Nov. 27, 1951 F. D. CASE 2,576,775

SEISMOMETER SYSTEM

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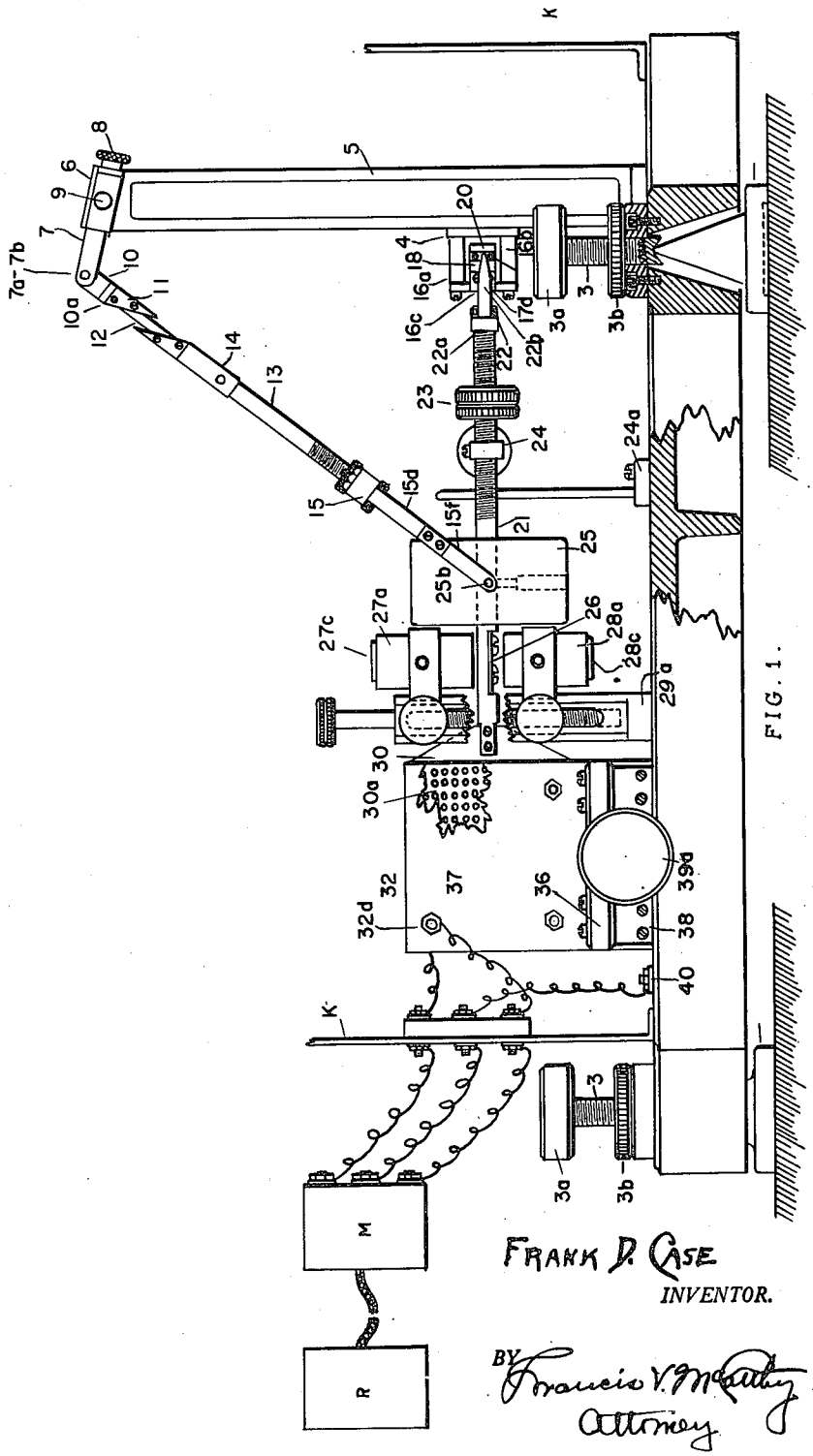


FIG. 1.

