United States Patent [19]

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[11] **3,835,271**

[45] **Sept. 10, 1974**

[54] **ENVIRONMENTAL FLUIDIC SWITCHING DEVICE WITH PLURAL DIAPHRAGMS**

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[22] Filed: **Aug. 20, 1973**

[21] Appl. No.: **389,859**

[52] **U.S. Cl.**..... **200/83 Y,** 200/83 SA, 137/610, 251/120

[51] **Int. Cl.**..... **H01h 35/34**

[58] **Field of Search**.... 200/83 R, 83 A, 83 N, 83 P, 200/83 SA, 83 S, 83 Y, DIG. 32; 137/608, 610; 251/118, 120, 331

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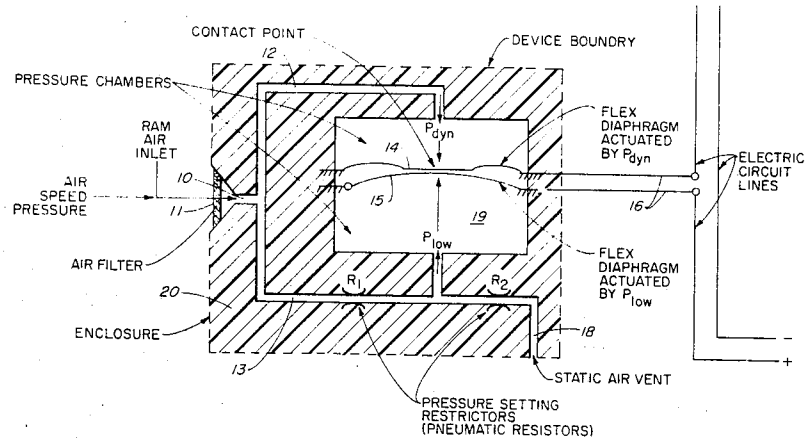
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[57] **ABSTRACT**

A fluidic switching device operating directly on ram air pressure differences to perform an electrical switching function. Operation is based upon the actuation of a micro switch by fluidic signal pressure acting against a flexible diaphragm and plate. The arrangement is self-compensating for altitude changes.

