United States Patent

[11] 3,580,057

[72] Inventor Ben L. Seegmiller
Salt Lake City, Utah
[21] Appl. No. 834,834
[22] Filed June 19, 1969
[45] Patented May 25, 1971
[73] Assignee The University of Utah
Salt Lake City, Utah

[54] **PROBE DEVICE USABLE IN MEASURING STRESS**
2 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **73/67.6,** 73/71.5
[51] **Int. Cl.** **G01n 29/00**
[50] **Field of Search** .... 73/67—67.9, 70, 71.1, 71.2, 71.4, 71.5, (Inquired); 310/8.2, 8.3, (Inquired)

[56] **References Cited**

UNITED STATES PATENTS

1,930,905	10/1933	Nicolson	73/88.5X
3,014,364	12/1961	Crooks	73/67.8X
3,101,608	8/1963	Benson	73/67.5
3,345,863	10/1967	Henry	73/67.5
3,350,582	10/1967	Attwood	310/8.1

FOREIGN PATENTS

732,083	6/1955	England	73/71.5
1,132,106	10/1968	England	73/71.5

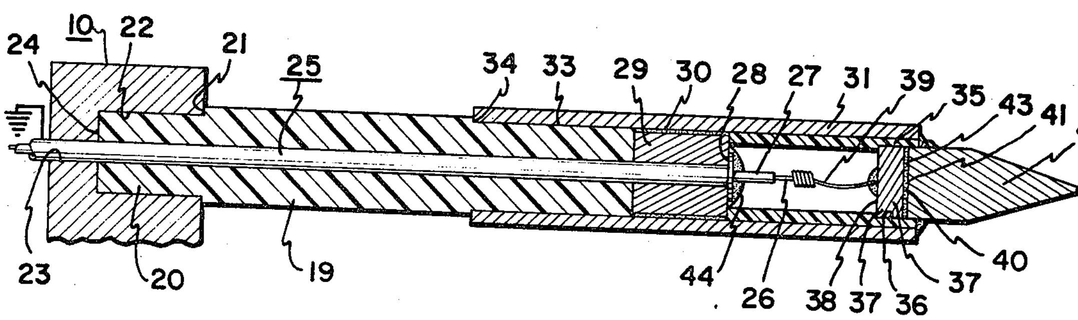
OTHER REFERENCES

" Variation of Elastic Wave Velocity with Frequency in Fused Quartz and Armcolron" — D. S. Hughes and J. M. Kennel— Journal of Applied Physics— Vol. 26, No. 11—November, 1955— pp. 1307— 1309

" Zero Drive— A New Zero Impedance Signal Conditioning Concept for Piezo-Electric Transducers" — J. E. Judd and E. P. Moran— Instr. Soc. of Amer. Reprint P13-2-Phymmid—67— rec' d in Office 12-3-68.— released 9-67.

Primary Examiner—Richard C. Queisser
Assistant Examiner—C. E. Snee, III
Attorney—M. Ralph Shaffer

ABSTRACT: A probe device for use with stress-measuring apparatus and having plural probes provided with mutually and, in one form of the invention, variably spaced tips. These tips preferably comprise parallel, chisel-contact tips. Transducers such as piezoelectric crystals are respectively operatively associated with said tips, with the intercoupling areas of the crystals and coaxial cable conductors coupled thereto being constructed to provide maximum shielding of such areas against external electromagnetic-wave or other interference. The rearward face of each crystal is connected by highly flexible conductor means to the central conductors of the coaxial cables. The forward faces of the respective crystals are preferably grounded through the tips and the jackets electrically connected thereto to the coaxial shields of the cables. Central members or plugs are employed to connect the shield to its respective jacket and at the same time isolate the crystal-connector junction areas.



