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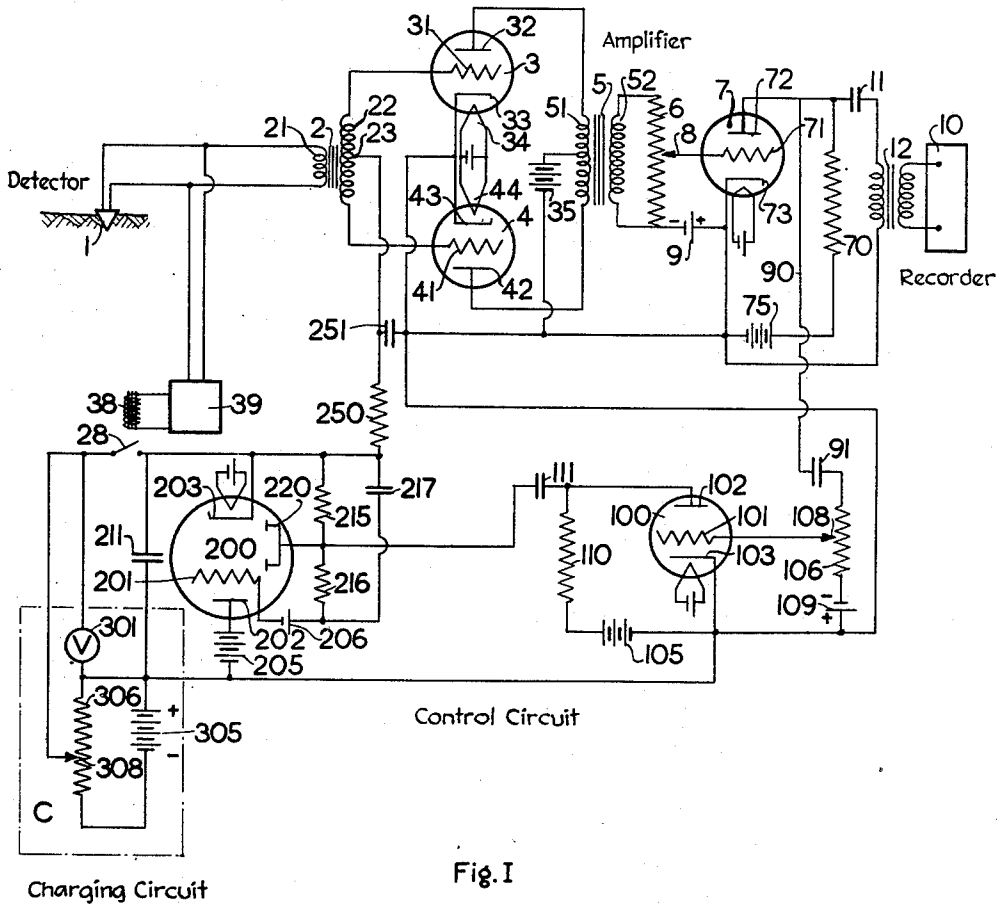
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2,352,825

