

June 12, 1956

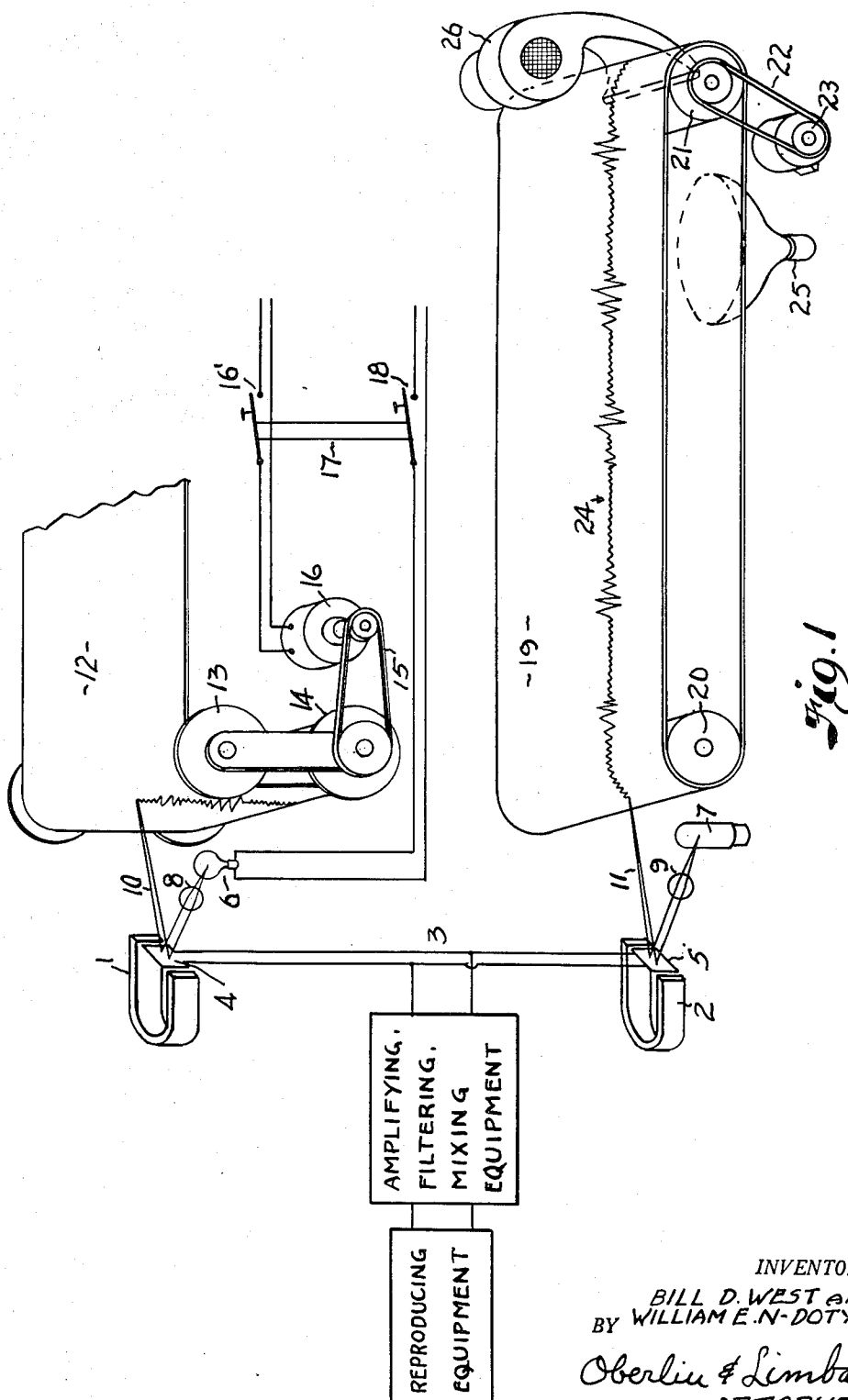
W. E. N. DOTY ET AL

2,750,575

METHODS OF AND APPARATUS FOR SEISMOGRAM ANALYSIS

Filed April 6, 1953

3 Sheets-Sheet 1



