Dec. 16, 1969 H. ÜBLACKER 3,483,745

BOREHOLE EXTENSOMETER

Filed Dec. 11, 1964 2 Sheets-Sheet 1

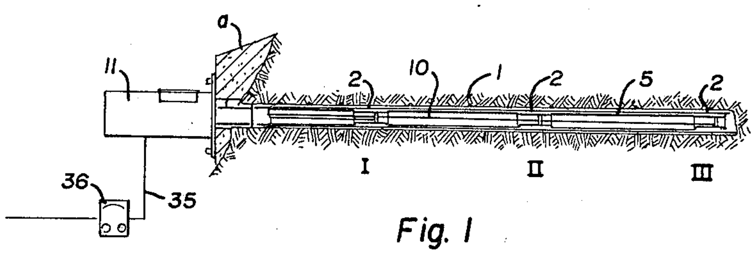

Fig. 1

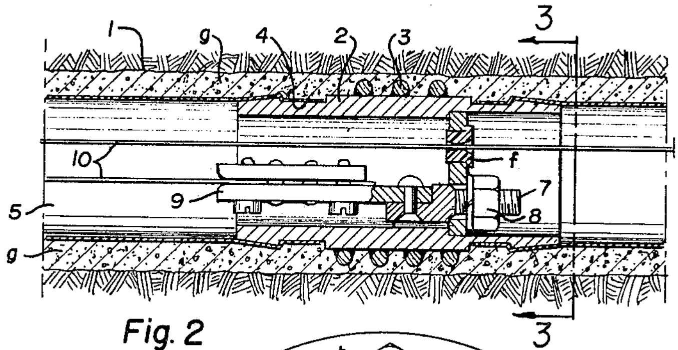

Fig. 2

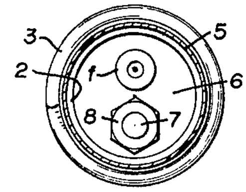

Fig. 3

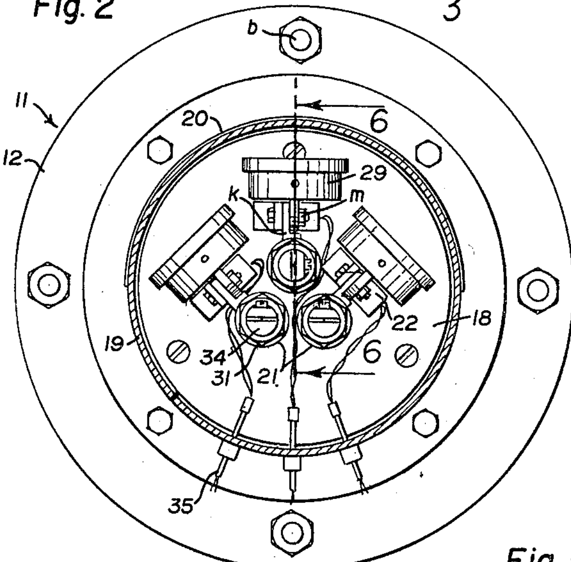

Fig. 5

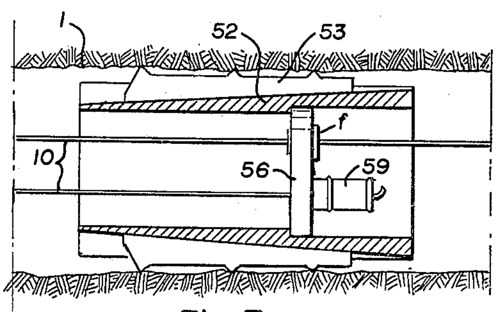

Fig. 7

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BOREHOLE EXTENSOMETER

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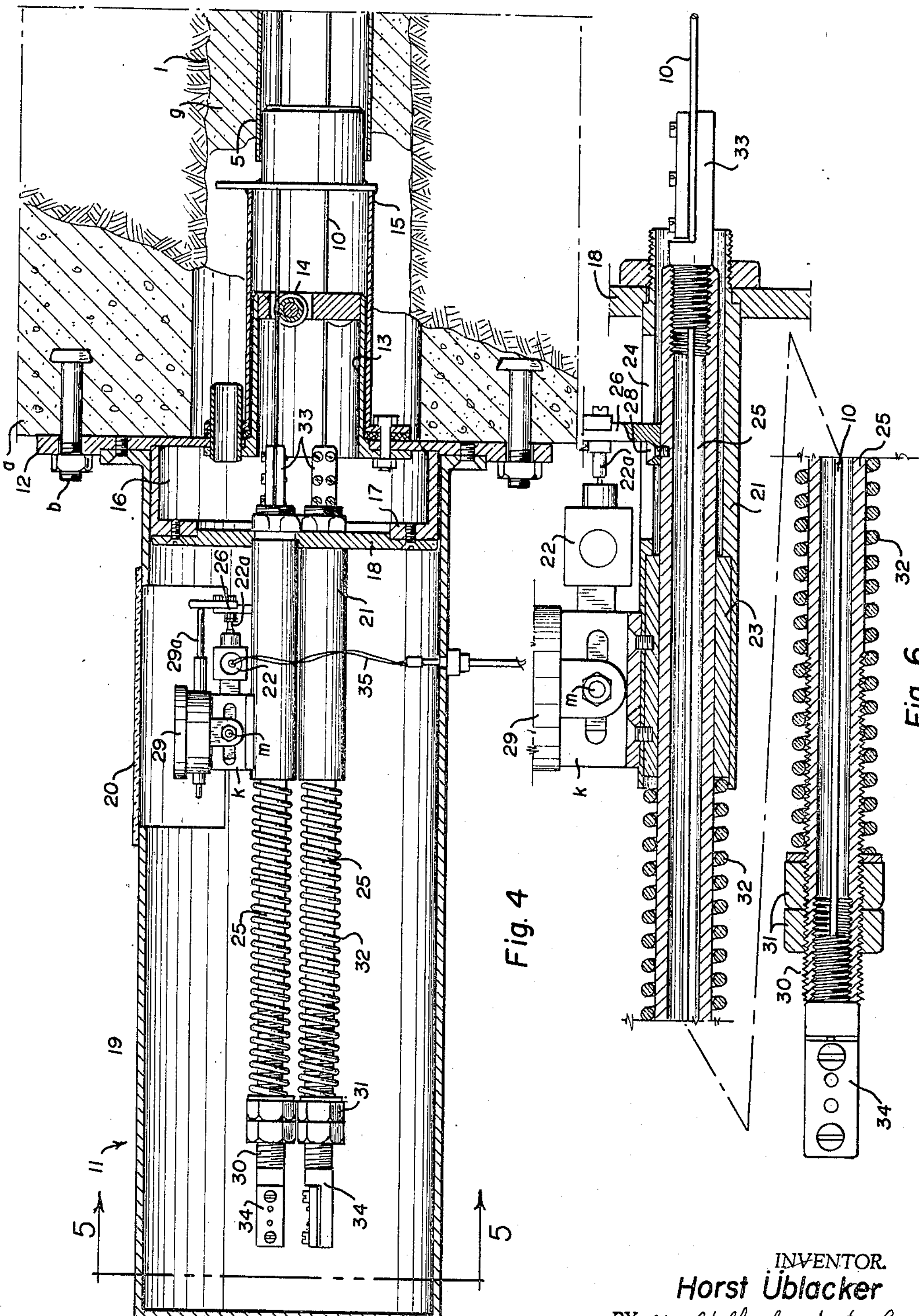

Fig. 4

Fig. 6

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BOREHOLE EXTENSOMETER

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U.S. Cl. 73—151 2 Claims

ABSTRACT OF THE DISCLOSURE

An apparatus for measuring longitudinal movements in a borehole, through a rock-like structure. An anchor is secured within the borehole. A wire connected to the anchor and extended to the mouth of the borehole and to an abutment at the mouth of the borehole. A spring mounted upon this abutment and is biased outwardly with respect to the borehole and is connected to the wire to tense the wire and to resiliently stretch it. A movement of the rock structure through which the borehole extends, causes movement of the anchor with respect to the abutment to initiate simultaneous deflection of the wire and spring. The wire and spring deflect together as a common system and the final basic feature involves a means for measurement of the resulting movement at a point adjacent to the connection of the wire and spring. This movement can be corrected to establish the true movement of the anchor with respect to the abutment by ascertaining the combined elastic characteristics of the wire and spring.

This invention relates to methods and apparatus for measuring changes in the depth or reach of a borehole to indicate the movement of a rock mass along the axis of the borehole, as between selected locations within the borehole and the earth or rock face at the entrance or mouth of the hole. As such, the invention will be hereinafter referred to as a borehole extensometer, or simply as an extensometer.

