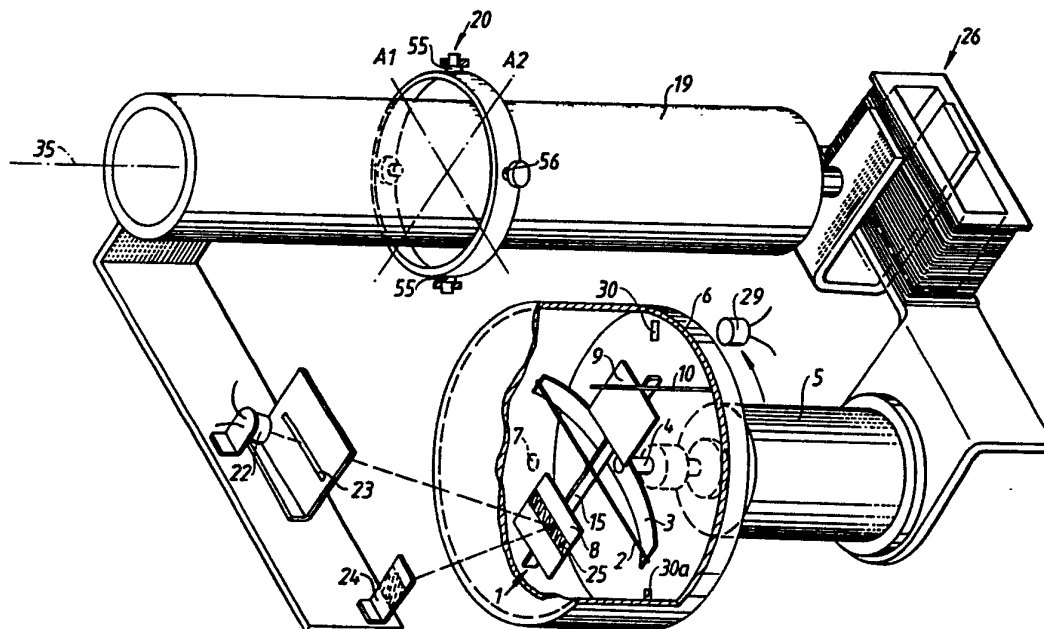




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁵ : G02B 27/64, G01C 19/28	A1	(11) International Publication Number: WO 91/02997 (43) International Publication Date: 7 March 1991 (07.03.91)
(21) International Application Number: PCT/SE90/00539 (22) International Filing Date: 21 August 1990 (21.08.90) (30) Priority data: 8902806-2 23 August 1989 (23.08.89) SE (71)(72) Applicant and Inventor: STRÖMBERG, Rolf [SE/SE]; Stavangergatan 8, S-163 33 Spånga (SE). (74) Agent: OSCAR GRAHN PATENTBYRÅ AB; P.O. Box 19540, S-104 32 Stockholm (SE). (81) Designated States: AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH (European patent), CM (OAPI patent), DE (European patent)*, DK (European patent), ES (European patent), FI, FR (European patent), GA (OAPI patent), GB (European patent), HU, IT (European patent), JP, KP, KR, LK, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL (European patent), NO, RO, SD, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US.		Published <i>With international search report.</i> <i>In English translation (filed in Swedish).</i>

(54) Title: INERTIAL STABILIZING SYSTEM

(57) Abstract

The present invention comprises an inertial stabilizing system to be used preferably in connection with image stabilizing of hand-held optical instruments. An ultralight oscillogyro (1-6) serves as a reference element by which the angular position in inertial space is detected. An electromechanical control system causes a gimbaled part (19) of the optics to assume essentially the same angular position in space assumed by the rotation plane of the rotor of the oscillogyro. The oscillogyro is modified for a widened angular range and the damping of the gyro is utilized for obtaining directly the possibility of target tracking.

DESIGNATIONS OF "DE"

Until further notice, any designation of "DE" in any international application whose international filing date is prior to October 3, 1990, shall have effect in the territory of the Federal Republic of Germany with the exception of the territory of the former German Democratic Republic.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	ES	Spain	MC	Monaco
AU	Australia	FI	Finland	MG	Madagascar
BB	Barbados	FR	France	ML	Mali
BE	Belgium	GA	Gabon	MR	Mauritania
BF	Burkina Fasso	GB	United Kingdom	MW	Malawi
BG	Bulgaria	GR	Greece	NL	Netherlands
BJ	Benin	HU	Hungary	NO	Norway
BR	Brazil	IT	Italy	PL	Poland
CA	Canada	JP	Japan	RO	Romania
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo	KR	Republic of Korea	SE	Sweden
CH	Switzerland	LJ	Liechtenstein	SN	Senegal
CM	Cameroon	LK	Sri Lanka	SU	Soviet Union
DE	Germany	LU	Luxembourg	TD	Chad
DK	Denmark			TG	Togo
				US	United States of America

Inertial stabilizing systemTechnical field

The present invention relates to an inertial stabilizing system to be used preferably in connection with image stabilization for hand-held optical instruments. An ultralight oscillogyro functions as a reference element by which the angular position in inertial space is detected, and an electromechanical control system causes a gimbaled part of the optics to assume substantially the same angular position in space as that assumed by the rotational plane of the rotor of the oscillogyro. The oscillogyro is modified for a widened angular range, and the damping of the gyro is utilized for obtaining directly the possibility of target tracking.

Prior art

Within the field of hand-held image stabilized binoculars and cameras a plurality of mutually different optical concepts have been presented. The great majority of these concepts have one feature in common, viz., that only one part of the optics within the instrument is maintained inertially stabilized, whereas the rest of the instrument is not stabilized. Relative angular movement of said inertially stabilized part of the optics and the instrument casing is made possible by a gimbaled bearing. This common principle of image stabilization is used in most instruments on the market intended for hand-held observation, and nowadays it can be considered as completely conventional.

Even if several solutions relating to the design of the gimbaled part have been proposed, the methods of inertially stabilizing said gimbaled part have exhibited remarkably few solutions working well. As a matter of fact, there is hardly any solution today which has not got at least some serious disadvantages

One of these solutions of the stabilizing problem is the one proposed in US 2 688 456. Unfortunately, this solution has great disadvantages among which sensitivity to bearing friction and play can be mentioned. Balancing of the gimbaled part must be carried out extremely accurately, still, good properties are never attained.

Therefore solutions have been presented where a gyro is mounted on the gimbaled part in order to enhance stability. Disadvantages here are a comparatively high power consumption for driving the rotor of the gyro, a long time before the gyro rotor reaches operative speed (15-60 seconds for some commercially available instruments) and a considerably increased weight, as in practice the gyro and the batteries have to be comparatively heavy. In order to make panning (target tracking) possible a precessing mechanism is necessary, which could cause a considerable loss of power when panning takes place.

In addition, there are problems associated with nutation oscillations when the gyro is rigidly secured to the gimbaled part. In order to solve these nutation problems a resilient and viscous coupling between the gyro and the gimbaled part can be used, which increases complexity, weight and volume. Examples of this technology is given in US 3 564 931, where also the nutation problem is more closely elucidated.

A third possible principle to apply in order to obtain best stability is to refrain from connecting the gyro mechanically to the stabilized part, but to detect instead the position of the gyro by means of electronics so that signals are generated which are then used to urge, via small electromechanical actuators, the gimbaled part towards stability. The expected advantage of this solution is i.a. that it ought to be possible to design the gyro much smaller, resulting in reduced total weight and volume, but up to now it would seem that advancements have been modest in practice; in few if any of the hand-held image-stabilizing instruments on the market at present this principle is applied. The problem of reducing starting time, weight, power consumption and complexity does not seem to have been satisfactorily solved, for which reason the potential advantages appear not to have justified selection of this concept.

Summary of the invention

The present invention is a representative of this third category. An ultralight rotor in an oscillogyro is dimensioned, in a preferred embodiment, to behave with respect to its angular position in space as the gimbaled optical part in an image

stabilized telescope should do, and this gimbaled optical part is then caused, by means of a simple electromechanical control system, to maintain the same angular position in space as that assumed by the rotor.

5 Unique practical advantages of a stabilizing system design according to the invention are i.a.: the starting time is so short, about 1/10 second, that the gimbaled optical part can be mechanically released at the same time as the oscillogyro is started, which eliminates the delays, often unacceptable,
10 of 15-60 s mentioned above. The power generation is so low that a very small drive motor and small batteries can be used which reduces weight and volume of the complete image stabilizing instrument. No precessing mechanism is necessary and, also, no nutation problems exist. No heavy, complicated or bulky components
15 are included and fabrication can take place without time consuming adjustments. In a preferred embodiment of the invention detection of the position of the rotor can be carried out optoelectronically by means of simple zero detectors, which eliminates the demand for good detector linearity.