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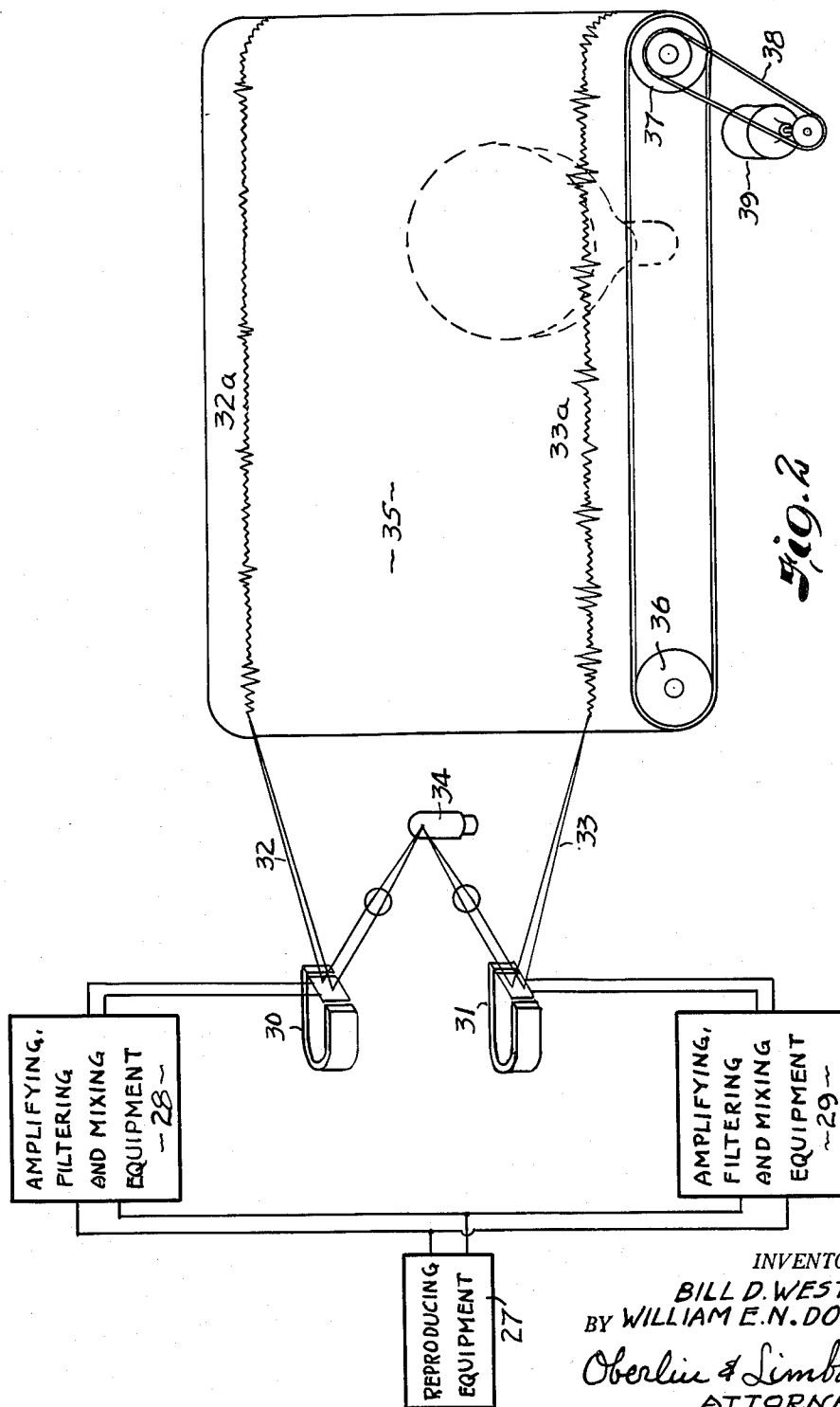
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METHODS OF AND APPARATUS FOR SEISMOGRAM ANALYSIS