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SEISMOMETER SYSTEM

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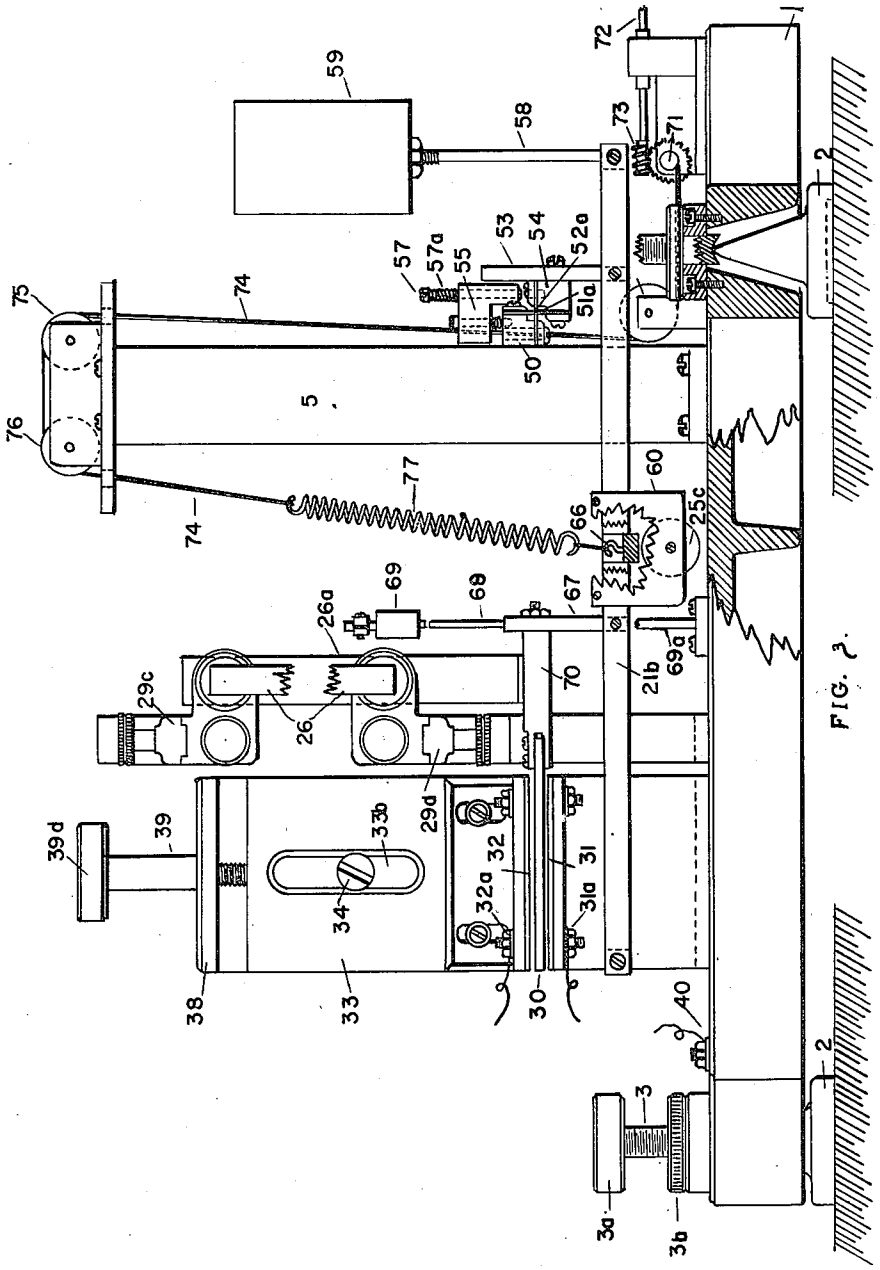


FIG. 3.