20 Description of the figures

The invention will be described below, primarily in connection with a preferred embodiment. Thus Fig. 1 shows the comprehensive mechanics of a control system according to the invention. Figs. 2a and 2b show a rotor start centering mechanism, Fig. 3 illustrates shock protection of the oscillogyro,
25 and Fig. 4 shows, in elevation, the gyro rotated an angle α , Fig. 5a shows a block diagram of the electronic system, Fig. 5b shows an associated voltage diagram, Fig. 6 shows an end view of the oscillogyro, and Fig. 7 illustrates an alternative method of rotor detection. Fig. 8 shows the associated block diagram,
30 Fig. 9 shows i.a. an alternative gyro rotor and an alternative rotor case, Fig. 10 shows a curve of the step response of the rotor and, finally, Fig. 11 shows an end view of the rotor 1.

Description of an embodiment

35 The general function is first described very briefly with reference to Fig. 1. A motor 5, motor shaft 4, leaf spring 3, torsion wire 2 and a rotor 1 constitute (with a minor exception, later to be described) an oscillogyro, which is generally

conventional. For a description of the oscillogyro principles reference is made to The Journal of Mechanical Engineering Science 1967, Vol. 9, No. 1, pp 55-61, by R Whalley, M J Holgate and L Maunder, "The Oscillogyro".

5 The gimbaled optical part 19 is illustrated in Fig. 1 in the form of a cylinder but it is to be understood that this optical part 19 corresponds to the stabilized part in an image-stabilized instrument. The appearance of this part and what optics it carries is of no consequence to the present invention.
10 Every completely stabilized optical part in an image stabilized instrument defines an optical line-of-sight, which is found in Fig. 1 as a line 35.

 The motor 5 is secured to the casing (not shown) of the instrument and thus it follows the movements of the casing.
15 Within the case 6 of the oscillogyro there is a rotor 1 rotating in a plane which, on a short time basis, is inertially stabilized and thus isolated from higher frequencies of turning movements of the instrument casing about all axes orthogonal to motor shaft 4. The gimbaled optical part 19 is movable by
20 way of gimbal 20 a small angle, about ± 5 degrees, in relationship to the instrument casing about gimbal axes 55 and 56 and thus about all axes orthogonal to the optical line-of-sight 35 of the instrument. However, gimbal 20 does not allow part 19 to rotate about line-of-sight 35 in relation to the instrument
25 casing. When the instrument is not used it is advisable that the gimbaled optical part 19 be mechanically locked to the instrument casing in a position where the optical line-of-sight 35 is parallel with motor shaft 4. This position is shown in Fig. 1. In use optical part 19 is disengaged but locked by way
30 of an electromechanical control system to the angular position in the inertial space assumed by the rotational plane of rotor 1. Consequently the optical part, as the rotor, is inertially stabilized on short time basis. In addition, the stabilized optical part 19 should be statically balanced on its bearings.

35 When the instrument casing is turned slowly, which takes place in panning or target tracking the rotational plane of the rotor will participate in this turning, with a certain lag, thanks to the specific properties of the present oscillogyro.

As the gimbaled optical part 19 is locked by way of the control system to the angular position of the rotational plane of the rotor, also optical part 19 will participate in the turning movement of the casing, rendering target tracking possible.

5 Rotor 1 has the form of a bar 15 having a length of the order of 40 mm. On this rotor bar two thin plates 8 and 9 are secured. Rotor 1 is secured to the thin torsion wire 2 which in turn is secured to and maintained tensioned by the bent leaf spring 3. On its central point spring 3 is secured to motor shaft 10 4. The case 6, containing all rotating parts, is secured to motor shaft 4. In practice rotor 1 need not have a greater moment of inertia than 1.10^{-7} kgm^2 , measured about the axis represented by torsion wire 2.

15 A practical detail is the fact that the force by which leaf spring 3 tensions wire 2 has to be so great that the angular resonance frequency relating to rotor 1 translation in a plane orthogonal to wire 2 is greater than the angular frequency by which motor shaft 4 rotates.

20 As rotor 1 is secured to torsion wire 2 it is obvious that rotor 1 can only tilt to and fro about the axis which wire 2 represents, as viewed in relationship to case 6. When the oscillogyro is in operation motor shaft 4 and thus case 6, leaf spring 3, torsion wire 2 and rotor 1 rotate at constant speed, and rotor 1 will then rotate or spin in a plane practically 25 maintaining its angular orientation in the inertial space, even if motor 5 is slewed a small angle about an axis orthogonal to motor shaft 4.

30 In principle the plane described by rotor 1 behaves, on a short time basis, as a free gyro rotor. There are very small deviations from the position completely inertially stabilized but such deviations can be disregarded in practice, which will be done in the following. Even if the function of a tuned oscillogyro (as described above) is well known it is mentioned here that the centering torsion moment of wire 2 during rotation 35 is neutralized by small dynamic decentering reaction moments generated in rotor 1, about the axis represented by wire 2. These decentering reaction moments increase with the speed (RPM) squared, whereas the centering torsion movement generated by

wire 2 is of course not depending on speed. From this follows that at a certain speed (the tuned one) the decentering reaction moment is equal to the centering torsion moment exercised by wire 2, the two moments neutralizing one another, and rotor 1 can then rotate uneffected by any undesired net moment. Therefore it is important in practice that the speed of motor 5 be maintained constant and equal to the tuned speed.

Case 6 encloses all gyro components, which is desirable as otherwise the surrounding air would have a negative effect on the stability of the ultralight rotor 1 by the turbulence which would have arisen. It is obvious that the air surrounding rotor 1 within case 6 participates in the rotation and is not turbulent in any disturbing way thanks to case 6. However, case 6 should not be completely tight; a small hole 7 sees to it that there can be no pressure difference within and without case 6 to deform the case. This hole should be located as shown in Fig. 1, thus in or near the longitudinal axis of drive shaft 4, an arrangement which does not cause any air turbulence within case 6.

It is also desirable that case 6 does not add too much rotational inertia to the rotating parts, which would increase unnecessarily the starting time of motor 5. A low rotational inertia of case 6 will be attained if thin plastics are used.

Reference is now made to Fig. 4. As the plane within which rotor 1 is rotating (in the following designated "rotational plane of the rotor" and indicated in Fig. 4 by dashed line RP) will behave, on a short time basis, as a free gyro rotor it will maintain its angular position in space immediately after motor 5 has slewed a small angle α about an axis orthogonal to motor shaft 4. In Fig. 4 rotor bar 15 is shown in that very moment of time when it is in the plane of the paper. The angle α between the rotational plane of the rotor and an imaginary plane P1 orthogonal to motor shaft 4 will be referred to in the following as "the angular deviation of the rotational plane".

Thus it can be established that the rotational plane RP of the rotor is essentially inertially stabilized on a short time basis.

On the other hand, on a long time basis the rotational

plane of the rotor should not, according to the invention, be inertially stabilized but travel slowly from a decentered position back to the central position perpendicular to motor shaft 4. This is accomplished by motor 5 being secured to the instrument casing at the same time as rotor 1 is dimensioned to exhibit a very low moment of inertia measured about the axis defined by wire 2. If at the same time plates 8 and 9 are suitably sized, with an area of the order of 1 square centimeter each, the viscous coupling between motor 1 and case 6 provided by the air within case 6 will have sufficient influence to bring about the desired centering of the rotational plane of the rotor. In other words, if the instrument casing and thus motor 5 is suddenly turned a small angle ϕ in relation to inertial space about an axis orthogonal to the rotational shaft 4 of the motor (t = 0 in Fig. 10) and then maintains its novel position, the rotational plane RP of the rotor will precess slowly back to the central position perpendicular to motor shaft 4 at an angular velocity which in any moment of time is proportional to the angular deviation α of the rotational plane. In other words, the angular deviation α will then exponentially approach zero, which is illustrated by Fig. 10.

The precessing back to the central position described above can be utilized as a possibility of target tracking. This is a great advantage as the centering takes place spontaneously; specific precessing devices are eliminated. This constitutes a preferred embodiment of the present invention. If the design parameters are selected such that the time constant of the centering process of the rotational plane of the rotor becomes about 1 second, the rotational plane of the rotor will behave, with respect to its angular position in space, in a manner which is also very suitable to the gimbaled optical part of image-stabilized binoculars. If the casing of the binoculars is turned at a certain limited angular speed the rotational plane of the rotor will participate, at a certain lag, in this turning movement, that is, target tracking occurs.