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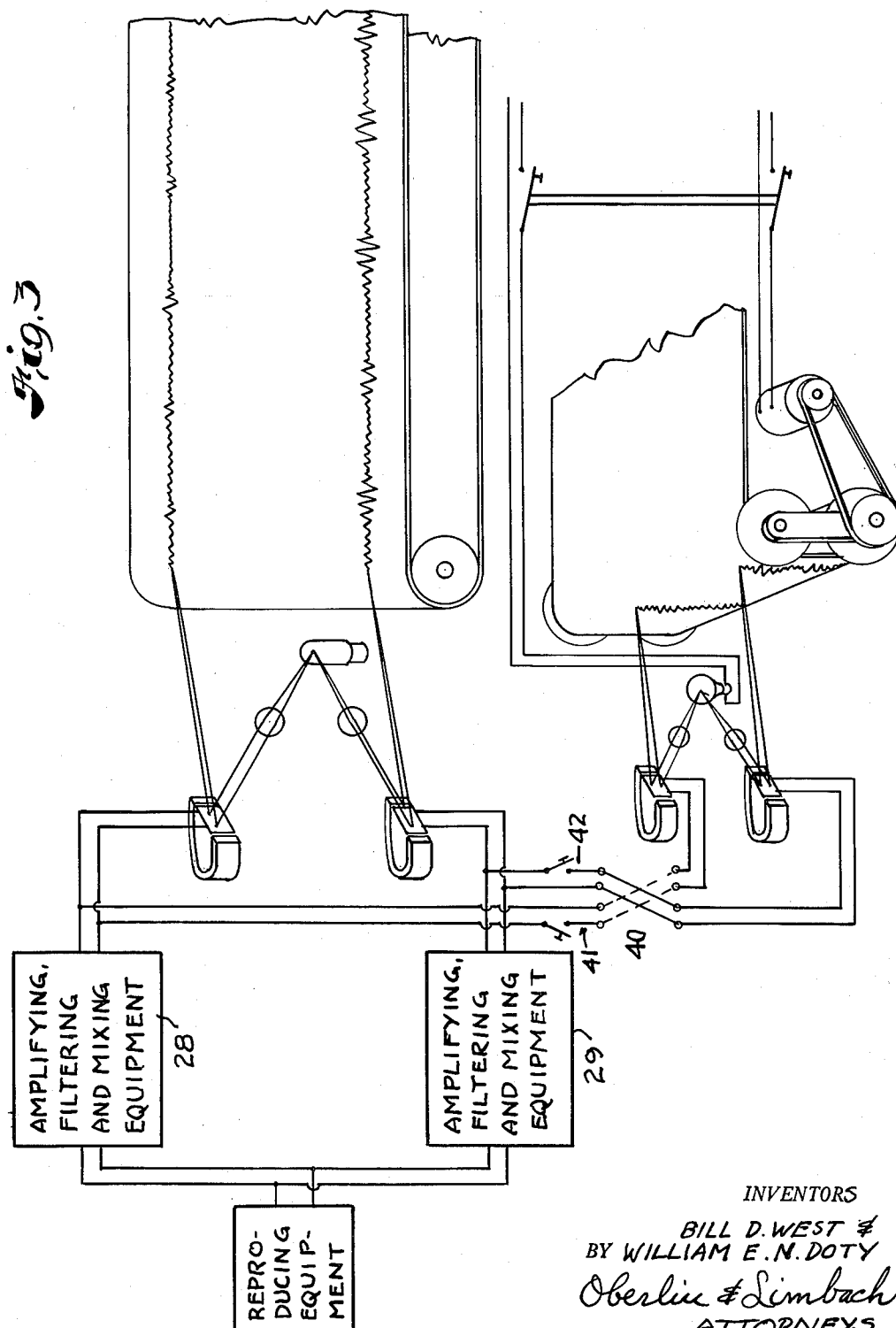
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METHODS OF AND APPARATUS FOR SEISMOGRAM ANALYSIS

