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(54) **ULTRA QUIET VACUUM CLEANER**

ULTRA-LÄRMARMER STAUBSAUGER

ASPIRATEUR ULTRA SILENCIEUX

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Description

[0001] The term vacuum cleaner can encompass a wide variety of appliances that use negative pressure to collect various solids and even liquids into a collection area for disposal. This invention relates to vacuum cleaners of all sizes that need to reduce broad band noise, with or without tonal components present.

[0002] The heart of any vacuum cleaner is the motor/blower unit. This is typically a universal motor with one or more stages of fan blades attached. A typical household unit might be a two horsepower motor with a two stage backward curved fan system. One fan might have 6 blades and the other 7.

[0003] On the inlet side of the motor/blower is the bag cavity area. Here, the negative pressure developed by the motor/blower is transferred to the hose and nozzle by the bag volume. There may be one or more filters in addition to the bag to keep dust and large particles from damaging the motor/blower.

[0004] The outlet of the motor/blower is exhausted to the environment usually through some type of dust filter.

[0005] Previous vacuum designs had size, weight, and performance, but seldom noise, as the primary concerns. Designing a vacuum cleaner solely from a noise point of view clearly separates the noise sources. These sources can be attacked with the most cost effective means, either using active, passive or a combination of the two.

[0006] The following patents describe the active noise control system used: U.S. Patent No. 5,091,953 to Tretter, U.S. Patent No. 5,105,377 to Ziegler and U.S. Patent No. 4,878,188 to Zeigler. This invention incorporates several of the techniques and apparatus described to actively cancel noise produced by the vacuum.

[0007] Also known from the prior art are vacuum cleaners having active noise compensation in accordance with Japanese Patent Specifications No. 5-3841, 5-3843 and 5-7536, which form the basis of the preamble of claim 1. All these vacuum cleaners have an exhaust passage from the motor/blower which has a wrapped configuration.

[0008] In summary, the vacuum cleaner designed following the teachings of the present invention, using passive and active noise control methods, has resulted in a vacuum cleaner with superior acoustic performance and comparable hydraulic performance to similar units. Random broad band noise and tonal noise can be reduced depending on the exact configuration of the vacuum cleaner.

[0009] The noise sources in the vacuum cleaner are as follows:

1. Nozzle
2. Hose
3. Bag Cavity

4. Coupling
5. Motor/Blower
6. Exhaust Area

[0010] The nozzle and hose will not be addressed in the present invention. After the other noise sources are reduced, the nozzle and hose are the major noise sources in the vacuum. Further reductions in noise level will result by redesigning these two components. Currently, this vacuum design is 10 dBA quieter than similar production vacuums on the market today (Figure 1a). Figure 1b is the active reduction of 8 dBA.

[0011] An object of the present invention is to provide acoustic design and isolation techniques on the bag cavity, motor/blower area and coupling on a vacuum cleaner to produce cost effective active noise control thereto.

[0012] According to the invention, there is provided a vacuum cleaner system adapted for quiet operation, said system comprising

an inlet means adapted to allow for the intake of solids and liquids, and including a cavity area (20) which is acoustically designed to produce the lowest pressure drop, the cross-sectional area of the inlet means being adapted to impede the transfer of acoustic energy to the cavity,
a motor/blower means (21) associated with said inlet means and adapted to provide negative pressure at said inlet means to facilitate the intake of said solids and liquids,
collection means associated with said inlet means so as to collect solids and liquids that are drawn into said inlet means by said negative pressure,
exhaust duct means (25) which conducts cooling air used to cool said motor/blower means (21) out of said system, and
active noise control means associated with said system to measure the noise generated by said system and to produce an equal counter noise so as to reduce the system generated noise.

[0013] These and other objects of the invention will become apparent when reference is had to the accompanying drawings in which:

Figures 1a and 1b are graphs showing the noise reduction the invention provides, passive and active respectively, versus a standard vacuum cleaner. Figure 2 is an elevation view of a vacuum cleaner showing major active noise control components. Figure 3 is a plan view of the vacuum cleaner of Figure 2, and Figure 4 is a schematic view of the active noise cancellation system of this invention.

