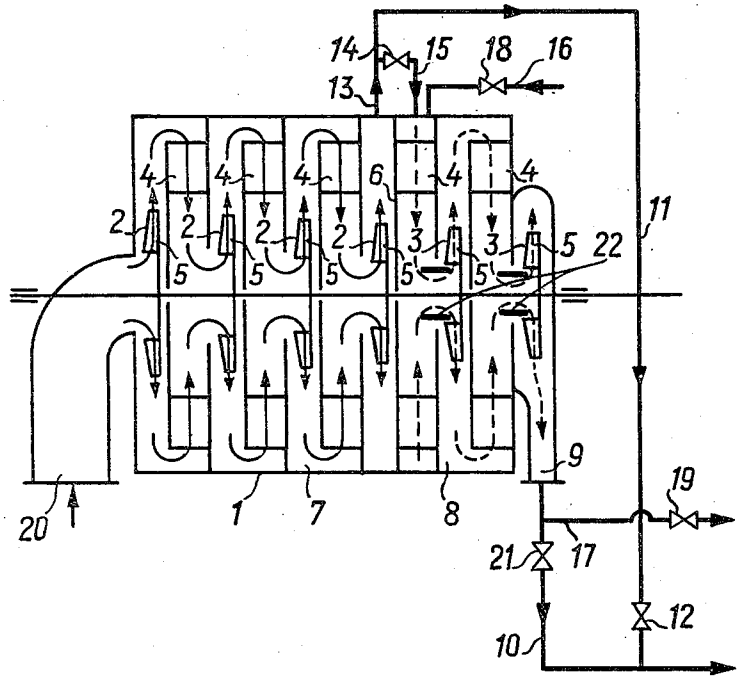
Jan. 14, 1958 M. EBERLE 2,819,836

MULTI-STAGE RADIAL COMPRESSOR

Filed Oct. 24, 1956



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United States Patent Office 2,819,836 Patented Jan. 14, 1958

2,819,836

MULTI-STAGE RADIAL COMPRESSOR

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Application October 24, 1956, Serial No. 618,030

Claims priority, application Switzerland October 29, 1955

2 Claims. (Cl. 230—114)

This invention relates to multi-stage air compressors of the radial flow centrifugal type and has particular reference to an improved mode of operation of such compressors, and to improvements in the construction thereof.

The term "air" as used herein is intended to include within its scope any other gaseous medium for which the compressor may be used.

In the practical utilization of air compressors it is frequently desirable to draw off and use the compressed air at a pressure less than the full pressure which the compressor is capable of affording. This is the case, for example, in mines, where full pressure may be required for drilling purposes, but only partial pressure is needed for air clearance or ventilation. It is known that this result can be achieved by simply tapping the compressor at an intermediate pressure stage, but this practice has the disadvantage that the stages beyond the tapped point, which for cooling purposes continue to convey part of the air, are subject to an undesirable oscillation known as "pumping." This oscillation manifests itself as soon as the quantity of air passing through these stages falls to an amount not far below the normal amount passing through them. For this reason it has been the practice heretofore to keep the quantity of conveyed air relatively high in the stages beyond the tapped point; but as a result of this the efficiency of operation of the compressor, when delivering air at only partial pressure, is quite low

The object of this invention is to avoid this disadvantage, and the achievement of this objective involves an improved method and means for operating a multi-stage compressor under circumstances in which air at less than full pressure is tapped off prior to one or more of the final stages. In accordance with this invention, a cooling medium is passed through such final stage or stages in an amount less than 20% of the normal capacity of such stage or stages, and "pumping" is avoided by appropriately throttling the cross-sectional area of the axial intake chamber of the rotor in each such stage. The cooling medium employed may be a fragment of the air conveyed through the earlier stages preceding the point of tapping off, or outside air at atmospheric pressure, or any gaseous medium at atmospheric or other than atmospheric pressure.

It is known that the cross-sectional area of the intake chamber of a compressor wheel or rotor can be throttled or otherwise varied by means of a cylindrical shell or valve concentric with the rotor shaft and axially shiftable. Because the air-conveying capacity of rotors thus throttled can be selectively reduced to a very small amount, the pumping limit being correspondingly influenced, the employment of such a sliding valve in one or more of the final stages of a multi-stage compressor, where air is to be drawn off at a point preceding such stage or stages, results in substantially increasing the efficiency of operation under such circumstances, and also prevents undesired "pumping."

The accompanying drawing is a schematic representation of a radial flow multi-stage compressor embodying the features of the invention.

In the compressor shown, the casing 1 encloses six compressor stages, four designated 2 and two indicated at 3. Between the stages there are coolers 4. The air travels through the vanes or blades of the rotors and through the coolers along the paths indicated by arrows.

The two end stages 3 are separated from the other stages 2 by a cross wall 6, thereby dividing the compressor into one part 7 composed of the four stages 2, and a second part 8 with the two last stages 3. Part 8 is merged with the compressor outlet 9 leading to the pressure system 10.

