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FLOW SPLITTER FOR REDUCING DOMINANT EDGE
TONE FREQUENCIES IN FLUID SYSTEMS
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3,294,103

FIG. 1

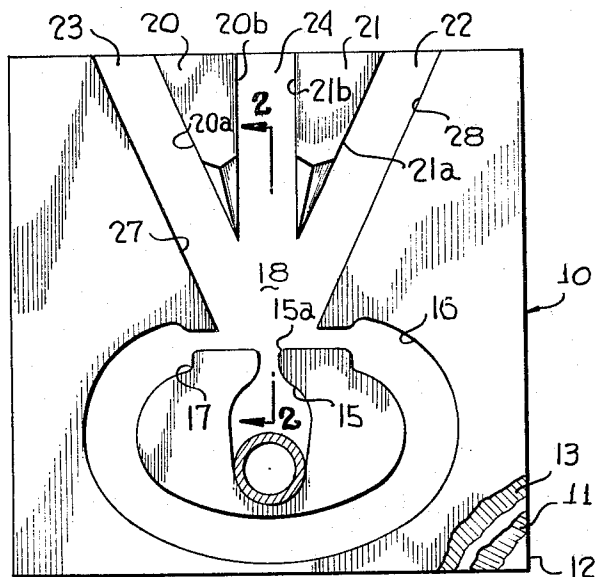


FIG. 2

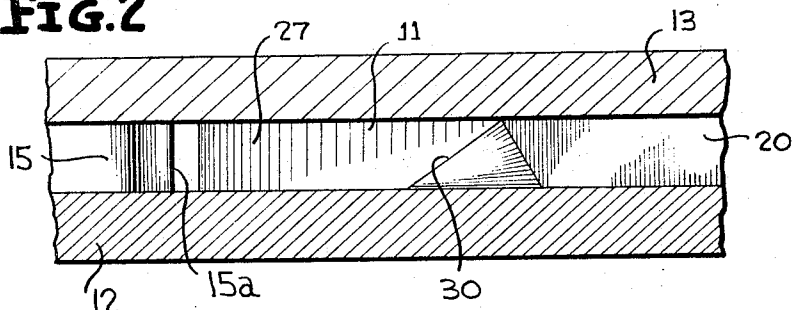


FIG. 3

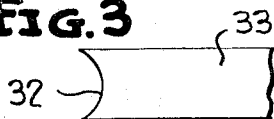


FIG. 4

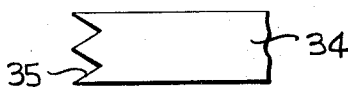
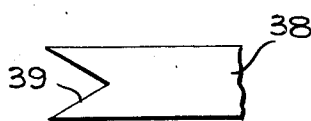


FIG. 5



FIG. 6



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FLOW SPLITTER FOR REDUCING DOMINANT EDGE TONE FREQUENCIES IN FLUID SYSTEMS

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The present invention relates generally to pure fluid amplifying systems and more specifically, to a flow splitter for use in a pure fluid amplifying system where reduces or minimizes dominant edge tone frequencies hitherto developed by conventional flow splitters in such systems.

Pure fluid devices; that is, fluid devices that do not employ moving parts for their operation, are now employed to perform functions such as amplification computation and control hitherto accomplished by other types of systems requiring electronics or moving mechanical parts for their operation. Such amplifiers and control elements are typically provided with a power nozzle for issuing a defined power stream from a source of fluid supply to an interaction chamber which is positioned downstream of the power nozzle. The interaction chamber is provided with orifices through which fluid control jets flow to effect the displacement of the power stream in the interaction chamber. The displacement of the power stream may be effected by momentum exchange between the control streams and the power stream or by boundary layer effects created by suitably positioning the chamber walls of the interaction chamber with respect to the orifice of the power nozzle so that pressure fields and flow patterns are created between the power stream and the chamber side-walls whereby the power stream flows generally along one chamber wall or an opposed chamber wall as determined by the amplitude and direction of the fluid streams issuing from the control nozzles. These principles of amplifier and control element operation are now well known to those working in the art and disclosed for example in U.S. Patents 3,024,805 and 3,093,306, the former patent disclosing a system utilizing stream interaction or momentum exchange to effect displacement of the power stream and the latter patent disclosing a boundary layer-type of fluid amplifier and a fluid oscillator incorporating this type of amplifier.

