

Dec. 12, 1944.

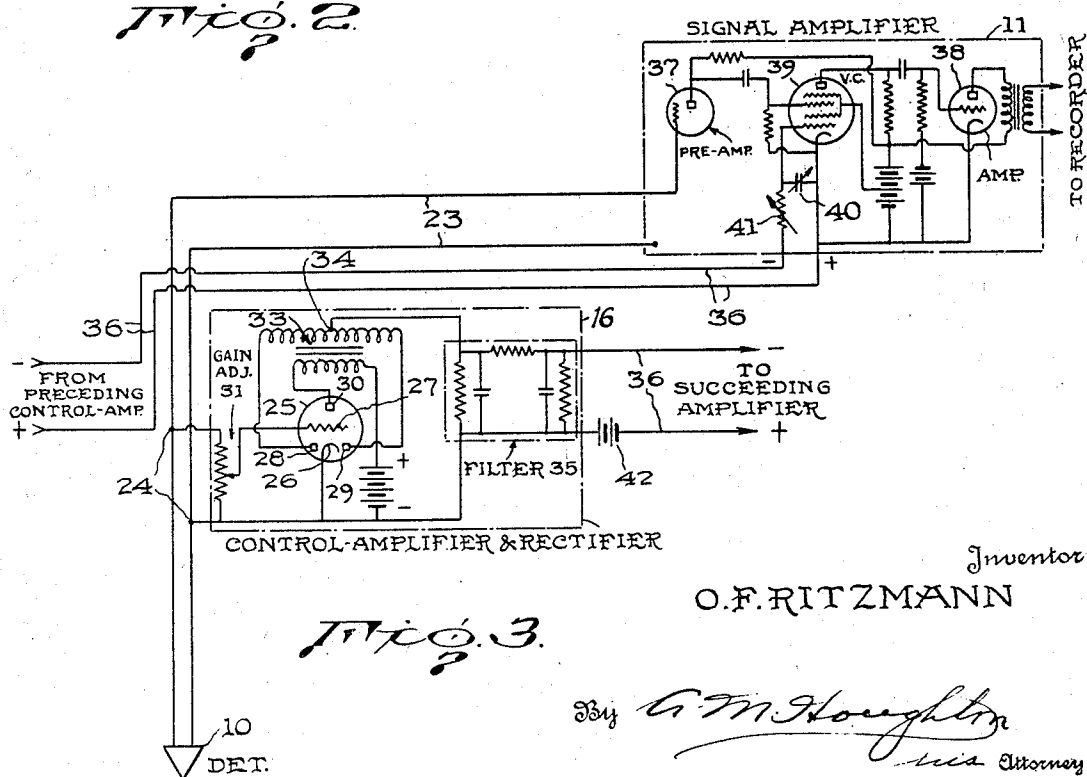
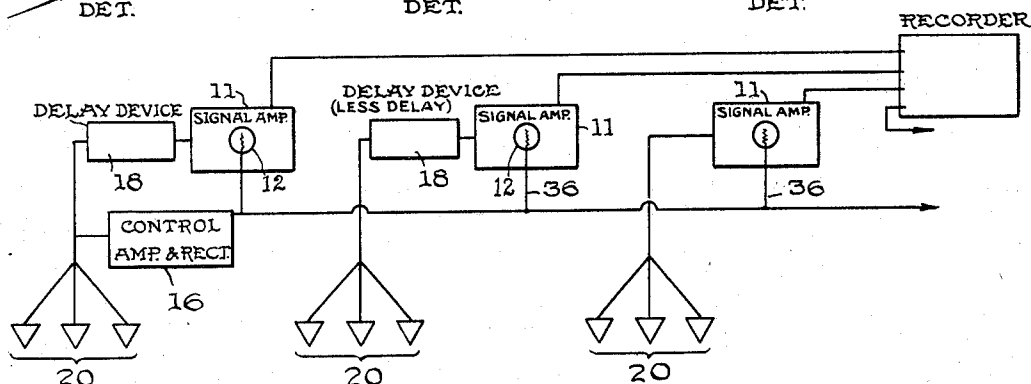
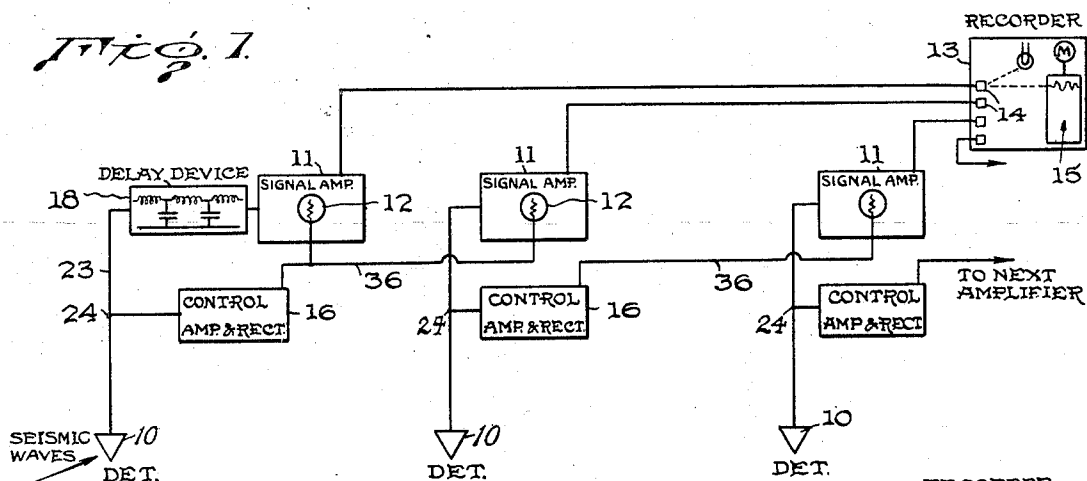
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2,364,755

