Oct. 17, 1967 A. F. CHILDRESS 3,347,338

SOUND SUPPRESSOR WITH BAFFLE GRIDS ARRANGED ACROSS FLUID STREAM PASSAGEWAY

Filed June 28, 1965 6 Sheets-Sheet 1

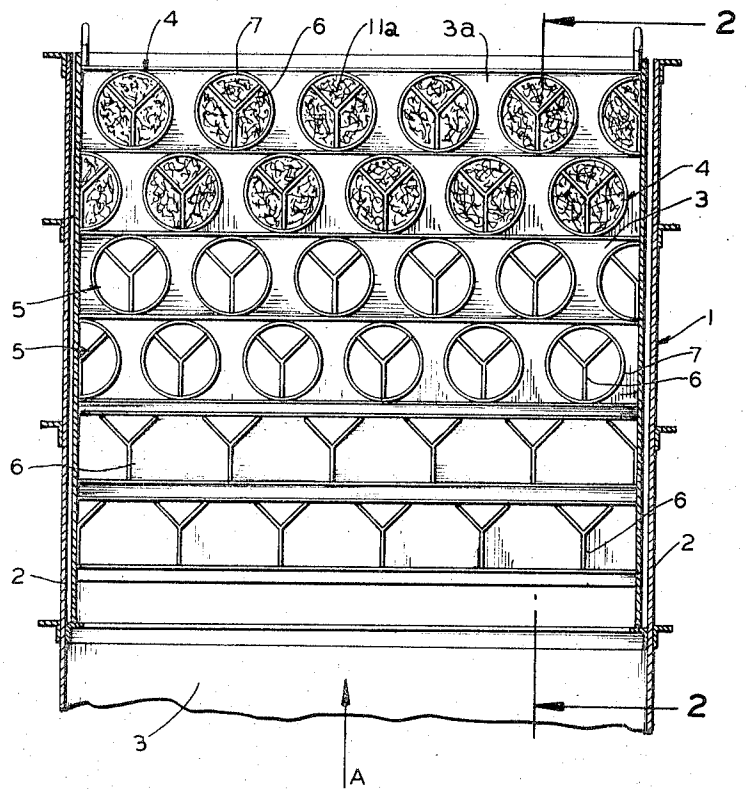


FIG. 1

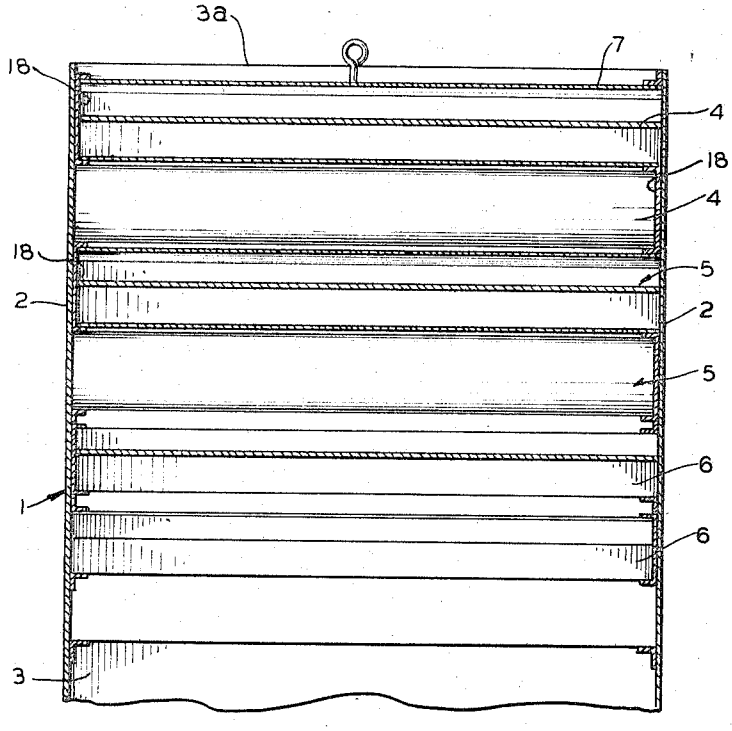


FIG. 2

Oct. 17, 1967 A. F. CHILDRESS 3,347,338

SOUND SUPPRESSOR WITH BAFFLE GRIDS ARRANGED ACROSS FLUID STREAM PASSAGEWAY

Filed June 28, 1965 6 Sheets-Sheet 2

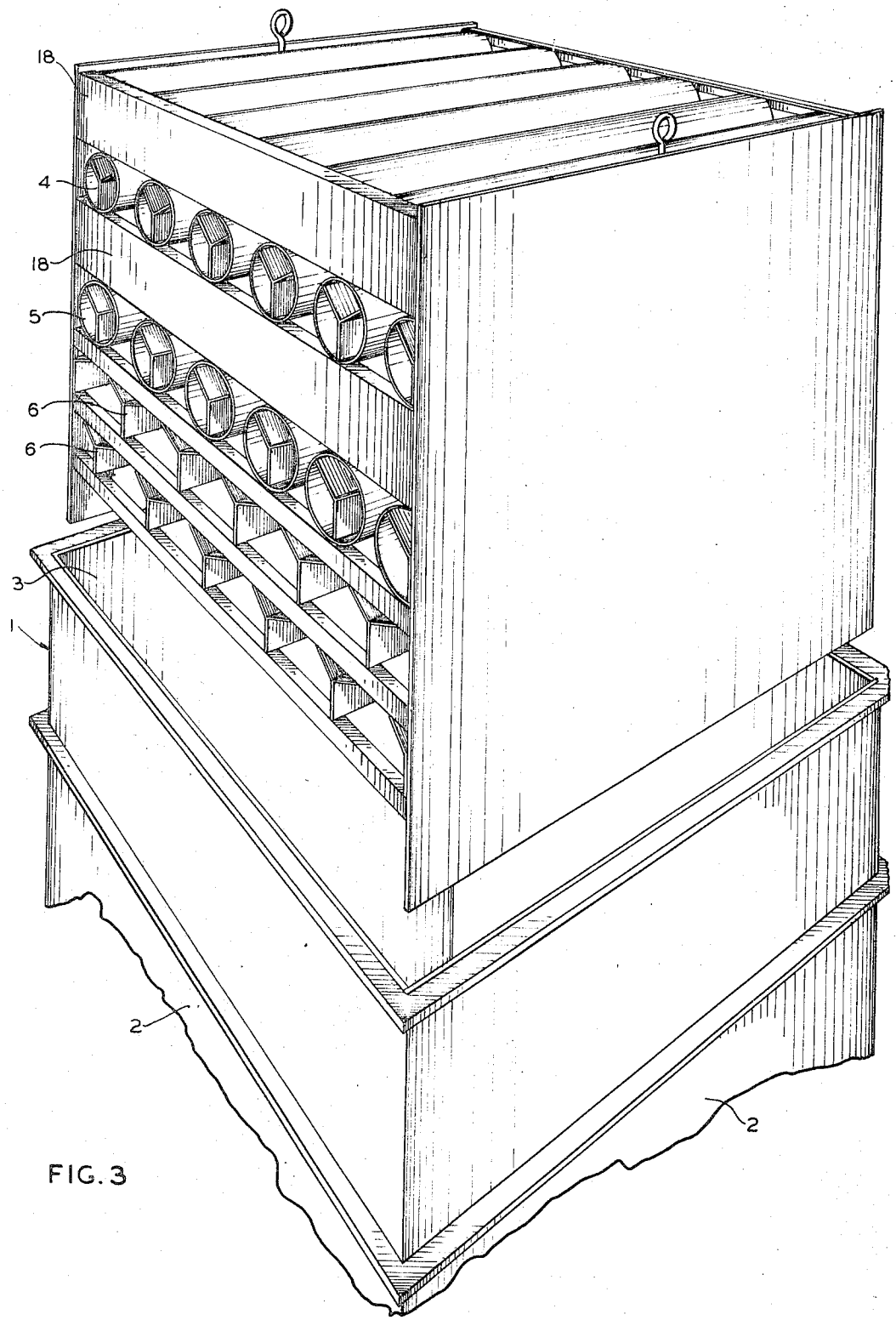


FIG. 3

Oct. 17, 1967 A. F. CHILDRESS 3,347,338
SOUND SUPPRESSOR WITH BAFFLE GRIDS ARRANGED ACROSS FLUID STREAM PASSAGEWAY
Filed June 28, 1965 6 Sheets-Sheet 3

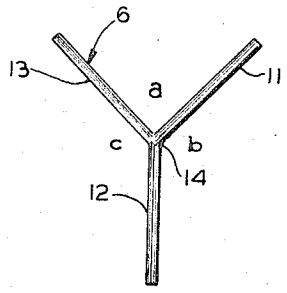


FIG. 5

