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DIFFUSER SCREEN WITH HEAT-INSULATING RUNGS FOR EXHAUST
NOISE SUPPRESSOR FOR REACTION ENGINES

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3 Sheets-Sheet 1

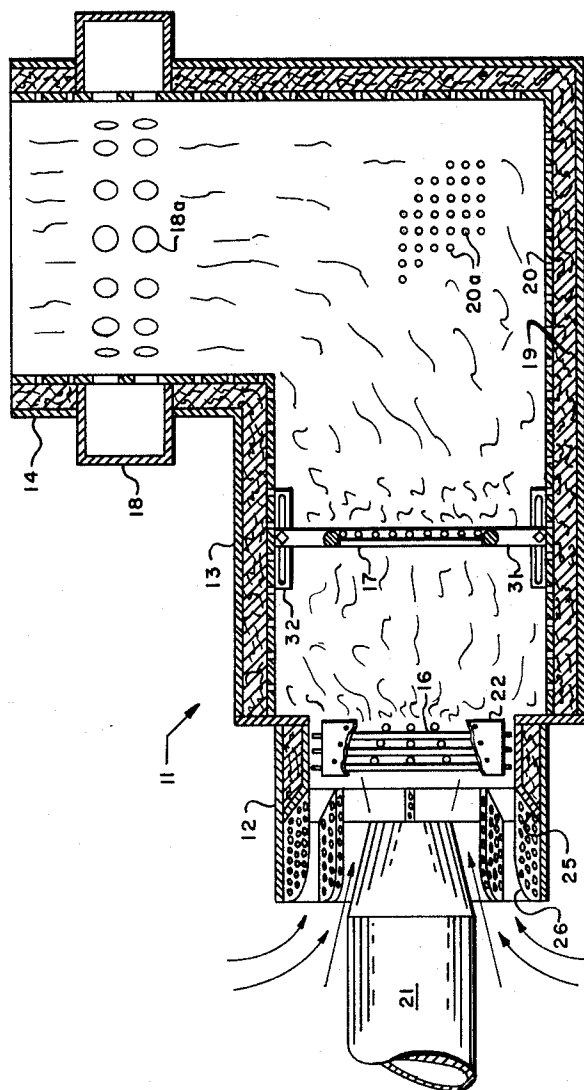


FIG. 1

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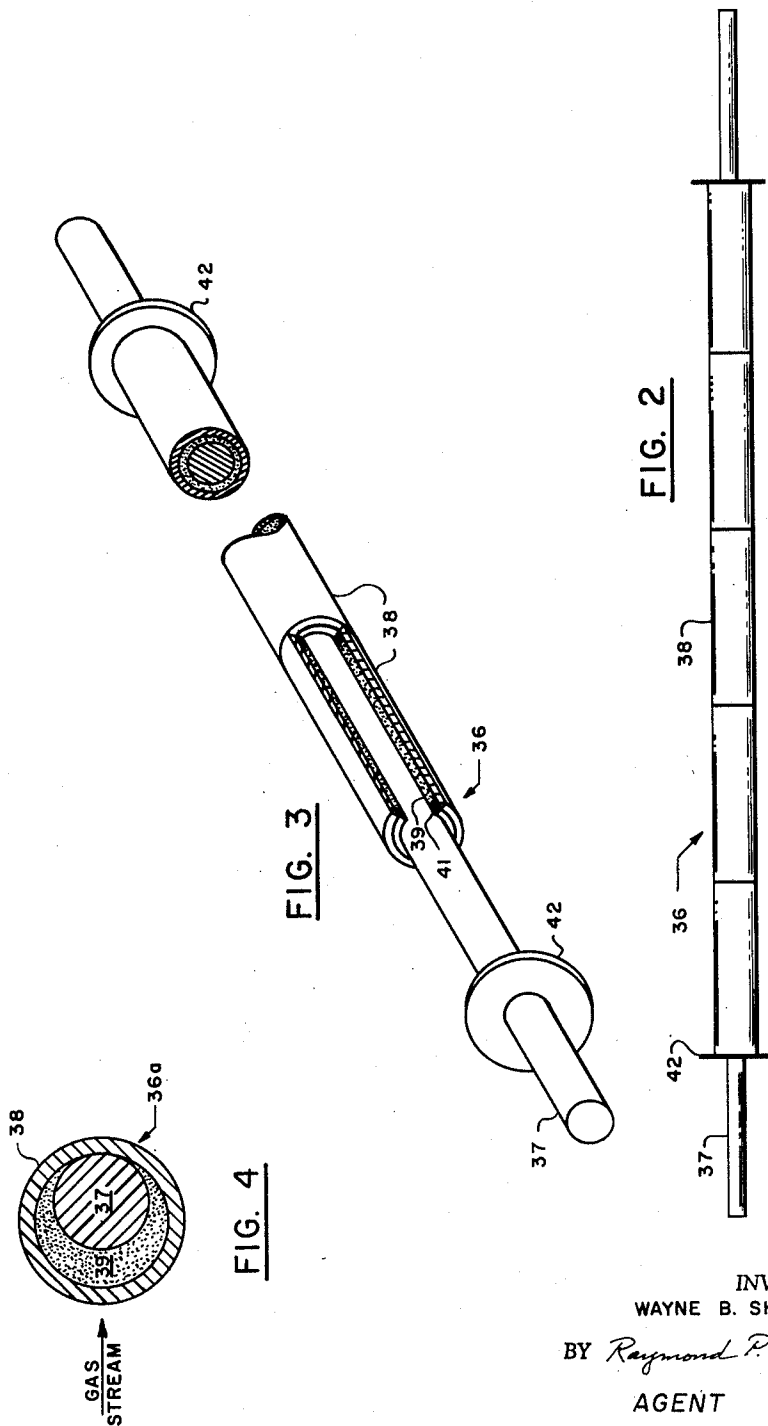
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DIFFUSER SCREEN WITH HEAT-INSULATING RUNGS FOR EXHAUST NOISE SUPPRESSOR FOR REACTION ENGINES

