the connections 7, 13, 8, the spring 11 will restore the piston 10 and the throttle valve 5 to the intermediate position indicated by dotted lines. The compressor 10 will then operate with about $\frac{3}{4}$ of the normal output, the increasing pressure at the outlet 15 will open the check valve 14, whereupon a further increase in the pressure of the air now passing through the pipe 12 will force the piston 10 downward. These operations or periods of operation will be repeated automatically as often as pressure goes above or below the limits mentioned above.

In this form of my invention, the opposing force constituted by the tension of the spring 11 is equal to the maximum pressure, minus the friction occurring between the piston and the cylinder and at the pivot joints. Therefore, the smaller this friction, the smaller will be the difference between the maximum pressure and the intermediate pressure corresponding to the critical output, and consequently, the more nearly constant will the air pressure be in the delivery conduit 4. It will therefore be understood that with an arrangement such as described above the air pressure in the delivery conduit may be kept almost absolutely constant.

Instead of reducing the pressure at the suction end by the interposition of a throttle in the suction conduit, the same result may be obtained, of course, by throttling the air current at some other suitable place. For instance, with a multi-stage compressor (this being a well-known type of rotary compressor) the air current may be throttled at any one of the compressor stages or simultaneously at a plurality of stages. The other parts or stages of the compressor will continue their normal operation even

while some of the parts or stages are subjected to the throttling action.

When it is desired to increase the sensitiveness of the regulator, this may be accomplished by means of a relay provided with a governing connection, an example of such an arrangement being shown in Fig. 2. The parts 1, 2, 4, 14, 15 not represented in Fig. 2, and their connections with the pipes 3, 12, are to be the same as in Fig. 1. The pipe 12 leads to a cylinder 16 in which is arranged a piston 17 subjected on one side to the pressure prevailing in the delivery conduit 4 and in the pipe 12 connected therewith, and on the other side to the opposing action of a spring 18, the tension of which may be adjusted. The piston rod 19 is connected by a transverse lever 20 with the rod 21 of a piston 22 arranged to move in a cylinder 23. The rod 21 extends entirely through the cylinder 23, and is pivotally connected at its lower end with the link 13, the said link, together with the arm 7, rock shaft 6 and throttle valve 5 being of the same construction as described with reference to Fig. 1.

The opposite ends of the cylinder 23 are connected with pipes 24, 25 respectively by means of which a suitable medium under pressure may be conveyed to one end of the cylinder and from the other end. Compressed air from the pressure chamber of the compressor may be utilized for this purpose.

In order that a definite position of the relay piston 22 and of the throttle 5 may correspond to each particular position of the piston 17, a governing connection has been provided. In the particular instance shown in Fig. 2, the lever 20 is pivotally connected, between the points at which it is connected with the piston rods 19, 21 respectively, with a slide valve rod 26 carrying two connected piston valves 28, 29 contained in a valve chest 27. This chest is connected between the valves 28, 29, with a pipe 30 for the supply of the medium under pressure (for instance, compressed air from the compressor). At the ends of the chest or casing 27 are provided outlet pipes 31 and 32 respectively, the distance between the outlets being greater than that between the valves 28, 29. The pipes 24, 25 are connected with the chest 27 at points the same distance apart as the valves 28, 29.

In the central position the slide valves 28, 29 cover the orifices of the pipes 24, 25 respectively, so that the medium under pressure supplied through the pipe 30 cannot reach the cylinder 23. If however the piston 17 is moved upward owing to an increase of pressure in the delivery conduit 4 (the spring 18 being compressed at the same time), the lever 20 will swing or rock about its connection with the piston rod 21, since the piston 22 cannot move. This will raise the slide valves 28, 29, so that the medium under pressure will pass from the supply pipe 30 through the valve chest 27 to the pipe 24 and to the upper end of the cylinder 23. At the same time, the chamber below the piston 22 will be placed in communication with the outlet pipe 32, by means of the pipe 25 and the lower portion of the valve chest 27.

The piston 22 being forced downward by the pressure of the medium admitted at the top of the cylinder 23, the air or other medium contained in the cylinder below the cylinder will be expelled through the pipe 32. At the same time, since now the piston 17 may be considered stationary, the lever 20 will swing about its left-hand end (that is to say, about the pivot connecting it with the piston rod 19). This movement will raise the slide valves 28, 29 to their initial central position in which they cover the ports of the pipes 24, 25 and thus hold or lock the piston 22, by confining the bodies of fluid contained above and below the piston respectively. When the piston 17 thereupon moves down under the influence of the spring 18 owing to a reduction of pressure in the delivery conduit 4 and in the pipe 12, similar operations will be performed. That is to say, the lever 20 will swing down about its right-hand end as a fulcrum, thus shifting the valves 28, 29 so as to admit compressed fluid from the pipe 30 under the piston 22 through the pipe 25, and to allow fluid to escape from above the piston 22 through the pipes 24, 31. This will cause the piston 22 to move upward so that the lever 20 will swing about its left-hand end as a fulcrum, restoring the valves 28, 29 to the position shown in Fig. 2.

