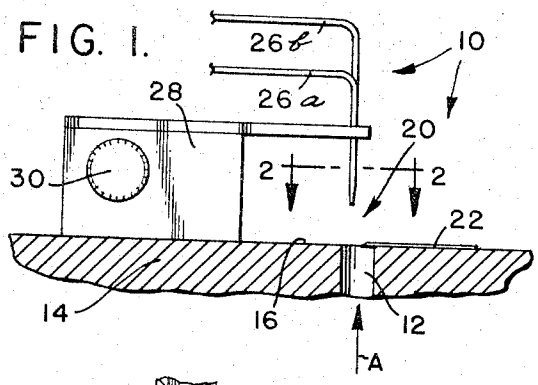
Aug. 22, 1967 J. D. BROOKS 3,336,932

HELICAL FLUID SIGNAL TO PRESSURE SIGNAL CONVERTER

Filed Oct. 11, 1965

FIG. 1.



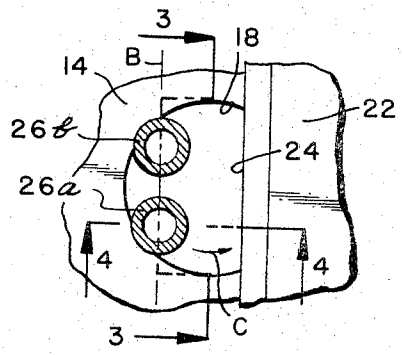


FIG. 2.

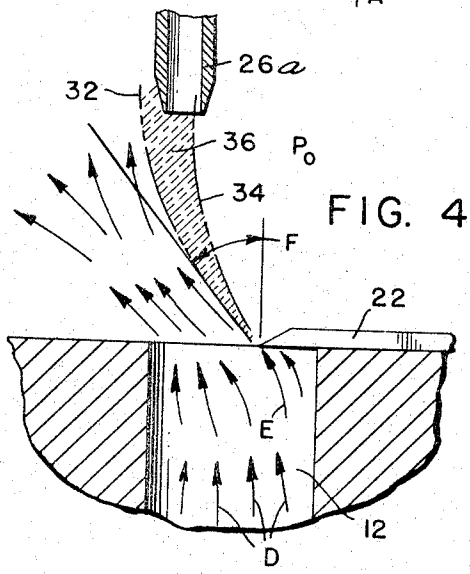


FIG. 4A.

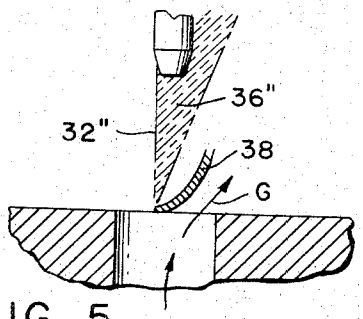


FIG. 5.

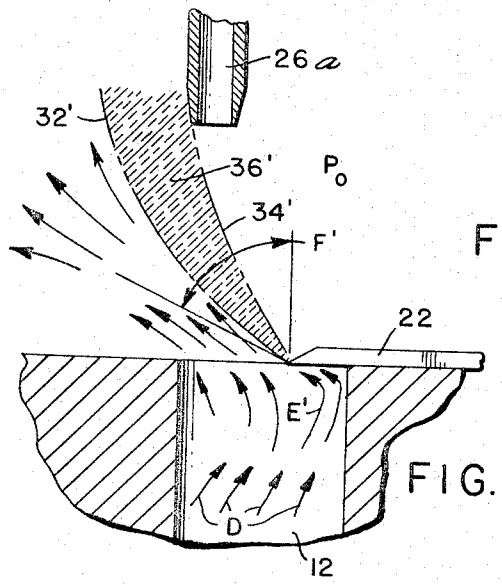


FIG. 4B.

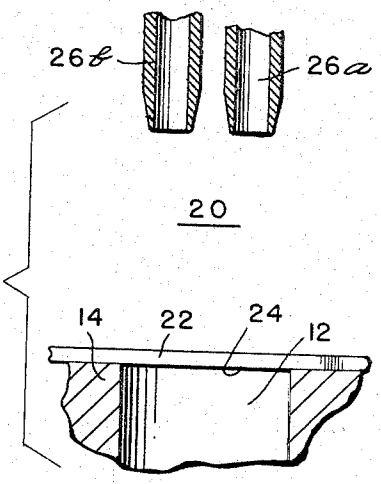


FIG. 3.

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United States Patent Office 3,336,932 Patented Aug. 22, 1967

3,336,932

HELICAL FLUID SIGNAL TO PRESSURE SIGNAL CONVERTER

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Filed Oct. 11, 1965, Ser. No. 494,987
5 Claims. (Cl. 137—81.5)

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

This invention relates to apparatus for transforming a pneumatic helical signal to a differential pressure signal.

