United States Patent [19]

White

[11] **3,802,537**

[45] **Apr. 9, 1974**

[54] **APPARATUS FOR FLUID FLOW PRECISION PRESSURE-REDUCTION, AND ATTENUATION AND DIFFUSION OF JET-PRODUCED SOUND WITHOUT SUBSTANTIAL SOUND-REGENERATION IN JET-PORT ARRAYS, INCLUDING VALVES AND THE LIKE**

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[21] Appl. No.: **226,871**

[52] **U.S. Cl.** ..... **181/36 R,** 137/625.3, 138/42, 251/127, 181/55, 181/56

[51] **Int. Cl.** **F01n 3/06**

[58] **Field of Search** ..... 181/37, 36 R, 36 A, 36 B, 181/36 C, 36 D, 63, 69, 50, 42, 55, 56; 137/14, 625, 625.28, 625.3; 138/40, 42, 43; 251/127, 118

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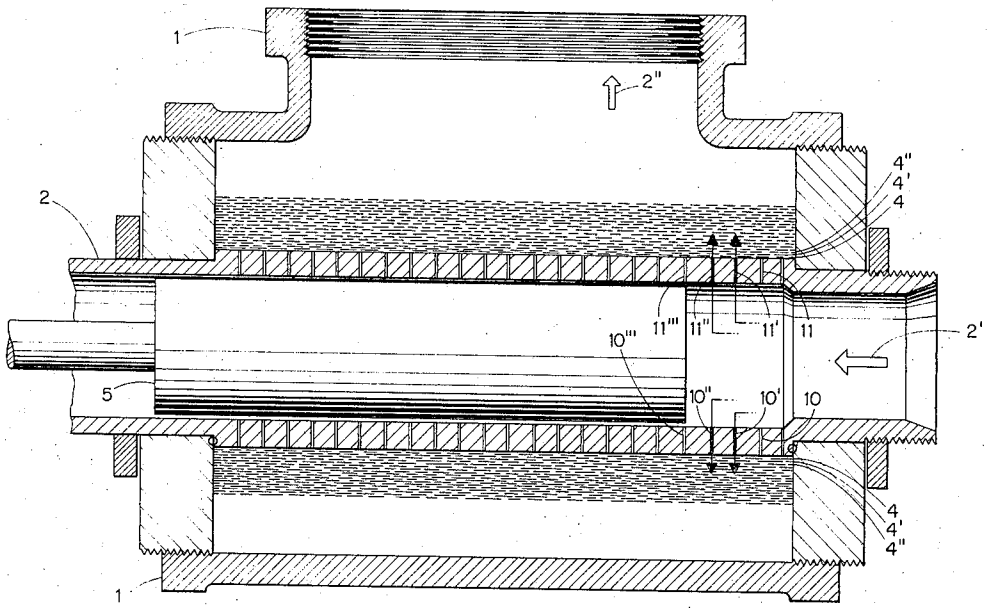
Assistant Examiner—John F. Gonzales
Attorney, Agent, or Firm—Rines and Rines; Shapiro and Shapiro

[57] **ABSTRACT**

This disclosure deals with the precision pressure reduction of a fluid stream while attenuating and diffusing jet-produced sound therein from a jet-port array as in valves and the like, but without substantial sound-regeneration during the same, through the use of enveloping apertured screens and the like positioned close to the vortex mixing region and adapted to produce a controlled gradual frictional reduction in pressure gradient while controlling the velocity of the streams exiting from the jet-port array.