[0014] Referring to Figures 2 and 3 the bag cavity 20 area is essentially an acoustically designed muffler.

A muffler can be described as a section of duct or pipe shaped to reduce the transmission of sound while allowing the free flow of air. The vacuum inlet muffler must meet acoustical, aerodynamic, geometrical and mechanical criteria. The acoustic criteria specifies the amount of noise reduction required from the muffler as a function of frequency. Aerodynamically, the muffler should produce the minimum pressure drop so that the smallest rated motor/blower unit can be used. As will be mentioned later, using a smaller rated motor/blower unit 21 will result in quieter noise levels.

[0015] The muffler should also possess the smallest practical dimensions. Since muffler acoustic characteristics are highly dependent on geometry, there will be a tradeoff between muffler performance and geometry. The muffler must be mechanically sound as well, meaning that it must have enough structural rigidity so the wall will not collapse due to the negative pressure in the bag cavity area. In addition, acoustic foam used to line the surface of the muffler must have a cleanable, puncture resistant surface in case the bag breaks.

[0016] The muffler is basically a combination reactive/dissipative type muffler. The geometry of the muffler determines the acoustical performance of the reactive portion of the muffler. In principle, the acoustic energy travelling through the pipe is reflected back towards the source because of the impedance mismatch created by a change in cross-sectional area. The acoustic performance of the dissipative portion of the muffler is determined by the absorption properties of the acoustic material used to line the inside of the muffler.

[0017] The coupling 22 between the bag cavity 20 and motor chamber 23 is a flexible rubber tube. This tube helps quiet the vacuum in two ways. First, the tube provides a smooth flow path for the air that minimises the noise produced by turbulence and separation. It is important that air flow coming into the entrance of the blower (fan) be as uniform as possible in order to keep fan noise to a minimum and fan efficiency at a maximum. Secondly, the flexible coupling 22 reduces the transmission of structural vibrations from the motor chamber to the bag cavity (muffler) walls. This is achieved through the large impedance difference between the motor chamber structure and the flexible coupling 22. Because the coupling is lower in impedance, it reflects the structural vibration wave back towards the source. Obviously, the greater the impedance mismatch, the greater the attenuation of structure borne noise will be. However, the hose must be rigid enough to withstand the negative pressure created by the vacuum motor 21.

[0018] The motor chamber 23 is the most important part of the vacuum acoustic design because it houses the primary noise source of the vacuum, the motor/blower unit 21. This motor chamber isolates the motor from the rest of the vacuum both acoustically and structurally by incorporating a sealed chamber design. It is important that all transmission paths be treated with

some noise reduction method or else a sound "short" will exist allowing the acoustic or vibration energy to escape to the surrounding medium. The only openings are for the flow of air at the inlet coupling and the exhaust duct. In essence, these represent acoustic sound shorts but they have been minimised by this design. On the inlet side, the use of a flexible coupling and cross-sectional area change impede the transfer of the acoustic energy to the bag cavity 20. In the exhaust duct, the use of passive materials and active noise cancellation reduce motor noise significantly.

[0019] Motor/blower noise is comprised of both discrete frequency and broad band noise. Discrete frequency signals are produced by the electrical line frequency and its harmonics, the fundamental shaft frequency and harmonics, and the blade passing frequency of the fan(s) and harmonics. Broad band noise is produced by turbulent air flow over the motor cage and other surrounding discontinuities. The nature of the noise will dictate the noise control method to be used for the motor/blower chamber. High frequency noise, typically above 2000 Hz, can be attenuated using simplistic passive noise control methods. Acoustic foam is used to absorb the acoustic energy and convert into mechanical energy (i.e. heat) for the high frequency noise attenuation. This method is effective because the wavelengths of the sound are short in this frequency region allowing them to penetrate the material. However, low frequency noise must be attenuated using a more complex method because the longer wavelengths tend to pass through the material. The use of massive and/or thick material will stop the transmission of the longer wavelengths. Thus, the material chosen for the motor chamber is a decoupled absorber/barrier. The barrier is massive enough to reduce low frequency noise while the absorber reduces the high frequency.

