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(71) Applicant: **THE COMMONWEALTH OF AUSTRALIA**
DEPARTMENT OF DEFENCE ANZAC Park
West Building
Canberra Australian Capital Territory(AU)

(72) Inventor: **Cameron, Keith**
67 Orlando Street
Hampton Victoria 3188(AU)
Inventor: **Keeler, Arthur Albert**
12 Seaview Street
Mt. Waverley Victoria 3149(AU)

(74) Representative: **Gordon, Michael Vincent et al**
GILL JENNINGS & EVERY 53-64 Chancery
Lane
London WC2A 1HN(GB)

(54) Ultrasonic transducers.

(57) A transducer comprises transmission means (10) for transmitting ultrasonic energy. The transmission means comprises insulating means and includes a diaphragm portion (11) and an amplifier portion (12). The diaphragm portion has a wave receiving/generating surface (14). Sensor/generator means is coupled to the apex (15) of amplifier portion (12) for sensing/generating ultrasonic energy passing through transmission means (10). The sensor/generator means is insulated by transmission means (10) from exposure to temperature variations.

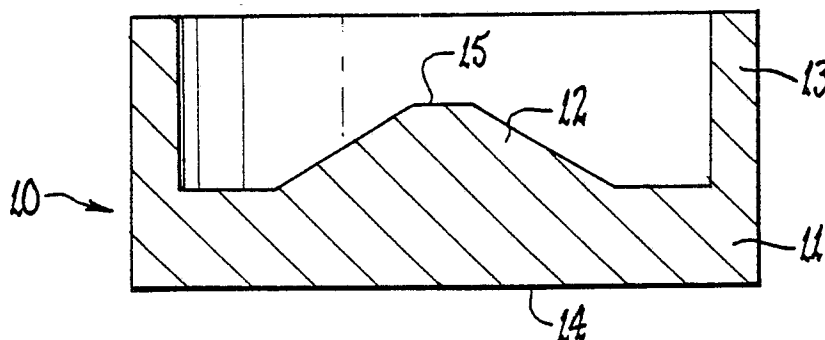


FIG 1

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ULTRASONIC TRANSDUCERS

This invention relates to transducers for generating or detecting ultrasonic energy in the form of acoustic waves. The invention is particularly applicable to ultrasonic transducers and it will be convenient to generally describe the invention in relation to such transducers although the invention is not thereby limited to such applications.

Ultrasonic transducers can be highly sensitive to temperature changes. Ultrasonic transducers are adapted to convert incident ultrasonic energy in the form of acoustic waves into electrical energy and vice versa. This conversion takes a finite time which produces an internally generated phase shift in the electrical output signal relative to the incident acoustic signal and vice versa. This internal phase shift varies with temperature changes. In applications where accurate or consistent sensing of the phase of an incident signal is important, the internal phase shift caused by temperature changes can lead to significant errors.

In International Patent Application PCT/AU85/00042 there is described movement sensing apparatus for a decoy rocket having a short flight time. The sensing apparatus uses ultrasonic waves to determine velocity of air movement in a number of passages. This air movement is used to determine the trajectory of the rocket relative to the ground and surrounding air mass. Correct operation of the ultrasonic transducers in this apparatus depends upon consistent operation of transducers throughout the expected flight time. Even though the rocket is expected to be airborne for a relatively short time, temperature changes between the launch site and the temperature of the air above the launch site where the rocket travels can produce significant errors in the sensing of rocket movement. In particular, movement sensing depends upon accurate detection of phase shifts of ultrasonic signals. The above described internal phase shift caused by temperature changes can lead to significant errors in the calculation of rocket trajectory.

It is an object of the present invention to provide a transducer which is effective in operation and operates consistently for relatively extended periods of time notwithstanding exposure to temperature changes.

The transducer of the present invention is suitable for use in pressure sensing apparatus of the kind described in the abovementioned PCT Application AU85/00042, the disclosure of which is incorporated herein by cross-reference.