6 Claims, 1 Drawing Figure



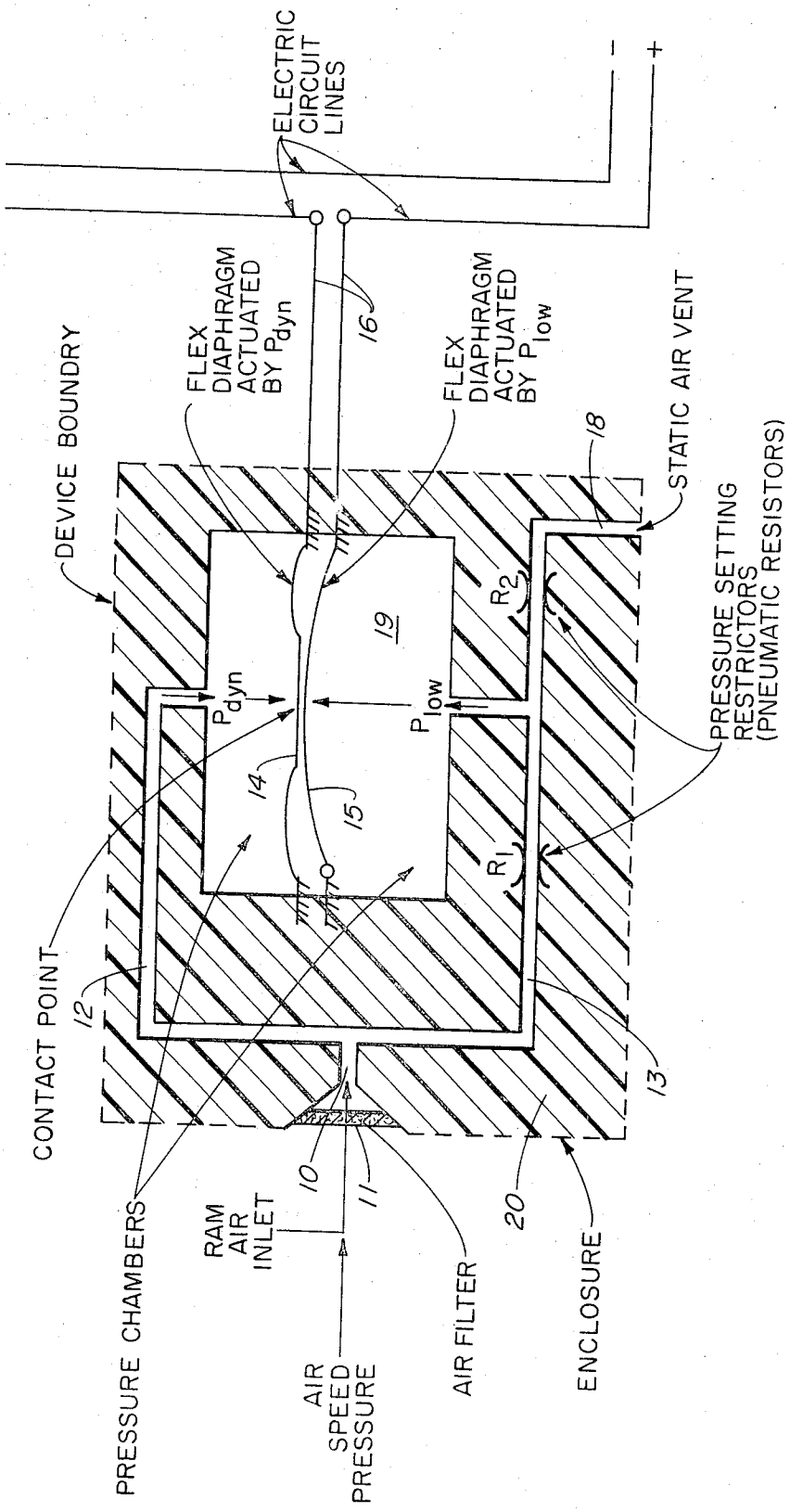

ELECTRIC CIRCUIT LINES
-
+
DEVICE BOUNDRY
FLEX DIAPHRAGM ACTUATED BY P_{dyn}
FLEX DIAPHRAGM ACTUATED BY P_{low}
16
18
STATIC AIR VENT
19
R_2
P_{dyn}
P_{low}
14
15
R_1
PRESSURE SETTING RESTRICTORS (PNEUMATIC RESISTORS)
CONTACT POINT
12
13
10
11
20
RAM AIR INLET
AIR SPEED PRESSURE
AIR FILTER
ENCLOSURE
PRESSURE CHAMBERS

Fig. 1.

ENVIRONMENTAL FLUIDIC SWITCHING DEVICE WITH PLURAL DIAPHRAGMS

BACKGROUND OF THE INVENTION

This invention relates to fluidic devices and more particularly to a ram air operated fluidic switching device. Prior fluidic operated switches are complicated devices involving moving valves or pistons, are not self-compensating for environmental changes, have slow response, or do not function in a satisfactory manner.

SUMMARY OF THE INVENTION

The present invention is a device which operates by ram air pressure generated by the speed of an aircraft carrying the device, for example, and responds directly to pressure signals of the airflow to actuate an electrical circuit at a predetermined airspeed. The air pressure is sensed by a dynamic pressure probe coupled to a differential pressure adjusted by a pneumatic resistance circuit.

A precision snap-acting microswitch is actuated by a differential pressure acting against a diaphragm and plate. It utilizes an extremely short stroke and a small volume permitting a fast response. The device is self-compensating for altitude ambient air density variation. There is a normally off-function for no pressure, and there is a normally on-function for pressures greater than a specified magnitude, the value of which is predetermined by pneumatic resistors in the circuit.

BRIEF DESCRIPTION OF THE DRAWING

The figure of drawing is a diagrammatic illustration of a preferred embodiment of the invention

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the figure of drawing, ram air enters the switching device via inlet **10.** The device may be mounted on an aircraft or airborne vehicle. A filter **11** may be used to eliminate foreign matter from entering the device. The dynamic pressure of the ram air, caused by the aircraft speed, is sensed via passages **12** and **13** by both pneumatic flex-diaphragms **14** and **15** which contain the circuit contacts of the electrical circuit line **16.** To close the switch at low aircraft speed, it is necessary to increase the restrictive value of pneumatic resistor R_1 relative to pneumatic resistor R_2. To close the switch at high aircraft speeds, the value of R_1 is decreased relative to R_2. Proper adjustment of pneumatic resistors R_1 and R_2 regulate the air flow and pressure to the low pressure side of the diaphragms. Since pneumatic resistor R_2 vents to the atmosphere via passage **18** and is influenced by that pressure, it is consequently affected by the altitude of the aircraft. The pneumatic pressure P_{dyn} to diaphragm **14** comes directly from the inlet **10** pressure and its value is that of the dynamic air speed. The pneumatic pressure P_{low} on diaphragm **15** is a resultant value of the pressures and air flow through resistors R_1 and R_2 in the pneumatic circuit. The relation of the pressure of diaphragm **15** to that of diaphragm **14,** necessary to make circuit contact, is as follows:

$$P_{low} = P_{dyn}\,(R_2/R_1 \pm R_2)$$

To properly adjust this ratio of resistors, it is necessary

to input to the device a dynamic air pressure corresponding to a prescribed aircraft speed. The resistors R_1 and R_2 are then varied until an electrical close circuit is attained by diaphragms **14** and **15** contacting each other. Values of pneumatic resistors R_1 and R_2 are selected to restrict the air passages. To obtain precision switching, at a predetermined aircraft speed, once set, these resistors remain fixed in the pneumatic circuit.

The diaphragms **14** and **15,** which in effect form a precision snap-acting microswitch, are mounted within a chamber **19** which is housed in enclosure **20.** Enclosure **20** also contains inlet passages **10, 12, 13** and **18.** The operation is based on the actuation of the precision snap-acting micro switch by fluidic signal pressure acting against diaphragm **14** and diaphragm or plate **15.** An extremely short stroke and small volume permits a fast response. As previously described, the device is self-compensating for altitude changes which affect the air density directly.

The fluidic switching device operates directly from pressure signals of the flowing fluid (air). As a result, no electrical power is required, making it ideal for use in environments where aircraft speed generates a pressure. This device provides a normally off-function with no pressure and normally on-function with pressures greater than specified magnitude whose value is predetermined by the pneumatic resistors R_1 and R_2 in the circuit.

Pneumatic resistors R_1 and R_2 may either be fixed for a specific application or may be made adjustable so the device can be adjusted for different applications. As aforementioned, the switching device can be set to close at any select altitude and ram air pressure by adjusting R_1 and R_2.

When setting the switching device to close at a low ram air pressure at sea level, for example, the pressure P_{dyn} applied to diaphragm **14** will be low and the pressure P_{low} on diaphragm **15** must be increased by increasing the air flow through pneumatic resistor R_1 and lessening the flow through pneumatic resistor R_2. If the device is set to operate at a high altitude and at a high air speed, the pressure P_{dyn} on diaphragm **14** will be high and the pressure P_{low} on diaphragm **15** must be lowered by increasing the flow through pneumatic resistors R_1 and R_2. The amount of restriction needed to be provided by pneumatic resistors R_1 and R_2 is determined by the required use of the device. The venting of the air pressure through the static air vent **18** by means of resistor R_2 and the adjusting of resistors R_1 and R_2 allows refinement of the opening and closing of the contact point of diaphragms **14** and **15** at a certain specified input pressure.

The test data given in Tables **1** through **4** show the performance of the device under normal sea level environment conditions.

The switching characteristics of the device were checked for repeatability and simulated aircraft speeds required to trigger the switch. The data in Table **1** show that an average speed of 192 knots, a ±1.34-knot differential was required for a complete switch operation. The limits corresponded to ±0.698 percent of the average aircraft speed value.

Switching Point Calculations were as follows:

Required velocity	=	192 knots
	=	223.68 mi/hr
	=	328.32 ft/sec

-Continued

Air density = 0.075 lb/ft³ (at sea level)

Dynamic pressure, P_{dyn} = $\rho V^2/2g$

$$= \frac{(0.075)\,(328.322)^2}{2\,(32.2)\,(144)}$$

= 0.87 lb/in²

The sensitivity of the switching limits can be increased, if desired, by varying the circuit impedance, R_1 and R_2 of the fluidic circuit shown in the figure of drawing.

Atmospheric density decreases with altitude. The required ram air pressures used are shown in Tables **2, 3,** and **4.** At an altitude of 40,000 feet, the device was found to stay energized as shown by the data in Table **4.** In the tables and calculations:

V_c = Aircraft velocity, ft/s

g = Gravitational acceleration (**32.2** ft/s²)

P_{dyn} = Dynamic pressure, lb/in²a

ρ = Air density of atmosphere, lb/ft³

P_{amb} = Ambient pressure, lb/in²a

P_{vac} = Environmental chamber pressure, inches of mercury, vac.