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METHODS OF AND APPARATUS FOR SEISMOGRAM ANALYSIS

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6 Claims. (Cl. 340—15)

This invention relates as indicated to methods of and apparatus for seismogram analysis. As usually practiced in seismic exploration for oil and other minerals, the acoustic signals from an explosion are converted to electrical signals and subjected to various adjustable schemes of amplitude control, frequency and phase discrimination, and recorded as oscillograph traces (seismograms) on photographic film or paper. If the optimum adjustments of filters, mixing, automatic amplitude control, etc. have yielded a seismogram having a favorable signal-to-noise ratio, various timed events will be identifiable on said seismogram and a skilled interpreter can deduce therefrom, information indicative of attitude and depth of subsurface strata.

As thus practiced, the observer, is limited to a single set of values for each variable in the frequency and phase discrimination schemes and if the values chosen are not satisfactory, he must make the necessary changes and then record the signals from another explosion.

Improved practice of exploration techniques embodies means for reproducibly recording, with a minimum of discrimination, the electrical signals on a magnetic tape, variable area or variable density track on photographic film or the like. This reproducible record may then be "played back" through the frequency and phase discriminating apparatus (filters, mixing etc.) and new modified photographic records made for as many different adjustments as the observer chooses. This operation will be referred to as adjustable analyzing, and will be more thoroughly described under the subheading: amplifying, filtering, limiting, and mixing equipment. The various adjustments may thus be evaluated without the necessity of setting off additional explosions, thus effecting considerable economy of time and money.

Although this method constitutes a very valuable advance and improvement over previous methods, it is still necessary to make and process a photographic record for each adjustment. This means a delay of several minutes between the time an adjustment is made and subsequent evaluation of the effectiveness or desirability of said adjustment and also means extra expenditure for photographic materials.

It is a principal object of our invention to provide methods of and apparatus for seismogram analysis in which the modified seismogram is displayed for visual examination by the observer without necessity for the delay and expense of conventional photographic or other graphic recording processes.

It is a further and more particular object of this invention to provide methods of and apparatus whereby the effect of different settings of the frequency and phase discriminating equipment may be directly compared by the operator in a side-by-side relation thus making it possible for him to quickly and accurately determine which setting of such equipment will provide a component of the analyzed signal which is truly significant and which accordingly may be recorded for further and detailed study in a leisurely fashion.

It is also an object of this invention to provide apparatus by which the foregoing ends may be readily accomplished, which apparatus because of its simplicity of design and construction gives reproducible results; is eco-

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nomical to produce and use and does not go out of adjustment when subjected to normal use.

Other objects of our invention will appear as the description proceeds.

To the accomplishment of the foregoing and related ends, said invention then comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principle of the invention may be employed.

In said annexed drawings, Fig. 1 is an illustration, in certain respects diagrammatic, of one form of apparatus by which a certain method of our invention may be performed;

Fig. 2 is an illustration of apparatus designed particularly for the purpose of comparing visually the simultaneous effect of different settings of amplifying, filtering, limiting and mixing equipment on the signal which correspond to a particular seismogram so that the operator may by such ready comparison determine which of such settings will produce a component which has the greatest significance; and

Fig. 3 illustrates apparatus which combines in one unit the apparatus which was separately illustrated in the previous figures.

Broadly stated, this invention relates to a new method of analyzing seismograms which comprises generating an electrical signal corresponding to at least a portion of the seismogram, adjustably analyzing said electrical signal, forming a visual representation of the electrical signal as thus analyzed, observing the visual representations of the electrical signal as thus analyzed, and permanently recording those modifications of the electrical signal, corresponding to particular analysis thereof, whose visual representations indicate them to possess certain desirable features for purposes of interpretation.

With regard to the apparatus which forms a part of the present invention it may be broadly described as apparatus of the character described comprising in combination means for generating an electrical signal corresponding to at least a portion of a seismogram, means for adjustably analyzing said signal, means for simultaneously forming visual representations of the modified seismogram corresponding to two different equipment adjustments, and means for selectively forming a permanent record of the modified seismogram provided by one of said equipment adjustments.