According to one aspect of the present invention there is provided a transducer for detecting ultrasonic energy in the form of acoustic waves,

said transducer comprising:

transmission means for transmitting ultrasonic energy to which said transmission means is exposed, said transmission means comprising insulating means to inhibit conduction of heat therethrough;

said transmission means including a diaphragm portion having a wave receiving surface, the diaphragm portion being arranged to receive acoustic waves at said receiving surface and to vibrate in response thereto,

said transmission means further including an amplifier portion located adjacent said diaphragm portion to receive vibrations therefrom, said amplifier portion converging towards an apex;

sensor means coupled to said apex of said amplifier portion so as to receive vibrations passing through said amplifier portion from said diaphragm portion, said sensor means being adapted to sense ultrasonic energy being transmitted through said transmission means and being substantially insulated thereby from exposure to temperature variations.

According to a further aspect of the present invention there is provided a transducer for generating ultrasonic energy in the form of acoustic waves, said transducer comprising:

transmission means for transmitting ultrasonic energy to which said transmission means is exposed, said transmission means comprising insulating means to inhibit conduction of heat therethrough;

said transmission means including a diaphragm portion having a wave generating surface;

said transmission means further including an amplifier portion located adjacent said diaphragm portion to transmit vibrations thereto, said amplifier portion converging towards an apex;

generator means coupled to said apex of said amplifier portion and adapted to generate ultrasonic vibrations through said amplifier portion to said diaphragm portion, said diaphragm portion being adapted to transmit ultrasonic energy in the form of acoustic waves, said generator means being substantially insulated by said transmission means from exposure to temperature variations.

The amplifier portion may comprise a right circular cone converging to a point or plateau at the apex. Alternatively the amplifier portion may comprise other tapering or reducing cross-sectional area configurations including truncated cones of right circular and other configurations, and variants of cones having decreasing cross-sectional areas such as pyramids, tetrahedrons etc. and truncated versions thereof.

The transmission means comprises insulating means to shield the sensor or generator means against ambient temperature changes which adversely affect operating characteristics of the sensor/generator means. In the case of ultrasonic transducers for use in apparatus of the kind disclosed in PCT Application AU85/00042, heat insulating properties are required to insulate the sensor/generator means for of the order of minutes. The transmission means may be made of any suitable material. Preferably the transmission means comprises a substantially rigid material so as to be effective for transmitting vibrational energy in the form of acoustic waves in the ultrasonic range, e.g. 30-40 KHz. Suitable materials may include ceramic or glass materials polymeric or plastics materials or suitable resin materials and composites thereof.

The rigid material preferably has good heat insulating properties. The heat insulating properties of the rigid material may be enhanced by mixing it with glass microballoons (commercially available as a filler substance). The rigid material may comprise a suitable resin based adhesive sold under the registered trade mark ARA LDITE. A type F resin has been found to have improved insulating properties.

The glass micro-balloons may be set in a matrix of polyester or epoxy resin. The micro-balloons may alternatively be set in a glass matrix or they may be fused together without a matrix present. The glass matrix, if used, preferably has a lower melting temperature than the glass from which the microballoons are formed. The micro-balloons provide a cavitated mixture having repeatable properties.

The diaphragm portion may comprise a rigid material as described above or it may comprise a solid heat insulating material. The diaphragm portion preferably has a flat wave receiving/surface wave generating surface. The wave receiving/generating surface may be substantially circular and may be formed of a heat insulating material as aforesaid. In one form the diaphragm portion may be approximately 1.5 millimetres thick and approximately 13 millimetres in diameter.

The amplifier portion may comprise a relatively thin conical surface filled with a substantially rigid material as described above. The amplifier portion may comprise a substantially solid material, such as the solid heat insulating material used for constructing the diaphragm portion of the preferred embodiment. This may be effective to increase the mass of vibrating components of the transducer thus reducing the natural frequency response of the transducer.