Table 1

Switching ON/OFF Repeatability Tests

Inlet Pressure of Fluidic Device		Fluidic Circuit		Simulated Airspeed	
Manometer Reading (In. of Water)	lb/in²	Open	Closed	ft/s	Knots
24.15	0.873		X	328.55	192.13
23.80	0.864	X		326.85	191.14
24.40	0.882		X	329.68	192.79
23.90	0.864	X		326.85	191.14
24.40	0.882		X	329.68	192.79
23.90	0.865	X		326.45	190.90
24.45	0.884		X	330.61	193.34
23.95	0.866	X		326.64	191.02
24.40	0.882		X	329.68	192.79

Switching values:

Average Speed = 192.00 knots

Average fluidic pressure = .87 lb/in²

Table 2

U.S. Standard Atmosphere

Altitude* (Feet)	Temperature* (°F)	Density* (lb/ft³)	Speed of Sound (ft/s)	Pressure (lb/in²g)
0	59.00	0.0750	1,116	14.70
5,000	41.17	0.0646	1,097	12.23
10,000	23.34	0.0554	1,077	10.11
15,000	5.51	0.0472	1,057	8.29
20,000	−24.62	0.0399	1,036	6.75
25,000	−30.15	0.0336	1,015	5.45
30,000	−47.99	0.0280	995	4.36
35,000	−65.82	0.0232	073	3.46
36,089	−69.70	0.0223	968	3.28
40,000	−69.70	0.0184	968	2.72
45,000	−69.70	0.0145	968	2.14
50,000	−69.70	0.0114	968	1.68
55,000	−69.70	0.0089	968	1.32
60,000	−69.70	0.0070	968	1.04
65,000	−69.70	0.0055	968	0.82
65,800	−69.70	0.0053	968	0.78
70,000	−67.30	0.0043	971	0.64
75,000	−64.55	0.0033	974	0.51
80,000	−61.81	0.0026	977	0.40

Table 3

Calculations For Environmental Fluidic Device

Aircraft Altitude Cruising Velocity = 500 knots

V_c = 854.3 ft/s

Altitude Dynamic Pressure, P_r = $\rho V_c^2/2g$

$$= \frac{\rho \times (854.3)^2}{2 \times 32.2 \times 144}$$

$$= 78.699\,\rho$$

P_r (lb/in²)	P_{amb} (lb/in²a)	Altitude (Feet)	Air Density, ρ (lb/ft³)
5.90	14.70	0	0.0750
5.08	12.23	5,000	0.0646
4.36	10.11	10,000	0.0554
3.71	8.29	15,000	0.0472
3.14	6.75	20,000	0.0399
2.64	5.45	25,000	0.0336
2.20	4.36	30,000	0.0280
1.83	3.46	35,000	0.0232
1.75	3.28	36,089	0.0223
1.45	2.72	40,000	0.0184
1.14	2.14	45,000	0.0145
0.89	1.68	50,000	0.0114
0.70	1.32	55,000	0.0089
0.55	1.04	60,000	0.0070
0.43	0.82	65,000	0.0055
0.34	0.78	70,000	0.0043
0.26	0.64	75,000	0.0033
0.20	0.40	80,000	0.0026

Table 4

Flight Parameters for Environmental Fluidic Device

Altitude (Feet)	Simulated Speed		Ram Pressure		P_{amb} (lb/in²a)	P_{vac}		Fluidic Circuit
	Knots	ft/s	lb/in²a	Inches of Mercury		lb/in²	Inches of Mercury	
				Sea-Level				
0	0.0	0.0	0.00	0.00	14.70	0	0	Open
0	50.0	85.5	0.06	0.12	14.70	0	0	Open
0	100.0	171.0	0.24	0.49	14.70	0	0	Open
0	190.7	326.09	0.86	1.75	14.70	0	0	Closed
				Cruising				
0	500	855	5.90	12.01	14.70	0.00	0.00	Closed
5,000	↓	↓	5.08	10.34	12.23	2.47	5.03	↓
10,000			4.36	8.87	11.11	3.59	7.31	
15,000			3.71	7.55	8.29	6.41	13.05	
20,000			3.14	6.39	6.75	7.95	16.18	
25,000			2.64	5.37	5.45	9.25	18.83	
30,000	500	855	2.20	4.48	4.36	10.34	21.04	Closed

Table 4—Continued

Flight Parameters for Environmental Fluidic Device

Altitude (Feet)	Simulated Speed		Ram Pressure		P_{amb}	P_{vac}		Fluidic Circuit
	Knots	ft/s	lb/in²a	Inches of Mercury	(lb/in²a)	lb/in²	Inches of Mercury	
				Crusing—Continued				
35,000	500	855	1.83	3.72	3.46	11.24	22.88	Closed
36,089	↓	↓	1.75	3.56	3.28	11.42	23.24	↓
40,000			1.45	2.95	2.72	11.98	24.38	
45,000			1.14	2.32	2.14	12.56	25.56	
50,000			0.89	1.81	1.68	13.02	26.50	Closed
55,000			0.70	1.42	1.32	13.38	27.23	Open
60,000			0.55	1.12	1.04	13.66	27.80	↓
65,000			0.43	0.87	0.82	13.88	28.25	
70,000			0.34	0.69	0.78	13.92	28.33	
75,000			0.26	0.53	0.64	14.06	28.62	
80,000	500	855	0.20	0.41	0.40	14.30	29.10	Open

The environmental fluidic switching device described herein can be used for environmental safing and fuzing of ordnance systems.