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SEISMOMETER SYSTEM

Filed July 31, 1948 5 Sheets-Sheet 3

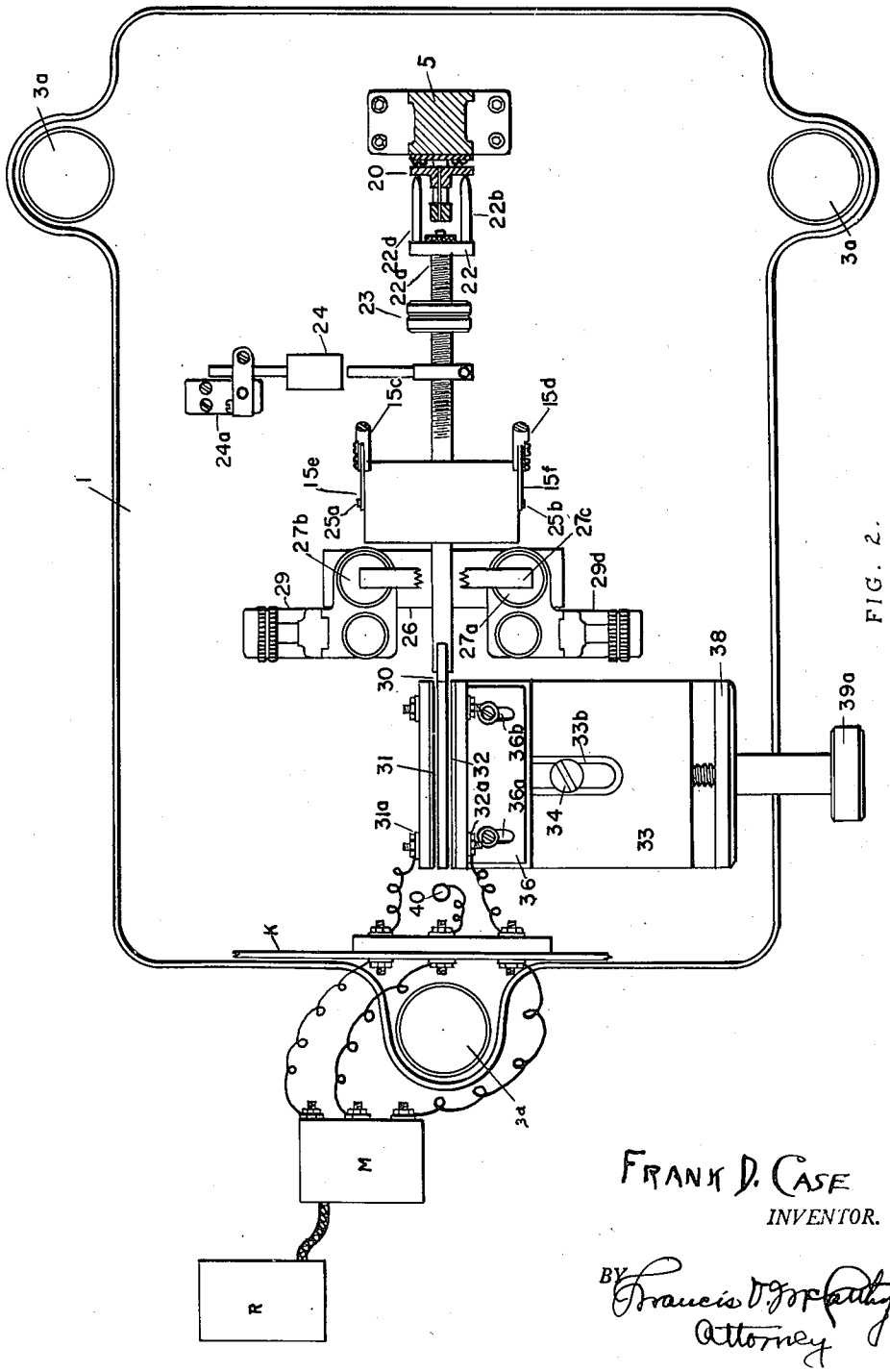


FIG. 2.

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SEISMOMETER SYSTEM

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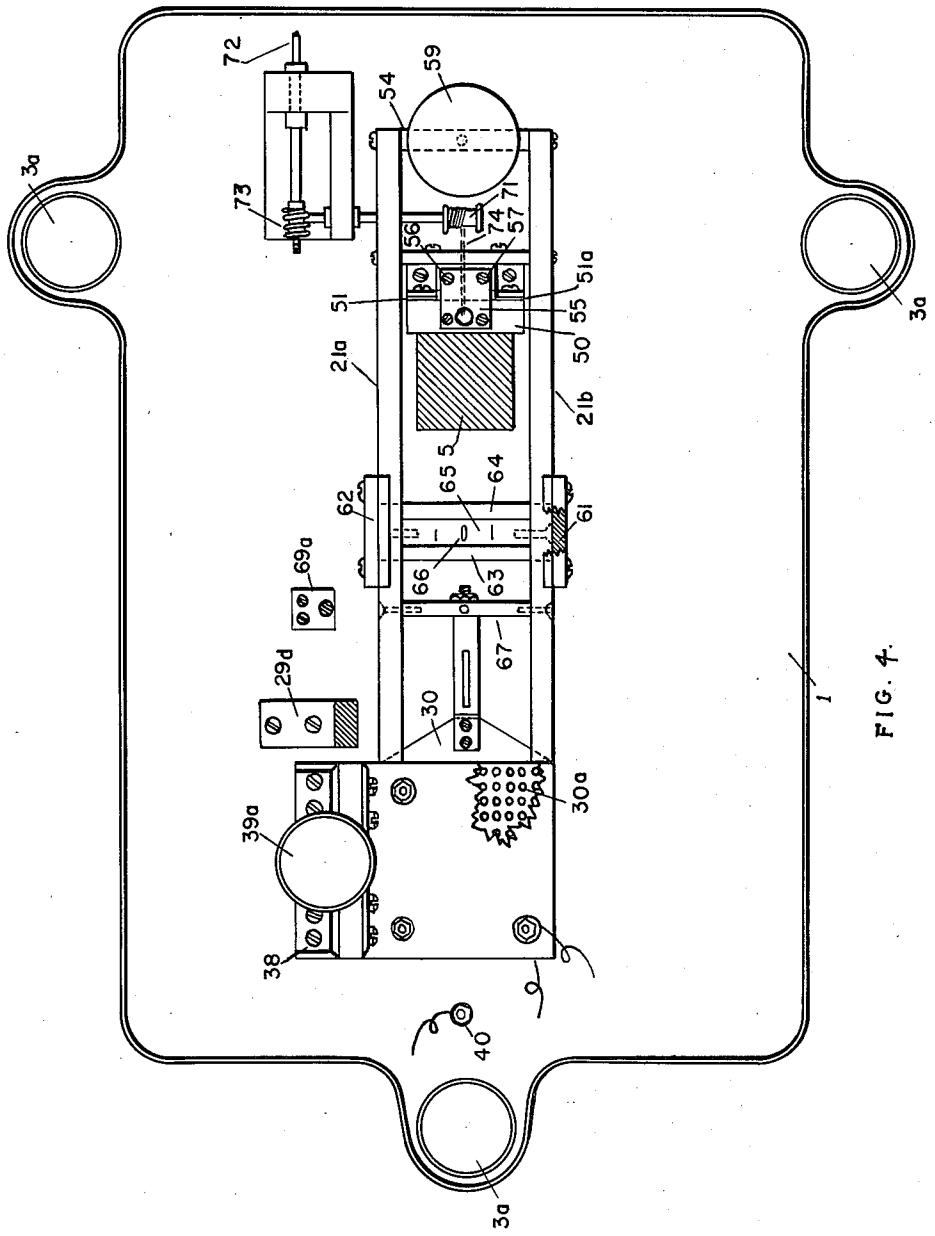


FIG. 4.

