United States Patent [19]

Grose

[11] **3,851,726**

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[54] **NOISE SUPPRESSOR**

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[73] Assignee: **Northern Natural Gas Company**, Omaha, Nebr.

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[52] **U.S. Cl.** **181/50**, 55/276, 55/337, 55/462, 181/53, 181/58

[51] **Int. Cl.** **F01m 1/10**

[58] **Field of Search** 181/37, 50, 53, 56, 57, 181/58, 66, 67; 55/276, 321, 326, 337, 416, 462, 464

[56] **References Cited**

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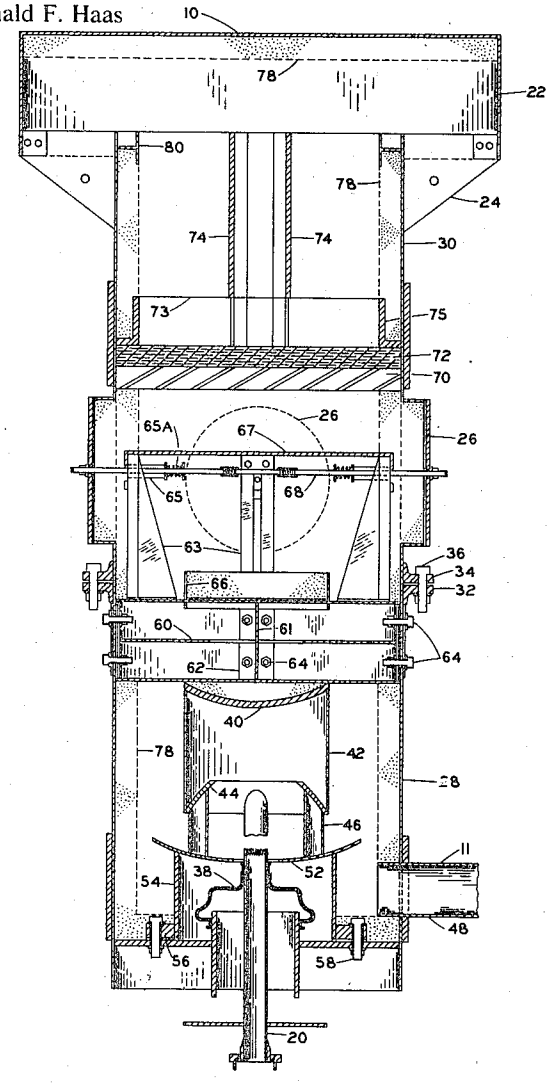
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Primary Examiner—Richard B. Wilkinson
Assistant Examiner—John F. Gonzales
Attorney, Agent, or Firm—Donald F. Haas

[57] **ABSTRACT**

A noise suppressor for use in blowing natural gas storage field wells and capable of handling multiphase fluid flow is formed of a vertically-aligned elongated cylindrical housing with an inlet at its bottom end and an outlet at its top end. The housing is coated along its inside wall with a sound insulating material and has a deflecting baffle therein opposite and spaced from the inlet to prevent water, ice and/or hydrates from moving into the upper part of the housing. Above and spaced from the deflecting baffle is an annular baffle extending radially inwardly from the inside wall of the housing to block acoustic waves therein. Above and spaced from the annular baffle is a second deflecting baffle which also blocks acoustic waves. Again, above and spaced from this second deflecting baffle is a plurality of inclined vanes extending radially inwardly from the inside wall of the housing to assist in acoustic wave blockage. Also to block acoustic waves there is a turbulence-dampening grid formed of truck radiator core material above and in close proximity to the vanes. Finally, longitudinally-aligned hollow tubes formed of a sound insulating material may be attached to the housing above the turbulence-dampening grid.