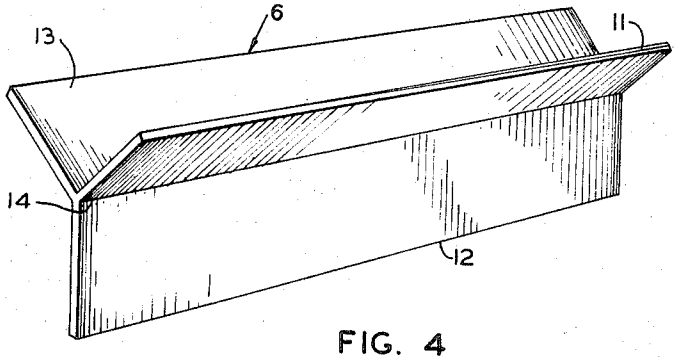


FIG. 4

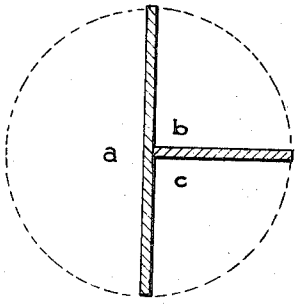


FIG. 8

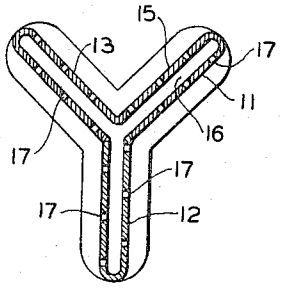


FIG. 7

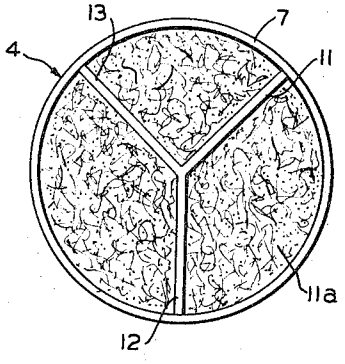


FIG. 6

Oct. 17, 1967 A. F. CHILDRESS 3,347,338
SOUND SUPPRESSOR WITH BAFFLE GRIDS ARRANGED ACROSS FLUID STREAM PASSAGEWAY
Filed June 28, 1965 6 Sheets-Sheet 4

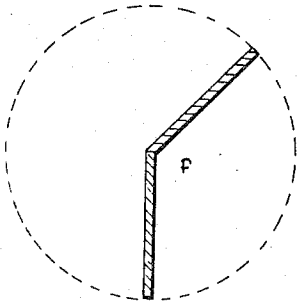


FIG. 9

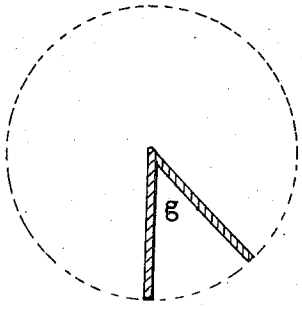


FIG. 10

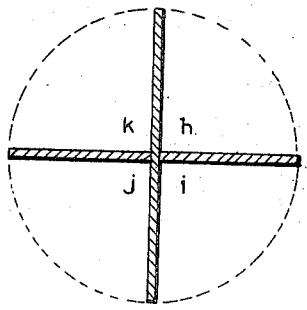


FIG. 11

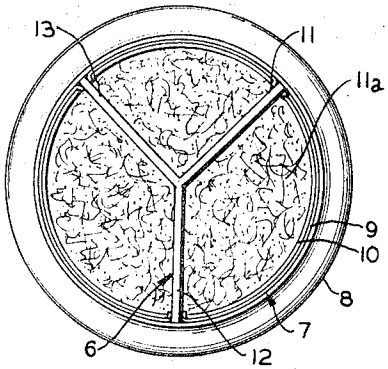


FIG. 15

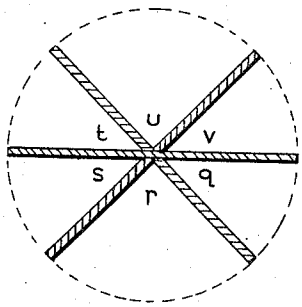


FIG. 13

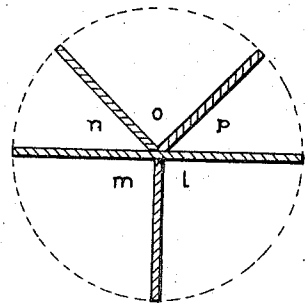
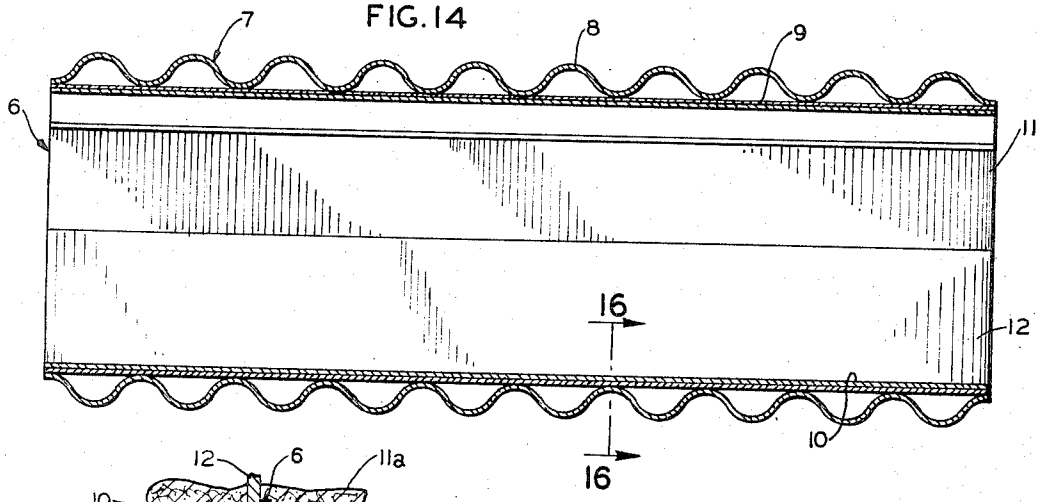