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SEISMOMETER SYSTEM

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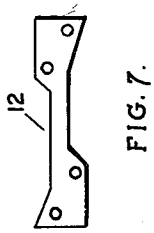


FIG. 7.

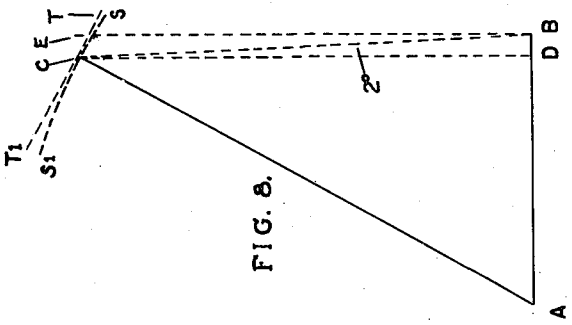


FIG. 8.

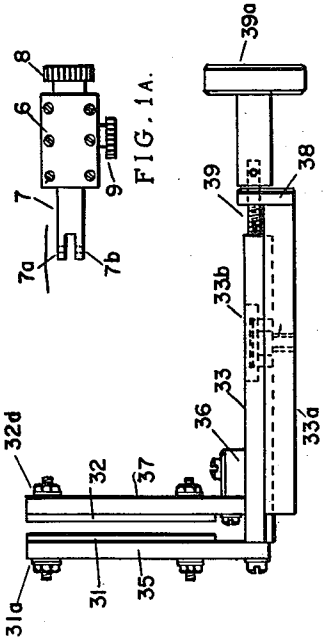


FIG. 1A.

FIG. 5.

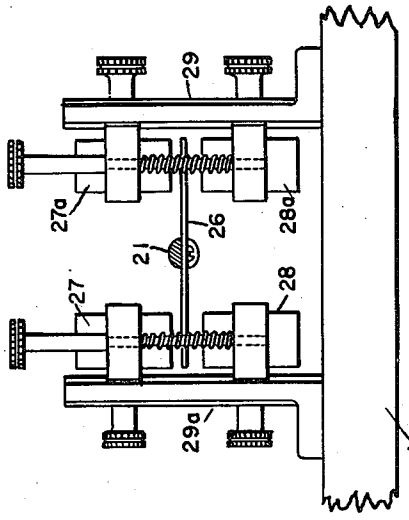


FIG. 6.

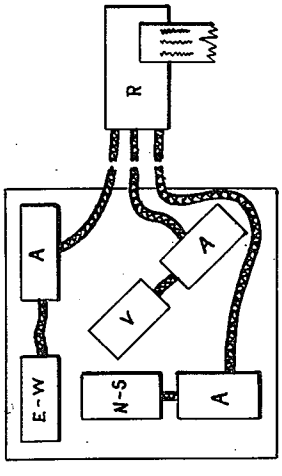


FIG 11

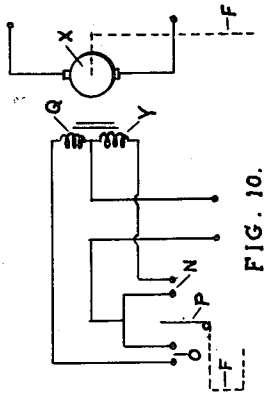


FIG. 10.

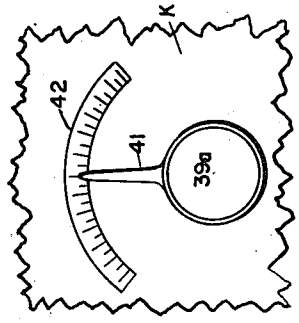


FIG. 9.

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Patented Nov. 27, 1951

2,576,775

UNITED STATES PATENT OFFICE

2,576,775

SEISMOMETER SYSTEM

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Application July 31, 1948, Serial No. 41,771

3 Claims. (Cl. 177—352)

1

This invention pertains to improvements in seismometers and comprises a system adapted to detect simultaneously a plurality of diverse earth movements.

Seismometers have been designed and produced with a single column supporting a plurality of earth movement detecting components. In the present state of the science of earthquake detection, amplification and recording, it is not practicable to have more than one long-period seismometer suspended from the column because, for such detecting, the suspension means are so delicately balanced that the action of adjusting one of the components may throw off-balance the others suspended from the same supporting column and result in inaccurate amplification and recording. It is advantageous, however, to have such instruments as compact as possible consistent with the results to be obtained, so as to avoid bulk and weight in transportation of the units. The advantages of my system over previous methods will be understood by those who are engaged in the manufacture and use of such instruments.

My seismo detecting system includes two seismometers for detecting horizontal earth movements and one for detecting vertical earth movements; these will be referred to hereinafter as the horizontal and vertical seismometers or components. Each seismometer has a horizontally disposed boom or pendulum. On each boom is a vane which is disposed between two conductive plates. The vane and plates constitute a transducer through which pulses indicating earth movements are transmitted through an electronic amplifier to a recorder. Period adjustment, drift compensation, air and magnetic damping and other features are included in the system.