2 Claims, 3 Drawing Figures



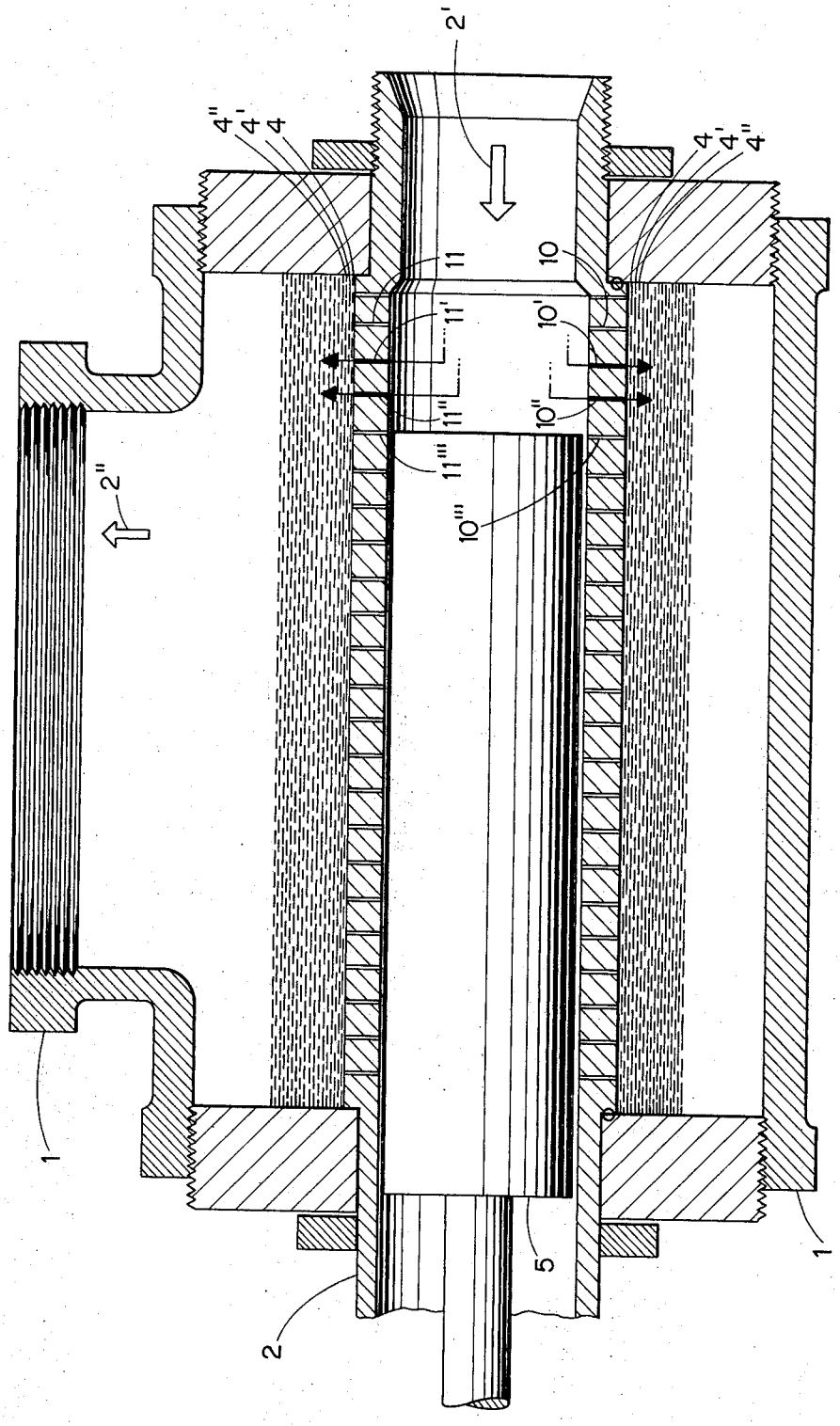


Fig. 1.