In the currently important art of "pure fluid" control apparatuses, certain devices have been introduced which modulate a power stream with a component of rotational flow motion about the power stream's longitudinal axis. The resultant signal is in effect a "helical fluid" signal. One example of a device which so modulates a pneumatic power stream and provides a helical pneumatic output signal, is a vortex formation type angular rate of motion sensing device. This device has a similar configuration of internal compartments to those of the device disclosed in the inventor's co-pending application entitled "Magnetohydrodynamic Vortex Stream Transducer," Ser. No. 435,096, filed Feb. 24, 1964. However, in the case of the motion sensing device, a penumatic power stream is employed instead of the conductive liquid, and the magnetohydrodynamic coupling element is replaced by an annular porous or mesh-like element, which couples the rotational motion of the device's housing to the pneumatic stream as it enters the disk-like vortex formation chamber. The manner of formation of the vortex stream in the dis-like chamber, and the formation of the helical output stream in the outlet passage, which extends axially from the center of the vortex formation chamber to the exterior of the device's housing, is essentially the same as described in that patent application.

Before the helical signal may be operated upon by amplifiers and utilized as an output, it must be converted to a pressure differential signal. A known way of doing this is to employ an arrangement of tilted Pitot tubes in confronting relationship to the opening where the helical stream is vented, the individual tubes being tilted in a direction for interception of one direction of rotaton of helcal motion better than the other. Such Pitot tube arrangements were found to be relatively inefficient, and are relatively insensitive to small changes in magnitude of a helical pneumatic signal.

An object of this invention is therefore to provide improved apparatus for transforming a pneumatic helical signal to a differential pressure signal, which provides greater transducing efficiency than heretofore available in the prior art.

Another object is to provide improved apparatus in accordance with the preceding objective, which is sensitive to small changes in the helical signal.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a side elevation of apparatus embodying the invention, a portion being shown in section;

FIG. 2 is an enlarged section taken along line 2—2, FIG. 1;

FIG. 3 is a section taken along lines 3—3, FIG. 2;

FIGS. 4A and 4B are sections taken along line 4—4, FIG. 2, showing the discharge flow patterns for different input conditions; and

FIG. 5 illustrates a modified form of invention.

Referring now to the drawing, and in particular to FIG. 1, the subject of the invention is transducer apparatus **10** for transforming a helical pneumatic signal into an ordinary differential pressure signal. A circular cross sectioned passage **12** is the outlet portion of a conduit through which a helical pneumatic signal is transmitted. Passage **12** is illustrated as a bore formed in a structural body member **14** (only partially shown), which opens into a flat exterior surface of the structural member. For example, in an instance in which apparatus **10** is employed at the output of the previously described vortex type rate of angular motion pickoff device, body member **14** would be the housing of the pickoff of device, and passage **12** would be the terminal end of the central outlet connected from the disk-like vortex formation chamber of that device. The helical stream in passage **12** would then be a signal representative of the rate of angular motion sensed by the pickup device.

Passage **12** is formed as a bore which extends into body member **14** in a direction perpendicular to surface **16**, thereby forming a circular outlet orifice **18** where the bore opens into surface **16**. Orifice **18** vents into the normal ambient atmospheric environment and as such the open space adjacent surface **16** constitutes an expansion zone for the fluid in passage **12**. A plate **22** is fixed to the flat surface and is disposed over a minor portion of orifice **18**, as best shown in FIG. 2. Plate **22** has a straight knife edge **24**, which is disposed across circular orifice **18** in chordal relationship thereto. An adjustable support mechanism **28** holds the end portions of a pair of pressure sensing tubes **26***a* and **26***b* longitudinally aligned relative to passage **12**, and with the ends of the tubes spaced a predetermined distance away from the orifice. The openings in the ends of the tubes confront orifice **18**. Both tubes are aligned in a vertical plane through reference chord line B, which is parallel to and laterally spaced from knife edge **24**. The lateral spacing between the tubes and knife edge **24** may be adjusted by a manual knob **30** in connection with the adjustable support mechanism.