The amplifier portion may be secured to the surface of the diaphragm portion remote from the

wave receiving/generating surface but preferably is formed integrally therewith. In a preferred embodiment the amplifier portion may comprise a truncated right circular cone having a base diameter of approximately 7 millimetres, a height of approximately 2 millimetres and an internal subtended angle of approximately 120° leaving a flat plateau at the apex of approximately 1.2 millimetres diameter. The integral diaphragm and amplifier portions preferably comprise a mixture of glass microballoons set in an epoxy resin matrix. This material can be premixed and cast in a mould.

The transmission means preferably comprises a material which decouples the wave receiving/wave generating surface from the sensor/generator means. At least a zone of decoupling material may be interposed between the wave receiving/generating surface and the sensor/generator means. Alternatively the transmission means may entirely comprise a suitable decoupling material. The coupling material may be adapted to decouple the wave receiving/generating surface sufficiently such that mass loading, e.g. via water droplets, of the wave receiving/generating surface does not substantially alter the resonant frequency of the sensor/generator means.

The sensor or generator means preferably is coupled to the apex of the amplifier portion by being secured directly to the apex of the amplifier portion but not otherwise constrained against movement. The sensor/generator preferably operates on an inertial principle as a "floating" seismic mass. Such a construction may reduce fabrication costs and helps to maintain a constant natural frequency for the transducer assembly. The sensor/generator means may comprise a piezo-electric element of conventional construction and operation. A piezo-electric bi-morph ceramic disc element manufactured by Matsushita Electric Company has been found to be suitable for this purpose. The element is preferably secured to the apex of the amplifier portion by means of a rigid adhesive. The adhesive may comprise a micro-balloon epoxy mixture as previously described.

The sensor/generator means may be tuned in any suitable manner. In one form the piezo-electric element may be tuned by attaching a tuning stub or rod substantially at the centre of the piezo-electric element and perpendicular thereto. The tuning rod may comprise copper wire. In one form the copper wire may be 1.2 mm in diameter and approximately 10 mm long before tuning. The tuning rod may be secured to the piezo-electric element by means of a micro-balloon epoxy mixture. Tuning may be achieved by cutting the tuning stub or rod to a suitable length.

The transducer may include a housing, the housing may comprise a heat insulating material

and may enclose the sensor/generator means so as to insulate the sensor/generator means against temperature changes. The housing may include side walls and a rear wall arranged, together with the diaphragm portion, to completely enclose the sensor means. The side walls may be generally annular right cylinders and may be made of a similar or the same heat insulating material as the transmission means. The side walls may be at least partly formed with the diaphragm and amplifier portions by providing a peripheral skirt extending approximately 4 millimetres rearwardly around the peripheral edge of the diaphragm portion. After the sensor/generator means is mounted to the apex of the amplifier portion, a closure portion may be secured to the skirt portion. Lead wires from the sensor/generator means may be passed through the housing in any convenient manner. In an alternative embodiment, the housing may comprise rubber or other resilient materials through which the transducer can be mounted to thereby provide isolation of the transducer from sources of vibration other than the incident ultrasonic waves.

An example embodiment of a transducer according to a preferred embodiment of the present invention will now be described with reference to the accompanying drawings wherein:-

Figure 1 shows in one form an integrally formed diaphragm and amplifier portion;

Figure 2 shows an ultrasonic transducer in accordance with a preferred embodiment of the present invention;

Figure 3 shows a cross-section through movement sensing apparatus incorporated ultrasonic transducers according to the present invention;

Figure 4 shows a sound source and location of sound receivers in the movement sensing apparatus of Figure 3;

Figure 5 shows a passage of the movement sensing apparatus having a fluidic vortex diode for restricting flow in the passage; and

Figure 6 shows air pressure distribution around a body moving in the direction of arrow V to be measured by the apparatus of Figure 3.

Figure 1 shows the transmission means 10 of the transducer of the present invention. The transmission means 10 comprises diaphragm portion 11 formed integrally with conical amplifier portion 12. A peripheral skirt 13 is also formed integrally with diaphragm portion 11.