APPARATUS FOR SEISMOGRAPH PROSPECTING

Filed Jan. 22, 1942

2 Sheets-Sheet 1



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Fig. 4

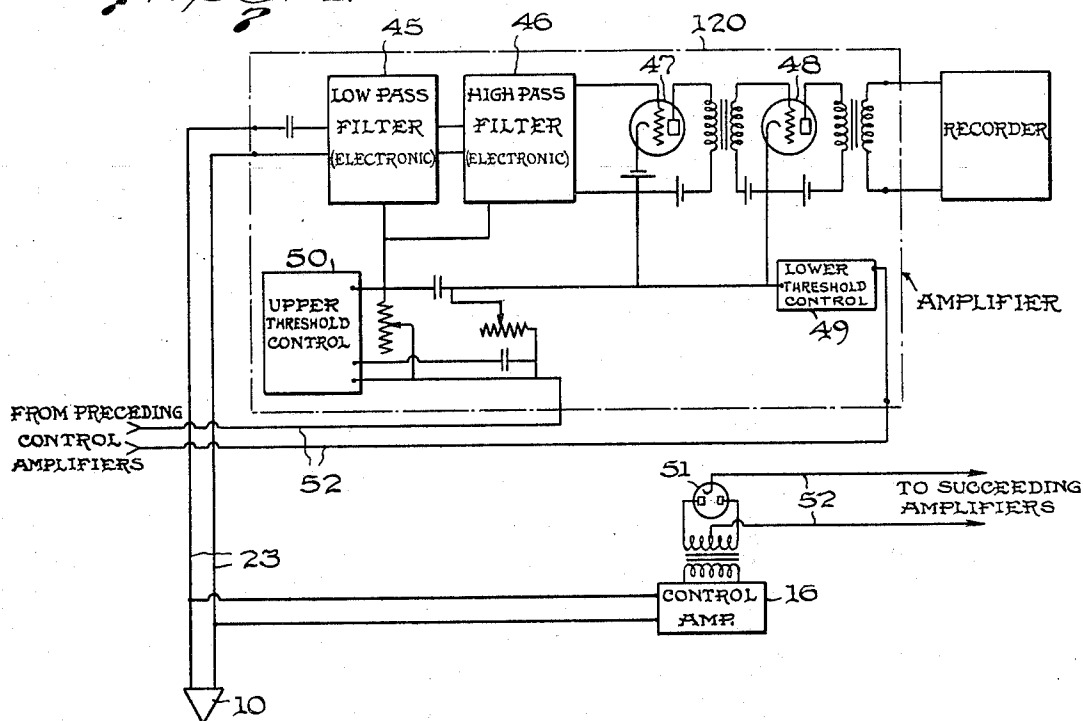
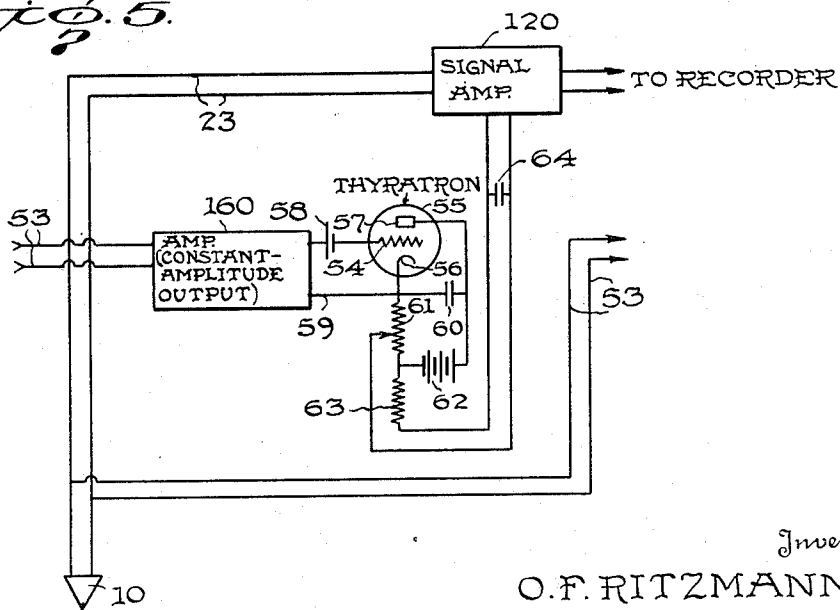