A purpose of the present invention, and also necessary in most cases, is to enable in practice a larger angular deviation α , at least 5 degrees, of the rotational plane of the rotor than

is possible to obtain by conventional oscillogyro mechanics. In image-stabilized binoculars there may occur in practice rapid oscillations of the casing in relation to inertial space of at least ± 5 degrees, and as motor 5 is unstabilized and thus follows the oscillations of the casing, but the rotational plane of the rotor is inertially stabilized and thus isolated from rapid oscillations, also the rotational plane RP of the rotor has to be able to assume an angular deviation α of at least the same degree in relation to the unstabilized parts (e.g. motor 5). This demand, thus that the rotational plane RP of the rotor should be able to carry out, with stability maintained, an angular deviation α of at least about 5 degrees, requires that special measures be taken. If not, the following phenomena will have a detrimental effect on the stability: as rotor 1 and motor shaft 4 do not rotate in the same plane when there is an angular deviation α present, but are interconnected by way of wire 2, there is introduced on rotor 1 a small disturbing moment which tends to destroy stability when the angular deviation of the rotational plane exceeds a few degrees only. It can be said that this disturbing moment is caused by the fact that rotor 1 is forced, because of said angular difference, to rotate in its rotational plane at a somewhat uneven angular velocity, one revolution considered. Said disturbing moment will increase in proportion to the angular deviation α cubed, for which reason it cannot, as distinguished from the centering moment of the wire 2, be compensated by tuning the motor RPM. As it is often necessary in practice that the angular deviation of the rotational plane of the rotor amounts to at least 5 degrees, this problem has to be eliminated.

According to the invention this is carried out in such a way that an angular resilience is introduced between wire 2 and rotor 1. This angular resilience enables rotor 1 to perform small angular movements (in practice $\ll 1$ degree) in relationship to wire 2 (and thus also in relation to motor shaft 4) in the rotational plane of the rotor, thus also permitting rotor 1 to rotate at a uniform angular speed in its rotational plane. The simplest way in practice to introduce this angular resilience is to make the distance L (shown in Fig. 11, where distance L

should not be seen as a measure of the width of rotor bar 15) between the securing points of the wire (2) on either side of rotor bar 15 sufficiently small, as wire 2 is maintained tensioned at a constant but limited force by leaf spring 3. It is obvious that the smaller distance L, the less stiff rotor mounting in relation to wire 2, considering small angular movements of rotor 1 in its rotational plane. Also, as a matter of course, some other equivalent type of flexible coupling can be introduced between wire 2 and rotor 1; the important fact is that the small mutual angular movements of wire 2 and rotor 1 in the rotational plane of the rotor are allowed to occur in operation.

This angular resilience creates a new problem which could be best understood if the case 6 and thus the rotor 1 with its several components are first considered at rest, thus not rotating. Now, as rotor 1 is not rigidly but resiliently secured with respect to small angular movements in a plane orthogonal to motor shaft 4 there is arising in this plane a tendency towards angular resonance Ω of rotor 1.

The angular frequency of the resonance concerned can be written:

$$\Omega = \sqrt{\frac{K(t)}{I}}$$

where $K(t)$ is a measure of the angular resiliency described above and I is the rotor moment of inertia measured about motor shaft 4. If behavior in rotation is now considered it turns out that a mechanical phenomenon of interference arises if Ω coincides with the angular frequency $\Omega(m)$ of motor shaft 4 rotation. This problem disappears if $\Omega(m)$ never reaches Ω . For attaining favourable results in practice $\{\Omega - \Omega(m)\} = 63 \text{ rad/s}$ could be selected.

There is a further problem arising, for which reason reference is now made once more to Fig. 1. In order to avoid that rotor 1, on account of the angular resilience, tilts too much transversely to wire 2 when starting the gyro, the angular acceleration of motor shaft 4 then being very high, a stop is required, in the form of a rigid bar 10 secured to case 6. When motor shaft 4 and thus all rotating components have reached their full speed in the direction of the curved arrow, the angular

acceleration ceases and rotor 1 will then leave bar 10, as bar 10 is located such that normally it does not make contact with rotor 1.

5 A practical detail is that rotor 1 should be locked in a central position, i.e. at an angle of 90 degrees to motor shaft 4, before motor 5 is started, to be freed for tilting about wire 2 only when a certain rotational speed has been reached. If this condition is not satisfied there could be, in practice, a considerable angular deviation of the rotational plane of the rotor immediately after start, which is mostly undesirable. Reference is now made to Figs. 2a and 2b illustrating a possible mechanism for locking the rotor before start. A locking clip 16 is pivotally carried in the base 17 and can tilt a small angle in relation to said base, which is rigidly connected with motor shaft 4. A coiled spring 18 urges locking clip 16 towards rotor bar 15 (as shown in Fig. 2a) when motor 5 is not running. Locking clip 16 is designed such that it will then contact rotor bar 15 on either side of wire 2, rotor 1 thus being locked in a centered position and prevented from tilting about wire 2. When motor 5 has reached a certain speed, but not full speed, after start, locking clip 16 is affected, by way of the weights 16a and 16b, by centrifugal force to tilt away from the position shown in Fig. 2a and remain in that shown in Fig. 2b, where rotor 1 is free to rock about wire 2.

25 Reference is now made to Fig. 3 where bumpers in the form in soft stops 11, 12, 13 and 14 are shown. They are secured to case 6 and limit gently the rocking movement of rotor bar 15 about wire 2 when the binoculars are panned so swiftly that the viscous air coupling between rotor 1 and case 6 does not suffice for precessing rotor 1. Stops 11-14 also receives rotor 1 at shock acceleration in a direction parallel to motor shaft 4, possibly occurring if the instrument e.g. is dropped. If the shock acceleration occurs in a direction parallel to rotor bar 15 there must also be stops, as wire 2 is rather resilient also in this direction. These stops can be formed, for example, by the inside of case 6 which the ends of rotor bar 15 may contact. For shock acceleration in a direction parallel to wire 2 no stops are needed as leaf spring 3 and wire 2 can be di-

mentioned sufficiently strong to assume the force. By these tricks it is gained that the complete rotor mechanism becomes very shockproof.

5 It is emphasized that all mechanical features described above are needed in order to attain a good result, but they are not all illustrated in one and the same figure, for reasons of clarity.

10 Still another practical detail is the fact that motor shaft 4 should be forced, immediately upon start, to reach its proper speed as soon as possible which, if motor 5 is DC-operated, can be readily brought about by maintaining the motor 5 drive voltage on a higher than normal level immediately after start, to be then decreased to a constant, lower value when motor 5 has reached its proper speed.

15 If the above instructions are followed and if the structural parameters are correctly selected, the rotational plane of the rotor will now be stable on a short time basis. It will precess aperiodically from a decentered position back to the centre position with a suitable time constant, of the order of 1 second, exactly as the stabilized part of a pair of image stabilized binoculars should do in order that a good result be attained.

20 Again reference is made to Fig. 1. The only step that remains to be taken is to lock by way of a control system the angular position of the gimbaled optical part 19 to the angular position of the rotational plane of the rotor in order to accomplish the desired stability of the gimbaled part 19. Two control systems have to be at hand which control the gimbaled part about two mutually perpendicular axes A1 and A2, orthogonal to the optical line-of-sight 35 of the instrument. However, only one of these control systems, viz., that operating about one of the axes A1, is described in detail here, as control about the second axis (A2) is exercised in the same manner.

25 An infrared light diode (LED) 22 emits short pulses of light, of the order of 100 microseconds/pulse, towards rotor 1 by way of a slot 23, which is parallel with the axis (A1) about which detection occurs. Case 6 has to be transparent to the infrared light where this passes the wall of the case. The light pulses are reflected by the plates 8 and 9 secured to rotor 1 (reflec-

tion by plate 8 is illustrated in Fig. 1), the plates being foil-
ed and thus also acting as mirrors. Upon reflection the light
finally strikes an optical zero-detector 24, whose back side
is visible in Fig. 1. The light striking zero detector 24 is
5 limited by slot 23 to a narrow band of a width adapted to the
zero detector concerned. As a matter of course the light will
also strike mirror 8 as a band 25. Light diode 22, slot 23 and
zero detector 24 are all secured to the gimbaled optical part
19. A zero voltage output from zero detector 24 can only occur
10 when the light band 25 is centered on the middle of zero detec-
tor 24 which, in turn, can only occur when part 19 and the
rotational plane RP of the rotor have a certain mutual angular
orientation about axis A1. This is the situation when the gim-
baled optical part is "locked" by way of the control system to
15 the rotational plane of the rotor. Any mutual angular deviation
from this situation gives cause to an output voltage from zero
detector 24, said voltage being treated electronically to form
a signal finally applied to an electromechanical actuator 26
which induces mechanically the gimbaled optical part 19 to
20 reassume its normal "locked" position about axis A1. Actuator
26 is thus adapted to turn optical part 19 about axis A1.