In the drawings that accompany this application for a patent as a part thereof, Figure 1 is a side elevation of a horizontal seismometer; Figure 1[a] is a detail showing forked end of the suspension hinge adjusting screw; Figure 2 is a plan view of horizontal seismometer; Figure 3 is a side elevation of the vertical seismometer; Figure 4 is a side view of the same component; Figure 5 is a side view of the cross-slide which supports the conductive plates of the transducer; Figure 6 is a view of the magnetic damping lay-out; Figure 7 is a detail of the suspension hinge for horizontal components; Figure 8 illustrates the period adjusting elements; Figure 9 is a detail showing the calibrater mounted on the cross-slide; Figure 10 is a diagrammatic illustration of the transducer control elements; Figure 11 shows how all three components and their amplifiers may be positioned when in use, and also shows the recorder.

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The amplifiers and the recorders are not shown in detail but are indicated in the drawings because the seismometers are adapted for use with any amplifying and recording means. The recorder may be positioned at a distance from the seismo detecting station where the seismometers and amplifiers are set up.

Each seismometer has an individual supporting column. Each column is vertically disposed on an adjustably horizontal base or platform to which it is firmly attached. The horizontal seismometers are identical in construction and a description of one of them will apply to the other. The vertical seismometer will also be described. When the three seismometers are in use as a system, the horizontal components are positioned so that their pendulum booms, when at rest, are perpendicular to each other, as, for example, in N–S, E–W positions. The supporting column of each seismometer is positioned near one side of and on the longitudinal axis of the platform, which is preferably oblong in shape, as shown in the drawings. Each seismometer is enclosed in a heat reflecting casing which is indicated by the letter K.

The platforms 1 are mounted on adjustable feet 2, each of which includes a base having a conical leg extending upward in a bore in the platform. The top of each bore is enlarged and threaded to engage a micrometer screw 3, the lower end of which is concaved to engage the top of the cone which is rounded off at the top. The screw is turned by means of knob 3[a] to make adjustments of the platform level. A locknut 3[b] holds the screw in adjusted position. Two of these platform adjusting devices are positioned opposite each other at the sides of the platform. A third support is positioned at the transducer end of the platform on the platform's longitudinal axis.

Horizontal components

A backplate 4 is affixed to column 5 on the side that faces the center of the platform. This side will be referred to hereinafter as the face of the column. The top of the column slopes downward and backward from its face. Secured to the top of the column is a period adjusting slide block 6, with a longitudinal bore in which is a slide 7. A micrometer screw 8 controls the movements of the slide. The front end of the

slide extends beyond the face of the column at an upward angle from the horizontal and is bifurcated as shown in Figure 1[a]. Arms 7[a] and 7[b] of the slide are bored. A checknut 9 makes contact with the slide through the slide block to hold the slide in adjusted position.

A swinging member 10 with a pin hole passing therethrough is positioned between the arms of the slide and is movably mounted on a pivot pin transversely disposed to the longitudinal axis of the column, thus positioning the swinging member so that it may move in a vertical arc. On the swinging member there is a shoulder 10[a] and an extension 10[b], the latter having threaded holes therein. A clamp 11, of the same size and shape as the extension has holes passing therethrough.

A flat hinge 12, preferably of beryllium copper and .0015 inch thick, shaped substantially as shown in Figure 7, has holes passing therethrough. The screw holes in the extension and the holes in the clamp and hinge are positioned so that screws passing therethrough hold one end of the hinge securely between the extension and the clamp. The shoulder on the swinging member aids in positioning the clamp and end of the hinge accurately for the above described assembly. On the upper end of suspension rod 13 is a cap 14, held in position thereon by a pin passing through the rod and cap. An extension on the cap, a shoulder and clamp provide means for fastening the lower end of hinge 12 to the suspension rod in the same manner as described above.

The lower end of the suspension rod is threaded to receive a cross-bar 15 which is adjustably positioned on the rod by passing the rod through a bore in the center of the cross-bar and securing it in position by means of a knurled nut mounted on the rod. At each end of the cross-bar is a bore. Arms 15[c] and 15[d] are secured to the cross-bar by passing reduced threaded ends of the arms through said bores and securing them in position by nuts which engage said threaded parts. The other end of each arm is slotted and bored. Fingers 15[e] and 16[f] are positioned in the slots and fastened with screws.

As already stated, the backplate is affixed to the face of the column. The position of the backplate above the surface of the platform is determined by the space required for positioning other elements of the assembly on the platform in relation to the boom. Affixed to the backplate is a bracket comprising arms 16[a], 16[b] and a cross support 16[c]. Screws pass through the cross support and arms into the backplate to hold the bracket in fixed position so that the longitudinal axis of the cross support is in the same vertical plane as that of the column. The cross support is recessed to receive the fixed hinge clamp 17[d] which is affixed thereto. An end of hinge 18 is affixed to the hinge clamp, as by screws. The other end of the hinge has attached thereto a free hinge clamp 19, to which is attached a movable cross-arm 20. In the face of the movable cross-arm are a small round indentation and an elongated indentation, both having the same depth of depression. The hinge is of flat spring metal of the same material as hinge 12.