Diaphragm 11 includes an outer surface 14. Outer surface 14 provides a wave receiving surface when the transducer is being used in receiving mode. Outer surface 14 acts as a wave generating surface when the transducer is being used in transmitting mode.

Conical portion 12 includes a truncated apex

15 for receiving the sensor means (receiving mode) or generator means (transmitting mode).

Transmission means 10 is moulded in one piece from a mixture of type F 'Araldite' epoxy and glass micro-balloons. The mixture preferably is formulated such that it exhibits a Young's modulus less than approx. 2×10^6 .

Diaphragm portion 11 is approximately 13 millimeter in diameter and approximately 1.5 millimeter thick. Conical amplifier portion 12 has a diameter adjacent diaphragm portion 11 approximately 7 millimeter and approximately 1.2 millimeter at the apex 15. Conical portion 12 has an included angle approximately 120° . Skirt portion 13 extends approximately 4 millimeters from diaphragm portion 11.

Figure 2 shows an ultrasonic transducer 20 according to the present invention. Transducer 20 includes the transmission means 10 of figure 1. A piezo-electric bi-morph disc element 21, e.g. as commercially produced by the Matsushita Electric Company, is secured to apex 15 via a micro-balloon epoxy mixture (as described) at 22. Leads 23, 24 connecting disc element 21 are secured to lip of skirt 13 via epoxy resin.

A tuning rod 25 comprising 1.2 millimeter diameter copper wire is secured to disc element 21 via a micro-balloon epoxy mixture (as described) at 26. Tuning rod 25 is nominally 10 millimeters long (before tuning).

The movement sensing apparatus of figures 3 to 5 is more fully described in PCT application AU85/00042. The apparatus includes a body 30 movable in an ambient fluid in a direction transverse to the longitudinal axis 31. A central chamber 32 has a plurality of radial passages 33 extending to outer surfaces 34 and opening at their outer ends to the ambient fluid so that as the body 30 moves a pressure differential between the inner ends 35 and the outer ends 36 causes fluid flow in the passages 33. Flow sensing means comprising an ultrasonic generator 37 and ultrasonic receivers 38 associated with respective passages 33 is adapted to detect phase shifts caused by fluid flow in each passage and hence the direction and speed of fluid flow. A processing means is used to determine air pressure distribution P around body 30 (figure 6) and hence the speed and direction of movement of body 30.

The embodiment of figure 5 includes a flow restrictor 39 in passage 33 in the form of a fluidic vortex diode 40. Fluidic diode 40 is adapted to provide a lesser resistance to flow in the direction from the bore outer end 36 to the inner end 35 than in the opposite direction. The ratio of the two flows resistances may be chosen to provide a pressure within chamber 32 substantially equal to ambient pressure.

The present invention provides a transducer for generating or detecting ultrasonic waves which is significantly thermally isolated from ambient atmosphere. When the transducer is in use, for example in the movement sensing apparatus of PCT Application AU85/00042, temperature changes between launch site of the rocket, say at sea level and the air above the launch site where the rocket travels do not significantly affect operation of the transducer. The transmission means provides significant heat insulation to the generator/sensor means while at the same time allowing transmission of ultrasonic energy to or from the outer surface of the diaphragm portion. The diaphragm portion also serves to protect the transducer from other environmental factors that may affect its operation such as weather, particularly rain, and ingress of dust. Furthermore the transducer of the preferred embodiment can be relatively inexpensive to manufacture.

Claims

1. A transducer for detecting ultrasonic energy in the form of acoustic waves, said transducer comprising:

transmission means for transmitting ultrasonic energy to which said transmission means is exposed, said transmission means comprising insulating means to inhibit conduction of heat therethrough;

said transmission means including a diaphragm portion having a wave receiving surface, the diaphragm portion being arranged to receive acoustic waves at said receiving surface and to vibrate in response thereto,

said transmission means further including an amplifier portion located adjacent said diaphragm portion to receive vibrations therefrom, said amplifier portion converging towards an apex;

sensor means coupled to said apex of said amplifier portion so as to receive vibrations passing through said amplifier portion from said diaphragm portion, said sensor means being adapted to sense ultrasonic energy being transmitted through said transmission means and being substantially insulated thereby from exposure to temperature variations.

