PUBLISHED

MAY 25, 1943.

BY A. F. C.

C. VON DEN STEINEN

MEASURING INSTRUMENT FOR DETERMINING THE ORBITAL ACCELERATION AND THE FUNCTIONS THEREOF

Filed Sept. 28, 1939

Serial No. 297,006

2 Sheets-Sheet 1

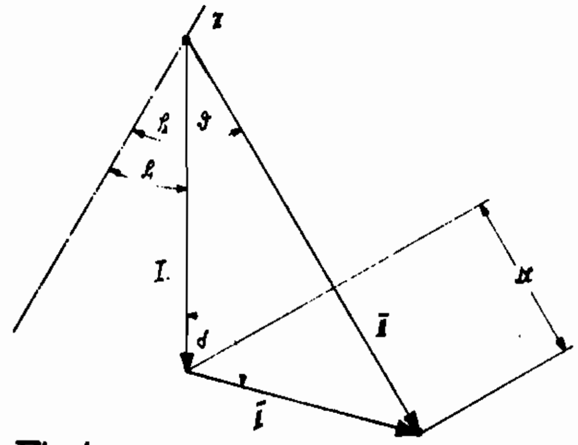

Fig.1

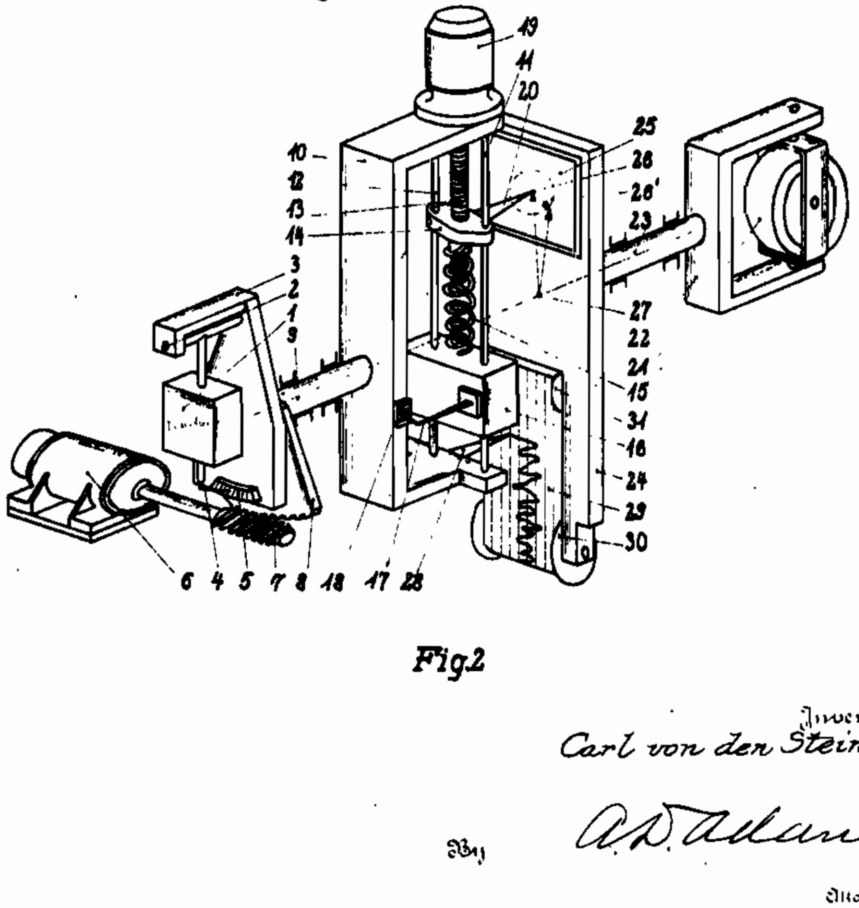

Fig.2

Inventor

Carl von den Steinen

By A. D. Adams

Attorney

PUBLISHED
MAY 25, 1943.
BY A. P. C.

