



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11) **EP 1 204 295 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
08.05.2002 Bulletin 2002/19

(51) Int Cl.7: **H04R 9/06, E04B 9/00**

(21) Application number: **01123980.3**

(22) Date of filing: **08.10.2001**

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE TR**
Designated Extension States:
AL LT LV MK RO SI

(72) Inventor: **Kenneth, P. Roy**
Holtwood, PA 17532 (US)

(74) Representative: **Finck, Dieter, Dr.Ing. et al**
v. Fünser Ebbinghaus Finck Hano
Mariahilfplatz 2 - 3
81541 München (DE)

(30) Priority: **03.11.2000 US 705313**

(71) Applicant: **Armstrong World Industries, Inc.**
Lancaster Pennsylvania 17603 (US)

(54) **Flat panel sound radiator with sound absorbing facing**

(57) An apparatus for mounting a flat panel radiator (200) into a ceiling grid to provide improved sound absorption. The ceiling grid system has openings defined by main beams (600) and cross beams (602). The main beams are secured through hanger wires (601) to a hard ceiling. The main beams and the crossbeams have flanges with the crossbeams resting on the flanges of the main beams. The mounting apparatus has a frame

(210), cushioning elements (214) attached to the frame, and an acoustically resistant facing (236) or scrim attached to the bottom of the frame. A layer of air is trapped between the facing (236) and the flat panel radiator (200). This combination of the air layer and the acoustically optimized facing form a sound absorber that alters the acoustic characteristics of the flat panel radiator.

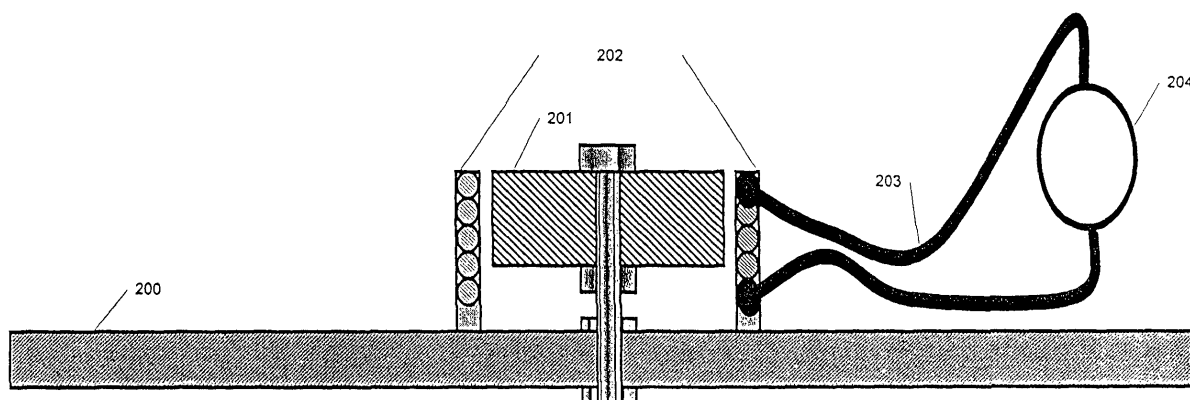


FIG. 2

Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This patent application is related to, and contains common disclosure with, co-pending European patent applications 01 112 253.8 "Flat Panel Sound Radiator and Assembly System" and 01 117 868.8 "Flat Panel Sound Radiator with Special Edge Details". The present invention is also related to EP 0 979 908 A2 (US-6 108 994 A). The co-pending European patent applications are hereby incorporated by reference into this description as fully as if here represented in full.

BACKGROUND OF THE INVENTION

[0002] This invention relates to sound masking and sound absorbing systems in a workplace environment. More specifically, it relates to sound masking and sound absorbing systems adapted for use with a suspended ceiling.

[0003] Noise in a workplace is not a new problem, but it is one that is receiving increasing attention as open workplace configurations and business models continue to evolve. A number of recent studies indicate that noise, in the form of conversational distraction, is the single largest negative factor impacting worker productivity.

[0004] As the service sector of the economy grows, more and more workers find themselves in offices rather than manufacturing facilities. The need for flexible, reconfigurable space has resulted in open plan workspaces, i.e., large rooms with reduced height, moveable partitions over which sound can pass. The density of workstations is also increasing, with more workers occupying a given physical space. More workers are using speakerphones, conferencing technologies, and multimedia computers with large, sound reflecting screens and even voice input. All these factors tend to increase the noise level in workplaces making the noise problem more difficult and costly for businesses to ignore.

[0005] In closed spaces, particularly in closed office and meeting room settings, speech intelligibility and acoustic performance are determined by a variety of factors, including room shape, furnishings, number of occupants, and especially ceiling, wall, and floor treatments. This acoustic environment will determine how much sound intrusion will occur, as well as the level to which the listeners within these spaces will be affected by extraneous noise and conversational distraction.

[0006] A more general examination of the interior environment of a room reveals other aspects that play a major role in how sound is perceived by the occupants. Recent research has indicated that when looking at the issue of sound intrusion between spaces, the transmission loss of materials and sound absorption characteristics of materials are not the only contributors to the perceived acoustical environment. Another factor is the

background noise in a space. This includes the sounds produced by overhead utilities such as heating, ventilation, and air conditioning (HVAC) systems. Another significant factor is the sound, much of which is conversational, that intrudes from adjacent spaces. This has become the focus of much current research. Sound can enter a space in a variety of ways. In a closed office settings, sound travels through walls or partitions; through open air spaces such as doorways and hallways; and through other air spaces such as HVAC ductwork, registers and diffusers, and between rooms through ceiling panels, across the utility/plenum space, and back down through the ceiling. In open plan offices, sound also travels by deflection over partitions that end below the ceiling, and by reflection off the ceiling between adjacent office cubicles. In both closed and open office layouts, noise intrusions also travel through the structural ceiling deck, the utility/plenum space, and the suspended ceiling from above; and conversely through the ceiling, utility/plenum space, and ceiling deck/floor from below.

[0007] There are two approaches to mitigating the presence of undesired sounds in a space. Sound can be attenuated as it travels from the source and within the room, or it can be covered up by application of masking techniques. The primary role of a ceiling system in promoting privacy in a closed office is to block transmission of sound, and to absorb the sound that strikes the ceiling plane and keep it from reflecting back into the work space. Absorption performance for the critical human speech frequencies between 500-4000 Hz is expressed in terms of the percentage of sound absorbed by the ceiling material. The ability of a ceiling panel to absorb sound (in closed room applications) is measured in terms of the noise reduction coefficient (NRC). An NRC of 0.60 is a recommended value to support the achievement of normal speech privacy and good sound quality in closed offices. In open plan offices, where speech intrusion between cubicles is the primary concern, the applicable ceiling performance is provided by the AC (articulation class) rating of the ceiling. A ceiling AC of a minimum of 170, and preferably 200 or more is recommended for good speech privacy design.

[0008] Conversational distraction and uncontrolled noise are the primary causes of productivity loss within office workspaces. The principle of sound masking involves the introduction of sound in a specified frequency range. The addition of sound at an appropriate level in the frequency spectrum occupied by the human voice provides a masking effect, in essence, drowning out the undesired sounds in such a way that it is not noticeable to the listener. A typical sound masking system includes the following elements:

1. a "pink noise" signal;
2. a means of filtering the signal to provide the desired spectrum of sound;
3. a means of amplification; and
4. a means of creating a uniform sound field in the

area being treated.

[0009] A pink noise signal contains equal amounts of sound energy in each one-third octave band, and covers a broad frequency range which includes the speech spectrum.

