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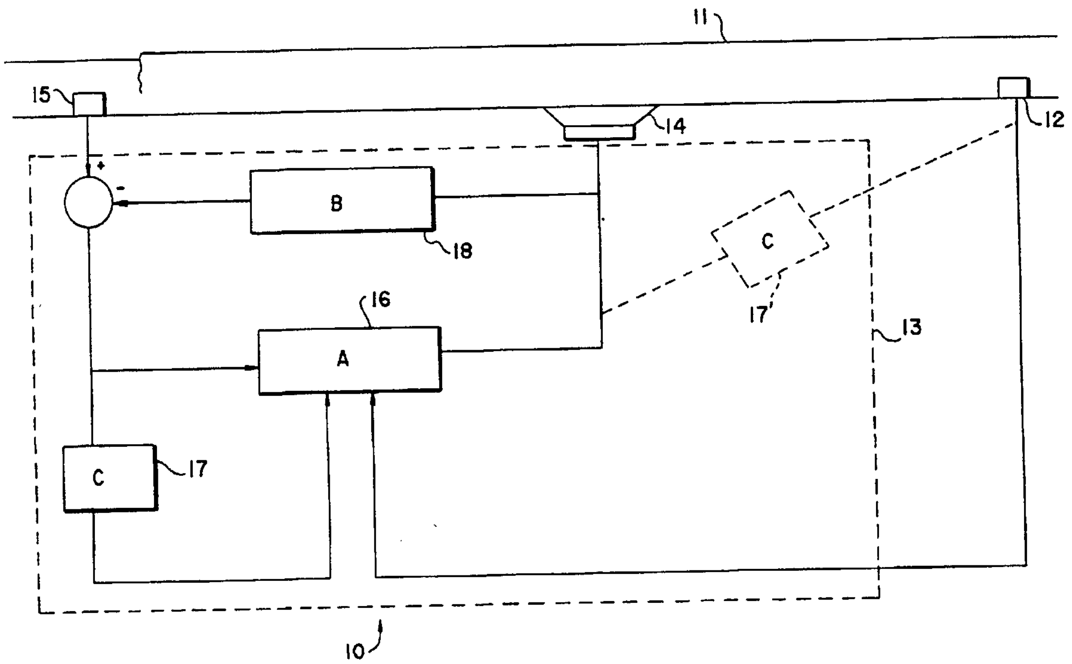
(54) Title: BROAD BAND ZONAL CANCELLATION IN A SHORT DUCT



(57) Abstract

A noise canceling system which utilizes an adaptive feedforward algorithm and inputs from microphones (12, 15) to model the system and provide an output signal to a speaker (14) in a relatively short duct (11, 33) to provide volumetric attenuation and a global canceling effect.

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BROAD BAND ZONAL CANCELLATION IN A SHORT DUCT

This invention relates to an active acoustic attenuation system that is used to attenuate broad band noise at the end of a short duct. The attenuation is zonal at the end of the duct. The system can be used to attenuate broad band noise generated by centrifugal fans, rotating machinery or other noise generators. All of the following text relates to tonal noise also, but since broad band is much more difficult to cancel it is used in all examples.

Background and Summary of the Invention

Aerodynamic noise from fans is a major noise source in air moving appliances and systems that need cooling air. Examples are exhaust fans, computer cooling fans, fans to cool refrigeration coils, etc. This noise consists of both tonal and broad band components.

The rotational component of noise is due to volume displacement effects of the moving surface of the fan's impeller blades and to unsteady forces applied by the solid surface on the flow or vice versa. This noise is generated by a pressure pulsation as the blades pass a stationary point such as the cutoff in a centrifugal fan. The vortex component is turbulent noise caused by vortices breaking away from the edges or along the sides of the fan blades and/or other locations. Therefore, the resultant noise spectrum consists of a blade passage tonal (with harmonics) on a broad band background.