C. VON DEN STEINEN
MEASURING INSTRUMENT FOR DETERMINING THE ORBITAL ACCELERATION AND THE FUNCTIONS THEREOF
Filed Sept. 28, 1939

Serial No. 297,006
2 Sheets-Sheet 2

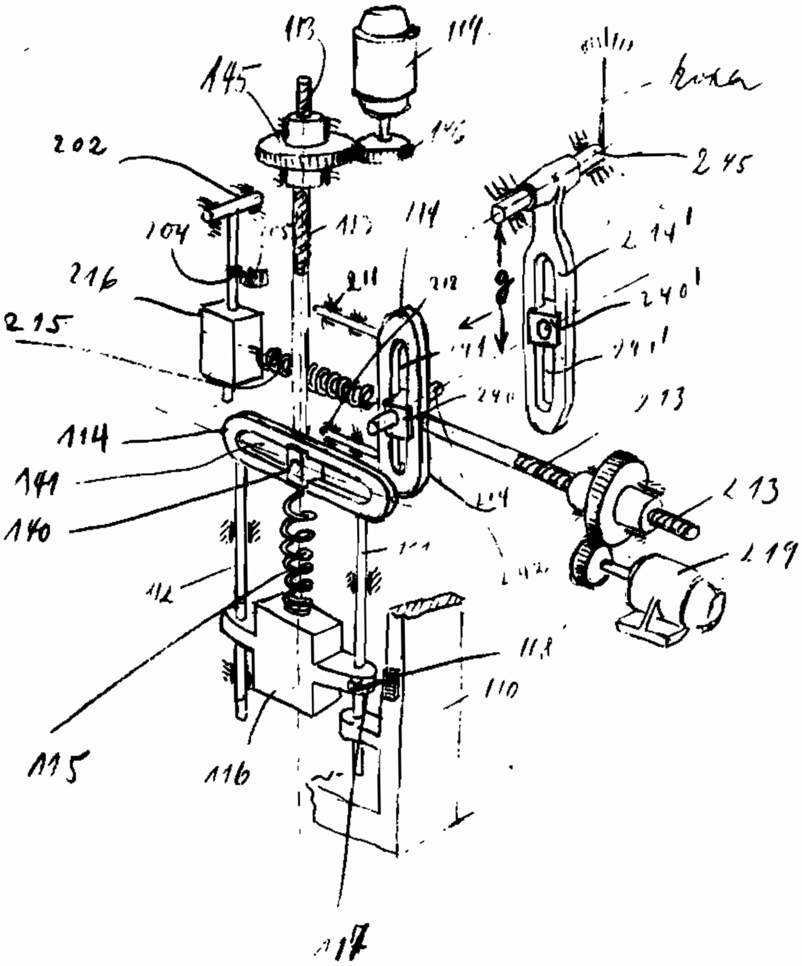

Fig.3

Inventor
Carl von den Steinen

By A. D. Adams
Attorney

Published May 25, 1943 **Serial No. 297,006**

ALIEN PROPERTY CUSTODIAN

MEASURING INSTRUMENT FOR DETERMINING THE ORBITAL ACCELERATION AND THE FUNCTIONS THEREOF

Carl von den Steinen, Hamburg 1, Germany; vested in the Alien Property Custodian

Application filed September 28, 1939

The invention relates to measuring devices, and it is the object of the invention to provide a device which measures the so-called orbital acceleration of a ship.

It is well known that the waves exert forces on the ship in consequence whereof movements of the ship take place. These movements consist of rotary oscillations, the axes of rotation passing through a fixed point of the ship's body, and of a parallel displacement (translation) of the ship around this point. As the latter movement generally takes place along a curved approximately circular line, it is termed an orbital movement, and its accelerations are termed orbital accelerations.

Heretofore, as far as I am aware, it has only been known to calculate the orbital acceleration from other measuring values instead of measuring it directly.

It is therefore the object of the invention to measure the orbital acceleration directly. According to the invention, a measuring device for determining the orbital acceleration or functions thereof comprises, in combination, a first instrument for measuring the vector of the gravity acceleration, a second instrument for measuring the vector of the apparent gravity acceleration and a recording appliance coupled with said first and second instruments for registering the vector of said orbital acceleration as the difference between said vector of the apparent gravity acceleration and said vector of the gravity acceleration.