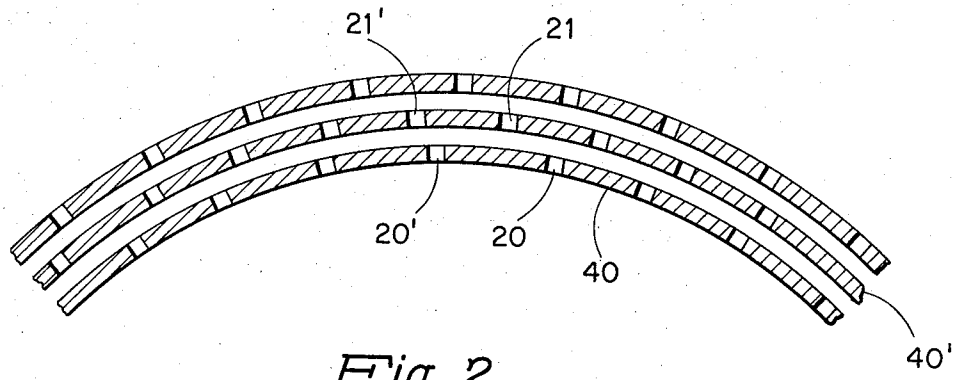


Fig. 2.

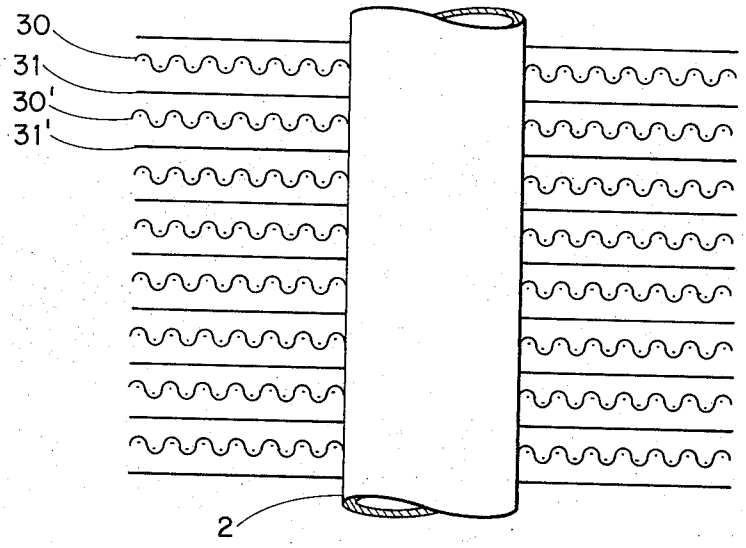


Fig. 3.