A common method used to reduce fan noise is to mount the fan in a housing that passively contains the noise, allowing noise to be heard only in the fan inlet and outlet. Ducts lined with acoustically absorbent material can then be used to attenuate the noise, but they necessarily increase the dimensions of the system. In addition, this passive absorption is only feasible and cost effective above 1000 Hz.

Active attenuation is feasible and a very cost effective way to reduce the lower frequency noise of the broad band background and tonals.

There are two main approaches to active noise attenuation. The first is to process the primary noise and inject it back into the sound field in anti-phase. This feedforward approach has been used for both tonal and random noise. The second approach is to synthesize the secondary waveform, with or without prior knowledge of the primary noise physical noise generator of the system, e.g., the rotation of a fan wheel. This approach is particularly effective with strong tonal noise. Any active noise control system consists of the primary noise source (compressor, fan, etc.), secondary noise source (loudspeaker), detector (tachometer, microphone) and electronic controller.

This invention utilizes an adaptive feedforward algorithm and incorporates by reference U.S. Patent 4,122,303 to Chaplin et al, U.S. Patent 4,153,815 to Chaplin et al, U.S. Patent 4,480,333 to Ross, U.S Patent 4,862,506 to Landgarten, and U.S. Patent 4,878,188 to Ziegler.

Previous fan attenuation solutions have specified several duct diameters between the noise source and secondary source and also several duct diameters between the secondary source and the detector. This constraint makes the active solution impractical for a large range of applications because of the extra space required.

With this invention, it is now possible to achieve a broad band zonal type attenuation at the end of a short duct. This feature will allow for wide range of industrial, commercial and consumer product applications.

Accordingly, it is an object of this invention to provide an adaptive active noise cancellation system for short ducts.

It is a further object of this invention to provide an adaptive noise cancellation system for stove range hoods and the like.

These and other objects will become apparent when reference is had to the accompanying drawings in which

Figure 1 is a diagrammatic view of the invention,

Figure 2 is a simplified view of the relationship of the duct to the noise canceling system,

Figure 3 is a front view of a range hood incorporating this invention,

Figure 4 is a side view of the range hood of Figure 3,

Figure 5 shows the front and side views of the electronics enclosure shown in Figures 3 and 4, and

Figure 6 is a sectional view of the range hood duct taken along line B-B of Figure 3.

Detailed Description of the Invention

The system 10 uses an Adaptive Feedforward algorithm to attenuate the broadband and tonal noise propagating in the duct, seen generally in Figure 1. The upstream microphone 15 senses the noise as it enters the duct. As the noise propagates down the duct, the processor 13 models the effect of the duct on the noise and then outputs an anti-noise signal through the speaker 14. The finite time the processor takes to sample, process and output the anti-noise signal determines the minimum length of the duct. The second microphone 12 samples the result of the mixing of the noise and anti-noise. This signal is used to adapt the feedforward A filter 16 coefficients. The C filter 17 is a model of the path from the controller to the residual microphone 12. It is necessary for convergence of the A filter.

One unique aspect of this system is the B, or feedback, filter 18. This filter is used to subtract the output of the speaker 14 from the upstream microphone 15. Thus the placement of the upstream microphone is not critical.

Another unique feature of the short duct cancellation system is that the assumption of plane wave propagation and cancellation is relaxed. In longer ducts, i.e., many duct diameters before and after the speaker, the assumption calls for plane wave propagation. This system, however, produces a zonal or volumetric attenuation around the residual microphone 12. Proper placement of the residual thus produces a global canceling effect at the end of the duct. This is the feature desired in most industrial or commercial applications.

