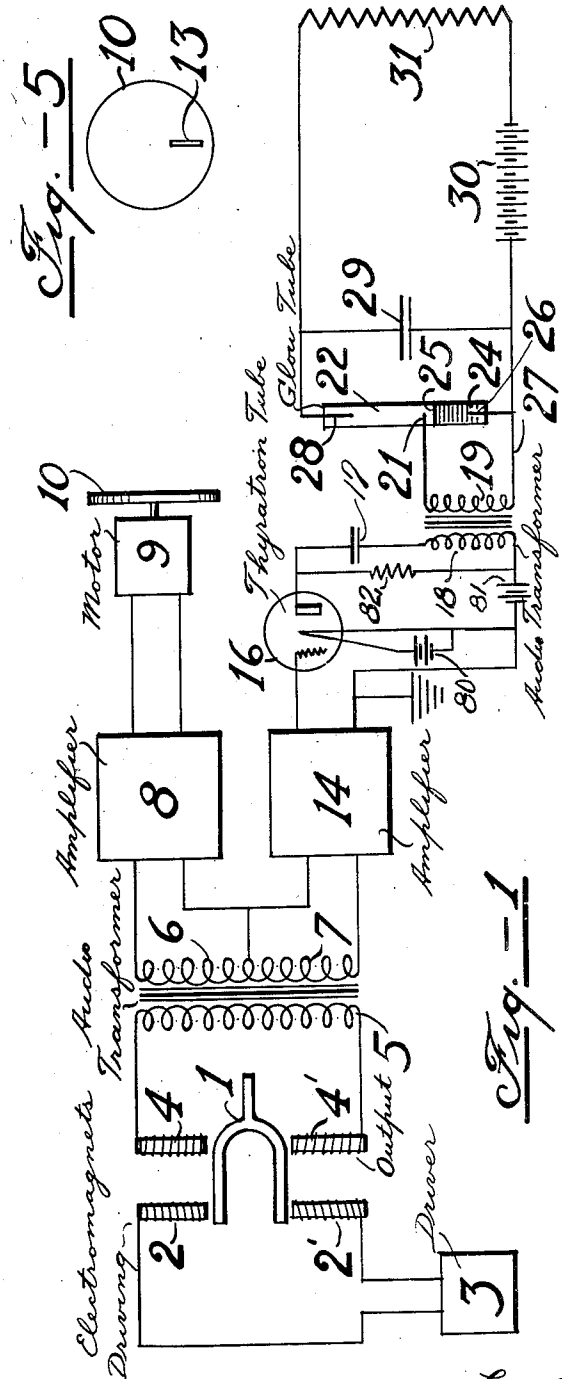
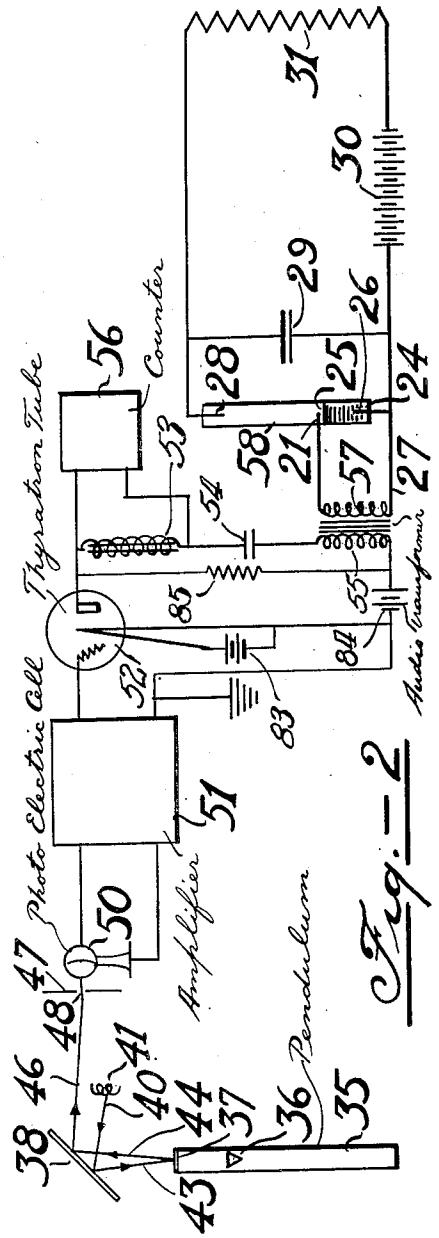
April 20, 1937. L. W. BLAU 2,077,390

