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2,936,040

ACOUSTICAL BARRIER FENCE

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2 Sheets-Sheet 1

FIG. 1.

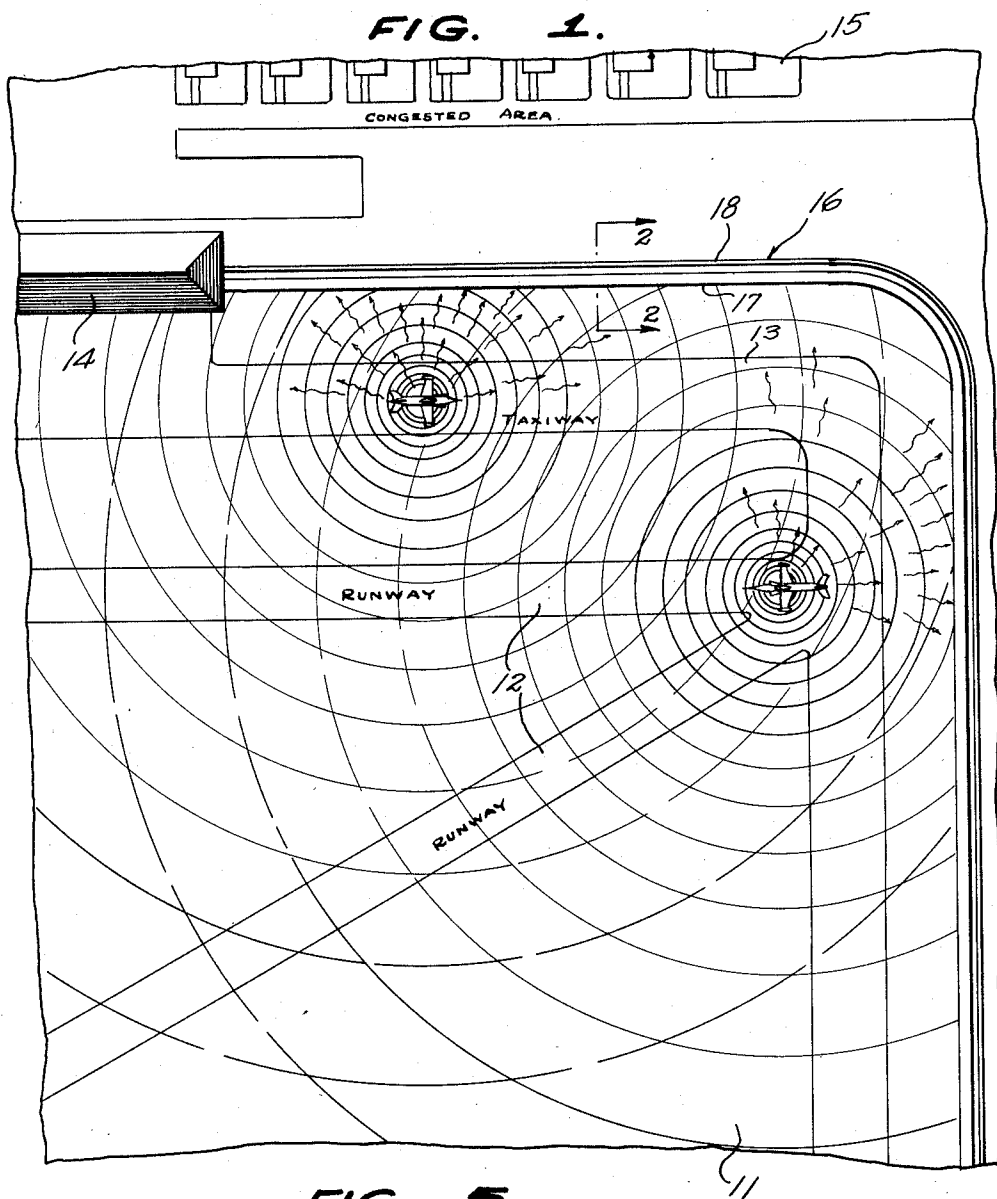
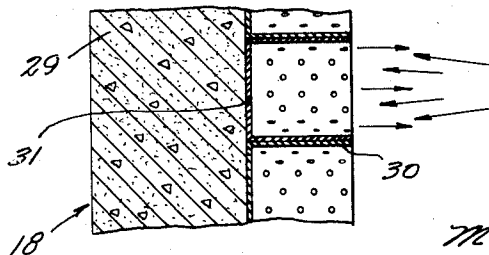


FIG. 5.



