June 3, 1958 B. N. TORELL 2,837,269

COMPRESSOR BLEED CONTROL

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FIG. 1

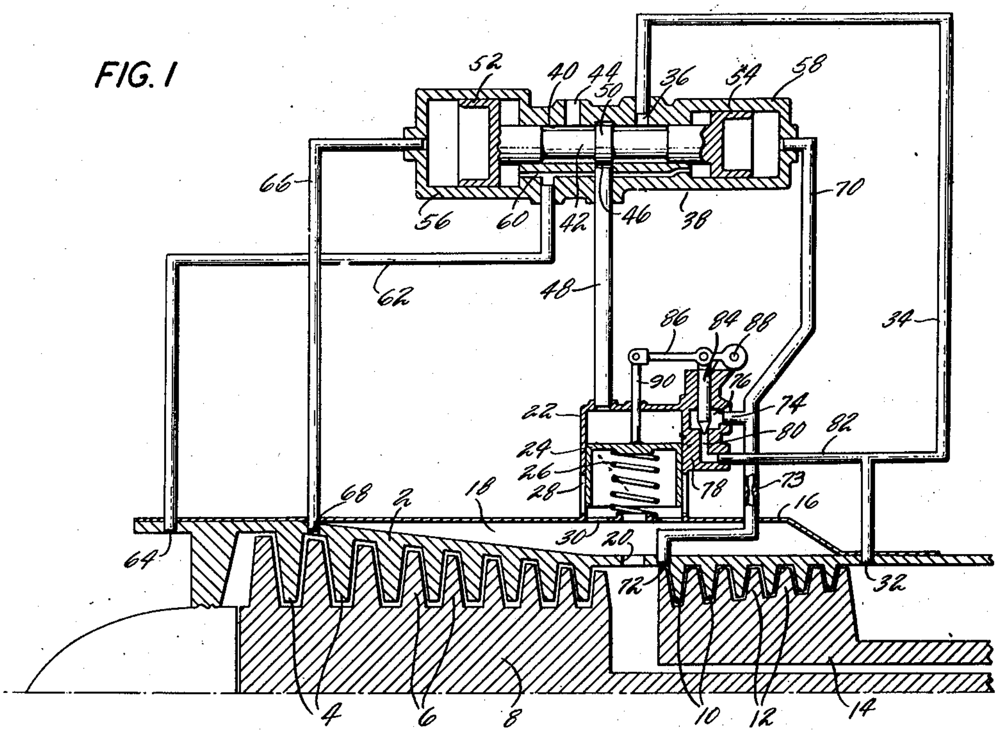
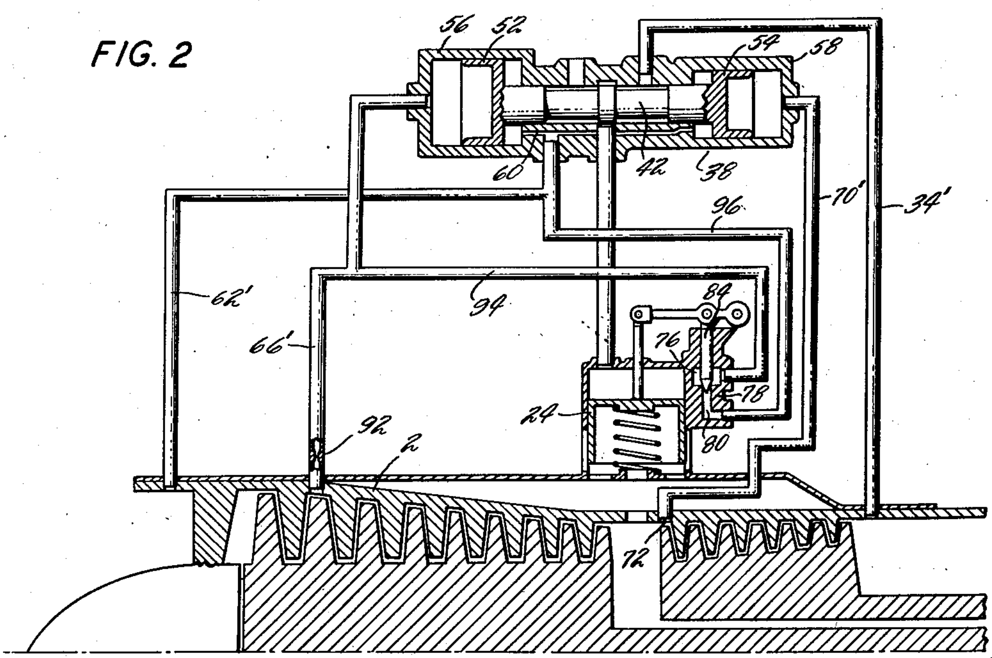