[0010] Sound masking is usually accomplished by the introduction of a precisely contoured broadband sound that is constant in level over time, and sufficiently loud to mask conversational distraction and unwanted noise, but not so loud as to be annoying by itself. This sound is similar to that which is attributed to the HVAC system air diffuser. The system generally consists of electronic devices which generate a sound signal, shape or equalize a signal and amplify a signal. This signal is then distributed to an array of speakers that are normally positioned above the ceiling in the plenum on 12 to 15 foot centers. Sound masking systems in open plan offices are typically set at a sound level which corresponds to 48 dBA (dB "A" weighted) +/- 2dB. This sound level generally insures conversational privacy without causing a distraction itself.

[0011] Typical electrodynamic cone loudspeakers have an acoustic radiation pattern that is very dependent upon the frequency of excitation. At low frequencies, these loudspeaker radiate sound fairly uniformly over a broad range of angles. As the frequency of the input wave increases, the sound radiation pattern produced by the loudspeaker becomes more focused and directed on-axis (like a flashlight as opposed to a floodlight). A common 6.5-inch speaker, for example, may have a forward radiation pattern approaching an omni-directional 180 degrees at 250 Hz, but when driven at 4 kHz, the majority of the forward sound energy produced is concentrated in a highly directional beam that is about 15 degrees wide.

[0012] Since conventional dynamic loudspeakers produce a directed, coherent sound field at the frequencies of interest in masking, their utilization to create a uniform, diffuse reverberant field presents a challenge.

[0013] One solution that has often been employed utilizes traditional dynamic loudspeakers mounted above a ceiling. An array of conventional dynamic loudspeakers is mounted above a suspended ceiling and driven by conventional electrical wiring. The loudspeakers are oriented to fire upwards into the hard floor slab above. This provides a longer reflective path for the sound to travel thus more evenly dispersing the sound in the plenum space. The reflected sound passes through the suspended ceiling system, where it may be further dispersed. The penalty for firing the speakers upwards, however, is that considerable additional power is required to drive the speakers to realize the desired sound levels to the listener. Pointing the loudspeakers directly down through the ceiling, or mounting conventional speakers on top of the ceiling panels, would create a non-uniform sound field at the audible frequencies of interest, with some areas sounding louder and other areas

sounding softer. Compensating for this non-uniform sound field would require the use of many more speakers at considerably higher cost. What is needed is a better way to deliver sound to the desired space, and to do so in such a way with a system that is easily installed and simple to configure and change.

[0014] In open plan office design it is desirable to make the entire ceiling highly sound absorbing, thus any disruptions in the ceiling plane such as those caused by air supply and return fixtures, lighting fixtures, and loudspeakers, have a negative effect on speech privacy due to incremental sound reflections. It would be advantageous to have a system that can introduce sound into a room without adding a sound reflective component into the ceiling plane.

SUMMARY OF THE INVENTION

[0015] This specification discloses a system for mounting a flat panel radiator on a suspended ceiling system. The flat panel radiator comprises a stiff radiating panel and a transducer that is composed of a magnet attached to the radiating panel, a voice coil assembly also attached to the panel, an optimized sound absorbing facing attached to the face side of the radiator frame, and wiring to an excitation source.

[0016] Flat panel sound radiators work on the principle that an exciter hooked up to the flat panels causes the panels to vibrate, generating sound. The sound field generated by the flat panel radiator is not restricted to the cone of sound that normal speakers generate. The vibration of the panel generates a complex random ripple of waveforms on the panel surface, which in an ideal model radiates sound in a broad circular pattern much as a floodlight would radiate light over a broad area. This differs from a standard cone speaker which can be considered as a piston, producing a beam of sound, much like a spot light would radiate light in a tight beam. The circular distribution pattern of the flat panel radiator means that the sound levels are equal across a large listening area.

[0017] Flat panel radiators have broad acoustic radiation patterns at the frequencies required for sound masking. As noted, the flat panel radiator includes a light, stiff radiating panel of arbitrary size, and a transducer. The transducer has a magnet clamped to the radiating panel, a voice coil assembly, also attached to the panel, and wiring connected to an excitation source. When electrical current is passed through the voice coil, the resulting combination of electromagnetic field forces with the magnetic field will induce a very small relative displacement, or bending, of the panel material at the mounting points. Rather than the coherent piston-like motion of a cone speaker, the motion of the flat panel is decidedly incoherent, containing many different complex modes spread over the entire surface of the radiator. This effect contributes significantly to the broad radiation pattern and lack of beaming behavior character-

istic of this technology. This can best be achieved through a flat panel made of honeycomb cell-type material, which is lightweight and does not rust. This honeycomb material provides minimal loss and a smooth sound pressure response at low, middle, and high frequency ranges.

[0018] The presence of a standard flat panel sound radiator in an otherwise highly sound absorptive ceiling plane will tend to compromise the speech privacy achievement in specific cases where a panel radiator is directly above, and in line, between two adjacent office spaces since the sound waves would reflect off of the flat panel radiator and into the adjacent office space.

[0019] This invention provides a mounting configuration with an optimized sound absorbing feature as the visual surface for a flat panel radiator. In this configuration a flat panel radiator is placed inside a frame element within a suspended ceiling system, and a specified acoustic facing is attached to the frame element enclosing a layer of air between the facing and the flat panel radiator. If the radiating panel is either directly finished with a lamination or coating, or if an acoustically porous facing is attached with an offset from the radiator surface, then the radiator panel will act as a sound reflector to sounds within the room. The specified facing has specific acoustic characteristics and is strategically placed below the flat panel radiator surface in such a way as to provide effective sound absorption. The facing and the air layer function as a sound absorber, and they can optimize the acoustic rating of the flat panel radiator. The facing also has aesthetic functions.

DESCRIPTION OF THE DRAWINGS

[0020] The invention is better understood by reading the following detailed description of the invention in conjunction with the accompanying drawings, wherein:

Fig. 1 illustrates a prior art sound system arranged to create a uniform, diffused, reverberant sound field.

Fig. 2 illustrates a cross-section of a flat panel radiator that can be utilized in the present invention.

Fig. 3 illustrates the mounting of a flat panel radiator in a standard inverted "T" ceiling grid.

Fig. 4 illustrates an embodiment of a "C"-shaped frame with a variable-sized containment element and an acoustically resistant facing for a flat panel radiator.

Figs. 5A-5B illustrate an alternate embodiment of a C-shaped frame with a variable-sized containment element and an acoustically resistant facing for a flat panel radiator.

Fig. 6 illustrates a cross-sectional view of a flat panel radiator assembly centered in a C-shaped frame with an acoustically resistant facing and equal-sized containment elements.

Fig. 7 illustrates an embodiment of a "L"-shaped

frame with a variable size isolation element and an acoustically resistant facing.

Fig. 8 illustrates a cross-sectional view of a flat panel radiator assembly centered in a C-shaped frame with an isolation element and equal-sized containment elements.

Fig. 9 illustrates an embodiment of a tegular "C"-shaped frame with a variable-sized containment element and an acoustically resistant facing for a flat panel radiator.

Fig. 10 illustrates an embodiment of a tegular "L"-shaped frame with a variable size isolation element and an acoustically resistant facing for a flat panel radiator.