9 Claims, 4 Drawing Figures



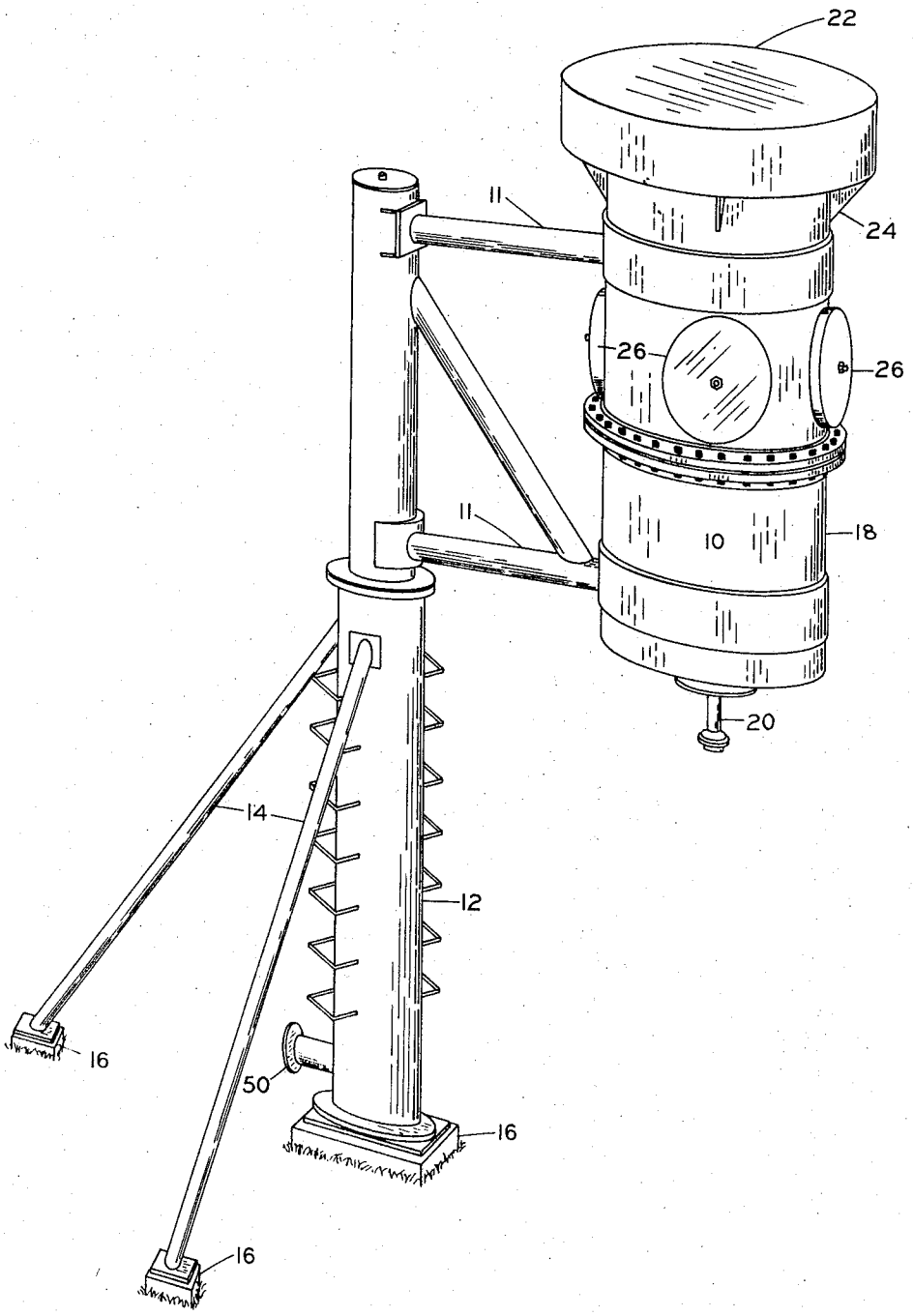


FIG. 1

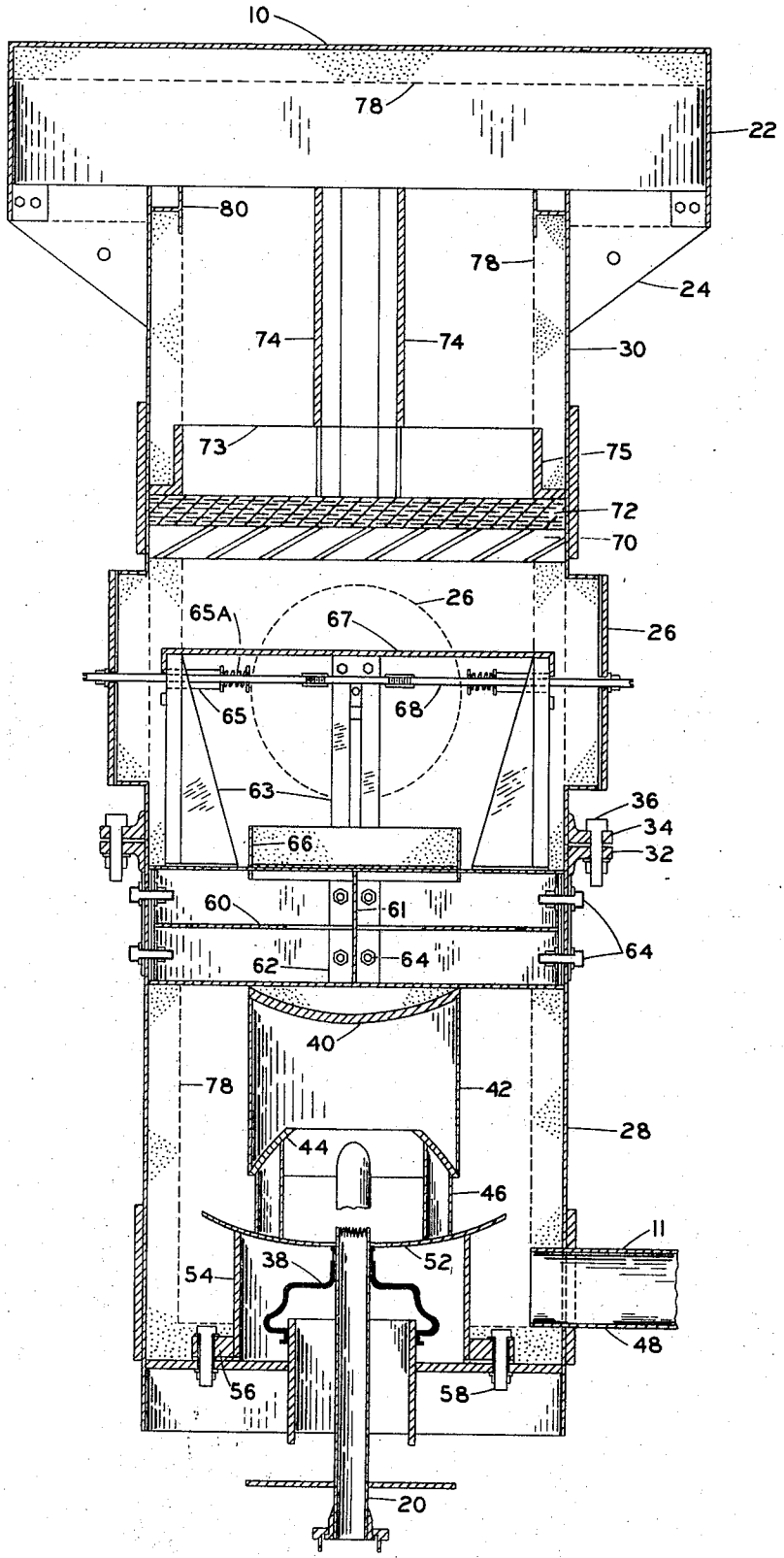

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FIG. 2

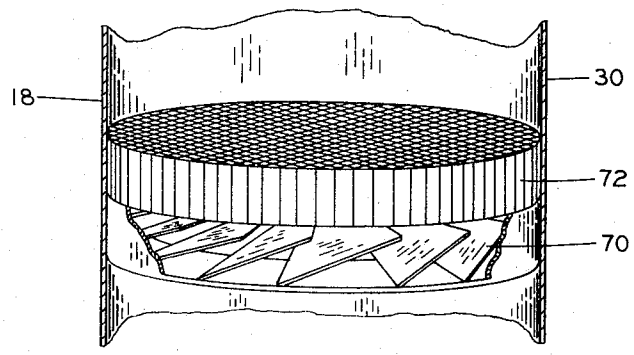


FIG. 3

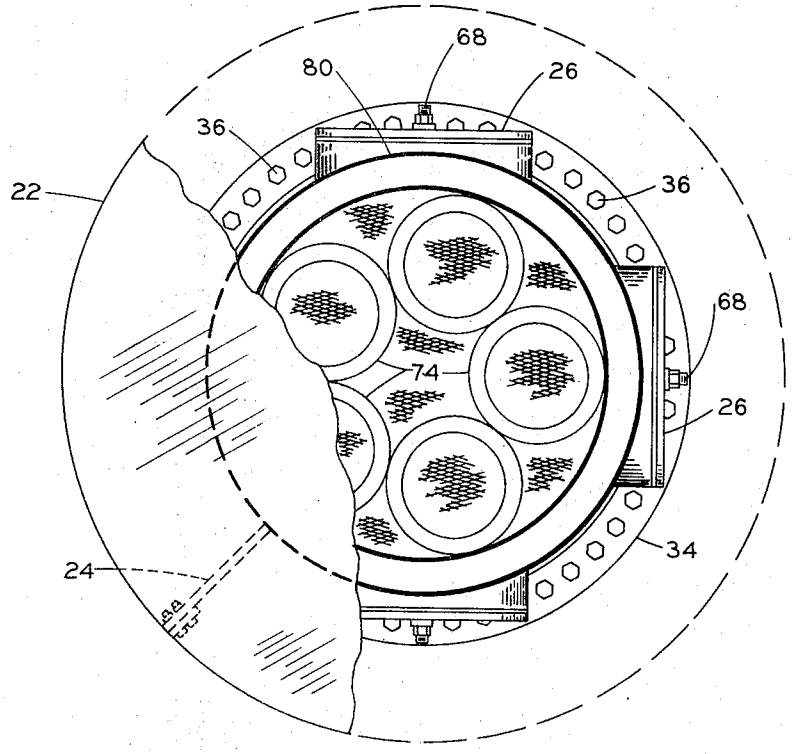


FIG. 4

NOISE SUPPRESSOR

BACKGROUND OF THE INVENTION

This invention generally relates to apparatus for attenuating noise and, more particularly, concerns a device for attenuating noises normally emanating from high velocity fluid flow through an exhaust or escape passage. The present invention is primarily designed to decrease the noise to a decibel range below the hazard level in accordance with the environmental conditions of the particular application.

Investigation into the suppression of noise which is hazardous to health or detrimental to a normal existence for both man and animals began in earnest in recent years with both private industry and governmental agencies contributing to the research. While many noise suppression problems have been solved through the application of ordinary engineering technology, some have defied the efforts of many researchers. Among these unsolved problems is that of the noise produced by rapid movement of fluid jets through the atmosphere. Such jet-induced noise remains a largely unsolved problem despite the expenditures of vast amounts of government and private funds.