FIG. 2



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COMPRESSOR BLEED CONTROL

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6 Claims. (Cl. 230—114)

This invention relates to a bleed control particularly for a multi-stage axial-flow compressor.

Bleed controls which function to prevent stalling or surging in a multi-stage compressor are well known. One feature of the present invention is the gradual closing of bleed in a multi-stage compressor so as to maintain a selected ratio between the pressure difference across the portion of the compressor from the inlet to the bleed and the pressure difference across a similar portion of the compressor from the inlet to a stage upstream of the bleed. Another feature is the biasing of one of the pressure signals as a function of the movement of the bleed valve thereby, to make the opening or closing of the valve a gradual operation.

One feature of the invention is the application of this bleed system to a split compressor in which a number of the low pressure stages operate as a unit with the rotor operating at a selected speed and the remaining or high pressure stages operating as a unit but with the rotating portions of the stages operating at a speed independently of the pressure stages.

Other objects and advantages will be apparent from the specification and claims, and from the accompanying drawing which illustrates embodiments of the invention.

Fig. 1 is a diagrammatical view of the bleed control.

Fig. 2 is a diagrammatical view similar to Fig. 1 showing a modification.

The invention is shown in connection with a multi-stage axial-flow compressor in which a number of low pressure stages operate as a unit and at a speed independent of the remaining or high pressure stages. As shown, the compressor includes a casing **2** having a number of rows of stator vanes **4** alternating with rotating blades **6**, the latter being carried by a rotor **8** constituting the low pressure rotor. The casing also carries another series of rows of high pressure stator vanes **10** alternating with rows of blades **12** carried by the high pressure rotor **14**. Each of the rotors **8** and **14** is separately rotated from a split multi-stage turbine.

For the purpose of improving the part-load operation of the compressor and to facilitate starting, a bleed is provided between the ends of the compressor, this bleed being located in the arrangement shown between the high and low pressure portions of the compressor. To provide for this bleeding, the casing **2** has a surrounding ring **16** defining an annular chamber **18** which communicates with one or more radially extending passages **20** in the casing. These passages provide communication between the chamber **16** and the air path through the compressor. On the outside of the ring is mounted a radially extending cylinder **22** having a piston valve **24** movable therein and urged by a spring **26** in a direction to uncover ports **28** in the wall of the cylinder **22**. The cylinder beneath the valve **24** communicates with the chamber **18** through ports **30** so that as the ports **28** are uncovered, bleeding of the compressor takes place and the amount of bleeding is controlled by the area of the ports **28** that is uncovered.

The piston valve **24** is moved in a direction to close the ports **28** by fluid under pressure, which in the arrangement shown, is supplied from the high pressure end of the compressor. In the arrangement shown, the compressor outlet has a port **32** connected by a conduit **34** to an inlet port **36** in a control valve casing **38**. The casing has a bore **40** which receives a valve plunger **42**. Axially spaced from port **36** is a vent port **44** and midway between these ports is an outlet port **46** connected by a conduit **48** to the cylinder **22** above the piston valve.

Plunger **42** has a land **50**, which, in the mid position of the plunger shown, covers the port **46**. Movement of the plunger **42** to the left, Fig. 1, permits fluid under pressure from port **36** to enter port **46** and from this port reach the cylinder **22** to move valve **24** to the closed position. Alternately, movement of the plunger **42** to the right vents the cylinder through port **44** to cause the bleed valve to open.