DETAILED DESCRIPTION OF THE INVENTION

[0021] Referring now in more detail to the drawings in which like numerals refer to like parts throughout the several views, Fig. 1 illustrates a prior art speaker arrangement to produce masking noise signals. The speaker arrangement of the current art utilizes traditional dynamic loudspeakers mounted above a ceiling, on 12 to 15-foot centers, as shown in the diagram of Fig. 1. An array of conventional dynamic loudspeakers 100 is mounted above a suspended ceiling 101, powered through conventional wiring 105. The loudspeakers are oriented to fire upwards into the slab 102 above. This arrangement provides a longer path for the sound to travel, and further disperses the sound field 103, depending upon the surface treatment of the hard slab. The sound passes through the suspended ceiling system 101, where it may be further dispersed, so that the sound field 103 at the listener 104 is relatively diffused and consistent, as indicated by the arrows. Pointing the loudspeakers directly down through the ceiling, or mounting conventional speakers atop the ceiling panels, would create a non-uniform sound field at the frequencies of interest, with some areas sounding louder and some sounding softer. Compensating for this would require the use of many more speakers at considerably higher cost. The penalty for firing the speakers upwards, however, is that considerable additional power is required to drive the speakers to realize the desired sound levels to the listener 104.

[0022] An alternative approach to generating sound masking has been the development of flat panel radiator technology. Historical attempts to make high quality flat panel radiators have focused on duplicating the behavior of cone speakers. These efforts have not met with much success until fairly recently. Flat panel radiators are now available that have broad acoustic radiation patterns at the frequencies required for sound masking in an open workplace environment. The flat panel radiator, shown in Fig. 2, includes a light, stiff radiating panel 200 of arbitrary size, and a transducer. The transducer contains a magnet 201 that is clamped to the radiating panel 200, a voice coil assembly 202, also attached to

the radiating panel 200, and electrical wiring 203 connected to an excitation source 204 that is not part of the radiator system. There are at least two embodiments of the transducer that can be used in flat panel products. Fig. 2 shows the "bender" or "clamped" driver. When electrical current is passed through the voice coil 202, the voice coil electromagnetic field interacts with the magnetic field produced by the magnet 201 thus producing a very small relative displacement, or bending, of the panel material 200 between the voice coil 202 and magnet 201 mounting points. Rather than the coherent piston-like motion of a cone speaker, the motion of the flat panel 200 is decidedly incoherent, containing many different complex modes spread over the entire surface of the radiator 200. This effect contributes significantly to the broad radiation pattern and lack of beaming behavior characteristic of this technology.

[0023] In the current art, a flat panel radiator is mounted in a frame to allow its installation in a standard inverted "T" ceiling grid. Fig. 3 shows a section of a ceiling grid, including inverted tee main beams 600, supporting hanger wires 601, and cross tee beams 602. The radiator panel frame element 603 with an attached bridge support element 604 and an enclosure 606 is placed into the grid elements as shown by the dotted lines 605. The enclosure 606 contains a terminal block (not shown) for connecting the transducer to an external-driving source.

[0024] Fig. 4 illustrates an embodiment of a C-shaped frame in which a flat panel radiator is mounted in a variable-sized containment element positioned within the C-shaped frame. The flat panel radiator 200 is supported, and the boundary conditions fixed, by C-shaped variable-sized containment element 212, and placed inside a C-shaped frame 210. A bridge support element 604 is positioned above and across the frame 210. The bridge support element supports box 610 containing electronic components, which are used to drive vibrations on the flat panel radiator 200. The frame 210 has an isolation element 214 below the bottom face of the frame that overlaps with the flanges of the ceiling grid system 600. The isolation element 214 can be made from a resilient material such as foam. The isolation element 214 isolates the flat panel radiator from the grid support elements 600 both mechanically and acoustically and prevents vibrations from the flat panel radiator being transmitted onto the suspended ceiling system. A facing 236 is added as an acoustically resistant covering for the flat panel radiator, and can be fabricated to aesthetically match the rest of the ceiling. The acoustic resistance of the facing is approximately 800 MKS rayls for sound absorption optimization. The acoustic resistance of the facing, in general, should be between 400 and 4000 MKS rayls. As shown, the containment element 212 can be varied in thickness to create a different design depth from the lower surface of the flat panel radiator to the acoustically resistant facing. An optimum spacing for sound absorption purposes in this and the following embodiments is a distance of between one and three inches

from the lower surface of the flat panel radiator to the acoustically resistant facing. In other embodiments, the distance between the acoustically resistant facing and the lower surface of the flat panel radiator can be up to four inches. The depth of the bottom portion of the containment element 212 is expressed as an offset from the bottom of the flat panel radiator to the bottom surface of the bottom plate of the C-shaped frame 210. The facing or scrim in this and in the following embodiments can have an acoustic flow resistance of approximately 800 MKS rayls for optimization.

[0025] Figs. 5A-5B illustrate alternate embodiments of the C-shaped frame in which the variable-sized containment element does not itself need to be C-shaped. The containment elements 218, 228 are positioned at the top and bottom of the flat panel radiator 200, respectively. Containment element 228 can be of a variable depth in order to position the flat panel radiator at an optimum distance for sound absorption from the acoustically resistant facing 236. In Fig. 5A, the acoustically resistant facing 236 is attached to the upper surface of isolation element 214. In Fig. 5B, the acoustically resistant facing 236 is attached to the lower surface of the isolation element 214. In cases where the containment elements 218 and 228 are chosen to be sufficient to isolate the flat panel radiator, then isolation element 214 may not be necessary.

[0026] Fig. 6 illustrates a cross-sectional view of one embodiment of a flat panel radiator assembly including a C-shaped frame 704 and equal-sized containment elements 708 that center and fix the boundary conditions of the flat panel radiator 200 in the frame 704. The flat panel radiator assembly is mounted in a suspended ceiling system that comprises ceiling grid support elements 600 that surround the location of the radiator installation and connect the assembly to a plurality of similar elements. Although grid support element 600 is depicted as having flanges, any type of tab structure can be used instead of flanges for providing the same support function for the frame element 704. The flat panel radiator 200 fits into a rectangular frame element 704 that has a C-shaped cross-section formed by a top plate, a side plate, and a bottom plate. Each plate has a standard size and thickness in order to be placed between the ceiling grid support elements 600. A bridge-supporting element 604, which is attached along the top surface of opposite sides of the rectangular frame element 704, provides a mounting structure for a terminal box. An acoustic transducer assembly 706 of the kind shown in Fig. 2, or similar design, is mounted to a flat panel radiator 200. A rectangular radiating panel/element 200 of a size slightly less than the inside dimensions of the rectangular frame element 704 is centered within the rectangular frame element 704 and attached to the acoustic transducer 706. Equal-sized containment elements 708 that may be attached by adhesive to the inside surfaces of the rectangular frame element 704 support the perimeter edge of the radiating panel 200. An isolation ele-

ment 214 is affixed to the bottom plate of frame 704 to isolate the radiator from the rectangular frame element 704. The transducer's wiring 203 is routed through the terminal box to an external power source (not shown).

[0027] Fig. 7 illustrates an embodiment of an L-shaped frame as opposed to a C-shaped frame. In this case, the edge of the flat panel radiator 200 cannot be clamped, and the variable-sized isolation element 214 both holds the flat panel radiator 200 in place with an adhesive material, and isolates the flat panel radiator mechanically and acoustically from the ceiling grid structure 600. More importantly, the isolation element 214 is of variable depth and is used to position the flat panel radiator 200 at a certain height above an acoustically resistant facing 236 which is attached to the lower surface of the L-shaped frame element 220.