FREQUENCY COMPARING DEVICE FOR DETERMINING THE FORCE OF GRAVITY

Filed March 6, 1933 2 Sheets-Sheet 1





Ludwig W. Blau Inventor

W. E. Currie Attorney

April 20, 1937. L. W. BLAU 2,077,390

FREQUENCY COMPARING DEVICE FOR DETERMINING THE FORCE OF GRAVITY

Filed March 6, 1933 2 Sheets-Sheet 2

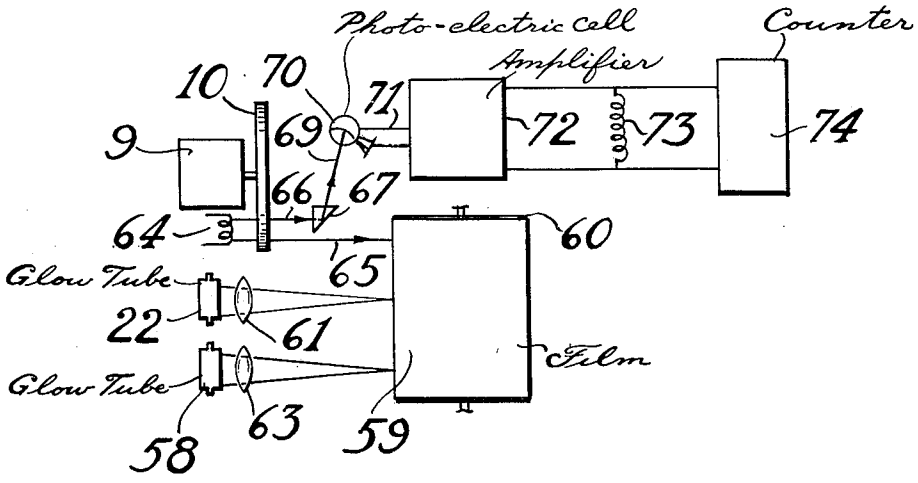


Fig. III

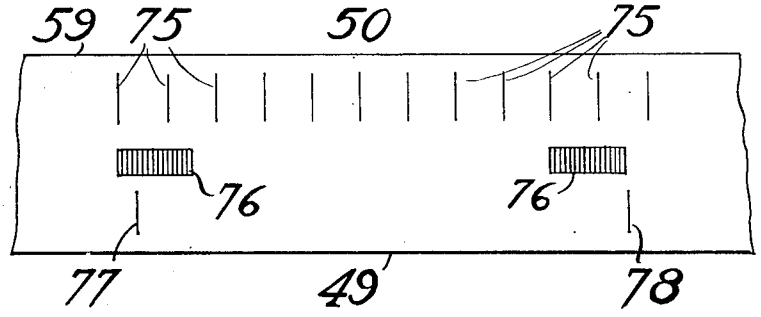


Fig. IV

Ludwig W. Blau Inventor

W. E. Currie Attorney

Patented Apr. 20, 1937 2,077,390

UNITED STATES PATENT OFFICE

2,077,390

FREQUENCY COMPARING DEVICE FOR DETERMINING THE FORCE OF GRAVITY

Ludwig W. Blau, Houston, Tex., assignor to Standard Oil Development Company, a corporation of Delaware

Application March 6, 1933, Serial No. 659,821

2 Claims. (Cl. 265—1.4)

This invention relates to improvements in geophysical gravitational prospecting.

The invention will be fully understood from the following description taken in connection with the accompanying drawings, in which latter

Fig. 1 is a diagrammatic view of a tuning fork assembly;

Fig. 2 is a diagrammatic view of a pendulum assembly;

Fig. 3 is a diagrammatic view of the apparatus for making the record;

Fig. 4 is a front view of a film showing a typical record; and

Fig. 5 is a front elevational view of the disk wheel.