Within the broad statements of the invention as given above there are numerous sub-combinations of apparatus and process steps which are in themselves novel and which will be recognized as such as the description of this invention proceeds.

In the further and more particular description of this invention it is believed best to first make reference to the various pieces of equipment illustrated in the drawings which have been brought together in making up the new and novel apparatus of this invention and by which our improved process may be performed.

Reproducing equipment

This reproducing equipment generates an electrical signal which is a parameter of at least a portion of the original seismogram which is under study. The generation of such an electrical signal is a well-known practice in the art of analyzing seismograms. If the original signal was recorded as on a magnetic tape and in that form brought from the field into the office for study, magnetic-tape reproducing equipment will be used for the purpose of generating an electrical signal which is a facsimile of the seismic signal picked up by the detectors. All of these ways of thus providing an electrical signal which is a

counterpart of the original seismic signal as recorded on the seismogram are well-known and many illustrations will be found in the literature and in the prior patents and since they form no part of the present invention, this reproducing equipment which will thus provide such an electrical signal has been indicated by block diagram.

Amplifying, filtering, limiting and mixing equipment

This equipment to which is fed the electrical signal generated by the reproducing means just described is for the purpose of analyzing such signal into component parts for recording and detailed study. The following are at least some of the modes by which the original signal is modified or analyzed in the amplifying, filtering, limiting and mixing equipment to which the reproduced electrical signal is fed.

It is common practice to feed the electrical signal to a multi-stage vacuum tube amplifier directly or through an adjustable input filter and to provide other variable high-pass, band pass and low pass filters between stages in such a manner that the overall frequency response of the amplifying equipment may be adjusted at will through the use of manual or electronic controls. These adjustable filters which can be of the LC, RC or mechanical types enable the operator to decompose the original seismogram into elementary narrow band frequency components. In order to compensate for the large reduction in amplitude of the signal received from the detectors between the beginning and the end of the seismograms and to give all traces a substantially equal amplitude, automatic volume control and limiting circuits described largely in technical literature and in prior patents may also be included. Furthermore, the provision for adding and combining in adjustable proportions two or more traces, commonly referred to as mixing by persons skilled in the art, may also be included for signal-to-noise ratio improvement.

Some or all of the so-described characteristics of the amplifying, filtering, limiting and mixing equipment are included in all the recording units in present use in the field and are well-known to persons skilled in the art.

By having reference to the functions to be performed by the amplifying, filtering, limiting and mixing equipment it will be readily apparent to those skilled in the art that there are a wide variety of different kinds of equipment available by which these specific objectives may be accomplished and since all of such equipment is well-known, readily available and forms no part of the present invention, its place in the system of the present invention has been illustrated by a block diagram.

In the embodiment of one form of apparatus constructed in accordance with our invention and for the purpose of carrying out one of the methods of our invention we provide a pair of D'Arsonval type galvanometers 1 and 2 which are connected in parallel in the output line 3 from the filtering, amplifying, limiting and mixing equipment. Each of these galvanometers is provided with the usual movable mirrors 4 and 5 onto which will be projected beams of light from lamps 6 and 7 which have been gathered and focused by suitable lenses 8 and 9 so that the beams 10 and 11 reflected from the mirrors 4 and 5 will oscillate and draw the well-known type of trace onto a moving surface against which they are projected.

The beam 10 from the galvanometer 1 is intercepted by a sheet 12 of photographic material which is supported and driven by rollers 13 and 14, the latter connected by a belt 15 to a suitable electrical motor 16, the energization of which is under control of the operator by means of the switch 16' which, being mechanically interconnected as at 17 with a switch 18, also controls the energization of the lamp 6. Thus, when the operator closes switches 16' and 18 the lamp 6 will be lighted and the motor 16 energized to drive the strip of photographic material at a predetermined rate so that the beam from the lamp 6 projected thereon will, when the film has been developed,

appear thereon as the well-known seismic trace. Arranged to intercept the beam 11 is a belt 19 trained about spaced rollers 20 and 21, the latter being driven through the belt 22 from the motor 23 which will be energized so as to drive the belt 19 at substantially the same speed as the rate of movement of the film strip 12.