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7 Claims. (Cl. 181-33)

This invention relates to a three-dimensional labyrinthine cribwork diffusing screen, and more particularly to an improvement on such a screen as described in the copending application of Maron L. Morris and John A. Sobel III, Exhaust Noise Suppressor for Reaction Engines, Serial No. 65,389, filed October 27, 1960, now Patent No. 3,120,877, patented February 11, 1964, and assigned to the same assignee.

As disclosed in the forementioned application, such an exhaust noise suppressor comprises in part a large chamber in which the exhaust from a reaction engine can expand, after first passing through a diffusing screen comprising a labyrinthine cribwork of rungs disposed transversely to the axis of discharge of the exhaust stream, the cribwork having considerable extension in the axial direction, whereby staged diffusion is provided in a plurality of planes at various distances from the engine nozzle, as the exhaust stream strikes the rungs of the cribwork and is broken up thereby.

Such a diffusing screen, when formed of corrosion-resistant carbon steel rungs, will satisfactorily withstand the exhaust temperature of the usual jet engine, of the order of 1150° F. With a rocket engine, however, the temperature of the exhaust gases is much higher, and a jet engine with an afterburner in operation discharges gas at a temperature of the order of 3150° F. To use the previous diffusing screen at such high temperatures it is necessary that it be formed of tubular rungs with a coolant flowing therethrough, to prevent it from being destroyed by the heat.

However, the use of a coolant, usually water, necessitates many connections, a circulating system, and a source of supply, and in addition limits the movability of the sound suppressor. There are many occasions for the use of a noise suppressor where such cumbersomeness is undesirable, or where a supply of coolant is not readily available.

It is therefore a principal object of this invention to provide a diffusing screen for an exhaust noise suppressor which may be used at elevated temperatures without cooling.

It is a further object to provide an uncooled diffusing screen suitable for use with afterburner operation.

Still another object is the provision of a diffusing screen of high mechanical strength at elevated temperatures.

Yet another object is to provide a diffusing screen not subject to corrosion from afterburner exhaust.

A further object is to provide a diffusing screen resistant to thermal shock.

The foregoing objects and advantages and others ancillary thereto will be better understood on reading the following specification in connection with the accompanying drawings, in which

FIGURE 1 is a longitudinal cross-sectional elevation of an exhaust noise suppressor;

FIGURE 2 is a view of one of the diffusing rungs of the present invention;

FIGURE 3 is a perspective view, partially broken away, of one of the diffusing rungs;

FIGURE 4 is a transverse cross-section of another embodiment of the rung; and

FIGURE 5 is a perspective view of the three-dimensional labyrinthine cribwork diffusing screen.

