Nov. 25, 1969 F. BAUER 3,480,199

CAPACITY CONTROL SYSTEM FOR COMPRESSOR UNITS

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FIG. 1

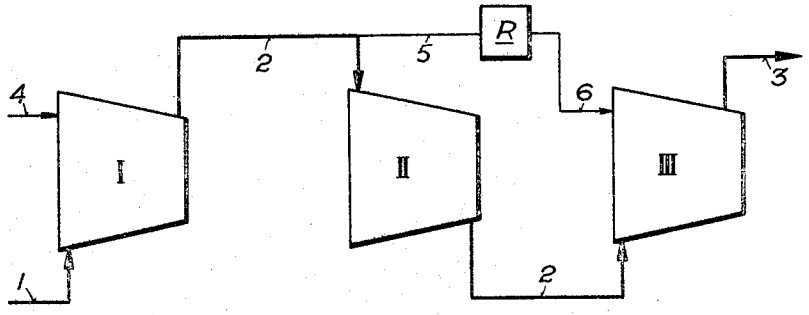
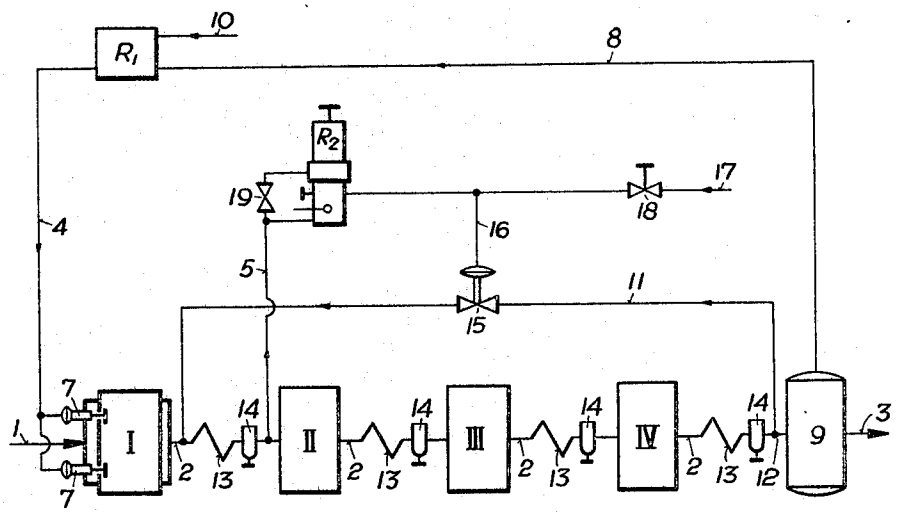


FIG. 2



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CAPACITY CONTROL SYSTEM FOR COMPRESSOR UNITS

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U.S. Cl. 230—4 5 Claims

ABSTRACT OF THE DISCLOSURE

A capacity control system for multi-stage compressor units comprising control means for altering the delivery of the first-stage compressor of the unit and additional control means for altering the delivery of one of the subsequent compression stages.

BACKGROUND OF THE INVENTION

This invention relates to a capacity control system for a compressor unit having a first-stage compressor followed by at least one subsequent compression stage, and connecting lines between the compression stages.

Compressor units, particulary of the type comprising a plurality of compression stages, are generally required to provide adaptation of the quantity delivered to the actual needs of the consuming unit or to the volume of gas produced so as to keep the suction, the final or an intermediate pressure at a constant level. The control systems used for this purpose are supposed to operate at low cost and possibly without any power losses and to offer the required degree of operational safety. Conventional systems wherein all compression stages are provided with individual regulators, such as for example, with lifting devices for the suction valves, operate at negligible power losses. However the structural expense involved is comparatively high. Consequently, in many cases only the first compression stage of a multi-stage compressor unit is subject to control whereas the higher compression stages remain uncontrolled, their deliveries diminishing only as a result of a corresponding decrease of the intermediate pressures.

If for example, the final pressure of a multi-stage compressor unit is to be kept at a constant level by controlling the delivery of the first compression stage only, the resulting lower periods being frequently of great length due to the slow alteration of individual intermediate pressures. Consequently, the compressor assembly will respond to each control pulse by altering the delivery of the last stage after a considerable delay only. Therefore, unless the alterations are very slow, oscillations are liable to occur running through the entire control circuit. In many cases stability may be maintained by the use of regulators featuring a specific time behaviour. This is, however, possible only at the expense of the quality of control, such operating conditions as the control system is meant to ensure, cannot as a rule, be maintained for any length of time within the desired limits.

SUMMARY OF THE INVENTION

It is the object of the invention to reduce objectionable lower periods in connection with the capacity control of compressor units and to provide a control system capable of adapting the compressor unit to given operating conditions with the least possible delay at low structural expense.