SEISMOGRAPH AMPLIFICATION GAIN CONTROL

Filed Aug. 18, 1942

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

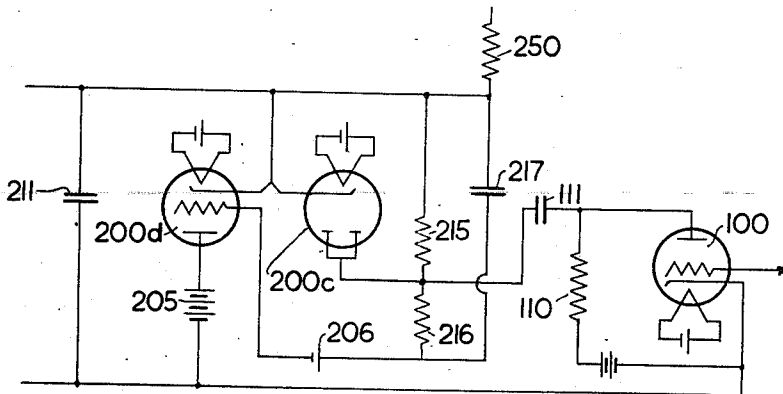


Fig. II

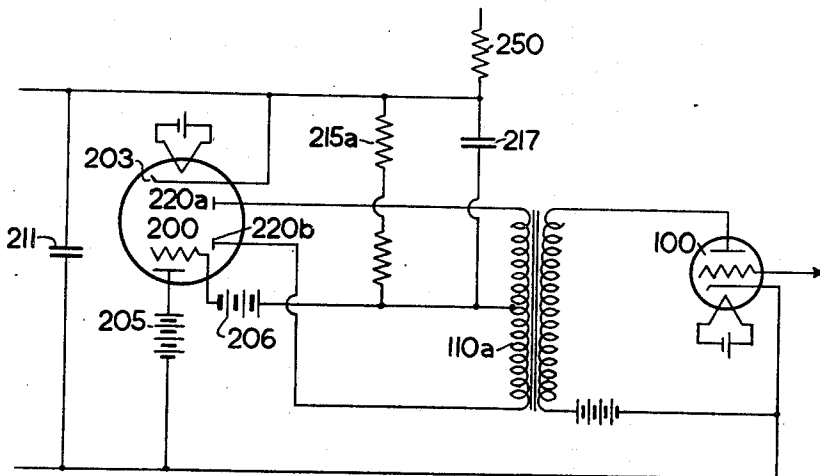


Fig. III

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UNITED STATES PATENT OFFICE

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SEISMOGRAPH AMPLIFICATION GAIN
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This invention pertains to the art of seismic exploration, and relates more specifically to methods and circuit means for controlling without distortion the amplitude of the oscillations recorded on a seismogram.

Seismic exploration normally consists in translating the mechanical energy of seismic waves artificially generated in the ground into electric impulses by means of a plurality of detectors, amplifying said impulses by means of electronic amplifiers, and photographically recording said impulses by means of a recorder.

The magnitude of the impulses generated by the detectors in response to seismic waves travelling along substantially direct or minimum-time paths, or to waves reflected from shallow strata, is very much greater than that of the impulses generated in response to waves reflected from deep strata. It becomes therefore necessary to compensate for the disproportion in the magnitude of said impulses by controlling the gain of the amplifiers used between the detectors and the recorder in such a manner as to produce recorded oscillations of substantially equal amplitude throughout the seismogram. Seismograms obtained without such control cannot be easily deciphered and interpreted.

The desired amplification gain control is usually achieved by varying the grid bias of the amplifier tube or tubes either as a function of time (in so-called semi-automatic control systems), or as a function of the intensity of the electric impulses generated by the detectors (in so-called fully automatic control systems).

None of these methods is, however, entirely free of drawbacks. In particular, the effectiveness of semi-automatic control systems is sometimes impaired by the fact that the strongest impulses do not necessarily arrive first, when the amplification gain of the system has its lowest value, or by the fact that the average amplitude of the impulses or oscillations decreases as a time function different from the time function according to which the amplification gain has been pre-set to increase.

In fully automatic control methods, when a strong electric impulse arrives from the detector to the amplifier and is applied to the grid of the latter for amplitude control purposes, this strong impulse temporarily reduces the gain of the amplifier to such low value that an equally strong impulse arriving, for example, one-tenth of a second later, will be recorded as a weaker one. In a similar way, a single impulse or reflection whose second or third peak is actually stronger than the

first, will often be recorded with the first peak having the greatest amplitude. The character of the recorded oscillations is thus disfigured or changed in a manner which is not uniform but is a function of the intensity of the first impulse received during a given time interval.

It is, therefore, an object of this invention to provide a seismograph amplification control system in which the gain of the amplifier cannot decrease with time, whereby distortion is eliminated or minimized.

It is also an object of this invention to provide a seismograph amplification control system wherein the gain of the amplifier constantly increases with time, while the rate of increase of said gain is controlled as a function of the intensity of the impulses or signals arriving from the detector.

