# United States Patent

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[54] **FLUID SYSTEM RESISTANCE TEMPERATURE COMPENSATION**
**1 Claim, 4 Drawing Figs.**


[52] U.S. Cl. ..... 137/82, 137/86, 137/608, 138/42, 235/201
[51] Int. Cl. ..... F15c 3/14, G06d 3/00
[50] Field of Search ..... 138/42, 44, 137/85, 82, 608, 235/201



[56] **References Cited**

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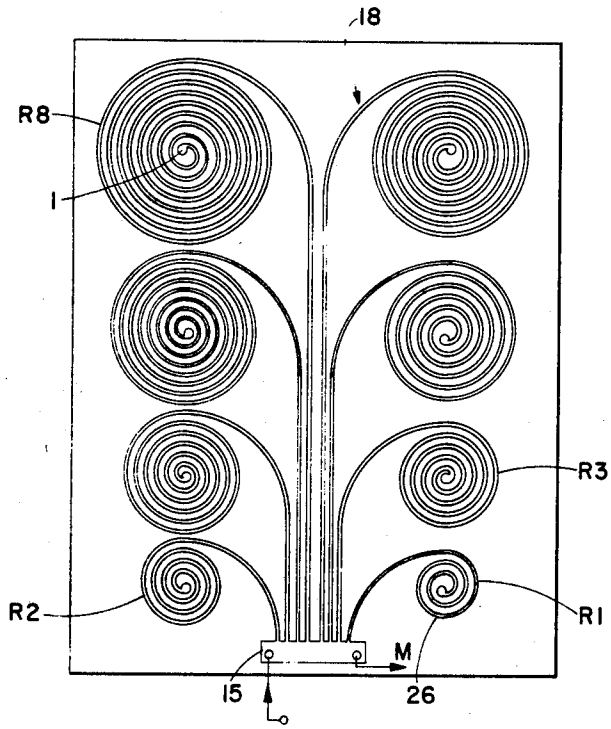
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**ABSTRACT:** Temperature compensation for fluid systems having fluid restrictors therein. Each restrictor is established as a laminar flow element. The result is an essentially constant flow ratio as between restrictors with temperature change. As an example, a digital to analog converter system is shown.

