

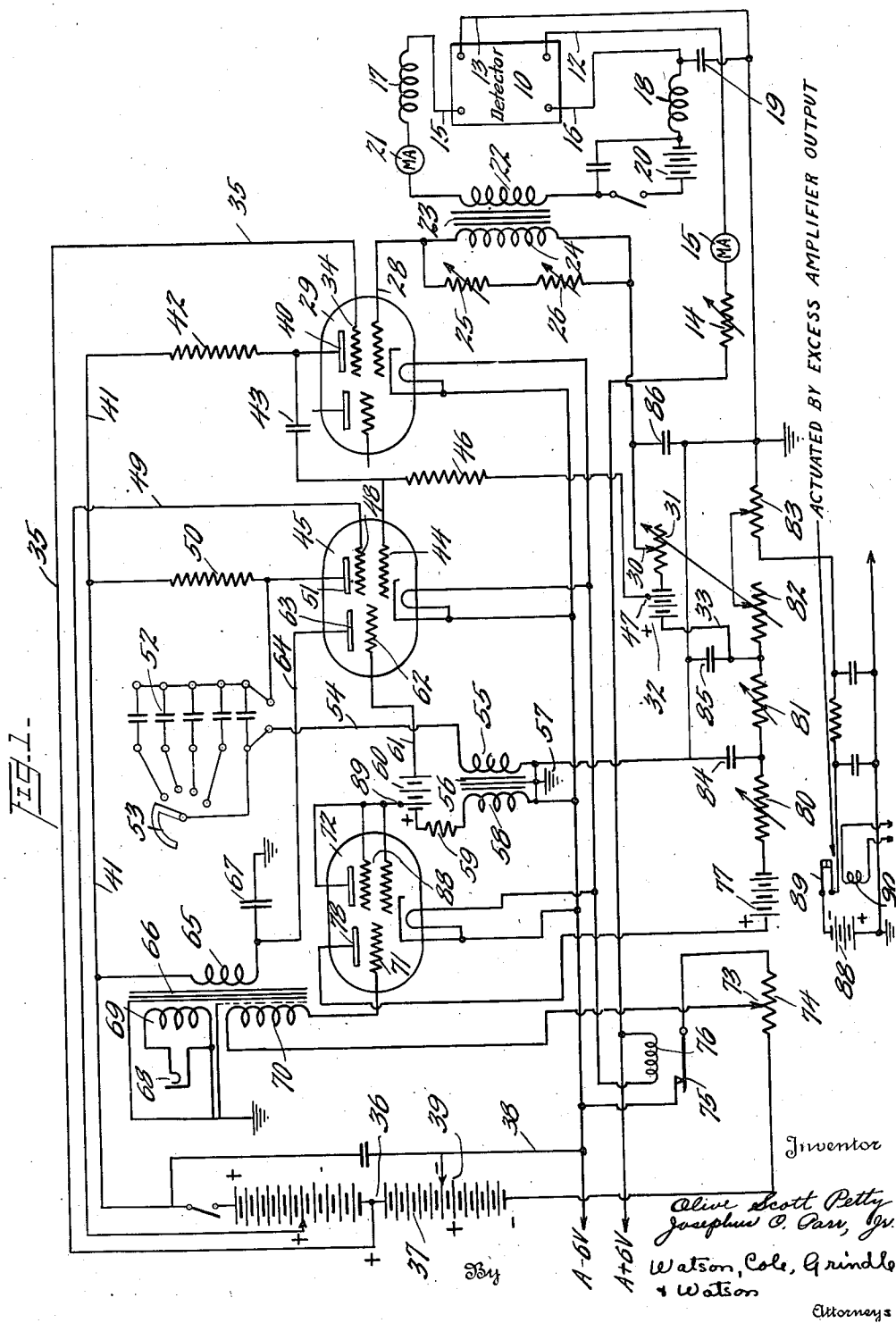
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AUTOMATIC VOLUME CONTROL FOR RECORDER AMPLIFIERS

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AUTOMATIC VOLUME CONTROL FOR
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This invention relates to methods of and apparatus for amplifying audio frequency signals as converted from seismic waves by suitable detecting means and includes the automatic controlling of the output volume of the amplifier, before delivery to a suitable recorder in order to prevent any excessive amplitude swings throughout any period of the recording of a shock wave train.