PATENTED MAY 25 1971 3,580,057

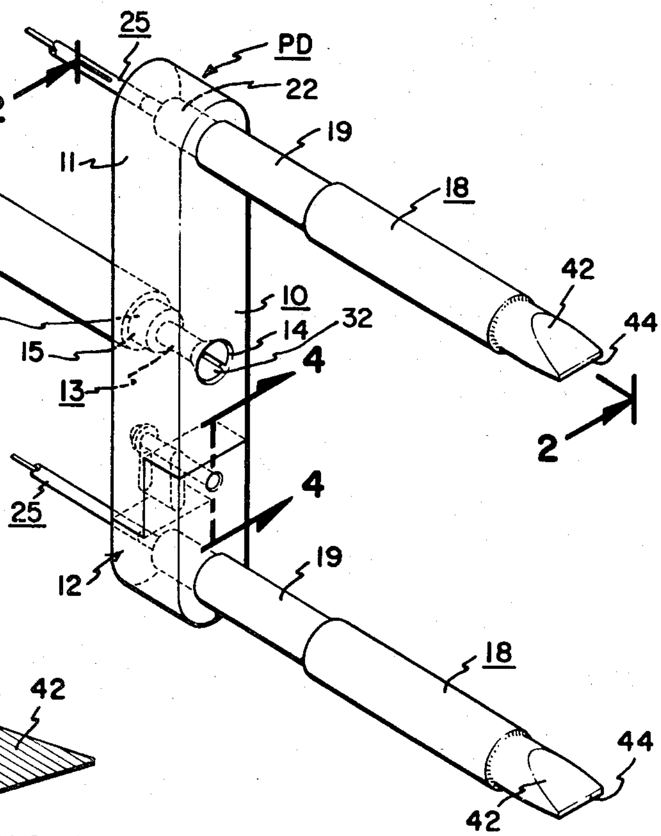


FIG. 1

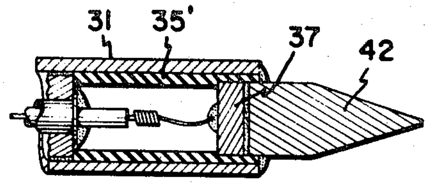


FIG. 3

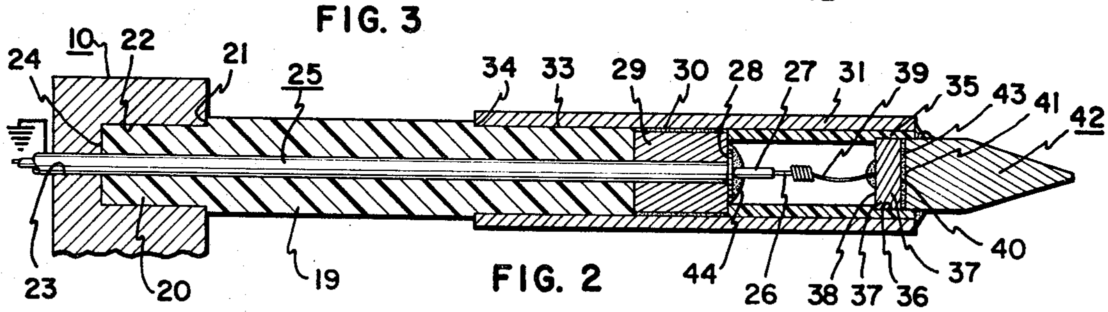
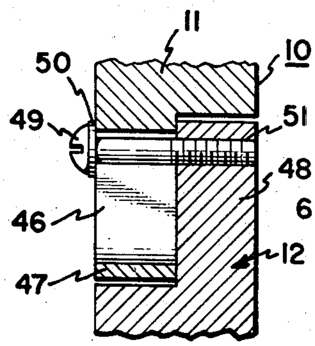
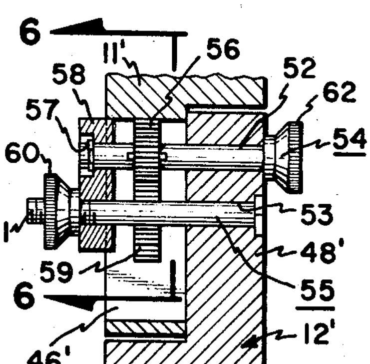


FIG. 2





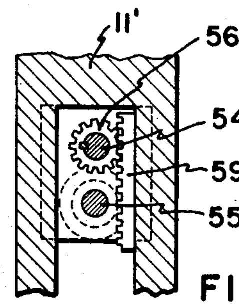


FIG. 6

FIG. 4

FIG. 5

INVENTOR.
BEN L. SEEGMILLER

BY

HIS ATTORNEY

PROBE DEVICE USABLE IN MEASURING STRESS

The present invention relates to probes used in stress-measuring equipment and, more particularly, to a new and improved probe device which insures optimum versatility and reliability in use.