One or more flow splitters or triangular plan form are positioned downstream of the interaction chamber, the triangular shape of the splitters providing an apex that serves to split the fluid egressing from the downstream end of the interaction chamber into two or more output passages, adjacent sides of the output passages being formed by diverging sides of the flow splitter. The number of flow splitters required is generally one less than the number of output passages desired; thus if three outlet passages are to be provided in the amplifier or oscillator, two flow splitters would generally be employed for splitting the fluid into the three output passages.

Conventional flow splitters terminate in an apex having a leading edge of constant profile perpendicular to the direction of power stream flow through the interaction chamber. It has been observed however that a non-varying leading edge profile permits the development of a narrow band of edge tone frequencies along the apex profile for various flow conditions in the amplifying or oscillating system of the type described above. The dominant edge tones so developed produce perturbations and instability in stream flow into the entrances of the output passages so that undesired oscillations may be created in the pure fluid amplifier or control element.

Broadly, it is an object of this invention to provide a flow splitter for use in a pure fluid amplifier or control

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elements the flow splitter being constructed to prevent the creation of narrow band edge tone frequencies.

More specifically, it is an object of this invention to provide a pure fluid amplifier or control element of the beam deflection type or boundary layer control type that includes a power nozzle and a flow splitter located downstream of the power nozzle wherein the distances along the power stream flow path between the orifice of the power nozzle and the leading edge of the flow splitter vary over at least a portion of the leading edge profile so as to prevent the creation of a narrow band of edge tone frequencies along the leading edge of the flow splitter and to cause the production of tones over a wide band of frequencies in which the amplitude of any tone is quite small.

According to this invention, the leading edge of the flow splitter incorporated in a beam deflection type of amplifying or control type fluid system is formed such that the distances along the power stream flow path between the orifice of the power nozzle and the leading edge of the splitter vary for at least a portion of the height of the leading edge. Variations in the distance between portions of the leading edge and the orifice of the power nozzle reduces the frequency concentration of energy along the leading edge resulting from the impingement thereagainst of the power stream and effectively increases the bandwidth of edge tones developed along the leading edge. Accordingly, noise and perturbations developed by dominant edge tone frequencies characteristic of a particular flow condition in the system are reduced, permitting an increase in the stability and the signal-to-noise ratio of the system as well as in the integrity of the fluid output signals issuing therefrom.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of several specific embodiments thereof, especially when taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 of the accompanying drawings illustrates a conventional pure fluid boundary layer type amplifier connected so as to constitute an oscillator and having flow splitters modified in accordance with the principles of this invention;

FIGURE 2 is a partial sectional side view of FIGURE 1 taken along section line 2-2; and

FIGURES 3-6 inclusive, are views in elevation of other possible embodiments of a flow splitter, constructed in accordance with the principles of this invention, for use in fluid amplifying and control elements.

Referring now to FIGURE 1 of the drawings for a more complete understanding of this invention, there is shown a pure fluid system 10 in which the flow splitter of this invention may be incorporated for the purposes described briefly hereinabove. The system 10 is shown to be a pure fluid oscillator using the boundary layer type pure fluid amplifier such as disclosed in U.S. Patent No. 3,093,306. It should be understood however, that the system 10 is merely one form of fluid system of the beam deflection type and that other forms of fluid systems of the beam deflection type may also incorporate the flow splitters of my invention.

The oscillator 10 is formed by cavities, passages and nozzles, cut or etched into a flat center plate 11 which is sandwiched between two flat plates 12 and 13, the three plates being sealed one to the other by adhesives, machine screws, or other suitable means in a fluid-tight relationship. Although any materials may be used to construct the oscillator 10 compatible with the fluid employed in the system, to the end of more clearly illustrating the invention, the plates 11, 12 and 13 inclusive are shown to be composed of a clear plastic material. The plate 12 is formed with a power nozzle 15 having an orifice 15a, a