In previous amplifiers used in seismic surveying as the link between the seismograph or detector and the recorder which prepares a trace of the seismic wave, efforts have been made to automatically control the general volume level of the output by returning a portion of any excess output into the circuit to reduce the gain of the amplifier. One such arrangement is shown and described in copending application Serial No. 290,928, filed August 18, 1939. In that application a portion of the output, when in excess of a predetermined maximum, serves to actuate an automatic volume control tube, the plate current of which charges a condenser whose discharge is fed in series with the bias on certain of the tubes to reduce their gain and hence the over-all gain of the amplifier. Such a device is very satisfactory in operation, but under certain conditions there is recorded on the output trace an undesirably large swing at the time of charging this condenser and for the initial discharge period thereof. This restricts the permissible over-all gain of the amplifier in order that these swings may be kept within reason. Hence the sensitivity of the whole system is somewhat reduced and, in addition, the resultant trace is not as usable and as desirable in certain portions thereof because of the relatively slow recovery of the amplifier from excess applied potentials resulting from "direct waves" being received with much greater amplitude at the detector than the more desirable and useful "reflected waves" which appear somewhat later. The early portions of the reflected waves offer important information which is sometimes masked out by the end of the partially uncontrolled trace resulting from the direct waves.

In accordance with the present invention improvements are made in the volume control system just described and in addition there is superposed thereon a further control which prevents the grid of the last tube from ever becoming within a predetermined voltage of positive at any time in spite of the size or duration of any excess waves, thus holding the level of the output al-

ways below a predetermined maximum and preventing blocking of the said tube.

It is therefore an object of the present invention to provide a novel and improved automatic volume control system for seismic wave amplifiers.

More particularly it is an object of the invention to provide a multi-stage amplifier in which automatic volume control is applied to the early stages and in which the last stage is prevented from being over-loaded by automatic non-blocking control which prevents the grid of this stage from approaching positive more than a predetermined amount.

An important feature of the invention comprises the combination of automatic gain control in the early stages of a cascade amplifier plus positive elimination of excess amplitude from the last stage, whereby a more desirable trace is produced.

Another important feature of the invention comprises the use of a rectifier tube, the anode of which is normally maintained at a low negative potential and adapted to be driven positive by excess signal swings causing a current flow in the rectifier which creates a voltage in opposition to the signal voltage about to be applied to the grid of the last stage of the amplifier, thereby preventing the amplifier grid from becoming positive and the tube from blocking.

Other and further objects and features of the invention will be more apparent to those skilled in the art upon a consideration of the accompanying drawing and following specification wherein is disclosed a single exemplary embodiment, with the understanding that such changes may be made therein as fall within the scope of the appended claims without departing from the spirit thereof.

In said drawing:

Figure 1 is a wiring diagram of an amplifier constructed in accordance with the present invention shown connected to the output of a seismic wave detector.

The seismic waves generated in the earth by an exploding charge travel in all directions and some arrive at the receiving or detecting stations, at remote points, by short paths of travel through strata near the surface of the earth. These are known as "direct waves" and because of their relatively short path and major horizontal component of vibration, usually arrive first at the detector. A second form of waves referred to as "reflected," travel down to horizons at various distances below the surface of the earth and at

various inclinations thereto and are reflected back to the receiver. Such waves from the upper horizons usually travel in longer paths than the direct waves, while those from the deeper horizons always travel in longer paths and take more time to reach the detector than do the direct waves. The reflected waves consisting largely of vertical components have an intensity probably one-tenth or less than that of the direct waves when travelling from upper horizons, while those from progressively deeper horizons are more and more attenuated.

It is customary to record on a single chart the record traces from a plurality of detectors and it is highly desirable to keep the physical size of the chart within reason. The waves are converted from seismic to electrical at the detector, but there still remains the tremendous discrepancy in peak amplitudes between the direct and the reflected waves (as much as 600 to 1 often occurs) as well as the problem of attenuation of the later arriving reflected waves. Most detectors seek to convert the seismic waves to electromotive-forces, the voltages of which are indicative of the amplitudes of the corresponding seismic waves. The outputs from such detectors are usually at such low levels that they are not adequate throughout the whole wave train to operate the recorder which includes a galvanometer having multiple moving elements each responsive to the voltages of the waves from one detector. Resort is therefore had to electric amplification to raise the level of the waves so that the weakest produce a usable trace on the chart. If this is done with the conventional amplifier having uniform gain throughout, the traces of the direct waves become so large that they cannot be kept within the physical confines of the chart and furthermore those on adjoining traces tangle on the record. Likewise there is difficulty of entanglement of the moving systems of a multiple galvanometer thereby vitiating the record and probably damaging the instrument. Even with excellent damping applied to the moving systems of the galvanometer, the tremendous swings given to them by the oversized direct waves make it difficult for them to quickly subside and give an accurate recording of the earlier portions of the reflected waves, and it is highly important to know the instant the first reflected wave is received. It is also important to know the instant of arrival of the first direct wave.