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Referring more particularly to FIGURE 1, there is shown a cross-section of an exhaust noise suppressor, the construction and operation of which will be briefly described. The suppressor comprises generally a cylindrical entrance portion 12, a larger cylindrical expansion chamber 13 downstream therefrom and communicating coaxially therewith, and a stack 14 angularly disposed to the expansion chamber and communicating therewith. An annular resonant chamber 18 surrounds the upper portion of the stack and communicates with the interior thereof through suitable apertures 18a. The expansion chamber and the stack are both double-walled and have acoustical packing material 19 disposed between the walls; the inner walls 20 are preferably of stainless steel and are provided with apertures, indicated at 20a, to allow acoustical access to the packing. The outer walls may be of mild steel or other suitable material.

A three-dimensional, labyrinthine cribwork diffusing screen 16 (later to be described in detail) is positioned within the inner diameter of the entrance section 12, in such a manner that the rearmost extension of the screen is at the plane of entrance into expansion chamber 13. The screen is of such dimensions in the transverse direction that it substantially spans the inner diameter of portion 12, and it may be mounted on the inner wall thereof by any convenient structural elements, in the present case a generally rectangular frame 22. A grid 17 of simple crisscross pattern and circular outline is adjustably positioned within the expansion section, disposed on the horizontal axis thereof and transverse to said axis. The grid may be supported and maintained in the selected position by a spider 31 as shown, or by other suitable structural elements.

The grid is nominally positioned approximately halfway between the diffuser screen and the stack entrance, but is provided with means for translating it along the axis of the expansion chamber so that its operating position may be either upstream or downstream from its nominal position, according to the flow conditions encountered. Suitable translating means may be the slotted brackets 32 to which the ends of the spider are bolted, or any other desired means of well known kind.

The operation of the exhaust noise suppressor is as follows. The suppressor is placed in apposition to a reaction engine 21 with the exhaust nozzle intromitted within the entrance portion, substantially coaxial therewith. When the engine is operated the exhaust is discharged into the suppressor entrance section 12 passing through the cribwork diffusing screen in a plurality of labyrinthine paths, whereby its velocity is greatly diminished, and it is diverted from the axial direction and expands with considerable turbulence into the expansion chamber. At the same time, the high velocity of the exhaust leaving the nozzle, in combination with the internal diameter of the entrance section and the restricted converging throat defined by the nozzle and the frustoconical internal wall 25 disposed inside the entrance section, causes external air to be aspirated into the suppressor.

Such aspirated air serves a double purpose. It cools the exhaust somewhat and assists in diffusing it and in creating turbulence and expansion downstream from the screen; also, owing to the high exit speed of the exhaust from the nozzle, the aspirated air will pass through the converging throat at a speed of Mach 1 or higher. Self-noise generated by the impingement of the exhaust stream on the diffusing screen cannot be radiated upstream against an inflow of air at Mach 1 or above. In the event that perfect adjustment between the engine and the suppressor has not been achieved and the aspirated air may not quite reach Mach 1, sound baffles 26 are provided in the upstream portion of the entrance section, attached to the inner wall thereof and extending radially

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inward, and so disposed that any self-noise which may be radiated upstream will be absorbed by the baffles.

After the initial expansion of the exhaust in the expansion chamber just downstream from the diffusing screen, there is some tendency for the central portion of it to re-form into a jet stream, although at lower velocity. This central portion now passes through the resistance grid 17, which is of considerably smaller diameter than the expansion chamber, in order not to impede the flow of peripheral, expanded, and diffused exhaust. The central stream of exhaust gas undergoes a second immediate diffusion and expansion, with further diminution of velocity, as a result of passing through the grid. The fully diffused exhaust now passes through the remainder of the expansion chamber and the stack, with further expansion and reduction of velocity, and with absorption of noise in the range of 300-600 c.p.s. by the resonant chamber. Upon exit from the stack the overall sound pressure level has been reduced, with present jet engines, by as much as 22 to 30 decibels, and in certain octave bands, particularly the third and fourth, the reduction may be as much as 40 decibels.

When such a noise suppressor is employed with the usual jet engine without afterburning, a diffusing screen having solid rungs of corrosion-resistant steel is satisfactory, and with afterburning, tubular rungs having an internal coolant flowing therethrough, both such screens having been described and claimed in the aforementioned copending application Serial No. 65,389. However, it is sometimes desired to use a noise suppressor without cooling in conjunction with a rocket engine or an afterburning engine, where the temperature of exhaust gases may be over 3000° F., and for this use the three-dimensional labyrinthine cribwork diffusing screen must be able to withstand the high temperature. Such a screen will now be described.