It is also an object of this invention to provide a seismograph amplification control system wherein the amplifier gain remains substantially constant when the amplitude of the oscillations being recorded is above a predetermined value or level, but begins to increase as soon as said amplitude falls below said predetermined value, the rate of said gain increase being a function of said amplitude decrease.

It is also an object of this invention to provide a seismograph amplification control system wherein a time-responsive grid-bias variation, resulting in a time-responsive amplification gain increase, is imposed on the amplifier by time-responsive means comprising, for example, a condenser which is discharged through a variable resistance, such as an electronic tube, while the rate of said condenser discharge, and therefore the rates of the amplifier grid-bias variation and of the amplification gain increase, are controlled by varying the value of said resistance by means responsive to the intensity of the impulses being recorded, for example, by applying said impulses to bias the grid of the electronic tube through which said condenser is discharged, and thereby varying the resistance of said tube to the condenser discharge current.

These and other objects of the present invention will be understood from the following description taken with reference to the attached drawings, wherein:

Fig. 1 is a simplified circuit diagram of the system of the present invention; and

Figs. 2 and 3 are modifications of a portion of the control circuit shown in Fig. 1.

Referring to Fig. 1, the present invention is shown for simplicity in application to a single seismograph channel, that is, to a circuit compris-

ing a detector, an amplifier and a galvanometer or recorder string, it being understood that the invention is likewise readily applicable to multi-channel systems, and to systems comprising any desired number of detectors of amplification stages per channel, in a manner well understood in seismic work.

A detector 1, in contact with the ground, translates the seismic waves, generated at a shot point not shown in the drawings, into electric impulses, and transmits them to a transformer 2, having a primary 21 and a secondary 22, which is connected to the grids 31 and 41 of amplifying tubes 3 and 4, respectively, said tubes forming a push-pull amplification stage. The amplification gain of this push-pull stage depends on the negative bias applied to the grids 31 and 41 through the center tap 23 of the secondary 22. This negative grid bias is supplied and controlled by the control circuit shown in the lower part of the drawings, in a manner to be described hereinbelow.

The tubes 3 and 4 may be of any desired type, such, for example, as triode, tetrode or pentode; for simplicity, they are shown as comprising grids 31 and 41, plates 32 and 42 cathodes 33 and 43, and heater elements 34 and 44. If multigrid tubes, such, for example, as those commercially known as 6L7, are used at 3 and 4, a fixed grid bias may be applied to grids 31 and 41, while the negative gain control bias may be applied to other grids of said multigrid tubes, the principle of operation being the same in both cases, as will be evident to those familiar with electronics.

The plates 32 and 42 are connected to the opposite ends of a primary 51 of a transformer 5, which is thus supplied with the output current of said tubes.

Since the tubes 3 and 4 are connected in push-pull arrangement, a varying bias applied to grids 31 and 41 of said tubes does not result in voltage variations across the transformer 5 connected to the plates of said tubes.

The secondary 52 of transformer 5 is in circuit with a resistance 6, and a source of potential 9 is connected between said circuit and the cathode 73 of tube 7.

The grid 71 of tube 7 is connected by a voltage divider 8 to the resistance 6, whereby a chosen fraction of the output of transformer 5 is applied to said grid. This arrangement forms in effect a volume control permitting the full sensitivity of the amplifier to be adjusted to a desired level with respect to ground unrest.

A voltage source 35 is connected to a center tap of the primary 51 to supply the desired positive potential to the plates of the tubes 3 and 4, and a voltage source 75, in series with a high resistance 70 serves the same purpose with regard to tube 7.

An impulse generated by the detector 1, after passing through transformer 2, push-pull amplifiers 3 and 4, transformer 5, and amplifier 7, is transmitted further by means of a condenser 11 and transformer 12 to the recording galvanometer 10, where it is recorded in a manner well known in the art.