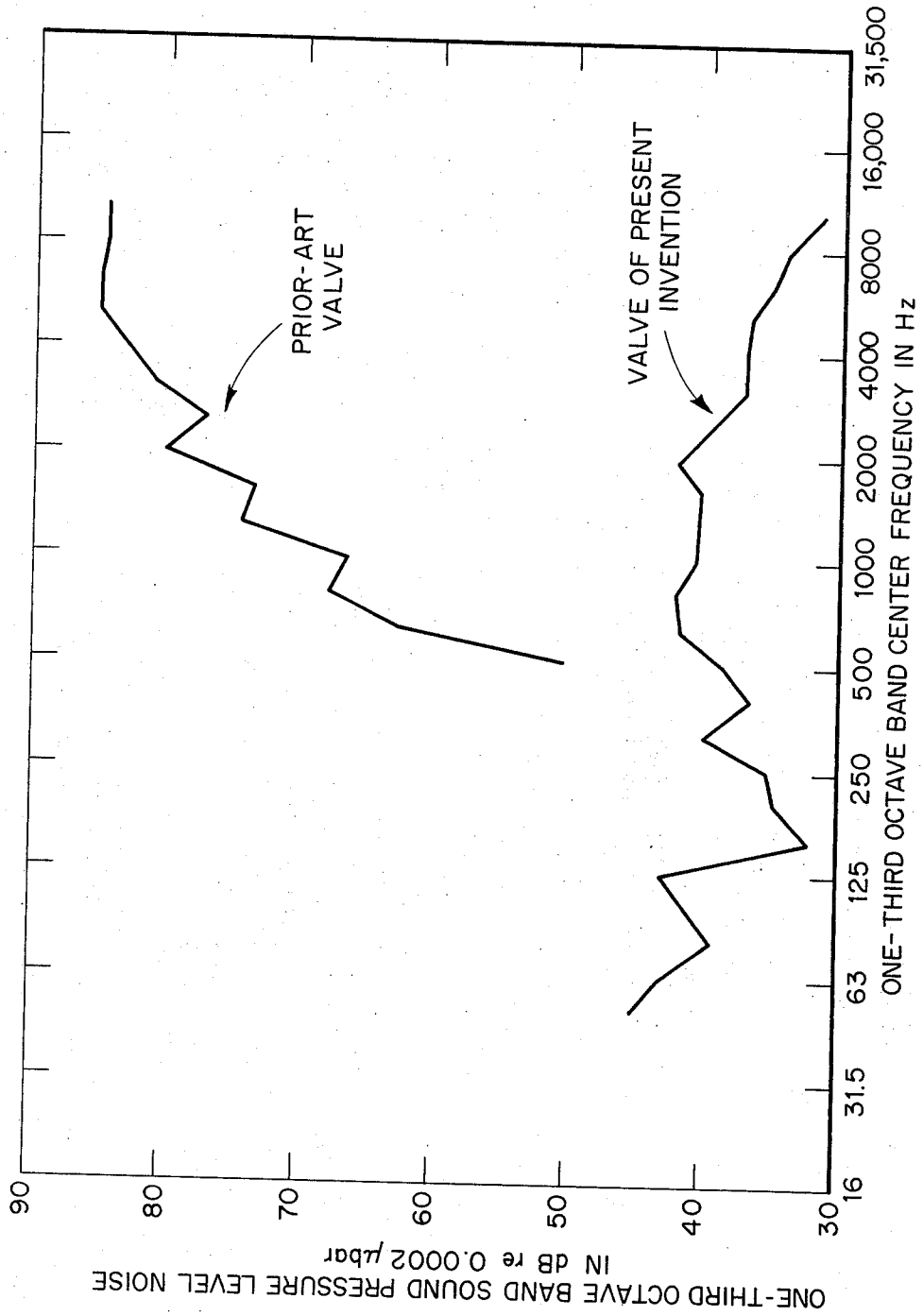

ONE-THIRD OCTAVE BAND SOUND PRESSURE LEVEL NOISE
IN dB re 0.0002 μbar
90
80
70
60
50
40
30
16
31.5
63
125
250
500
1000
2000
4000
8000
16,000
31,500
ONE-THIRD OCTAVE BAND CENTER FREQUENCY IN Hz
PRIOR-ART VALVE
VALVE OF PRESENT INVENTION

Fig. 4.

APPARATUS FOR FLUID FLOW PRECISION PRESSURE-REDUCTION, AND ATTENUATION AND DIFFUSION OF JET-PRODUCED SOUND WITHOUT SUBSTANTIAL SOUND-REGENERATION IN JET-PORT ARRAYS, INCLUDING VALVES AND THE LIKE

The present invention relates to methods of and apparatus for attenuating and diffusing the sounds normally produced by jet ports exiting gas or liquid under pressure (hereinafter generically referred to as "fluid"), being more particularly directed to jet-port arrays as may be used in valves or other apparatus requiring the successive exiting of fluid streams from a plurality of successive jet ports or the like.

The problems attendant upon the quieting or muffling of the sounds produced by pressurized jet fluid streams have been approached in a myriad of ways ranging from diffusers, as described, for example, by U. Ingard in "Attenuation and Regeneration of Sound in Ducts and Jet Diffusers," appearing, commencing with page 1,202, in the Journal of the Acoustical Society of America, Vol. 31, Number 9, September 1959, to the use of deflecting vane structures and vortex turbulence inhibitors, as described, for example in AIAA Paper No. 68–1023, "Perspective of SST Aircraft Noise Problem," October, 1968, G. S. Schairer et al. and Journal of Fluid Mechanics, Vol. 44, Part I, 1970, "Vortex Growth in Jets," G. S. Beavers et al.