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SHEET 1 OF 2

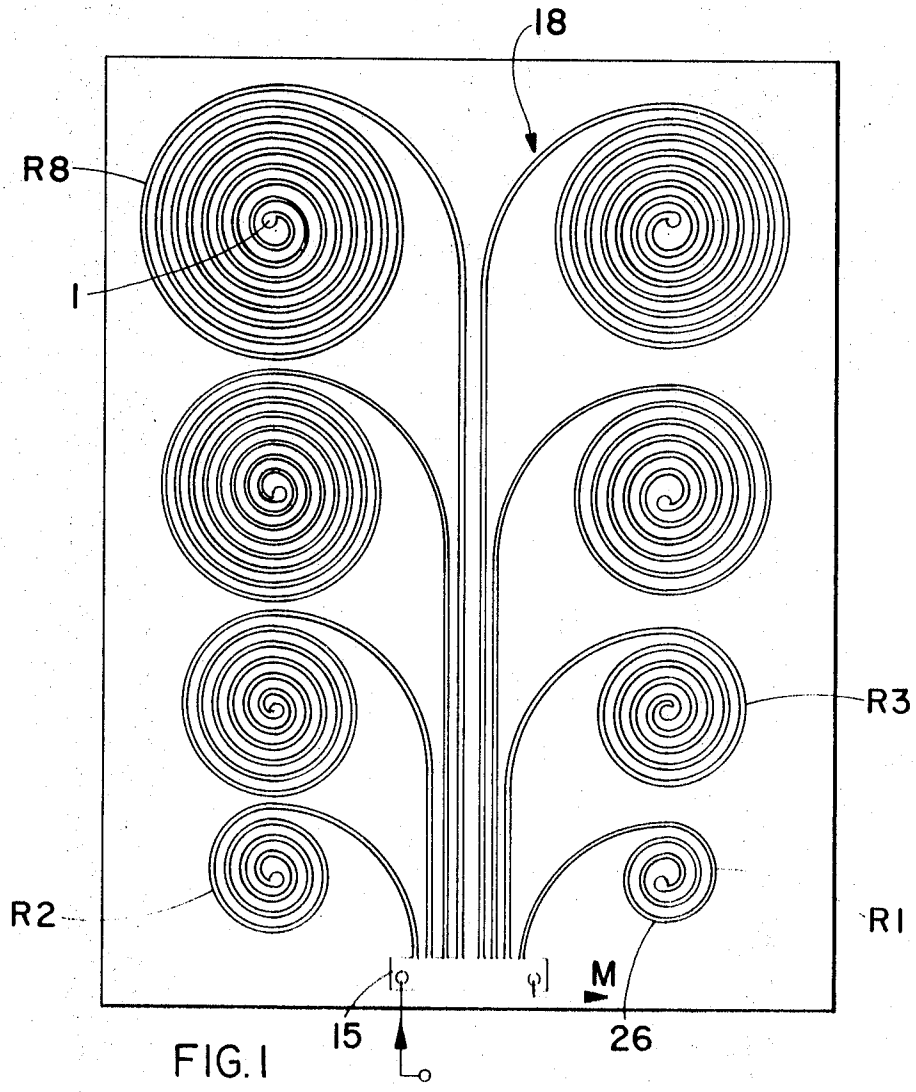



FIG. 1

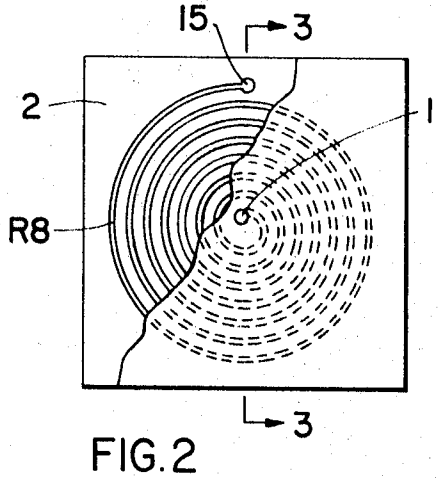



FIG. 2

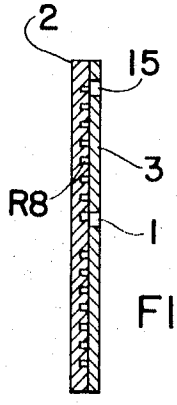



FIG. 3

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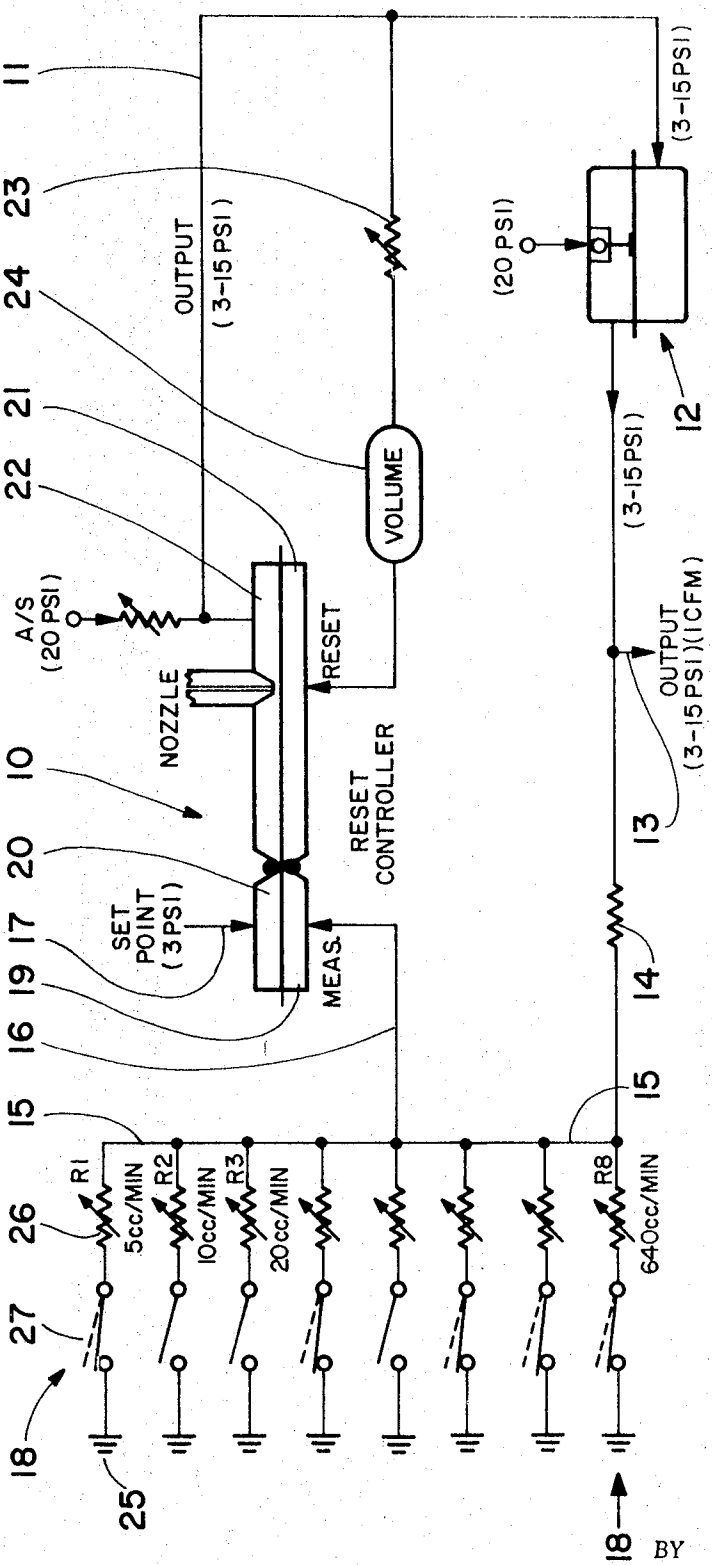