A problem in underground mining which has arrested the attention of many individuals and groups is that of properly supporting overburden. The ever-present problem of mine cave-in with its hazards to life, let alone production costs, has stimulated research into rock mechanics. The basic goal in this area is to design equipment that can accurately determine in a reasonably short time the magnitude of stress present in a given mine pillar. While the present invention will be described in terms of mine operations, it will nonetheless be understood that the invention is not restricted in such use but may, on the other hand, be used with any equipment employing electrical pulse, transducer techniques, requiring determination of interprobe, pulse-travel velocity to produce, ultimately, intelligence bearing upon the stress present in the solid object against which the probes are pressed.

As is disclosed in a pending U.S. Pat. application entitled "-Measuring Stress," Ser. No. 658,422, filed Aug. 4, 1967, now abandoned, the present inventor being a co-inventor herein, which application is fully incorporated herein by way of reference, a basic scientific phenomenon utilized by the inventor is that the velocity of ultrasonic waves through a structural member such as a rock changes in correspondence with change in stress. Very often this will not be a straight line correlation but rather a characteristic curve for an object of a given constituency. In general, however, it may be stated that the velocity of a given mechanical wave or pulse through a rock, for example, is increased as the stress in the rock is increased.

In usual procedure, a stress-velocity relationship for a particular rock type will be developed in the laboratory by applying known stress to a rock sample by measuring the velocity of pulse travel between a pair of test probes spaced a given distance apart. A stress-velocity relationship will be developed for the particular rock type by incrementally changing the stress and measuring the velocity of a pulse traveling as a surface wave between a pair of spaced probes engaging the rock. The stress velocity relationship will be prepared in the form of a graph. Such a system readily lends itself to electronic feasibility in that where a pair of spaced contact probes incorporate transducers, e.g. piezoelectric crystals proximate and operative with their contact ends, then an electrical pulse sent to one probe will be converted by its crystal into a mechanical pulse transferred to the rock surface.

In the science of wave mechanics, when a mechanical impulse is transferred to a solid formation such as a rock, there are generated thereby three different waves, to wit: a slow surface wave (otherwise known as a Rayleigh wave), a shear wave which is somewhat a faster wave, and a longitudinal or primary wave, also known as a P-wave. The latter is the faster wave and is the wave which will generally be used practicing the invention. Such selection is desired as one should look for the wave of first arrival, the fastest wave, or P-wave.

Thus, the selected mechanical wave generated by such pulse will proceed to the remaining probe, be converted back to an electrical pulse, and there routed to suitable comparator circuitry, forming no part of the present invention, which can measure the time duration between the time that the initial pulse was first generated and sent to the first probe and the time of occurrence of the second pulse generated in the second probe in the manner aforesaid. Innumerable circuitry has been developed over the last 30 years which measures time intervals between a pulse echo, as in radar, and initial pulse generation.

The real challenge comes, however, in developing a suitable multiprobe device which is sufficiently versatile, and, most importantly, which is accurate and free from external, electromagnetic-wave or other interference.

Accordingly, a principal object of the present invention is to provide a new and improved probe device which may be used by or incorporated in stress-measuring equipment.

A further object is to provide a new and useful probe device incorporating transducers proximate their mutually spaced contact tips in such manner that the respective electrical connections between transducer, conductor, and preferably tip are properly shielded.

An additional object is to provide a new and improved probe device wherein maximum mechanical vibration of the incorporated piezoelectric crystals is facilitated.