The present invention is an improvement over conventional types of extensometers which are used to measure earth movements. A common type of extensometer consists of a rigid rod having one end anchored in a borehole, as by grouting, so that movements of the other end may be measured by instruments anchored to an abutment at the mouth of the borehole. Another type consist of a wire having one end anchored within the hole and the other end passed over a pulley and loaded with weights to pre-tension the wire. A movement indicating device is associated with this wire at a suitable point adjacent to the mouth of the borehole. Another type of wire extensometer substitutes a spring for weights to pre-tension the wire, and includes a manual adjustment device adapted to move the spring longitudinally with respect to the wire to the selected pre-tension before measuring the movement of the wire. Such an extensometer, known as the "potts type," is described in the publication, Quarterly of the Colorado School of Mines, vol. 52, No. 3, July 1957, at pages 174 to 178.

The use of rigid rods is awkward especially where the boreholes are of any substantial depth. Conventional wire type extensometers using pulleys and counterweights require a bulky arrangement at the mouth of the borehole and have been found to be of limited accuracy because of the friction of the pulley wheel over which the wire extends. The latter disadvantage is overcome by the use of the spring to pre-tension the wire; however, a manual adjustment is required every time a reading is

being taken which also limits the accuracy, especially where very small deflections are to be measured. Moreover, this type is unsuitable where repeated access to the device itself is difficult and inconvenient.

The present invention was conceived and developed to overcome these disadvantages and comprises, in essence, an improved wire extensometer of a spring-loaded type which combines the spring action of the wire itself with the pull of a tensioning spring to provide a system which required no setting or adjustments and gives a continuous dynamic action to indicate the movement of rock within a borehole.

It follows that the objects of the invention are to provide a novel and improved borehole extensometer which:

(a) Requires no further adjustments once set;

(b) Is sensitive to very slight movements and can be read with a high degree of accuracy;

(c) Is especially adapted for measurement with electrical instruments to record rock movements either periodically or continuously;

(d) Is a low-inertia system and is thereby capable of measuring comparatively rapid rock movement, as that which occurs shortly after a blasting operation;

(e) Once set, does not require further attention and may be read at a remote location without the necessity of access to the unit as for adjustments; and,

(f) Is a simple, neat, inexpensive and compact unit.

A further object of the invention is to provide a borehole extensometer which may be easily arranged as a composite device to measure the deflection at several positions in a single borehole, and such an embodiment of the invention is hereinafter described.

With the foregoing and other objects in view, all of which more fully hereinafter appear, my invention comprises certain constructions, combinations and arrangements of parts and elements as hereinafter described, defined in the appended claims and illustrated in the accompanying drawing, in which:

FIGURE 1 is a diagrammatic longitudinal sectional view of a borehole within a rock mass having the improved extensometer mounted wi'hin the hole and with anchors being placed at three positions with the hole, and with the measuring head being mounted upon an abutment at the mouth of the hole.

FIGURE 2 is an enlarged longitudinal sectional view through a portion of the borehole, illustrated at FIG. 1, including a longitudinal sectional view through an intermediate anchor box.

FIGURE 3 is a transverse sectional view of the anchor box per se, as taken from the indicated line **3—3** at FIG. 2.

FIGURE 4 is an enlarged longitudinal sectional view at the mouth of the borehole and a longitudinal sectional view through the measuring head of the apparatus.

FIGURE 5 is a transverse sectional view as taken from the indicated line **5—5** at FIG. 4.

FIGURE 6 is a longitudinal sectional view of a portion of the showing at FIG. 4, as taken on the indicated line **6—6** at FIG. 5, but on an enlarged scale and with the view being broken and staggered to conserve space.

FIGURE 7 is a longitudinal sectional view, similar to FIG. 2, but showing an alternate type of anchor.

The diagram of FIG. 1 shows a composite arrangement of an extensometer where three points are measured in a borehole **1**. To initiate measurement studies in a rock mass, the hole **1** is bored therein to a selected depth location. Selected anchor positions I, II and III are located within this hole where anchor boxes **2** are located. Measuring wires **10** are connected to each anchor box to extend from the mouth of the hole to the measuring head **11**. The measuring head **11**, as hereinafter further described, is set upon a prepared abutment *a* at the mouth of the hole. Deflections of the system are indicated at the head **11** and may be read either visually or through an electrical system at a remote location, as by signal conduits **35** extending to a conventional type of readout device **36**, as will be further described.

The anchor box **2**, illustrated in detail at FIGS. 2 and 3, is formed as a short tubular member having a heavy rod spiralled and welded to the outer surface to form a gripping spiral **3** which facilitates securely holding the box in position within the hole. The end of each box **2** is turned to form a pipe lock **4** for connection with a protective tubular casing **5**.

