Nov. 5, 1946. W. S. POWELL 2,410,522

INLET VALVE FOR GAS COMPRESSORS

Filed June 17, 1942

Fig. 1.

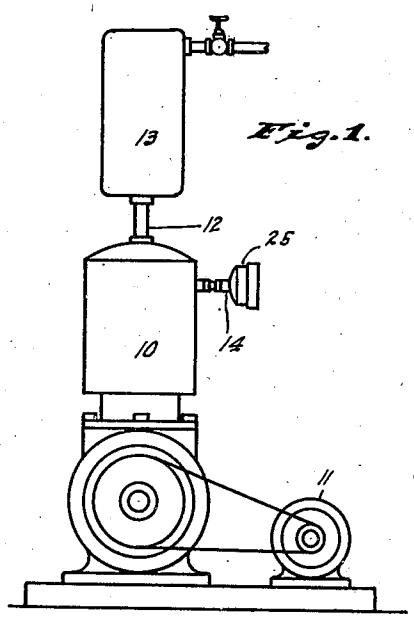


Fig. 2.

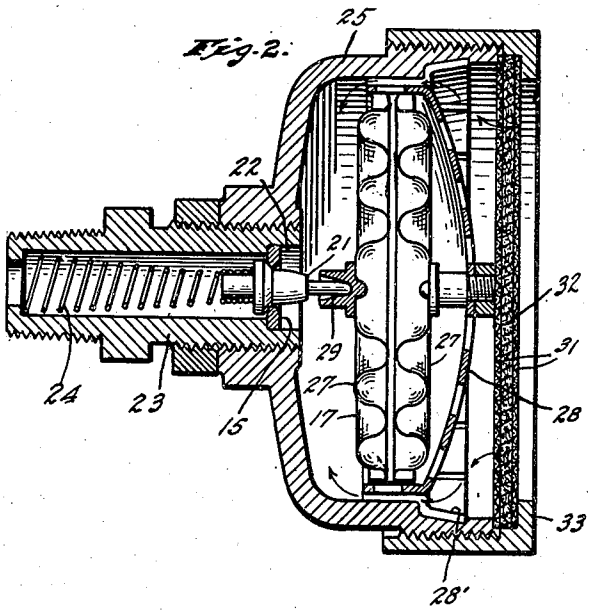


Fig. 3.

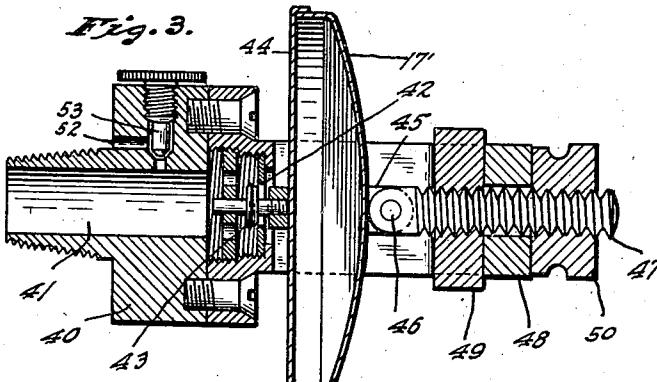


Fig. 4.

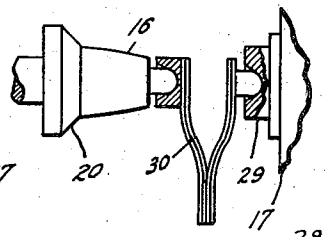


Fig. 5.

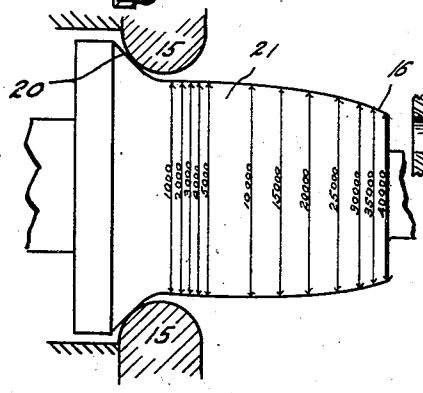
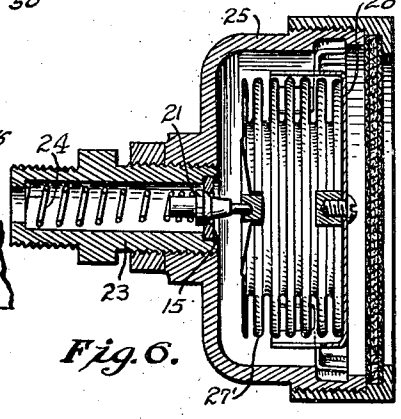


Fig. 6.