This same impulse, after amplification in tubes 3-4 and 7, is likewise transmitted, through lead 90 and condenser 91, to the grid 101 of the amplifier 100, forming a part of the amplification gain control circuit.

A resistance 100, potential source 109 and voltage divider 108 are used to form, with regard to amplifier 100, a volume control arrangement

similar to that described above with regard to tube 7, whereby the magnitude of the impulse applied to the grid 101, and thus the particular amplitude on the record at which the gain is to be held constant, may be adjusted to a desired value.

A voltage source 105 is used to supply the necessary positive potential to the plate 102.

The amplifier 100 is coupled, through the arrangement comprising resistance 110 and condenser 111, to the plate 220 of the diode section of a multi-electrode tube 200, such as a diode-triode, diode-pentode, duplex-diode triode or pentode, etc., for example, any of the tubes commercially designated as types RCA-IF6, 2A6, 2B7, 6B7, 6B8, 6R7, 6SQ7, 55, 75, 85, etc.

When the A. C. impulse coming from the plate 102 of tube 100 is applied, through the resistance-capacity coupling 110-111 to the diode plate 220, the direct current produced by the rectification of said impulse in the diode section of tube 200 flows through the resistance 215 and produces a voltage which is applied, through a low-pass filter comprising a resistance 216 and a capacity 217, to the grid 201 of the triode section of the tube 200, making this grid the more negative with respect to the cathode 203, the stronger the impulse applied from the tube 100 to the diode plate 220.

A voltage source 205 is used to apply the necessary positive potential to the plate 202 of the triode.

A voltage source 206 is used to prevent the grid 201 from assuming at any time a bias value more positive than a predetermined negative value.

A control condenser 211 is connected across the cathode 203 and plate 202 of tube 200.

This control condenser 211 may be charged to any desired predetermined potential by a charging circuit designated at C and comprising a source of voltage 305, a resistance 306 and voltage divider 308, and a voltmeter 301 adapted to indicate the voltage to which the control condenser 211 is charged. A switch 28 connects the charging circuit to the circuit of the condenser 211 and tube 200, said switch being operable either manually or by means of a relay 38, which is energized by the impulses originating in detector 1 through a suitable kick-off amplifier 39.

The control condenser 211 is connected to the grids of the push-pull amplifiers 3 and 4 through the tap 23 and a suitable delay filter circuit comprising a resistance 250 and a condenser 251.

Instead of coupling tubes 100 and 200 by means of the resistance 110 and condenser 111, these tubes may obviously be coupled in other suitable ways, for example, as shown in Fig. 3, by means of a transformer 110a, whose secondary is connected at each end to the diode plates 220a and 220b of the tube 200, while the load resistor 215a, across which the rectified voltage is caused to appear, is connected between the cathode 203 of the tube 200 and a center tap on the secondary of said transformer 110a.

It is also obvious that instead of using a multi-electrode tube 200, which combines the rectifier and the variable-resistance functions described above, independent diode tube 200c and triode tube 200d may be used to separate these functions, as shown in Fig. 2, all the other connections being similar to those of Fig. 1 or Fig. 3.

The sequence of operations in the present system is as follows:

Preliminary to firing the shot, the switch 28 is

closed, and the full voltage to which the control condenser 211 is charged by the charging circuit C is applied as a strong negative bias between the grids and the cathodes of push-pull amplifiers 3 and 4 through the filter 250—251 and the mid-tap 23 of the secondary 22.

When the first strong seismic waves arrive at detector 1, and are translated into strong electrical impulses, these impulses are amplified with a relatively small amplification gain by tubes 3 and 4 because of the strong negative bias applied to the grids of said tubes at this time.