Actuator 26 can be designed optionally but it should not
introduce friction. A possible design is shown in Fig. 1, where
a wire coil 27 is secured to the instrument casing and the U-
25 -shaped permanent magnet 28 is secured to the gimbaled optical
part 19. An input voltage on coil 27 then gives rise to a force
tending to rotate the gimbaled part 19 about the axis concerned
(A1).

A light pulse from light diode 22 is to be emitted only at
30 the time when case 6 and thus rotor 1 are in a position for in-
dicating the relative angular position, about the axis concerned
(A1), of optical part 19 and plane of rotation RP of the rotor.
This occurs only twice per revolution, namely, when wire 2 is
parallel with that axis (A1) about which the control system
35 operates. Hence, in practice one light pulse is to be emitted
when wire 2 is parallel with that axis about which the actuator
26 is able to turn optical part 19.

It suffices to emit a light pulse only once per revolution

although two light pulses per revolution are recommended, but the light pulse is to be emitted only when rotor 1 is in position, in accordance with the rule above. In order to render this possible in practice the angular position of case 6 has to be detected in some way, which can be brought about by means of a reflex detector 29 mounted on the instrument casing. See now also the block diagram in Fig. 5a and the voltage diagram in Fig. 5b. Reflex detector 29 scans two diametrically opposed reflecting indications 30 and 30a near the periphery of case 6, thereby giving rise to a pulsing digital voltage U3.

U3 is conveyed to a pulse generator 50 which emits, for each positive flank of U3, a voltage pulse of a length of the order of 100 uS, a pulsating voltage U then being obtained which controls, via an exciter 53, light diode 22 so as to emit light only when voltage U is high.

It is understood that the two indications 30 and 30a shown give rise to two voltage pulses U3 and thus two light pulses per revolution. To attain one light pulse only per revolution, one of the indications should be excluded.

The situation we now have means that short light pulses strike zero detector 24 regularly, the detector therefore creating via an input stage 54 short voltage pulses U1, provided that the light does not strike exactly at the centre of zero detector 24. To convert these voltage pulses U1 to a voltage more continuous they are conveyed to a "sample and hold" circuit 31 which is held open only when voltage U is high. After "sample and hold" circuit 31 there will thus be a more continuous voltage U2, which is amplified and frequency filtered in a filter 51 in accordance with conventional regulation theory, before it is applied to actuator 26 by way of an output stage 52. In Fig. 5b curve 61 is arbitrarily chosen for illustrative purpose in order to show how U2 depends on U1.

The adding circuit 40 will be discussed later.

The control device described above only operates about one single axis (A1), which is orthogonal to the line-of-sight of the instrument, but as stated above it is necessary, in order to bring about a complete image-stabilizing process, to add a second similar control device to attain stabilizing about all

axes orthogonal to the line-of-sight 35 of the instrument. Suitably this second control device operates in the same way as that described above but about an axis (A2) orthogonal to the first axis (A1), also this axis (A2) being orthogonal to the line-of-sight 35 of the instrument. In Fig. 6 the position of the rotor is illustrated by dashed lines in the moment of time when light diod 57 is to emit a light pulse. The light from light diod 57 passes slot 32, is reflected by the mirror 8 of the rotor and strikes finally zero detector 33.

10 A second actuator capable of turning the stabilized optical part 19 about axis A2 will also be added.

Furthermore: it is noted that the relative position of the gimbaled part 19 (in its centered position) and the oscillogyro need not be such as shown in Fig. 1, however, it must be seen to it that the light bands from light diods 22 and 57 never miss mirrors 8 and/or 9 in operation.

Although the invention has been described above in its preferred embodiment a few alternative embodiments will be described below.

20 In the first place it could be desirable in certain instruments to stabilize the optical part about one axis only, orthogonal to the line-of-sight. In this case this optical part should be movable in relationship to the instrument casing about this axis only, and only one control system is then required.

25 It should be made clear that a stabilizing system according to the invention should be possible to use without prejudice together with other types of instruments or apparatus where a body is inertially stabilized on a short time basis and, on a long time basis, connected to the instrument casing. Thus the gimbaled part 19 need not necessarily contain optics, a prerequisite up to now.

30 If desired the air within case 6 can be replaced by an optional gas which, having another viscosity than the air, could create, other conditions alike, a changed viscous coupling between rotor 1 and case 6 and thus a changed time constant for precessing of the rotational plane of the rotor back to the central position perpendicular to motor shaft 4.

Another coupling between rotor 1 and motor shaft 4, provid-

ed optionally and operating equivalently, can replace in whole or in part the viscous effect of the air enclosed within case 6. This is exemplified in Fig. 9 where, for the sake of clarity, leaf spring 3 is not shown. A pin 44 mounted on rotor bar 48 extends through a very thin and resilient diaphragm 47 into a container 45 mounted on motor shaft 49 and containing a viscous liquid 46. In this case the two mirrors (8 and 9 on rotor 1) could suitably be replaced by one single mirror 43 mounted on the centre of rotor bar 48. Mirror 43 only couples insignificantly to the air enclosed in case 34, for which reason the viscous coupling provided by pin 44 in container 45 is required in order to render possible centering of the rotational plane of the rotor and thus target tracking. This also illustrates the fact that the rotor can be designed optionally within rather wide limits if only the mechanical parameters are selected such that the rotor behaves as desired.

Case 6, which according to the foregoing description has been mounted on motor shaft 4 and thus did participate in the rotation, can be replaced if desired by a stationary housing 34, also shown in Fig. 9, mounted on the motor. However, this is not recommended as disturbances caused by air turbulence can arise.

The case can also be eliminated completely, but this is even less recommended, for the same reasons.

Furthermore: torsion wire 2 can be replaced by some other type of single axis bearing, for example, a conventional such bearing having crossed leaf springs.

It is not necessary that the gimbaled optical part is maintained completely locked to the rotational plane RP of the rotor, with respect to mutual angular position. If desired small mutual angular differences can be obtained in a simple manner if a voltage (U4) is connected to adding circuit 40 in Fig. 5a, U4 being added to voltage U2. If the zero detector 24 is replaced by an optical position detector of greater linearity, substantial mutual angular differences between the rotational plane of the rotor and the gimbaled optical part 19 can be obtained by way of voltage U4. It is not essential to the invention what this voltage U4 looks like or how it is obtained. As a special case

of some practical importance, that could be mentioned where the gimbale optical part 19 is designed in such a way that it has to describe, for image stability, an angular movement proportional to the angular movement of the instrument casing. A detection, finally producing U4, is then to take place of the mutual angle, between the gimbale optical part and the instrument casing about the axis (A1, A2) under consideration.

An alternative method of detection for stabilizing purposes will be described briefly below in connection with Figs. 7 and 8. In doing so control of the mechanical angular position of the gimbale part about one axis only (indicated A3) orthogonal to the line-of-sight 35 of the instrument will be discussed. A position detector 36, a light diod 37 pulsed in accordance with the description above and a slot 38 are here secured to the casing and will thus participate in the movements of the instrument casing. A voltage U5 is then obtained after gating into a "sample and hold" circuit in analogy with the description above. It is appreciated that U5 is proportional to the angular deviation α of the plane of rotation.

A second optionally operating detector (not shown) is adapted to give rise to a voltage U6 which is proportional to the angular position of the gimbale optical part about axis A3 in relation to the instrument casing. Now, if U5 and U6 are compared in a subtracting circuit 42, an output will be obtained from this circuit in the form of a third voltage U7 which, after frequency filtering in accordance with conventional regulation theory, is applied to an actuator which can turn the gimbale optical part about the axis (A3) under consideration.

It is to be made clear that the procedures above described of opto-electronic detection of the angular position of the rotor only represent a preferred embodiment. Another type of opto-electronic detection can very well be used, and alternative detection procedures utilizing capacitive or other principles are also conceivable.

If desired motor 5 can be mounted relative to the instrument casing by way of a soft coupling, e.g. a rubber damped coupling. This can be to advantage when it is desired to isolate the instrument casing against possible vibrations which

can be transmitted from motor 5 if the rotating parts are not sufficiently balanced dynamically. This will in no way alter the function; what is essential is that motor 5 participates in the slow turning movements of the instrument casing, which makes target tracking possible.

As a matter of course two separately mounted bodies can be stabilized by the same oscillogyro carrying out detecting. Each of these bodies is then mounted about each its axis, the axes being mutually perpendicular. An optical arrangement requesting this kind of mechanics for image stabilizing is exemplified by US Patent No. 3 437 397.

The gimbaled optical part 19 can very well be provided with a further bearing axis parallel to line-of-sight 35 to offer the possibility of turning part 19 small angles about said line 35 in relation to the instrument casing. The control system described above will function also in this case if only it being seen to it that the gating in of the voltage from zero detector 24 via the sample and hold circuit always takes place at the proper time, in accordance with the rule given in the foregoing.