Fig. 5



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## UNITED STATES PATENT OFFICE

2,364,755

APPARATUS FOR SEISMOGRAPH  
PROSPECTING

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Application January 22, 1942, Serial No. 427,808

7 Claims. (Cl. 177—352)

This invention relates to apparatus for seismo-  
graph prospecting.

In Patent No. 2,281,949, issued May 5, 1942, for  
Apparatus for seismograph prospecting, of which  
the present application is a continuation-in-part, I  
have disclosed and claimed an apparatus, includ-  
ing a set or "spread" of seismic detectors and  
associated amplifiers, in which the amplifiers are  
automatically controlled as to gain or frequency  
during receipt of seismic waves with the aid of  
wave signal energy obtained from an auxiliary  
"advance detector" located in the earth nearer to  
the source of seismic waves than other detectors,  
so as to receive waves before the other detectors;  
all with the object of compensating for a time  
lag or delay inherent in the functioning of the  
controlling devices. In such system, by suitable  
spacing of the advance detector the amplifier  
controlling action is caused to be exerted not  
later than receipt of the main signal at the con-  
trolled part of the amplifier.

The present invention has for its principal ob-  
jects the provision of a system of this general  
type in which a separate advance detector need  
not be employed, the control energy for a given  
detector-amplifier assembly being derived from a  
previous detector or detectors of the same spread;  
the provision of such a system in which a portion  
of the energy from the first detector is caused to  
control an amplifier connected to a subsequent  
detector, and so on throughout the group; and  
the provision of such a system in which the en-  
ergy from the first detector is caused to control  
a plurality of later amplifiers, delay means being  
provided in some of the amplifier circuits to com-  
pensate for the varying distance of the corre-  
sponding detectors from the source of waves.

The present invention is especially advanta-  
geous in that it achieves the desired results, with-  
out requiring additional elements beyond those  
ordinarily present in a seismograph prospecting  
setup, and in that the new system is readily  
adaptable to irregular detector spacings and to  
very great detector spacings.

These objects are achieved by provision of a  
system which in its best embodiment involves a  
plurality of spaced detectors each delivering sig-  
nals to an amplifier, and means for diverting a  
fraction of the output of each detector and caus-  
ing the diverted energy to control the tuning or  
gain of a succeeding amplifier in the series. In  
a simplification, the output of the first detector  
only is partially diverted and the diverted energy  
is caused to control the rest of the amplifiers,  
electrical delay means being provided to compen-

sate for the changing spacing of the succeeding  
detectors from the first detector.

In the accompanying drawings are shown dia-  
grammatically several examples of specific em-  
bodiments of apparatus within the purview of the  
invention. In the drawings,

Fig. 1 is a diagrammatic showing of one em-  
bodiment of the invention, in which each ampli-  
fier of a detector spread is controlled as to gain  
in accordance with signal energy taken from a  
preceding detector associated with a preceding  
amplifier,

Fig. 2 is a diagrammatic showing of a modifi-  
cation in which all amplifiers are controlled  
through signal energy from a detector near the  
shot, electrical delay means being employed to  
compensate for different detector spacings.