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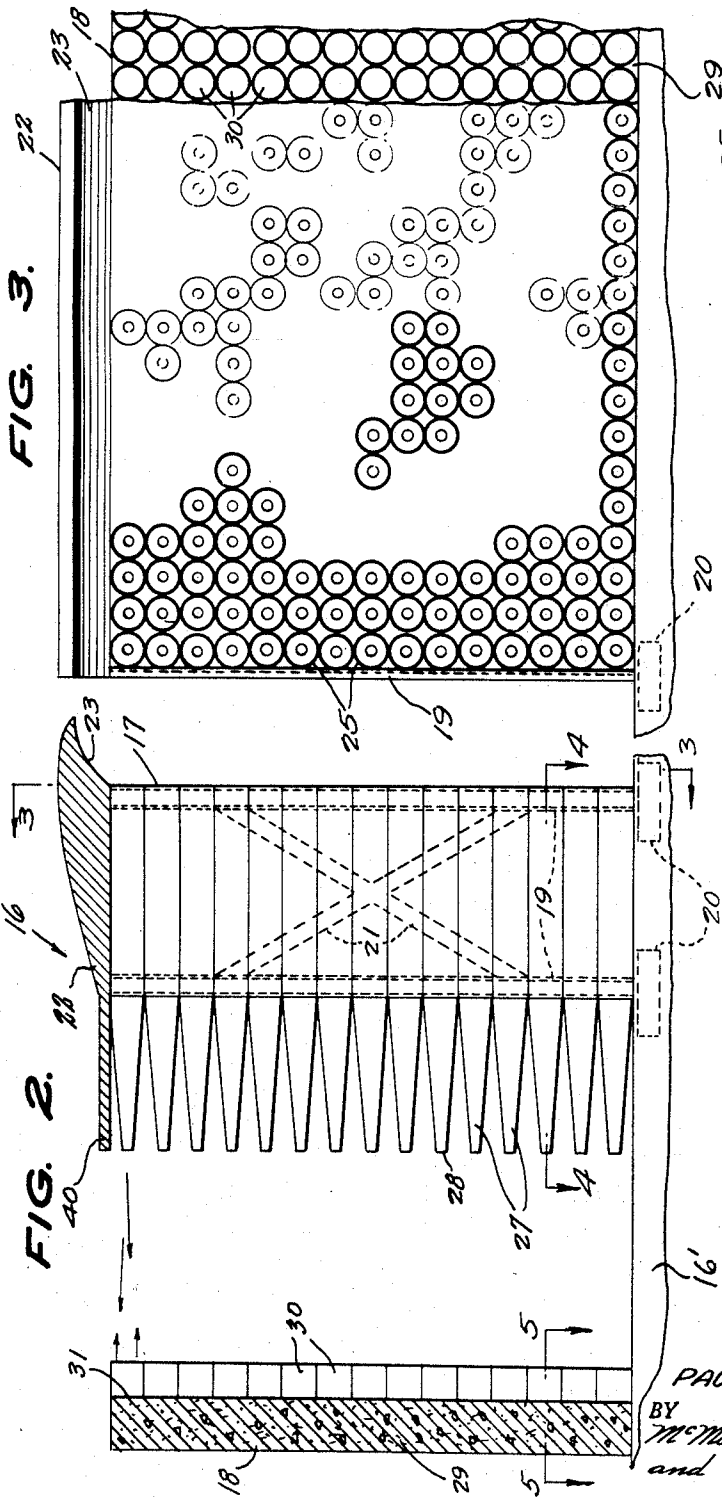
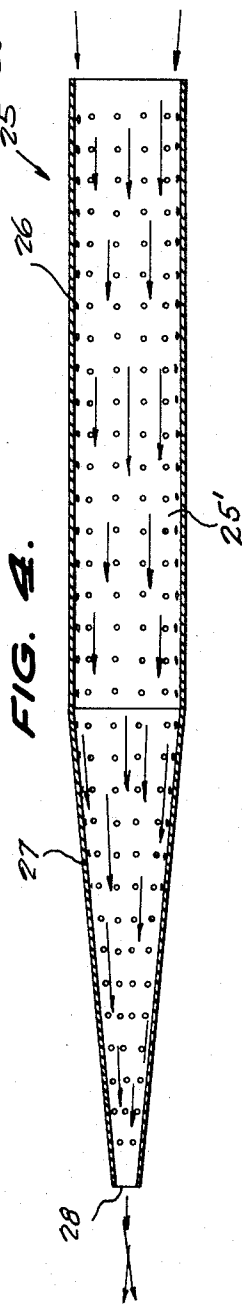
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ACOUSTICAL BARRIER FENCE