INVENTOR.
WILLIAM S. POWELL,

BY Hood + Hahn

ATTORNEYS.

Patented Nov. 5, 1946

2,410,522

UNITED STATES PATENT OFFICE

2,410,522

INLET VALVE FOR GAS COMPRESSORS

William S. Powell, Indianapolis, Ind., assignor to Marmon-Herrington Company, Inc., Indianapolis, Ind., a corporation of Indiana

Application June 17, 1942, Serial No. 447,473

3 Claims. (Cl. 230—2)

1

In the operation of modern airplanes, maintenance of a supply of compressed air is an essential, while, at the same time, conservation of power requisite for such maintenance is desirable.

Heretofore, it has been customary to provide a compressor and a motor, generally electric, so proportioned that the motor is capable of actuating the compressor at full capacity at ground level to deliver compressed air to the desired maximum pressure and in such an arrangement, at higher levels due to the lower pressure of air supply, the maximum power of the motor is much greater than is required.

The object of my invention is to provide an improved method and means by which the quantity of air which may be supplied to a compressor on its suction stroke, at its normal rate of speed, will be varied in accordance with the barometric pressure of the air supply and, as a supplement, in accordance with the temperature of the air supply, so that the mass of compressed air discharged at each stroke (unit operation) of the compressor will be substantially uniform irrespective of the altitude of the apparatus and temperature of the air supply.

The accompanying drawing illustrates my invention.

Fig. 1 is a diagrammatic illustration of an embodiment of my invention;

Fig. 2 an axial section of an appropriate compressor inlet valve and associate barometrically-sensitive controller;

Fig. 3 an axial section of another form of controlled inlet valve;

Fig. 4 a fragmentary section showing a thermally-responsive addition to the structure of Fig. 2;

Fig. 5 a section, on an enlarged scale, of an appropriate needle valve and associate seat; and

Fig. 6 a section, on a smaller scale, of a modified form.

In the drawing, 10 indicates an air-compressor of any desired form driven by a motor 11 and provided with a discharge duct 12 leading to a storage chamber 13, and an inlet duct 14 open to atmosphere.

The motor 11 need only be powerful enough to effectively drive the compressor at the highest contemplated altitude and, therefore, much too small to effectively drive the compressor at full capacity when at ground level. Therefore, in order to render such a motor effective at ground level, part of the inlet duct 14 comprises a valve seat 15 and cooperating valve 16, the position of which relative to seat 15 is subject to the control

2

of a barometrically sensitive cell 17 in such manner that the passage between seat 15 and valve 16 will vary inversely with variations of barometric pressure so that the successive masses of air which may enter the compressor during successive suction strokes, at normal speed of operation of the compressor, will be uniform, i. e., less volume of admitted air at atmospheric pressure at low altitudes than at high altitudes.

As the mass of air in a given volume varies inversely with its temperature, it may also be desirable to control the position of valve 16 in accordance with variations in temperature of the air supply, valve 16 being nearer to its seat, at a given barometric pressure, when the air supply is cold than when the air is at a higher temperature.

For that purpose, cell 17 may be supported upon a thermally responsive support so that its effect on valve 16 will vary with the temperature on the surrounding air supply, or a thermally-responsive element may be installed as a part of the connection between cell 17 and valve 16 to attain the desired end. It seems probable that a valve of the needle type, as shown in Fig. 5, will be most convenient, though I wish it understood that my invention is not limited to such form.

The proper contour of valve 16 may be readily determined mathematically so that for all positions of the valve relative to its seat under current conditions of supply pressure (and temperature if desired) it will permit only a flow of a predetermined mass of air per unit of time into the compressor.

