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WASHINGTON, D.C. 20546

REPLY TO
ATTN OF: GP

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for
Patent Matters

SUBJECT: Announcement of NASA-Owned U. S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code USI, the attached NASA-owned U. S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U. S. Patent No. : 3,563,135

Government or Corporate Employee : U.S. Government

Supplementary Corporate Source (if applicable) : _____

NASA Patent Case No. : MSC-12121-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

Yes No

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of . . ."

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Enclosure

Copy of Patent cited above

FACILITY FORM 602

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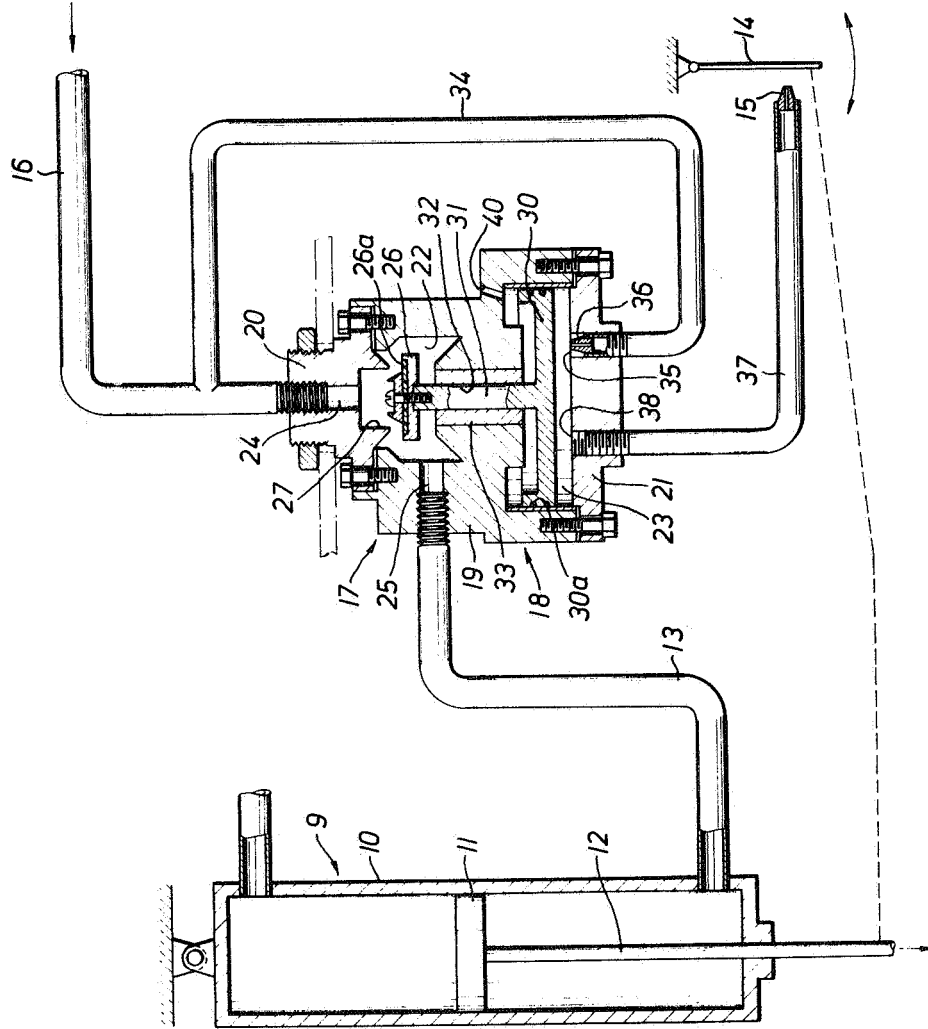
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ORIGIN OF THE INVENTION

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to a pneumatically powered servosystem, and more particularly to such a system including a pneumatic amplifier for regulating the flow of pneumatic fluid to the system.

The pneumatic amplifier of this invention can be used in various pneumatic systems, but is particularly advantageous when used with a pneumatic servomotor, or a pneumatically powered actuator. In servosystems, some device is required to control the flow of pneumatic fluid to the pneumatic motor in response to either automatic or manual controls. Mechanically operated valves can be used, but they suffer from high friction losses and are inherently slow in responding to the desired changes. Flapper valves are commonly used to vary the amount of pneumatic fluid being bled from the system to in turn vary pressure of the pneumatic fluid in the servomotor, thereby controlling its position and its force output. Such control requires a sizable flow restriction in the pneumatic fluid supply line, and line and, therefore, limits the response available from the pneumatically powered motor to something less than what it could be if full pneumatic fluid pressure was available to it.