The first impulse from detector 1 is also transmitted to the kick-off relay 38 through the amplifier 39, and operates to open the switch 28. The charging circuit is thereby disconnected from the control condenser 211, which begins to discharge through the resistance constituted by the triode section of the tube 200. The negative bias applied to the grids of tubes 3 and 4 begins accordingly to decrease, and the gain of the system to increase at a rate dependent on the rate of said condenser discharge, which is controlled in the following manner:

The impulses originating in the detector 1, after being successively amplified by tubes 3—4, 7 and 100 to a level determined by volume controls 8 and 108, are rectified in the diode section of the tube 200, and the voltage derived from passing this rectified current through resistance 215 is applied, through filter 217—216 as a negative bias to the grid 261 of the triode section of tube 200, thus determining the rate at which the triode section of said tube permits the control condenser 211 to discharge. In other words, so long as the impulses originating in detector 1 and amplified in tubes 3—4, 7 and 100 are strong, resulting in a strong rectified current and a strong negative bias on the grid of the triode section of tube 200, said tube offers a high resistance to the discharge of the control condenser 211. The rate at which the potential across said condenser decreases at such time is therefore extremely slow, or may be made substantially equal to zero by proper adjustment of the volume controls 8 and 108. The rate at which the negative bias applied by tube 200 to tubes 3—4 through the filter 250—251 changes is therefore also extremely slow, and the amplification gain of the system is kept at a low value during the time when strong impulses are generated by the detector 1.

When, however, these impulses become weak, the rectified current originating therefrom in the control circuit becomes smaller, the negative bias on the triode section of tube 200 becomes smaller, and said tube permits a faster rate of discharge of the control condenser 211 therethrough, which results in a faster rate of decrease of the negative bias applied to the push-pull amplifiers 3—4, and in a faster rate of increase of the amplification gain of the system.

By varying the voltage of the potential source 206, or the capacitance of condenser 211, or by effecting other desired adjustments, it is possible to control the maximum rate of change of the gain control bias voltage and thus to choose the optimum maximum rate of increase of gain to suit the area under exploration.

It will be seen, therefore, that the method of the present invention consists in increasing the

gain of a seismic amplification system throughout a period of time, as determined by a gradual discharge of a condenser, while further modifying or controlling the rate of change of said amplification gain as a function of the intensity of the electrical impulses being recorded. In this manner, the amplification gain of the system cannot decrease with time, the recorded oscillations are not distorted, and the amplitude of said oscillations on the record is effectively maintained at a desired level.

It will be obvious to those familiar with seismic amplification circuits that the present system can be constructed with a separate control circuit for each channel, or with a common control circuit for all channels, and that in either case a single charging circuit is sufficient to charge the control condenser or condensers, said condensers being disconnected from the charging circuit and from each other by the kick-off relay and switch 38—28.

It is also obvious that the energization of the switch 38 is not necessarily effected by the detector 1, but may be derived from other sources, for example, from the electrical firing circuit connected to the shot-point charge.

I claim as my invention:

1. In a seismograph system comprising a seismic detector adapted to generate electric impulses and a recorder adapted to record said impulses, amplifier means comprising two tubes connected in push-pull circuit between said detector and said recorder, a control circuit comprising rectifier means adapted to rectify to direct current the impulses amplified by said amplifier means, a grid controlled tube, a condenser, a source of potential, switch means for selectively charging said condenser from said source and discharging it through said grid-controlled tube, circuit means connecting said tube with said rectifier means for varying the resistance of said tube by applying to the grid thereof a biasing potential derived from the direct current output of said rectifier means, whereby the rate of the condenser discharge is controlled as a function of the magnitude of the impulses rectified by said rectifier means, and means comprising a filter symmetrically connecting said control circuit to the grids of said push-pull amplifier means for applying thereto a control potential derived from said impulse-controlled condenser discharge, whereby the amplification gain of said push-pull amplifier means is modified by the variations of said control potential without distortion of the output voltage of said amplifier means by said control potential.

2. In a method of seismic exploration, the steps of generating electric impulses, amplifying in parallel each of said impulses throughout symmetrical portions of its cycle, combining the symmetrically amplified impulses, rectifying said impulses, causing a potential variation between an initial and a final value throughout a period of time, controlling the rate of change of said potential variation as a function of said rectified impulses, and controlling the parallel amplification of said impulses by symmetrically applying thereto said controlled potential variation.

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