Uniform masses of air may be compressed to a predetermined pressure by the expenditure of uniform quantities of power. Consequently, the motor 11 at low altitudes will be called upon for the same amount of work as at higher altitudes and thereby maximum efficiency of the apparatus obtained because a small motor capable at its maximum capacity of producing desired compression of air obtained at a high altitude will still be capable of effectively operating the compressor at low altitudes.

Referring to Figs. 2 and 5, the valve 16 comprises a circumferential flange 20 which may seat on the annular seat 15, and a tapered plug portion 21 the various diameters of which are so proportioned as to variably block the eye of seat 15 as the valve is axially shifted in accordance with altitude variations.

Valve seat 15 is anchored in bore 22 of nipple 23 and valve 16 is biased toward seat 15 by a spring 24.

Attached to the inlet end of nipple **23** is a cup **25** within which is the barometrically-sensitive cell **17**.

In order that cell **17** may respond in sufficient amplitude to variations of pressure of the surrounding atmosphere, it is composed of two cups **27, 27**, sealed together, mouth to mouth, at their perimeters and axially slidable in a foraminous shell **28** which, at its perimeter, is formed to fit cup **25** and, at the same time, afford air passages to valve seat **15**, as indicated by arrows. Shell **28** is held in place by a retainer ring **28'**.

One cup **27** of the barometric cell, at its center, is anchored to shell **28** while the other cup **27**, at its center, is provided with a pocket **29** into which the adjacent end of valve **16** seats. As the pressure of the air surrounding cell **17** decreases, the cell bulges at its center and this so positions valve **16** relative to its seat **15** in accordance with the altitude of the device that uniform masses of air are admitted to the compressor at whatever may be the altitude of the apparatus.

The proper contour of valve **16**, taking account only of barometric pressures, may be determined as follows:

If the total amount of movement of valve **16** is designated by the letter M then the requisite movement of the valve for proper altitude position will be proportionate parts of M as shown in Fig. 5 and outlined below.

If the diameter of the total opening is designated by the letter D then the diameter of the valve at various altitudes must be made to match the amount of motion of the plunger and regulate the air in the proper amount.

Actual values of D and M vary with the capacity of any device upon which the valve is used. The proper relationship, when the compressor operates to attain a maximum pressure of 1000 pounds, may be determined in the following manner:

Altitude (feet)	Valve motion (M)	Diameter of valve at M (alt.)
0	0	0.966D
1,000	.044	.965D
2,000	.084	.963D
3,000	.128	.961D
4,000	.168	.960D
5,000	.208	.959D
10,000	.384	.951D
15,000	.532	.940D
20,000	.659	.926D
25,000	.771	.908D
30,000	.860	.891D
35,000	.936	.854D
40,000	1.000	.809D

The variables involved in the calculations can all be simplified by utilizing the weight of the air to be handled rather than the volume, because the mass varies continually with the altitude and the temperature.

1 cubic foot of air at 40,000 ft. weighs

$$.231\times.0864=.0199 \text{ lb. } @\begin{cases}-80^\circ\\ 2.8 \text{ lb./in.}^2\end{cases}$$

Assuming the compressor speed to be 4000 R. P. M. and the displacement to be 3000 in.^{3} or 1.736 cu. ft./min., the inlet orifice must admit at all times $1.736\times.0199=.0346$ lb. per min., .000576 lb./sec.

Fliegner's equation for orifices (Trans. A. S. ME. XXVII #194) is $W=.53A(P/\sqrt{T})$. Weight= .000576 as above, solving for

$$A=\frac{W}{\frac{.53P}{\sqrt{T}}}$$

Note: Comparative areas:

A ⅛ in. dia. hole has an area .0122 in.^{2}

$$\frac{\frac{.000576}{.53\times2.8}}{\sqrt{380}}=\frac{.000576\times19.5}{1.485}=\frac{.01122}{1.485}=.00756 \text{ sq. in.}$$

A $\frac{3}{32}$'' dia. hole has an area .0069 in.^{2}

.00756 sq. in.=area of the orifice to pass .000576 lb. of air/sec.