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11 Claims. (Cl. 181—33)

This invention relates to acoustical barrier devices, and more particularly to a sound-reducing fence structure intended to be employed primarily around air fields adjacent to taxi-ways and runways and being arranged to absorb or otherwise substantially attenuate the sound emitted by jet aircraft and other types of aircraft, so as to minimize the amount of sound energy from such sources reaching populated areas adjacent to the air field.

A main object of the invention is to provide a novel and improved sound barrier fence which is simple in construction, which is easy to install, and which is arranged to act as an acoustical barrier to prevent sound energy from passing therethrough to any substantial degree.

A further object of the invention is to provide an improved acoustical barrier particularly adapted for use around air fields and adapted to be installed between runways or taxi-ways on air fields and neighboring populated areas, the acoustical barrier involving relatively inexpensive components, being durable in construction, and acting to substantially block the passage of appreciable quantities of sound energy therethrough by serving as a means for absorbing a considerable amount of the sound energy and for canceling a substantial portion of said sound energy by means of the phenomenon of interference.

A further object of the invention is to provide an improved sound barrier which is adapted to be employed as a sound insulating means between a source of sound energy comprising a large number of frequency noise components, and an area to be shielded therefrom, the sound barrier being arranged to attenuate the higher frequency components by direct absorption, to compress and diffract the lower frequency noise components, and to destroy a major portion of the lower frequency components by reflection and interference.

Further objects and advantages of the invention will become apparent from the following description and claims, and from the accompanying drawings, wherein:

Figure 1 is a schematic view of a portion of an air field and showing the manner in which an acoustic barrier fence is installed between the taxi-way and runways of air fields and an adjoining congested populated area, whereby said populated area is shielded to a substantial degree from the noise generated by aircrafts using the air field.

Figure 2 is an enlarged cross sectional view taken transversely through a portion of the sound barrier fence of Figure 1 on the line 2—2 of said figure.

Figure 3 is a fragmentary elevational view taken substantially on the line 3—3 of Figure 2.

Figure 4 is an enlarged horizontal cross sectional view taken through one of the sound conductor tubes employed in the sound barrier fence of Figures 1 to 3, said view being taken on the line 4—4 of Figure 2.

Figure 5 is an enlarged horizontal cross sectional view taken on the line 5—5 of Figure 2.

Referring to the drawings, 11 designates an air field

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which is generally conventional in its arrangement, said air field including several runways 12 and being provided with taxi-ways 13 extending adjacent the marginal portions of the air field and communicating with the runways 12, so that aircrafts may move along the taxi-ways into the starting portions of the runways. As illustrated in Figure 1, the air field may include a typical administration building 14 which is located at the edge of the air field and which is arranged so that access may be obtained to aircraft on the taxi-way 13 adjacent to the building.