FIG. 12

FIG. 14



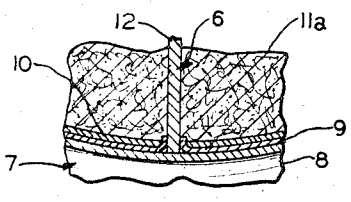


FIG. 16

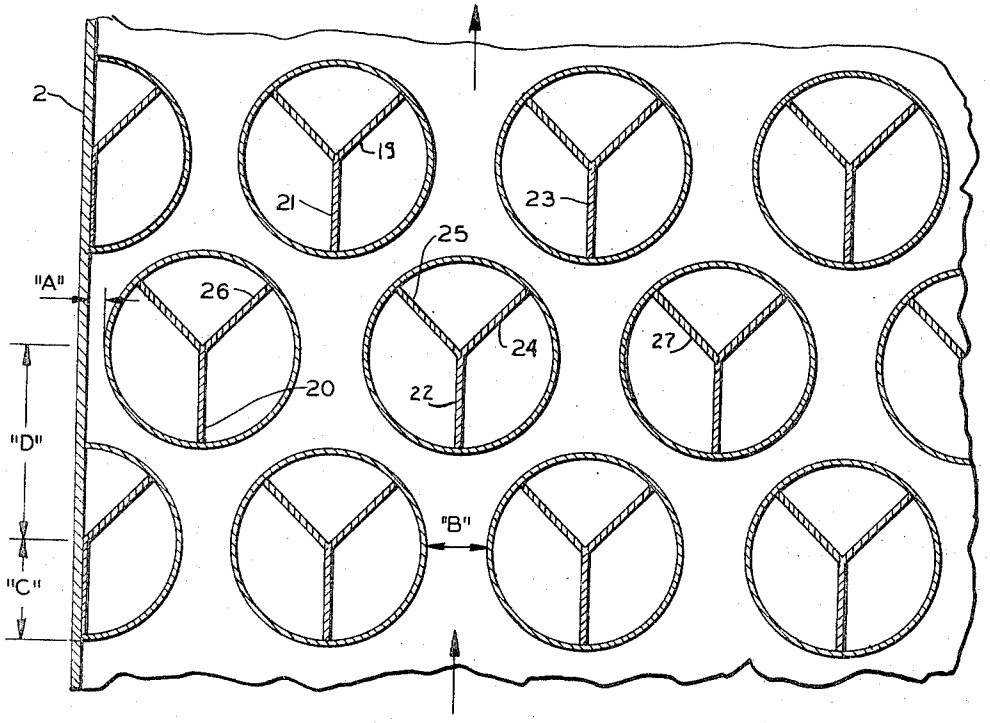


FIG. 17

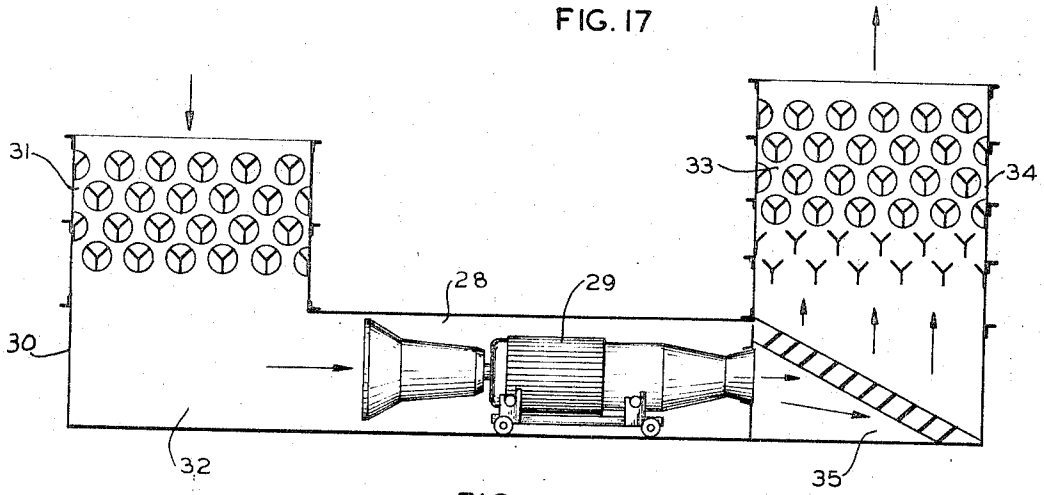


FIG. 18

Oct. 17, 1967 A. F. CHILDRESS 3,347,338
SOUND SUPPRESSOR WITH BAFFLE GRIDS ARRANGED
ACROSS FLUID STREAM PASSAGEWAY
Filed June 28, 1965 6 Sheets-Sheet 6