[0028] Fig. 8 illustrates an embodiment of the present invention in which a flat panel radiator is mounted through an isolation element in a suspended ceiling. The flat panel radiator 200 is supported by two equal-sized resilient containment elements 708, one on each side of the flat panel radiator, and placed inside a frame element 704 of a C-shaped cross-section. A bridge support element 604 is placed above and across the frame element 704. The frame element 704, which is slightly larger than the openings of the suspended ceiling system, has a resilient isolation element 806 attached to its bottom face that overlaps with the flanges of the ceiling system. Any type of tab structure can be used instead of flanges for providing the same support function for the frame element. In one embodiment, the resilient containment element and isolation elements cover the entire perimeter of the radiator's flat panel. An example of the resilient isolation element 806 and containment elements 708 is a foam material. The isolation element 806 isolates the flat panel radiator from both the grid support elements 700 mechanically and acoustically and prevents vibrations from the radiator panel onto the suspended ceiling system. A facing or scrim 810 is added as an acoustically resistant cover for the flat panel radiator.

[0029] Figs. 3 through 8 illustrate simple lay-in mounting configurations. In these configuration a flat panel radiator 200 can be installed into a standard suspended ceiling system 101 (Fig. 1) by laying it between the inverted "T" grid elements 600, as shown, for example, in Fig. 6. The radiating surface 200 of the flat panel radiator is roughly even with, or even slightly above, the plane of the ceiling grid. An acoustically resistant facing or scrim 710 added to cover the flat panel radiator provides a sound absorption function.

[0030] Fig. 9 illustrates an embodiment of a tegular "C"-shaped frame with a variable-sized containment element and acoustically resistant facing for a flat panel radiator. The variable-sized C-shaped containment element 212 is placed inside the tegular C-shaped frame element 230. The tegular C-shaped frame element 230 includes a lower plate, a first side plate, an upper plate,

a second side plate, and a top plate. The lower plate and first side plate extend below the bottom of the ceiling grid 600. The acoustically resistant facing 236 is attached to the lower surface of the lower plate of frame 230. By varying the depth of the lower portion of the C-shaped containment element 212, the distance between the flat panel radiator and the acoustically resistant facing can be optimized for sound absorption. Isolation element 214 isolates the frame from the ceiling grid both mechanically and acoustically.

[0031] Fig. 10 illustrates an embodiment of a tegular L-shaped frame with a variable-sized isolation element. In this embodiment, the edge of the flat panel radiator 200 cannot be clamped, and the variable-sized isolation element 214 functions both to hold the flat panel radiator in place with an adhesive and to provide isolation. More importantly, it serves to position the flat panel radiator 200 at an optimum height above an acoustically resistant facing for sound absorption purposes. The tegular L-shaped frame 240 is positioned on the ceiling grid structure and has a side and a bottom plate that extend below the ceiling grid flanges. The acoustically resistant facing 236 is attached to the bottom plate of the tegular L-shaped frame 240.

[0032] Although the present invention has been described in the context of a ceiling grid system, the sound radiator and assembly system can also be used in a grid structure of a wall or wall partition having discrete panels similar to those used for the ceiling grid. In particular, the flat panel radiator would be supported in the same way but with the radiator positioned vertically, rather than horizontally between the upper and lower plates of the frame element. In addition the acoustic scrim can be affixed to edges of the frame element facing into the listening area to again cover the opening created by the main beams and cross beams of a wall partition. The scrim would be acoustically resistant as described above.

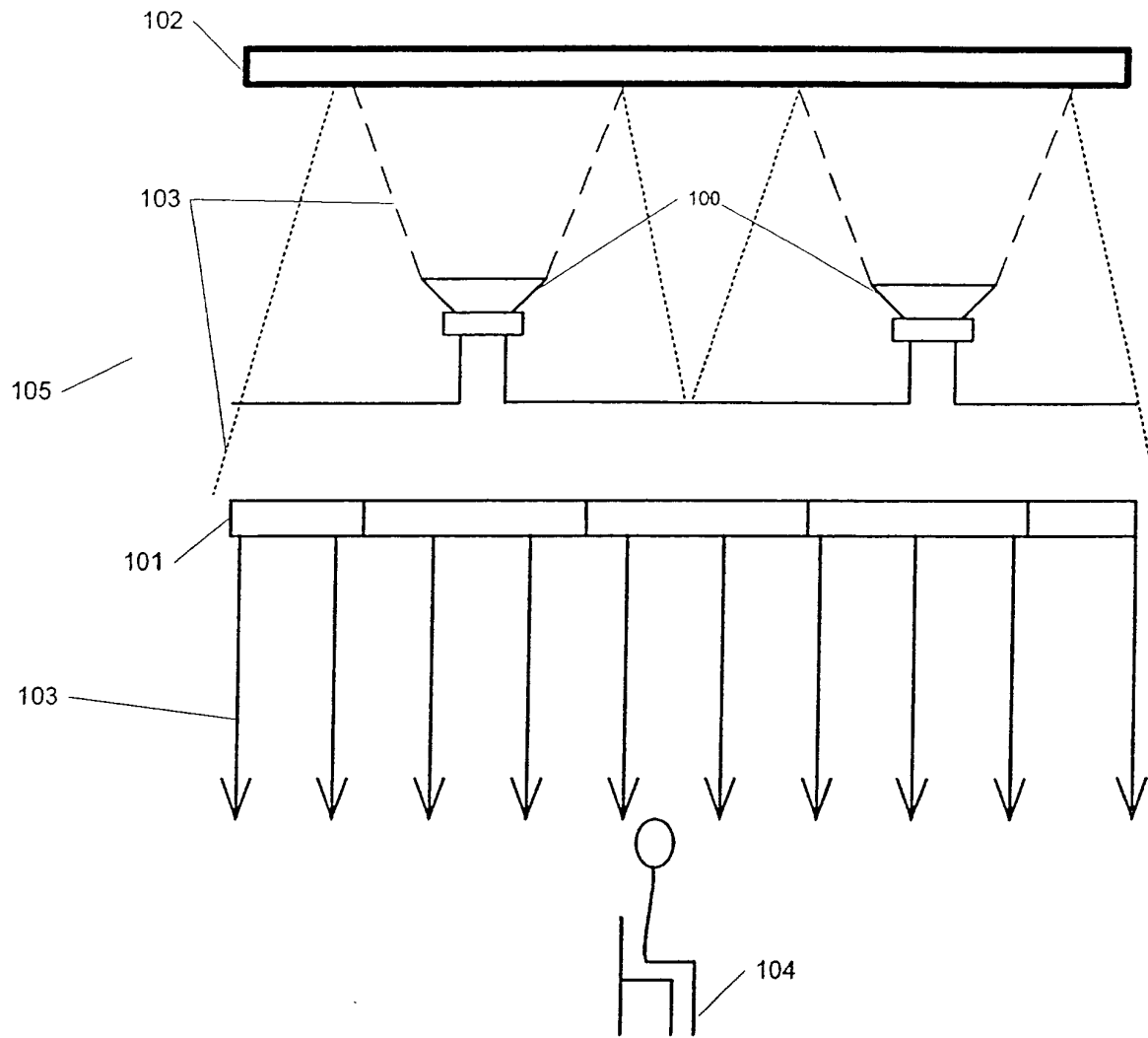
[0033] The corresponding structures, materials, acts, and equivalents of any means plus function elements in any claims below are intended to include any structure, material, or acts for performing the functions in combination with other claimed elements as specifically claimed.

[0034] Although the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and detail may be made without departing from the spirit and scope of the present invention.

Claims

1. A flat panel radiator/sound absorbing apparatus comprising a flat panel sound radiator and an acoustically resistant facing spaced apart from the flat panel radiator.