The natural gas industry, for example, finds itself confronted with a basically unsolved problem in those situations where large volumes of high-pressure gas must be released into the atmosphere. Such situations arise in proving wells, testing and repairing pipelines, blowing storage field wells, compressor stations startup and shutdown procedures, and in various emergency operations. The present invention is particularly applicable to the solution of the "blowdown noise" problem which arises when storage field wells are blown, although it is equally applicable to air and steam flow. The blowdown noise problem has been intensified by the recent encroachment of residential areas upon gas storage fields. Whereas, in the past, the primary concern was with the physiological damage caused to people working at the storage field, the residential encroachment has made annoyance the principal factor in this area. Therefore, there is a real need for a noise attenuator which can significantly lower the level of blowdown noise.

The suppression of blowdown noise at the natural gas underground storage wellhead presents a constraint which is not found in the usual blowdown situation. Such wells are plagued with excess water and natural gas hydrate formations, thus causing blockage problems which necessitate clearing the well via the blowdown technique. Any suppressor placed on the wellhead must, therefore, be designed to accommodate the passage of large masses of the hydrate and water without excessive back pressure so that the well can be cleared. Also, the presence of water vapor and low temperatures must not cause the suppressor to become blocked because of ice formations within the suppressor. Up to the present time, the suppressor design most frequently proposed to handle the blowdown noise problem at storage field wells is the so-called "straight