One common way to limit the maximum level that occurs is to have the gain of the amplifier reduced so much that at no time is any cycle too big. In practice, the third or fourth cycle is often the largest while the first cycle amplitude is less than $\frac{1}{10}$ (or even in some cases less than $\frac{1}{100}$) of that of the third or fourth cycle. Limiting the size of the third or fourth cycle to the predetermined level by merely reducing the gain of the amplifier often causes the first cycle trace to be so small that it cannot be seen much less have a sharp break indicating its beginning. This break is often very valuable to have for computation purposes, and to get it well on the chart saves a separate shot, and the accompanying time and cost, as well as the disadvantage of error from being made at a slightly later time when conditions may have changed. It is very desirable to get all of the information at one time and with one shot from computation standpoint as well as cost, time, etc.

To overcome the difficulties outlined above, the present invention provides a method of and ap-

paratus for amplifying the converted electric waves from the detector and supplying them to the galvanometer of the recorder in such a manner as to provide on the chart a trace of the seismic waves which is more usable throughout its whole length than has heretofore been obtained and in which the amplitude of the swings of the direct waves is materially reduced, the amplitude of the early portion of the reflected waves is moderately reduced, and the latter portion of the reflected wave trace is increased in size to compensate for the normal attenuation of such waves. Furthermore, any "wild" swings of the galvanometer are held in much greater restraint than heretofore and the trace resumes its normal characteristics much more rapidly.

To obtain these superior results, resort is had to the apparatus schematically shown in the drawing where 10 represents any conventional form of seismic wave detector, seismograph, or the like, having the property of converting ground waves to electric waves of corresponding form and amplitude. Such a detector, which may include a single stage pre-amplifier, is supplied with current for the filament or heater of the amplifier tube through conductors 12 and 13 leading from the "A" battery depicted at the left-hand side of the figure. An interposed variable resistor 14 and milliammeter 15 permit control of the filament current. The output from the detector is brought by means of conductors 15 and 16 to the apparatus of the present invention, there being interposed radio frequency chokes 17 and 18 in these two conductors to eliminate any stray pick-ups from various sources, a condenser 19 between the choke 18 and ground providing a filter to improve this operation.

The battery 20 provides plate current for the pre-amplifier, the amount of which is indicated by the milliammeter 21, this current as well as the A. C. of the signal passing through the primary 22 of the input transformer 23, the secondary 24 of which is shunted by a pair of variable resistors 25 and 26, one for coarse and one for fine adjustment. These serve to shunt away a portion of the signal to determine the size of the trace on the record and are set for each trace in accordance with the experience of the operator or as a result of previous "shots."

The output from the secondary 24 is supplied to the grid 28 of a thermionic tube 29 while the opposite end of the secondary is connected to a slider 30 on a resistor 31 leading from the negative side of a bias battery 32 which is connected back to ground by means of conductor 33 and variable resistors which will be later described. The tube shown at 29 has two complete sets of elements except for the common heated cathode, but the left-hand set is in this particular case not used. The multi-element tube is used in this location so that it will be identical with the others in the apparatus and only one type of spare will have to be provided. The screen grid 34 of tube 29 receives its positive potential through wire 35 from tap 36 on the large "B" battery 37 shown at the left side of the drawing. The ground return from this "B" battery is the conductor 38 leading to the A-wire from the point 39 intermediate the ends of the battery.

The plate 40 of the tube 29 receives the potential of the "B" battery 37 through the wire 41. It has interposed therein the plate coupling resistor 42.

From a point between the resistor 42 and the plate 40 is connected the coupling condenser 43, a

conductor from which leads to the control grid 44 of the second stage amplifier comprising the right-hand elements in the tube 45. The coupling resistor 46 connected to this grid receives its negative bias from a tap 47 on the battery 32. The screen grid 48 in this second stage amplifier is supplied with "B" potential through wire 49 from an appropriate tap on the battery, while the plate is tapped into the wire 41 through the interposed coupling resistor 50.