2. The flat panel radiator/sound absorbing apparatus of claim 1 wherein a layer of air is interposed between the acoustically resistant facing and lower surface of the flat panel radiator to increase the low to mid-frequency sound absorption by the apparatus. 5
3. The flat panel radiator/sound absorbing apparatus of claim 1 wherein the acoustically resistant facing is spaced apart from the lower surface of the flat panel radiator at a distance up to about four inches. 10
4. The flat panel radiator/sound absorbing apparatus of claim 3 wherein the acoustically resistant facing is spaced apart from the lower surface of the flat panel radiator at a distance of between about 1 inch and about 3 inches. 15
5. The flat panel radiator/sound absorbing apparatus of claim 1 wherein the acoustically resistant facing has an acoustic flow resistance from about 400 MKS rayls to about 4000 MKS rayls. 20
6. The flat panel radiator/sound absorbing apparatus of claim 5 wherein the acoustically resistant facing has an acoustic flow resistance from about 500 MKS rayls to about 2000 MKS rayls. 25
7. The flat panel radiator/sound absorbing apparatus of claim 6 wherein the acoustically resistant facing has an optimized acoustic flow resistance of approximately 800 MKS rayls. 30
8. The flat panel radiator/sound absorbing apparatus of claim 1 wherein the apparatus is contained in a ceiling system. 35
9. The flat panel radiator/sound absorbing apparatus of claim 1 wherein the apparatus is contained in a structure selected from the group consisting of a fixed wall and a moveable wall partition. 40
10. The flat panel radiator/sound absorbing apparatus of claim 1 wherein the radiator panel vibrates to produce a generally circular sound pattern that is uniform over a predetermined listening area. 45
11. The flat panel radiator/sound absorbing apparatus of claim 1 wherein the radiator panel is supported on a grid structure and the apparatus includes an isolation element which isolates the radiator panel both mechanically and acoustically from the grid structure. 50
12. The flat panel radiator/sound absorbing apparatus of claim 11 wherein the isolation element is interposed between the frame and the grid structure to both mechanically and acoustically isolate the frame from the grid structure. 55
13. The flat panel radiator/sound absorbing apparatus of claim 1 wherein the radiator panel is supported on a grid structure and the apparatus includes an isolation element which isolates the radiator panel both mechanically and acoustically from the grid structure, and a containment element which captures the flat panel radiator and fixes its boundary condition.
14. The radiator panel/sound absorbing apparatus of claim 1 wherein the radiator panel is supported on a grid structure and the apparatus includes a frame element design selected from the group consisting of lay-in and tegular.