Remaining minor modifications of the mechanics disclosed should also be considered falling within the scope of the invention. An example of such a modification could be replacing leaf spring 3 by some other mechanism for tensioning wire 2, and another modification could be designing light diod 22 such that it gives directly a limited light spread, thus producing directly light band 25 on the rotor mirrors and eliminating slot 23.

Claims

1. Inertial stabilizing system for an instrument including a casing and a body (19) pivotally mounted in relation to the casing of the instrument, characterized in that the system includes an oscillogyro (1-6) as a stability reference which is associated
5 with the casing in such a way that the longitudinal axis of the driver (4) of the oscillogyro follows essentially the movements of the casing, detecting means (22-24, 57, 32, 33) for detecting the angular position of the rotational plane (RP) of the oscillogyro, and a control system for affecting the angular position
10 of the pivotally carried body (19) in accordance with the rotational plane (RP) detected.

2. A system according to claim 1, characterized in that it is component of an image stabilized optical instrument where the
15 pivotally mounted body (19) includes at least part of the optics of the instrument, and that the control system affects the pivotally carried body (19) such that the body, about at least one axis (A1; A2) and with respect to its angular position, is inertially stabilized or describes angular movements proportional
20 to but separated from the angular movements of the instrument casing.

3. A system according to claim or 2, characterized in that the rotor (1) and driver (4) of the oscillogyro are arranged mutual-
25 ly resilient whereby minor mutual angular movements between the rotor (1) and the driver (4) of the oscillogyro are permitted, substantially in a plane orthogonal to the longitudinal axis

of the driver (4) of the oscillogyro, in order to enhance considerably the stability of the rotational plane (RP) of the oscillogyro at larger angular deviations (α).

5 4. A system according to claim 1, 2 or 3, characterized in that
the rotor (1) of the oscillogyro is located within a case (6;
34), that there is a coupling between the rotor (1) and the driver
(4) introducing a moment between the rotor (1) and the driver
(4) about a single axis bearing (2) of the oscillogyro, said
10 moment being substantially proportional to the relative angular
speed of the rotor (1) and the driver (4) about said single axis
bearing (2) of the oscillogyro, said coupling enabling intentional
angular change of the rotor-reference plane (RP) and thus,
via said control system, an angular change of the pivotally
15 carried body (19), for example, in target tracking or panning.

5. A system according to claim 4, characterized in that air or
gas within said case (6; 34) provides the major part at least
of said coupling between the rotor (1) and driver (4) of the
20 oscillogyro.

6. A system according to claim 4, characterized in that
said control system is adapted to maintain a constant mutual
angular orientation between the rotational plane (RP) of the
25 rotor and the pivotally carried body, at least about one axis
(A1).

7. A system according to claim 4, characterized in that the case
(6) is adapted to participate in and follow the rotation of the

driver (4) of the oscillogyro.

5 8. A system according to claim 4 or 5, characterized in that the single axis bearing of the oscillogyro consists of a tensioned torsion wire (2) which is secured on either side of the rotor, the distance between securing points being sufficiently small to bring about said angular resilience between the rotor and driver of the oscillogyro.

10 9. A system according to claim 8, characterized in that the possibility of the rotor (1) to move in the radial direction of the torsion wire (2) is limited by stops (11-14).

15 10. A system according to claim 4, characterized in that an element (16) is adapted, when the driver (4) is at rest, to engage resiliently the rotor (1) and thereby lock the rotor in a centered position and that, after start of the oscillogyro, said element (16) frees the rotor at a predetermined rpm by action of centrifugal force.

20 11. A system according to claims 1-10, characterized in that the detection means includes at least one light diod (22) and a zero detector (24), the light diod emitting short light pulses which are reflected by at least one reflecting surface (8; 9)
25 on the rotor to then strike the detector (24).

12. A system according to claim 11, characterized in that the output signal (U1; U8) of the detector (24; 36) is connected to a sample and hold circuit (31) whose output signal is fre-

quency filtered and supplied to an actuator (26) which is adapted to affect the angular position of the pivotally mounted body (19).

- 5 13. An inertial stabilizing system according to claim 1, characterized in that it includes an oscillogyro forming a stability reference, that the oscillogyro includes a driver (4) which rotates about a longitudinal axis, said driver (4) driving a rotor (1) by way of a single axis bearing (2) to rotate about
- 10 said longitudinal axis at a substantially constant rpm, that the longitudinal axis of the driver (4) participates in the low frequency angular movements of the casing in relation to inertial space, in which process an angular deviation (α) between the plane (RP) wherein the rotor (1) rotates and a plane (P) ortho-
- 15 gonal to said longitudinal axis can arise, that the rotor (1) is situated within a case (6; 34) where air or gas within the case mostly participates in the rotation of the driver, that there is a coupling between the rotor (1) and the driver (4) introducing between the rotor (1) and the driver (4) a moment
- 20 substantially proportional to the relative angular speed of the rotor (1) and the driver (4) about the single axis bearing (2), a centering of the rotational plane (RP) occurring on a long time basis because of the angular displacement in inertial space which the rotational plane (RP), due to the effect of
- 25 said coupling, is subjected to at angular deviation (α), that an essential increase of the stability of the rotational plane in relation to inertial space is obtained over an angular interval of the angular deviation (α) by the feature that an angular resilience is adapted to render possible mutual angular movements,

sufficiently large for the purpose, between the rotor (1) and driver (4) of the oscillogyro in the plane (RP) wherein the rotor (1) rotates.