The use of different types of pressure-varying and valving mechanisms, air-flow dividers and shutters and the like in other fluid-flow systems, moreover, is also well known, as illustrated, for example, in U.S. Letters Patent Nos. 2,893,508 and 3,103,941, assigned to the assignee of the present invention.

None of these proposals, however, has proven particularly useful for the specific and unique problems underlying arrays of closely spaced adjacent jet ports exiting pressurized fluid streams and requiring sound attenuation and diffusion without having the proposed sound-reducing apparatus itself give rise to substantial sound (noise) regeneration While the Ingard publication, supra, does deal with the use of a perforated disc or a basket diffuser disposed at the end of an individual jet, and extending from its peripheral opening, the present invention is particularly concerned with the pressurized streams of successively different velocities substantially simultaneously exiting from an array of adjacent jet ports, as in a valve or other structure wherein the use of such an individual basket mounted from the periphery of the jet opening for each port is not feasible. More than this, it was not a priori predictable that such diffusion is possible over an extended array of jet ports, particularly of such different-velocity and escape-pressure distributions along the array.

It has also been proposed to attain relatively quiet valve operation by controlling or limiting the fluid velocity within the valve to that of the associated line, or piping multiple disc structures that divide the incoming flow stream into a series of smaller flow streams as described, for example, in Bulletin CC–48 of Control Components, Inc. of Los Alamitos, California, entitled "Self 'Drag' Valve." Such an approach, however, requires ancillary divider structures, and modifying the incoming stream.

Underlying the present invention, however, is the discovery that, through rather critical positioning, geometry and dimensioning, appropriate common apertured surface(s) can be used simultaneously to quiet an array of jet ports without altering the incoming stream, even over extensive dimensions, and without itself introducing substantial sound regeneration; and it is to providing a novel method of and apparatus for effecting such a result that the present invention has its primary objective.

A further object of the invention is to provide a new and improved jet muffling apparatus and technique of more general applicability, as well.

Still another object is to provide a novel quiet valve structure embodying a plurality of jet ports.

Other and further objects will be explained hereinafter and are more particularly delineated in the appended claims. In summary, however, from one of its broader aspects, the invention contemplates a method of precision pressure-reduction of a fluid stream while attenuating and diffusing jet-produced sound therein without substantial sound regeneration during the same, that comprises, passing a high velocity fluid stream under pressure along a conduit; exiting the stream into a relatively low velocity medium at successive jet ports along the conduit as the stream passes therealong, thereby normally generating noise as the exiting stream at the successive ports produces jet vortex turbulence in mixing at relatively high velocity with the relatively low velocity medium external to the conduit; and producing a controlled gradual frictional reduction in pressure gradient close to the jet ports and enveloping all said jet ports in the regions of the commencement of said mixing. Preferred details, including the application to quiet valving structures, are hereinafter set forth.

The invention will now be described with reference to the accompanying drawings, FIG. 1 of which is a longitudinal section of the invention in preferred form, shown for illustrative purposes as applied to a valving system.

FIG. 2 is a fragmentary transverse section of a modified spirally wound apertured screen portion;

FIG. 3 is a transverse section of a further modification; and

FIG. 4 is a graph plotting the actual improved performance of a valve constructed in accordance with the embodiment of FIG. 1, as measured in a reverberant chamber, with the ordinate plotting one-third octave band sound pressure level (noise) expressed in decibels (dB) referred to 0.0002 microbar, and the abscissa plotting one-third octave band center frequency in Hz.