A measuring device permitting the orbital acceleration or functions thereof to be read off directly as measuring value or diagram is particularly valuable in connection with the distinguishing of forces exerted on a vessel by the movements of the sea and of the chronological course of such forces. The measuring of the orbital acceleration and of the functions thereof affords the possibility of investigating the connections—hitherto to a great extent unknown—between movements of the sea, shape of vessel, travelling speed and travelling direction, and of drawing conclusions therefrom in regard to the effects on the stability of the vessel by the respective motions of the sea. In addition, the measuring of the orbital acceleration and the functions thereof is important in connection with questions concerning the stabilization of ships.

The invention will be more clearly understood by reference to the accompanying drawings. It is to be understood, however, that the description is not to be taken in a limiting sense, the scope of the invention being defined in the appended claims.

Fig. 1 shows a vector diagram which serves to represent the acceleration vectors cited in connection with the invention.

Fig. 2 shows a measuring device according to the invention.

Fig. 3 shows an instrument for measuring the apparent gravity acceleration, by which the corresponding instrument of the device shown in Fig. 2 may be substituted.

To begin with, the terms frequently occurring in the following may be explained and defined with reference to the vectorial diagram shown in Fig. 1.

If the gravity acceleration g is represented in the vertical by the vector I and the orbital acceleration to be measured is joined thereto as vector II, the resultant vector III represents the value g', this being the apparent or the effective or the relative gravity acceleration. Z represents the vertical axis of the ship. The angle between the vertical I and the ship's vertical axis Z is the absolute rolling angle φ_1. The angle between the apparent vertical III and the ship's vertical axis is the effective rolling angle φ_2, this being a function of the orbital acceleration. The difference between the absolute and the effective rolling angle, i. e. the angle between the vertical and the apparent vertical, is defined as effective wave slope ϑ. This is based upon the perception that the resultant g' of the acceleration, viz. the apparent vertical III, must always assume a normal position relative to the water surface.

Finally, the angle between the vertical I and the orbital acceleration vector II is the wave frequency angle δ, the vector II rotating with the wave frequency

$$\omega=\frac{d\delta}{dt}$$

Essential as regards the invention is the term dipping acceleration b_t, i. e. the difference between the effective gravity acceleration g'—represented by the vector III—and one component of the true gravity acceleration g represented by the vector I, this component being taken in the direction of the vector III. The dipping acceleration b_t is of course likewise a function of the orbital acceleration b. It is $b_t=g'-g$, if the angle δ is small.

The measuring device of the invention is characterized by two measuring instruments, of which the first represents the vector I of the gravity acceleration and the second the vector of the apparent gravity acceleration. Two such measuring instruments may be combined simply in such manner that the orbital acceleration to be determined is registrable as the revolving differential vector of the vectors III and I. The simplest apparatus serving to represent the gravity acceleration may consist in a system governed by a vertical gyroscope and stabilized so as to render its position independent of the position of the ship. The apparent vertical vector may be represented in various ways. For instance an acceleration meter may be used, the measuring direction of which is automatically directed into the apparent vertical direction and whose measuring value may be read off as a line of displacement proportional to the acceleration. The measuring of the acceleration in the direction of the apparent vertical has heretofore never been undertaken at all. This measuring, however, even apart from the representation of the apparent vertical vector in the sense of the present invention, is very valuable also in cases where merely its course in time is registered with a view to deducing therefrom the dipping acceleration b_t by shifting the abscissa by the amount g. The vector of the apparent vertical may, however, be likewise determined by means of two accelerometers operating in a plane vertical to the ship's longitudinal axis in order to measure the components of the vector III, the measuring values being brought into relation to one another by means of a suitable mechanical or electrical appliance thus representing the direction and the magnitude of the resultant vector III.

It is advantageous according to the invention to have the measuring instrument consist in two co-axially supported systems of which one is automatically directed into the true vertical direction and the other into the apparent vertical direction. The relative movement of these two systems may be directly recorded dependent on time whereby the practically very important chronological course of the effective wave slope is obtained. If the acceleration meter is arranged on the apparent vertical device in such a way that the device's center of motion is determined by the zero deflection of the accelerometer, the deflections of the accelerometer may be registered on the vertical system, the result obtained being a polar diagram, whose radial vector is the apparent vertical acceleration g' and whose argumental wave slope ϑ. If the pole of this polar diagram is shifted by the amount of the constant vector of the gravity acceleration g, the direct result is the polar diagram of the orbital acceleration, this being dependent on the argument of the wave frequency angle δ.