Fig. 1

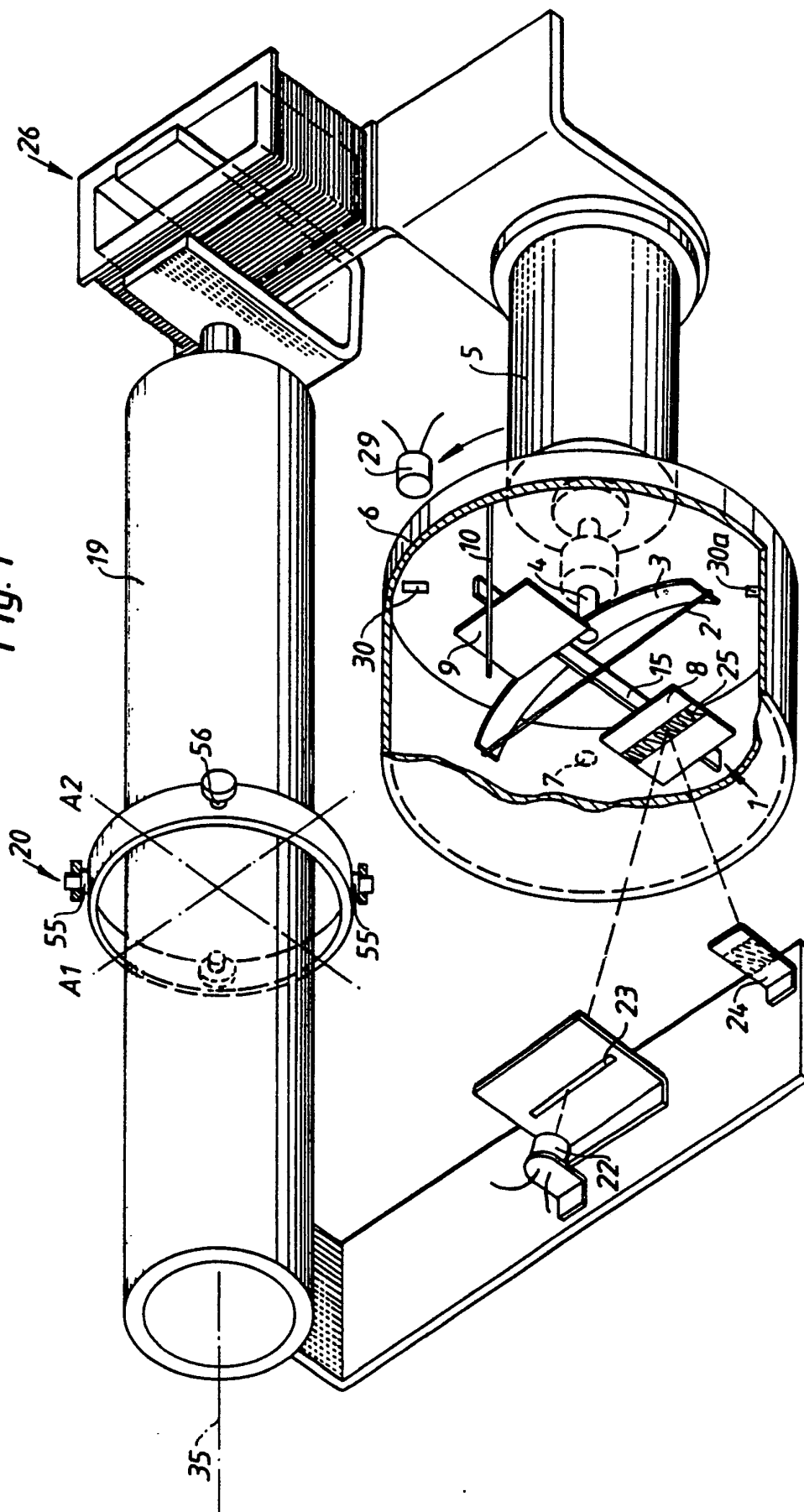


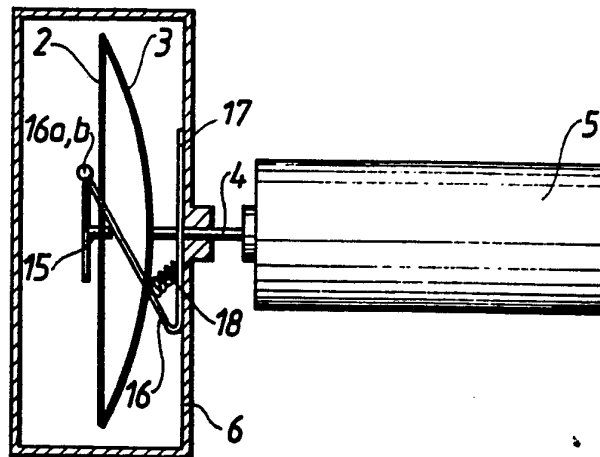
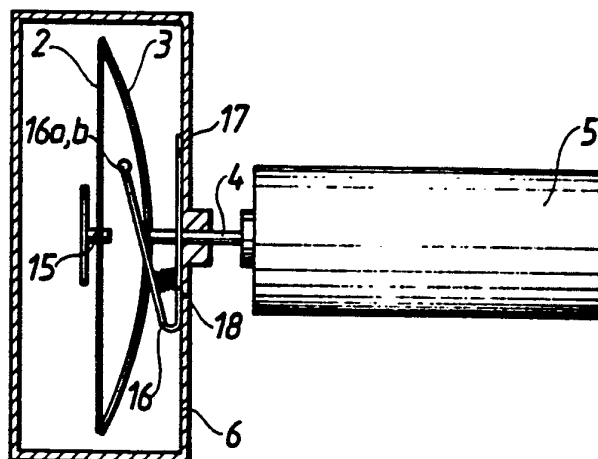
Fig. 2a*Fig. 2b*