Most prior gas pressure-reducing valves achieve a pressure drop by passing the gas through a constriction which acts as a sonic nozzle. While this achieves the pressure reduction goal, unfortunately, it also generates significant acoustic energy. This is particularly true if the pressure ratio across the valve exceeds the critical ratio for the gas; generally about 1.9 for air. Above a pressure ratio of about 2.5, the acoustic efficiency of the process is approximately 5×10^{-3}, meaning that one-half percent of the total gas-stream power is radiated as acoustic energy. This, moreover, is approximately the same value as a choked jet engine.

If the pressure were reduced gradually, say by viscous friction, there would be (theoretically, at least) no noise generated because the excess energy would be dissipated as heat. This, indeed, would be an ideal solu-

tion, but the volume required to achieve this type of process is prohibitive for most practical systems and certainly for valves.

Consider, however, the reduction of pressure that could be achieved by a sequence of small but finite pressure drops such as might be produced by passing the gas through a sequence of surfaces or plates with tiny apertures or through a sequence of apertured screens. If the total pressure drop is represented by ΔP, the pressure drop for each of N apertured surfaces or plates is $\Delta P/N$. If all the pressure drops were absorbed in one apertured surface or plate, then the noise power generated would be

$$\text{Power} \approx K_1(\Delta P)^2,$$

where the constant K is dependent upon the mass flow and acoustic efficiency, K being generally an increasing function of ΔP. If, however, the pressure is reduced in steps by successive N apertured surfaces or plates, the acoustic power generated is given by

$$\text{Power} \approx NK_N[(\Delta P/N)]^2,$$

demonstrating that the acoustic power goes down with increasing N, even if K is considered a constant. The objective of the present invention in a quiet pressure reduction in a jet-port valve and the like is thus to achieve pressure reduction by many small steps in a controlled manner.

Referring to the illustrative jet-port-array valve of FIG. **1**, the illustrative structure is shown comprising a standard pipe tee **1** serving as the valve body and containing an inner conduit tube **2** drilled or otherwise provided with a plurality or array of successive closely spaced adjacent openings or jet ports **10, 10′, 10″, 10‴**, etc., shown longitudinally extending linearly along one side of the conduit **2.** A circumferentially displaced opposite array of similar jet ports is also shown at **11, 11′, 11″, 11‴**, etc.; with the openings being indeed preferably, though not essentially, spaced around the circumference of the tube **2.** A pressurized fluid stream is fed into the conduit inlet **2′**, successive portions of which exit from the successive jet ports **10, 10′, 10″**, etc. and **11, 11′, 11″**, etc. as the stream passes along the conduit **2.** A variably axially positioned valving piston **5** is provided within the conduit **2** to control the valving action by varying the number of jet ports that are open for exiting; FIG. **1** showing the jet ports **10‴** (and **11‴**) and beyond, closed off by the valving piston **5.** The piston **5** may slide longitudinally or be advanced and retracted by threads.

In accordance with a preferred form of the invention, the conduit **2** is shown coaxially enveloped or wrapped with successive layers of fine apertured screen wire **4, 4′, 4″**, etc., the closely spaced apertures of which are much smaller than the jet port openings. The fineness of the mesh determines the flow resistance and hence the pressure drop per screen.

High pressure gas enters the inlet **2′** of the conduit **2,** and, depending upon the position of the piston **5,** exits through as many of the adjacent jet ports in the conduit wall as are left open by the piston **5.** The effective opening of the valve structure, of course, is dependent upon how many jet ports are uncovered. In the absence of the apertured screen surfaces, the adjacent high velocity exiting fluid streams will initiate mixing with the zero or low velocity fluid external to the jet ports **10, 10′**, etc. (and **11, 11′**, etc.) in the tee structure **1** and its valve outlet **2″**, creating jet vortex turbulence and self-generating noise sounds. In accordance with the invention, the apertured screen surfaces **4, 4′**, etc. are disposed closely enough to the jet ports **10, 10′**, etc. (and **11, 11′**, etc.) and in what would be the commencement of the mixing region in the vortex potential core to produce gradual and controlled pressure reduction without permitting such violent mixing and achieving sub-sonic velocity, eliminating the resulting vortex-produced noise generation. Exiting or emerging from the jet ports **10, 10′**, etc. (**11, 11′**, etc.), the gas passes through the successive layers of appropriately positioned apertured screens **4, 4′, 4″**, etc., taking a pressure drop at each layer. As the gas loses pressure, it expands; but since the area of each screen (being greater than that of the jet ports) increases with increasing radius, there is maintained an approximately constant, controlled velocity across each screen layer. Consequently, noise generation by the diffusing structure is substantially eliminated or minimal, and the jet-port array valve is muffled.