2. A transducer for generating ultrasonic energy in the form of acoustic waves, said transducer comprising:

transmission means for transmitting ultrasonic energy to which said transmission means is exposed, said transmission means comprising insulating means to inhibit conduction of heat therethrough;

said transmission means including a dia-

phragm portion having a wave generating surface;

said transmission means further including an amplifier portion located adjacent said diaphragm portion to transmit vibrations thereto, said amplifier portion converging towards an apex;

generator means coupled to said apex of said amplifier portion and adapted to generate ultrasonic vibrations through said amplifier portion to said diaphragm portion, said diaphragm portion being adapted to transmit ultrasonic energy in the form of acoustic waves, said generator means being substantially insulated by said transmission means from exposure to temperature variations.

3. A transducer according to claim 1 wherein said transmission means comprises a substantially rigid material.

4. A transducer according to claim 1 wherein said transmission means includes at least a zone of decoupling material.

5. A transducer according to claim 1 or 2 wherein said diaphragm portion and said amplifier portion are formed of dissimilar materials.

6. A transducer according to claim 1 or 2 wherein said diaphragm portion and said amplifier portions are formed of similar materials.

7. A transducer according to claim 6 wherein said diaphragm portion and said amplifier portion are formed integrally.

8. A transducer according to claim 6 wherein said transmission means comprises a mixture of glass micro-balloons and epoxy resin.

9. A transducer according to claim 1 or 2 wherein said transmission means is formed with a peripheral skirt depending from said diaphragm portion.

10. A transducer according to claim 1 wherein said sensor means comprises a piezo-electric ceramic disc.

11. A transducer according to claim 10 wherein said sensor means is bonded to said apex via a mixture of glass micro-balloons and epoxy resin.

12. A transducer according to claim 2 wherein said generator means comprises a piezo-electric ceramic disc.

13. A transducer according to claim 12 wherein said generator means is bonded to said apex via a mixture of glass micro-balloons and epoxy resin.