The apparent vertical system may consist either in an accelerometer operating in the direction of the apparent vertical or a mechanical or electrical appliance producing the resultant of the vector of the apparent gravity acceleration.

In Fig. 2 is represented a measuring device according to the invention. The device consists of a first system or instrument 21 for measuring the vector of the gravity acceleration, this instrument being a gyro-vertical with a frame 22, the latter being rigidly mounted around an axle 23, which is stable relative to the ship's body and parallel to the ship's longitudinal axis. The axle 23 is rigidly connected with an appliance 24 having the shape of a long-stretched rectangle the long sides of which always run in the direction of the true vertical as the axle of the gyrorotor alwayse runs in the true vertical direction.

Two fixed points 26 and 27 are marked on the appliance 24, the point 27 being in the axis 23 while 26 lies a distance g from the point 27, g representing the gravity acceleration. The line joining 26 and 27 is parallel to the long sides of the rectangle of the appliance and always runs in the direction of the true vertical, so that it represents the vector g of the gravity acceleration. When the gravity acceleration g is zero, the point 26 coincides with the point 27 and therefore the point 27 represents the zero deflection of the instrument for determining the gravity acceleration.

The second system or instrument for measuring the vector of the apparent gravity acceleration consists of the elements 1—20. The most essential element is the pendulum 1, which is mounted about an axle 2 supported by a frame 3 which is rigidly connected with the ship's body. The axle 2 has the direction of the ship's longitudinal axis. The pendulum 1 tends to direct itself automatically into the apparent vertical. According to the invention, an accelerometer 10—20 is provided, which is automatically directed into the apparent vertical by means of the pendulum 1. For this purpose the frame 10 of the accelerometer is rigidly mounted around an axle 9, the axes of rotation of 9 and of 23 being identical. The axle 9 is fixedly supported relative to the ship's body. The axle 9 is rigidly connected to a segment 9, engaging a worm-wheel 7, so that the axle 9 is turned together with the frame 10, when said segment is turned. The worm-wheel is fixedly supported to the axle of an electro-motor 6, which is controlled by the pendulum 1. The speed of the motor can be adjusted by means of a potentiometer resistance 5, this latter being mounted on the frame 3 and forming a part of the circuit of said motor (not shown). The resistance can be varied by means of a stap 4, which is rigidly connected with the pendulum 1. Therefore, if the pendulum swings, the motor is controlled and consequently the segment 8 is engaged, so that the axle 9 turns to an extent permitting the frame 10 to be directed into the apparent vertical.

The frame 10 contains two rods 11 and 12, on which a member 14 is slideably mounted, said member engaging a screw spindle 13, which can be rotated by means of an electro-motor 19. The member 14 carries a spring 15 which is connected with a heavy substance 16, this substance being slideably mounted about the rods 11 and 12.

The frame 10 is provided with a potentiometer resistance 18, which forms a part of the electrical circuit of the motor 19 (not shown), thus adjusting the motor if a tap 17 of the potentiometer slides along it. The tap 17 is attached to the heavy substance 16 and is deflected if the weight 16 slides along the rods 11, 12. The member 14 is provided with a pen 20.

The accelerometer operates as follows:

As the spring 15 is automatically directed into the apparent vertical, the length of the spring between said member 14 and said weight 16 represents the apparent gravity acceleration g'. If g' has the constant value g for some time, the tap 17 is so placed that the motor is at a standstill. The distance of the pen 20 from the point 27 then corresponds to the gravity acceleration g, and if the true and the apparent vertical have the same direction, the pen 20 will also point at 26. If g' increases or diminishes, the tap will move downwardly or upwardly, respectively, thereby causing the motor to turn in the one or other direction causing the member 14 to slide up or down according to the rotation of the screw spindle **13**.

If g' increases, the member **14** slides upwardly, i. e. it slides so as to approach the motor **19**. Together with the movement of the member **14** a corresponding movement of the tap **17** takes place. The sliding movement will cease as soon as the tap has again reached the first position, when g' was equal to g. Now the distance of the pen **20** from **27** is equal to the increased value of g'. Therefore, the line joining the point **27** and the point of the pen **20** represents the vector of the apparent gravity acceleration.