As an example of the efficacy of the invention, a jet-port array valving structure about one-half inch in diameter as shown in FIG. **1,** was successfully operated with the vastly improved silencing shown in the graph of FIG. **4.** The valve of the invention was found to be 30 to 50 dB quieter than a conventional similar-dimensioned gate valve ("prior-art") over a wide frequency range up to about 11,000 Hz one-third octave center band frequency. For this operation, ΔP was 85 pounds per square inch, with 0.0344 pounds per second; the valve of the invention having an acoustical efficiency of approximately 10^{-6}, as opposed to 10^{-2} for other valves. In addition to its other advantages, the present invention, moreover, enables valve and other constructions of easily fabricated and standard parts and components, and at reduced cost.

There are many alternate configurations which provide viscous, multi-layer pressure drops of this controlled nature. Instead of using fine-mesh screens, for example, a coil of perforated metal sheet may be used, wound in a spiral form as shown in FIG. **2**; preferably with the apertures **20, 20′**, etc., **21, 21′**, etc., somewhat staggered from spiral layer **40** to layer **40′**, etc., as illustrated.

Another alternate configuration is a series of transversely mounted elements fitted over the conduit **2,** FIG. **3**; with alternate layers of fine-aperture screens **30, 30′**, etc. and impervious metal discs **31, 31′**, etc.

While the long array of jet openings is illustrated as constituted of separate successive ports, the elongated long-dimension effective opening may in some cases be formed of a continuum of jet ports constituting a single long slot, again enveloped by the screen or screens. Where successive gradual reduction and sub-sonic emerging effect is not desired, moreover, the resistive screen will still serve to prevent vortex mixing and reduce sound generation.

Further modifications will also occur to those skilled in this art, and all such are considered to fall within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. Apparatus for the precision pressure-reduction of a fluid stream without substantial sound-regeneration during such reduction, said apparatus having, in combination, a longitudinally extending conduit provided

with an inlet and having a plurality of jet ports extending through the thickness of a wall of the conduit and spaced thereâlong, at least several of said jet ports being open concurrently; means for applying to the inlet a fluid stream under pressure so as to enable the successive exiting of successive portions of the stream at successive open jet ports as the stream passes along the conduit; means enveloping the jet ports externally of the conduit for breaking up each portion of the fluid stream from each of the jet ports into a multiplicity of relatively small independent streams and for producing a controlled reduction in pressure by viscous friction, the last-mentioned means comprising apertured surface means immediately adjacent to the jet ports where mixing vortex turbulence would normally be produced by the stream portions exiting therefrom, and a plurality of additional apertured surface means closely surrounding the first-mentioned apertured surface means at successive positions transversely away from said conduit, each of said surface means extending longitudinally of said conduit and having a multiplicity of closely spaced apertures much smaller than the jet ports and thus frictionally resistive to the exiting stream portions, and said plurality of surface means being of progressively greater area transversely away from said conduit for maintaining the exiting stream portions at substantially constant velocity during passage through said apertured surface means and while being reduced in pressure, the outermost surface means having its multiplicity of apertures open to a medium of low velocity relative to the velocity of said stream.

2. Apparatus as claimed in claim **1** and in which valving means is disposed along said conduit to vary the number of jet ports that may be opened for exiting fluid stream portions.

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