pair of control nozzles 16 and 17, an interaction chamber 18, a pair of flow splitters 20 and 21, and output passages 22, 23 and 24, respectively. The diverging sides 20a and 21a of the flow splitters 20 and 21, respectively, and extended sidewalls 27 and 28, respectively, of the interaction chamber 18 form the opposed sidewalls of the output passages 23 and 22, respectively; whereas the opposite sidewalls 20b and 21b of the flow splitters 20 and 21, respectively, form the sidewalls for the central output passage 24. The sidewalls 27 and 28 are positioned sufficiently close to the orifice of the power nozzle 15 so that the fluid amplifying system incorporated in the oscillator 10 is of the boundary layer type as will be evident to those working in the art, and the power stream exiting from the power nozzle 15 can therefore be alternately switched between the output passages 22 and 23 by alternating fluid control pulses issuing from the control nozzles 16 and 17. Fringe quantities of the power stream flow may also enter the central output passage 24, the quantity of fluid received by this passage being primarily determined by the degree of power stream diffusion in the chamber 18 after switching. Alternating fluid streams issuing from the output passages 22 and 23 may be utilized to drive other types of fluid systems and the flow from the output passage 24 may be used as a double frequency fluid stream to drive other types of fluid system or alternately may be delivered to a sump or to an environment of ambient pressure. The general operation of this type of oscillator is described in detail in the aforementioned Patent No. 3,093,306 and hence will not be discussed further herein.

Referring now to FIGURE 2 of the drawing, there is shown an enlarged view of the profile of the leading edge 30 of the flow splitter 20, the leading edge 30 being identical to the leading edge of the flow splitter 21 and inclined in the direction of power stream flow from the power nozzle orifice 15a. As previously mentioned, in prior art fluid systems, the profile of the leading edge of the flow splitter is such as to be at a constant or nonvarying distance from the power nozzle and as such is perpendicular to the direction of power stream flow in the interaction chamber 18. When the profile of the leading edge of the flow splitter is positioned perpendicular to the direction of power stream flow from the orifice 15a, fluid flow through the chamber 18 impinging against the leading edge of the flow splitter, creates periodic energy level fluctuations across the edge, this energy creating dominant edge tones of narrow band frequency ranges the frequency range being a function of the distance between the leading edge of the flow splitter in the direction of power stream flow and the downstream edges of the power nozzle orifice 15a. It has been observed that the characteristic dominant edge tone frequency developed is proportional to the distance between the leading edge of the flow splitter and the downstream edges of the orifice 15a. For a particular flow condition in the interaction chamber 18, one edge tone frequency dominates and creates perturbations and noise across the leading edge of the flow splitter. Such perturbations oftentimes change the character of the output signal resulting from oscillation of the power stream in an oscillator and in general adversely affect the switching of the power stream into the output passage in a pure fluid system, whether the system be an amplifier, oscillator or other type of fluid control element of the beam deflection type. In pure fluid amplifiers of the beam deflection type disturbances to flow downstream of the power nozzle orifice created by dominant edge tones may cause the system to go into undesired oscillation. These oscillations appear as "noise" masking the desired output signal in most applications and it is desirable to suppress or minimize this source of internally generated noise of the amplifier.

If the distance between the orifice 15a and the leading edge of the flow splitter is varied over at least a portion of length of the leading edge, different frequency edge

tones are developed across the edge and as a result, the bandwidth of edge tone frequencies increases as the variations in distances between the leading edge of the flow splitter and the orifice 15a increase but the peak amplitudes of dominant frequencies are reduced. The variation of distance between the power nozzle orifice 15a and the flow splitter or splitters may be accomplished by inclining the leading edge of the flow splitter with respect to the power nozzle orifice in the plane of symmetry of the flow splitter. The plane of symmetry of the splitter is a plane perpendicular to plates 12 and 13 which is equidistant at all points from the sides of the splitter, for instance, from sides 20a and 20b of splitter 20. The desired variation may be achieved by tapering, for instance, the sides 20a and 20b of the flow splitter 20, in the region of the apex of the splitter, to provide triangular shaped surfaces 20c and 20d which have a common leg or edge 30 as illustrated in FIGURE 2. The profile of the edge 30, in a plane perpendicular to the plates 12 and 13 lies along the centerline of the divider 20, sloping away from the plane of the plate 13 toward the nozzle orifice 15a at an acute angle. The taper provided to the sidewalls of the flow splitter apex further increases variations in distances between the leading surfaces of the flow splitter and the orifice 15a, as will be obvious.

FIGURES 3-6 illustrate various leading edge profiles for the dividers 20 and 21 which are viewed in plane perpendicular to the plates 12 and 13 and lying along the centerline of the divider. With reference to FIGURE 3, the leading edge 32 of a flow splitter 33 is shown to be concave to the direction of power stream flow. FIGURE 4 illustrates a flow splitter 34 having a leading edge 35 the profile of which is serrated. FIGURE 5 illustrates a flow splitter 36 wherein the leading edge 37 is inclined at an obtuse angle to the direction of power stream flow. FIGURE 6 illustrates a flow splitter 38 wherein the profile of the leading edge 39 is formed with an essentially V-shaped groove.