As in the case of many air fields, the field may be located fairly close to a congested populated area, such as the area designated generally at 15 in Figure 1, and consequently the noise from aircraft using the taxi-ways and runways of the air field frequently becomes a serious problem, not only due to the nuisance of the noise produced by the aircraft using the air field but also because the noise level with the newer types of aircrafts is substantially increased as over the older types, so that as more and more of the newer types of aircraft are used on air fields the noise level of the sound energy reaching the congested areas adjacent the air field tends to increase substantially. This is especially true in the case of the jet types of aircraft which are becoming increasingly common in commercial use and which may be expected to become accepted as conventional aircraft for commercial use.

In accordance with the present invention, a sound barrier fence, designated generally at 16 is provided at the edge of the air field, preferably extending between the taxi-way 13 and the adjacent congested populated areas and being spaced preferably by a distance of the order of 300 feet from the taxi-ways or other points which may be considered as primary sound sources, for example, locations where aircraft may be expected to operate before and during takeoff. As will be readily apparent from the ensuing discussion, the required height of the sound barrier fence 16 will be increased as the distance from the sound barrier fence to the adjacent taxi-way is increased, since the effective angle presented by the sound barrier to the sound source decreases as the distance from the sound source to the barrier fence increases. In a typical installation where the distance from the taxi-way 13 to the sound barrier fence is of the order of 300 feet, the height of the fence may be approximately 10 feet and will serve to block out a major portion of the sound energy emitted by an aircraft using the taxi-way 13 adjacent to the fence, so that very little of the sound energy reaches an adjacent congested area 15.

Referring now to Figures 2 to 5, the fence 16 comprises a sound receiving section 17 and a sound reflecting section 18 spaced outwardly from the sound receiving section relative to the inside of the air field, said sections being interconnected by an intervening open ground area 16'. The sound receiving section 17 comprises a vertical framework formed of regularly spaced upstanding pairs of transversely spaced vertical channel bars 19, 19 which are securely anchored in the ground, for example, which are embedded in concrete footing blocks 20 and which are rigidly fastened together by crossed brace bars 21, so as to define transverse vertical panels rigidly spaced along the acoustic fence sound-receiving section 17. Rigidly secured to the top ends of the channel bars 19 is a metal cover plate 22 which is integrally formed at its inner edge with a parabolic sound reflecting surface 23 facing inwardly of the air field and being concaved downwardly and inwardly, as is clearly shown in Figure 2.

Stacked between the transverse vertical panels defined by the frame bars 19 and brace bars 21 are sound conductor tubes 25 which are supported on each other and

which fill the entire areas defined between the top plate 22 and the ground between adjacent pairs of vertical panels, said tubes defining elongated horizontal passages 25'.

The tubes 25 are preferably formed of suitable sound absorbing, rigid durable material, such as plastic material or paper impregnated with vibration resistant material to impart rigidity thereto and to render same weather-resistant. The tubes 25 may be thus formed of perforated paper material impregnated with suitable resinous plastic compound such as that commonly employed for soundproofing machinery, or such as that employed for undercoating motor vehicles to damp out vibrations of the motor vehicle body walls.

Each sound conductor tube 25 comprises a cylindrical sound-receiving portion 26 defining a horizontal passage of uniform cross sectional area which is of substantial length, for example, which is approximately four feet in length in a typical design, and which communicates with the tapering discharge portion 27 of frustro-conical shape and which is of substantial length, for example, which is three feet in length in the above-mentioned typical design. The frustro-conical portion 27 terminates in a discharge orifice 28 which may have a diameter depending upon the major frequency components considered necessary to be attenuated by the acoustic carrier fence, which will naturally depend upon the type of aircraft producing the noise to be controlled. As will be presently pointed out, the size of the orifice 28 also determines the spacing between the sound-receiving section 17 and the sound reflecting section 18, since this spacing is an important factor in determining the phase displacement of diffracted sound waves leaving the orifices 28 and being reflected back thereto from the reflecting section 18.