through" suppressor wherein the gas, water, and hydrate jet is allowed to expand into a sound insulated chamber with a much greater flow volume than the flow volume of the wellhead pipe and then pass into the atmosphere. This design does not provide very good sound attenuation.

Other devices which have been used to attenuate the noise in blowdown situations are disclosed in U.S. Pat. Nos. 2,998,860 and 3,454,129 to W. S. Everett and U.S. Pat. No. 3,702,644 to N. Y. Fowler, Jr., et al. All of these devices postulate sound attenuation, but only one of them (Everett U.S. Pat. NO. 2,998,860) can potentially handle the multiphase situation which occurs at the natural gas underground storage wellhead. However, each of the units disclosed by these patents has the additional problem of being very large. The device of the present invention provides similar or better sound attenuation with a unit which is significantly smaller in size.

Devices which are utilized to muffle the exhaust gases of internal combustion and jet engines also provide attenuation of the noise created thereby. U.S. Pat. Nos. 2,158,030 to E. D. Latulippe, 2,325,905 to E. W. Caulfield, and 3,447,630 to G. L. Davidson all disclose devices which postulate that kind of sound attenuation. The first of those patents discloses a device utilizing inclined vanes to assist in the sound attenuation. The present invention is designed to be applicable to all sound attenuation problems due to turbulent flow and to the above-mentioned blowdown noise problems in particular, whereas the devices of these three patents cannot be utilized in the blowdown noise situation.