PRIOR ART

FIG. 1

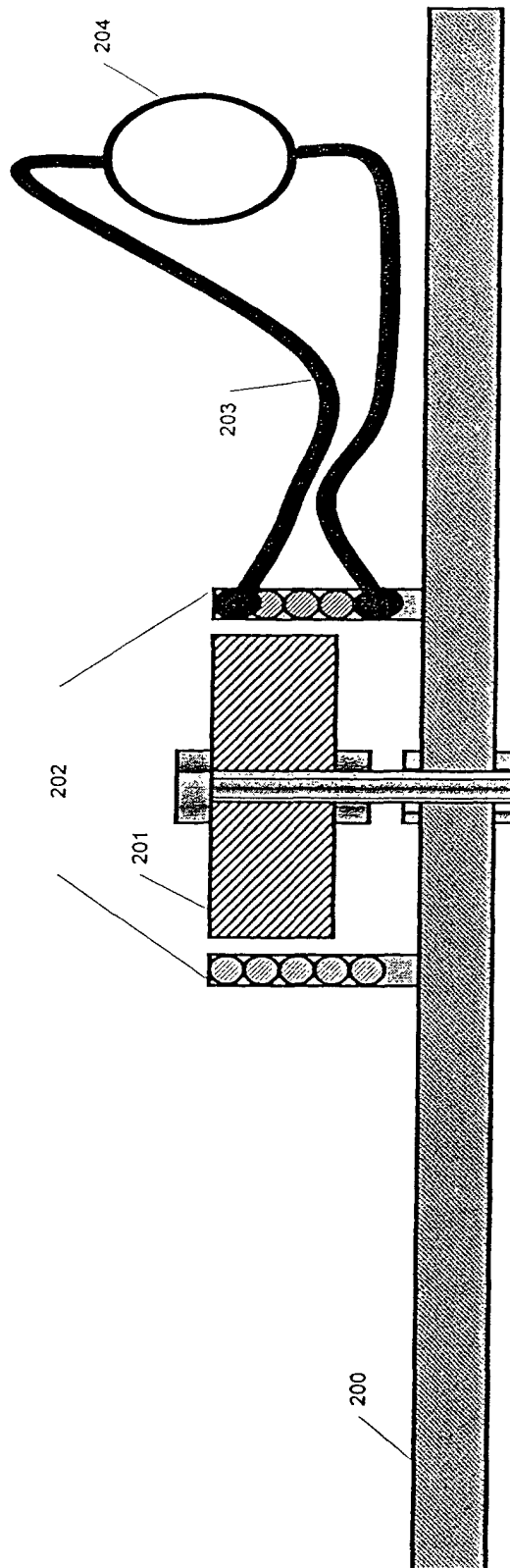


FIG. 2

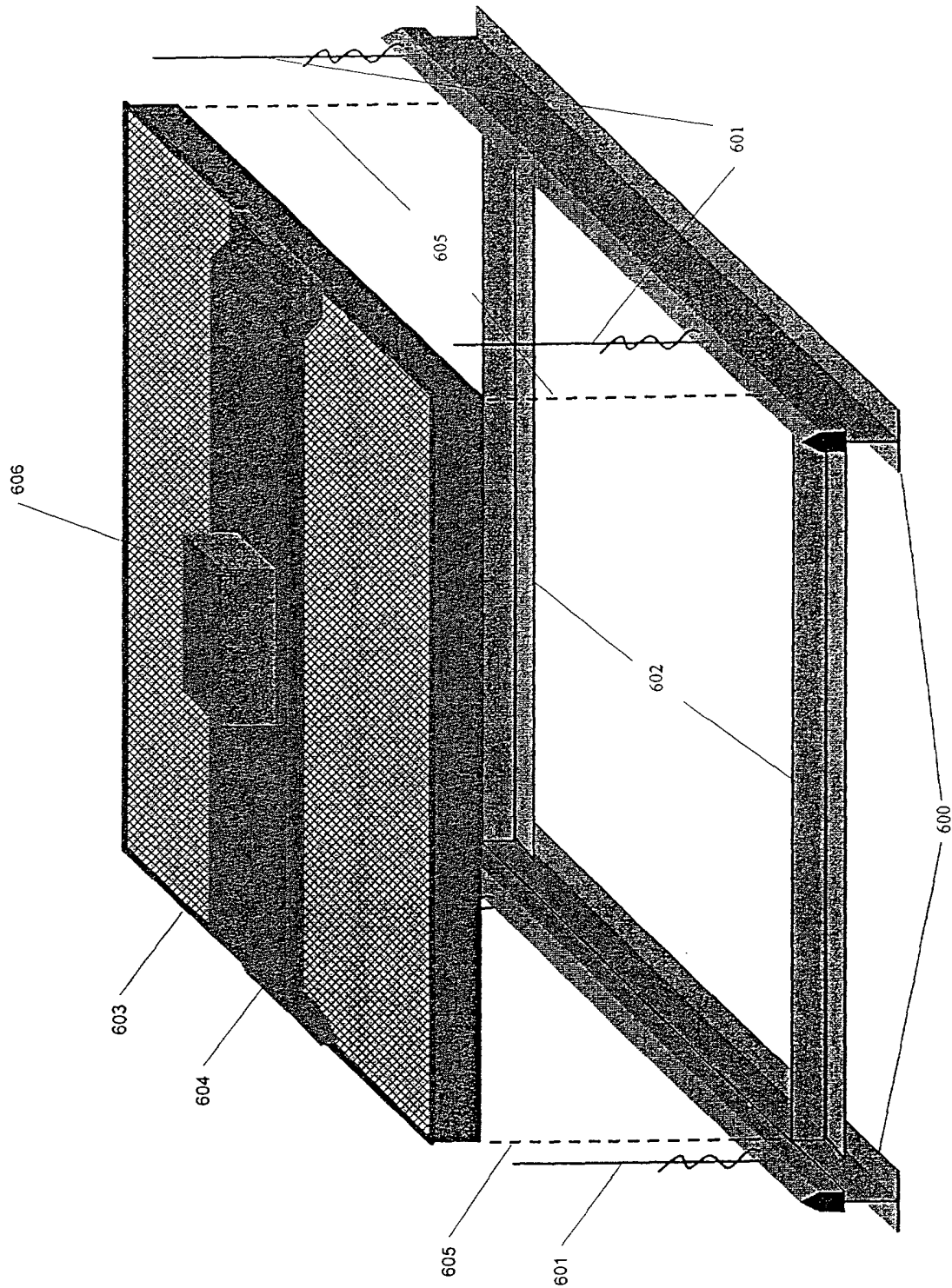


FIG. 3

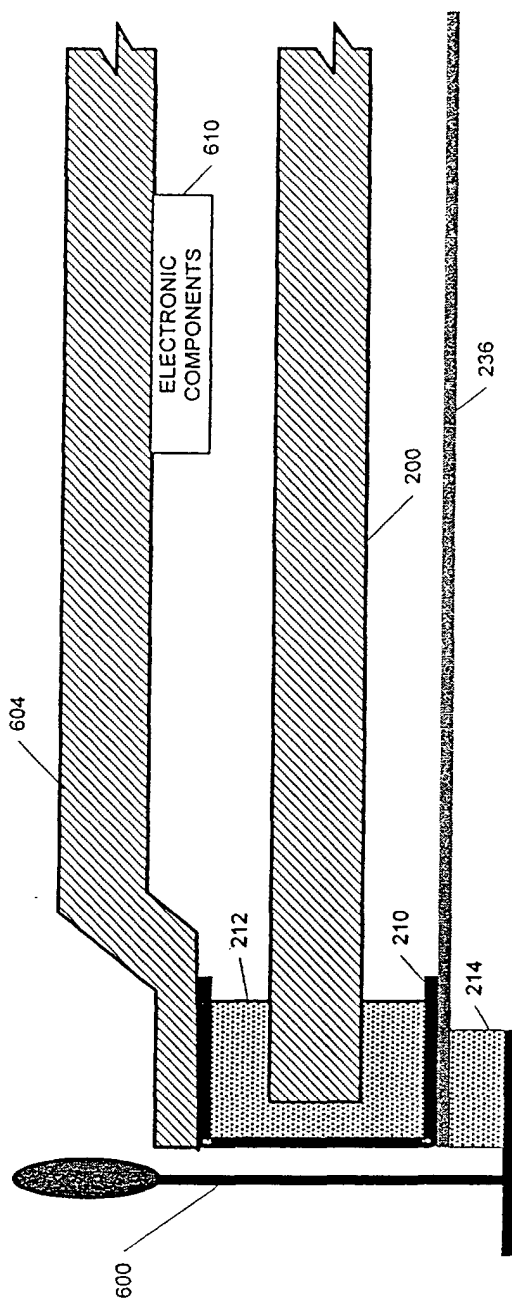


FIG. 4

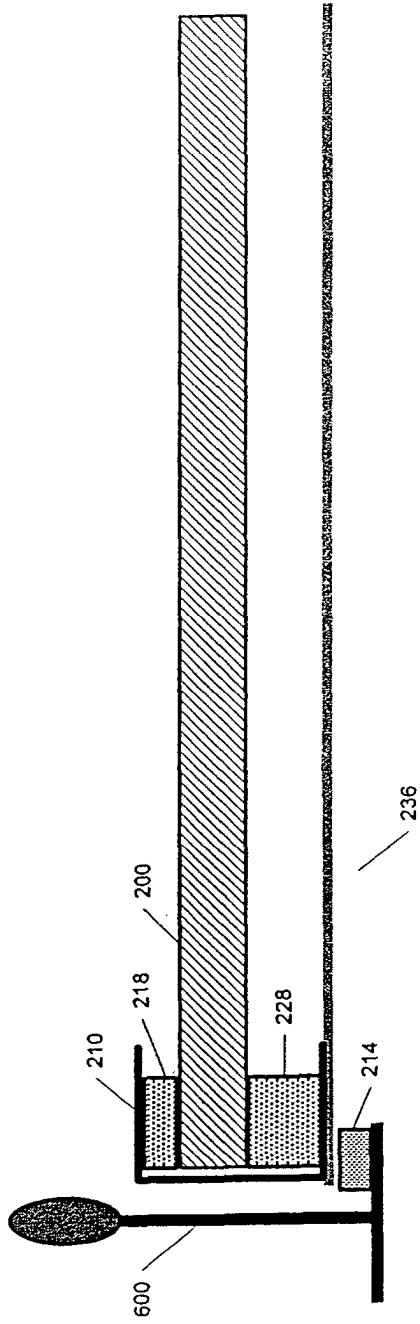


FIG. 5A

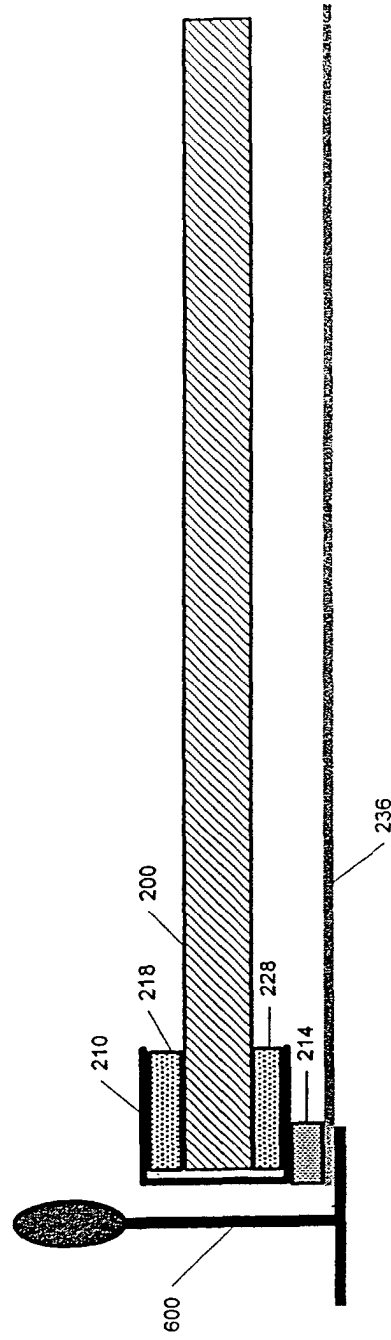


FIG. 5B

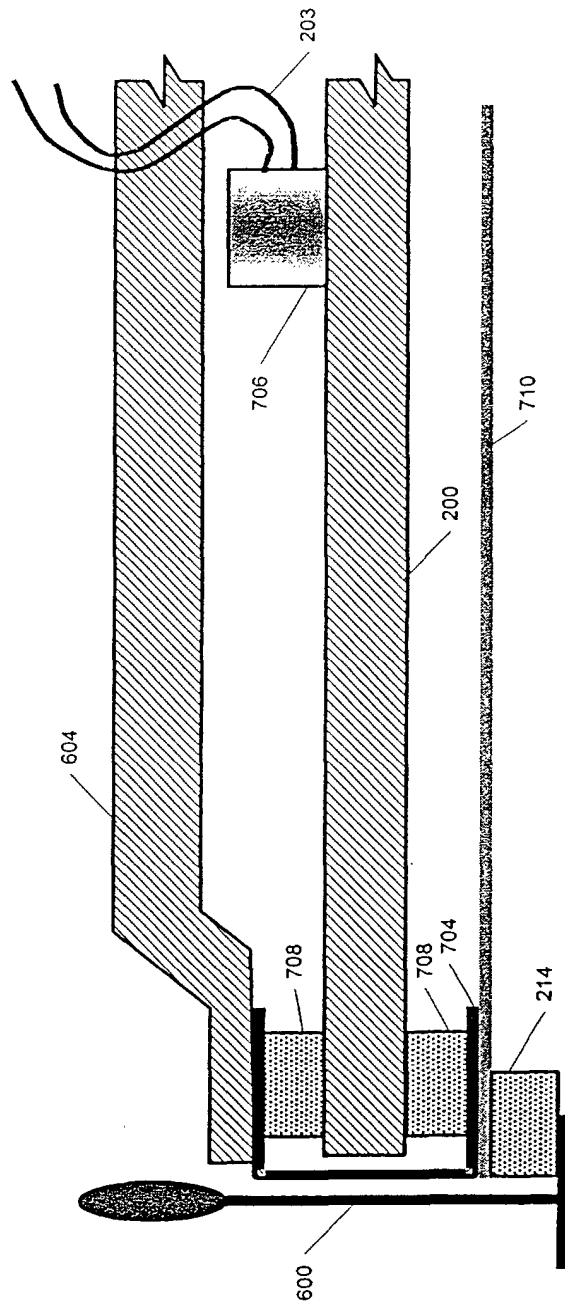


FIG. 6

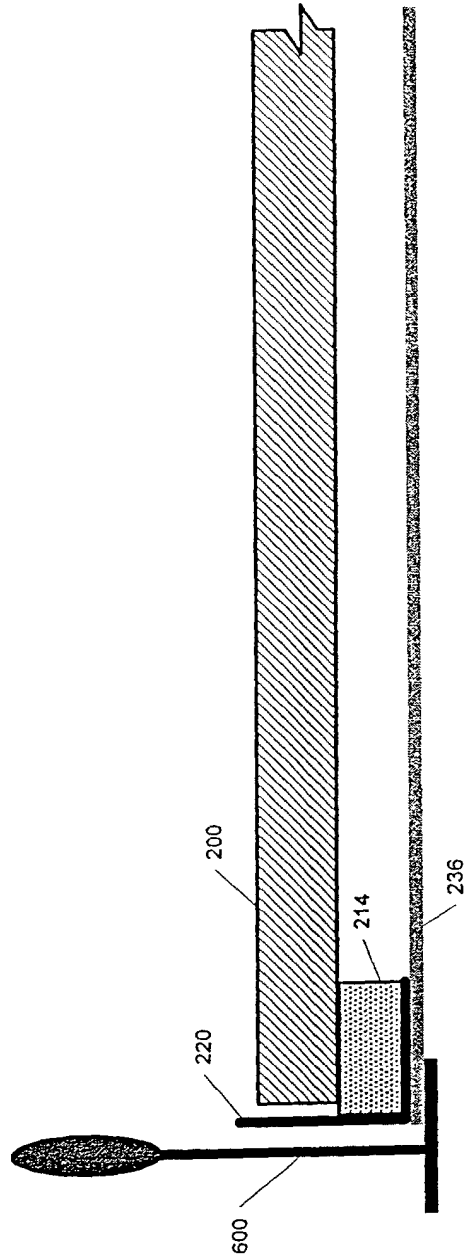


FIG. 7

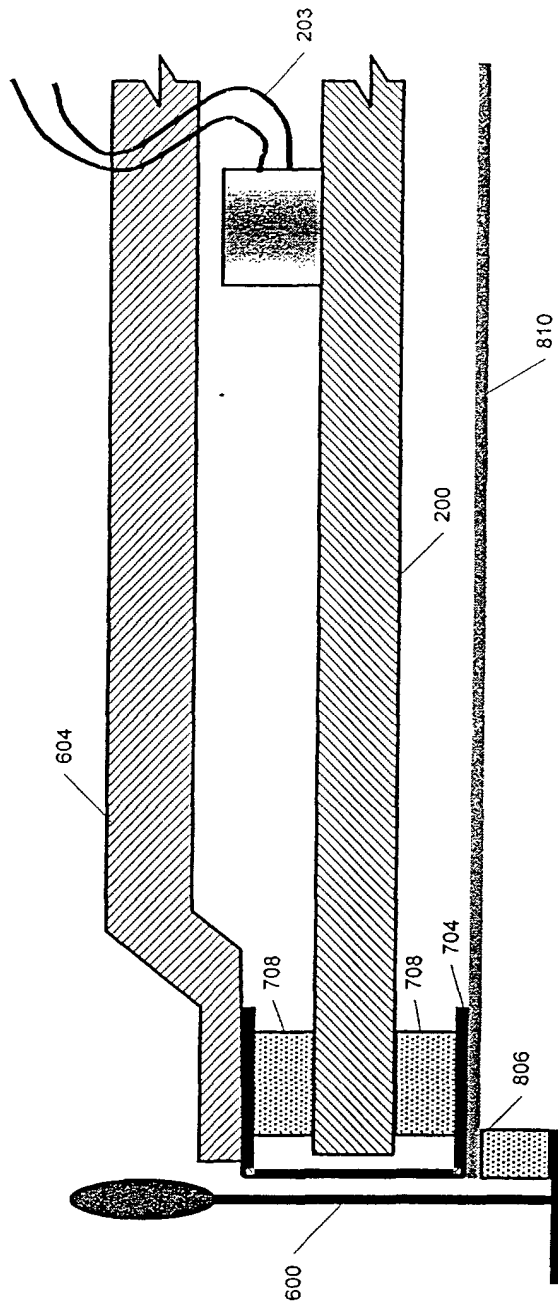


FIG. 8

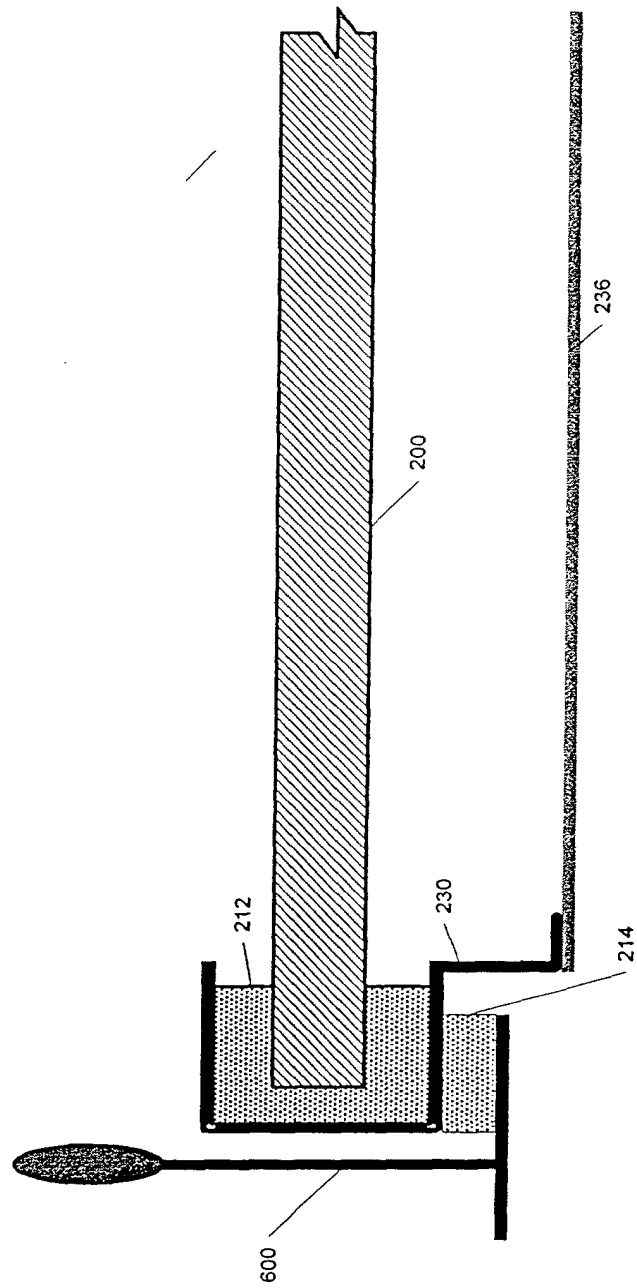


FIG. 9

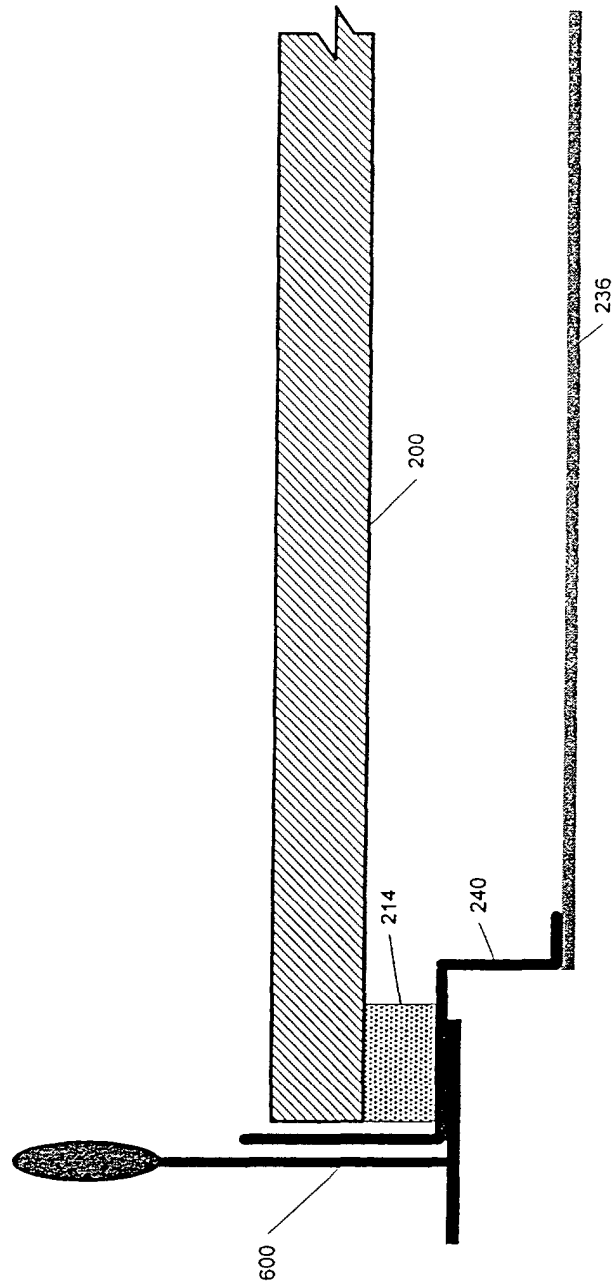


FIG. 10



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 12 3980

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 4 385 210 A (MARQUISS STANLEY L) 24 May 1983 (1983-05-24) * column 4, line 30 - column 6, line 31; figure 5 *	1-4,9,10	H04R9/06 E04B9/00
Y	---	5-7	
X	US 4 330 691 A (GORDON THEODORE J) 18 May 1982 (1982-05-18) * column 2, line 42 - column 5, line 61; figures 8,14 *	1-4,8, 11-14	
Y	GB 1 496 663 A (CHAMPION INT CORP) 30 December 1977 (1977-12-30) * claim 1 *	5-7	
A	US 4 923 032 A (NUERNBERGER MARK A) 8 May 1990 (1990-05-08) * figure 1 *	11-14	
