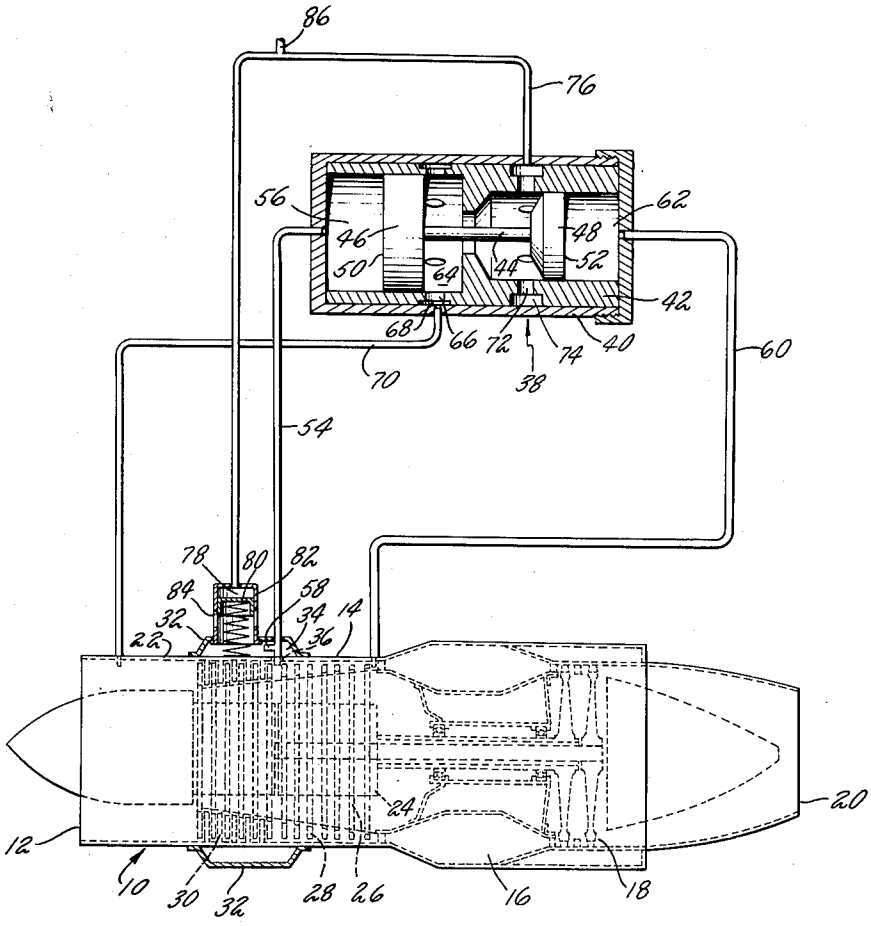
Jan. 24, 1956 L. E. RUBY 2,732,125

DIFFERENTIAL AREA COMPRESSOR BLEED CONTROL

Filed Oct. 17, 1952



INVENTOR
LOWELL E. RUBY
BY Russell M. Lyles, Jr.
AGENT

United States Patent Office 2,732,125
Patented Jan. 24, 1956

2,732,125

DIFFERENTIAL AREA COMPRESSOR BLEED CONTROL

Lowell E. Ruby, Marlborough, Conn., assignor to United Aircraft Corporation, East Hartford, Conn., a corporation of Delaware

Application October 17, 1952, Serial No. 315,289

6 Claims. (Cl. 230—115)

This invention relates to axial flow compressors, more particularly to controls for bleeding axial flow compressors.

Compressors of the axial flow type are made up of a plurality of bladed stages which act to increase the pressure of gases flowing through the compressor, each succeeding stage further compressing the gases. By varying the number of stages, the pressure ratio, that is the ratio of compressor discharge pressure to compressor inlet pressure, can be controlled. A detrimental characteristic of axial flow compressors is a tendency to surge or pulsate at low speeds, sometimes resulting in physical damage to the compressor or its associated structure. This characteristic is due to the fact that the various stages of the compressor are designed for maximum efficiency as a unit at one particular compressor speed. At a speed lower than the design speed the various stages are not correctly matched for the volume of air flowing through the compressor. The tendency is for the first stages to overpump the latter stages with the result that the first stages stall out and cause surging or pulsating of the compressor.

The speed at which an axial flow gas turbine power plant can be started is below the design speed of its compressor and, consequently, starting is very difficult if surge or pulsation exists. It is known that by bleeding the compressor the operating characteristics of the compressor can be changed and the detrimental characteristic overcome. More is gained in compressor performance than is lost by dumping or wasting the gases which have been compressed and had work done on them.

Various methods have been used for bleeding axial flow compressors and for controlling the bleeding thereof. The subject of this invention is a differential area control which controls bleeding as a function of compressor pressure ratio. This ratio changes with a change in compressor speed, but it remains substantially constant with an increase in altitude. Consequently, the only working fluid employed by the control is compressor air, and altitude correction features are not required.