The operation of device **10** will now be explained according to the present understanding of the invention, for which reference will be made to FIGS. 4A and 4B. FIG. 4A, which is a section in a vertical plane through sensor tube **26***a* and transverse to the knife edged plate **22**, which illustrates flow stream conditions adjacent the knife edge and the sensor tube for a flow stream emanating from the interior of passage **12** having a zero component of rotational motion. FIG. 4B, taken along the same section, illustrates the flow stream conditions for the case of a flow stream emanating from the interior of passage **12** having a counterclockwise component of rotational motion, represented by arrow C, FIG. 2. Reference is first made to FIG. 4A, which represents the instance in which the stream through passage **12** has a zero component of rotational motion. Arrows D, which represent the stream emanating from the interior of the passage, are aligned along the direction of the passage. Plate **22** partially obstructs this stream from discharging into expansion zone **20**, and in so doing deflects flow lines which would otherwise flow directly out of the obstructed portion of the orifice. For example the flow line, arrow E, which flows immediately adjacent the tip of knife edge **24**, is deflected away from the direction of longitudinal alignment of passage **12** by a deflection angle F. The stream issuing from the unobstructed portion of the orifice is also deflected by the same deflection angle, so that the nominal boundary along the side of the stream adjacent plate **22**, which is symbolically represented by broken line **32**, is also inclined from the direction of the passage by angle F. The portion of expansion zone **20** behind

plate 22 is substantially stagnant, and therefore is at the static pressure of the atmosphere, P_0, as marked on the drawing. It is therefore a low pressure zone relative to the stream, which has a large component of dynamic pressure. The nominal boundary of this low pressure zone at its side adjacent the stream is symbolically represented by broken line 34. The space between the nominal boundaries of the stream and of the stagnation zone constitutes the so-called separation zone 36, and is represented by diagonal cross hatching consisting of a combination of unbroken and broken lines. The separation zone increases in width in the direction away from its origin at the knife edge, and is characterized by a pressure gradient in its width directions. The high pressure end of the gradient is at the side of the separation zone adjacent to the stream, and the low end of the gradient is at the side of the separation zone adjacent the stagnant zone. In accordance with conventional hydrodynamic theory, the generation of a well defined separation zone is enhanced by the sharp tip of knife edge 24. In the case of separation zone 36 in its position illustrated in FIG. 4A, tube 26*a* intercepts somewhat more than half the width of the separation zone, starting from the low pressure side of the zone. Identical flow stream conditions occur in the corresponding vertical plane (not shown) through the other sensor tube 26*b*, and tube 26*b* intercepts the same portion of the separation zone. Since both tubes of the pair of sensors intercept the same portions of the separation zone there is no differential pressure between the tubes.

Reference is now made to FIG. 4B, which represents the instance in which the stream through passage 12 has a counterclockwise (Arrow C, FIG. 2) component of motion. Arrows D, which represent the flow emanating from the interior of the passage are inclined from the vertical to represent the resultant helical flow motion. In the vertical plane in which the cross section of FIG. 4B is taken, the counterclockwise helical flow motion produces edgewise impingement of the stream against knife edge 24, and in so doing results in even greater deflection of the flow lines issuing from the unobstructed portion of the orifice than for the case of FIG. 4A. For example the flow line, arrow E', which flows adjacent the tips of knife edge 24 is now deflected by a greater magnitude of deflection, angle F' away from the direction of the passage. The separation zone 36' is correspondingly deflected in the direction away from the knife edge to a greater extent than in the case of FIG. 4A. With separation zone 36' in its position illustrated in FIG. 4B, the aperture of tube 26 opens into the stagnation zone adjacent the boundary 32' of the separation zone, which is a very low pressure zone. However, the counterclockwise component of motion has just the opposite effect on tube 26*b*. The flow in the corresponding vertical plane through tube 26*b* (not shown) results in edgelong impingement of the stream against the knife edge. Edgelong impingement causes the deflection angle of the separation zone to be even less than that for the instance of a zero component of rotational motion and tube 26*b* intercepts a portion separation zone near the high pressure side of the pressure gradient across the separation zone width. The combined effect of tube 26*a* opening to low pressure stagnation zone, and tube 26*b* intercepting a portion of the separation zone near the high end of its pressure gradient acts in a push-pull relationship upon the pair of tubes to generate a differential pressure therebetween. The pair of tubes communicate this differential pressure to wherever it is to be utilized.

From the foregoing it will be apparent that for a helical stream having a clockwise direction of rotation, the edgewise impingement of the stream will occur in the vertical plane through tube 26*b*, and that edgelong impingement will occur in the vertical plane through tube 26*a*, causing an opposite sense of push-pull action on the tubes than that for counterclockwise rotation. It will be further appreciated that the magnitudes of deflection of the chordal ends of separation zone, which are in opposite directions of angular deflection under a rotational component of motion, depend upon the magnitude of angular velocity of the rotation component of the stream motion. Thus, the extent to which the two tubes intercept opposite ends of the pressure gradient across the separation zone width, and in turn the magnitude of differential pressure between the tubes, also depends upon the angular velocity of the rotation component of stream motion. Accordingly the pressure differential signal from tubes 26*a* and 26*b* is of a sense and a magnitude in accordance with the sense and magnitude of the rotational component of motion in the helical flow stream. Through lateral adjustment of tubes 26, by means of manual adjustment knob 30, the tubes may be positioned where they intercept those portions of the separation zone which provide maximum sensitivity to change in the helical stream over a given range of helical stream signals.