FIG. 4

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# FLUID SYSTEM RESISTANCE TEMPERATURE COMPENSATION

This invention relates to fluid operated instrumentation wherein fluid flows and pressures are used in situations such as measurement or control of processes or energy or parameters of these, in which fluid restrictors, resistances, are used as part of systems in such instrumentation.

This invention relates more specifically to problems created in such instrumentation by temperature changes and provides means of achieving temperature compensation.

In pneumatic systems, restrictors are subject to flow change with temperature change, with consequent potential of error in the systems. This flow change results from viscosity change since viscosity is a strong function of temperature.

This invention effects temperature compensation on the basis that in laminar flow, change in resistance is mainly due to change in viscosity. Mainly due in the order of 90 percent. In gases, increased temperature results in increased viscosity and consequently decreased flow.

Flow is 'laminar', 'viscous' or 'streamline' when the Reynolds number is less than 2100.

Thus, in order to make flow through a pneumatic restrictor responsive to temperature change is a usefully repeatable manner, the restrictor is to be formed and dimensioned, in view of the nature of the gas to be used and the flows and pressures of its use, to achieve laminar flow in the restrictor.

Accordingly, this invention provides that in a system including two or more operationally sensitive restrictors, flow through these restrictors is made to be laminar. Thus, temperature compensation is accomplished in that the ratio of flow as between such restrictors remains essentially constant with temperature change.

As a vehicle of illustration, this invention is set forth herein as applied to a digital to analog converter system of pneumatics, in which a control loop maintains a constant pressure in a manifold, from which pneumatic bleeds are established in response to a digital input pattern as applied to a matrix of pneumatic restrictor systems. The control in maintaining the manifold pressure, produces an analog output signal representative of the digital input signal.

In this converter system, a summing, reference restrictor is used in the control loop, and this restrictor, with the bleed restrictors, are all sensitive in the operation of the system. That is, errors related to the restrictors, especially as to temperature change errors, go to the character of the output of the system.

In this example of this invention, all these restrictors are made to achieve laminar flow, and in consequence, the flow ratio pattern between all these restrictors is maintained essentially constant with temperature change, and temperature compensation is achieved.

Other objects and advantages of this invention will be in part apparent and in part pointed out hereinafter and in the accompanying drawings, wherein:

FIG. 1 is a schematic illustration of a group of fluid resistances in accordance with this invention;

FIG. 2 is a structural showing of a single resistance, in one form thereof, as a sandwich structure, in plan, with partial cutaway, and according to this invention;

FIG. 3 is a section of the structure of FIG. 2, as if it were whole, taken on line 3–3; and

FIG. 4 is a digital to analog fluid converter system as an example of a temperature compensation system according to this invention.