Fig. 3

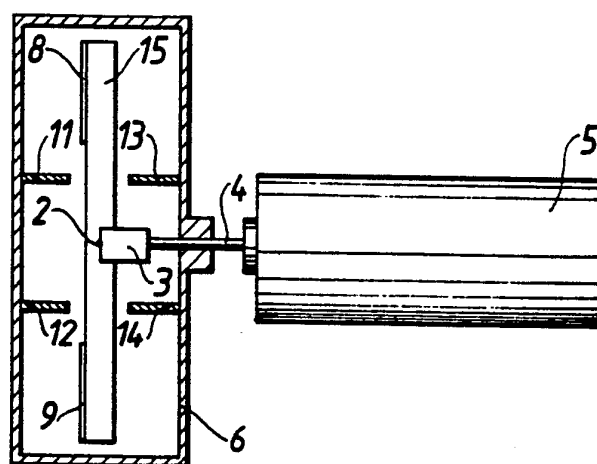


Fig. 4

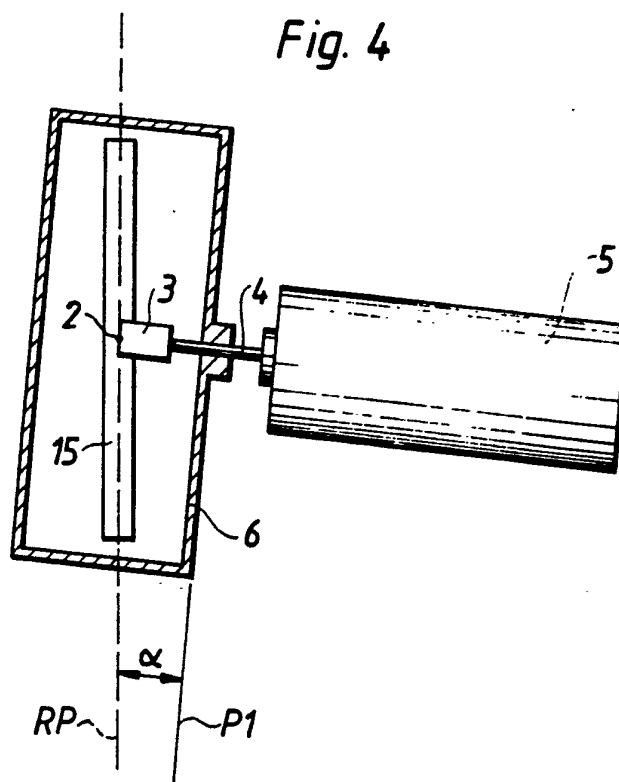


Fig. 5a

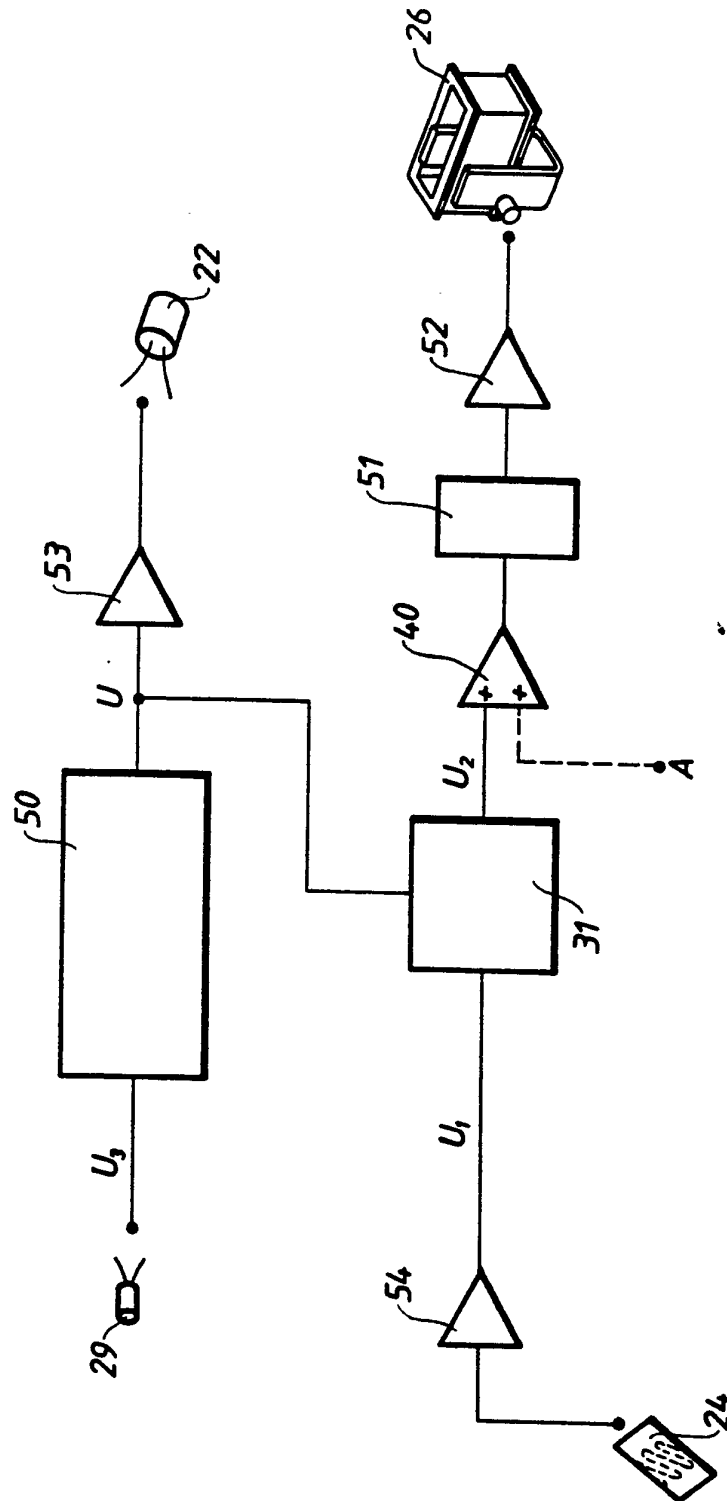


Fig. 5b

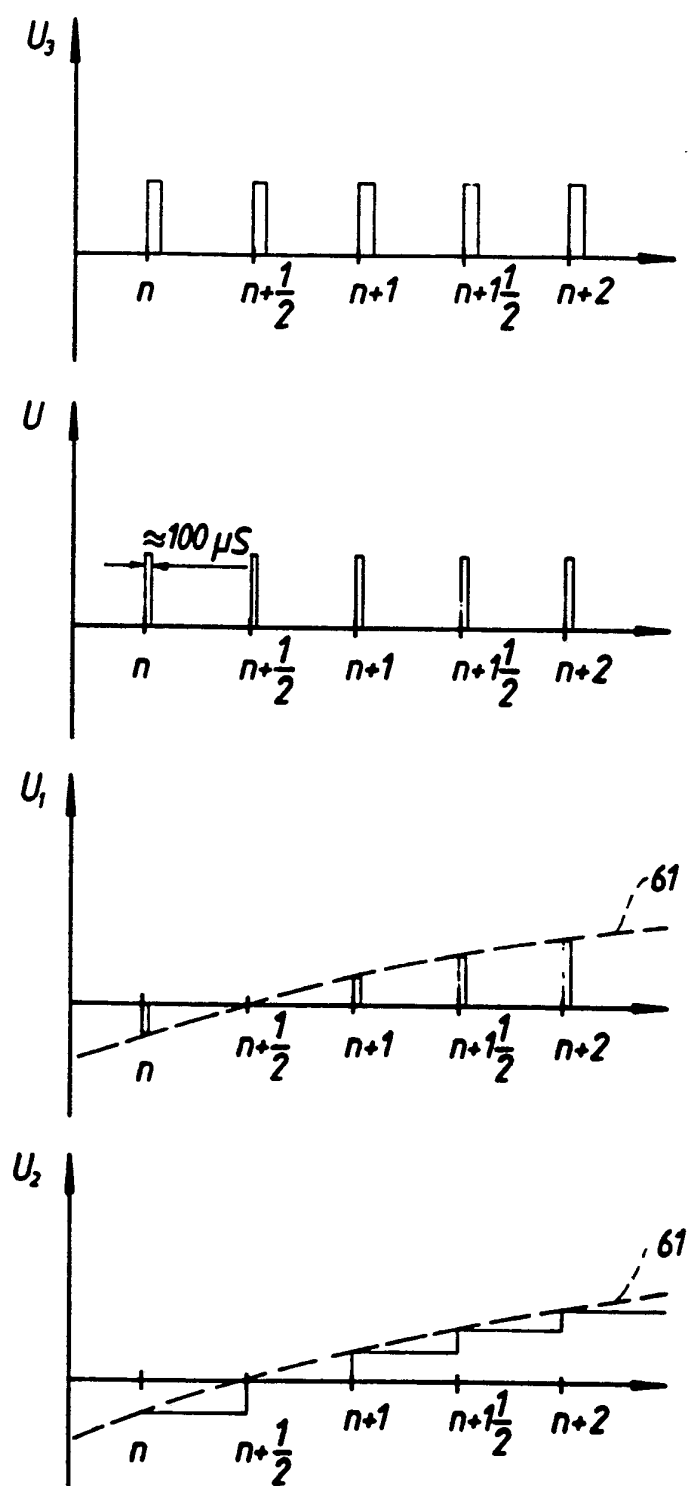


Fig. 6

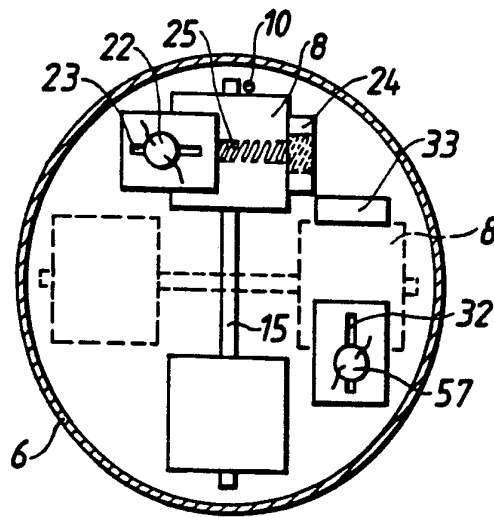


Fig. 7

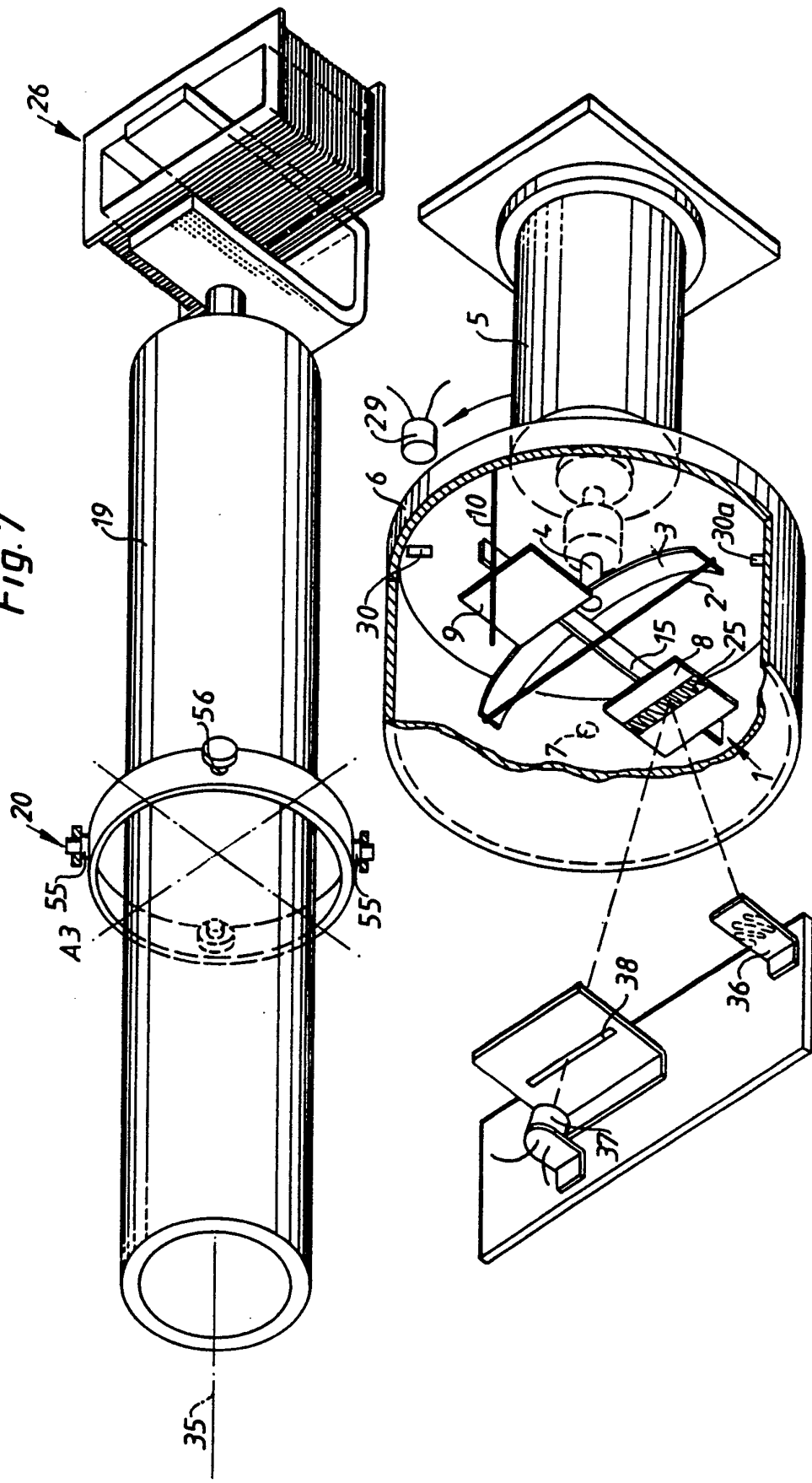


Fig. 8

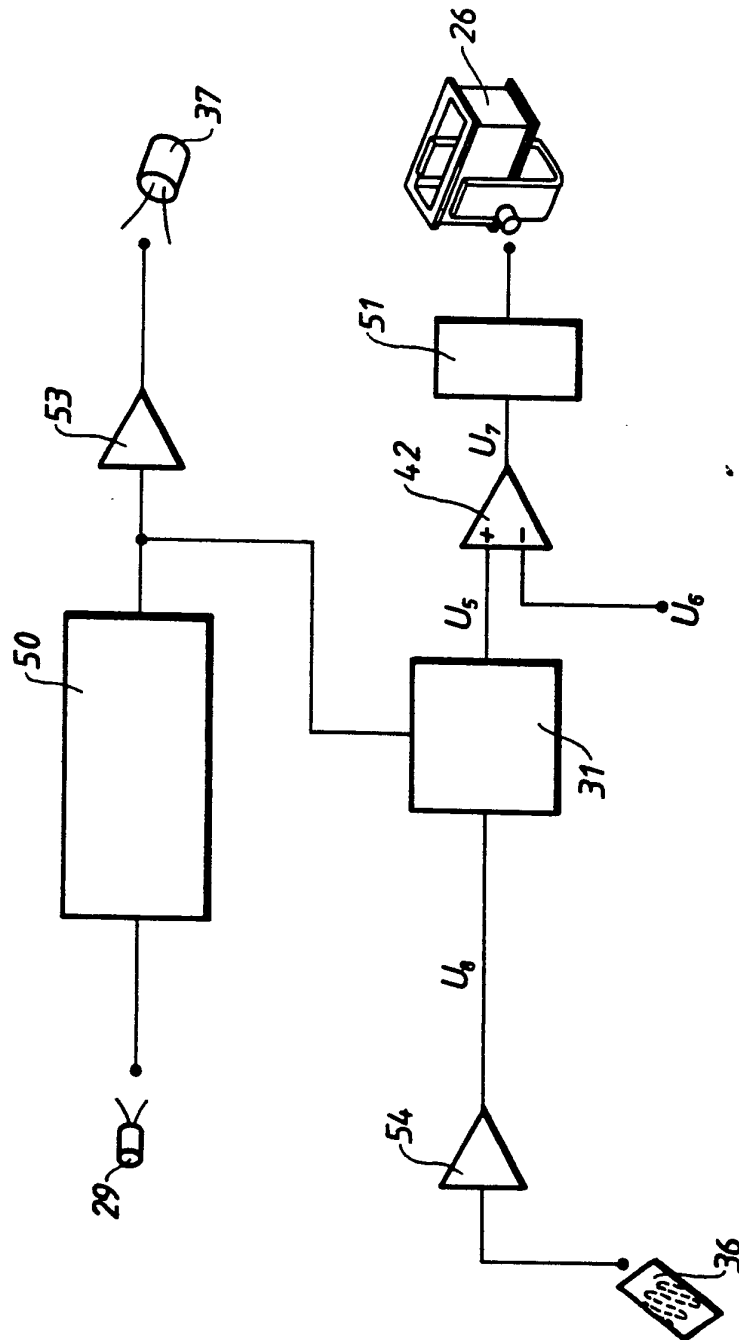


Fig. 9

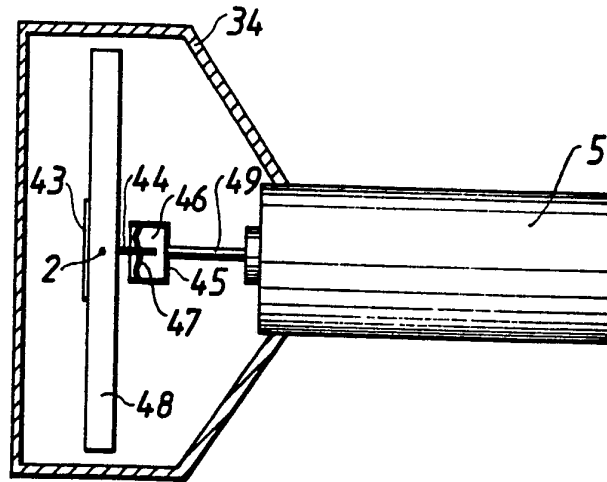


Fig. 10

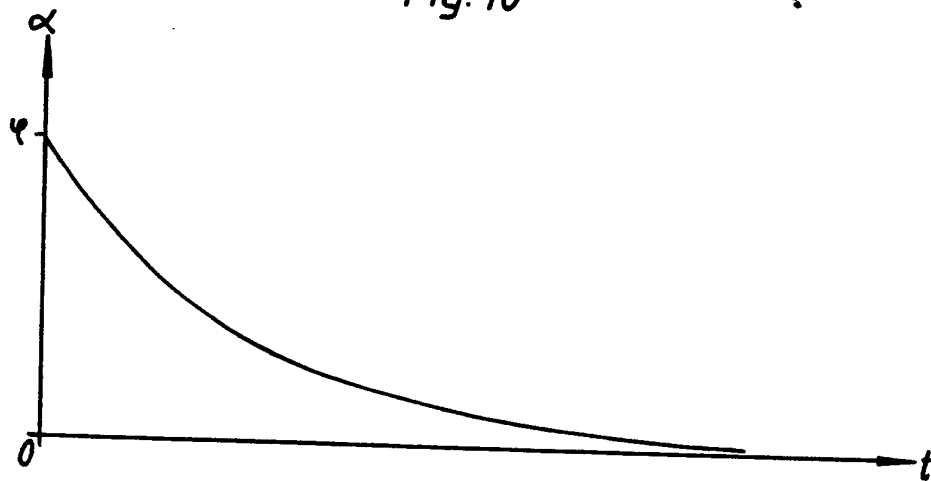
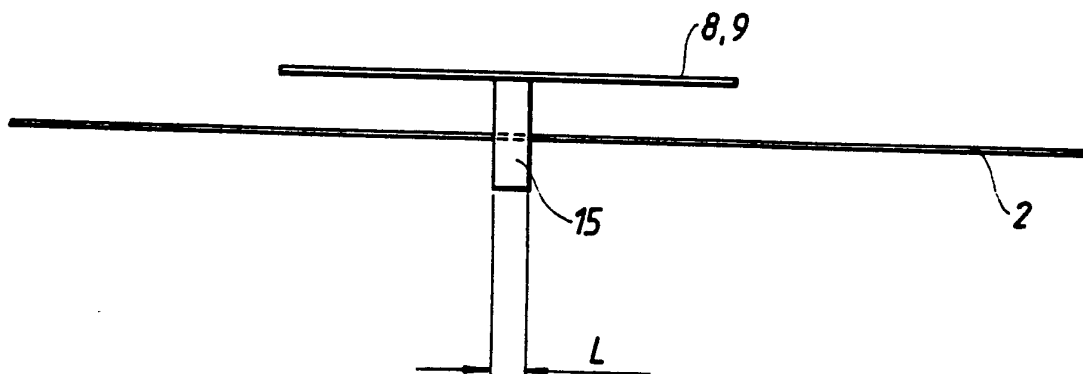
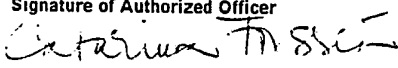


Fig. 11



INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 90/00539

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶ According to International Patent Classification (IPC) or to both National Classification and IPC IPC5: G 02 B 27/64, G 01 C 19/28		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
IPC5	G 02 B; G 01 C	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched ⁸		
SE,DK,FI,NO classes as above		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category *	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
Y	US, A, 4662727 (GRIFFIN) 5 May 1987, see the whole document --	1-13
Y	The Journal of mechanical Engineering Science 1967, Vol. 9, nr. 1, page 55-61 by R. Whalley, M.J. Holgate and L. Maunder, "The oscillogyro" see the whole document --	1-13