A	WO 97 09843 A (AZIMA HENRY ;HARRIS NEIL (GB); COLLOMS MARTIN (GB); VERITY GROUP P) 13 March 1997 (1997-03-13) * claim 1; figure 3B *		TECHNICAL FIELDS SEARCHED (Int.Cl.7)
A	US 4 928 312 A (HILL AMEL) 22 May 1990 (1990-05-22) * claim 1; figures 2,3 *		H04R E04B
The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 15 January 2002	Examiner Rosborough, J
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document</p>			

EPO FORM 1503 03 82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 01 12 3980

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

15-01-2002

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4385210 A	24-05-1983	CA 1180437 A1	01-01-1985
		DE 3171229 D1	08-08-1985
		EP 0048434 A1	31-03-1982
US 4330691 A	18-05-1982	NONE	
GB 1496663 A	30-12-1977	NONE	
US 4923032 A	08-05-1990	NONE	
WO 9709843 A	13-03-1997	AT 177579 T	15-03-1999
		AT 177574 T	15-03-1999
		AT 177580 T	15-03-1999
		AT 177575 T	15-03-1999
		AT 186617 T	15-11-1999
		AT 177581 T	15-03-1999
		AT 177582 T	15-03-1999
		AT 177583 T	15-03-1999
		AT 177578 T	15-03-1999
		AT 177576 T	15-03-1999
		AT 179297 T	15-05-1999
		AT 177577 T	15-03-1999
		AT 179563 T	15-05-1999
		AT 176826 T	15-03-1999