[0020] Air used to cool the motor is vented through a substantially straight exhaust duct 25. The exhaust is vented out the back away from the operator to minimise the noise the operator hears. The duct 25 is attached to the motor chamber 23 and extends beyond it to the back of the cleaner. It therefore has a length relatively short when compared to the overall length of the system, and as compared to a wrapped duct. This design purposely forces motor noise into the duct because this vacuum, unlike any existing vacuum design, utilises active noise cancellation to cancel the low frequency noise that is not addressed by passive noise control measures. The duct 25 is a primary source of noise because of the turbulent flow in the duct and discrete frequency motor noise. As previously discussed in the design of the motor chamber, passive noise control works for the high frequency. In this case, acoustic foam lines the ductwork to attenuate the high frequency. For low frequency control, active noise cancellation is employed for the first time on a vacuum. Active noise control is necessary for the low frequency because passive noise control methods would require very thick and massive materi-

als that would cause the vacuum to be bigger and heavier than necessary.

[0021] Microphones 28, 29 are placed along the straight exhaust duct and act as an upstream noise and a downstream residual error sensor, respectively, to sense noise to be cancelled and to provide feedback. The active cancelling noise is introduced via speaker 27 to counter the existing noise in the duct and is run by controller 26. Take up reel 24 is located between the speaker and the motor chamber. Controller 26 houses the power supply and processor having the cancellation algorithm.

Claims

1. A vacuum cleaner system adapted for quiet operation, said system comprising

an inlet means adapted to allow for the intake of solids and liquids, and including a cavity area (20) which is acoustically designed to produce the lowest pressure drop, the cross-sectional area of the inlet means being adapted to impede the transfer of the acoustic energy to the cavity,
a motor/blower means (21) associated with said inlet means and adapted to provide negative pressure at said inlet means to facilitate the intake of said solids and liquids,
collection means associated with said inlet means so as to collect solids and liquids that are drawn into said inlet means by said negative pressure,
exhaust duct means (25) which conducts cooling air used to cool said motor/blower means (21) out of said system, and
active noise control means associated with said system to measure the noise generated by said system and to produce an equal counter noise so as to reduce the system generated noise.

2. A vacuum cleaner system according to claim 1, characterised in that the active noise control means includes sensing means (28, 29) in the path of air passing through said exhaust duct means (25) to sense the noise.
3. A vacuum cleaner system according to claim 2, characterised in that the microphone means comprise an upstream noise sensor (28) and a downstream residual error sensor (29) in a straight region of the exhaust means.
4. A vacuum cleaner system as claimed in claim 1 or claim 2 or claim 3, characterised in that said motor/blower means is housed in a sealed chamber means (23) which is adapted to isolate the motor

from the remainder of the vacuum system both acoustically and structurally.

5. A vacuum cleaner system as claimed in claim 4, characterised in that said chamber means (23) has an air inlet and an exhaust outlet, and in that said chamber air inlet is connected to said cavity means by a flexible tube coupling (22) to provide for a smooth flow to minimise noise produced by turbulence and separation and to reduce structural vibrations.
6. A vacuum cleaner system as claimed in claim 5, characterised in that the relative cross sections of said chamber means (23) and said flexible coupling (22) create a substantial acoustic impedance difference.
7. A vacuum cleaner system as claimed in claim 5 or claim 6, characterised in that said chamber means (23) is constructed as a decoupled absorber/barrier which allows for reduction of low frequency noise while absorbing high frequency noise.
8. A vacuum cleaner system according to any of claims 1 to 7, characterised in that the loudspeaker (27) producing the counter noise is located in the exhaust means (25).
9. A vacuum cleaner system according to claim 8, characterised in that the loudspeaker (27) is positioned adjacent the exit of the exhaust means (25).