14. A transducer according to claim 1 including a tuning rod attached to said sensor means.

15. A transducer according to claim 2 including a tuning rod attached to said generator means.

16. Movement sensing apparatus incorporating a transducer as claimed in claim 1 or 2.

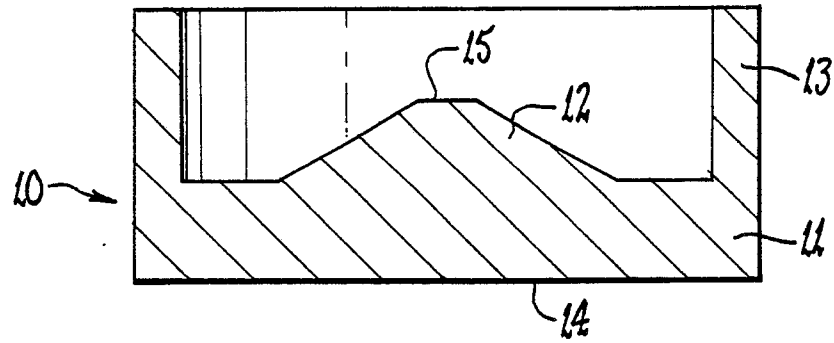


FIG 1

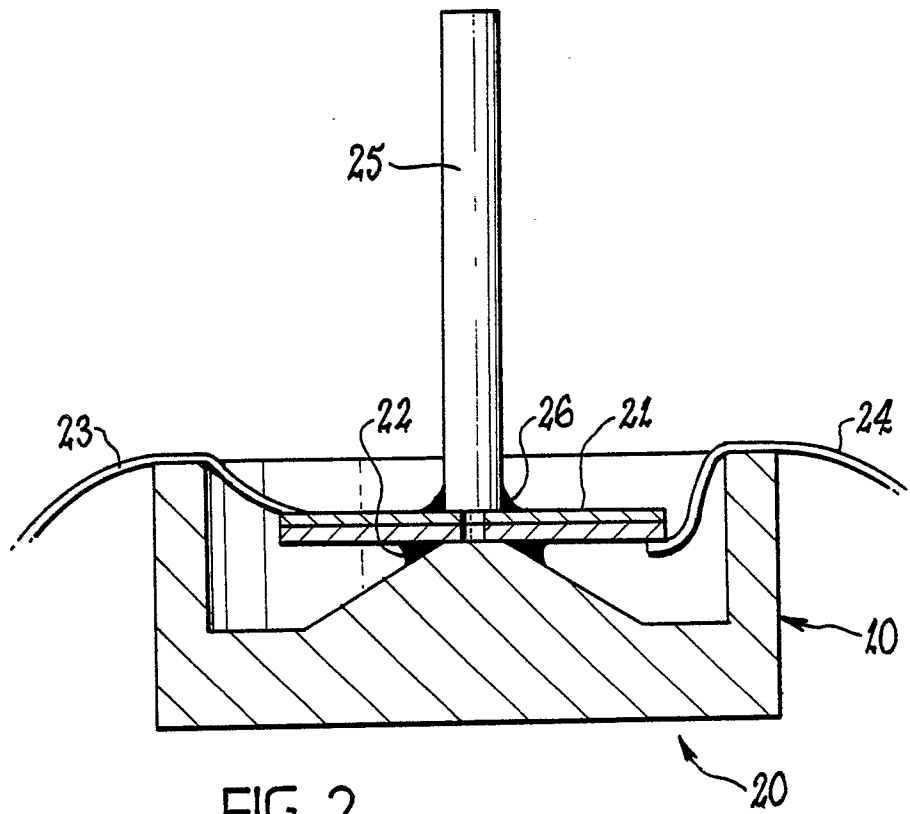
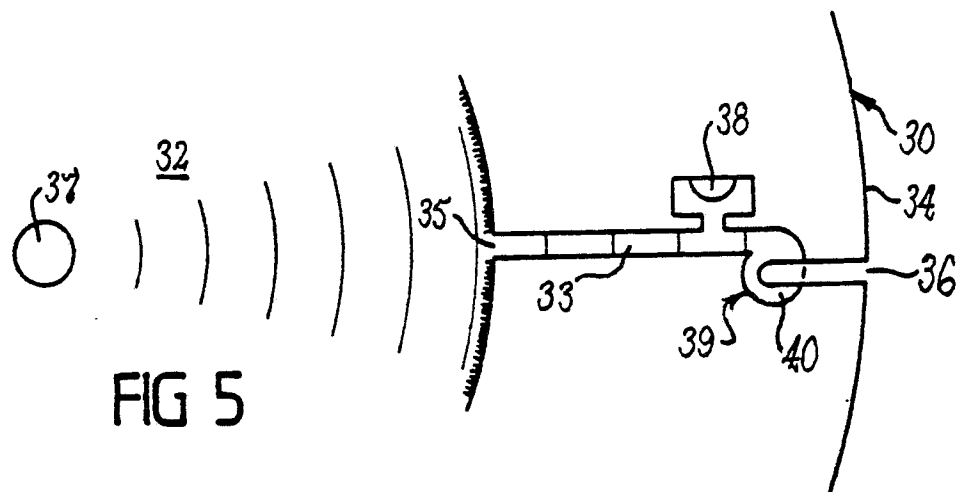
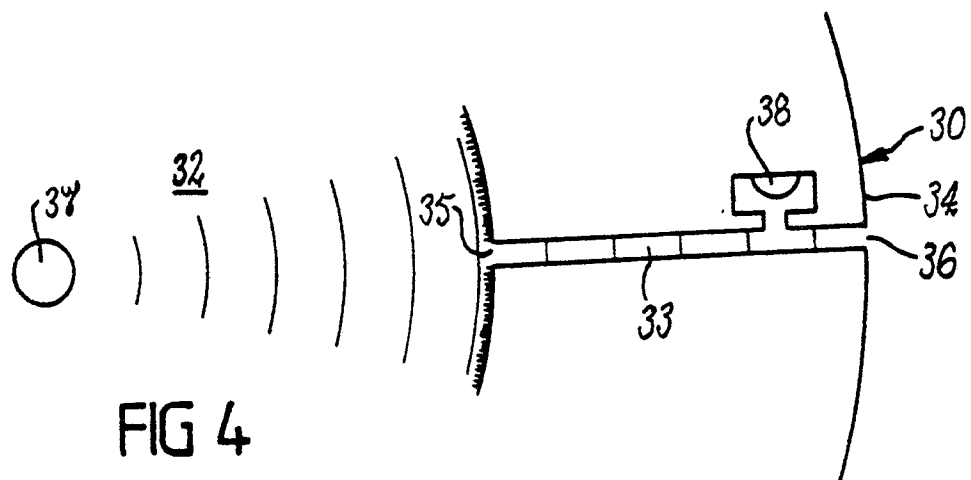
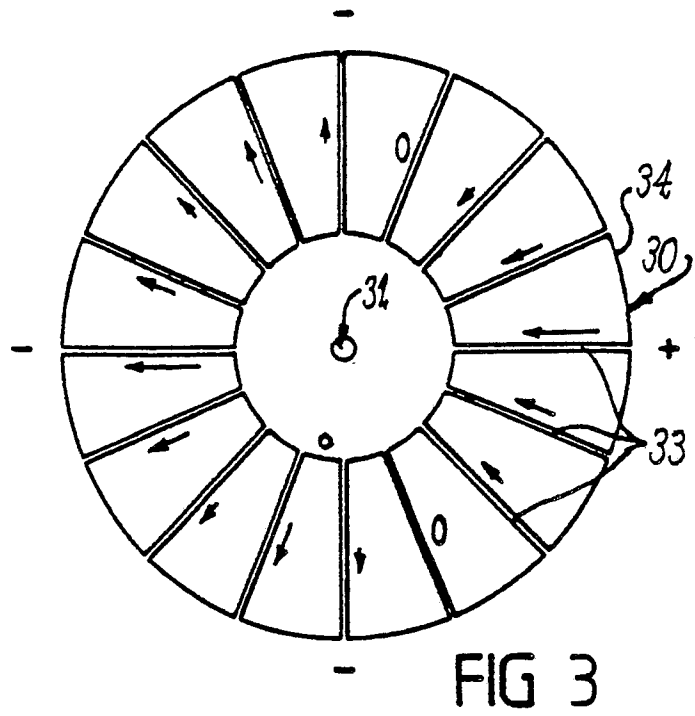
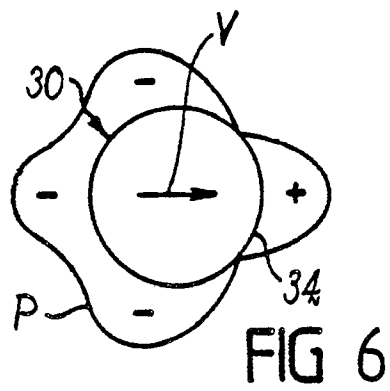


FIG 2





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.4)
Y	GB-A-2 015 296 (FISCHER AND PORTER) * Page 3, lines 49-57; figure 3 *	1-3,6,7 ,10,12, 14,15	G 10 K 9/12 G 10 K 9/20
Y	--- US-A-3 113 288 (SNAVELY) * Column 2, lines 25-42; figure 1 *	1-3,6,7 ,10,12, 14,15	
A	--- US-A-2 983 901 (PASLAY) * Figure 3 * -----	9	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			G 10 K
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 21-03-1988	Examiner ANDERSON A.TH.
CATEGORY OF CITED DOCUMENTS 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 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			