

April 30, 1940.

M. ARTZT

2,199,192

COMPENSATION AMPLIFIER SYSTEM

Filed June 8, 1938

4 Sheets-Sheet 1

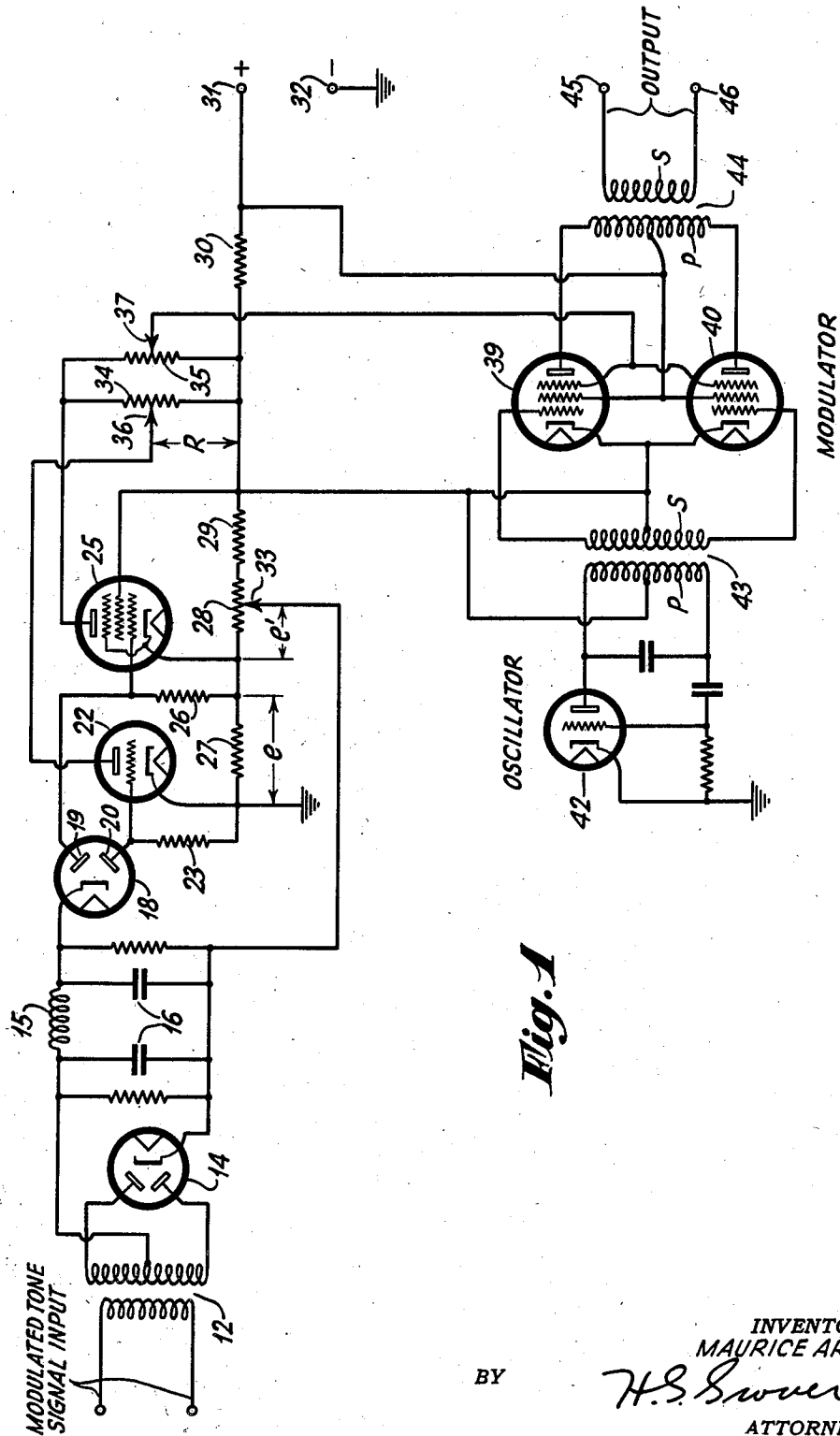


Fig. 1