Referring particularly to Fig. 1 of the drawings, reference numeral 1 designates a tuning fork. A vibrating reed or any other suitable vibrating system can be used in place of the tuning fork and some of the advantages of the invention will be retained. The tuning fork 1 is electrically driven by means of electromagnets 2 and 2'. The leads of the electromagnets 2 and 2' are connected to a suitable driving arrangement 3 whereby the electromagnets are energized to produce sustained vibrations of the prongs of the tuning fork. The electromagnets 4 and 4' constitute the output units in the tuning fork, The output leads from the electromagnets 4 and 4' are connected to the primary coil 5 of an audio transformer to deliver electrical impulses from the tuning fork. The audio transformer has a split secondary winding one of which is designated 6 and the other is designated 7. The secondary winding 6 is connected to a vacuum tube amplifier 8 whereby the electrical impulses are amplified. The amplified electrical impulses drive a synchronous motor 9. A disk wheel 10 is fastened to the driving mechanism of the synchronous motor 9. The disk wheel 10 is provided with a slot 13 for a purpose to be later described. The disk wheel is geared to the motor 9 so as to give it the desired frequency of rotation.

The secondary winding 7 of the audio transformer delivers electrical impulses from the tuning fork 1 to an amplifier 14 the output of which is connected across the grid and filament of a thyratron tube 16. A condenser 17 and the primary winding 18 of an audio transformer are put into the plate filament circuit of the thyratron tube. The A battery of the tube 16 is designated 80, the B battery is 81 and the plate resistance is 82. One of the leads from the secondary winding 19 of the transformer is connected to an electrode 21 in an intermediate portion of a glow tube 22. The lower portion of the glow tube 22 contains a body of mercury 24 the upper surface 25 of which underlies the electrode 21 and constitutes a second electrode. The second lead 27 from the secondary winding 19 of the transformer is connected to the electrode 26. A third electrode 28 is disposed in the upper portion of the glow tube 22 and leads to a large condenser 29. The condenser 29 is connected in parallel with a battery 30 and in series with a resistance 31. The glow tube 22 operates as follows:

The voltage drop across the transformer secondary 19 ionizes the path between the upper electrode 21 on the secondary and the surface 25 of the body of mercury. The ionization decreases the resistance of the glow tube 22 so that the voltage drop across the condenser 29 which is charged through the resistance 31 by the battery 30 is sufficiently high to flash the tube. The voltage of the battery 30 is so adjusted that the glow tube 22 will not flash unless part of the path through the tube is ionized by an impulse from the thyratron tube 16 through the transformer secondary 19.

Referring particularly to Fig. 2, reference numeral 35 designates a pendulum having a knife edge 36. A mirror 37 is secured to the upper surface of the pendulum 35. A mirror 38 is disposed above and in spaced relation to the pendulum and inclined at an angle to the mirror 37. A beam of light 40 is directed from a lamp 41 to the mirror 38 and is reflected along the line 43 to the mirror 37. A beam of light is reflected from the mirror 37 along the line 44 to the mirror 38 and is reflected again along the line 46. Oscillation of the pendulum alters the direction of the beam of light lines.

A screen 47 provided with a slot 48 is disposed in the path of the light rays along the line 46. The screen 47 and the mirror 38 are so arranged that the beam of light from the lamp 41 is reflected through the slot 48 into a photo-electric cell 50 only when the pendulum 35 is swinging through a predetermined position, preferably the equilibrium position.

An electric current is generated by the photo-electric cell upon illumination of the cell by the beam of light along the line 46. This current is conducted from the photo-electric cell 50 to a suitable amplifier such as a vacuum tube amplifier 51. The amplified current is conducted through the output leads of the amplifier 51 across the grid and filament of a thyratron tube 52. The plate-filament circuit of the thyratron tube 52

includes a relay 53, a condenser 54, and the primary winding 55 of an audio transformer. The relay 53 actuates a suitable counter 56. The secondary winding 57 of the audio transformer is connected to two of the electrodes of a glow tube 58 the function and circuit of which are identical in all respects with the glow tube circuit previously described, and like reference numerals have been applied to like parts of the glow tube circuits. The A battery of this circuit is designated 83, the B battery is 84 and the plate resistance is 85.