It is an object of this invention to provide a pneumatic servosystem having a pneumatic amplifier that responds quickly to changes in conditions and which can supply the servosystem with the full pressure and/or flow rate of the available pneumatic fluid supply system.

It is another object to provide a pneumatic amplifier for a pneumatic servosystem which isolates the pneumatic fluid supply from the effects of changes in control pressure.

It is another object to provide a pneumatic amplifier with high pneumatic gain to control a valve in the pneumatic fluid supply line which is opened and closed by a piston of relatively large diameter, and in which the piston is powered by a control fluid having a pressure which is low enough in value relative to the pneumatic fluid supply pressure that the pneumatic fluid for powering the control piston can be obtained from the pneumatic fluid supply through a flow restriction operating at supercritical flow so that the pneumatic fluid supply line will be isolated from the effects of variations in the pressure of the control fluid acting on the control piston.

These and other objects, advantages, and features of the invention will be apparent to those skilled in the art from a consideration of this specification, including the attached drawings and appended claims.

The invention will now be described in connection with the attached drawing in which the preferred embodiment of the pneumatic amplifier of this invention is arranged to control the flow of pneumatic fluid to a pneumatic actuator.

The pneumatic actuator 9 in the drawing consists of cylinder 10, piston 11, and piston rod 12. The piston rod is connected to a load (not shown). The force exerted on the load and its position may be changed by varying the pressure of pneumatic fluid supplied cylinder 10 through inlet line 13. If actuator 9 is functioning as a servomotor, the pressure of the pneumatic fluid supplied to the actuator will be varied in response to either manual or automatic controls. This can be done in various ways as is well known in the art, and will not be described in detail here. For our purposes, it is sufficient that desired changes in the force exerted on piston 11 and rod 12 by the pneumatic fluid can be changed by varying the position of flapper 14 relative to orifice 15 in the manner to be described below.

Controlling the flow of pneumatic fluid from line 16 to line 13 is pneumatic amplifier 17. The pneumatic amplifier includes housing 18 made up of body 19, valve cap 20, and cylinder head 21. Body 19 has first and second chambers 22

and 23, which are closed by the valve cap and cylinder head, respectively. First chamber 22 has inlet 24 through the valve cap and outlet 25 through body 19. The pneumatic fluid for the actuator flows through inlet 24 from line 16 and into line 13 to the actuator through outlet 25.

Valve means are provided to control the flow of pneumatic fluid through chamber 22. In the embodiment shown, valve element 26 is located in chamber 22 for movement into and out of engagement with annular valve seat 27 on valve cap 20 to close and open chamber 22 and inlet 24.

Valve element 26 has a conically shaped portion 26a that extends past valve seat 27 toward inlet 24 when the valve is closed. When the valve opens, this section causes the opening through the valve to increase in size at such a rate that the increase in the flow of pneumatic fluid will be linear. Further, the forces required to open the valve vary regularly with valve opening, so that the valve can be opened to any particular position and remain in such position. After the valve has moved a substantial distance away from the valve seat, conical element 26a will have little if any effect on the flow rate of pneumatic fluid through chamber 22. However, in the stages where flow through the valve is not great, the conical element provides a uniform change in the rate of flow of pneumatic fluid through the valve for a given movement of the valve element and a regular variation of valve force versus valve opening which allows the increase or decrease in force, as the case may be, to be more uniformly applied by actuator 9.

To control the position of valve element 26 relative to the valve seat, piston 30 is located in second chamber 23. Piston rod 31 connects the piston to the valve element so that they move together. The piston rod extends through opening 32 in sleeve 33 which is located in an opening connecting the first and second chambers.

Piston 30 fits the inside diameter of cylinder 23 relatively close, however, the cylindrical wall of the piston is provided with circumferential grooves 30a which permit air to leak past the piston to provide an air bearing between the piston and the cylinder, thereby eliminating the static friction of the control unit. Also, air can leak through opening 32 between sleeve 33 and piston rod 31 to further reduce the friction resisting movement of the piston and the rod relative to the body.

Line 34 connects inlet 35 of the second chamber to the pneumatic fluid flowing through line 16. A flow restriction comprising fixed orifice 36 is located in line 34 to cause a pressure drop between the pressure of the pneumatic fluid supply and the pressure of the pneumatic fluid entering chamber 23. Line 37 connects outlet 38 of the second chamber to the atmosphere through orifice 15.