Reading from right to left in Figures 1 and 2: On the end of the horizontal boom 21 is a boom fork comprising a cross-support 22 with pointed arms 22[a] and 22[b] attached thereto. The arms of the boom fork are disposed transversely to the longitudinal axis of the column and are held in position by engagement with the cross-arm 20, the point of one of the arms being positioned in

the round depression and the other in the elongated depression in the cross-arm. Extending from the boom fork for a predetermined distance, the surface of the boom is provided with a fine thread. A checknut counter-weight 23 and a solenoid armature are threaded for adjustment of their positions on the boom. Adjustment of the counterweight maintains the center of gravity of the boom in its axis of suspension.

Also mounted on the boom is the mass 25, which is preferably cylindrical and is positioned on the boom by passing the boom through a bore in the longitudinal axis of the mass. The mass is held in position on the boom by a sunk screw. At each end of the transverse axis of the mass is a stud 25[a] and 25[b], which are adapted to be engaged by the bores in fingers 15[e], 15[f] of the suspension rod cross-bar. This engagement holds the boom in suspension from the hinge 12 at the top of the column, the boom being pivoted horizontally on the free cross-arm 20 by engagement of the boom fork therewith, which engagement has already been referred to.

A damping vane 26 is attached to the boom in a horizontal transverse plane. This vane is positioned between magnets. The magnetic damping means includes four magnets, two of which, 27[a] and 27[b], are positioned above and two, 28[a] and 28[b], below the damping vane as shown in Figure 1. Each of these pairs of magnets is provided with an equalizer 27[c] and 28[c]. The magnets are mounted in movable brackets which are slidably positioned on standards 29 and 29[a]. Locknuts and springs on the standards hold the magnets in adjustable relation to the damping vane.

The end of the boom beyond the damping vane is bifurcated to receive the boom vane 30, which is disposed vertically and is fastened to the boom, as by screws. The boom vane is perforated as indicated by the numeral 30[a] in Figure 1, and is positioned between conductive plates 31 and 32, which are mounted on the cross-slide assembly shown in Figure 5. The conductive plates are adjustably mounted in parallel spaced relation to the vane and to each other to permit horizontal movement of the vane between them. The position of the vane with respect to each conductive plate determines the amount of radio frequency voltage between them. Changes in position cause changes in the voltage in direct ratio to the change of position. Thus, the variable movements of the vane resulting from earth movements set up electrical pulses in plates 31 and 32 which are transmitted to an amplifying system and from thence to a recording instrument.

The cross-slide 33, which supports plates 31 and 32, is mounted on a base 33[a] affixed to the platform 1 and is held in slidable relation to the boom at right angles thereto by the head of screw 34 which is mounted in the base, the screw head being position in slot 33[b] in the slide. A vertical support 35, of nonconductive material, is affixed to the cross-slide and supports conductive plate 31. A block 36 is adjustably mounted on the cross-slide, as by screws passing through elongated holes 36[a], 36[b] in the block and into the cross-slide. Secured to the block is the vertical support 37, of nonconductive material, and which supports conductive plate 32. Each conductive plate is provided with a conductive post or stud 31[a] and 32[a]. Secured to the base of the cross-slide is a face plate 38 and in the plate is a bore through which a micrometer screw 39 extends and engages a threaded bore in the cross-

slide. Adjustments of plates 31 and 32 are made by turning knob 39a on the screw. 40 is a contact post mounted on the platform.

Vertical component

The column is positioned as shown in Figures 3 and 4. A block 50 is attached to the rear side of the column. The block is provided with vertical faces and also with horizontal faces. Attached to the vertical faces of the block are the ends of two vetrical hinges 51 and 51a; and attached to the horizontal faces are the horizontal hinges 52 and 52a, in parallel relation to each other and equidistant from the longitudinal center of the boom frame. The hinges are of thin metal as referred to in the description of the hinges used on the horizontal components.

The boom frame includes two parallel bars 21a and 21b, which are tied together by cross-bars. Affixed to the boom frame is a vertical plate 53, to which is attached a block 54 with vertical and horizontal faces, these faces being positioned with relation to the faces on block 50 so that the vertical faces on block 54 receive and hold in position the vertical hinges and the horizontal faces on block 54 do the same in regard to the horizontal hinges.

A locking device 55, mounted on block 50, is positioned in relation to the hinges so that, by turning screws 56 and 57 against springs 56a and 57a, the hinges are held in immovable position when the instrument is not in use.

Attached at the rear end of the boom frame and extending upward therefrom is a vertical post 58 which is threaded to receive a counter-weight 59 adjustably mounted thereon. The purpose of this counter-weight is to bring the center of gravity of the boom assembly into the horizontal plane of the hinges, this being essential in order to prevent horizontal motion of the earth from setting the boom assembly in motion.

Adjustably mounted on the boom frame and slidable thereon is a carriage 60 comprising two vertical plates 61 and 62 attached to each other by cross-bars 63 and 64, which also support a block 65 to which is attached a hook 66.

Also attached to the carriage is a mass 25c, which is held suspended below the boom frame. By moving the carriage along the boom frame, the mass may be positioned as desired to change the free oscillation period of the boom assembly and its supporting spring.