An additional object is to provide maximum shielding, from extraneous electrical and electromagnetic impulses, those areas of the respective probes at which the transducers thereof are electrically connected to the central conductors of the coaxial cables incorporated by the probes.

A further object is to provide in the subject probe device suitable shielding for connector-crystal junctures completely around such junctures.

A further object is to provide a probe device wherein the spacing between the probes of the device may be accurately varied.

In accordance with the invention the probe device is provided with a handle and a base spacedly mounting a pair of probes. The contact tips of the probes are preferably chisel shaped and parallel, this to provide for a maximum energy transmission to and from the rock formation the probes are to engage as well as permitting unobstructed wave generation along the surface of the rock being tested. Transducers such as piezoelectric crystals are incorporated in each of the respective probes of the device, and those areas of the crystals which are electrically connected to respective input and output leads are appropriately shielded completely around the junction areas so that external radiations will not effect the operation of the device. The probes are likewise sufficiently spaced apart and elongate such that external mechanical waves along the probe device itself will not interfere with its operation. The contact tips themselves in addition to being parallel and accurately configured, are grounded back to the coaxial shields of the respective coaxial cables. Adjustment apparatus is provided for varying the spacing between the probes when desired.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages thereof, may best be understood by reference to the following description, taken in connection with the accompanying drawings in which:

FIG. 1 is a perspective view of a probe device incorporating the features of the present invention.

FIG. 2 is a fragmentary, enlarged section taken along the line 2–2 in FIG. 1.

FIG. 3 is a fragmentary view of the structure of FIG. 2, wherein an alternate spacer cylinder is employed between the piezoelectric crystal of the probe and the plug contained therein.

FIG. 4 is an enlarged fragmentary section taken along the line 4–4 in FIG. 1.

FIG. 5 is a fragmentary section similar to FIG. 4 but illustrates an optional embodiment of the invention wherein a length of the base of the probe device may be discretely adjusted.

FIG. 6 is a fragmentary section taken along the line 6–6 in FIG. 5.

In FIG. 1 base 10 of probe device PD may either comprise an integral member, or constitute a plural-element part including base member 11 and base segment 12 slideably connected thereto in a manner hereafter indicated. At all events, base 10 includes a central aperture 13 which is countersunk at 14 and also enlarged at 15 for receiving the turned end 16 of grasping handle 17. Screw 32 secures handle 17 to base 10, as shown. Handle 17, will, of source, be used to manipulate the device in the manner desired by the user.

Probes **18** each include mounting member **19**, the latter having end **20**, see FIG. **2**, provided with abutment shoulder **21**. End **20** is disposed within aperture **22** of the base **10**. Aperture **23** is concentric with respective aperture **22** and is also contiguous therewith at the shoulder **24** against which end **20** seats.

Passing through aperture **23** is a coaxial cable **25**. The latter is provided with a central conductor **26** having insulation **27** which is surrounded by the conventional coaxial shield **28**. If desired, the coaxial cable may include outer insulation covering the coaxial shield **28**.

The coaxial shield **28** of each of the probes **28** is secured by a conductive binder, such as silver solder or a silver epoxy, to conductive plug **29**. The latter may be made of copper, aluminum, or other suitable material. Plug **29**, in turn, may be silver-soldered at **30** to external-interference-shielding jacket **31**, forming in effect a part thereof. Jacket **31** is likewise fabricated from conductive material such as copper or aluminum, by way of example. Mounting member **19** may be made of plastic such as "Lucite" and can be provided with a recess area **33** terminating in shoulder **34**. It is seen that jacket **31** seats in recessed area **33** and abuts shoulder **34**.

A nonconductive, plastic or other spacer **35** abuts plug **29** and itself includes a recessed area **36** terminating in a shoulder. Seated within recessed area **36** is a transducer such as piezoelectric crystal **37**. The rear surface thereof at **38** receives the forward end of flexible conductor **39** and is electrically connected thereto by a silver solder or silver epoxy by way of example. The forward surface **40** of piezoelectric crystal **37** may be coated with a silver-flake containing epoxy or other bonding agent for securing the rear surface **41** of electrically conductive probe tip **42** to the forward surface of the piezoelectric crystal.