The lamp 7 will preferably be formed so as to emit ultra-violet light so that the ultra-violet beam 11 may energize a phosphorescent coating on the web 19 and generate thereon a trace which thus will correspond exactly with the trace generated by the beam 10. The trace 24 on the phosphorescent belt will have a life of sufficient duration so that the operator may study such trace and determine whether the setting of the amplifying, filtering, limiting and mixing equipment is correct; i. e. whether the trace 24 is significant of some characteristics of the original seismogram which is under study.

The construction and mode of operation of the equipment on which is recorded for momentary inspection by the operator of the trace formed by the beam 11 is like that illustrated in Patents Nos. 1,724,575 and 2,210,565 so that a more detailed description of the apparatus is believed unnecessary at this point. Suffice it to say that we provide an infrared lamp 25 closely adjacent the under side or return run of the web 19 so as to erase therefrom the previously formed phosphorescent trace. We have found that by providing a blower such as 26 by which the air between the two runs of the belt which is heated in the one end of the machine under the influence of the infrared lamp is caused to circulate under the upper portion of the belt thereby keeping it warm, the phosphorescent image traced thereon by the beam 11 will be intensified.

The apparatus shown will of course be enclosed in a suitable housing provided with an appropriate opening through which the operator may view the trace 24. It will be understood of course that the photographic equipment by which the record of the trace is made on the film strip 12 will likewise be enclosed in a light-proof housing.

At this point it should be noted that it is within the contemplation of our invention to provide means other than a photographic recording means for the purpose of making a record at least initially of the component of the original signal which is picked out by a suitable analysis of the original signal. Thus, for example, it is within the contemplation of our invention to provide a magnetic record of such component instead of a photographic record.

The apparatus illustrated in Fig. 2 includes an input signal reproducer generally indicated at 27 which will of course be like the reproducer equipment previously described, instead of using one set of amplifying, filtering, limiting and mixing equipment such as was employed with the arrangement shown in Fig. 1, two such sets of preferably identical equipment, generally indicated at 28 and 29, will be employed in parallel and each connected with a separate galvanometer 30 and 31 respectively which reflect beams 32 and 33 respectively from an ultraviolet lamp 34. While we have shown only one galvanometer associated with each set of amplifying, filtering, limiting and mixing equipment, it will be understood of course that a plurality of such galvanometers will be employed, the number depending upon the number of traces in the individual seismogram under study.

A phosphorescent belt 35 trained about rollers 36 and 37, the latter being driven by a belt 38 from a motor 39 is so arranged as to intercept the beams 32 and 33 and as the belt is driven by said motor there will be formed on the belt a trace representative of the component or parameter of the original signal which is passed by the amplifying, filtering, limiting and mixing equipment. By the use of apparatus such as illustrated in Fig. 2 the operator may set the equipment 28 for a certain condition and observe the trace 32a representative of the component

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of the original signal selected by such setting. He may then by seeking to improve on such setting or for the purpose of selecting a different component adjust the equipment 29 to a slightly different condition and then by operating the apparatus observe not only the effect of the different setting, but by comparing the traces 32a and 33a quickly and accurately determine the differences resulting from the differences in the setting of the equipment. Thus, if the new setting of equipment 29 is superior to the setting of the equipment 28 he may then, by keeping equipment 29 in its previously set condition vary equipment 28 in an effort to still further improve the analysis of the original signal and in this way by comparison of the results of each setting proceed stepwise to the condition for best results.

The apparatus illustrated in Fig. 3 is as previously indicated a combination of the equipment shown in the previous figures, and accordingly like parts have been given like reference characters.