SUMMARY OF THE INVENTION

The present invention concerns an apparatus for attenuating noises which result when fluid escapes through an exhaust passage at high velocity. The apparatus of this invention will decrease the sound which can be perceived at some distance from the apparatus. The apparatus of this invention is basically formed of an elongated cylindrical housing which is lined along its inside wall and a sound-insulating material and which has an outlet at one end and an inlet at the other end. It should be noted at this point that while the following description refers to the present invention in terms of cylindrical, annular, and circular, the apparatus of this invention is by no means limited to such shapes even though they are preferred. The inlet of the housing has a diameter substantially smaller than the inside diameter of the housing (as the gas pressure increases, the inlet diameter should be smaller in comparison to the housing inside diameter) and is adaptable to be connected to a fluid exhaust passage. There is an upstream impact baffle located within and attached to the cylindrical housing to deflect the flow of fluid entering the inlet. The upstream baffle is positioned between and spaced from the inlet and the outlet, and has a diameter smaller than the inside diameter of the cylindrical housing but greater than the diameter of the inlet. The primary purposes of the upstream baffle are (1) to separate water from the gas, (2) to disintegrate solids, such as ice, in the fluid flow, and (3) to reduce the velocity of the fluid flow, and thereby its kinetic energy, before the gas leaves the suppressor. Further, there is a plurality of inclined vanes attached to and extending radially inwardly from the inside wall of the cylindrical housing. The inclination of these vanes is such that fluid flow openings are defined between them. The vanes are positioned between and spaced from the upstream baffle and the outlet. Finally, a fluid permeable turbulence-dampening grid is attached to and positioned across the entire inside cross-section of the cylindrical housing between the vanes and the outlet. The grid is located in

close proximity to the vanes, but is spaced from the outlet. The primary purpose of the vanes and grid is to block the acoustic waves created by the reduction in kinetic energy at the upstream baffle and thus decrease the amount of acoustic energy entering the atmosphere.

The apparatus described above may also have an annular baffle attached to the housing and positioned therein between and spaced from the upstream baffle and the vanes. This annular baffle extends radially inwardly from the inside wall of the cylindrical housing and defines a fluid flow passage with a diameter smaller than the diameter of the upstream baffle. The primary purpose of the annular baffle is to help block the acoustic waves within the suppressor.

The above-described apparatus may also have a downstream baffle located within and attached to the cylindrical housing, and positioned between and spaced from the annular baffle and the vanes. Fluid flowing through the fluid flow passage defined by the annular baffle will be deflected by this downstream baffle. The downstream baffle has a diameter smaller than the inside diameter of the cylindrical housing, but greater than the diameter of the fluid flow passage defined by the annular baffle. Its primary purpose is also to help block acoustic waves. Additional downstream baffles may be added to assist blocking.

The above apparatus can have a number of hollow acoustic cylindrical tubes formed of a sound-insulating material attached to the housing downstream of the turbulence-dampening grid. These tubes should be placed in longitudinal alignment with the housing and are utilized to provide more exposed acoustically-lined surface area for additional sound attenuation.

To help accommodate multiphase fluid flow, the apparatus of this invention can utilize a nongaseous material removal system. Such a system may utilize a hollow cylindrical separation drum with the upstream baffle forming the downstream end of the drum. The drum is open at its upstream end and has an annularly-shaped inwardly-extending downstream-facing gutter thereat. Fluid from the inlet flows into the drum through its open end, is deflected back upstream and flows out of the drum through the same open end, and while this is going on the gutter skims the nongaseous material from the fluid and collects it. The gutter has a plurality of drains thereon which convey the nongaseous material from the drum and facilitate its removal from the housing. The drains support the drum and can themselves be supported on and extend through an annular supporting baffle which is attached to the housing and located upstream of the drum. The inlet extends through this annular supporting baffle without contacting it. This annular supporting baffle deflects the fluid downstream around the drum.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of the apparatus of the present invention showing it as it would be used to suppress blowdown noise from a gas storage field wellhead.

FIG. **2** is a longitudinal cross-section taken along line **2—2** of FIG. **1.**

FIG. **3** is a closeup cut-away view of the apparatus illustrated by FIG. **1,** showing the turbulence-dampening grid and the inclined vanes.