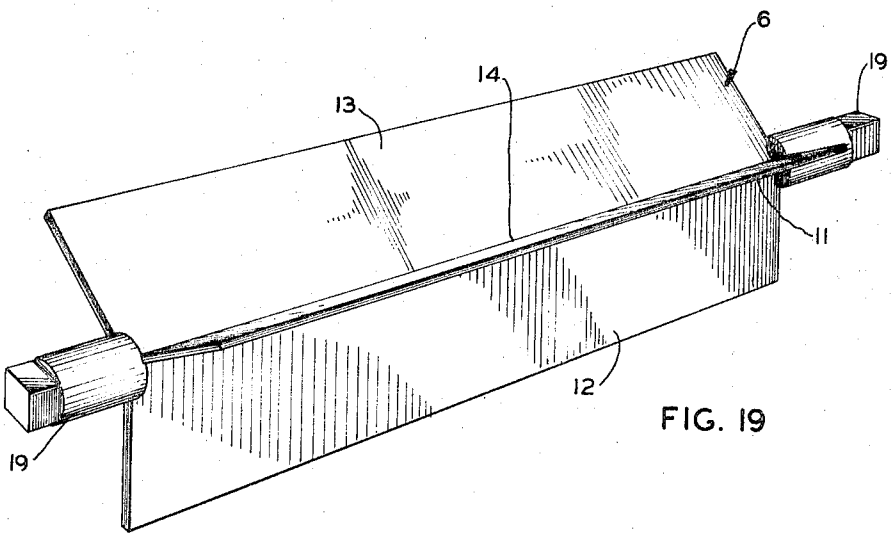


FIG. 19

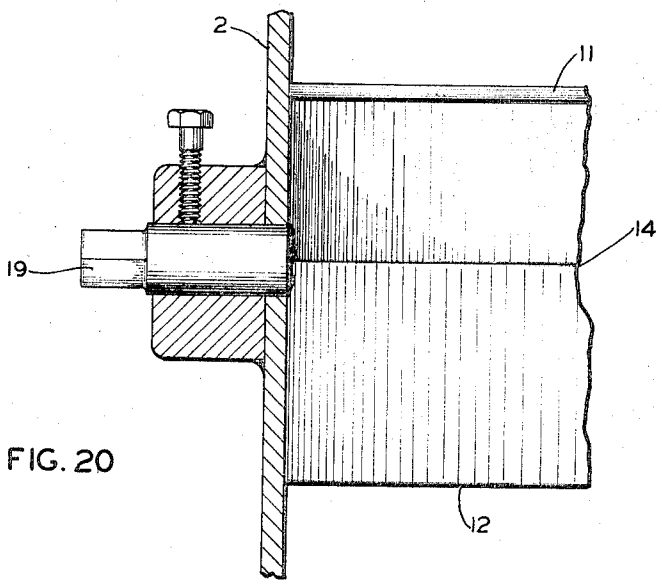


FIG. 20

United States Patent Office

3,347,338

Patented Oct. 17, 1967

3,347,338

SOUND SUPPRESSOR WITH BAFFLE GRIDS ARRANGED ACROSS FLUID STREAM PASSAGEWAY

Albert F. Childress, 101 W. 5th Ave., Scottsdale, Ariz. 85251

Filed June 28, 1965, Ser. No. 467,292
18 Claims. (Cl. 181—56)

ABSTRACT OF THE DISCLOSURE

The present invention, in part, relates to a sound suppressor element for use in a sound deadening system wherein sound carried by a high velocity fluid stream is substantially attenuated. Such element comprises a longitudinally extending sheath having a cross-section in the shape, for example, of a circle, triangle, rectangle, hexagon, octagon and the like, and having at least one perforation therein and containing a baffle grid. This baffle grid comprises a plurality of webs which are angularly disposed with respect to each other along a common longitudinal point and extend substantially the full length of the aforesaid sheath. These webs in turn divide the interior of the sheath into separate and substantially non-interconnecting compartments which preferably contain a mass of sound-absorbent material.

The second part of the present invention relates to an apparatus for suppressing sound carried by a high velocity fluid stream comprising a passageway through which said stream is moving and a detachably removable, sound deadening means positioned within such passageway. The sound deadening means comprises a plurality of longitudinally extending baffle grids arranged in a series of tiers. The first series of tiers which are contacted first by the fluid stream comprise only the baffle grids. The second series of or middle tiers comprise such baffle grids, each of which is enclosed within a sheath, heretofore mentioned, having at least one perforation therein and is attached thereto. The third series of or last contacted tiers comprise the baffle grid-containing sheath described in the second series but also containing a mass of sound-absorbent material within said sheath. These baffle grids are so positioned within the aforesaid passageway as to be perpendicular to the flow of such stream thereto.

This invention relates to sound suppressing structures and to novel components for use in such structures. The sound suppressing structures and components thereof which embody the invention hereinafter described are generally suitable for the suppression of sound carried by gaseous media and particularly are suitable for the suppression of sound carried in high velocity gas streams. This invention is more particularly related to reducing the decibel level of jet engine driven aircraft exhaust gases.

The sound suppressing structures embodying the present invention are generally suitable for suppressing the escape of objectionable sound into an ambient gaseous medium such as the atmosphere. High velocity gas streams are frequent sources of objectionable sound in the atmosphere due to generation and/or transmission of objectionable sound by such high velocity gas streams.

Several examples of such high velocity gas streams are air flowing with high mass velocity in duct work for ventilating systems which are used in heating or cooling of buildings; gases flowing in pipe line transmission systems; and, the exhaust gas streams from all types of piston, rocket turbine, jet, and turbo-jet engines. Highly objectionable sound carried in such gas streams can be created by: (1) the mechanical means, utilizing pistons or rotating impellers to propel gases, such as fans, compressors, blowers and turbines; (2) the shearing action of the moving gases upon themselves due to the fact that there is not a uniform velocity of movement of the mass of gas across an entire cross-section of the confining conduit and also due to a high velocity gas stream moving into or through an ambient gas mass or relatively lower velocity gas stream as represented by a gas stream expanding into a plenum; exhaust of a jet ejection pump; the atmospheric discharge of a pressure relief valve for high pressure equipment such as steam boilers, storage tanks for highly compressed gases or liquefied hydrocarbons; the exhaust of piston, turbine, jet and turbo-jet engines into the atmosphere; and, the air induction systems for piston engines, turbine engines, jet engines, air compressors, and ventilating systems; and (3) combustion noises as represented by the exhausts of piston, turbine, rocket, jet or turbo-jet engines.

The word "noise" as used hereinafter has been technically defined as "unwanted sound" or "objectionable sound" and depending upon the sound pressure level and frequency of a sound wave, the "noise" may be unwanted because of a result ranging from being merely disturbing to a human ear, to being physically detrimental to a human being.

The term "sound suppression" as used hereinafter generally connotates reducing sound pressure levels or sound levels of noise or unwanted sound from an objectionable level to an acceptable level. Various other terms are used in this art, such as "sound attenuation," "sound absorption," "sound muffling," "sound deadening," "noise silencing," etc. All of these terms have reference to the reduction of the sound pressure or sound level of a sound wave, and, therefore, synonymous terms for "sound suppression" which has been selected for use in this specification.

The prior art has generally recognized the problem of noises created by gaseous media in motion as exemplified by the publications referred to below.

U.S. Patent 2,720,276 issued to Carl C. Droeger describes a sound suppressing structure which is particularly adapted for use in connection with a jet engine mounted in an aircraft engine test stand. The patentee discloses a sound suppressing means which comprises a plurality of sound-suppressor elements identified in said patent by reference numerals **20** and **25** parallelly stacked alongside and over each other and disposed in the path of the induced gas stream. The elements are cylindrical and elongate and constitute an outer foraminous shield within which is housed a filling of sound absorbent material. In this case, a hollow central core may run the full length of each cylinder in order to allow relatively free passage of the gases or air therethrough, and these cylindrical elements are shown to be positioned with their respective longitudinal axes extending parallel to the direction of the induced gas stream so that the gas must flow longitudinally through the interior of the elements and also longitudinally through the space which exists between adjacent stacked elements.

Alternatively, in the prior art as represented by U.S. Patent 2,959,254, issued to Cloyd D. Smith, the cylinders (identified by the reference numeral **40** and described as sound or space resonators) may be positioned with their respective longitudinal axes extending transversely to the air stream whereby the air flows around the solid outer cylindrical shells of said cylinders and, therefore, sound suppression is effected by essentially that of energy transmission loss through the solid cylindrical shells.

The prior art quickly becomes outdated and ineffective with the advent of newer and more powerful gas turbines and/or jet engines, each having progressively higher air stream velocity. Furthermore, more effective sound suppression constitutes a continually recurring requirement

imposed by the continual development of new and high velocity heating, cooling and/or ventilating systems.