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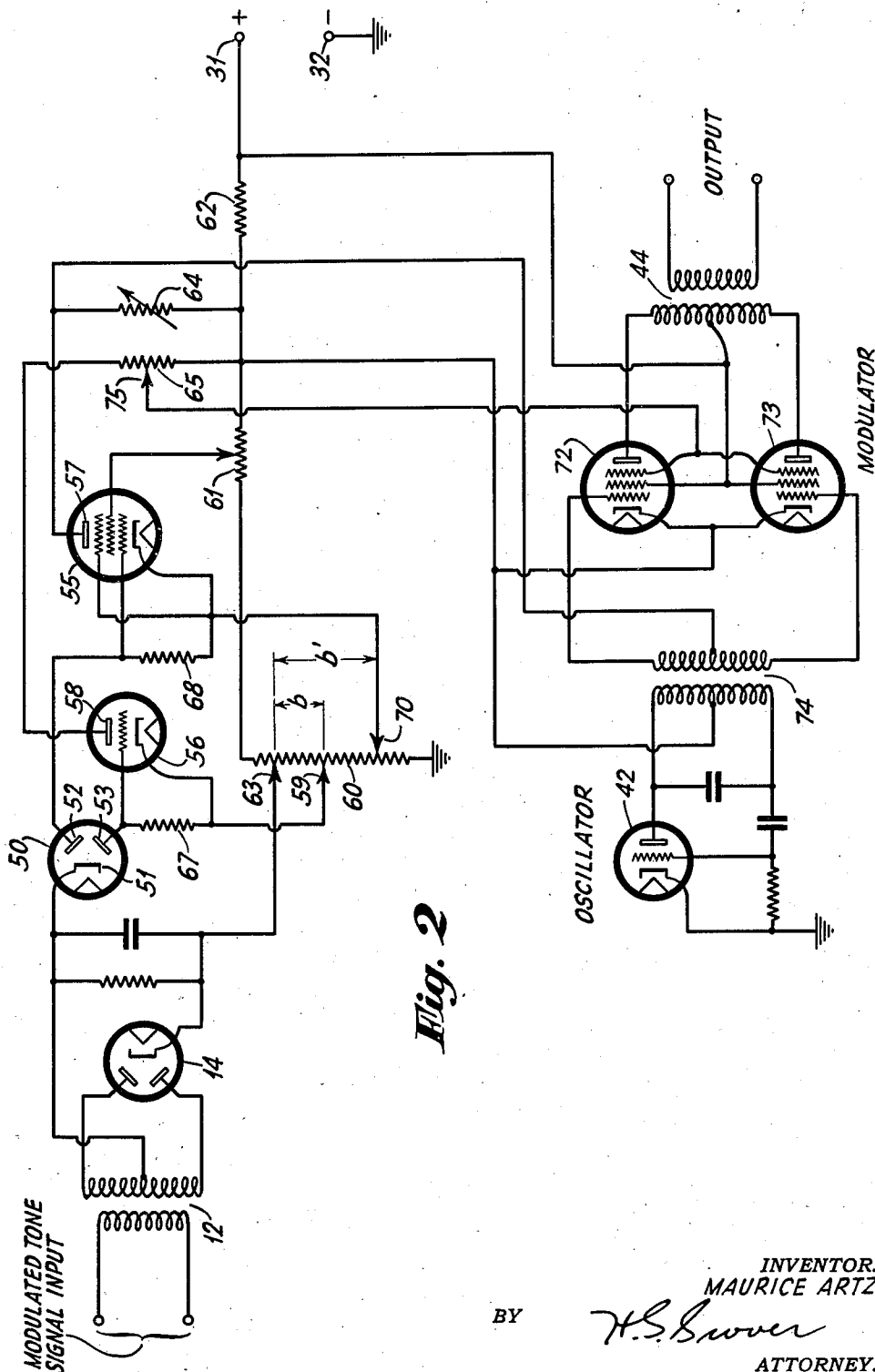
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COMPENSATION AMPLIFIER SYSTEM