Adjacent to the wall 6 there is an intermediate or partial-pressure outlet 13 leading from the part 7. It is connected to the system 10 by a conduit 11 in which there is a valve 12. The compressor parts 7 and 8 are in communication through an overflow conduit 15 leading from the outlet 13 and provided with a valve 14. In practice, at least two parallel intermediate outlets, like that shown at 13, and overflow conduits such as that shown at 15, should be provided, in order that favorable flow conditions may be obtained.

At 16 and 17 are shown two conduits leading to and from the inlet and outlet ends, respectively, of the compressor part 8. These conduits communicate with the atmosphere and are provided with valves 18 and 19 respectively. Conduit 16 may communicate with any desired source of gaseous cooling medium, either at atmospheric or other than atmospheric pressure.

The plurality of rotors etablishes a path of air flow from the inlet at the first stage of the compressor to the full-pressure outlet at the final stage. Accordingly, when air at full pressure is desired, during normal operation, the air enters the compressor inlet 20 and leaves through turbine outlet 9, passing into the pressure system 10 through the valve 21. Under these circumstances, valve 14, as well as valve 21, are open, while valves 12, 18 and 19 are closed.

During operation of the compressor for delivery of air under partial pressure, with valves 14 and 21 closed and valve 12 opened, the air is drawn off after the fourth stage 2 and fed through conduit 11 and valve 12 to the pressure system 10. Under these circumstances, if the last two compressor stages 3 are to run idle, or were to receive only such small quantity of air as might leak through valve 14 under a pressure corresponding approximately to the outlet pressure of the fourth stage 2, frictional heat would be produced to an undesirable extent, thereby not only excessively increasing the required output but also creating a condition detrimental to compressor operation. For this reason, valve 14 is not fully closed but is opened sufficiently to allow a small fraction of the air passing through stages 2 to be fed to stages 3 for cooling purposes. At the same time, valve 19 is opened. To ensure the least possible output of stages 3, only a very small amount of cooling air, much below 20% of the normal flow capacity, is allowed to pass to stages 3. Such a small flow would ordinarily cause stages 3 to "pump," and in order to avoid this they are each equipped with a hollow cylindrical slide or shell 22, axially arranged and shiftable in known manner during partial pressure operation, so that the intake of each of the stages 3 is narrowed or throttled to an appropriate extent.

As a result, stages 3 can run practically idle during partial pressure operation, and hence nearly all of the air entering the compressor at 20 can be tapped off for use at intermediate outlet 13.

Similarly desirable results can be achieved with the valve 14 entirely closed. Under these conditions, valves

18 and 19 are opened to an extent sufficient to allow a small quantity of air or other gaseous medium for cooling purposes to enter stages 3 through conduit 16 and to leave through conduit 17. This air or gas may be at atmospheric or other selected pressure, and it passes into each stage 3 through a throttled or narrowed intake opening controlled by the corresponding slide valve or shell 22.

Where cooling medium through conduits 16 and 17 is to be employed, the switch-over from full pressure operation (compressed air drawn off at 9) to partial pressure operation (compressed air drawn off through conduit 11) can be achieved by manually or automatically performing the following sequence of operations: shift slides 22 to throttle intakes of stages 3, open valve 12, close valves 21 and 14, and open valves 18, 19. The order of these operations is reversed when changing from partial pressure to full pressure operation.

If desired, some or all of the valves shown in the drawing can be constructed as check valves. For example, valve 12 may be designed as an automatically closing check valve so that when valves 21 and 14 are opened the increase of pressure at the outlet of valve 12, as compared with the pressure on the other side, will close valve 12 automatically.

Having thus described my invention what I claim as new and desire to secure by Letters Patent is:

1. In a radial flow multi-stage centrifugal compressor, a plurality of rotors establishing a path of air flow from an inlet at the first stage to a full-pressure outlet at the final stage, each rotor having an axial intake chamber, a partial-pressure outlet from the compressor at a point preceding at least one of the final stages to permit air to be drawn off at less than full pressure, means for selectively opening and closing said outlets, means for introducing a relatively small amount of cooling medium to the rotor of each unused final stage during periods of partial-pressure operation when the partial-pressure outlet is open and the full-pressure outlet closed, an an axially movable cylindrical shell in the intake chamber of each of said final stage rotors concentric with the latter and adapted to vary the cross-sectional area of said intake chamber.

2. In a radial flow multi-stage centrifugal compressor, a plurality of rotors establishing a path of air flow from an inlet at the first stage to a full-pressure outlet at the final stage, a casing enclosing said rotors and provided with a cross wall dividing the casing into a part that houses a group of rotors defining final stages of the compressor and another part that houses rotors of preceding stages, a partial-pressure outlet from the last-named part, means for selectively opening and closing said outlets so that air may be drawn off at full pressure from the full-pressure outlet or at less than full pressure from the partial-pressure outlet, valved conduits for cooling medium leading respectively to the inlet and outlet of said group of final stage rotors, and means for varying the cross-sectional area of the intake chamber of each of said last-named stages so that a relatively small quantity of cooling medium may be employed when the full-pressure outlet is closed and the partial-pressure outlet is open for drawing off air.

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