As will be presently explained, the selected spectral portion of the sound energy received by the acoustic barrier is diffracted from the orifices 28 and encounters the reflecting wall section 18, being reflected back toward the orifices and arriving at the orifices with a phase displacement which is an integral multiple of 180 degrees, whereby it effectively cancels the waves emitted at the orifices, creating nodes at said orifices.

The reflecting wall section 18 comprises a vertical wall 29 formed of suitable durable material, such as cinder blocks, or the like, and rising to substantially the same height as the sound-receiving wall section 17, for example, 10 feet in the typical embodiment above mentioned. Secured to the inside surface of the wall 29 and axially aligned with the respective vertically stacked tubes 25 are cylindrical shell members 30 formed of the same relatively inert material, namely, plastic or perforated paper tubing impregnated with vibration-resisting material, as above described in connection with the tubes 25. The face of the wall 18 which is directed inwardly, namely, toward the tubes 25, is preferably coated with a suitable highly reflective rigid material so that sound waves impinging thereagainst will be efficiently reflected back toward the nozzle orifices 28.

The cylindrical shell members 30 are of the same diameter as the cylindrical portions 26 of tubes 25 but are considerably shorter in length, for example, being in the range between eight and twelve inches in length in the case above described, wherein the tubes 25 have an overall length of about seven feet.

As above mentioned, the distance between wall 29 and the discharge nozzles 28 will depend upon the diameter of the discharge nozzles, namely, upon the selected frequency components to be primarily attenuated. In a typical design the nozzle diameter was 2 inches and the diameter of the main cylindrical portions of the tubes 25 was 8 inches. The distance between the inner ends of shell members 30 and the nozzle discharge apertures 28 in this case was six feet. As an alternative design, the nozzle discharge aperture diameter was 4 inches, with the diameter of the cylindrical portions 26 remaining eight

inches. In this design the distance between the discharge apertures 28 of the nozzles 27 and the inner ends of shell members 30 was 4 feet. As will be readily apparent, where the diameter of the discharge nozzles 28 is increased, a somewhat lower frequency band of spectral noise components will be selected for destruction. As will be also apparent, the distance between the nozzle apertures 28 and the reflective inside facing the wall 29 must be at least great enough to allow diffraction to occur at the nozzle orifices and to allow at least one diffracted wave to be reflected from the inside surface of wall 29 in a manner such that it will return to the nozzle with a phase displacement of 180 degrees. The spacing, however, may be selected such that any integral multiple of one-half wave length will be defined by the distance required by the diffracted wave to travel from the nozzle 28 and return to said nozzle after being reflected from wall 29.

In operation, sound energy from the taxi-way 13 or from the takeoff portion of the runways 12 reaches the sound barrier fence, the included angle being substantially adequate to block off most of the sound energy with respect to the adjacent congested area 15. The sound energy, which may be of heterogenous spectral composition passes through the relatively long conductor tubes 25, wherein the higher frequency components are substantially absorbed, and whereby most of the higher frequency sound energy is dissipated in the form of heat. However, in the case of jet aircraft and similar types of aircraft, a major portion of the noise energy is concentrated in the lower audible range. In the case of jet aircraft such concentration may occur in a relatively narrow band of frequencies, and the acoustic barrier fence is designed to control primarily this selected band, although it is quite effective with respect to other adjacent spectral noise components.

The residual sound vibrations which are not extinguished by absorption in the cylindrical portions 26 of the tubes 25 pass through the convergent nozzle portions 27 and the vibrating air is compressed in the nozzles to a substantial degree, whereby diffraction takes place when the compressed vibrating air is discharged from the nozzle orifices 28. Since the sound conductor tubes 25 are, in effect, tuned to a predetermined selected band of sound frequency components, considered to represent the major spectral components of the noise to be controlled, the diffracted waves leaving the apertures 28 contain a major portion of the noise not previously dissipated by passage through the sound conductor tubes 25.