In connection with Fig. 3 it should be noted also that the single pair of galvanometers shown associated with the phosphorescent belt and the single pair of galvanometers shown with the recording film strip are representative of the equipment necessary for the analysis of the single trace on the original seismogram and that accordingly such galvanometers will be duplicated as many times as there are different traces on the original seismogram which should be analyzed.

It will be observed that the circuits to the galvanometers associated with the recording film strip are provided with a reversing switch 40 by which the relative location on the film strip of the two traces (or sets of traces if multiple galvanometers are employed) may be varied. The provision of additional switches 41 and 42 makes it possible to select for record purposes the signal provided by either or both sets of amplifying, filtering, limiting and mixing equipment. Ordinarily, one of the switches 41 and 42 would remain open since ordinarily the two sets of equipment 28 and 29 would be used simultaneously only for the purpose of providing a single carefully selected component of the original signal and when such component has been selected it alone would be recorded instead of being recorded alongside of the signal from the other equipment with which it might be compared. There are instances, however, when the operator may find that the time permitted for visual inspection of the traces on the phosphorescent belt is insufficient for him to determine which of the two is preferable and in those cases he may then make a permanent record of both traces and study and compare them more leisurely and in this way arrive at an accurate determination of which setting gives best results.

From the foregoing it will be observed that we have provided a novel method and apparatus for seismogram analysis which not only reduces considerably the time and expense as compared with prior art procedures, but also provides a surer way of separating out of the entire seismogram those components which are most significant of the formations under investigation.

Other modes of applying the principle of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims or the equivalent of such be employed.

We, therefore, particularly point out and distinctly claim as our invention:

1. Apparatus of the character described comprising in combination means for generating an electrical signal which is a parameter of at least a portion of a seismogram, means for adjustably modifying said signal to provide at least two different modifications of said signal, means for instantaneously, simultaneously, and momentarily forming visual representations of the different modifications of said signal, and means for selectively forming a permanent record of one of such modifications of said signal.

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2. Apparatus of the character described comprising in combination means for generating an electrical signal which is a parameter of at least a portion of a seismogram, means for adjustably modifying said signal to provide at least two different modifications of said signal, means for instantaneously, simultaneously, and momentarily forming in side-by-side relationship visual representations of the different modifications of said signal, and means for selectively forming a permanent record of at least one of such modifications of said signal.

3. In combination: (a) means for converting to electrical form previously recorded seismic energy, (b) two sets of galvanometers of the D'Arsonval type with reflecting mirrors and associated ultraviolet sources, (c) means including variable filtering, limiting, and mixing controls for transmitting instantaneously and simultaneously different modifications of said electrical signals to said separate sets of galvanometers, respectively (d) a phosphorescent belt arranged to intercept the beams of ultraviolet light from all of said galvanometers, (e) means for driving said phosphorescent belt at a substantially uniform speed, and (f) means for permanently recording at least one of said modified signals.

4. The method of analyzing seismograms which comprises: generating an electrical signal corresponding to at least a portion of a plurality of traces of a seismogram, directing said generated signal in two paths to provide a first signal and a second signal which are duplicates of said generated signal, adjustably modifying said first signal in one respect and adjustably modifying said second signal in a different respect, instantaneously, simultaneously, and momentarily forming visual representations of said modified signals, and permanently recording one of said modified signals.

5. The method of analyzing seismograms which comprises: generating an electrical signal which is a parameter of at least a portion of a plurality of traces of a seismogram, directing said generated signal in two paths to provide a first signal and a second signal which are duplicates of said generated signal, adjustably modifying said first signal in one respect and adjustably modifying said second signal in a different respect, instantaneously, simultaneously, and momentarily forming visual representations of said modified signals, and permanently recording one of said modified signals.

6. Apparatus of the character described comprising means for generating an electrical signal, said generating means having parallel outlet channels, adjustable modifying means interposed in each of said channels for modifying the component of the signal therein, common display means for forming instantaneous and simultaneous visual representations of said components as modified, said visual representations being formed in juxtaposition, and means for recording either of said components as modified.

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