Extending upward from the boom frame and in vertical position is a plate 67, to which is attached a rod 68. A standard 69a supports a solenoid armature 69 in operatively related position with relation to the free end of rod 68. Also mounted on the plate is a horizontal arm 70, which supports the damping vane 26a in vertical position above the boom frame. The boom vane 30 is attached to the free end of the arm and is disposed horizontally instead of vertically. Otherwise this vane is identical with the vane already described.

The damping vane is positioned between strong magnets as described in relation to the horizontal components, the magnets being turned at a 90 degrees angle with the positions already described, so that the damping vane is positioned between them vertically instead of horizontally, the frame-work 29c, 29d, which supports the magnets, being raised and supported in this position by brackets or otherwise.

The conductive plates 31 and 32 are positioned, one above and the other below the boom vane in parallel adjustable relation thereto and to each other. These positions of the plates are obtained by turning the cross-slide assembly 90 degrees from its position shown in Figures 1 and 2. The correlated actions of the boom vane and the plates are the same as hereinbefore described, except that the vane moves in the vertical instead of in the horizontal plane.

Mounted on the platform below the boom frame hinges is a windlass 71. An electric motor (not shown) is adapted to operate worm gear 73 through connection 72. The motor is driven by the voltage system to actuate the windlass through the worm gear to automatically adjust the tension of the fine wire 74. This wire is wound around the windlass, passes over wheels 75 and 76 on top of the column to engage a helical spring 77, which is also attached to hook 65 to hold the boom frame in horizontal suspension.

The cut threads, both internal and external, on the adjusting elements of all of the components are very fine, thus providing very close adjustments throughout the system.

Platform supports

The construction described provides extreme accuracy of adjustment of the platform to provide and maintain the true horizontal position of the seismometer. The conical projections extend to approximately the upper surface of the platform and the micrometer screws are positioned thereon. By means of this adjusting assembly the platform may be raised or lowered so that it will be positioned properly.

Period adjustments of horizontal components

By means of the micrometer screw at the top of the column, the position of hinge 12 in relation to hinge 18 can be adjusted accurately. By reference to line B—C in Figure 8, it will be noticed that C, which represents the pivot point of hinge 12, is slightly forward of the pivot point B of the lower hinge. This increases the sensitivity of the boom to lateral motion because, the pivots being off-set vertically, the tendency of the boom to swing is increased. By means of the micrometer screw, to which the upper hinge is attached, the angular differential between the hinges may be adjusted, without affecting the horizontal position of the boom, for the purpose of changing the operating period of the instrument.

Heretofore, two common practices have been employed in the construction of horizontal pendulums for seismometers. In one case, provision is made for tilting the column represented by C—B in Figure 8, which changes angle 2° and thereby changes the period. The boom is then levelled by adjusting the length of C—A, consisting of fine wire. In the other case, provision is made for tilting the base or platform to which the column is rigidly affixed, which also changes the period. The pivoting means are constructed ruggedly enough to withstand the vertical forces and the angle of the boom with the horizontal is neglected.

It is important in the construction of a seismometer pendulum to have the boom, represented by A—B in Figure 8, level at all times and to have the boom suspended through an axis about which the longitudinal weight moments are equal. When the boom is suspended in the above manner the force acting along the boom toward the hinge or pivot point B lies entirely within the horizontal plane. If the forces were not in the horizontal plane at all times, a flexible hinge

would be distorted by the vertical forces and, in the case of a pivot and jewel construction, for example, the pivot would tend to ride either up or down in the jewel and not directly in the center of the jewel where the optimum operating conditions are to be realized.

As shown in Figure 8, when the boom A—B, pivoted about the fixed point B, is suspended by a member A—C having a fixed length but being free to rotate about the pivot A, as provided in my construction, point C may be supported at any point along the arc S—S' and the position of boom A—B will not be changed, the point C moving through such a small distance in making the necessary period changes that point C may be moved in a straight line T—T', tangent to the arc S—S' at the center of the operating range.

Calibration of recordings

The pointer 41, mounted on micrometer screw 39 on the cross-slide, passes over a graduated segment 42 (see Figure 9) as the screw is turned, thus providing a calibrating means for the electronic system A and recorder R. By this calibrating means, the conductive plates on the seismometers may be moved a known amount with respect to the boom vane. The linear displacement of the corresponding recording pen caused by turning the calibrating screw 39 may then be measured, and, when this measurement is divided by the known displacement of the plates, the result is the static magnification ratio of the system.

Drift compensation

The drift compensation devices overcome the very slight drift of the suspension springs that may occur during temperature changes at the higher manifestations. Also, the self-returning system indicated in Figure 10, while it may be included in the assembly of each of the seismometers in the system, is particularly important as part of the vertical component because it automatically compensates for the drift which occurs in all spring suspensions due to temperature changes and fatigue of the spring metals which heretofore have made displacement type vertical long-period seismometers of high magnification impracticable. Referring to Figure 10, the gear train is driven through a flexible shaft F by a reversible motor X which is wired to switches N and O. When the motor deviates from its center position, being that position at which the recording pen is in the center of the recording strip, an arm P attached to the motor shaft closes one of the switches, which drives the motor in a direction to either raise or lower the boom, thus bringing it back to the position at which the motor shaft no longer closes the switch. When the switch N is closed, field Y of the motor becomes energized and the motor will turn in one direction. It will turn in the opposite direction when field Q is energized by the closing of switch O.