A tetrode tube is used in the first stage of the amplifier and resistance-coupled to the second tetrode stage as just described to obtain a certain amount of band-pass filter action in favor of the most wanted frequencies. Control of the filter action to permit these frequencies to be amplified more than unwanted ones is had by fixing the sizes of the coupling resistors and condenser and the potential on the screen grid.

The third stage amplifier is a triode comprising the left-hand elements in tube 45, and coupling between the second stage and the third stage is a combination of resistance and transformer, for a tap between the plate resistor 50 and the plate 51 of the second stage leads to one side of a bank of condensers 52, any number of which may be selected by switch 53, connected by wire 54 to the primary 55 of transformer 56.

One end of each winding of this transformer as well as the core and case is directly connected to ground as shown at 57 so that at no time is there a direct current voltage between any of the windings, the core, or the case, thereby preventing any electrolytic action which might take place in moist climates due to leakage. This materially lengthens the life of the transformer and makes it more stable.

A secondary winding 58 of this transformer leads through a resistor 59 to the positive end of a bias battery 60, the opposite end of which is connected by wire 61 to control grid 62 of the third stage amplifier.

The combination of plate resistor 50 and variable coupling condenser 52 constitutes a further frequency selective filter to ensure substantial flat topping and sharp cut-off of the desired band of frequencies.

The output from the third stage of the amplifier is fed from the plate 63 by conductor 64 to winding 65 of output transformer 66. The opposite end of the winding 65 is connected to the conductor 41 to supply "B" battery to the plate. A filter in the form of a condenser 67 connected between ground and the plate side of the winding 65 further contributes to frequency selection and at the same time provides excellent damping for the recorder galvanometer connected to the output jack 68 of the secondary 69 of the transformer 66.

A portion of the output is taken off through an additional secondary winding 70, one end of which is connected to the grid 71 of the left-hand or automatic volume control triode elements in tube 72. The opposite end of the winding 70 is connected to the slider 73 movable along the potentiometer 74 energized from the lower portion of the "B" battery through the contacts 75 of a relay, the winding 76 of which is energized when the "A" battery is turned on to the cathode heaters.

By means of the potentiometer 74, the bias on the grid 71 can be adjusted to any desired amount and is normally set below "cut-off," that is, sufficiently negative to prevent the flow of any plate current in the tube. In other words, the

bias is more than that necessary to stop the flow of current from the separate "B" battery 77 to the plate 78 of the A. V. C. tube. Under these conditions the grid will have to become less negative by an amount slightly more than the extent of negative bias below "cut-off" before any current can flow in the plate circuit. Such an adjustment then ensures that positive excursions of the output as taken from the secondary 70 must be greater than the amount the grid is biased below the cut-off point before any current can flow in the plate circuit of the A. V. C. tube. This amount can be adjusted by the slider 73 whereby the threshold operating value of the A. V. C. tube may be set as desired with the assurance that on every positive excursion beyond the predetermined amount, a plate current will flow in this tube and may be used to control the gain of the amplifier by means about to be explained.

It is found convenient in the case of a three-stage amplifier to provide gain control for only the first two tubes or stages, leaving the third stage without such automatic volume control, whereby the filter 50, 52 and the inter-stage transformer 56 operate at substantially the same level all of the time and do not have a changing filter action since there is no radical change of level. Such an arrangement also keeps the change in plate current, due to the automatic volume control voltage, out of the output transformer where any time constants must be extremely long. In the first two stages, however, the time constant (time required for the A. V. C. to take hold or release) can be fairly short and in the second stage can be extremely short.

The "B" battery 77 supplying the plate of the A. V. C. tube is connected to ground through a succession of resistors 80, 81, 82, and 83, all being variable. Around all of these except 80 is shunted the condenser 84 leaving the adjustment of 80 most effective for regulating the quantity of plate current since the condenser by-passes the D. C. surges to ground. At the same time the condenser is charged with a substantially pure direct current voltage, the potential of the lower plate being negative. The condenser discharges through resistor 81 and wire 33 to the positive side of the bias battery 32 which is connected to the control grids of the first and second stage amplifiers as previously described. In so discharging, the condenser 84 increases the bias on the two control grids and reduces the gain of the first two stages in accordance with the amount of over-potential delivered into the output.