Sections of the casing **5** extend between the several boxes **2** to provide for a fully protected system in the borehole and to facilitate proper location of the anchor boxes **2** when they are inserted into the bore. When the system formed by the casing and anchor boxes is inserted, the annular space between the casing and boxes and the hole wall is filled with grout to cement the boxes **2** in place. It is to be noted that the outer surface of the casing **5** is oiled or otherwise treated so that it will not stick to the grout cement and that this casing is generally a thin-walled member of little strength, easily crumpled or pulled from the outlet boxes **2** and will in no way affect the rock movements and the accompanying movements of the anchor boxes.

Each anchor box is formed with an internal, transverse shoulder which supports a transversely disposed disc **6**. A clamp bolt **7** is extended through an orifice within the disc and is held in position as by a lock nut **8** at the opposite side of the clamp. A wire clamp **9** secured to the bolt **7** is adapted to hold the end of the measuring wire **10** extending to the box, as clearly illustrated at FIG. 2.

A suitable orifice is located on the disc **6** for each wire **10** passing through the anchor with the orifice, or orifices, being in an arrangement which will not interfere with the clamp bolt **7** or its wire **10**. A low-friction toroidal button *f* is mounted in each orifice so that other wires **10** may pass through the button and through the anchor box **2** with no significant frictional effect at the point of contact with the button *f*.

The measuring head **11** is mounted upon a flange **12** which is affixed to the abutment *a* at the mouth of the hole **1**, as by a ring of anchor bolts *b*. A tubular housing **13** is affixed to this flange and projects into the mouth of the hole with an end plate thereon supporting rollers **14** which position and align the wires **10** emerging from the hole **1** for connection with tensioning components on the measuring head, as will be described. This housing **13** is encased within a nipple **15** which extends beyond it a short distance and connects with the casing **5** to completely encase the wire system within the borehole **1**.

A second short tubular housing **16** is attached to the flange **12** to project outwardly therefrom, and it includes an inturned flange **17** at its outer end. A support disc **18** is affixed to the flange **17** as by a ring of screws, as illustrated. This disc encloses the passageway into the cased hole and also carries the spring tensioning members on its outer face, as will be hereinafter described. The outer housing **16**, the disc **18** and the spring tensioning members are all enclosed within a cover housing **19** which is secured to the flange **12** by a ring of bolts. This housing **19** is installed only after the system is set and adjusted; however, a glass window **20** is located in this housing **19** for visual observations of the instruments therewithin.

Three movement-indicating instruments, to hold the three wires **10** extending into the borehole, are mounted upon the outer face of the support disc **18**, each being in axial alignment with its respective wire **10**. Each unit is carried in a base tube **21** with the three tubes **21** outstanding from the support disc **18** in a triangular arrangement, as with the three being oriented at 120-degree positions from a common axis point. Each tube is secured to the support disc in a socket-like orifice with a short threaded end of the tube projecting through the disc and being secured thereto by a lock nut. Each base tube **21** also includes a slide bushing **23** at its outer end and a longitudinal slot **24** at an intermediate reach.

The bushing **23** is adapted to slidably hold a tubular retainer rod **25** within the base tube **21**, and the rod **25** is connected to the wire **10** and is spring loaded to hold the wire under tension. The movement of this rod **25** with respect to the base tube is indicated by a caliper arm **26** which is secured to the rod **25** as by a connecting screw **28** and outstands from the rod **25** to extend through the slot **24**. The caliper arm **26** carries an insertion core **22*a*** of an electric transducer **22** of any conventional type capable of measuring small deflections. This transducer is mounted upon a longitudinally disposed flange *k* attached to the base tube **21**, the mounting being in a slot in the flange to permit longitudinal adjustments of the transducer **22**. The attachment of the transducer to flange *k* is as by a bolt *m* which extends through the flange slot and also supports a dial gage **29**, the pin **29*a*** of the dial gage abutting against the caliper arm **26** above the connection of the core **22*a***. It follows that the dial gage **29** and transducer **22** will both record movement of the arm **26** and that both will be adjusted and zeroed simultaneously by movement of the bolt *m* in the slot of flange *k*.

Each retainer rod **25** extends through and beyond the base tube **21**, and its outer end is threaded as at **30** to receive holding and locking nuts **31**. A helical compression spring **32** is positioned upon the rod **25** between the end of the base tube **21** and the nuts **31**, whereby the spring **32** urges the retainer rod outwardly to pull the wire **10** attached to it. The wire is attached to the retainer rod **25** by an inner clamp **33** which includes an abutment which is screwed into position in a threaded socket at the inner end of the rod. From this connection, the wire extends through the retaining rod and is connected to an outer clamp **34** which also includes an abutment which is screwed into position in a threaded socket at the outer end of the rod, the two clamps **33** and **34** providing a secure anchorage for the wire when it is held under a substantial tension.