As will be further apparent, diffraction also occurs of other frequency components remaining in the air pulsations discharging from the orifices 28, and diffracted waves of such other frequency components will be present, such diffracted waves being reflected from the inside surface of wall 29 and impinging upon the external surfaces of the nozzle elements 27. Since these external surfaces are in themselves largely sound absorbent, the extraneous sound energy will be absorbed to a large degree by contact with the non-reflective exterior surfaces of the conductor tubes 25.

The main diffracted sound waves leaving the nozzle apertures 28 impinge on the smooth inside surface of wall 29, being guided by the cylindrical shell elements 30 so as to be maintained in direction in axial alignment with the respective source tubes 25. The cylindrical shell member 30 thus acts to direct the reflected waves back toward their respective source nozzle apertures 28, whereby refraction of the sound waves is avoided and whereby the diffracted waves return to their associated emitting apertures 28 with the desired phase displacement of 180 degrees and act to cancel the pulsations in the selected frequency band by interference action.

As will be seen in Figure 5, the shell members 30 are rigidly secured to the highly reflective inside facing 31 of the wall 29, said shell members being made of the

same material as the sound conductor tubes 25, and being in themselves relatively sound-absorbing. As in the case of the cylindrical portions 26 of the sound conductor tubes, high frequency components are attenuated in the cylindrical shell members 30, particularly if said shell members are of substantial axial length. However, the primary purpose of the shell members 30 is to insure axial alignment of the wave front directions so that a wave front leaving a nozzle aperture 28 will be reflected accurately back toward said nozzle aperture.

Summarizing, it will be seen that the higher frequency components are attenuated by being absorbed in the cylindrical portions 26 of the sound conductor tubes 25 and that the selected portion of the noise spectrum considered to contain the major part of the noise energy is compressed in the convergent nozzle elements 27 and destroyed by interference due to diffraction of the selected spectral noise energy from the nozzle apertures 28, reflection of the diffracted waves from the inside surface of wall 29 and subsequent return of the deflected waves to the nozzle apertures 28 with a phase displacement of 180 degrees. The remaining noise energy, namely, the spectral components outside of the band to which the apparatus is tuned is also diffracted and reflected from the inside surface of wall 29, returning to the sound-receiving section 17 of the acoustical barrier fence and impinging on the absorbent outside surfaces of the conductor tubes 25, being, to a large extent, absorbed thereon and dissipated in the form of heat. Thus, the fence acts to block out a major portion of the sound energy reaching same and to prevent this sound energy from traveling toward the adjacent congested area 15.

In a typical design of an acoustic barrier fence according to the present invention, the forward edges of the reflector tubes 30 are spaced 6 feet from the orifices 28, said orifices being 2 inches in diameter, the nozzles 27 being 3 feet in length and the cylindrical portions 26 of the sound conductor tubes being 4 feet in length. In this design the reflector tubes 30 are 8 inches in axial length and are of the same diameter as the cylindrical portions 26 of the sound conductor tubes 25, namely, 8 inches. The height of the wall sections is approximately 10 feet, and the top plate 22 is secured so that its bottom surface is substantially at the same horizontal level as the top edge of the sound reflecting wall section 18. As shown in Figure 2, the top plate 22 is provided with a horizontal flange portion 40 which covers the nozzles 27, and which terminates substantially at the vertical plane containing the orifices 28.

As will be readily apparent, the closer to the source of the sound to be controlled that the fence is located, the more effective will be the shielding action of the fence. However, due to regulations pertaining to airports, the fence will ordinarily be placed at least at a distance of 300 feet from the source.

Although the sound conductor tubes 25 have been illustrated and described as having cylindrical main body portions, it will be readily apparent that said main body portions may be of any other shape, for example, may be square in cross sectional shape, and may be disposed so as to completely fill the area defined between the successive pairs of vertical frame bars 19, 19 between which the sound conductor tubes are retained. If cylindrical sound conductor tubes are employed, as illustrated in the drawings, there will be spaces between the tubes, but said spaces are relatively small and do not affect the operation of the sound barrier fence to any substantial degree.