An object of the invention is to provide an axial flow compressor bleed control which is relatively simple and which provides dependable operation.

Another object of the invention is to provide an axial flow compressor bleed control which provides gradual closing of the bleeds over a given speed range so as to obtain maximum performance from the compressor.

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

In the drawing, the single figure illustrates an axial flow gas turbine power plant having the compressor bleed control connected thereto.

Referring to the drawing in detail, **10** indicates an axial flow gas turbine power plant having inlet **12**, compressor section **14**, combustion section **16**, turbine section **18** and exhaust nozzle **20**. The compressor section is surrounded by casing **22** and has mounted therein rotor **24** comprised of a plurality of discs **26**, each disc having blades **28** about its periphery. Interspaced between each row of rotor blades **28** are rows of stator vanes **30** which serve to turn the gases flowing through the compressor so that they strike the succeeding rotor blades **28** at the most efficient angle. The compressor illustrated is a thirteen-stage compressor but it is to be understood that it can be comprised of any suitable number of stages.

Compressor casing **22** is surrounded by wall **32** which together with the casing defines annular manifold **34**. The compressor is vented to the manifold as by one or more ports **36** immediately downstream of the sixth compressor stage, although any convenient stage of the compressor may be picked for locating the bleed port or ports. The sixth compressor stage has been used here because it yielded the best results for the compressor configuration.

A differential area bleed control **38** is used to regulate bleeding of compressor gases. The control comprises housing **40**, sleeve **42** and piston **44**. The piston has lands **46** and **48** which are subject on land faces **50** and **52**, respectively, to pressures from two different points in the power plant. The area of face **50** on land **46** is substantially larger than the area of face **52** on land **48**.

The left end of bleed control **38** is connected by line **54** to the same compressor stage to which manifold **34** is vented, one end of the line being mounted within port **36**. In this way sixth stage compressor pressure is ducted to chamber **56** adjacent to land face **50**. Line **54** has a branch **58** extending into manifold **34** through which the pressure in the manifold also is ducted to chamber **56**, the pressure in the latter chamber being in effect an average of the pressure at the sixth stage of the compressor and that in manifold **34**. The right end of bleed control **38** is shown connected by line **60** to a port at the discharge end of the compressor so that compressor discharge pressure is ducted through the line to chamber **62** adjacent to land face **52**.

Lands **46** and **48** have a chamber **64** therebetween which is connected to compressor inlet pressure through ports **66** and groove **68** in sleeve **42**, and line **70**. While chamber **64** can be connected to some other compressor stage pressure, compressor inlet pressure has been selected because it is a convenient norm. A second set of ports **72** in sleeve **42** are connected through groove **74**, also in sleeve **42**, and line **76** to chamber **78** adjacent to bleed shut-off piston **80**. The bleed shut-off piston is contained in housing **82**, mounted in wall **32**, and controls the area of bleed ports **84** in the housing through which compressor air is bled to the atmosphere or to any desired receiver. Line **76** has an extension **86** for connecting the line with any additional number of bleed shut-off pistons disposed around the power plant, only one being shown here for convenience.

In operation the compressor bleed control works as follows: The power plant is started and as compressor speed is increased, compressor discharge pressure acting upon land face **52** increases at a faster rate than the combination of sixth stage static pressure and the pressure in manifold **34**, which pressures act upon land face **50**. This causes piston **44** to move to the left to partially uncover ports **72** and admit compressor discharge pressure through line **76** to the top of bleed shut-off piston, or pistons, **80**. This pressure forces the bleed shut-off piston downward to restrict bleed port **84**, reducing the volume of gases bled and increasing the pressure within manifold **34**. This increased manifold pressure acts upon land face **50** to restrain movement to the left of piston **44** and finally the system achieves a balance

with bleed shut-off piston **80** partially closing bleed port **84**.

As compressor speed further increases, compressor discharge pressure increases at a faster rate than the new sixth stage compressor pressure and manifold pressure **34** and piston **44** moves to a new balanced position with the bleed port **84** further closed. This relationship continues as compressor speed increases until bleed port **84** is completely closed, piston **44** having moved to the left sufficiently far to fully uncover ports **72**. As should be evident, a gradual closing of the bleed openings is obtained. The control can be designed so that bleeding is terminated at any particular compressor speed.

Expressing operation in another sense, when the pressure ratio

$$\frac{\text{Compressor discharge-compressor inlet}}{\text{Compressor intermediate, manifold-compressor inlet}}$$

equals or exceeds area ratio

$$\frac{\text{Land 46}}{\text{Land 52}}$$

piston **44** moves to admit compressor discharge pressure to the top of bleed shut-off pistons **80**. When manifold pressure equals compressor intermediate pressure, here sixth stage compressor pressure, and the ratio of

$$\frac{\text{Compressor discharge pressure-compressor inlet pressure}}{\text{Compressor intermediate pressure-compressor inlet pressure}}$$

equals the area ratio of

$$\frac{\text{Land 46}}{\text{Land 52}}$$

the bleed openings will be completely closed.