A	WO, A1, 8601307 (HUGHES AIRCRAFT COMPANY) 27 February 1986, see figure 1 --	1
A	EP, A1, 0321342 (AEROSPATIALE SOCIETE NATIONALE INDUSTRIELLE) 21 June 1989, see figure 1 --	1
* Special categories of cited documents:¹⁰ "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
14th November 1990	1990 -11- 16	
International Searching Authority	Signature of Authorized Officer	
SWEDISH PATENT OFFICE	 Catarina Forssén	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	US, A, 3591250 (H.W. FEINSTEIN) 6 July 1971, see figure 4 --	1
A	US, A, 3756686 (HUMPHREY) 4 September 1973, see figure 2 --	1
A	US, A, 4643539 (BRIGNALL) 17 February 1987, see figure 1 and 2 -- -----	1

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.PCT/SE 90/00539**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the Swedish Patent Office EDP file on **90-09-27**.
The Swedish Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4662727	87-05-05	AU-B- 572537	88-05-12
		AU-D- 3155684	85-03-04
		EP-A-B- 0150207	85-08-07
		JP-T- 60501977	85-11-14
		WO-A- 85/00668	85-02-14
WO-A1- 8601307	86-02-27	EP-A-B- 0190311	86-08-13
		JP-T- 61502911	86-12-11
		US-A- 4701602	87-10-20
EP-A1- 0321342	89-06-21	FR-A- 2624989	89-06-23
		JP-A- 1194009	89-08-04
US-A- 3591250	71-07-06	NONE	
US-A- 3756686	73-09-04	NONE	
US-A- 4643539	87-02-17	CA-A- 1232443	88-02-09
		EP-A-B- 0141665	85-05-15
		GB-A-B- 2149259	85-06-05