The inherent disadvantages of the prior art are overcome by the utilization of the novel apparatus of the present invention. Specifically, the use of said apparatus has substantially reduced the "noise" whereby in some instances the level of "noise" is less than that experienced in an average office.

Accordingly, it is the principal object of this invention to provide an improved structure for the suppression of sound carried by gaseous media.

A further object of this invention is to provide structures for the suppression of objectionable sounds carried by or generated by high velocity gas streams and in particular, structures for suppressing the escape of objectionable sound into the atmosphere where the objectionable sound is generated or carried by high velocity gas streams.

A further object of this invention is to provide structures which are particularly adapted or suitable for the suppression of noise attendant to the operating of jet engines under ground test conditions whether mounted on a test stand or while mounted in an air frame, such attendant noise resulting from the air induction and exhaust systems as well as the engine operation.

A further object is to provide novel components particularly adapted for use in structures for the suppression of sound carried by gaseous media, which components are more effective in sound suppression than analogous known components.

Another object is to provide the aforesaid element through a simple and inexpensive construction thereof.

Another object is to provide an aforesaid component which is easily interchangeable with already known analogous components, thereby obviating the necessity to reconstruct completely an already existing sound suppressing structure in order to take advantage of the novel components of this invention.

These and other objects will become apparent from a reading of the following detailed description of the present invention, wherein reference is made to the appended drawings, more or less diagrammatic, in which:

FIGURE 1 is a transverse sectional view of an improved sound suppressing structure embodying features of the present invention.

FIGURE 2 is a plan view of the structure illustrated in FIGURE 1.

FIGURE 3 is a perspective view showing some of the internal features of the structure illustrated in FIGURE 1, the external sidewalls of FIGURE 1 being removed.

FIGURE 4 is a perspective longitudinal view of a basic triplanar sound suppressing component of the present invention and of the type used as a part of the arrangements shown in FIGURES 1, 2 and 3.

FIGURE 5 is an end view of the same basic triplanar component of FIGURE 4.

FIGURE 6 is an end view of the same sound suppressing component shown in FIGURE 4, but incorporated in a hollow cylinder and having sound suppressing material around the elements of the triplanar device.

FIGURE 7 is a transverse sectional view of a triplanar sound suppressing component similar to the component of FIGURE 4 but with the additional feature of having a hollow core for the passage of heat transfer fluid.

FIGURE 8 is a transverse sectional view of another triplanar sound suppressing component of this invention.

FIGURE 9 is a transverse sectional view of a biplanar sound suppressing component of the present invention.

FIGURE 10 is a transverse sectional view of another biplanar sound suppressing component of the present invention.

FIGURE 11 is a transverse sectional view of a four plane multiplanar sound suppressing component of this invention.

FIGURE 12 is a transverse sectional view of a five plane multiplanar sound suppressing component of this invention.

FIGURE 13 is a transverse sectional view of a six plane multiplanar sound suppressing component of this invention.

FIGURE 14 is a longitudinal sectional view of a corrugated cylindrical component containing a triplanar element and having sound suppressing material around the triplanar element.

FIGURE 15 is an end view of the same sound suppressing component shown in FIGURE 14.

FIGURE 16 is a cross-sectional view taken along lines **16—16** of the same sound suppressing component shown in FIGURE 14.

FIGURE 17 is a transverse sectional schematic drawing of a portion of a sound suppressing structure utilizing triplanar sound suppressing components.

FIGURE 18 is a longitudinal sectional view of a jet engine test stand embodying the sound suppressing structure of FIGURES 1, 2 and 3 in a practical combination with the intake and exhaust sections of a jet engine test stand.

FIGURE 19 is a perspective longitudinal view of a basic triplanar component with a nipple located on each of the opposite ends thereof.

FIGURE 20 shows a partial cross-section of the triplanar of FIGURE 19 wherein the nipple is positioned within a pillow block which is attached to the outside wall.

The appended drawings and the subsequent description of the specific and preferred embodiments of the present invention are intended to be illustrative and not limitative, and changes may be made in the specific constructional details herein illustrated and described without departing from the scope and spirit of the appended claims.

Referring more particularly to the drawings, FIGURES 1, 2 and 3 show various views of a sound suppressing structure **1**, which structure is hereinafter referred to as a "stack" The stack shown in FIGURES 1 and 2 is constructed iwth an enclosing sidewall **2** having a perimeter shown as being generally rectangular and defining an enclosed space, duct or passageway **3** in which is disposed a spaced arrangement of a plurality of sound suppressing components **4**, **5** and **6**.

In the arrangements shown in FIGURES 1 and 3, the sound suppressing components **6** in the lowest two tiers generally conform to the component shown in greater detail in FIGURES 4 and 5. The sound suppressing components **4** in the top tiers conform generally to the components as shown in greater detail in FIGURES 6 and 14 The sound suppressing components **5** in the middle two tiers consist of the triplanar component **6** in combination with and encased by the cylindrical sheath **7** as described in greater detail in connection with FIGURES 6, 14 and 15.

FIGURES 5, 7, 8, 9, 10, 11, 12 and 13 show cross-sectional views of various multiplanar components representing embodiments of the present invention. FIGURES 5, 7 and 8 show triplanar components. FIGURES 9 and 10 illustrate biplanar components and FIGURES 11, 12 and 13 show multiplanar components having 4, 5 and 6 planes, respectively. It is to be noted that each of the aforementioned components disclose a "non-parallel baffle grid," i.e. the planes of the webs of said components are not parallel to each other nor are the planes of the nearest webs of two adjacent components parallel to each other.

FIGURES 4 and 5 illustrate a basic triplanar sound suppressing component **6** of the present invention. Extensive research has indicated that the triplanar configuration is a preferred embodiment; however, the present invention is not limited to this specific embodiment. Variations from this triplanar configuration will be herein-

after described; however, the main description herein is directed to the triplanar configuration which will be referred to specifically and in greater detail than the variations therefrom.

The triplanar component **6** consists of three planes **11**, **12** and **13**, as shown in FIGURE 5, which have a common line of intersection **14** along the longitudinal axis of the element as shown in FIGURE 4. The dihedral angles between the planes are indicated in FIGURE 5 by the designations *a*, *b* and *c*. A sound suppressing component which has been found to be generally effective over a wide range of sound frequencies and which is a preferred embodiment has dihedral angles wherein *a*, *b* and *c* are respectively 90°, 135° and 135°. For the basic triplanar component, the dihedral angle *a* will be generally effective within the range of about 30° to about 180°; dihedral angles *b* and *c* will then be correspondingly effective within the range of about 45° to about 165°. FIGURE 8 illustrates an effective triplanar component wherein the dihedral angles *a*, *b* and *c* are respectively 180°, 45° and 45°.

FIGURE 9 illustrates a biplanar sound suppressing component wherein the dihedral angle *f* is about 135° but can be varied within the range of from 90° to 180° with a preferred range of from about 120° to about 170°.