Fig. 3 is a circuit diagram of one of the ampli-  
fier-control-detector units of Fig. 1.

Fig. 4 is a showing illustrative of a modifica-  
tion wherein tuning of the amplifiers is controlled  
rather than gain, and

Fig. 5 shows a modification wherein tuning of  
the amplifiers is controlled, as a function of fre-  
quency of received waves.

Referring to the drawings and more especially  
to Fig. 1, a "spread" or plurality of seismic de-  
tectors 10 is set up in the earth (not shown) at  
various distances from a source of seismic waves  
(not shown) such as a dynamite charge. The  
detector outputs are supplied to signal amplifiers  
11, of type known per se and each including a  
controlling element adapted to vary a character-  
istic of the amplifier according to the magnitude  
of energy applied to the controlling element. In  
Fig. 1 the controlling element is a tube 12 which  
regulates the amplifier gain, in accordance with  
a voltage applied to the tube, as described below.  
The amplifier outputs are applied to a recorder  
13, of conventional type, including a plurality of  
electro-optical oscillograph elements 14 which  
produce a record of the seismic waves on a mov-  
ing sensitized band 15. The circuit elements de-  
scribed constitute the main signal channels.

Each detector has associated therewith a con-  
trol amplifier and rectifier, 16, which diverts de-  
tected signal energy at 24, amplifies and rectifies  
it and applies it to the controlling element 12 as  
shown; this amplifier and rectifier and its con-  
nections constituting a control channel.

By reason of the spacing of detectors 10, the  
control energy for any amplifier (except the first)  
comes from a detector nearer to the source than  
the detector associated with that amplifier. By  
suitably selecting detector spacings and circuit

constants the controlling action is caused to take place practically simultaneously with the receipt of main signal energy at the controlled part of the amplifier.

As for the first amplifier, it can be left uncontrolled, or an electrical delay means of conventional type shown at 18 can be interposed in the amplifier input, as shown.

If the detectors are spaced very close together, it is sometimes desirable to take the control energy not from the next preceding detector, but from a detector two or more steps down the line. In this event it is convenient to provide the first two or three amplifiers with delay means, of progressively less delay time constant, as is described in connection with Fig. 2.

Instead of single detectors, detector groups, connected to act as one, can be employed, as shown at 20 in Fig. 2. This expedient is sometimes adopted to compensate for local irregularities in the earth in which the detectors are buried.

In Fig. 2 a single control amplifier and rectifier 16 is employed to control all elements 12. The first two, or more, amplifiers have associated therewith delay devices, of progressively less delay time constant, to assure that the control energy sufficiently anticipates the receipt of signal energy at the amplifiers. The next few amplifiers need have no delay devices, and the last one or two can even have delay devices in the control channel, if they are very remote from the shot, though this is usually unnecessary.

The first detector (or detector group) can be buried deeper than the others if it is desired to "anticipate" for waves coming up very steeply from very deep strata.

The detectors can be of any of the usual types, giving responses according to earth displacement, velocity, acceleration, etc.

Fig. 3 shows the circuits of one of the amplifier-control-detector units of Fig. 1. Detector 10 is connected to signal amplifier 11 through leads 23. Part of the signal energy is diverted at 24 and applied to the control amplifier and rectifier, which makes use of an amplifier-rectifier duodiode-triode 25, containing a hot cathode 26, a grid 27 and three plates 28, 29 and 30. An amplitude adjuster 31 regulates the gain of the control amplifier. The amplifier diverted signal appears across the secondary of a transformer 33 and is returned to plates 28 and 29. A rectified current, taken off at a center tap 34 of the transformer, is filtered in a network 35 to smooth out ripples. While the amplifier and rectifier are shown combined in a single tube they can of course be separate units if desired.

The rectified control energy is applied through leads 36, to the control of a succeeding amplifier (Cf. Fig. 1) whereas the signal amplifier shown for detector 10 receives its control energy from the control amplifier connected to a preceding detector (not shown). Signal amplifier 11 contains one or more pre-amplifier tubes 37 and amplifier tube 38, and a variable gain tube 39, adjustment of whose grid bias determines the amplification factor or gain of the amplifier as a whole. A variable condenser 40 and resistor 41 are provided in the control channel as shown; also a battery 42 which serves to supply optimum bias to the grid of the control tube so that in the absence of an applied controlling voltage the tube has a relatively high amplification.

On increase of control (strong detected signal) the control tube grid is made more negative,

thereby reducing the transconductance and reducing the gain of the tube.