Patentansprüche

1. Staubsaugersystem für geräuscharmen Betrieb, gekennzeichnet durch

eine Einlass-Vorrichtung, die das Aufnehmen von Feststoffen und Flüssigkeiten ermöglicht und einen Hohlraumbereich (20) aufweist, der akustisch so konstruiert ist, dass er einen möglichst geringen Druckabfall ergibt, wobei die Querschnittsfläche der Einlass-Vorrichtung in der Lage ist, die Übertragung der akustischen Energie in den Hohlraum zu unterdrücken,
eine Motor-Gebläsevorrichtung (21), die der Einlass-Vorrichtung zugeordnet und in der Lage ist, einen negativen Druck an der Einlass-Vorrichtung zu erzeugen, um das Einbringen der Feststoffe und Flüssigkeiten zu erleichtern,
eine Sammelvorrichtung, die der Einlass-Vorrichtung so zugeordnet ist, dass sie Feststoffe und Flüssigkeiten sammelt, die in die Einlass-Vorrichtung durch den negativen Druck eingesaugt werden,
eine Auslaßleitung (25), die Kühlluft führt, welche zum Kühlen der Motor/Gebläse-Vorrich-

- tung (21) aus dem System dient, und eine aktive Geräusch-Steuervorrichtung, die dem System zugeordnet ist, um das Geräusch zu messen, das von dem System erzeugt wird, und um ein gleichgroßes Gegengeräusch zu erzeugen, damit das vom System erzeugte Geräusch reduziert wird. 5
2. Staubsaugersystem nach Anspruch 1, dadurch gekennzeichnet, dass die aktive Geräusch-Steuervorrichtung eine Abfühlvorrichtung (28, 29) im 10 durch die Auslass-Leitung (25) strömenden Luftpfad zum Feststellen des Geräusches aufweist.
3. Staubsauger nach Anspruch 2, dadurch gekennzeichnet, dass die Mikrophon-Vorrichtung einen Sensor (28) für das stromaufwärts auftretende Geräusch und einen Sensor (29) für den stromabwärts auftretenden Restfehler in einem geradlinigen Bereich der Auslass-Vorrichtung aufweist. 15 20
4. Staubsaugersystem nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, dass die Kombination aus Motor und Gebläse in einer abgedichteten Kammer (23) aufgenommen ist, die den Motor gegenüber dem übrigen Teil des Vakuumsystems sowohl akustisch als auch baulich isoliert. 25
5. Staubsaugersystem nach Anspruch 4, dadurch gekennzeichnet, dass die Kammer (23) einen Lufteinlass und einen Abluft-Auslass aufweist und dass der Kammer-Lufteinlass mit der Hohlraumvorrichtung durch eine flexible Rohrkupplung (22) verbunden ist, um einen ungestörten Fluss zu erzielen, damit das durch Turbulenzen und Ablösen erzeugte Geräusch ein Minimum wird und bauliche Vibrationen reduziert werden. 30 35
6. Staubsaugersystem nach Anspruch 5, dadurch gekennzeichnet, dass die relativen Querschnitte der Kammer (23) und der flexiblen Rohrkupplung (22) eine erhebliche akustische Impedanz-Differenz erzeugen. 40
7. Staubsaugersystem nach Anspruch 5 oder 6, dadurch gekennzeichnet, dass die Kammer (23) als eine entkoppelte Absorber/Barriere-Vorrichtung konstruiert ist, die eine Reduzierung von Geräusch niedriger Frequenz ermöglicht, während Geräusch hoher Frequenz absorbiert wird. 45 50
8. Staubsaugersystem nach einem der Ansprüche 1 - 7, dadurch gekennzeichnet, dass der das Gegengeräusch erzeugende Lautsprecher in der Auslass-Vorrichtung (25) angeordnet ist. 55
9. Staubsaugersystem nach Anspruch 8, dadurch gekennzeichnet, dass der Lautsprecher (27) in der

Nähe des Ausgangs der Auslass-Vorrichtung (25) angeordnet ist.