In the FIG. 1 schematic, a digital matrix of restrictors, each and together according to this invention, are shown as spiral form passages $R_1$ through $R_8$ in ascending logic flow capacities in the relative order of 1, 2, 4, 8, 16 and so on.

Each of the restrictors $R_1$—$R_8$ are laminar flow passages, so constructed by length and form, in view of the air pressures of the particular application with which they are to be involved—FIG. 4 illustrates one such application.

In FIG. 1, a common supply manifold 18 is provided for all the restrictors and each restrictor has its own outlet, at the internal terminus of its spiral, as exemplified in $R_8$ at 1. These restrictors are formed, as in FIGS. 2 and 3, in a sandwich structure with a base 2, in which the restrictor passages as $R_8$, may be formed by etching or other suitable slot forming means, in the surface of the base 2. Thereafter a cover plate 3 is placed over this surface to close off the open side of the slot and form a continuous spiral pneumatic restrictor passage.



This structure is suitable for one or more restrictors, and lends itself to the modern needs of simplification and miniaturization.

FIG. 4 illustrates a digital to pneumatic analog converter, which is a combination of a digital input matrix of fluidic resistances and a pneumatic analog controller, with a manifold supply to the resistances maintained at constant pressure by the controller, and a pneumatic analog output to a value established by the controller change necessary to maintain the manifold pressure.

This invention relates to digital to analog converters, in the FIG. 4 system, the digital input may be pneumatic, electrical or mechanical, and the analog output is pneumatic. This is a pneumatic system to which digital input signals may be applied to switches controlling $R_1$, $R_2$....$R_8$, including a pneumatic controller which maintains a fixed pressure at the digital input, and has an analog pneumatic output whose pressure level is representative of the digital input signal, this pressure level being accomplished through operation of the pneumatic controller in the course of its changes as necessary to maintain the fixed pressure at the digital input.

The controller of this invention is of the nature of the disclosure in patent application to Prescott et al., Ser. No. 772,787, filed Nov. 1, 1968 and entitled Pressure Device Having Layered Construction and Pivoting Seal with Operator. The abstract of the disclosure of this patent application is as follows:

In a multilayer sandwiched-type of construction, an operator activated by at least one pressure chamber is brought through a sealing configuration which also provides for pivoting of the operator; the operator itself is formed from a layer of the sandwiched construction and the sealing at the operator pivot is formed from sealing layers of the sandwiched construction; the operator layer may be backed by a resilient sheet layer for sealing the pressure chamber actuating the operator; this construction may be readily adapted to a plurality of pressure chambers employed in conjunction with motion-sensing devices, or alternatively weight and springs, to perform the functions of alarms, relays, repeaters, amplifiers, and a variety of other pneumatic devices.

The illustration of FIG. 4 is of an 8 bit digital to analog pneumatic converter which accepts parallel binary inputs, and transmits a 3—15 p.s.i. analog signal.

One application of this converter is in a fluidic programmer, and it is capable of accepting low level fluidic signals for such purpose. It may be used in conjunction with a punched card and pneumatic reader, to control rates, set points, or values in an analog fashion.

The system of FIG. 4 comprises a pneumatic reset controller 10, with a control loop associated therewith including an output passage 11 through a flow booster 12, past an analog output passage from the control loop at 13, through a summation resistor 14 through a supply manifold 15, and finally back to the controller 10 as a measurement input 16, in opposition to a set point input 17 to the controller.

A digital input is generally indicated at 18, and comprises a resistance matrix to the supply manifold 15 such that the individual flows through the individual digital resistances, for a given differential pressure, are in binary ascending ratio, as 1, 2, 4, 8, .... etc.

The function of the controller 10 is to maintain the pressure in the supply manifold 15 essentially constant. The resistance matrix 18 is the recipient of digital input signals, whereas the result of the application of a digital input combination to the matrix 18 is a like combination of air bleeds to atmosphere through the specific resistances which are individual to the various units of the particular digital input combination.

The result of each bleeding of air to atmosphere is a tendency to lowering of the pressure in the supply manifold **15**. The controller **10** responds, to counteract this tendency, and the amount of this response, as necessary to achieve again a balanced condition in the control loop, is a measure of an analog output through **13**, representative of the particular digital combination input signal.