While a specific embodiment of an acoustic barrier has been disclosed in the foregoing description, it will be understood that various modifications within the spirit of the invention may occur to those skilled in the art. Therefore, it is intended that no limitations be placed on the invention except as defined by the scope of the appended claims.

What is claimed is:

1. A sound barrier for suppressing sound energy containing a substantial level of frequencies in a predetermined audible band comprising a first wall member formed with a plurality of elongated horizontal passages of substantially uniform cross sectional area, convergent discharge nozzles at the ends of said passages, a reflective wall member spaced from said first wall member at the same side thereof as said nozzles and spaced from said nozzles by a distance substantially equal to one-half of an integral multiple of half wave lengths of a frequency in said predetermined band, and an open ground area interconnecting said wall members.

2. A sound barrier for suppressing sound energy containing a substantial level of frequencies in a predetermined audible band comprising a first wall member formed with a plurality of elongated horizontal passages, convergent discharge nozzles at the ends of said passages, a reflective wall member spaced from said first wall member at the same side thereof as said nozzles and spaced from said nozzles by a distance substantially equal to one-half of an integral multiple of half wave lengths of a frequency in said predetermined band, respective tubular shell members mounted on the face of said reflective wall member in axial alignment with and directed toward said nozzles, and an open ground area interconnecting said wall members.

3. A sound barrier for suppressing sound energy containing a substantial level of frequencies in a predetermined audible band, said barrier comprising a first wall member including a plurality of horizontal tubular members of substantial length and arranged perpendicular to the plane of the first wall member, a second wall member spaced from and being parallel to said first wall member and having a reflective inside surface, convergent nozzles at the ends of said tubular members extending toward said second wall member and being spaced therefrom by a distance substantially equal to one-half of an integral multiple of half wave lengths of a frequency in said predetermined band, and an open ground area interconnecting said wall members.

4. A sound barrier for suppressing sound energy containing a substantial level of frequencies in a predetermined audible band, said barrier comprising a first wall member including a plurality of horizontal tubular members of substantial length and arranged perpendicular to the plane of the first wall member, a second wall member spaced from and being parallel to said first wall member and having a reflective inside surface, convergent nozzles at the ends of said tubular members extending toward said second wall member and being spaced therefrom by a distance such that diffracted sound waves developed at said nozzles and reflected from said second wall member return to the nozzles substantially 180 degrees out of phase with respect to the sound waves originating at said nozzles, and an open ground area interconnecting said wall members.

5. A sound barrier for suppressing sound energy containing a substantial level of frequencies in a predetermined audible band, said barrier comprising a first wall member including a plurality of horizontal passages of substantial lengths of substantially uniform cross sectional area and arranged perpendicular to the plane of the first wall member, a second wall member spaced from and being parallel to said first wall member and having a reflective inside surface, convergent nozzles at the ends of said passages and extending toward said second wall member and being spaced therefrom by a distance such that diffracted sound waves developed at said nozzles and reflected from said second wall member return to the nozzles substantially 180 degrees out of phase with respect to the sound waves originating at said nozzles, and an open ground area interconnecting said wall members.

6. A sound barrier for suppressing sound energy containing a substantial level of frequencies in a predeter-

mined audible band, said barrier comprising a first wall member including a plurality of horizontal tubular members of substantial length and arranged perpendicular to the plane of the first wall member, a second wall member spaced from and being parallel to said first wall member and having a reflective inside surface, convergent nozzles at the ends of said tubular members integrally formed thereon and extending toward said second wall member and being spaced therefrom by a distance such that diffracted sound waves developed at said nozzles and reflected from said second wall member return to the nozzles substantially 180 degrees out of phase with respect to the sound waves originating at said nozzles, said tubular members being formed of sound absorbing material, and an open ground area interconnecting said wall members.