As to flexible conductor **39**, the latter may comprise a conventional fine-wire mesh connection. It is essential that this be completely flexible so as not to deter in any way the proper vibration of the piezoelectric crystal **37** in response to electrical energy imparted thereto via conductor **26** and the flexible conductor **39**. The spacer **35** will, of course, be made of nonconductive material such as a suitable plastic as seen in FIG. **2** or an elastomeric, insulative material such as rubber, as shown at **35'** in FIG. **3**.

Referring to FIG. **2**, the probe tip **42** is maintained at ground or common reference potential, i.e. the potential existing at coaxial shield **28**. Such is desirable, for further interference reduction. This can be done by the employment of silver epoxy **43** physically and electrically connecting the tip **42** with jacket **31**.

Of importance is the shape of the probe tips **42**. It has been found through experimentation that the chisel-configured edges **44** are most satisfactory in use. These should be parallel and flat on their ends, howbeit of reduced transverse dimension of the order of three-sixteenths", for example. In this way there can be a maximum transfer of energy from a tip **42** of one of the probes **18**, where maximum reception of the desired energy wave by the remaining probe tip and probe is desired. It is here to be mentioned that, preferably, both the probes **18** are constructed in similar fashion as shown in FIGS. **2** and **3**, with both of the same being mounted in the respective apertures **22** in the manner indicated in FIG. **2**.

The operation of the probe device PD as thus far described is as follows.

An external source of electrical energy, not shown, supplies a pulse of electrical energy to central conductor **26** of coaxial cable **25** of a given one of the probes. This pulse will take the form of a voltage difference of specific time duration as between conductor **26** and the coaxial shield **28**; in the system the latter is preferably maintained at a ground or common reference potential, for proper shielding effect. It is noted in FIG. **2** that the tip **42** also is grounded to the coaxial shield of the coaxial cable **25** through the tip **42**, solder or epoxy **43**, jacket **31**, and the electrical connection of the latter through solder **30** to plug **29**. The latter is, of course, physically and electrically connected to the coaxial shield **28** via silver epoxy **44**. Thus, in referring to FIG. **2**, and considering the upper probe **18** of FIG. **1** to be the input probe, this pulse of electrical energy is transmitted to the piezoelectric crystal, which by its nature, and in a manner well known in the art, converts such electric impulse into a physical vibration pulse. This pulse of mechanical energy is immediately transmitted to tip **42** and through the same to the rock formation or other structure being tested. The first-arrival or P-wave produced in the formation travels to the remaining probe via the formation which it touches, and the mechanical energy is converted by piezoelectric crystal **37** in the remaining probe to electrical energy, the latter traveling through flexible conductor **39** and conductor **26** of the remaining probe, back through the remaining probe **18** to external detector equipment. It would be understood that the pulse generating equipment and detector equipment form no part of the present invention.

It is most important to note that by virtue of the construction of the present invention, see specifically FIG. **2**, the area within spacer **35** is completely shielded from exterior influence.

For experimentation or other purposes it may be desirable to have the parallel tip edges **44** of the probes variably spaced apart. This can be accomplished by constructing base **10** as a plural element unit in the manner heretofore indicated in connection with FIG. **1**. Where such is the case, then base member **11** and base segment **12** may be configured in the manner shown in FIG. **4**. In such event, base member **11** is provided with slot **46** in a downward extension **47**. Correspondingly, base segment **12** may be provided with an upward extension **48** is slideably disposed and cooperative with downward extension **47**. Screw **49** is provided with washer **50** and is threaded into threaded aperture **51** of upper extension **48**. This screw, of course, is disposed in slot **46**.

By virtue of such construction, the loosening of the screw will provide for slightly slideable adjustment of base segment **12** relative to base member **11** so that the chisel-shaped ends **44** of the probe may be variably and adjustably spaced apart.