The invention provides for a capacity control system for a compressor unit having a first-stage compressor followed by at least one subsequent compression stage, and connecting lines between the compression stages, comprising control means for altering the delivery of the first-stage compressor and additional control means for altering the delivery of at least one of the subsequent compression stages, the said first control means being adjusted as required by control pulses, said additional control means being temporarily adjusted for a brief period of time only dependent on a change in a physical condition prevailing in the connecting line between two preceding compression stages thereby altering the delivery of the said subsequent compression stage and reducing the time required by a control pulse released to the first-stage compressor controlling the means for altering the delivery of the first-stage compressor, for its passage through the entire compressor unit.

By this simple measure any control intervention with the first-stage compressor is immediately transmitted to the end of the control range, for example, to the last compression stage so that lower periods are largely eliminated and overriding is avoided. Consequently, the control system according to the invention assures permanent maintenance, with a high degree of precision, of the operating condition required at the end of the control range, such as for example, of the final pressure of the compressor unit, within narrow limits.

Preferably the last compression stage of the compressor unit is provided with said additional control means for altering the quantity delivered. The additional control means may be controlled as a function of a physical condition, preferably of pressure, in the connecting line between the first-stage compressor and the adjacent compression stage. All or part of the compression stages may consist of piston-type compressors. Moreover, the temporarily acting additional control means for altering the delivery of one of the subsequent compression stages may be operated according to any control system. Since in normal operation the compressor unit is controlled by means of the control means acting upon the first-stage compressor only and the additional control means are in operation only temporarily, a power loss-involving method can be used for the purpose without perceptibly impairing the efficiency of the whole system.

Therefore, the additional temporary control means in a simple manner may comprise a control line branching off the delivery side of the said subsequent compression stage, a throttle valve inserted in the control line for the purpose of altering its cross-sectional area, and a control device liable to be influenced by a physical condition prevailing in the connecting line between two compression stages and controlling the said throttle valve. The control line may terminate into the atmosphere or return at any convenient point to the connecting line between two compression stages, preferably to the connecting line by which the associated control device is impinged upon, such as for example, to the connecting line between two compression stages, thereby forming a by-pass.

BRIEF DESCRIPTION OF THE DRAWING

Further optional details and advantages of the invention will appear from the following description of several embodiments with reference to the accompanying drawing in which:

FIGURE 1 is a schematic view of a three-stage compressor unit for the purpose of explaining the control system according to the invention, and

FIGURE 2 is a schematic illustration of a compressor unit comprising four compression stages and equipped with a control system according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The individual compression stages are designated by reference numbers I to IV, stage I defining the first-stage compressor and the remaining stages II to IV the subsequent compression stages following the first-stage compressor. A suction pipe **1** terminates in the first-stage compressor I, connecting lines **2** are provided between individual compressor stages and the consumption pipe **3** emerges from the last compression stage.

As illustrated schematically in FIG. 1, a control pulse is released to the first-stage compressor I via a control line **4**, the effect of the said pulse being a decrease of the quantity delivered by the first-stage compressor I into the adjacent connecting line **2**. As a result, the intermediate pressure in the connecting line **2** drops and so does the suction pressure of the second compression stage II, thereby decreasing also the quantity delivered by that stage accordingly. Without an additional control of the higher compression stages the suction pressure of the third compression stage II will then drop with a retardation of the second order and so will the quantity delivered by the compression stage II, and finally the control pulse released to the first-stage compressor I will become effective in the consumption line **3** with a retardation of the third order.

In order to shorten the time required by the control pulse to pass through the compressor unit, the quantity delivered by the compression stage III is temporarily altered in accordance with the control pulse as a function of the intermediate pressure prevailing in the connecting line **2** emerging from the first-stage compressor I. For that purpose, a control device R is provided which is connected to the connecting line **2** via a line **5** and releases a control pulse to the compression stage III via a control line **6**. The retardation due to the passage of the control pulse through the compressor unit in the compression stage II is thus eliminated so that the down time of the compressor unit is correspondingly reduced. The reaction velocity of the control system is thereby increased to a considerable extent. This feature is particularly important for compressor units comprising a plurality of compression stages.