The filter 35 introduces a time delay or lag which makes the output control voltages change in a smooth or gradual manner, whereby abrupt gain changes in the main signal amplifier are avoided and the character (shape) of the wave trains being amplified therein are not greatly altered. This time constant is long compared to the time duration of any of the individual waves received by the system, and results in a delay in the control action.

Variable condenser 40 and resistor 41 serve as an additional adjustment of the time constant or lag of the control system. That is, the setting of the condenser determines the interval of time between a sudden increase in control energy in leads 36, and initiation of the controlling action of tube 39. Elements 40 and 41 are not strictly essential but they increase the flexibility of the system by enabling individual lag adjustment in the amplifiers. In omitting elements 40 and 41, the upper lead 36 in Fig. 3 is connected directly to the grid of tube 39.

Considering the invention quantitatively: The filter 35 and elements 40 and 41 are adjusted so that the application of the control is sufficiently smooth and gradual; sharp gain changes being undesirable even when the seismic wave energy changes abruptly. These adjustments are made more or less empirically, to secure a record of minimum distortion and of greatest reading ease. The controlling action may be said to have a time lag, in that upon an abrupt change in signal energy appearing at points 24, gain is not reduced, or increased, a tube 39, until say 0.05 to 0.4 seconds later.

The velocity of seismic waves in the superficial portions of the earth is not ordinarily greater than 2000 yards a second.

The horizontal spacing of detectors 10 is usually about 10 to 200 yards. Since the seismic waves of interest do not come in horizontally, but at an inclination greater or less depending on the depth of the subterranean interfaces from which they come, the effective detector spacing is less than the horizontal spacing. For a wave coming in at 30 degrees to horizontal the effective spacing, by trigonometry, would be 0.87 times these spacings.

Assuming a control time lag of 0.1 second, a detector spacing of 173 yards (effective spacing 100 yards for a 30-degree wave), then in the system of Fig. 1 the control element 12 of each amplifier would be supplied with energy from the second preceding detector (200 yards) to compensate exactly for the lag.

In the system of Fig. 2, the first and second detectors would be provided with delay means 18, of delay time constant 0.1 second, and 0.05 second, respectively. Theoretically the fourth, fifth, sixth, etc., amplifiers would be provided with delay means at the control input (leads 36) but actually this is unnecessary, as it does no harm to have the controlling action come a short time before appearance of the wave to be controlled. What is to be avoided, is the exertion of controlling action only after receipt of sudden strong burst of seismic wave energy.

The signal amplifiers of Figs. 1 and 2 can be of a type adapted to be controlled as regards frequency, i. e. tuned, rather than adjusted as to gain, by the energy derived from a preceding detector. Referring to Fig. 4, the signal amplifier 120 is of a type which is tunable according to ap-

plied control energy, similar to that described in Patent 2,053,841 to Harold R. Prescott. The amplifier includes electronic low pass and high pass filters 45 and 46, amplifier tubes 47 and 48, a lower threshold control 49, and an upper threshold control 50; and a diode control tube 51 delivering to leads 52 is provided, all as described in the Prescott patent. The construction of amplifier 120 is such that a control voltage applied across the plates of tube 51 varies the tuning of the amplifier in accordance with the magnitude of the control voltage. The upper and lower frequency limits are adjustable by means 49 and 50, in a manner described in the Prescott patent.

The arrangement of the detectors and control amplifiers is as described in connection with Figs. 1 and 2. In operation, upon decrease in signal strength at the preceding detector, the amplifier 120 is tuned for lower frequencies, and vice versa. The control operates at the right time, due to the spacing of the detectors.

It is sometimes advantageous to tune the amplifiers in accordance with the changing frequency of seismic waves as detected; especially in situations where a desired frequency predominates over all undesired frequencies. Fig. 5 shows a modification of the invention for accomplishing this end. Referring to Fig. 5, voltage diverted from a preceding detector, through leads 53, is supplied to an amplifier 160, which is of a known type having automatic control adjusted for a high degree of control so that the output signal is of substantially constant amplitude whatever the amplitude of the input. A patent to Smith No. 1,904,552 describes an amplifier which is suitable for the present purposes; the automatic volume control of the patent amplifier being adjusted to "full control," so as to secure a high degree of leveling as described.