Since the charging current for condenser 84 is pulsating, this grid biasing current is not entirely free from ripples and before being fed into the grids is filtered by an additional condenser 85 and a resistor 81 to form a filter for smoothing out the ripples and causing substantially direct current to be applied to the grids. To further reduce the ripple of the control voltage applied to the first stage, since this would be amplified the most by the two succeeding stages, an additional filter comprising the resistor 31 and condenser 86 is interposed in the grid return circuit of the first stage, this resistor 31 preferably being adjustable along with resistor 82 as shown by the arrow. The filter just described also assists in providing a longer time constant and one which is adjustable for the rate at which the A. V. C. takes hold on the first stage.

The several filters just described determine the

rate at which the charge leaks off of condenser 84 to the grids and by appropriate settings of the resistors regulate the time of discharge as well as the changing slope thereof in accordance with certain characteristics desired to be accentuated on the record chart. The variable resistor 82 affects the rate of leakage from the second condenser 85 and of course indirectly from 84 and is therefore effective in selecting the total voltage available for return to the control grids.

The variable resistor 83 is connected as a potentiometer by having the lead 87 thereof connected to the negative pole of a battery 88, the positive pole of which is grounded. Contacts 89 of relay 90 are interposed and normally closed to quiet the galvanometer string prior to the arrival of the "direct waves" by reducing the amplification of the amplifier. This, however, does not reduce the gain sufficiently to prevent the "break" of the first direct impulse. The stronger impulses from the amplifier actuate and open the relay contacts and the charge from battery 88 leaks slowly off of condensers 84, 85, and 86.

Operation of the automatic gain control is particularly effective for seismic recording since the output from the detector comprises the early arriving direct waves of large amplitude and the later arriving reflected waves of much less amplitude which are attenuated over a period of several seconds. The setting of the resistor 74 fixes the bias on the A. V. C. tube such that each of the swings of the "direct wave" voltages causes the A. V. C. tube to function, maintaining the condenser 84 charged until the last of the direct waves ceases, thus holding the gain of the first two stages of the amplifier at a minimum during the excess input to the amplifier.

The amplitude of the reflected waves is normally too small to cause functioning of the A. V. C. tube but the gain of the amplifier does not immediately return to normal since the charge on condenser 84 leaks off slowly over several seconds and hence holds the amplifier grids at an excess bias over a period of time which can be determined by appropriate adjustment of the various resistors. The gain of the amplifier slowly increases as the strength of the reflected waves is reduced since the current is leaking off of the condenser 84 slowly and permitting the grid biases to reduce to normal. This produces a record more nearly uniform in character for it automatically elevates the swings which would normally be attenuated. However, should at any time the reflections become too large, the A. V. C. could function over and over again as many times and as much as required.

It is found that with this automatic volume control a certain time is essential for it to take hold, i. e., the output of the whole amplifier must be too large before the automatic volume control goes into effect, so that at each tendency for the amplitude to become too great there is a slight excess output which is reflected on the chart in an undesirable swing, sometimes requiring too long an interval to return to normal because of momentum in the galvanometer moving system. As an added means of ensuring against this, and at the same time permitting larger useful swings of the chart trace, the second set of elements in tube 72 is made use of as a diode rectifier, the plates and both grids being tied together as shown to operate as one element 88 corresponding to the anode of a two-element rectifier tube. This anode is preferably connected so as to always receive from the battery

60, providing the bias on the third stage amplifier grid, a negative potential of one and one-half volts in respect to its cathode.

In operation, the signal voltage being supplied to the grid 62 of the third stage of the amplifier is also conducted through this one and one-half volt bias to the element 88 of tube 72 in such a manner that whenever the signal at this point goes positive by more than one and one-half volts, a current flows in the rectifier which, passing through resistor 59, causes a potential drop across the same in a direction to oppose the signal voltage therein, which prevents the element 88 from ever becoming positive by more than a fraction of a volt, since the more it attempts to become positive the larger the opposing voltage in 59 becomes. Under these conditions the grid 62 can never be driven positive by excess positive excursions of the signal for there always remains the balance, i. e., three volts, of the bias battery 60 to bias this grid in respect to the positive potential of not more than a fraction of a volt existing at the tap point 89.