Plunger **42** is moved in response to pressure changes within the compressor. As shown, this plunger has piston enlargements **52** and **54** at opposite ends, the piston **52** being larger than the other piston, as shown. These pistons are positioned in cylinders **56** and **58** forming a part of the casing **38**. The inner ends of cylinders **56** and **58** are in communication by means of a passage **60** in the casing and a conduit **62** extends from the passage to a static pressure tap **64** located in the casing **2** at the inlet to the compressor. The outer end of cylinder **56** is connected by a conduit **66** to a pressure tap **68** located in the compressor casing at a point between the compressor inlet and the point where the bleeding of the compressor takes place. That is to say, at a point downstream of the inlet and upstream of the bleed.

The outer end of the cylinder **58** is connected by a conduit **70** to a pressure tap **72** at or closely adjacent to the bleed ports **20** in the casing. With this arrangement, the plunger **42** is moved in response to changes in the ratio of low pressure compressor discharge pressure (Pt_3) minus compressor inlet pressure (Pt_2) divided by the intermediate stage pressure (P_1) minus compressor inlet pressure. That is to say, at a selected ratio of

$$\frac{Pt_3-Pt_2}{Pi-Pt_2}$$

the control valve will be in the neutral position shown in Fig. 1.

By suitably biasing the pressure signal from the low pressure compressor discharge so that movement of the bleed valve **24** toward its open position tends to raise the low pressure compressor discharge pressure signal above its true value, opening or closing of the bleed valve is made a gradual operation which is some function of engine speed. To accomplish this, the conduit **70** has a restriction **73** therein and downstream of the restriction a branch conduit **74** communicates with a chamber **76** in a casing **78** forming a projection on the cylinder **22**. The outlet of the chamber **76** is a passage **80** communicating by a branch conduit **82** with the conduit **34**. The casing **78** has a needle valve **84** therein which engages with the end of the passage **80**, thereby controlling the rate of flow out of the chamber **76**. The needle valve **84** is connected to a lever arm **86** which is pivoted on a pin **88** to the casing **78** and connected to its other end to a rod **90** projecting from the piston valve **24**. As the bleed valve **24** opens, the needle valve **84** also opens, thereby permitting air under pressure from the outlet of the compressor to pass through conduits **34** and **82** and past the needle valve **84** to increase the pressure in the passage **70**, thereby raising the pressure acting upon the piston **54** to a higher value than the actual pressure at the discharge of the low pressure portion of the compressor. Since the needle valve 84 is closed as the bleed valve is closed, the point of complete bleed valve closure occurs at a specific ratio of

$$\frac{Pt_3-Pt_2}{Pi-Pt_2}$$

which ratio closely aproximates a specific value of Pt_3/Pt_2.

The arrangement shown in Fig. 2 is quite similar to Fig. 1. In this figure the bleed valve 24 is actuated by air under pressure from the compressor outlet through the conduit 34' as controlled by the valve plunger 42. The conduit 62' connects the pressure tap at the compressor inlet to the passage 60 and the conduit 66' delivers air from an intermediate pressure tap in the compressor to the cylinder 56 at the left hand end of the control valve. The conduit 66' has a restriction 92 therein, for a purpose that will hereinafter appear. The conduit 70' connects the cylinder 58 at the right hand end of the control valve to the pressure tap 72 at or adjacent to the point where bleeding occurs.

In the arrangement of Fig. 2, instead of using the needle valve 84 for increasing the pressure acting on the right hand end of the control valve, the needle valve in Fig. 2 functions to reduce the pressure acting on the left hand end of the control valve. To accomplish this, conduit 94 extends from the conduit 66' downstream of the restriction 92 to the chamber 76 in the casing 78. The passage 80 is connected by a branch conduit 96 to the conduit 62'. Thus, as the bleed valve 24 moves into open position, the needle valve 84 also opens and increases the rate of flow from the conduit 66' into the conduit 62', thereby reducing the pressure on the left hand side of the piston 52 and increasing the pressure on the right hand side of this same piston. That is to say, the pressure signal from the intermediate low pressure compressor stage is suitably biased so that movement of the bleed valve toward open position tends to lower this pressure signal below its true value. Opening and closing of the bleed valve is thus made a gradual operation with complete closure occurring at a fixed low pressure compressor ratio (Pt_3/Pt_2).