Amplifier 160 applies an amplified signal of practically constant amplitude to the grid 54 of a thyratron tube 55, which also has a cathode 56 and plate 57. The connection to the grid is made through a bias battery 58 and the connection to the cathode is made through a lead 59, as shown. The plate is connected to the cathode through a condenser 60. An adjustable resistor 61 and a B-battery 62 are connected in circuit as shown, and the tube output is taken off through a resistor 63 through a variable tap for resistor 61, as shown. A condenser 64 is connected across the output leads which take the place of leads 52 (Cf. Fig. 4) for an amplifier 120 of the type shown in Fig. 4.

Tube 55 serves as a pulse integrator. In operation, the preceding detector picks up seismic waves and delivers a portion of their energy to amplifier 160 as an oscillating signal of varying amplitude and of varying frequency. The amplified signal is of varying frequency but of substantially constant amplitude. Bias battery 58 keeps the thyratron grid sufficiently negative so that current will flow only on the peaks of the output wave of amplifier 160. On each peak, current flows, discharging condenser 60 through the plate circuit of the thyratron. Between peaks, this condenser becomes recharged from battery 62 through resistor 61, which is so adjusted that the condenser becomes practically completely recharged between peaks, even with the highest frequencies encountered. The average current through the resistor 61 depends on the number of times per second that condenser 60 is discharged; i. e. on the signal frequency. Thus the voltage across resistor 61 is proportional to the

signal frequency delivered by amplifier 160. Part of the voltage is picked off as shown and applied to the tuning controller of the signal amplifier 120. The condenser 64 and resistor 63 serve as a filter to smooth out this control voltage.

What I claim is:

1. In a seismograph prospecting apparatus including a series of detector means spaced in the earth at different distances from a source of seismic waves, amplifiers coupled to each of the detector means, the amplifiers having elements which control a characteristic of the amplifier in accordance with the magnitude of energy supplied to the control element, and exhibitor means responsive to the amplified energy transmitted from each detector means: the improvement comprising a control energy channel which diverts a portion of the signal energy from one of said detector means, which is located at a position nearer to the source than other detector means, means for amplifying and rectifying the diverted energy and means for applying the amplified rectified energy to the control element of at least one amplifier which is connected to detector means spaced farther away from the source; said control channel being so constituted as to delay the change in control energy at said element, upon change in signal energy output of said first detector means, for a period of time not greater than the interval between receipt of a given seismic wave at said near detector and receipt thereof at said amplifier connected to said farther detector.

2. The apparatus of claim 1 wherein the control elements are gain-controlling elements.

3. The apparatus of claim 1 wherein the control elements are frequency-controlling elements.

4. The apparatus of claim 1 wherein the control elements are frequency-controlling elements, and the said control energy channel is of such character as to supply thereto control energy which varies in magnitude according to the predominating frequency of the seismic waves detected at said detector nearer the shot.

5. The apparatus of claim 1 wherein said amplifier connected to detector means farther from the source includes electrical signal delay means at its input.

6. In an apparatus for seismograph prospecting, a plurality of signal channels each including detector means, an exhibitor, and an amplifier having an element which is adapted to vary a characteristic of the amplifier in accordance with the magnitude of electrical energy applied to the element, said detector means being spaced at increasing distances from a source of seismic waves, the improvement comprising at least one control channel including means for diverting a portion of the signal energy from one of said detector means which is nearer the shot than other detector means and means for applying the diverted energy to the control element of an amplifier which is connected to a detector means farther from the shot than said near detector means, said control channel being so constituted that an abrupt change in signal energy at the input thereof is followed, after a time delay, by a change in energy as applied to said control element, and means in at least one of said signal channels for introducing time delay therein such that upon a change in seismic wave energy as detected, the control energy at said control element changes not later than appearance of signal energy thereat.

7. In apparatus for seismograph prospecting

having detector means variously spaced with respect to a source of seismic disturbance, amplifiers coupled to such detector means, with elements which control a characteristic of the amplifier in accordance with the magnitude of energy supplied to the control element, and means for exhibiting energy impulses transmitted by said amplifiers, each detector means, amplifier, and exhibiting means therefor constituting a signal channel, the improvement comprising a control channel including means to divert a portion of the signal energy from a proximate detector means' signal channel to means for amplifying

and rectifying the diverted energy, and means for applying the amplified rectified energy to the control element of at least one amplifier which is in the signal channel of detector means farther from the source of seismic disturbance thereby to delay the change in control energy at said element for a period of time not greater than the interval between receipt of a given seismic wave at said proximate detector means and receipt thereof at said amplifier in the signal channel of the farther detector means.

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