FIG. **4** is a plan view of the apparatus illustrated by FIG. **1** with most of the end cap removed.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The noise suppressor **10** illustrated by the accompanying FIGS. **1** to **4** is the preferred embodiment of the present invention and is particularly applicable to the attenuation of blowdown noise. It should be recognized that there are many other configurations which are also within the scope of the invention. The noise suppressor **10,** as illustrated in FIG **1,** is vertically aligned because it has been found that when there is ice in the fluid flow from the underground storage well, curved or L-shaped inlet pipes can rupture. The suppressor **10** is rotatably mounted above ground level by arms **11** on a supporting column **12** so that the suppressor **10** can be easily connected to or disconnected from the wellhead valve (not shown) and swung to the side out of the way. The column **12** is itself stabilized by legs **14** which are affixed to concrete blocks **16** sunk into the ground, as is the column **12.**

The noise suppressor **10** itself is comprised of a substantially hollow cylindrical housing **18** having a fluid inlet pipe **20** at its bottom end and a top end cap **22** at its top end. The top end cap **22** has an inside diameter which is substantially larger than the outside diameter of the cylindrical housing **18** and is removably supported on the housing **18** by struts **24** such that there is a substantial area between the top edge of the housing **18** and the cap **22** for fluid to flow out of the housing **18.** The principal purpose of the cap **22** is to protect the suppressor **10** from rain, snow, sleet, etc., but it also assists in blocking acoustic waves. Additionally, emergency pressure relief blowout doors **26** are located on the outside of the housing **18.**

Turning our attention to FIG. **2,** it can be seen that the cylindrical housing **18** is comprised of a lower section **28** and an upper section **30** to facilitate maintenance. The sections **28** and **30** have outwardly extending upwardly and downwardly facing, respectively, concentric flanges **32** and **34** at their upper and lower edges, respectively. The flanges **32** and **34** are bolted together at several locations **36** around the outside of the housing **18** to provide a pressure-tight fluid impermeable seal between the sections **28** and **30.**

The fluid inlet pipe **20** has a saw-toothed upper end and extends upwardly well into the hollow interior of the housing **18** but has no direct contact with the housing **18.** The inlet pipe **20** is supported therein only by reinforced rubber gasket **38** which is clamped to the inlet pipe **20** and the inside wall of the housing **18.** The purpose of gasket **38** is to prevent the transfer of vibration from the inlet pipe **20** to the rest of the suppressor **10** and thus achieve a significant reduction in the noise level. The gasket **38** may be made of any suitable material which will support the inlet pipe **20** and not transfer its vibrations (conventional wellhead casing seals are used in the preferred embodiment).

Positioned directly above the upper end of the inlet pipe **20** and concentric with the horizontal cross-section of the cylindrical housing **18** is the convex (with respect to the fluid flow direction) upstream baffle **40.** The upstream baffle **40,** which is substantially greater in diameter than inlet pipe **20,** deflects the fluid flow from the inlet pipe **20** downwardly to prevent any water, ice, or hydrates therein from moving into the upper

section **30** of the housing **18** and to disintegrate the solid material in the fluid flow. The baffle **40** also reduces the velocity of the fluid flow and thereby its kinetic energy. The baffle **40** forms the top end of cylindrical separation drum **42** which is open at its bottom end and also has a V-shaped gutter **44** at its bottom end. The gutter **44** operates to skim the water, ice, and hydrates out of the gas flow.

It is theorized that as it is deflected downwardly by the baffle **40,** the fluid swirls inside the drum **42** at high velocity in an annular doughnut pattern. The water, ice, and hydrates are disengaged from the gas by centrifugal forces and direct impact with the inside wall of the drum **42,** and flow down the inside wall into the gutter **44.** Next, the water flows into small drains **46** at the bottom of the gutter **44,** down to the bottom of section **28,** and out of the housing **18** through drain pipe **48** which is within the lower arm **11** (see FIG. **1**). From the arm **11,** the water flows into the supporting column **12** and out of the water outlet **50.** The outlet **50** has an automatic dump valve (not shown) to prevent venting of gas therethrough if there is no water in the column **12.**