It will be understood that the low pressure compressor pressure ratio at which bleed closure begins can be adjusted through proper contouring of the needle valve and by proper choice of the fixed orifices of the biasing circuits.

It is to be understood that the invention is not limited to the specific embodiments herein illustrated and described, but may be used in other ways without departure from its spirit as defined by the following claims.

I claim:

1. A bleed control for a multi-stage compressor having means for bleeding air therefrom at an intermediate stage, said control including a fluid actuated closure for regulating the area of said bleed means, valve means for regulating the effect of fluid on said closure, means for actuating said valve means in one sense in response to fluid pressure adjacent to the point in the compressor where bleeding occurs, means for actuating said valve means in an opposite sense in response to fluid pressure at a point in the compressor upstream of said first point and means for actuating said valve means in both senses in response to fluid pressure at the compressor inlet.

2. A bleed control for a multi-stage compressor having means for bleeding air therefrom at an intermediate stage, said control including a fluid actuated closure for regulating the area of said bleed means, valve means for regulating the effect of fluid on said closure, means for actuating said valve means in one direction in response to the fluid pressure rise in the compressor between the inlet and the bleed point and means for actuating said valve means in the opposite direction in response to the fluid pressure rise in the compressor between the inlet and an intermeidate point between the inlet and the bleed point.

3. A bleed control for a multi-stage compressor having means for bleeding air therefrom, said control including a fluid actuated closure for regulating the area of said bleed means, valve means for regulating the effect of fluid on said closure, means for actuating said valve means in one sense in response to fluid pressure adjacent to the point in the compressor where bleeding occurs, means for actuating said valve in an opposite sense in response to fluid pressure at a point in the compressor upstream of said first point, means for actuating said valve means in both senses in response to fluid pressure at the compressor inlet and means for biasing the actuation of said valve means by one of said fluid pressures in accordance with the position of said closure.

4. A bleed control for a multi-stage compressor having means for bleeding air therefrom, said control including a fluid actuated closure for regulating the area of said bleed means, a valve for regulating the effect of fluid on said closure, means for actuating said valve in one direction in response to fluid pressure from an intermediate point between the compressor inlet and the point where bleeding occurs, means for actuating said valve in the opposite direction in response to fluid pressure from the compressor adjacent to the point where bleeding occurs, valve means connected to and movable with said closure, and conduit means in which said valve means is located for biasing the actuation of said valve means by said fluid pressure adjacent to the point where bleeding occurs in accordance with the position of said closure.

5. A bleed control for a multi-stage compressor having a plurality of low pressure stages independent of the remaining high pressure stages such that the rotor speed for the low pressure stages is independent of the high pressure rotor speed, said bleed control including bleed means for bleeding air between the low and high pressure stages, a fluid actuated closure for regulating the area of said bleed means, a valve for regulating the effect of fluid on said closure, means for actuating said valve in one direction in response to fluid pressure from an intermediate point between the compressor inlet and the point where bleeding occurs, means for actuating said valve in the opposite direction in response to fluid pressure from the downstream end of the low pressure compressor stages and means operatively connected with said closure for biasing the actuation of said valve means by one of said fluid pressures in accordance with the position of said closure.

6. A bleed control for a multi-stage compressor having a plurality of low pressure stages independent of the remaining high pressure stages such that the rotor speed for the low pressure stages is independent of the high pressure rotor speed, said bleed control including bleed means for bleeding air between the low and high pressure stages, a fluid actuated closure for regulating the area of said bleed means, valve means for regulating the effect of fluid on said closure, means for actuating said valve means in one direction in response to the fluid pressure rise in the low pressure compressor stages and means for actuating said valve means in the opposite direction in response to the fluid pressure rise in the low pressure compressor between the inlet and an intermediate point between the inlet and the downstream end of the low pressure compressor stages.

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