The flow booster **12** provides the volume requirements of the supply manifold **15** and isolates the controller **10** from the loads produced through the digital input resistance matrix **18**.

As an example of a controller **10**, suitable for the system of this invention, the drawing controller illustration is a representation of one form of the previously mentioned disclosure in the patent application to Prescott et al. In this illustrative application, a proportional-reset controller form is used with pressure chambers **19**, **20**, **21** and **22** as measurement, setpoint, reset, and supply-bleed chambers respectively. A reset resistance-capacity system **23** and **24** is connected between the chambers **21** and **22**.

Throughout the drawings, an illustration of one working example, various labels as to flow and pressure are shown. These are set forth simply as guide line values.

In the FIG. **4** resistance matrix **18**, there are 8 digital bits, each one comprising an air passage from the manifold **15** to atmosphere at **25** through a resistance such as **26**, with switch **27** in the passage between the resistance **26** and atmosphere at **25**.

Thus, in a digital input of 0 or 1 to the switch **27** the switch **27** may be operated to open or close the passage from the manifold **15** to atmosphere, to close off that particular bit, or to bleed it off to atmosphere as the case may be.

In the showing of FIG. **4**, the $R_1$ bit digital input is shown as logic 'zero' and the fluid line is open to flow from the manifold **15** to atmosphere at **25**. In the illustrative input showing, the $R_2$ but has a logic 'one' input and the fluid line is broken from the manifold to atmosphere. The switch condition of $R_2$ in FIG. **4** involves a shutoff of flow from the manifold to atmosphere so that there is essentially zero air flow from the manifold **15** through $R_2$.

In the FIG. **4** system, the digital restrictors $R_1$ through $R_8$, and the summing, reference restrictor **14**, all go to the essence of the operation of the system, in the sense that they are subject to error under conditions of temperature change.

In this invention, however, all of these restrictors are established as laminar flow elements. Accordingly, the flow ratio between these restrictors is maintained essentially constant with temperature change.

The other restrictors of the FIG. **4** system are not sensitive in the temperature error sense and flow therethrough need not be laminar. The 20 p.s.i. supply restrictor to the controller **10** is one of these, as is the feedback restrictor **23** to the controller.

While it is not usually desirable, from a space standpoint, to have straight laminar restrictors, these are within the scope of this invention.

The $R_1$—$R_8$ and **14** restrictors are shown in FIG. **4** schematically. Their preferred form is that of FIGS. **1**, **2** and **3**.

This invention therefore provides new and useful means for temperature compensation in fluid systems, as related to fluid restrictors therein, in the form of laminar flow through such restrictors, to maintain essentially constant ratio of flow through these restrictors under temperature change conditions.

As many embodiments may be made of the above invention, and as changes may be made in the embodiment set forth above without departing from the scope of the invention, it is to be understood that all matter hereinbefore set forth and in the accompanying drawings is to be interpreted as illustrative only and not in a limiting sense.

I claim:

**1.** Temperature compensation means as between fluid restrictors in a fluidic system, comprising said restrictors as laminar flow elements in said system such that flow ratio as between said restrictors remains essentially constant with temperature change applied alike to said restrictors, said system comprising a fluid control loop with one of said restrictors in said loop, and a group of restrictors as means for selectively providing different bleeds to atmosphere from said loop,

said group of restrictors being provided in a structure comprising a plate, a group of channel forms in one face of said plate, and a cover plate overlying said channel plate whereby said channel forms become peripherally closed passageways;

said passageways comprising a manifold passage as a part of said control loop with a control loop input to said manifold at one end of said manifold and an exit to said control loop at the other end of said manifold, and a graduated series of single flat plane spiral restrictor passages as graduated leaks to atmosphere;

each of said spiral restrictor passages having one end individually connected to said manifold and the other end exited to atmosphere from the central point of its spiral, with said spirals of sufficient length and suitable form to establish laminar flow therethrough according to operating flow parameters; and

said manifold ends of said passages together forming a central, trunklike stem grouping of parallel passages, with said individual passages flowering laterally from said stem grouping into individual spirals in essentially symmetrical increments of separated placement in said structure.