As illustrated in Fig. 3, the mechanism for recording the pulsations of energy generated in the systems illustrated in Figs. 1 and 2 includes a sensitive film 59 carried by a recording drum 60 and driven in travel by any suitable means not shown. The flashes of light from the glow tube 22 of the tuning fork circuit are focused upon the film 59 by means of a lens 61. In like manner, the flashes of light from the glow tube 58 of the pendulum circuit are focused upon the film 59 by means of a lens 63. Intermittent pulsations of energy generated by the tuning fork 1 are recorded as follows:

A lamp 64 is positioned behind the disk wheel 10. A ray of light from the lamp 64 passes through the slot 13 of the disk wheel 10 intermittently along the line 65 during rotation of the disk wheel and is directed upon the film 59. Another ray of light intermittently passes through the slot 13 upon rotation of the disk wheel 10 along the line 66. A prism 67 intercepts this light and reflects it along the line 69 into a photo-electric cell 70. An electric current is generated by the photo-electric cell 70 upon illumination of the cell by the beam of light. This current is conducted from the photo-electric cell 70 through a line 71 to a current amplifier 72. The output leads of the amplifier 72 are connected to a relay 73 which actuates a counter 74.

In the record illustrated in Fig. 4 the lines 75 along the upper edge of the film 59 are due to the light which fell upon the film from lamp 64 through the slot 13 in the disk wheel 10, and are proportional to the number of intermittent oscillations of the tuning fork 1. Lines 76 are due to the light which similarly fell upon the film 59 from the glow tube 22, and are proportional to the number of oscillations of the tuning fork 1. Lines 77 and 78 are due to light which fell upon the film from the glow tube 58 and represent each beat of the pendulum.

In the preferred arrangement a tuning fork is used the frequency of which is 1,000 cycles per second. The disk wheel 10 rotates ten times per thousand vibrations of the tuning fork and has the one radial slot 13. Alternatively, the wheel 10 can be provided with ten radial slots and be rotated one time for each one thousand vibrations of the tuning fork. Consequently, there is one line 75 for each one hundred lines 76. The lines 77 and 78 represent the instant of time when the pendulum 35 passed through its position of equilibrium. The lines 75 mark 0.1 second intervals. The counter 74 registers the lines 75, so that at the end of the observation period the number of vibrations which the tuning fork has executed is known exactly.

In the preferred use of the equipment every hundredth vibration of the tuning fork has been counted and every oscillation of the pendulum has been counted. The total number of vibrations in a certain interval of time being known, it is only necessary to record for a few seconds at the beginning and at the end of the observation period and with such a film speed as would enable the recorder to read to one-fifteenth of the distance between the individual lines 76, thereby gaining an accuracy of one part in ten million. The pendulum and tuning fork apparatus above described is set up at the point which is to be used as a reference point. During the observation period of ten minutes, the pendulum having a period of approximately one second will oscillate, say 600 times. From the record the number of tuning fork vibrations for 600 pendulum oscillations will then be determined to one-fifteenth or approximately 7/100ths of a tuning fork vibration. The apparatus is then moved to some other location, where a ten minute observation again yields the number of tuning fork vibrations for 600 pendulum oscillations. The difference between the number of tuning fork vibrations per 600 pendulum oscillations at the base station and the number of tuning fork vibrations per 600 pendulum oscillations at the second location then yield the difference in gravity by a simple computation to one part in ten millions. By the construction described the time of observation for determining relative gravity measurements is minimized. Relative gravity measurements are obtained at spaced stations without a necessity for any sort of communication between the stations.

Various changes and alternative arrangements may be made within the scope of the appended claims, in which it is my intention to claim all novelty inherent in the invention as broadly as the prior art permits.

I claim:

1. In an apparatus for geophysical gravitational prospecting, a gravity responsive pendulum, means for converting the beats of the pendulum into pulsations of energy, means for counting the pulsations, a source of vibrations of constant frequency, means for converting the vibrations into pulsations of energy proportional to the vibrations, means for selecting pulsations from the source proportional to predetermined multiples of the vibrations, means for counting the last mentioned pulsations, and means for recording the three sets of pulsations near the beginning and end of the observation period upon a common record for the purpose of comparing the frequencies of the pendulum and source.

2. In an apparatus for geophysical gravitational prospecting, a gravity responsive pendulum, means for converting the beats of the pendulum into pulsations of energy, means for counting the pulsations, means for transforming the pulsations into flashes of light, a source of vibrations of constant frequency, means for converting the vibrations into pulsations of energy proportional to the vibrations, means for transforming the pulsations from the source into flashes of light proportional to the vibrations, means for transforming the pulsations from the source into flashes of light proportional to predetermined multiples of the vibrations, means for counting the last mentioned flashes of light, and means for recording the three sets of flashes of light near the beginning and end of the observation period upon a common record for the purpose of comparing the frequencies of the pendulum and the source.

LUDWIG W. BLAU.