By preventing the grid of the final stage from ever becoming positive, there is no opportunity for grid current flow. As is well-known, grid current flow causes a blocked tube which takes a fraction of a second to recover and since the charts prepared by such apparatus as that described extend only over several seconds, it can be seen that no portion thereof even to the extent of that period in which tube blocking might exist can be spared.

To prevent excess amplification of negative signal excursions of large size, the third stage amplifier is operated close to the cut-off point so that large negative swings increase the negative bias below the cut-off point and plate current is stopped. By appropriate adjustment of the various constants, the swings at either side of zero can be maintained substantially the same size.

With the diode tube in operation as just described, it can be seen that there is never an opportunity for the output to increase above a predetermined amount so that all swings of excess amplitude are limited, even those which normally would last but for a moment prior to operation of the other automatic volume control feature. The condenser discharge type of automatic volume control is important in the combination since it reduces the gain of each amplifier and prevents the flat topping of the recorded waves which would result if all control were left entirely to the operation of the diode. The purpose of the diode is only to take hold where the condenser discharge is not quite adequate to hold the swings to the size desired. Furthermore, the condenser discharge feature provides the gradual build-up of the attenuating reflected waves to maintain their record at substantially the same size as the first arriving reflected waves.

The use of the combination of condenser discharge and diode automatic volume control results in an extremely satisfactory and highly usable chart in which no parts are masked by excessive swings and in which the average size of the amplitude swings remains substantially uniform throughout the whole length of the chart.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. In an amplifier for use between a seismic wave detector and a recorder, the combination of a plurality of thermionic tubes, means associating said tubes for cascade seismic frequency amplification, an automatic volume control tube re-

sponsive to the output of one of said tubes, means associating said A. V. C. tube with one of said amplifier tubes to control the gain of the latter, and means to prevent blocking of a subsequent tube only in said cascade by the signals flowing thereto, said means being limited to operation when the signals applied thereto exceed a predetermined threshold value.

2. In an amplifier for use between a seismic wave detector and a recorder, the combination of a plurality of thermionic tubes, means associating said tubes for cascade seismic frequency amplification, an automatic volume control tube, means associating the output of said A. V. C. tube with one of said amplifier tubes to reduce the gain thereof concomitant with increase in output, means associating said A. V. C. tube with the amplifier output to regulate the operation of said A. V. C. tube, a substantially fixed normal bias for the grid of the last amplifier tube in the cascade, and means to positively prevent the said grid becoming positive when signals impressed thereon are of excessive size.

3. In an amplifier for use between a seismic wave detector and a recorder, the combination of a plurality of thermionic tubes, means associating said tubes for cascade seismic frequency amplification, an automatic volume control tube, means associating the output of said A. V. C. tube with one of said amplifier tubes to reduce the gain thereof concomitant with increase in output, means associating said A. V. C. tube with the amplifier output to regulate the operation of said A. V. C. tube, a diode tube, a bias battery for the grid of the last amplifier tube and arranged between the same and the signal input thereto, a tap from said battery applying a lower negative potential to the plate of said diode tube whereby it is negative in respect to its cathode, said potential being less than the maximum positive signal swings, whereby current flows in said diode upon said excess positive swings and opposes the signal current to maintain the potential of said tap near zero thereby preventing said grid becoming positive.

4. In a three-stage seismic frequency amplifier for use between a seismic wave detector and a recorder, in combination, three thermionic tubes, interstage coupling elements therefor, means to supply the detector output to the first of said tubes, and means to deliver the last tube output to said recorder with large amplitude swings subject to less gain than those of less amplitude comprising an automatic volume control tube, means associating the grid of said tube with the amplifier output, means placing the plate current thereof in control of the amount of bias on only the first two amplifier tubes, a normally fixed bias on the grid of the third tube and a diode tube normally inoperative, said tube being driven to operation only by excess positive signal voltage delivered to the grid circuit of the third amplifier tube, such operation causing said diode to deliver current, and means for converting said current to a voltage and opposing it to the excess positive signal voltage to prevent blocking of the third amplifier tube.

5. Means for preventing blocking of an amplifier tube resulting from the grid thereof becoming positive comprising in combination, a two element rectifier tube, a bias battery connected between the grid of the amplifier and the source of signal applied thereto, a portion of said bias potential being applied to the anode of said rectifier to normally hold the rectifier tube inoperative to

pass any portion of said signal, positive signal swings which overbalance said anode bias causing said rectifier to pass a current, means to utilize this current to prevent the said rectifier anode ever becoming more than a fraction of a volt positive at any time, whereby the grid of the amplifier always remains negative substantially by the amount of the remainder of said bias battery voltage.