Check:

If the pressure is 14.7 lb. 1 in.^{2} and the temperature is 0, one ft.^{3} of air will weigh .08635 lb.

An opening .00756 in.^{2} will pass

$$W=.53\times.00756(14.7/\sqrt{460})$$

$$.00402\times\frac{14.7}{21.42}$$

$$.00402\times.685$$

.003742 lb. of air per sec. (6½ times too much). Therefore the opening will have to close to

$$\frac{.000576}{.003742}\times.00756=.1538=.00116 \text{ in.}^2 \text{ at } 125^\circ \text{ F.}$$

An opening .00116 in.^{2} will pass

$$.000615\frac{14.7}{24.2}\times.607=.000374 \text{ lb. of air/sec. at } 125^\circ \text{ F.}$$

In order to compensate for temperature variations, a bi-metallic temperature responsive cushion **30** (Fig. 4) may be interposed between valve **16** and pocket **29**, expansion or contraction of this cushion by reason of temperature of the surrounding air serving to lengthen or shorten the connection between cell **17** and valve **16**.

Cup **25** may be provided at its mouth with screens **31** and filter **32** held in place by ring **33**.

Referring to Fig. 3, **40** indicates the main body of an inlet valve structure having an entry passage **41** provided with a valve seat **42**. Cooperating with seat **42** is a valve **43** anchored on one wall **44** of a barometrically sensitive cell **17'**, the opposite wall of which is provided with ears **45** pivoted at **46** to one end of a stem **47** projected through an arch **48** of body **40** between nuts **49** and **50**.

Leading into passage **41**, on the discharge side of valve **43**, is an inlet passage **52** controlled by a needle-valve **53**.

In use, stem **47** may be so adjusted that, at ground level, valve **43** is spaced from seat **42** to afford entry of the proper mass of air to permit motor **11** to function.

As the altitude of the structure rises, cell **17** will bulge so as to move valve **43** away from seat **42** to admit additional volumes of air, at lower pressure due to altitude, so that the air flow through the structure in a unit of time, will be a predetermined mass within the capacity of the compressor motor.

It will be noted that with the described arrangement, the masses of air which may enter the compressor for successive charges will be uniform irrespective of variations of atmospheric pressure. Therefore, this desired mass having been determined, an energizing motor for the compressor may be selected which, at its delivery speed, will operate at its highest efficiency at all times. Such an arrangement therefore reduces to a minimum, weight and size of the unit.

In order to minimize temperature effects, a construction like that shown in Fig. 6 may be used. In this form an evacuated "sylfon" cell **27'** has sufficient expansive axial resilience, when

external pressure is reduced, to move valve 21 from its seat. This cell is supported in the main body 25 by the foraminous shell 28', as in the construction shown in Fig. 2. Because of the reduced air content of cell 27' variations of temperature of the surroundings of the cell have little effect on the pressure within the cell.

I claim as my invention:

1. An inlet valve structure for air compressors, comprising a pair of elements relatively shiftable to control passage of air therebetween and a barometrically-sensitive unit associated with said elements so as to control their relative position in accordance with the pressure of air admissible between said two elements, and including a thermally-responsive element interposed between the barometrically-sensitive unit and one of said pairs of elements.

2. An inlet valve structure for air compressors, comprising a pair of elements relatively shiftable to control passage of air therebetween and a

barometrically-sensitive, evacuated, inherently expansive cell associated with said elements so as to control their relative position in accordance with the pressure of air admissible between said two elements, and including a thermally-responsive element interposed between said cell and one of said pair of elements.

3. The combination with an air compressor and an actuator of insufficient power to drive the same at full capacity at ground level, of a valve controlling the inlet of said compressor, and a barometrically-sensitive, evacuated, and inherently expansive cell within the influence of the air supply for said compressor and connected to said inlet valve to control its effective position relative to the compressor inlet, whereby substantially uniform masses of air will be drawn into the compressor upon unit operation of said compressor irrespective of the pressure of air supply due to altitude of the compressor.

WILLIAM S. POWELL.