A typical system 20 is seen in Figure 2. The airflow is going into the fan. The system consists of a motor 23 and fan wheel 21, plenum 22, short duct 24, and active attenuation electronics 25. The fan wheel as tested had thirty nine blades. It was mounted in a scroll and discharged into a filter that simulated typical system backpressures. An acoustically designed plenum 22 sits over the fan motor and wheel and serves as the interface between the fan and the duct. Next to the plenum is the short duct with an overall length of less than thirteen inches. One side of the duct in the tests contained a small amount of acoustically absorbent material 29 for passive attenuation of higher frequencies. A nominal duct cross sectional area of 3 by 8 inches was chosen and resulted in a linear velocity of 500 fpm.

The active control system consisted of an electronic controller 25, two microphones 26, 27 and a three inch diameter loudspeaker 28. One detector microphone is located just inside the duct nearest the fan and behind the absorbent material 29. The secondary source loudspeaker 28 has its center located 9.5 inches from the upstream microphone. A second microphone 26 is located at the end of the duct furthest from the fan and detects the residual noise.

Practical applications often dictate broad band noise attenuation. Performance can be limited in short ducts and several criteria must be satisfied simultaneously for the active attenuation system to work in a short duct - spatial matching of noise and anti-noise, coherence, filter lengths, stability and causality.

Current literature depicts several duct diameters from the noise source to the secondary source and then several duct diameters from the secondary source to the residual microphone still inside the duct. This invention produced results concerning cancellation in constrained spaces by essentially truncating the duct just after the speaker.

In applications where space is at a premium and small zonal cancellation is acceptable, the system described herein works within the constraints described above.

Figures 3, 4, 5 and 6 show a production model of a range hood 30 incorporating the teachings of this invention. It constitutes a housing 31 having a bottom plate 32 with its aperture to short duct 33 which extends upward to a plenum 34 in which a fan (not shown) is adapted to provide negative pressure in the duct. An electronics enclosure 35 is adjacent the bottom of the duct and contains a controller 36 having a speaker 37.

The front of the duct has passive quieting which consists of acoustic packing 38 within a perforated metal liner 39. An upstream microphone 40 is located in the adjacent passive packing 38. The other microphone is located at the entrance to the range hood duct at 41 (Figure 3). The passive quieting unit is removable.

CLAIMS

1. An active noise control system adapted to attenuate broadband and/or tonal acoustic noise from any noise source, said system comprising

a duct means having an inlet at one end,

a first noise sensor means located adjacent said first end of said duct means,

a speaker means located upstream relatively close to said first noise sensor means relative to the length of said duct means,

a second noise sensor means located in said duct means upstream from said speaker means,

controller means operatively connecting said first and second sensor means and said speaker means and adapted to use an adaptive feedforward algorithm to attenuate the noise propagating in said duct means.

2. An active noise control system as in claim 1 wherein said first sensor means is an error microphone and said controller means is adapted to model the effect of the duct on the noise and to output a canceling noise signal through said speaker means.

3. An active noise control system as in claim 1 wherein said controller means includes feedforward filter coefficients and a filter means simulating the path from the controller to said second sensor means.

4. An active noise control system as in claim 1 wherein said controller means includes a feedback filter means which is adapted to subtract the output of said speaker means from the output of said second sensor means.

5. An active noise control system as in claim 1 wherein a plenum means transition from noise source to duct is located on said duct means upstream from said second sensor means.

6. An active noise control system as in claim 5 wherein the length of said duct means is short enough between said speaker means and said first sensor means so to produce a volumetric attenuation around said first sensor means which is so placed so as to produce a global canceling effect rather than plane wave propagation.

7. An active noise control system as in claim 6 wherein said duct means from said speaker means to said second sensor means minimum distance is determined by delays through said electronic means, said processor means and said speaker means and maximum distance is determined by the particular application.

8. An active noise control system as in claim 6 wherein said duct means includes passive quieting means on one or more sides thereof.

9. An active noise control system as in claim 6 wherein said system is a range exhaust hood and includes a fan means located so as to draw air up said duct and through said plenum.

10. An active noise control system as in claim 6 wherein said system encloses the primary noise source and directs the noise through said duct.