6. The combination claimed in claim 5 in which the bias battery has such a potential that the amplifier tube is operated near cut-off to prevent excessive negative signal swings from being delivered to the amplifier output.

7. In a seismic frequency amplifier of the type described, in combination, a plurality of stages of cascaded amplification, each having a thermionic tube, an A. V. C. tube actuated by excess seismic frequency output from the amplifier, means charging a condenser as a result of current flow in the plate circuit of said A. V. C. tube, means to augment the bias on some of said amplifier tubes by discharge from said condenser, and means to individually regulate the bias changing effect of said condenser charge on said several tubes.

8. The system as claimed in claim 7 wherein the A. V. C. acts on all but the last stage tube and means controlled by the output of said controlled stages to automatically prevent blocking of said last stage tube from excessively large signals.

9. The system as claimed in claim 7 wherein the A. V. C. acts on all but the last stage tube, means controlled by the output of said controlled stages to automatically prevent blocking of said last stage tube from excessively large signals, and means exercising a band pass filter action associating said last tube with the preceding one, said automatic gain control maintaining the signal handled by said means substantially uniform.

10. In a seismic frequency amplifier of the type described, in combination, a tetrode first-stage amplifier tube, a tetrode second-stage amplifier tube, resistance coupling means associating said tubes, said means having band pass frequency selectivity, an A. V. C. tube, means associating the output of said tube with said first two tubes to automatically regulate the gain thereof a third amplifier tube, interstage coupling means associating it with the second-stage tube, said means constituting a band pass filter, means to apply a portion of the output of said third-stage to said A. V. C. tube to control the same, and means actuated by the input to said third-stage to prevent the grid thereof from ever becoming positive in spite of the size of the input.

11. The amplifier of claim 10 in which said last mentioned means is a rectifier tube and means normally maintaining the anode thereof at a low negative potential in respect to the cathode thereof.

12. In an amplifier of the type described, in combination, a plurality of stages of cascaded amplification, each having a thermionic tube, an A. V. C. tube actuated by excess seismic frequency output from the amplifier, means charging a condenser upon actuation of said A. V. C. tube, means to augment the bias on some of said tubes from said condenser charge, a battery also adapted to charge said condenser, and means to cut out said battery upon the receipt of such excess output.

13. For use with a seismic wave detector having an electric wave output whose general level is subject to major changes, an amplifier for raising the

general level to a usable value for operation of a recorder, said amplifier including a plurality of stages of cascaded amplification each having a thermionic tube, an A. V. C. tube adapted to be actuated by excess output from said amplifier, means to effect a change of bias on at least two of said thermionic tubes as a result of operation of said A. V. C. tube, and means to effect more rapid change of bias on a subsequent tube than on a preceding one.

14. For use with a seismic wave detector having an electric wave output whose general level is subject to major changes, an amplifier for raising the general level to a usable value for operation of a recorder, said amplifier including a plurality of stages of cascaded amplification each having a thermionic tube, an A. V. C. tube adapted to be actuated by excess output from said amplifier, means to effect a change of bias on all tubes but that of the last stage, and a coupling means between said last and the preceding stage including a frequency selective filter, the absence of A. V. C. control for said last stage preventing substantial volume level change in said filter, and means to prevent overloading of said last stage tube, said

means comprising a circuit to positively limit grid potential increase in said tube.

15. The system as claimed in claim 7 wherein the A. V. C. acts with a different time constant on the several stages to prevent interstage coupling.

16. In a multistage amplifier for use between a seismic wave detector and a recorder, the combination of a plurality of thermionic tubes, means associating said tubes in stages for cascade seismic frequency amplification of the signal from said detector and including a filter between the last and preceding stage tubes, an A. V. C. tube associated with the output of the last amplifier stage tube for control thereby, means associating the output of said A. V. C. tube with at least one of the amplifier stage tubes ahead of the last stage to reduce the gain of that stage concomitant with increase in said output, the last stage of said amplifier being free from control by said A. V. C. tube and said filter being constructed to prevent the application to the last stage of a signal voltage resulting from variations in the average value of the plate currents of the preceding tubes produced by said A. V. C. tube.

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