Revendications

1. Système d'aspirateur apte à fonctionner silencieusement, ledit système comprenant un moyen d'entrée apte à permettre l'aspiration de solides et de liquides, et comportant une zone de cavité (20) conçue, d'un point de vue acoustique, pour produire une perte de charge minimale, la section transversale du moyen d'entrée étant apte à empêcher le transfert de l'énergie acoustique vers la cavité,

un moyen formant moteur/ventilateur (21) associé audit moyen d'entrée et apte à créer une pression négative au niveau dudit moyen d'entrée pour permettre l'aspiration desdits solides et liquides,

un moyen de collectage associé audit moyen d'entrée afin de collecter des solides et des liquides qui sont entraînés jusque dans ledit moyen d'entrée par ladite pression négative,

un moyen formant conduit d'échappement (25) qui conduit de l'air de refroidissement servant à refroidir ledit moyen formant moteur/ventilateur (21) à l'extérieur dudit système, et

un moyen d'insonorisation active associé audit système pour mesurer le bruit généré par ledit système et pour produire un bruit antagoniste égal afin de réduire le bruit généré par le système.
2. Système d'aspirateur selon la revendication 1, caractérisé en ce que le moyen d'insonorisation active comporte un moyen de détection (28, 29) sur le trajet de l'air passant par ledit moyen formant conduit d'échappement (25) afin de détecter le bruit.
3. Système d'aspirateur selon la revendication 2, caractérisé en ce que des moyens formant microphones comprennent un détecteur amont (28) de bruit et un détecteur aval (29) d'erreur résiduelle dans une région rectiligne du moyen d'échappement.
4. Système d'aspirateur selon la revendication 1 ou la revendication 2 ou la revendication 3, caractérisé en ce que ledit moyen formant moteur/ventilateur est logé dans un moyen formant chambre hermétique (23) apte à isoler le moteur du reste du système d'aspirateur du point de vue de l'acoustique et de la structure.
5. Système d'aspirateur selon la revendication 4, caractérisé en ce que ledit moyen formant chambre

(23) a une entrée d'air et une sortie d'échappement, et en ce que ladite entrée d'air de la chambre est reliée audit moyen formant cavité par un raccord tubulaire flexible (22) pour assurer un écoulement régulier afin de limiter le bruit produit par turbulence et séparation et de réduire les vibrations de la structure. 5

6. Système d'aspirateur selon la revendication 5, caractérisé en ce que les sections transversales relatives dudit moyen formant chambre (23) et dudit raccord flexible (22) créent une différence notable d'impédance acoustique. 10
7. Système d'aspirateur selon la revendication 5 ou la revendication 6, caractérisé en ce que ledit moyen formant chambre (23) est construit sous la forme d'un absorbeur/écran découplé qui permet de réduire le bruit à fréquence basse tout en absorbant le bruit à fréquence élevée. 15 20
8. Système d'aspirateur selon l'une quelconque des revendications 1 à 7, caractérisé en ce que le haut-parleur (27) produisant le bruit antagoniste se trouve dans le moyen d'échappement (25). 25
9. Système d'aspirateur selon la revendication 8, caractérisé en ce que le hautparleur (27) est placé au voisinage de la sortie du moyen d'échappement (25). 30