In its general features, the operation of the apparatus shown in Fig. 2 is the same as that of the arrangement shown in Fig. 1. As long as the consumption of air equals the output of the compressor, the several parts of the regulator remain in the position indicated by solid lines. When the consumption diminishes, the throttle 5 will be closed gradually, and when the output has been reduced to about ⅔ of its normal value, the throttle 5 and connected parts will be in the intermediate position indicated by dotted lines. Should the consumption decrease still further, the parts of the regulator will assume the extreme position indicated by dot-and-dash lines, in which the check valve 14 closes to disconnect the compressor 2 from the delivery conduit 4.

If, after a certain maximum pressure has been exceeded, the throttle 5 is brought immediately into the extreme (substantially closed) position corresponding to the idle running of the compressor, so that the pressure at the suction end is reduced to ~~$\frac{1}{10}$~~

of an atmosphere (absolute) or less, this will effect a material further diminution of the power required to operate the compressor during the time it is disconnected from the delivery conduit. According to the example shown in Fig. 3, the pipe 12 (leading from the delivery conduit 4) is connected with the upper end of a cylinder 33, so that the pressure prevailing in the delivery conduit will act on the upper surface of a piston 34. The piston rod 35 is provided with a pin 36 pivotally connected with the link 13 which is connected with the throttle 5 in the same manner as described before. The pin 36 further passes into a slot 37 provided in the arm 38 of a lever fulcrumed at 40 upon a bracket 39. The other arm 41 of this lever carries a weight 42, which for instance may be adjustable along an arc 43 and secured after adjustment, say by means of a set screw.

The weight 42 is adjusted to such a position that at a predetermined maximum pressure the effect or moment of the weight (weight multiplied by horizontal projection of its radius from the fulcrum 40) will balance the pressure exerted on the upper surface of the piston 34. In this case the throttle 5 will be in the open position indicated by solid line, so that the compressor will operate with a normal output and produce an increase of pressure in the delivery conduit 4.

When this maximum pressure is exceeded (as in the event of a reduced consumption) the piston 34 will be forced down until the pin 36 reaches the outer end of the slot 37 and thus brings the throttle 5 and other parts into the nearly closed position indicated by the dot-and-dash lines, which corresponds to the idle running of the compressor. In this position the rocking of the lever 38, 41 has brought the weight 42 nearer to the vertical plane passing through the fulcrum 40 so that the effective leverage of said weight, that is to say, the horizontal projection of its distance or radius from the fulcrum 40, has been reduced, so that the effective moment of the weight has become smaller than the fluid pressure acting on the piston 34 when the latter is in its upper position. Since the substantial closing of the throttle causes the compressor to be disconnected from the delivery conduit (by the action of the check valve 14), the pressure will fall in the delivery conduit 4 and in the pipe 12, but the weight 42 will be unable to bring the piston 34 back to its upper position until the reduction of pressure in said delivery conduit corresponds to the automatic reduction in the effective leverage of the weight 42.

By adjusting the weight 42 along the arc 43 the minimum pressure may be varied within wide limits.

In order to avoid the load fluctuations to which the motor 1 is subjected by the sudden increase and decrease of the load on the compressor 2, I may employ an arrangement such as shown in Fig. 4. Here the output is at first reduced gradually, as in the constructions illustrated by Figs. 1 and 2, until the critical output is reached, and then the throttle 5 is brought into the approximately closed position which corresponds to the idle running of the compressor. The pipe 12 is connected with the cylinder 44 having a hollow extension 45 at its upper head. A double piston is employed, composed of a large piston 46 in the cylinder 44, and of a small piston 47 in the extension 45. The annular upper surface of the piston 46 is exposed to the pressure prevailing in the delivery conduit and in the pipe 12; a coiled spring 48 presses against the lower surface of the piston 46. The space below the said piston is open to the surrounding air, and the piston has a pivotal connection with a rod 49, pivotally connected at its lower end with the arm 7 on the rock shaft 6 of the throttle valve 5. When this valve is open, the piston is in its upper position, slightly below the port connected with the pipe 12. At a point slightly above the position of the piston 46 when the throttle 5 is in the intermediate position corresponding to the critical output, a pipe 50 leads from the cylinder 44 to a point of the extension 45 above the piston 47.