FIGURE 10 illustrates a biplanar sound suppressing component wherein the dihedral angle *g* is about 45° but can be varied from about 15° to 90°.

FIGURE 11 illustrates a multiplanar component having four planes; the dihedral angle *h* will generally equal angle *j*; and dihedral angle *i* will generally equal angle *k*. In FIGURE 11, dihedral angles *h*, *i*, *j* and *k* are all 90° and equal, however these dihedral angles can be varied generally within the range of about 15° to 165°.

FIGURE 12 illustrates a multiplanar sound suppressing component having five planes and in a typical example the dihedral angles *l*, *m*, *n*, *o* and *p* are respectively 90°, 90°, 45°, 90° and 45°.

FIGURE 13 illustrates a multiplanar sound suppressing component having 6 planes and wherein the dihedral angles *r–q* can vary within the range of from about 15° to about 60°.

Each plane or web of a planar component in the present invention can be constructed from a shingle sheet of homogeneous material or can be built-up of successive layers of the same or different materials. In a multiplanar component, each plane can be constructed alike and of the same material or can be of different construction of varying materials.

The surface of each plane can be smooth, or rough; flat, corrugated, "waffled" or with other surface configurations and with or without fins or projections, for example, to induce or eliminate surface eddy currents in the gas streams passing over the surfaces of the planar components.

Furthermore, each plane can be hard-surfaced, essentially gas impervious and sound reflecting as when constructed of metals, for example, structural steel, galvanized iron, stainless steel, aluminum, copper, glass- or on-steel, ceramic-on-steel, polyester-glass fiber; epoxy, phenolic, melamine resins, etc.

The various planes can have a continuous impervious surface, perforated, or foraminous. Also a plane can be built up of successive layers of the same or different materials, including hard-surfaced, gas-impervious layers; foraminous, porous or perforated layers; air, gas or other fluid layers; and foamed, cellular or honeycomb layers.

The individual web or plane of a planar element can be constructed from a single sheet of homogeneous material or can be built-up of successive layers of the same or different materials including gas impervious layers, foraminous porous perforated layers, air-layers, and foamed, cellular or honeycomb layers.

The material of construction of each sound suppressing component will be dictated primarily by structural soundness, operating temperatures, mass and linear velocities, and presence or absence of corrosive qualities in the gas stream being inducted into the sound suppressing structure.

The individual planes or webs of a sound suppressor component can be joined at the common line of intersection in a fixed manner, such as by welding, or various other mechanical arrangements and/or means can be utilized whereby the dihedral of the angles between the planes can be adjusted to the desired angle even after installation in the stack. While it was found that for convenience of construction and installation it is desirable to have a multiplanar component assembled as a unit for installation, it is also within the scope of the present invention to have a stack constructed whereby each plane is individually installed in the designated relationship to each other, although the planes are not physically connected with each other.

FIGURES 8 and 17 show the details of a sound suppressor component wherein the basic planar component is surrounded by a sheath or hollow cylindrical member. As a preferred embodiment, the basic planar element is shown as being a triplanar component as previously described and the sheath is shown as being cylindrical. The cylindrical sheath can be in the form of a rigid metal tube whereby the surface of said tube can be smooth or, as shown in the detail of FIGURES 14 and 15, corrugated in the longitudinal direction. Generally, a corrugated surface aids in sound attenuation. While the cross-section of the sheath is shown as being a circle, the cross-section of the sheath can have a curvilinear perimeter other than a circle, such as elliptical or ovoid. Furthermore, the cross-section of the sheath instead of being curvilinear can be polygonal, such as triangular, rectangular, hexagonal, octagonal, and it is not necessary that the polygonal figure be equilateral; the departure from symmetry frequently contributes to the more effective attenuation of sound. The cross-section of the sheath can be a combination of curvilinear and straight sections and, while such a configuration might more nearly approach an optimum from the standpoint of use in a sound suppressing system, generally the circular cross-section will be preferred because of the economy of construction and satisfactory sound suppressing qualities.

The sheath surrounding the planar element can be solid or perforated. While the perforations can be uniformly distributed over the surface of the sheath, it is also within the scope of the present invention to have the perforations in a random pattern with a portion of the sheath being essentially solid and unperforated, and another portion of the sheath being perforated. Depending upon the relative size of the sheath, the perforations can range from within the order of ⅛ inch in diameter up to an inch or two in diameter. However, it is generally desired that not more than 30% to 45% of the total surface of the sheath be removed or covered by the perforations. FIGURES 6 and 14–16 show further details of a sound suppressor component embodying a basic planar component encased in a sheath, with the additional features of the segmental spaces, defined by the dihedral planes and the outer sheath, being filled with a material having low sound transmission loss characteristics or high sound absorption coefficient. The materials appropriate for the filling include, but are not necessarily limited to, expanded slag, pumice aggregate, volcanic ash, rock wool, steel wool, glass wool, mineral wool, expanded vermiculite, resinous foams, etc. Fiberglass is a very effective filling, such as that having a density of 4¼ pounds per cubic foot and commercially designated as TWF. The details of FIGURES 6 and 14–16 show the triplanar component **6** encased in the cylindrical sheath **7** having corrugations **8**. Inside the corrugated tube is a close-fitting concentric tube **9** of 20 mesh screen and inside of this there is a third concentric close-fitting tube **10** of fiberglass cloth. The purpose of the screen and fiberglass tubes **9** and **10**, re-

spectively, is merely to contain the filling material **11** previously referred to; various size mesh screens and different fiberglass cloths can be utilized contingent upon the properties of the said filling material.

FIGURE 7 is a cross-section of a triplanar sound suppressing component wherein each plane **11**, **12** and **13** is built-up or of a laminated construction. The exterior surface **15** is continuous and when each plane is considered separately, the exterior surface is in effect two exterior laminae enclosing an inner air layer **16** between them. This air layer can also function as a defined space or hollow core through which a heat transfer fluid can pass; several typical heat transfer fluids are air, water, steam, chlorinated biphenyl, biphenyl, diphenyl ether, liquid silicones, silicate esters, etc. On the other hand, the space **16** can be filled with a cellular material such as expanded polystyrene, flexible or rigid foamed-in-place polyurethanes, etc., and in such cases the filled space **16** becomes a cellular lamina. While FIGURE 7 shows a triplanar component, this same laminated construction, including the hollow core, is applicable to any of the multiplanar configurations as exemplified by FIGURES 4 to 13 inclusive.

In the construction of sound suppressing structures for use in connection with the exhaust gas streams of turbine or jet engines, it is very desirable that the first tiers of sound suppressing components be constructed so as to have such hollow cores through which a heat transfer fluid can pass, as exemplified by FIGURE 7, water being frequently selected as the heat transfer fluid for purposes of cooling the sound suppressing components in order to extend the service life of the component.

It is known that an addition of water to the exhaust gas stream of a jet engine or gas turbine aids materially in sound suppression and, therefore, even more effective sound suppression can be obtained by perforating the planes of the planar component, as shown for example in FIGURE 7, so that water passing through the hollow core **16** for cooling purposes can also pass through the perforations **17** like small water jets into the gas stream.