FIGURES 2 and 3 show one of the rungs of the diffusing screen of this invention. There is provided a rod 37 which serves as the structural element of the rung and supports the other elements against the thrust of the exhaust stream. The material of which such a rod is formed must be resistant to corrosion, oxidation, and thermal shock, and must retain its strength at elevated temperatures. Various metals such as corrosion-resistant steels and other alloys having these properties are known and are suitable for such use. A particularly satisfactory material is the alloy sold under the name Inconel "700," a registered trademark of the International Nickel Company, having the following composition:

	Percent
Carbon -----	0.10
Manganese -----	0.05
Silicon -----	0.2
Chromium -----	15.0
Titanium -----	2.0
Aluminum -----	3.0
Cobalt -----	28.0
Molybdenum -----	3.0
Iron -----	0.5
Nickel -----	Balance

Inconel "700" has a melting point around 2500° F., and a rupture life at 1800° F. of five hours under stress of 10,000 p.s.i. or ninety hours under stress of 6000 p.s.i. Although the exhaust temperature may be higher than the melting point of the metal, the rung is so formed that the metal is insulated from a large part of the heat, and the material directly exposed to the hot gases is well able to withstand the temperatures reached in afterburning operation.

Rod 37 is surrounded by a plurality of cylindrical sleeves 38 threaded end-to-end on the rod and formed of a material of high melting point and high resistance to thermal shock. Various ceramics and cermets possess the desired characteristics; a material which has been

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found particularly suitable for the sleeves is silicon carbide, especially when sintered with a silicon nitride binder, having a melting point above 4892° F., and being very little affected by thermal shock.

The sleeves are of such internal diameter as to leave an appreciable annular space between the sleeves and the rod when they are positioned coaxially thereon. This annular space is filled with an insulating material 39 of high melting point and a low coefficient of heat transfer. Although various ceramic and cermet materials are suitable for this purpose, powdered zirconium oxide has been found particularly satisfactory, with a melting point of about 4892° F. The insulating material is retained within the annular space by a small annulus of cement 41 at each end of each sleeve. Powdered zirconium oxide with a binder of sodium silicate makes a suitable cement.

If the entire cribwork diffusing screen is to be assembled at once, no further structure for the individual rungs is required. However, it is often desirable to manufacture a quantity of rungs which may be handled as units, and even though the sleeves are cemented at each end they may not be very firmly attached to the central rod. For this reason, a metal flange 42 may be welded, brazed, or otherwise securely fastened around the rod at each end of the assemblage of sleeves, leaving a length of rod protruding therefrom at each end for positioning the rungs in the cribwork.

FIGURE 4 is a transverse cross-section of another embodiment 36a of one of the rungs. In this embodiment the elements of the rung are the same as previously described, comprising a rod 37, a plurality of sleeves 38, insulating material 39, and cement 41, but these elements are differently assembled. Instead of the sleeves being positioned coaxial with the rod, they are positioned with the sleeves being coaxial with each other, but with the rod disposed off center and in contact with the inner wall of the sleeves, tangent thereto, leaving a space of lune-shaped cross-section between the rod and the sleeves. This space of lune-shaped section is filled with insulating material and stopped with cement at each end of each sleeve as before. Rungs 36a may also be provided with end flanges 42. The advantage of this construction is that rungs 36a may be assembled in the cribwork screen in such a manner that the exhaust blast impinges on them on the side furthest from the metal and having the largest amount of insulating material upstream from the rod.

FIGURE 5 shows a three-dimensional labyrinthine cribwork diffusing screen 16, completely assembled and ready for installation in an exhaust noise suppressor. There is provided a generally rectangular frame 22 having sides of flat metal plates welded or otherwise joined, and preferably having beveled corners 43 for attachment to the inner diameter of the entrance portion of the suppressor, the diagonal dimensions of the frame being such as to provide a suitable fit therein.

The sides of the frame are bored for positioning a plurality of ranks of rungs 36 or 36a, the free ends of the rods 37 projecting outwardly through the bored apertures. The rods or the flanges may be welded or brazed to the frame at the points of contact, if desired. In the embodiment shown there are six such ranks. The first rank 46a comprises a plurality of parallel rungs spanning the frame with the rod ends positioned by the apertures, the rungs being equally spaced apart with the center rung on the vertical centerline, in the same plane, and with the outermost rungs just inside the bevels at the corners.