The tension of the spring 48 is so adjusted in any suitable manner that with the throttle 5 open the spring tension will balance the minimum pressure exerted on the annular upper surface of the piston 46. When the consumption of air decreases, the resulting increase of pressure in the delivery conduit and in the pipe 12 will force the piston 46 down gradually and shift the throttle 5 so as to decrease the output of the compressor. When the critical output is reached (with the throttle 5 in the position indicated by the dotted line) the piston 46 will be below the lower end of the pipe 50 so that the latter will be in communication with the pipe 12. The pressure in this latter pipe will therefore also prevail in the chamber of the extension 45 above the piston 47. On account of the increased total pressure tending to force the piston 46 down, the spring 48 will be compressed strongly, and the throttle 5 will be brought into the extreme, nearly closed position indicated by the dot-and-dash line, which position corresponds to the idle running of the compressor.

When the compressor is cut off from the delivery conduit 4, the pressure in the latter will fall, but the spring 48 will not be able to return the compound piston 46, 47 to its uppermost position until the pressure

has been reduced by an amount corresponding to the pressure exerted against the effective surface of the small piston 47. Thus when the minimum pressure is restored the compressor will be connected again with the delivery conduit.

By properly selecting the effective area of the small piston 47 the difference between maximum and minimum pressure may be increased or decreased within wide limits.

The construction shown in Figs. 1 and 2 may also be made to operate in the same manner as the device shown in Fig. 4, if instead of the springs 11 and 16 respectively I employ double springs, that is to say, two springs one of which (like the springs 11 and 16) engages the piston and the cylinder head at all times while the other comes into action only after a certain travel of the piston; the first part of the travel of the piston will therefore compress only one of the springs and adjust the throttle 5 to its intermediate position, without interrupting the connection between the compressor and the delivery conduit, while the further travel will compress both springs and bring the throttle 5 to the extreme position, in which the check valve disconnects the delivery conduit 4 from the compressor 2.

The sensitiveness of the regulators shown in Figs. 3 and 4 can be increased by using in connection therewith a relay of the same character as shown in Fig. 2. That is to say, in one case the piston 34 of Fig. 3 with its rod 35 and pin 36, cylinder 33 and weighted lever arrangement 37, 38, 39, 40, 41, 42, 43 will take the place of the parts 16, 17 and 18 of Fig. 2, the other parts of Fig. 2 remaining unaltered, with the lever 20 pivoted in this case to the piston rod 35. In the other case the cylinder 44, 45, double piston 46, 47, spring 48 and connection 50 would be substituted for the parts 16, 17, 18 of Fig. 2, the other parts of Fig. 2 remaining unaltered, with the left-hand end of the lever 20 pivoted to the rod of the compound piston 46, 47.

In the form of my invention illustrated by Fig. 5, the reduction of the pressure at the suction end, required to carry out my method of operation, is obtained by utilizing the excess of air delivered by the compressor.

From the outlet 15^a of the compressor 2 a pipe 51 leads to an injector or rather ejector 52, indicated in diagrammatic fashion, said ejector being so disposed within the suction pipe 3 that the current of air issuing from the ejector nozzles will be directed against the current of air flowing to the compressor. A shut-off valve 53 or equivalent device is provided at a suitable point of the pipe 51. Furthermore, a check valve 14^a is interposed between the delivery conduit 4^a and the point at which the pipe 51 is branched off from the outlet 15^a.

When the consumption of air is considerably below normal, the compressor is operated with the valve 53 closed, until the pressure in the delivery conduit 4^a has attained a predetermined value. Then the valve 53 is opened to such an extent that the excess of air over that required for consumption will flow through the pipe 51 to the ejector 52. The air current discharged at the nozzles in opposition to the main air current, as indicated by arrows, will reduce the pressure at the suction end to such an extent that the pressure at the outlet 15^a will fall below the pressure prevailing in the delivery conduit 4^a, so that the check valve 14^a will close automatically and disconnect the compressor 2 from the delivery conduit 4^a. Thereupon the valve 53 is opened fully, causing the entire amount of air delivered by the compressor 2 to be returned to the suction pipe 3 through the pipe 51 and ejector 52, and to be discharged against the current of air flowing to the compressor. The strength of the opposing current issuing from the ejector nozzles being thus increased, the pressure at the outlet 15^a is reduced to a minimum depending on the particular conditions of each individual case.

In this form of my invention also, the air required for consumption during the time that the delivery conduit is disconnected from the compressor, is taken from the amount stored in the said conduit, including the distributing pipes; this will cause the pressure to fall in said conduit and as soon as it equals the pressure in the outlet 15^a, the check valve 14^a will open. Thereupon the valve 53 is closed and the operation is repeated in the same manner whenever the consumption falls considerably below the normal output of the compressor.