According to the embodiment of the invention illustrated in FIG. 2, the first-stage compressor I, such as a double-acting piston-type compressor, is provided with a lifting mechanism **7** for the suction valves on each side of the cylinder, which are controlled in accordance with the stroke rhythm by means of a main control device R_1 via a control line **4**. Via line **8** the control device R_1 is impinged upon by the final pressure of the compressor unit prevailing in a pressure tank **9** interpolated between the last compression stage IV and the consumption line **3**, and serves to keep the said final pressure at a constant level. The control device R_1 is fed via a feed pipe **10**. The higher compression stages II to IV are by-passed by a by-pass line **11** emerging from the delivery pipe **12** of the last compression stage IV terminating in the pressure tank **9**, the said by-pass line **11** terminating in the connecting line **2** between the first stage compressor I and the compression stage II. An intermediate cooler **13** and a liquid draining device **14** are interpolated in each of the connecting lines **2** between individual compression stages and in the delivery pipe **12**. The by-pass line **11** is controlled by means of an infinitely variable throttle valve **15** actuated via a control line **16** by means of a control device R_2, which is in turn controlled via line **5** as a function of the intermediate pressure between the compression stages I and II. The control device R_2 and the throttle valve **15** are fed via a feed line **17** having incorporated an adjustable throttle valve **18**.

The control device R_2 may for example, be a diaphragm governor comprising a retarding throttle **19** and altering the pressure in the control line **16** when the intermediate

pressure in the connecting line **2** drops, as a result of which the throttle valve **15** opens, allowing the compressed medium to flow from the delivery pipe **12** via the by-pass line **11** back into the connecting line **2** between the compression stages I and II. At the same time, the pressure difference acting upon the control device R_2 is reduced by means of the retarding throttle **19**, so that the former slowly returns to its original position, thereby closing the throttle valve **15**. By means of the retarding throttle **19** the closing velocity can be adapted to compensate the lack of reactivity of the higher compression stages II to IV in such a manner that no oscillations will occur in the pressure tank **9**.

The diaphragm governor R_2 has an initial tendency to keep the intermediate pressure between the compression stages I and II at an approximately constant level, as a result of which precisely the excess quantity of the pressure medium is blown from the delivery pipe **12** into the connection line **2** forming the suction pipe of the compression stage II and causes a slow transition from the by-pass control to the nondissipative capacity control by means of reduced intermediate pressures, without influencing the final pressure in the process. Thus the reaction velocity of the compressor unit control system is substantially increased by means of the additional temporary control mechanism. Since the by-pass control is operative only temporarily for brief intervals following sudden major changes in consumption, the resulting loss of power is negligible.

The control system according to the invention is generally suitable for use in conjunction with any compressor unit control involving the problem of influencing the physical condition at one or several points of the compressor unit by means of a control pulse released to the first-stage compressor. In any case, the reaction velocity of the control system is considerably increased by the reduction of the time required for the passage of the control pulse through the entire compressor unit, so that objectionable oscillations and overriding are avoided and maintenance of the desired operational condition is assured within narrow limits.

I claim:

1. In combination with a compound compressor unit having a first-stage compressor followed by at least two subsequent compression stages connected by connecting lines, a capacity control system comprising control means for the first-stage compressor and additional control means for at least one of the subsequent compression stages, the first control means being controlled by control signals, a control device for the additional control means and initiated by a change in a physical condition prevailing in the connecting line between two preceding compression stages, and adjustable regulator means for limiting the working time of the control device, the said additional control means being temporarily in working condition for a brief period of time only, altering the delivery of the said subsequent compression stage and reducing the time required for the passage through the entire compressor unit of a control signal released to the first-stage compressor.

2. In combination with a compound compressor unit a capacity control system according to claim **1**, in which the compressor unit comprises a first-stage compressor and at least two subsequent compression stages, the said additional control means controlling the last compression stage.

3. In combination with a compound compressor unit a capacity control system according to claim **1**, in which the compressor unit comprises a first-stage compressor and at least two subsequent compression stages, the said additional control means controlling the last compression stage, being controlled as a function of a physical condition prevailing in the connecting line between the first-stage compressor and the adjacent compression stage.

4. In combination with a compound compressor unit a capacity control system according to claim **1**, in which the

additional control means for altering the delivery of at least one of the subsequent compression stages comprising a control line branching off the delivery side of the controlled subsequent compression stage, a throttle valve being provided inserted in the control line for the purpose of altering its cross-sectional area and controlled by the said control device liable to be influenced by a physical condition prevailing in the connecting line between two compression stages.

5. In combination with a compound compressor unit a capacity control system according to claim 1, in which the additional control means for altering the delivery of at least one of the subsequent compression stages comprising a control line branching off the delivery side of the controlled subsequent compression stage, a throttle valve being provided inserted in the control line for the purpose of altering its cross-sectional area and controlled by the said

control device liable to be influenced by a physical condition prevailing in the connecting line between two compression stages, the control line forming a by-pass connecting the delivery side of the controlled subsequent compression stage with the connecting line between two preceding compression stages.

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