Transducer adjustments

The adjustment of the positions of the conductive plates of the transducer by the means described increases the efficiency of the electronic reproductions of earth movements as indicated to the transducers by the movements of the pendulum.

Electrical damping

The adjustments of the magnets of the damping assembly are easily made so that the magnets are kept in most efficient relation to the pendulum.

Air dumping

In order to prevent delayed movement of the pendulum vane between the transducer plates due to air bank between them, I have made apertures in the vane, as described hereinbefore, the apertures being of sufficient number and size and so positioned as to permit the air to pass through them freely and thus prevent delay of pendulum oscillations.

The fulcrum hinge

The movable cross-arm on the fulcrum hinge of the horizontal components and the pointed arms of the boom fork provide freedom and delicacy of motion to the pendulum not heretofore provided. As already stated, one point is positioned in a round depression and the other in an elongated depression in the cross-arm. This provides accuracy of positioning of the points on the cross-arm and automatic adjustment of the points with relation to the hinge at all times.

Amplifiers and recorder

Each of the seismometers has its own amplifier or servochassis and when the seismometers are used in combination with each other the amplifiers transfer the pulses caused by earth movements to a single recorder through individual recording instruments or pens, by means of which the pulses from all of the detecting components are recorded on the same paper of the recorder. It is obvious, however, that the seismometers may be used singly, in which case each seismometer has its own recorder.

Positioning the recorder at a distance from the detecting station, as in the observer's laboratory or workroom, enables him to obtain information at any time from the recorder roll without visiting the station.

Hurricane detection

The seismometers described in this specification are so delicately balanced that they are able to pick up earth tremors caused by hurricanes and record them in the same manner as earthquake tremors are reported. The system is adapted to determine the intensity, distance from the detecting station and direction of movement of the hurricane so that it may be under constant observation from the moment that its existence is indicated on the recorder. In this case a plurality of horizontal components, as three, are used, set a mile or two apart, preferably at the points of a right-triangle and set in N—S, E—W and NW—SE detecting positions, with the recorder set up in the weather observatory or elsewhere away from the detecting instruments, if desired. In this way information of the hurricane and warnings can be given quickly and accurately.

Mines

By adjusting the period to microseismos, a single seismometer with its amplifier and recorder, can be used to detect cave-ins and faults in mines.

The combined effect of the novel features disclosed results in more accurate detection of earth movements and more accurate transmission of pulses created thereby that has heretofore been provided as well as more speedy production of recorded tremors and more convenient reading of the records produced.

All of the adjusting knobs on the seismometers are of a special nonmetallic substance which minimizes the flow of heat from the operator's hands

into the instruments while making adjustments during operation. The magnetic damping means and the solenoids are installed for obtaining decay curves at any time desired.

I claim:

1. A system of earth tremor detecting assemblies comprising, in combination, a plurality of seismometers, the seismometers being adapted to pick up earth tremors and transmit them through transducers and amplifying means to a recording assembly, each seismometer including a vertical column and a transducer affixed to an adjustable horizontal platform, seismometer elements operatively suspended on each column for, respectively, detecting longitudinal, transverse and vertical earth disturbances, each assembly of said elements including a horizontally disposed pendulum, a vane on the pendulum adapted to be oscillated betweeen the poles of a transducer by movements of the pendulum, means for adjustably positioning the platform in the horizontal plane, means for adjustably suspending the seismometer elements on the column and on the pendulum, magnetic damping means mounted on the platform and adapted to be adjustably disposed in relation to the pendulum, the transducer poles being adjustably mounted in relation to the pendulum vane, air damping means including apertures in the vane, and electronic means adapted to maintain the elements of the assembly in accurate relation to each other.

2. In a device of the class described having a platform and column on which the elements of the device, including a pendulum, are mounted, means for suspending the pendulum for vertical oscillation thereof, said means including a bracket mounted on the column, a bracket mounted on the pendulum, said brackets being adapted to hold in operative positions vertically and horizontally disposed hinges, an electrically controlled windlass mounted on the platform, pulleys mounted on the column, a wire attached to the windlass and passing over the pulleys, a helical spring attached to the wire and to the pendulum, an adjustable counter-weight, a mass and damping means mounted on the pendulum, a vane mounted on the pendulum in operative relation to transducer plates mounted on the platform, and means for connecting the transducer plates and platform with electronic amplifying means and with recording means.

3. In a device of the class described having a platform and column on which the elements of the device, including a pendulum, are mounted, means for pivoting the pendulum in horizontally suspended position for horizontal oscillation, said means including a backplate mounted on the column, a bracket, including a cross-support and arms, mounted on the backplate and disposed vertically thereon, a hinge attached to the cross-support of the bracket, a movable cross-arm mounted on the hinge, a round and an elongated depression in the movable cross-arm, a fork mounted on the pendulum, the fork including a cross-bar with pointed arms attached thereto, the points of the arms being adapted to be positioned in said depressions in the movable cross-arm.

FRANK D. CASE.

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