The second rank 46b comprises a plurality of similar rungs, parallel to each other and similarly spaced, but crossing those of the first rank at substantially 90° in a plane behind or downstream from that of the first rank, the center rung being on the horizontal centerline. A third rank 46c is provided having rungs parallel to those of the first rank, but in a plane downstream from the second rank; the center rung is again on the vertical centerline, but the flanking rungs are positioned somewhat

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closer together than those of the first rank. A fourth rank 46d of similar rungs is provided in a plane behind the third rank, substantially normal thereto but having the same spacing as the third rank. A fifth rank 46e is provided in a plane behind the fourth, parallel to the third rank and having the center rung on centerline, but spaced more closely together, so that the flanking rungs are positioned more inwardly than those of the third rank. The sixth and last rank 46f occupies a plane behind the fifth rank, the rungs being normal to those of the fifth but similarly spaced.

The foregoing construction provides a three-dimensional lattice or cribwork, with none of the rungs except the center ones occluding any parallel rung in the axial direction, and so arranged that the exhaust stream in passing therethrough is broken up and takes a plurality of labyrinthine paths, with a plurality of minor shocks arising in different planes of depth, at a plurality of transverse locations.

It is to be understood that this particular design of six ranks of rungs has been adopted for convenience, and that the diffusing screen may be made with more or less ranks of rungs, with more or less rungs in each rank, and with rungs of the form of either 36 or 36a. Spacing may also be different, and the rungs may be arranged so that none of them occlude each other. It is immaterial which rungs may be vertical in the operating position of the screen, or whether any are. The rungs may, if desired, be made of varying lengths as shown, so that they more or less completely span that portion of the entrance section in which they are positioned.

The reason for using a plurality of ceramic sleeves rather than a single one is that under the enormous pressure of an exhaust stream some flexibility of the rungs is desirable, which would not be provided by a single sleeve. However, if it is desired to use the screen with a reaction engine of relatively low thrust, rungs having single continuous sleeves may be employed. The exterior surface of the sleeves may also be given an oxidation-resistant coating of flame-sprayed refractory material, such as aluminum oxide, zirconium oxide, molybdenum disilicide, or molybdenum diboride.

Although the improved three-dimensional labyrinthine cribwork diffusing screen has been described above in a preferred embodiment, it will be understood that various changes and modifications may be made by those skilled in the art without departing from the scope of the invention. It is intended to cover all such modifications by the appended claims.

What is claimed is:

1. A rung for an exhaust diffusing screen, comprising in combination a straight metal rod, a plurality of cylindrical ceramic sleeves having a fusing temperature above 3200° F. disposed in end-to-end relationship and surrounding said rod and defining with said rod a space between said rod and said sleeves, and a powdered ceramic heat-insulating material having a fusing temperature above 3200° F. disposed in said space.

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2. The combination recited in claim 1, wherein the inner diameter of said sleeves is tangent to the surface of said rod at one side, said sleeves and said rod defining opposite to the tangency a space of lune-shaped cross-section, said powdered ceramic heat-insulating material being disposed in said space.

3. The combination recited in claim 1, wherein said sleeves are formed of silicon carbide and said insulating material is zirconium oxide.

4. The combination recited in claim 2, wherein said sleeves are formed of silicon carbide and said insulating material is zirconium oxide.

5. A three-dimensional labyrinthine cribwork diffusing screen for an exhaust noise suppressor, comprising in combination a plurality of ranks of rungs; each of said ranks comprising a plurality of parallel rungs spaced apart from each other in a plane; said ranks being stacked in laminar fashion; each of said rungs comprising a straight metal rod, a plurality of cylindrical ceramic sleeves having a fusing temperature above 3200° F. disposed in end-to-end relationship and surrounding said rod and defining with said rod a space between said rod and said sleeves, and a powdered ceramic heat-insulating material having a fusing temperature above 3200° F. disposed in said space.

6. The combination recited in claim 5, wherein said sleeves are formed of silicon carbide and said insulating material is zirconium oxide.

7. A three-dimensional labyrinthine cribwork diffusing screen for an exhaust noise suppressor, comprising in combination a plurality of ranks of rungs; each of said ranks comprising a plurality of parallel rungs spaced apart from each other in a plane; said ranks being stacked in laminar fashion; each of said rungs comprising a straight cylindrical rod of high-temperature alloy, a plurality of cylindrical silicon carbide sleeves having a fusing temperature above 3200° F. disposed in end-to-end relationship and surrounding said rod with the inner diameter of said sleeves tangent to the surface of said rod at one side, said sleeves and said rod defining opposite to the tangency a space of lune-shaped cross-section, and powdered zirconium oxide having a fusing temperature above 3200° F. disposed in said space.

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