Although the invention has been disclosed in a form in which the partial obstruction is by a flat plate across the orifice opening, it is to be appreciated that the partial obstruction may be provided by any bluff body. For example, in FIG. 5, the partial obstruction is a curved plate 38 which obstructs part of the flow to form a separation zone 36'', but allows the obstructed flow to be vented to the side of the plate as indicated by the flow line represented by arrow G. It is to be noted that the effect of allowing the obstructed flow to vent laterally away from the unobstructed stream is to tend to cause the boundary of the separation zone adjacent the unobstructed stream, line 34'', to assume a position of longitudinal alignment relative to passage 12.

Also, although the invention has been disclosed in a form in which apparatus 10 is employed at a vent outlet to the ambient atmosphere, it will be understood that the expansion zone 20 could also be an enclosed chamber, provided that it is large enough for the described stream effects to occur. By thusly enclosing the expansion chamber the invention may be adapted for use with devices having a liquid as its working fluid, such as is disclosed in the inventor's aforementioned co-pending patent application.

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.

What is claimed is:

1. Fluid signal transducer apparatus for converting an input helical fluid stream signal into a differential pressure output signal, the stream of said input signal being confined by a circular cross sectioned signal stream transmission passage, said transducer apparatus comprising;

(a) a fluid signal passage outlet member for delivering said fluid signal stream into an expansion zone, said outlet member forming an extension of said signal stream transmission passage and forming a circular outlet orifice of the same diameter as the passage in a plane transverse to the longitudinal axis of the passage,

(b) a partial obstruction and separation zone deflection member disposed adjacent to and across a portion of the outlet orifice, said partial obstruction and separation zone deflection member including a linear edge portion disposed essentially in the transverse plane of the orifice, said linear edge portion extending across the outlet orifice and through a pair of points along the periphery of the orifice, said points being disposed at the intersection of a first reference chord line and the periphery of the orifice, said partial obstruction and separation zone deflection member being shaped to form a transverse obstruction to the discharge of fluid disposed across the area of the orifice between the linear edge portion and the

periphery of orifice between the pair of points, the area of the orifice disposed at the unobstructed side of the edge portion communicating wtih the expansion space for discharging the fluid thereinto said linear edge portion serving to define a flow separation zone along the side of the unobstructed fluid discharge stream adjacent to said edge portion, said linear edge portion being so shaped that impingement of a fluid having a rotational component of motion against said linear edge portion causes the one and the other of chordally opposite portions of the flow separation zone to be unequally deflected from its position in absence of a rotational component of stream flow, with the relatively greater deffection at a selectively one or the other of such of the chordally opposite portions of the flow separation zones depending on the angular direction of the rotational component of motion of the fluid in said passage, and with the difference between the deflection of the separation zone at one and the other chordally opposite portions depending upon the magnitude of the angular velocity of the rotation component of stream flow, and

(c) differential pressure pick-off means disposed in said expansion zone and spaced away from said circular outlet orifice in the direction of the orifice axis, said differential pick-off means including a pair of pressure sensor apertures in confronting relationship to the outlet orifice and aligned along a second reference line parallel to said first chord reference line, said second reference line having a center point corresponding to the mid-point of the first reference chord line and said pair of apertures being disposed to one and the other side of said center point, said first and second reference lines being in predetermined lateral positions such that the pressure sensor apertures are located to intercept fluid flow in the region of the flow separation zone of unobstructed discharge stream at points having differences in dynamic pressure under the unequality of deflection at the opposite chordal portions of the flow separation zone, whereby the difference in dynamic pressure acts in a push-pull relationship upon the pressure

sensing apertures to develop a differential pressure therebetween.

2. Apparatus in accordance with claim 1,

(d) the first reference chord line having a length less than the diameter of the orifice and said partial obstruction and separation zone deflection member covering the area between the first reference chord line and the periphery of the orifice along the smaller included angle between the pair of points,

3. Apparatus in accordance with claim 2, wherein

(e) said partial obstruction and separation zone deflection member is a plate abuttingly disposed over a portion of the orifice, said plate having a straight edge forming said linear edge portion and aligned along the first reference chord line.

4. Apparatus in accordance with claim 2,

(f) the opposite faces of the plate having a marginal portion thereof adjacent its straight edge, said marginal portion being shaped to form said linear edge portion of the obstruction and separation zone deflection member as a knife edge.

5. Apparatus in accordance with claim 1, wherein

(g) said differential pressure pick off means comprising the end portions of a pair of tubes supported in longitudinal alignment with the orifice axis and with the ends of the tubes in confronting relationship to the orifice to intercept the fluid flow in or near the flow separation zone.

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