11. An active noise control system as in claim 6 wherein said controller means includes feedforward coefficients and a filter means adapted to simulate the path from the controller means to said first sensor means.

12. An active noise control system as in claim 6 wherein said controller means includes a feedback filter means which is adapted to subtract the output of said speaker means from the output of said second sensor means.

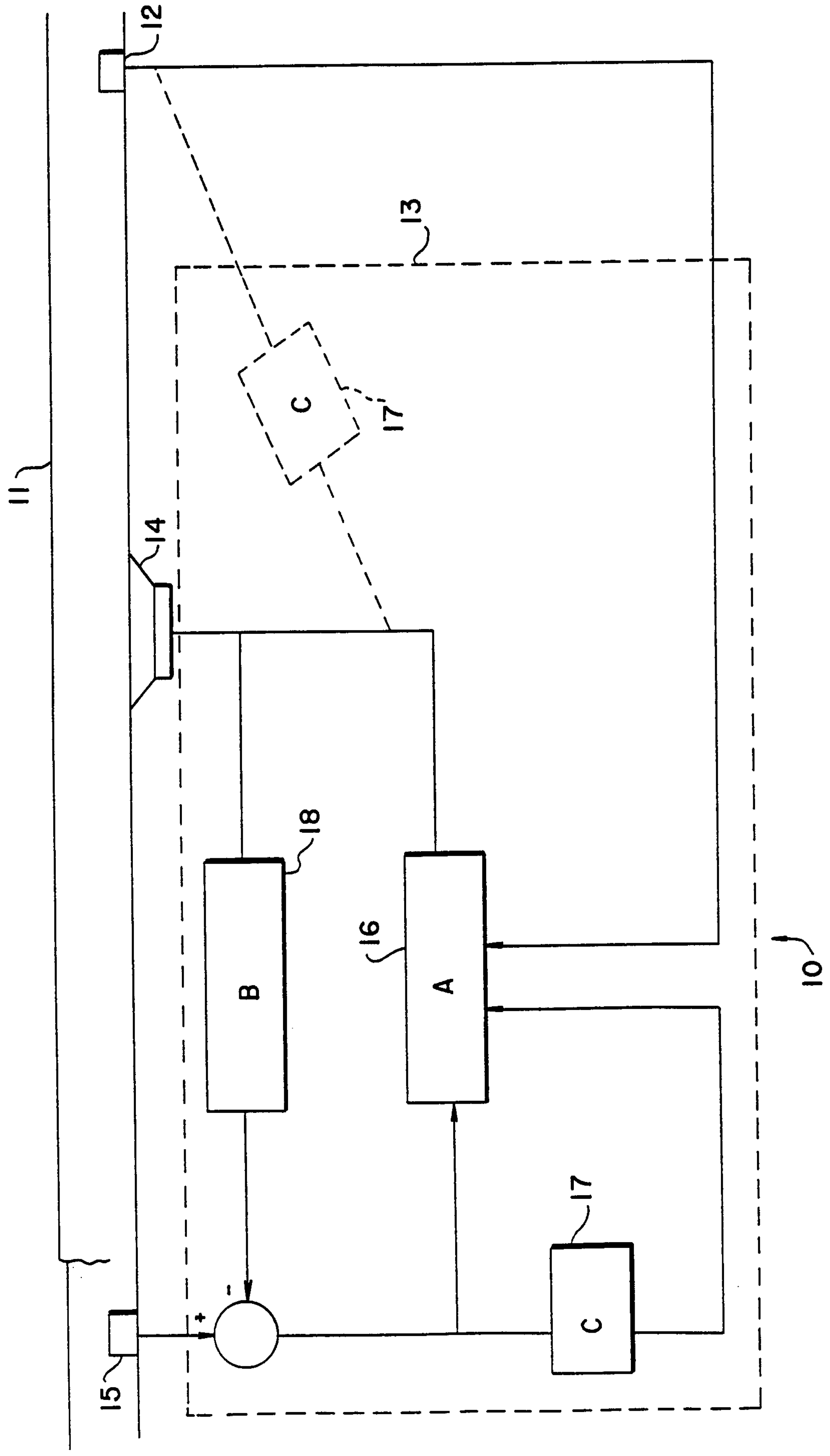

FIG.1

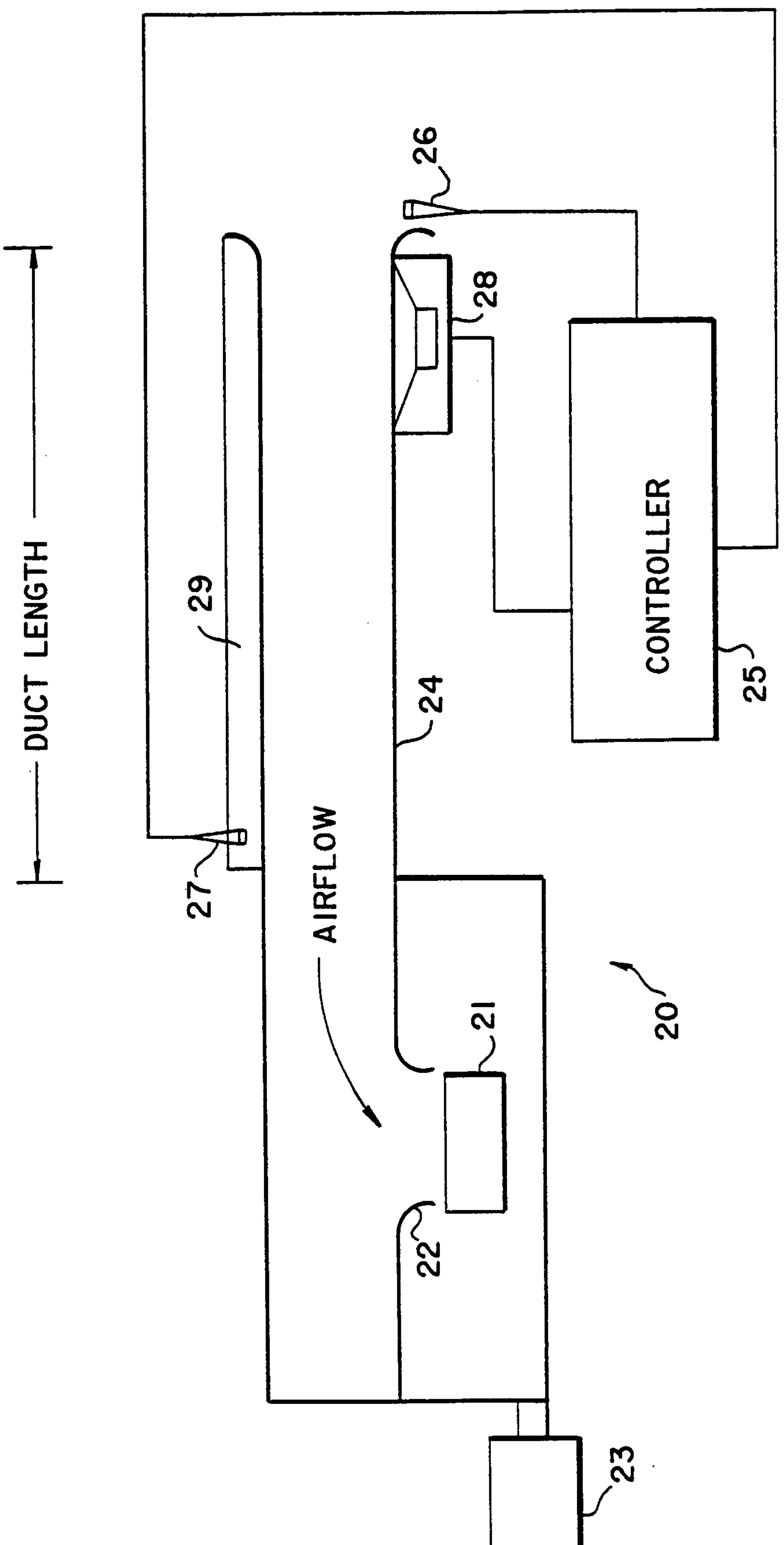

FIG.2

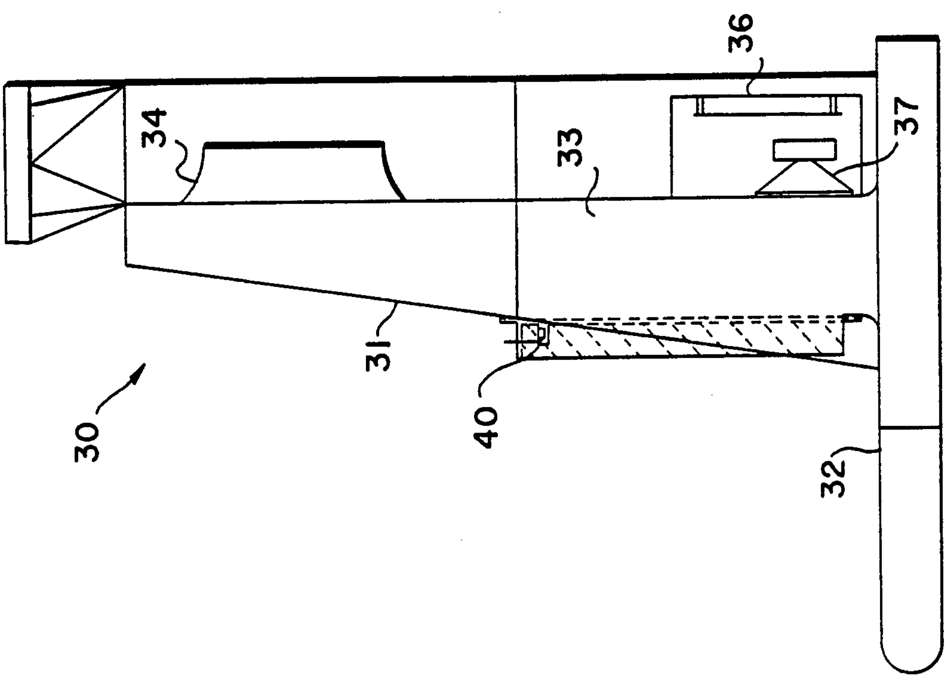

FIG.4

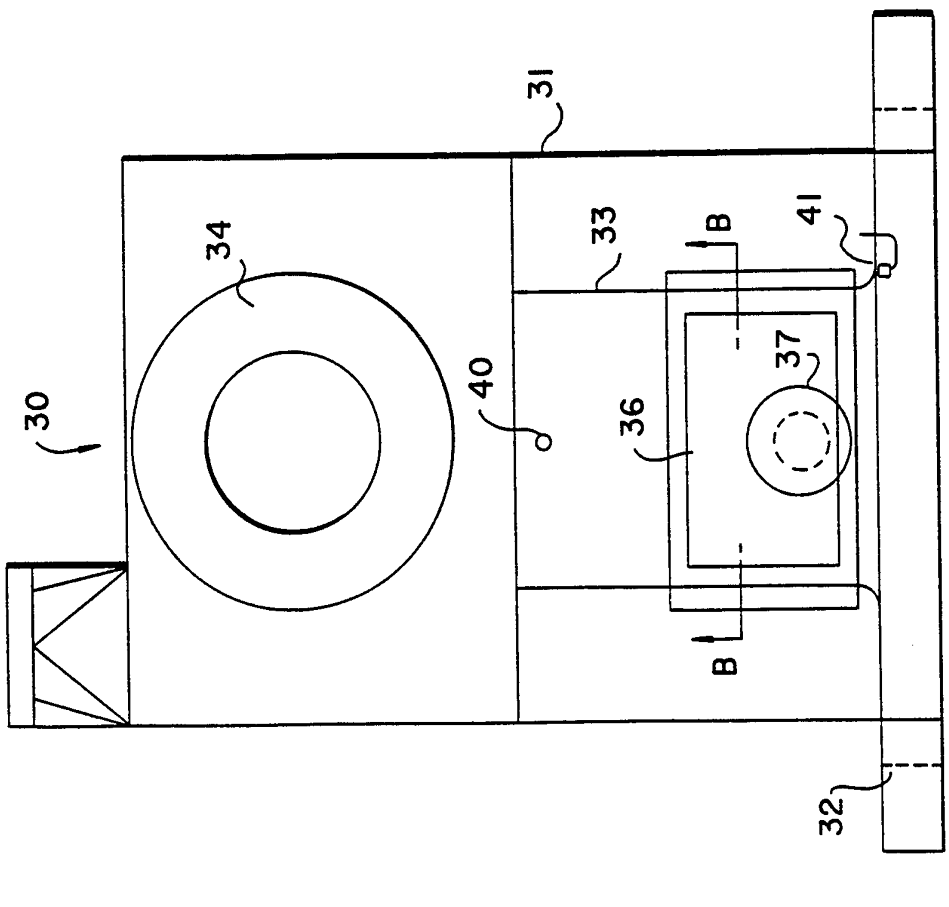

FIG.3

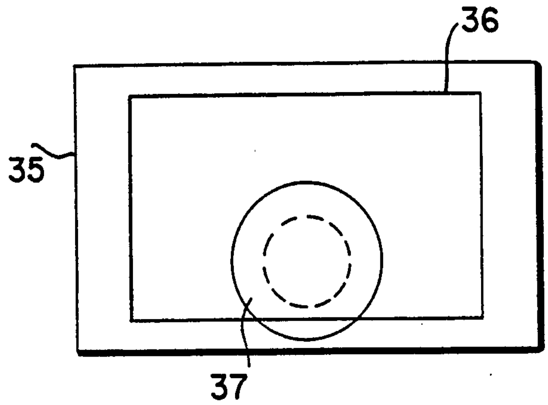

FIG.5a

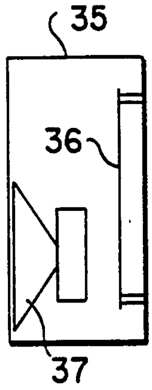