The gas flows out of the drum **42** through the opening in the gutter **44** at the bottom of the drum **42** and is deflected upwardly around the outside of the drum **42** by concave (with respect to the gas flow direction) lower baffle **52.** Lower baffle **52** protects the draining water from the chaotic motions of the gas as it makes a 180° flow direction reversal. Note that the inlet pipe **20** extends upwardly through the baffle **52** without contacting it. The drum **42** is supported on the lower baffle **52** by the small drains **46.** The lower baffle **52,** in turn, is supported on the bottom wall of the housing **18** by supporting cylinder **54** which is slotted (not shown) to allow water to flow out drain pipe **48.** The cylinder **54** has a horizontally outwardly extending flange **56** which is bolted at **58** to the housing **18.**

Located above the upstream baffle **40** is the annular baffle **60** which is welded to crossed I-beams **61** having end flanges **62** which themselves are bolted at **64** to the inside wall of the housing **18** to support the annular baffle **60.** Upstream baffle **40** and drum **42** are also welded to I-beams **61** for primary structural support. To provide the maximum sound attenuation, the baffle **60** must be spaced sufficiently from the bottom end of the housing **18** to provide an expansion chamber therebetween with a flow volume very much greater than that of the inlet pipe **20.** The gas flows up around the drum **42** through the opening in the annular baffle **60,** which should be somewhat smaller in diameter than the upstream baffle **40.** Located directly above the opening in the annular baffle **60** to again deflect the flow of the gas, is downstream baffle **66.** The downstream baffle **66** is greater in diameter than the opening in the annular baffle **60** and is supported by the I-beams **61,** to which it is welded. The primary purpose of the downstream baffle **66,** as well as the annular baffle **60,** is to block acoustic waves produced within the suppressor **10,** thereby lowering the noise level perceived at a distance from the suppressor **10.** Additionally, these baffles further reduce the velocity of the gas flow and thereby its kinetic energy.

The emergency pressure relief doors **26** are formed in the side wall of the upper section **30** of the housing **18** just above the baffle **66.** The doors **26** are symmetrically aligned in pairs to prevent asymmetrical forces from knocking the suppressor **10** over. The doors **26** are held in place by pairs of attached rods **68** which are designed to give way and release the doors **26** if the pressure inside the suppressor **10** reaches a dangerous level. Triangular-shaped stops **63,** which are welded to the I-beams **61** and which have apertures through which the rods **68** can move reciprocally, prevent the doors **26** from becoming projectiles. The rods **68** have crumpable sleeves **65** and springs **65A** thereon which contact the stops **63** as the rods **68** move outwardly to absorb the kinetic energy of the doors **26** and halt their outward movement. Structural restraint **67** prevents the stops **63** from bending under the impact load due to the outwardly moving doors **26.**

A plurality of vanes **70** are located just above the blowout doors **26.** The vanes **70** extend radially inwardly from the inside wall of the housing **18** and are inclined to provide fluid or gas flow openings between them. In order to obtain acceptable results, the inclination of the vanes **70** should be greater than 10° from the horizontal (here the inclination is 20°). FIG. **3** illustrates the vanes **70** and the fluid permeable turbulence-dampening grid **72,** which is located just above the vanes **70,** in more detail. The turbulence-dampening grid **72** extends across the entire inside cross-section of the housing **18** and is preferably formed of truck radiator core material. It is supported on the vanes **70.** Any material which has a high aspect ratio, i.e., long fluid flow channels compared to the size of the openings, and which does not itself create turbulence can be utilized in the turbulence-dampening grid **72.** The elements which form the fluid flow channels are preferably very thin in comparison to the size of the openings and no sound insulating material is used within the grid **72.** The grid **72** is restrained from upward movement (as might occur if the grid **72** becomes blocked by ice) by restraining member **73** which is comprised of a number of hollow cylindrical pieces welded together. The restraining member **73** is welded to flanged retaining ring **75** which, in turn, is attached to the housing **18.** The chief beneficial action of the inclined vanes **70** and the turbulence-dampening grid **72** is blockage of the acoustic waves produced within the suppressor **10,** thereby decreasing the sound level perceived at a distance from the suppressor **10.**

In addition to the above noise attenuation elements, the entire inside wall of the cylindrical housing **18** should be coated with a sound insulating material **78** such as, for example, waterproofed open-cell polyurethane foam. The material **78** is held in place by end retaining ring **80.** It has been found that better noise attenuation is obtained as the ratio of exposed acoustically-lined surface area to cross-sectional area within the housing is increased. If the fluid flow rate is at a very high level, it becomes economically advantageous to increase the exposed acoustically-lined surface area without unduly increasing the height of the suppressor **10.** As illustrated in FIG. **4,** this is accomplished by placing hollow acoustic tubes **74** in the upper section **30** of the housing **18** above the hollow cylinders of the restraining member **73.** The tubes **74** are removably attached to the member **73** and are preferably made of waterproofed open-cell polyurethane foam held in place by formed wire mesh.