FIGS. **5** and **6** disclose another type of adjustable construction wherein the upward extension **48'** corresponding to upward extension **48** in FIG. **4** is this time provided with apertures **52** and **53** for receiving screw **54**, and stud **55**, respectively. Keyed to screw **54** is a pinion **56**, and the end of the screw **54** is provided with a retainer **57** for retaining the end in keyed block **58**. Rack segment **59** may be secured in any conventional manner to base member **11'**, corresponding to base member **11** in FIG. **4**, at the slot area **46'** corresponding to **46** in FIG. **4**. Knurled nut **60** is threaded upon the threaded shank **61** of stud **55** where engages the slide block **58** in the manner seen in FIG. **5**.

The manner of adjustment of the structure is seen in FIGS. **5** and **6** as follows. Knurled nut **60** is first unthreaded so as to release the interlocking of the parts. Screw **54** is then turned by head **62** so as to rotate pinion **56**. Such rotation of pinion **56** and its engagement with rack **59** provides a downward traveling of the pinion along the rack and hence a carrying of the part **12'**, corresponding to part **12** in FIG. **4**, downwardly relative to part **11'**. Upon a sufficient separation of the ends **44** of probes **18** being achieved, then the turning of screw **54** is ceased and the disposition locked in place by the threading down of nut **60** against slide block **58**.

Hence, the construction of FIG. **4** and of FIGS. **5** and **6** represent different embodiments suggesting ways in which the contact edges **44** of probes **18** in FIG. **1** may be adjustably spaced relative to each other. This adjustability feature in spacing may well be desirable in certain instances so as to correlate any electronic equipment and any limitations thereof to the particular formation and velocity of wave travel anticipated.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects.

I claim:

1. For a stress-measuring system, including a readout device, that sends and receives pulsed mechanical waves between two probes in contact with the sample whose stress is being measured, such that the time delay between transmission and reception of such pulses is measured in the readout device, indicating the actual stress present in said sample, a probe device including, in combination, a pair of mutually spaced probes, and means for mounting said probes in mutually spaced relationship, each of said probes including: an electrically conductive contact tip, a piezoelectric crystal having a front surface engaging said contact tip and a rear surface, and a coaxial cable having a central conductor and an electrically conductive coaxial shield circumscribing and insulated from said central conductor, said coaxial shield being electrically grounded, means for electrically coupling said central conductor to said rear surface of said piezoelectric crystal, and electrically conductive means encasing said piezoelectric crystal and the juncture thereof with said central conductor for forming an enlarged, grounded continuation of said coaxial shield thereabout, said electrically conductive means being coupled electrically to said tip, whereby to be electrically coupled to and between said front surface of said piezoelectric crystal and said coaxial shield, said coaxial shield, electrically conductive encasing means, and contact tip completely shieldingly enclosing said piezoelectric crystal and said central conductor where connected thereto, to electrically shield the same from external interference.

2. For a stress-measuring system, including a readout device, that sends and receives pulsed mechanical waves between two probes in contact with the sample whose stress is being measured, such that the time delay between transmission and reception of such pulses is measured in the readout device, indicating the actual stress present in said sample, a probe device including, in combination, a pair of mutually spaced probes, and means for mounting said probes in mutually spaced relationship, each of said probes including: an electrically conductive contact tip, a coaxial cable having a central conductor and a coaxial shield circumscribing and insulated from said central conductor, and ultrasonic electromechanical transducer means interposed between and operatively coupled to said central conductor and said contact tip for, as to one probe, converting electrical energy received by its central conductor into mechanical vibration for said probe's contact tip and, as to the remaining probe, for receiving mechanical vibration from its respective contact tip and converting the same into electrical energy for its respective central conductor, and respective, electrically conductive, shielding means circumscribing said ultrasonic electromechanical transducer and said central conductor and being electrically connected to said respective coaxial shield and also to the tip, said coaxial shield, electrically conductive shielding means, and contact tip completely shieldingly enclosing said piezoelectric crystal and said central conductor where connected thereto, to electrically shield the same from external interference.