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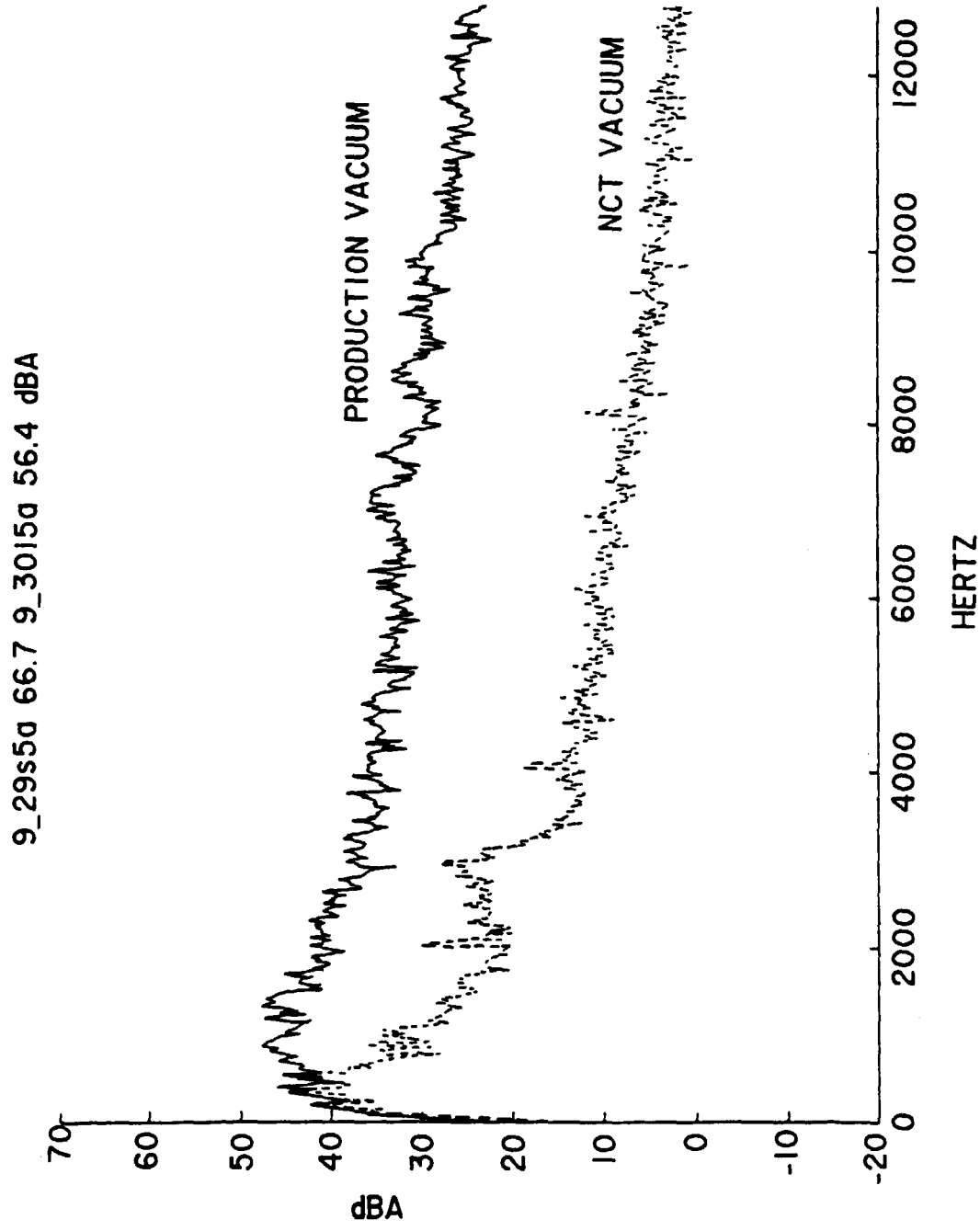