For example, at a gas flow rate of **90** pounds per second, a decrease of 30–35 decibels at a distance of 50 feet from the suppressor **10** can be obtained without

using the tubes **74.** At a gas flow rate of 140 pounds per second, the same attenuation can be obtained by using the tubes **74** without increasing the length of the suppressor **10.**

I claim:

1. An apparatus for attenuating noises which result when fluid escapes through an exhaust passage at high velocity, said apparatus comprising:

a. an elongated cylindrical housing lined along its inside wall with a sound-insulating material and having an outlet at one end and an inlet at the other end, said inlet having a diameter substantially smaller than the inside diameter of said cylindrical housing and adaptable to be connected to a fluid exhaust passage;

b. an upstream impact baffle located within and attached to said cylindrical housing, and positioned between and spaced from said inlet and said outlet to deflect the flow of fluid entering said inlet, said baffle having a diameter smaller than the inside diameter of said cylindrical housing and greater than the diameter of said inlet;

c. a plurality of inclined vanes attached to and extending radially inwardly from said inside wall of said cylindrical housing such that fluid flow openings are defined between said vanes, said vanes positioned between and spaced from said upstream baffle and said outlet; and

d. a fluid-permeable turbulence-dampening grid attached to and positioned across the entire inside cross-section of said cylindrical housing between said vanes and said outlet, said turbulence-dampening grid being located in close proximity to said vanes and spaced from said outlet.

2. An apparatus as defined in claim **1** and further characterized in that an annular baffle is attached to said housing and positioned therein between and spaced from said upstream baffle and said vanes, said annular baffle extending radially inwardly from said inside wall of said cylindrical housing and defining a fluid flow passage with a diameter smaller than the diameter of said upstream baffle.

3. An apparatus as defined in claim **2** and further characterized in that a downstream baffle is located within and attached to said cylindrical housing, and is positioned between and spaced from said annular baffle and said vanes such that fluid flowing through said fluid flow passage defined by said annular baffle is deflected by said downstream baffle, said downstream baffle having a diameter smaller than the diameter of said cylindrical housing and greater than the diameter of said fluid flow passage defined by said annular baffle.

4. An apparatus as defined in claim **3** and further characterized in that at least one hollow acoustic cylindrical tube formed of said sound-insulating material is removably attached to said housing in longitudinal alignment therewith to provide additional exposed acoustically-lined surface area, said tube positioned downstream of said grid.

5. An apparatus as defined in claim **4** and further characterized in that a nongaseous material removal system is included within said housing, said system comprising:

a. a hollow cylindrical separation drum of which said upstream baffle forms the downstream end and which is open at its upstream end to allow fluid from said inlet to flow into and out of said drum;

b. an annularly-shaped inwardly-extending downstream-facing gutter at the upstream end of said drum for skimming said nongaseous material from the fluid flowing therein and for collecting said nongaseous material; and

c. a plurality of drains attached to said housing and extending from said gutter to support said drum within said housing and to convey said nongaseous material from said drum to facilitate removal of said nongaseous material from said housing.

6. An apparatus as defined in claim **5** and further characterized in that said drains are attached to and extend through an annular supporting baffle which is attached to said housing and is positioned therein upstream of said drum, said supporting baffle defining an opening through which said inlet extends without actually contacting said supporting baffle.

7. An apparatus as defined in claim **5** and characterized further in that said inlet is supported in said housing by a reinforced rubber gasket which prevents the vibrations of said inlet from being transferred to said housing, said gasket being the only point of contact between said inlet and said housing.

8. An apparatus as defined in claim **7** and characterized further in that at least one pair of symmetrically aligned blowout doors are formed in the side wall of said housing to provide emergency pressure relief, said pair of doors are held in place by pairs of attached rods which are designed to release said doors at a desired pressure, at least two stop means are attached to said housing, said rods positioned for reciprocal movement through apertures in said stop means, and said rods have springs and crumpable sleeves mounted thereon to contact said stop means, absorb the kinetic energy of said doors, and halt the outward movement of said doors.

9. An apparatus as defined in claim **8** and characterized further in that said housing has an end cap mounted thereon at the outlet thereof, to allow fluid flow between said end cap and said housing, said end cap having an inside diameter substantially larger than the outside diameter of said housing.

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