In the preferred embodiment, the opening through orifice 36 and the maximum restriction to flow offered by orifice 15 and flapper 14 is such that the pressure downstream of orifice 36 will never be greater than about 53 percent of the pneumatic fluid supply pressure. This will result in the flow through orifice 36 being supercritical, therefore, regardless of fluctuations in pressure downstream of orifice 36, the volume of pneumatic fluid flowing through orifice 36 will remain substantially constant. In this way, changes in the pressure in chamber 23 will have no effect whatsoever on the system upstream of orifice 36 and, therefore, will not affect the pressure of the pneumatic fluid available to actuator 10 once this pressure has been established for the critical flow rate through orifice 36.

In operation, when valve element 26 is in engagement with valve seat 27, the area of the valve element times the differential pressure across the valve will equal the downward force exerted on rod 31. This is balanced by the upward force of the pressure in chamber 23 acting against piston 30. Since the pressure in the second chamber is no greater than 53 percent of supply gas pressure and is usually much less, the area of piston 30 is substantially greater than the area of the valve element. By using a piston of relatively larger diameter, more sensitive control is produced since a relatively smaller change in the pressure in the second chamber will produce the necessary change in force.

When it is desired to supply more pneumatic fluid to actuator 9, flapper 14 will be moved away from orifice 15 by the automatic or manual controls being used. This will permit the pressure in second chamber 23 to drop, accordingly the pressure in inlet 24 will move valve element 26 further away from valve seat 27, opening up the valve. Since the area of piston 30 is considerably greater than the area of valve element 26, a slight change in the pressure in the second chamber will result in valve movement. Accordingly, high pressure flow of pneumatic fluid may be controlled by an extremely small force moving flapper 14. Moreover, since the flow restriction is not in the supply line, full flow and pressure can be delivered to actuator 9. Further, since there is supercritical flow downstream of flow, restricting member 36, fluctuations in pressure in chamber 23 will not be reflected in the pneumatic supply line. The increased flow of pneumatic fluid will increase the pressure in cylinder 10. As the pressure in cylinder 10 increases, the force exerted by the actuator will be likewise increased and accordingly flapper valve 14 will be moved toward orifice 15 which will result in a reduction of flow through orifice 15 and an increase in pressure in chamber 23 which will cause piston 30 to move upward. As a result, valve 26 will move toward its seat decreasing flow of high pressure pneumatic fluid to the actuator until a state of equilibrium is achieved. As previously mentioned, the movement of the flapper 14 may be controlled by various means. The dash line between rod 12 and flapper valve 14 indicates that there is a feedback system between the pneumatic powered system and the flapper valve.

If the force being exerted by the actuator is too great, then flapper 14 will be moved toward orifice 15, decreasing the flow of gas from chamber 23 and increasing the pressure therein. This, in turn, will cause piston 30 to move upwardly closing the valve in chamber 22. If the valve is completely closed, flow of high pressure gas through inlet 24 into chamber 22 will be terminated. Therefore, there will be no flow of high pressure gas through outlet 25 into cylinder 10. In effect, a state of equilibrium is achieved. The portion of chamber 23 above the piston 30 is connected to the atmosphere by vent 40. Thus, the gas escaping around the piston and the piston rod is exhausted from chamber 23 through vent 40 to ambient atmosphere.

From the foregoing it can be seen that with the novel pneumatic servosystem which includes the novel pneumatic amplifier, a high pressure supply of pneumatic fluid can be precisely controlled with an extremely small force acting on the flapper valve. The control may be mechanically connected to the pneumatically powered system (closed loop) or it may be controlled by other means such as an operator (open loop). The conical valve element of the supply valve provides linear flow in the control range and the force required to operate the valve varies regularly with the amount of valve opening, thereby the valve can be stably positioned with a regulated control pressure. The pneumatic fluid in the control section passes through an orifice at sonic velocity. The orifice acts as a diode thereby preventing pressure changes in the control section from being reflected back into the pneumatic fluid supply. Since the control piston is relatively large compared to the size of the valve element, a high pressure pneumatic fluid source can be controlled by a relatively small force acting on the control pneumatic fluid supply.

The response and instantaneous power of the system is increased since all of the pneumatic fluid does not have to go through an orifice. The overall power is increased because full line pressure can be supplied to the actuator. The pneumatic amplifier makes the system more flexible since the flapper valve can be controlled pneumatically, mechanically, or electromechanically with extremely low control forces.