FIG.1a

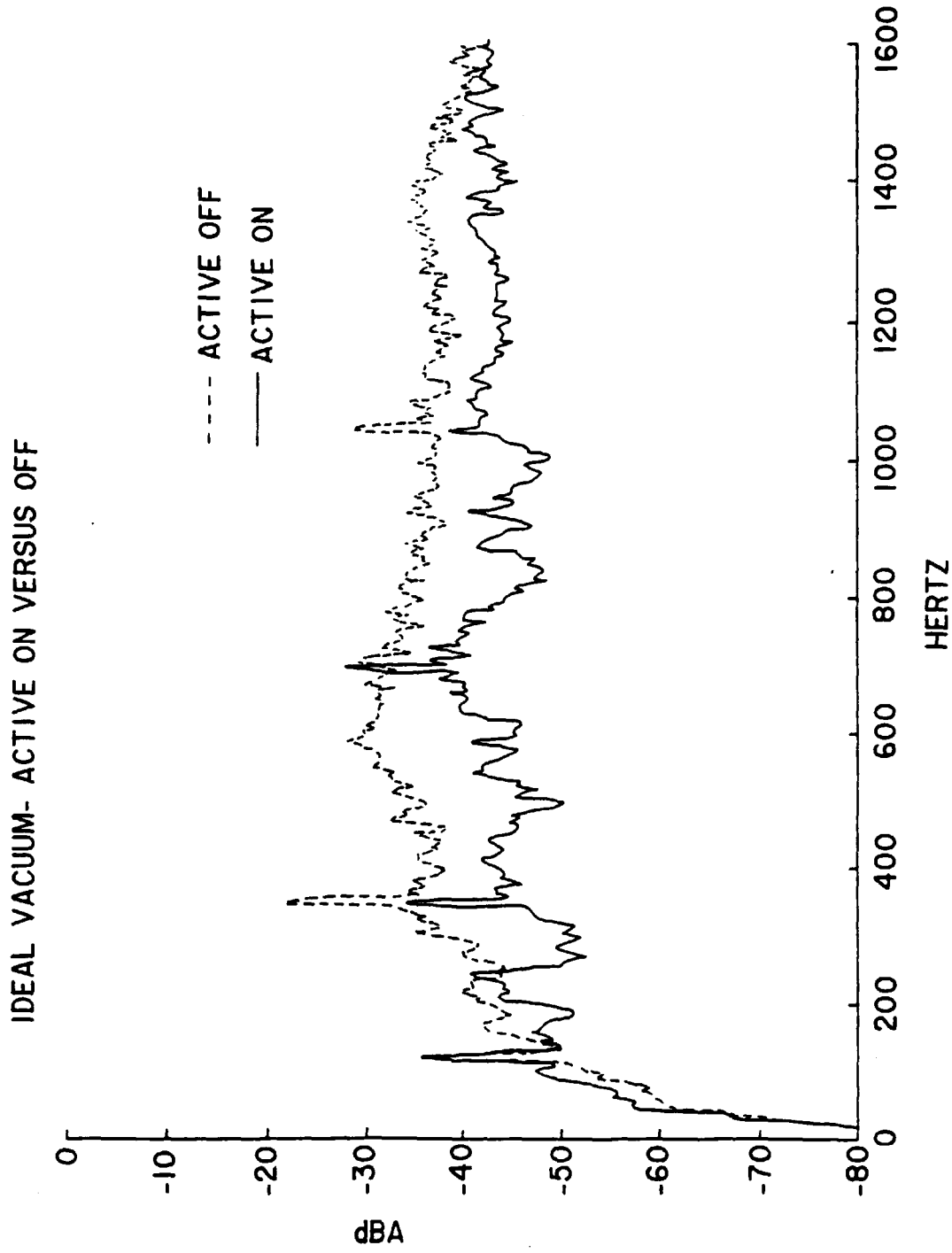


FIG.1b