Referring now more specifically to the overall unit incorporating the aforementioned multiplanar component and in the particular construction shown in FIGURES 1, 2 and 3, transversely extending I-beams **18** span the distance between the right and left sidewalls **2** of duct **3**. There are at least two such parallel I-beams for each tier of elements.

Each sound suppressor component **4**, **5** and **6** is positioned transversely across the two beams in the same plnae. It will be noted in FIGURES 1 and 3 that the components **4**, **5** and **6** are arranged in horizontally parallel tiers and in vertically staggered rows with spacing between tiers and rows. This spacing is for the purpose of permitting the gas stream A (indicated by the arrows in FIGURE 1) to flow freely in the duct **3** supplying the gas stream to the sound suppressing stack **1** and thence permitting the gas stream A to flow freely from the stack **1** to the exit duct **3***a*.

While in FIGURES 1, 2 and 3 the elements are shown as being supported by I-beams, which is a very economical method of construction, FIGURES 19 and 20 show that the longitudinal axis of the triplanar element terminating on either end with a nipple, journal or boss **19** which is adapted to mate with a pillow block (as shown) mounted on the side walls of the stack. Such a construction has many advantages; first, the mounting of the element with the journal and pillow block arrangement permits a rotation of the element about its axis and thus would facilitate rotational adjustment if this is desired to achieve maximum sound suppression after the elements are in place within the stack. Furthermore, where the pillow blocks are mounted onto the side walls of the stack in such a manner as to allow horizontal adjustment of the pillow blocks, this can permit adjustment of the spacing between the elements after they are installed in the stack if it becomes necessary to do so to achieve maximum sound suppression or because of a change in the tolerable allowable back pressure in the preceding duct or change in the tolerable pressure drop across the stack. It is also within the scope of the present invention to cause the rotation of the multiplanar components either manually or by a completely automated system, such as for example, wherein the multiplanar components rotate in response to the sound level being emitted into the surrounding atmosphere, said sound level being continuously monitored and, under predetermined conditions, consequently energizing an electric motor or motors and causing the rotation of said components via a series of linkages, etc. In order to avoid the unnecessary enlargement of the present invention it is considered within the scope of the present invention to incorporate herein the present day servo-mechanism, feed-back, and similar automatic systems to operate the above-described multiplanar components.

The sound suppressing structures of the present invention require the use of planar elements so disposed that any two planes in closest proximity to each other do not have a parallel relationship, consequently the aforementioned term "non-parallel waffle grid." This can be readily understood by reference to FIGURE 17 which is a schematic drawing of a part of a transverse section through a sound suppressing stack embodying the novel triplanar sound suppressing elements. Each triplanar element **6** is enclosed in a cylindrical sheath **7**. The absence of I-beams supporting the elements is due to the fact that these elements would have the trunnion type of installation provided by journals on each end of the elements' longitudinal axes mating with pillow blocks on the sidewalls of the stack as shown in FIGURES 19 and 20. The trunnion installation permits much closer "nesting" of the elements and consequently more effective sound attenuation.

In FIGURE 17, each plane **21** and **26** is in closer proximity to plane **25** than any other plane shown in two or more triplanar components and it will be noted that planes **21**, **25** and **26**, which are the planes in closest proximity, are not in parallel relationship. Furthermore, it will be noted that plane **20** is in parallel relationship to plane **21** but plane **25** or **26** is in closer proximity to plane **21** than plane **20** and, therefore, plane **20** is not in parallel relationship to plane **25** or **26** which are in closest proximity to plane **21**. Likewise, while plane **26** is in parallel relationship to plane **24** and plane **21** is parallel to plane **23**, plane **26** is not in parallel relationship with plane **21** or **25** which is in closer proximity to plane **26** than is plane **24** and likewise plane **23** is not in parallel relationship with either plane **24** or **27**, both of which are in closer proximity to plane **23** than is plane **21**. It is also within the scope of the present invention without departing from the critical and most important feature thereof to insert in the stack a series of smaller planes where planes in closest proximity with each other are also in parallel relationship, but said series of planes would merely serve as gas stream directional baffling.

For illustrative purposes only and without being limited thereto, it is desirable that, as an order of magnitude, the sound suppressor elements be within the range of 2 to 10 feet long and, referring to FIGURE 17, dimension C be within the range of 6 to 48″, with 12″ being the preferred embodiment for use in connection with jet engine air intake and exhaust systems. Dimension B should be initially set as about ½ of dimension C and dimension D about two times dimension C.

The spacing of the elements with respect to each other in a tier (i.e., dimensions B and A in FIGURE 17), and the spacing of tiers with respect to each other (i.e., dimension D in FIGURE 17) is mainly determined by the length of the sound waves to be suppressed and by the pressure drop that can be tolerated as a result of a gas stream passing through the sound suppressor stack for a particular application. In other words, the closer the

spacing of the elements in a tier and the closer the spacing of the tiers, the higher is the pressure drop across the sound suppressor stack which results in higher back pressures in the supply duct and lower exit pressures to the eduction duct.

A substantial portion of the sound attenuation or sound suppression is effected to a highly efficient degree with the portion of the stack having these basic multiplanar elements, said multiplanar elements providing a large plurality of reflective surfaces so positioned within a relatively small volume as to effectively form resonating chambers whereby the energy of the sound waves "decay" due to multiple incidence and reflection with sound energy being absorbed by the surfaces upon each incidence and reflection. It is theorized that as the absorption coefficient is a function of both angle of incidence and frequency, the present invention provides numerous effective resonance chambers with many planes of reflection and a wide range of angles of incidence and reflection. While sound suppression becomes more efficient and effective with these multiplanar elements as dimensions B and D are reduced, the tolerable gas pressure drop across the stack places lower limits on dimensions B and D. In other words, the final choice on dimensions B, C and D, considering the angle of rotation of the element set into the stack and the dihedral angles, is a compromise between the tolerable pressure drop and final reduction of the noise to desired levels.

The practical applications of the sound suppression structures of this invention will be readily understood by the following structural details of a jet engine test stand constructed in accordance with the principles of this invention and the description set forth in the foregoing specification.

Referring more particularly to FIGURE 18, a test stand comprising a chamber **28** in which is mounted a jet engine **29**, so positioned as to induce, when in operation, a stream of air flowing generally horizontally through the chamber **28** from left to right as seen in the drawings. An air induction or inlet passage, indicated generally by the reference numeral **30**, may comprise a vertical section **31** and a horizontal section **32** merging with the left-hand end of chamber **28**; and an air eduction or outlet passage, indicated generally by the reference numeral **33**, may comprise a vertical section **34** and a horizontal section **35** merging with the right-hand end of the chamber **28**. Sound suppressing elements of this invention are installed in one or more of the passage sections **31** and **34**. Sound suppressing components can be selected so that each "stack" in **31** and **34** are identical; however, the sound suppressing structure will generally have a better overall sound absorption coefficient where a selected assortment of sound suppressing components, e.g., FIGURES 4–13 components, are disposed within the stack.