		AT 179045 T	15-04-1999
		AT 179296 T	15-05-1999
		AT 177281 T	15-03-1999
		AT 179564 T	15-05-1999
		AT 177282 T	15-03-1999
		AT 179043 T	15-04-1999
		AT 179044 T	15-04-1999
		AU 702865 B2	11-03-1999
		AU 6880196 A	27-03-1997
		AU 702920 B2	11-03-1999
		AU 6880296 A	27-03-1997
		AU 702867 B2	11-03-1999
		AU 6880396 A	27-03-1997
		AU 703015 B2	11-03-1999
		AU 6880496 A	27-03-1997
		AU 702863 B2	11-03-1999
		AU 6880596 A	27-03-1997
		AU 702873 B2	11-03-1999
		AU 6880696 A	27-03-1997
		AU 702999 B2	11-03-1999
		AU 6880796 A	27-03-1997
		AU 703061 B2	11-03-1999

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 01 12 3980

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

15-01-2002

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9709843 A	AU	6880896 A	27-03-1997
	AU	703000 B2	11-03-1999
	AU	6880996 A	27-03-1997
	AU	703071 B2	11-03-1999
	AU	6881096 A	27-03-1997
	AU	703058 B2	11-03-1999
	AU	6881296 A	27-03-1997
	AU	705592 B2	27-05-1999
	AU	6881396 A	27-03-1997
	AU	703296 B2	25-03-1999
	AU	6881496 A	27-03-1997
	AU	699890 B2	17-12-1998
	AU	6881596 A	27-03-1997
	AU	703198 B2	18-03-1999
<hr/>			
US 4928312 A	22-05-1990	NONE	
<hr/>			