Some of the attractive features of this fluidic switching system are: high reliability, operation under extreme environmental conditions, resistance to radiation, and low cost. This fluid system is inherently very reliable by virtue of the fact that the only moving parts are the diaphragms. No electrical power is required, making the fluidic device ideal for use in environments where aircraft speed generates a pressure.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

I claim:

1. A fluidic switching device operable in response to dynamic and environmental air pressure differences, comprising:

a. a housing;

b. a pressure chamber within said housing;

c. pressure sensing means mounted within said pressure chamber;

d. said pressure chamber being divided into two separate compartments by said pressure sensing means; each of said two pressure chamber compartments, respectively, having only a single fluid flow part thereto;

e. a ram air inlet to said housing;

f. a first passageway in said housing from said ram air inlet directly to the fluid flow port of the first of said two pressure chamber compartments, where dynamic ram air pressure is sensed;

g. a second passageway in said housing from said ram air inlet to the fluid flow port of the second of said two pressure chamber compartments;

h. a third passageway in said housing from the fluid flow port of the second of said two pressure chamber compartments to the ambient atmosphere;

i. a separately adjustable pressure setting restrictor in each of said second and third passageways, respectively, said second and third passageways and restrictors forming a pneumatic resistance circuit, the pressure in the second of said two separate compartments being adjusted to provide a differential in pressure between the two compartments when there is ram air pressure at the ram air inlet; said device being selfcompensating for altitude ambient air density variation;

j. said pressure sensing means sensing the pressure differential between said two compartments and operable to actuate an electrical circuit connected thereto at a selected desired differential in pressures;

k. said pressure sensing means comprising first and second spaced apart, flexible diaphragms actuated by the differential in pressure in said two compartments, the spaced apart diaphragms containing electrical contacts to said electrical circuit and forming a pressure actuated switch means;

l. said first and second flexible diaphragms being normally separated at no pressure differential wherein the switch is thus normally open at no pressure differential, and said first and second diaphragms making electrical contact and thus closing the switch for pressures greater than a specified magnitude, the pressures required to close the switch being predetermined by the setting of said pressure setting restrictors;

m. the pressure in each of said pressure chamber compartments being sensed by said first and second pressure sensing diaphragms, the ram air pressure being sensed in the first of said pressure chamber compartments directly on said first diaphragm via said first passageway and partially in said second compartment on said second diaphragm via said second passageway, said second compartment being the low pressure side of said pressure chamber, and the pneumatic pressure on said second diaphragm being a resultant value of the pressures and air flow through the pressure setting restrictors in said second and third passageways, a closed electrical circuit being attained when the pneumatic pressures on said first and second diaphragms cause the two diaphragms to contact each other, the device actuating at low altitude and low ram air pressures when the restrictive value of the restrictor in said second passageway is increased relative to the value of the restrictor in said third passageway, and the device being actuated at high altitude and high ram air pressures when the restrictive value of the restrictor in said second passageway is decreased relative to the value of the restrictor in said third passageway.

2. a device as in claim **1** wherein said pair of spaced apart diaphragms form a precision snap-acting microswitch.

3. A device as in claim 2 wherein said snap-acting microswitch utilizes a short stroke and small volume permitting fast response.

4. A device as in claim 1 wherein a filter means is provided at the entrance to said ram air inlet to eliminate any dirt and foreign matter which would operate to clog the passageways from entering therein.

5. A device as in claim 1 wherein the ram air pressure is provided and generated by the speed of an aircraft carrying said device.

6. A device as in claim 1 wherein the relationship of pressures necessary to actuate the device is expressed by the following formula:

$$P_{low} = P_{dyn} [R_2/R_1 \pm R_2]$$

where: P_{low} = pressure in said second compartment
P_{dyn} = pressure in said first compartment
R_1 = restrictive value of the restrictor in said second passageway
R_2 = restrictive value of the restrictor in said third passageway.

* * * * *