It is advantageous to use the method of operation described with reference to Fig. 5, in conjunction with the method employed according to Figs. 1 to 4 inclusive, that is to say, the pressure at the suction end would be reduced by means such as the throttle valve 5 shown in Figs. 1 to 4, and in addition to this, the air delivered by the compressor after it has been cut off from the delivery conduit, would be returned to the suction pipe, and discharged into the same in the direction contrary to the flow of the air on its way to the compressor. In this manner the power required to run the compressor during the time it is disconnected from the delivery conduit, will be reduced to a minimum. Thus, the structure illustrated by Fig. 6 combines the features of Figs. 1 and 5, and the structure shown in Fig. 7 is a combination of the features shown in Figs. 1, 3, and 5, that is to say, the construction of Fig. 7 differs from that of Fig. 6 chiefly by the fact that Fig. 7 employs the weighted-lever resistance 41, 42, 43 of

Fig. 3 in lieu of the resistance-spring 11 of Fig. 1.

In the examples described above, it has been assumed that the reduction of pressure at the suction end takes place in the initial suction pipe of the compressor, that is, before the air reaches the first rotor of the compressor. My invention is however capable of a broader application. Thus the reduction of the pressure at the suction end may occur at some intermediate point so that it will not affect the entire compressor. For instance, in the case of a compressor constructed with two casings or sections, one of them a low-pressure section and the other a high-pressure section, the reduction of pressure at the suction end may, if desired, be effected only between the two sections or stages, that is to say, immediately before the air passes to the high-pressure section or stage. This is advantageous in some cases, as when the compressor is used to supply air of different pressures at the same time; air of a low pressure would be delivered from a point between the two compressor sections, and air of a higher pressure from the outlet of the high-pressure section. With my invention applied to a multi-stage compressor of this character, the high-pressure section could be disconnected from its delivery conduit at times, as described, while the low-pressure section would always operate to deliver its normal output.

These modifications and others may be made without departing from the nature of my invention as set forth in the appended claims.

I claim:

1. The method of operating compressors, and particularly rotary compressors, which consists in disconnecting the compressor from the delivery conduit when owing to reduced consumption the pressure in said conduit rises above the allowable minimum pressure, reducing the pressure at the suction end during the time of such disconnection, so as to diminish the power required to run the compressor at such time, and reëstablishing the connection between the compressor and the delivery conduit after the pressure in said conduit has fallen to a predetermined point.

2. The method of operating compressors, and particularly rotary compressors, which consists in utilizing the increase of pressure which occurs at the delivery end of the compressor owing to reduced consumption, to reduce the pressure at the suction end and in consequence of such reduction to interrupt automatically the connection from the compressor to the place of consumption.

3. The method of operating compressors, and particularly rotary compressors, in the event of an irregular consumption, which consists in reducing the pressure at the suction end gradually until the critical output is attained and then further reducing such pressure to the point corresponding to the idle running of the compressor and at the same time interrupting the connection between the compressor and the place of consumption.

4. The method of operating compressors, and particularly rotary compressors comprising a plurality of sections or stages, which consists in disconnecting the compressor from the place of consumption when owing to reduced consumption the pressure rises at such place, reducing the suction pressure in a portion of the compressor during the time of disconnection, and reëstablishing the connection between the compressor and the place of consumption after the pressure at the place of consumption has fallen to a predetermined point, the other portion of the compressor continuing to operate regularly.

5. In connection with a rotary compressor, a check valve arranged in the delivery conduit, a throttle located in the suction conduit, and means whereby the throttle is placed under the influence, on the one hand, of the pressure prevailing in said delivery conduit, and on the other hand, of an opposing force which is smaller in the closed position of the throttle than in its open position.

6. In connection with a rotary compressor, a device connected with the delivery end of the compressor and arranged, in the event of reduced consumption, to discharge fluid under pressure into the suction conduit in a direction contrary to that of the main current of fluid therein, to reduce the pressure prevailing in said suction conduit.

7. In connection with a rotary compressor, a device connected with the delivery end of the compressor and arranged, in the event of reduced consumption, to discharge fluid under pressure into the suction conduit in a direction contrary to that of the main current of fluid therein, to reduce the pressure prevailing in said suction conduit, means for shutting off the connection of the said device with the delivery end of the compressor, and a check valve located in the delivery conduit at a point farther away from the compressor than the connection leading to the said device.

8. In connection with a rotary compressor, a device connected with the delivery end of the compressor and arranged, in the event of reduced consumption, to discharge fluid under pressure into the suction conduit in a direction contrary to that of the main current of fluid therein, to reduce the pressure prevailing in said suction conduit, and a throttle located in the suction conduit, to assist in reducing the pressure in said conduit.

9. In connection with a rotary compressor,

a throttle located in the suction conduit, a piston operatively connected with said throttle, a spring exerting pressure on said piston in one direction, and means for causing the pressure prevailing in the delivery conduit of the compressor to act on the piston in opposition to said spring.

In testimony whereof I have signed this specification in the presence of two subscribing witnesses.

ADOLF HINZ.

Witnesses:
JEAN GRUND,
CARL GRUND.