An electrical signal wire **35** extending through the housing **19** connects the electrical transducers **22** to the readout device **36**, and in the installation of the electrical circuits, it is to be noted that the housings and electrical lines may be suitably insulated and protected from weather and other factors.

The illustrated arrangement of the apparatus is capable of determining the movement in the borehole at positions I, II or III with respect to the abutment *a* at the mouth of the borehole. The wires **10**, anchored in the borehole at separate positions, and secured to individual movement indicators, operate independently of each other. Individual readings can be taken by means of a switching unit, not shown, which switches each circuit **35** into the readout unit **36** in a selected sequence. Multiple readout units **36** or a multiple channel readout unit **36** may also be used to permit simultaneous readings. Direct reading of the movement of the end of a wire at the mouth of a hole is also possible, for the dial gages **29** can be observed through the window **20**. The measuring accuracy of the dial gages is between 0.1 and 0.01 millimeter. The use of an electrical transducer of a suitable type permits an accuracy of 0.0025 millimeter, and such sensitive and precise measurements can be made continuously if desired.

The mechanism formed in accordance with the invention may be substantially air-tight if desired. Also the housing **19** may be insulated to protect the apparatus from temperature changes at the mouth of the borehole where the apparatus is exposed. However, it is to be noted that the expansion or contraction effect due to temperature changes to the portion of the apparatus extending outwardly from the flange **18** will not be significant, for that portion of the system is self-compensating insofar as expansion or contraction is concerned. Although the temperature in the borehole itself will usually not change significantly to require corrections, a thermometer can be included in the system to determine temperature within the borehole itself.

FIGURE 7 illustrated a modification of the apparatus where the tubular anchor **52** is secured in a borehole **1** without grouting. This may be accomplished by providing wedge locks **53** which may be mounted in suitable inclined grooves about the periphery of the anchor **52**. The wires **10** are connected to or pass through this anchor in substantially the same manner as heretofore described. In the illustration, a disc **56** includes a suitable orifice for the end of a wire **10** to extend therethrough and be held in a lock **59** and another orifice to hold a button *f* where another wire extends completely through the anchor for connection with an anchor deeper in the hole.

It is to be noted that with the system above described, the observed movement of a wire **10** at the mouth of a hole is not the true measurement of the movement of the anchor within the hole with respect to the abutment position. The wire **10** and the spring **32** function in unison as components of a single elastic system, and where a long wire is used, such as 100 meters, the wire may be comparatively more flexible than the spring. Accordingly, the movement readings obtained by the dial gage and by the transducer **22** must be corrected to determine the true distance movement of a point within the borehole with respect to the abutment. It is necessary to ascertain the comparative longitudinal flexure characteristics of the spring and of the wire to compute the necessary correction factors required to give a precise indication of their comparative movements based upon the fact that pull on the wire is balanced by the compression on the spring. Once this is pointed out and the operative system of the extensometer is understood, it is but a simple matter for a skilled technician to determine the necessary elastic characteristics of the wire and spring, and then set up formulae to determine the true movement from the observed movement.

I have now described my invention in considerable detail; however, it is obvious that others skilled in the art can build and devise equivalent and alternate constructions which are nevertheless within the scope of my invention. Hence, I desire that my protection be limited, not by the constructions illustrated and described, but only by the proper scope of the appended claims.

I claim:

1. Apparatus for measuring rock movement in a borehole comprising: an anchor means adapted to be secured in the borehole at a selected position therein and to hold the end of a wire; a small-diameter stretchable wire secured to the anchor means and adapted to extend to the mouth of the borehole; an abutment at the mouth of the borehole; a base member carried upon the abutment traversing the mouth of the borehole; a base tube outstanding from the base member and being axially aligned with the wire extending therethrough; a retainer rod telescopically slideable within the base tube, extending outwardly therefrom with the inner end thereof connecting with the wire; a helical spring telescopically embracing the outward end portion of the retainer rod having its inner end abutting against the base tube and its outer end connected to the end of the rod, said spring being thereby held in compression and biased away from the borehole; means for connecting the wire with the anchor means with sufficient tightness to stretch the wire, compress the spring, and establish a common elastic system, whereby the wire and spring will deflect together responsive to movement of the anchor means within the borehole with respect to the abutment; and means adapted to measure the movement of the end of the wire at a point adjacent to the spring means whereby to permit the true movement of the anchor means with respect to the abutment to be calculated.

2. In the organization set forth in claim **1**, including an arm outstanding from the retainer rod and a deflection means mounted upon the base tube having its movement indicator adapted to move parallel with the base tube and to contact the arm.

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