As will be evident to those skilled in the art, the leading edge profile configurations illustrated in FIGURES 2-6 of the drawing are merely exemplary of possible profile configurations and other leading edge profile configurations that provide substantial variations in the distances between the leading edge and the downstream edges of the orifice of the power nozzle may be alternatively used to prevent the generation of characteristic, dominant edge tone effects along the leading edge of a flow splitter. In addition, the sidewalls forming the apices of the flow splitter may be tapered as shown in the embodiment of FIGURE 1 to further increase the bandwidth of edge tones. The inclination of the taper relative to the horizontal plane of the plate 11 is ordinarily a matter of choice. In general, the greater the variation in distance between orifice 15a and various points on the splitter leading edge, the broader the range of frequencies generated as a result of impact of power stream on the leading edge and the lower the maximum amplitude of this type noise at its peak frequency.

Although the figures illustrate the invention as applied to a boundary layer unit employed as an oscillator, the principles of the present invention are equally applicable to analog pure fluid amplifiers, bistable elements not employed as amplifiers or combinations thereof such as an analog amplifier employing boundary layer effects to produce positive feedback.

What I claim is:

1. In a fluid amplifying system of the beam deflection type including a chamber for receiving and confining fluid flow, a power nozzle having an orifice through which a defined power stream issues into said chamber, plural output passages located downstream of said chamber for receiving fluid therefrom, means for deflecting said power stream in a predetermined plane so as to vary the proportion of fluid directed to said outlet passages, a flow splitter having an apex positioned downstream of said

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chamber, said apex provided with a leading edge positioned for splitting power stream flow into said output passages, said edge having a profile, said splitter being arranged such that the entire leading edge profile is inclined with respect to power stream flow in a plane perpendicular to the plane of deflection of said power stream and parallel to the axis of symmetry of said splitter.

2. In a fluid system, a chamber for receiving and confining fluid flow, means for issuing a fluid stream into said chamber, at least one output passage located downstream of said chamber for receiving fluid therefrom, means having an edge extending into the downstream end of said chamber for splitting a portion of flow into said output passage, means for preventing the generation of a narrow band of edge tone frequencies along said edge, said means constituting a slope of said edge away from said means for issuing over the entire length of said edge.

3. In a fluid amplifying system of the beam deflection type including a chamber for receiving and confining fluid flow, a power nozzle having an orifice through which a defined power stream issues into said chamber, plural output passages located downstream of said chamber for receiving fluid therefrom, means for deflecting said power stream in a predetermined plane so as to vary the proportion of fluid directed to said outlet passages, a flow splitter having an apex positioned downstream of said chamber, said apex provided with a leading edge positioned for splitting power stream flow into said output passages, said edge being serrated.

4. In a fluid amplifying system of the beam deflection type including a chamber for receiving and confining fluid flow, a power nozzle having an orifice through which a defined power stream issues into said chamber, at least one passage located downstream of said chamber for receiving fluid therefrom, means for deflecting said power stream in a predetermined plane so as to vary the proportion of fluid directed to said outlet passages, a flow

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splitter having an apex positioned downstream of said chamber, said apex provided with a leading edge positioned for splitting power stream flow into said output passage, said edge having a profile, said splitter being arranged such that the entire leading edge profile is inclined with respect to said power nozzle orifice in a plane perpendicular to the plane of deflection of said power stream and parallel to the axis of symmetry of said splitter.

5. In a fluid amplifying system of the beam deflection type including a chamber for receiving and confining fluid flow, a power nozzle having an orifice through which a defined power stream issues into said chamber, at least one passage located downstream of said chamber for receiving fluid therefrom, means for deflecting said power stream in a predetermined plane so as to vary the proportion of fluid directed to said outlet passages, a flow splitter having an apex positioned downstream of said chamber, said apex provided with a leading edge positioned for splitting power stream flow into said output passage, said edge having a profile, said splitter being arranged such that the distance between said leading edge profile and said power stream orifice varies as a monotonic function over the entire length of said leading edge profile and said orifice in a plane perpendicular to the plane of deflection of said power stream and parallel to the axis of symmetry of said splitter.

References Cited by the Examiner

UNITED STATES PATENTS

3,071,154	1/1963	Cargill et al.	137—81.5
3,194,253	7/1965	Havee	137—81.5

M. CARY NELSON, *Primary Examiner*.

W. CLINE, *Assistant Examiner*.