FIG.5b

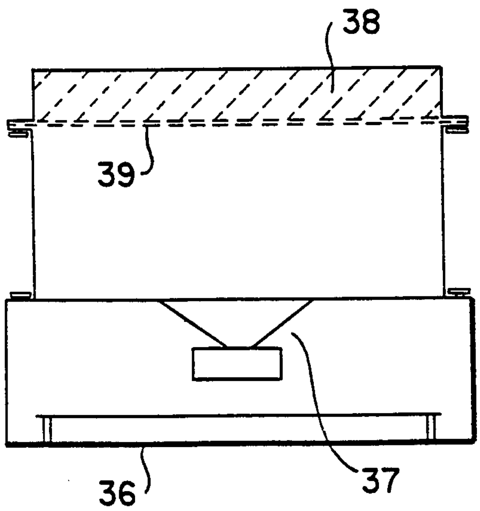

FIG.6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/01189

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :A61F 11/06
US CL : 381/71
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 381/71, 94; 454/67

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, plenum(p)fan and 454*67/ccls

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 4,677,677 (ERICKSSON) 30 JUNE 1987, Figures 3, 4	1-4
Y	US, A, 4,825,848 (MACIAS) 02 May 1989, Figure 1	5-7, 9-12
Y	US, A, 4,665,549 (ERICKSSON, ET AL.) 12 May, 1987, Figure 1, Col. 2	8

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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