The appliance **24** is provided with a sheet **25**, whereupon the pen **20** records a diagram **26'** which is the diagram of the orbital acceleration, as the vector from the point **26** to any point of the diagram **26'** represents the difference between the vector of the apparent gravity acceleration and the vector of the gravity acceleration, i. e. the vector of the orbital acceleration.

As it is desirable to record the wave slope ϑ chronologically, a second appliance **29** is provided consisting of a registering strip **29** guided around the rollers **30** and **31**. The appliance **29** is coupled with the means for automatically adjusting the first system in the direction of the true vertical and the second system in the direction of the apparent vertical. A pen **28** is further provided, said pen being rigidly mounted on the frame **10**. As the angle between the angular deflections of the first system **21**, **22** and the second system **1—20** is equal to the angle ϑ of the effective wave slope, the pen **28** records on the appliance **29** the effective wave slope ϑ when the strip **29** is moved with constant velocity.

In Fig. 3 is shown an instrument for measuring the apparent gravity acceleration comprising two accelerometers for measuring two components of said vector, the components lying in a plane vertical to the ship's longitudinal axis.

The first accelerometer which corresponds to the accelerometer shown in Fig. 2 comprises a frame **110**, which is in rigid connection with the ship's body. Two rods **111** and **112** are slideably arranged within the frame, which rods bear a slideably mounted heavy substance **116**, this latter being connected by means of a spring **115** to a guide member **114** which is rigidly connected with the rods **111** and **112**. The guide member **114** is also connected with a screw spindle **113** engaging a gear wheel **145**, which is supported by the frame **110** (not shown). The gear **145** engages another gear wheel **146**, the latter being driven by an electro-motor **119** by which said screw spindle is rotated in consequence whereof the member **114** is moved together with its rods **111** and **112** in the direction of these rods. The motor is controlled by a potentiometer **118** the tap **117** of which is rigidly connected to the weight **116**.

The first accelerometer acts in exactly the same manner as the accelerometer **10—20** shown in Fig. 2. Therefore the length of the spring **115** or the position of the member **114** represents the component of the vector of the apparent gravity acceleration in the direction of the rods **111** and **112**, which may have the direction of the ship's vertical.

The second accelerometer is similar to the first one and consists of the pendulum **216**; this is rotatably mounted about the axle **202**, which is parallel to the ship's longitudinal axis. The pendulum is connected by means of a spring **215** to a guide member **214**, which is mounted on rods **211** and **212** and supported by a screw spindle **213**, which is driven by a motor **219**, said motor being controlled by a potentiometer **205** the tap **204** of which is connected with the pendulum **216**. The screw spindle **213** and the axle **202** are fixed relative to the ship's body. The screw spindle **213** lies in a plane vertical to the ship's longitudinal axis, as is also the case with rods **111** and **112**. Therefore, the length of the spring **215** or the position of the member **214** represents another component of the vector of the apparent gravity acceleration, said component being vertical to the first component.

In order to obtain the vectorial sum of these two components, mechanical means are provided. For this purpose, the guide member **114** has a slot **141**, in which a member **140** is slideably mounted. The guide member **214** has a slot **241** with a member **240** slideably mounted within the slot. The member **140** comprises an opening while the member **240** bears an axle **242**, and both accelerometers are coupled in such a manner that said axle passes through said opening; said axle likewise passes through an opening of a member **240'**, this member being mounted in a slot **241'** of a guide member **214'** which is parallel to the guide member **214**.

The member **214'** is rigidly connected with an axle **245**, which has a fixed position relative to the ship's body, the direction of said axle being parallel to the ship's longitudinal axis.

The whole system operates as follows:

If g and g' have the same value and the same direction, the members **140**, **240**, **240'** are situated in the center position of their respective slots whereby the member **240'** is removed from the axle **245** by the distance g. If g' changes, the member **240'** will assume a position in which the vector joining the member **240'** and the axle **245** represents the vector of the apparent gravity acceleration, as one component of this vector is determined by the position of the member **114** and the other component by the position of the member **214**. In other words, the direction of the slot **241'** is the direction of the apparent vertical, and the position of the member **240'** within this slot corresponds to the length of the vector of the apparent gravity acceleration.

Therefore, the system shown in Fig. 3 is suitable for substituting the corresponding instrument of the embodiment shown in Fig. 2 for measuring the apparent gravity acceleration.

CARL VON DEN STEINEN.