While the overall sound suppressing unit incorporating the novel multiplanar components, as shown in FIGURE 18, is stationarily mounted, it is within the scope of the present invention to have a portable unit in order to permit a noise reduction of a jet engine aircraft which is operating near "full thrust" for test purposes and which is positioned on a runway.

While the particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects.

What is claimed is:

1. An apparatus for suppressing sound carried by a high velocity fluid stream comprising (a) a passageway through which said stream is moving and (b) a detachably removable, sound deadening means positioned within said passageway comprising a plurality of longitudinally extending baffle grids arranged in tiers, said tiers which are contacted first by the fluid stream comprising only the baffle grids, the middle tiers comprising such baffle grids, each of which being enclosed within a sheath having at least one perforation therein and being attached thereto, the last contacted tiers comprising such baffle grids each of which being enclosed within a sound absorbent material-containing sheath and being attached thereto; and said grids being so positioned within said passageway as to be substantially perpendicular to the flow of such stream therethrough.

2. The apparatus as set forth in claim **1** wherein (a) the tiers which are first contacted by the fluid stream also include a sheath enclosing each of said baffle grids, the very first tier contacted by said fluid stream having sheaths, each of which have a cross section which is a combination of curvilinear and straight sections, said sheaths also containing sound absorbent material; (b) the aforesaid middle tiers contain sound absorbent material within each of said baffle grid-containing sheaths; and (c) the aforesaid sheaths in said first, middle, and last contacted tiers are respectively positioned substantially one above another and are respectively interconnected therebetween by means of a pair of baffles which serve as gas stream directional baffling, each baffle having at least one perforation therein.

3. The apparatus as set forth in claim **1** wherein each longitudinally extending, baffle grid consists of a triplanar component wherein one of the three angles between the three webs forming said triplanar component is from about 30° to about 180° and the remaining two angles are from about 45° to about 165°.

4. The apparatus as set forth in claim **3** wherein said triplanar component has connected thereto, at the intersection of the three webs and extending outwardly from each end portion thereof, a journal whereby said journal is contained within a pillow block which is attached to the vertical walls which surround said sound deadening means, said journal being adapted to be rotated in order to increase the efficiency of reducing the noise being carried in said passageway by the said stream therein.

5. The apparatus as set forth in claim **4** wherein the triplanar component is so positioned within the aforementioned passageway whereby one web is contained in a plane parallel to the directional movement of said fluid stream, and the other two webs are in a position downstream of said first-mentioned web and are at an angle thereto, said two webs having an angle therebetween from about 30° to about 180°.

6. The apparatus as set forth in claim **1** wherein each longitudinally extending baffle grid consists of a multiplanar component having from about two to about six webs positioned at various angles around and connecting at a common longitudinal joint which lies along the longitudinal axis of said component.

7. The apparatus as set forth in claim **1** wherein the said grids located in the tiers of said sound deadening means, which are contacted first by the fluid stream, each consist of a triplanar sound suppressor component comprising three hollow webs which are joined together at a common and hollow longitudinal joint whereby a heat transfer fluid may be circulated therethrough.

8. The apparatus as set forth in claim **7** wherein said three hollow-webbed triplanar component contains perforations therein thereby permitting escape of said heat transfer fluid into the said fluid stream passing through the passageway.

9. A device for suppressing sound carried by a high velocity fluid stream comprising a passageway through which said stream is moving, and sound deadening means, positioned within said passageway and perpendicular to the directional flow of said stream, comprising a plurality of longitudinally extending multiplanar components having from about 2 to about 6 webs positioned at various angles around and connecting at a common longitudinal joint and said components being arranged in a series of tiers wherein the distance between the ad-

jacent components in the same tier, as measured by the distance between two parallel planes, which are also parallel to the directional flow of said fluid stream, each of which are tangent to the respective circumferential arcs formed between the two webs adjacent to each other in each component, is about one-half the width of a web of one multiplanar component, and the distance between the longitudinal extending axis of a multiplanar component in one tier and a similar axis of another component in an adjacent tier, both of said axes being measured in one plane which is parallel to the directional flow of said stream, is twice the width of a web of one multiplanar component, said webs forming planes which are non-parallel to each other in the said component nor are the planes of the webs in adjacent components nearest each other parallel to each other.

10. A sound suppressor element, for use in a sound deadening system wherein sound carried by a high velocity fluid stream is substantially suppressed, comprising a longitudinally extending sheath having at least one perforation therein and containing a baffle grid, said baffle grid comprising a plurality of webs being angularly disposed with respect to each other and meeting each other along a common longitudinal joint and extending substantially the full length of said sheath, said webs dividing the interior of said sheath into separate and substantially non-interconnecting compartments.

11. The element of claim **10**, wherein said baffle grid comprises three of said webs arranged in a Y-configuration, and the three dihedral angles between said three webs are respectively within the range of from about 30° to about 180°, from about 45° to about 165°, and from 45° to about 165°.

12. The element of claim **10**, wherein said joint lies along the central longitudinal axis of said conduit.

13. The element of claim **10**, wherein said baffle grid comprises two of said webs arranged in a V-configuration.

14. The element of claim **12**, wherein said baffle grid comprises at least four of said webs, the respective dihedral angles between angularly adjacent webs being all equal.

15. The element of claim **10** wherein said compartments are substantially filled with a mass of sound-absorbent material.

16. A sound suppressor element, for use in a sound deadening system wherein sound carried by a high velocity fluid stream is substantially suppressed, comprising a longitudinally extending cylindrical sheath, having at least one perforation therein and whose surface has a series of corrugations thereon; a concentric, close-fitting mesh screen positioned within said corrugated sheath; a concentric, close-fitting cloth conduit positioned within said concentric mesh screen; and a baffle grid extending longitudinally within said corrugated conduit and surrounded thereby, said baffle grid being surrounded by a mass of sound-absorbent material which is also positioned within the interior portion of said cloth conduit.

17. The element as set forth in claim **16**, wherein said concentric cloth conduit is constructed of fiberglass, and the said baffle comprises three webs arranged in a Y-configuration and which extends substantially the full length of said corrugated sheath, said webs dividing the interior of said corrugated sheath into separate and non-interconnecting compartments, which are substantially filled with said mass of sound-absorbent material.

18. The element as set forth in claim **16**, wherein said baffle grid comprises from about two to about six webs angularly disposed with respect to each other and meeting each other along a common longitudinal joint.

References Cited

UNITED STATES PATENTS

1,865,677	7/1932	Cheyney	181—60 X
2,706,013	4/1955	Wigle	181—33
2,720,276	10/1955	Droeger	181—33
2,940,537	6/1960	Smith et al.	181—33 X
2,942,682	6/1960	Bergh et al.	181—56 X
2,959,243	11/1960	Smith	181—33
2,994,401	8/1961	Bourne et al.	181—42
3,018,840	1/1962	Bourne et al.	181—33
3,195,679	7/1965	Duda et al.	181—56

FOREIGN PATENTS

1,153,298	9/1957	France.
1,199,789	6/1959	France.
638,407	6/1950	Great Britain.

RICHARD B. WILKINSON, *Primary Examiner.*

ROBERT S. WARD, JR., *Assistant Examiner.*