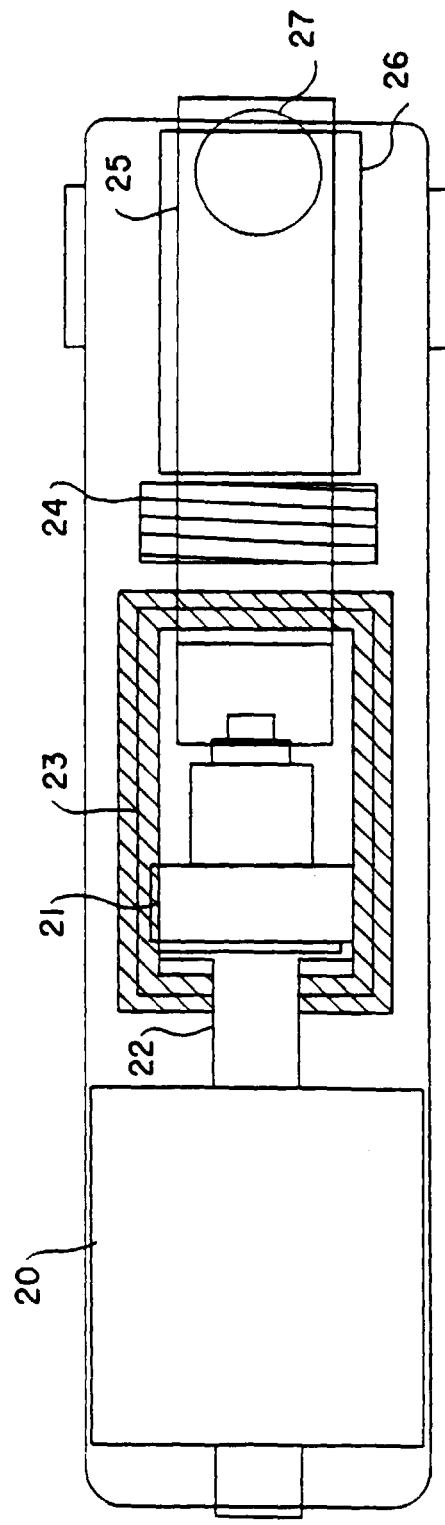
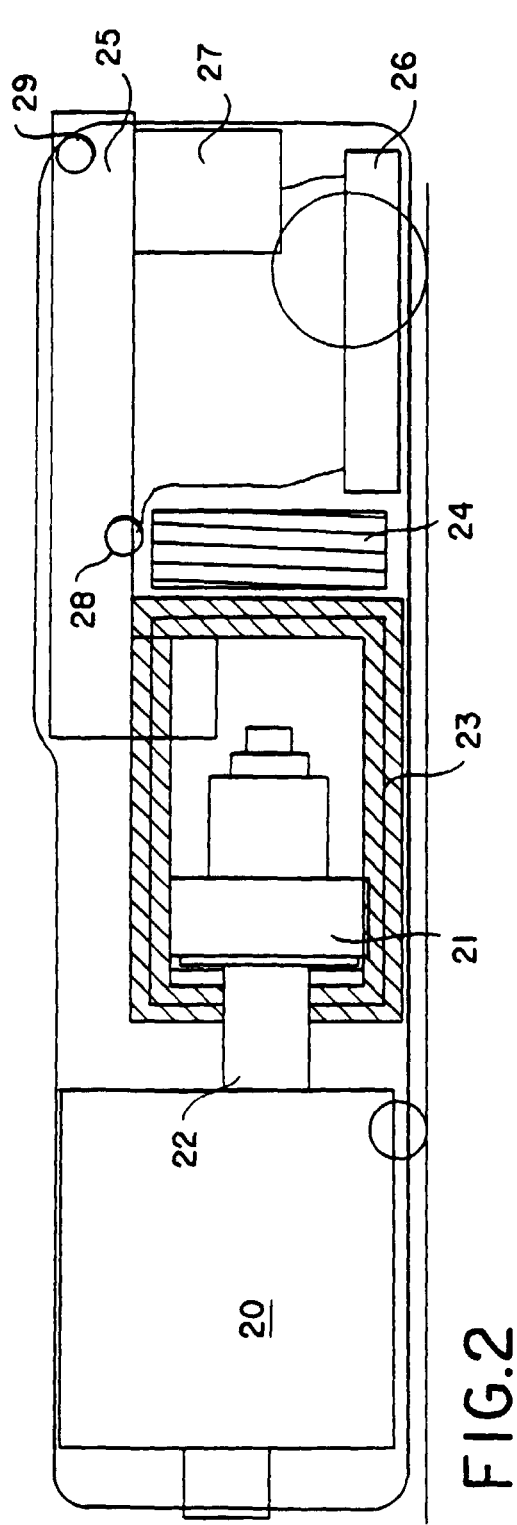


FIG.4