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

I claim:

1. A multi-stage axial flow compressor having means for bleeding an intermediate stage thereof and means for regulating flow through said bleeding means in combination with a bleed control comprising a housing containing a differential area piston capable of reciprocal motion therein, means subjecting one end of said piston to compressor discharge pressure and the other end to the pressure at the intermediate compressor stage being bled so that said piston is moved as a function of compressor pressure ratio, and means controlled by motion of said piston for admitting compressor discharge pressure to said flow regulating means to actuate said flow regulating means and control compressor bleeding.

2. A multi-stage axial flow compressor having at least one bleed port for bleeding an intermediate stage of the compressor and at least one valve for regulating flow through said port in combination with a bleed control comprising a housing containing a differential area piston capable of reciprocal motion therein, means subjecting one end of said piston to compressor discharge pressure and the other end to the pressure at the intermediate compressor stage being bled so that said piston is moved as a function of compressor pressure ratio, and means controlled by motion of said piston for admitting compressor discharge pressure to said valve to progressively close said valve as compressor speed increases.

3. A bleed control for a multi-stage axial flow compressor in a gas turbine power plant, said control including a chamber surrounding the compressor, said chamber being vented to an intermediate stage of the compressor, a port in said chamber through which compressor gases in the chamber can be bled, means regulating the area of said bleed port, a housing having a differential area piston therein, capable of reciprocal motion, means subjecting the larger end of said piston to the pressure within said chamber as well as to the pressure at the intermediate compressor stage to which said chamber is vented, means subjecting the smaller end of said piston to compressor discharge pressure, and means controlled by motion of said piston for admitting compressor discharge pressure to said bleed area regulating means to regulate said bleed port as a function of compressor pressure ratio.

4. A bleed control for a multi-stage axial flow compressor in a gas turbine power plant, said control including a chamber surrounding the compressor, said chamber being vented to an intermediate stage of the compressor, a port in said chamber through which compressor gases in the chamber can be bled, valve means regulating the area of said bleed port, a housing having a slidable piston therein capable of reciprocal motion, one end of said piston having a larger surface area than the opposite end, means subjecting the larger area end to the pressure within said chamber and also to the pressure at the compressor intermediate stage to which said chamber is vented, means subjecting the opposite end to compressor discharge pressure, a groove around said piston and between said ends, means venting said groove to compressor inlet pressure, and means controlled by motion of said control piston for admitting compressor discharge pressure to said valve to actuate said valve and regulate said bleed port as a function of compressor pressure ratio.

5. A bleed control for a multi-stage axial flow compressor in a gas turbine power plant, said control including a chamber surrounding the compressor, said chamber being vented to an intermediate stage of the compressor, a port in said chamber through which compressor gases in the chamber can be bled, valve means regulating the area of said bleed port, a housing defining a cylinder having a slidable control piston therein capable of reciprocal motion, one end of said control piston having a larger surface area than the opposite end, a connection between the compressor intermediate stage to which said chamber is vented and said housing cylinder through which the larger area end of said piston is subjected to the pressure at said compressor intermediate stage, a connection between said chamber and said housing cylinder through which said larger area end is also vented to the pressure within said chamber, a connection between compressor discharge and said housing cylinder through which the opposite end of said control piston is vented to compressor discharge pressure, a groove around said control piston and between said ends, a connection between compressor inlet and said housing cylinder for venting said groove to compressor inlet pressure, and means controlled by motion of said piston for admitting compressor discharge pressure to said valve means to actuate said valve and regulate said bleed port as a function of compressor pressure ratio.

6. A bleed control for a multi-stage axial flow compressor in a gas turbine power plant, said control including a chamber surrounding the compressor, said chamber being vented to an intermediate stage of the compressor, a plurality of ports in said chamber through which compressor gases in the chamber can be bled, valve means regulating the area of said bleed ports, a housing defining a cylinder having a slidable control piston therein capable of reciprocal motion, one end of said control piston having a larger surface area than the opposite end, a connection between the compressor intermediate stage to which said chamber is vented and said housing cylinder through which the larger area end of said piston is subjected to said pressure at the compressor intermediate stage, a connection between said chamber and said housing cylinder through which said larger area end is also vented to said pressure within said chamber, a connection between compressor discharge and said housing cylinder through which the opposite end of said control piston is vented to compressor discharge pressure, a groove around said control piston and between said ends, a connection between compressor inlet and said housing cylinder for venting said groove to compressor inlet pressure, and

means controlled by motion of said control piston for admitting compressor discharge pressure to said valve means to actuate said valve and regulate said bleed ports as a function of compressor pressure ratio.

References Cited in the file of this patent

UNITED STATES PATENTS

1,241,372 Guyer ---------- Sept. 25, 1917

2,398,619 Clark et al. ---------- Apr. 16, 1946

2,455,292 Borden ---------- Nov. 30, 1948

FOREIGN PATENTS

586,710 Great Britain ---------- Mar. 28, 1947