We claim:

1. A pneumatic amplifier for controlling the flow of pneumatic fluid to a pneumatically powered system, comprising: a housing having first and second chambers, each of which has an inlet and an outlet; means for connecting the inlet of the first chamber to a pneumatic fluid supply and the outlet of the

first chamber to the pneumatically powered system; valve means in the first chamber including a movable valve member to control the flow of pneumatic fluid through the first chamber from the inlet to the outlet; a piston located in the second chamber; means connecting the piston to the movable valve member; means connecting the inlet of the second chamber to the pneumatic fluid supply including flow restricting means to introduce gas under pressure into the chamber to act against one side of the piston to urge the piston in the direction to close the valve means; means venting the second chamber on the other side of the piston to atmosphere; and variable flow restricting means located in the outlet to said second chamber and responsive to the pneumatically powered system, the pressure of the pneumatic fluid in the second chamber thereby controlling the position of the piston and the movable valve member to regulate the amount of pneumatic fluid flowing to the pneumatically powered system through the first chamber.

2. The pneumatic amplifier of claim 1 in which the flow through the variable orifice and the size of the flow restricting means maintains the pressure downstream of the flow restricting means no greater than 53 percent of the upstream pressure to keep changes in the pressure in the second chamber from being reflected upstream of the flow restricting means.

3. The pneumatic amplifier of claim 2 in which the valve means controlling the flow of pneumatic fluid includes a conical element which extends into a valve seat when the valve means is closed, and which provides a linearly increasing flow rate through the valve means while the conical element is located in the vicinity of the valve seat.

4. The pneumatic amplifier of claim 2 in which the piston is provided with a plurality of circumferential grooves forming an air bearing with the wall of its chamber to eliminate static friction.

5. A pneumatic amplifier for controlling the flow of pneumatic fluid to a pneumatically powered system, comprising a housing having first and second chambers each of which has an inlet and an outlet; means connecting the inlet of the first chamber to a pneumatic fluid supply and the outlet of the first chamber to the pneumatically powered system; valve means in the first chamber, including a movable valve member to control the flow of pneumatic fluid through the first chamber from the inlet to the outlet, said movable valve member having an area against which the pneumatic fluid acts tending to open the valve means; a piston located in the second chamber having an area against which pneumatic fluid in the second chamber acts; a piston rod extending between the chambers and connecting the movable valve member and the piston so they move together; means connecting the inlet of the second chamber to the pneumatic fluid supply, including flow restricting means to introduce pneumatic fluid under pressure in the second chamber to act against one side of the piston to urge the piston in the direction to close the valve means; means venting the second chamber on the other side of the piston to atmosphere; variable flow restricting means located in the outlet of said second chamber and responsive to the pneumatically powered system to vary the pressure of the pneumatic fluid in the second chamber, thereby controlling the position of the piston and the movable valve member to regulate the amount of pneumatic fluid flowing to the pneumatically powered system through the first chamber, said variable flow restricting means and said flow restricting means being arranged to maintain the pressure downstream of the flow restricting means no greater than 53 percent of the upstream pressure to keep changes in the pressure in the second chamber from being reflected upstream of the flow restricting means.

6. The pneumatic amplifier of claim 5, in which the movable valve member includes a conical element which extends into a valve seat when the valve is closed, and which provides a linearly increasing flow rate through the valve means while the conical element is located in the vicinity of the valve seat.

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7. The pneumatic amplifier of claim 6 in which there is an air bearing between the piston and the chamber in which it is positioned.

8. A pneumatic servosystem comprising a pneumatically powered system adapted to be controlled by pneumatic fluid; a source of pneumatic fluid for controlling the pneumatically powered system, a pneumatic amplifier for controlling the flow of pneumatic fluid from the pneumatic fluid source to the pneumatically powered system; and a control valve for controlling the action of the pneumatic amplifier responsive to the pneumatically powered system: the pneumatic amplifier having a supply section and a control section; the supply section having an inlet connected to the pneumatic fluid source, an outlet connected to the pneumatically powered system, and a supply valve between the inlet and outlet regulating the flow

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of pneumatic fluid from the pneumatic fluid source to the pneumatically powered system, the control section having an inlet connected to the pneumatic fluid source through a flow restricting means which is so sized that the flow through the flow restricting means is at or above sonic velocity; an outlet having a variable flow restricting means responsive to the control valve; and a control piston which is connected to the supply valve, one side of the control piston being subject to pneumatic fluid supplied by the inlet and regulated by the outlet, and the other side of the piston subject to atmospheric pressure whereby the flow of pressurized pneumatic fluid can be controlled by a relatively small force and pneumatic fluid at full pressure and flow can be delivered to the pneumatically powered system.

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