7. A sound barrier for suppressing sound energy containing a substantial level of frequencies in a predetermined audible band, said barrier comprising a first wall member including a plurality of horizontal tubular members of substantial lengths and arranged perpendicular to the plane of the first wall member, a second wall member spaced from and being parallel to said first wall member and having a reflective inside surface, convergent nozzles at the ends of said tubular members integrally formed thereon and extending toward said second wall member and being spaced from said second wall member by a distance such that the diffracted sound waves developed at said nozzles and reflected from said second wall member return to the nozzles substantially 180 degrees out of phase with respect to the sound waves originating at said nozzles, said tubular members being formed of sound absorbing material, tubular shell members mounted on said reflective inside surface substantially in axial alignment with said nozzles, and an open ground area interconnecting said wall members.

8. A sound barrier for suppressing sound energy containing a substantial level of frequencies in a predetermined audible band, said barrier comprising a first wall member including a plurality of horizontal tubular members of substantial lengths and arranged perpendicular to the plane of the first wall member, a second wall member spaced from said first wall member and being parallel to said first wall member and having a reflective inside surface, convergent nozzles at the ends of said tubular members integrally formed on said tubular members and extending toward said second wall member and being spaced therefrom by a distance such that diffracted sound waves developed at said nozzles and reflected from said second wall member return to the nozzles substantially 180 degrees out of phase with respect to the sound waves originating at said nozzles, said tubular members being formed of sound absorbing material, tubular shell members mounted on said reflective inside surface substantially in axial alignment with said nozzles, said shell members being of sound absorbing material and being substantially the same in diameter as said first-named tubular members, and an open ground area interconnecting said wall members.

9. A sound barrier for suppressing sound energy including a spectral portion having a relatively high intensity comprising a pair of spaced wall members, one of said wall members comprising a frame and vertically stacked horizontal tubular members mounted in said frame and extending perpendicular to the plane of said one wall member, said tubular members having open sound-receiving ends, convergent nozzles on the other

ends of the tubular members, said tubular members being arranged so that said convergent nozzles are directed toward the other wall member, said nozzles having discharge orifices spaced from said other wall member by a distance such that diffracted sound waves developed at said orifices and reflected from said other wall member return to the orifices substantially 180 degrees out of phase with respect to the waves emitted at the orifices, and an open ground area interconnecting said wall members.

10. A sound barrier for suppressing sound energy including a spectral portion having a relatively high intensity comprising a pair of spaced wall members, one of said wall members comprising a frame and vertically stacked horizontal tubular members mounted in said frame and extending perpendicular to the plane of said one wall member, said tubular members having open sound-receiving ends, and convergent nozzles on the other ends of said tubular members, said tubular members being arranged so that said convergent nozzles are directed toward the other wall member, said nozzles having discharge orifices spaced from said other wall member by a distance such that diffracted sound waves developed at said orifices and reflected from said other wall member return to the orifices substantially 180 degrees out of phase with respect to the waves emitted at the orifices, said tubular members being formed of sound absorbing material, respective sound absorbing shell members mounted on said other wall member opposite said discharge orifices, and an open ground area interconnecting said wall members.

11. A sound barrier for suppressing sound energy including a spectral portion having a relatively high intensity comprising a pair of spaced wall members, one of said wall members comprising a frame and vertically stacked horizontal tubular members mounted in said frame and extending perpendicular to the plane of said one wall member, said tubular members having open sound-receiving ends, convergent nozzles on the other ends of said tubular members directed toward the other wall member, said nozzles having discharge orifices spaced from said other wall member by a distance such that diffracted sound waves developed at said orifices and reflected from said other wall member return to the orifices substantially 180 degrees out of phase with respect to the waves emitted at the orifices, said tubular members being formed of sound absorbing material, respective sound absorbing shell members mounted on said other wall member opposite said discharge orifices, a rigid cover member mounted on said one of the wall members and being formed with a parabolic concave surface overlying the sound-receiving open ends of the tubular members, and an open ground area interconnecting said wall members.

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