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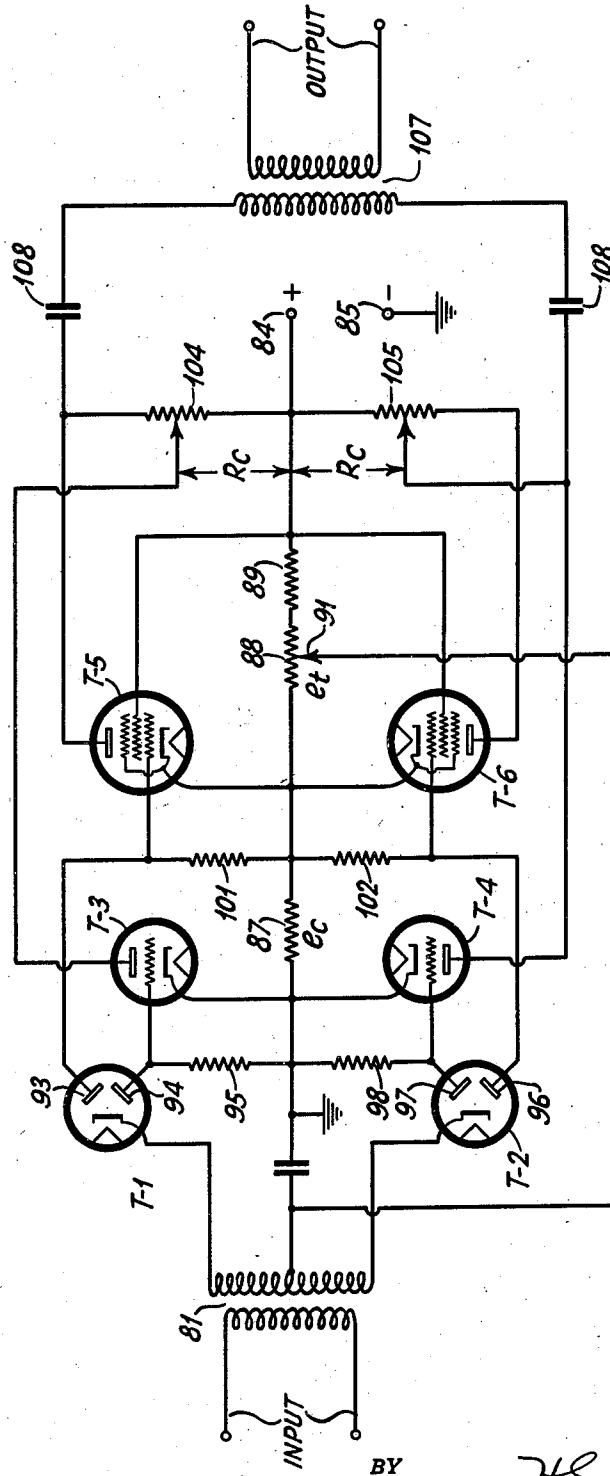
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# COMPENSATION AMPLIFIER SYSTEM

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4 Sheets-Sheet 3



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COMPENSATION AMPLIFIER SYSTEM

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4 Sheets-Sheet 4

**Fig. 4**

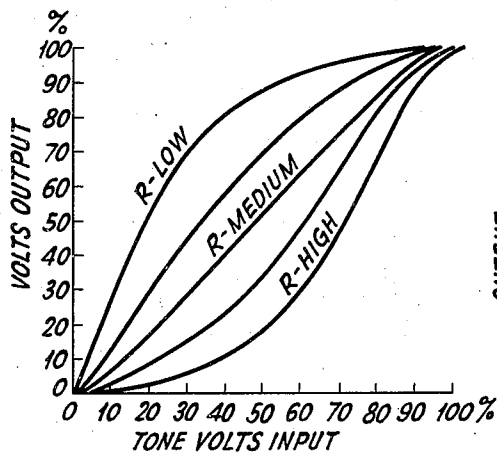


**Fig. 5**

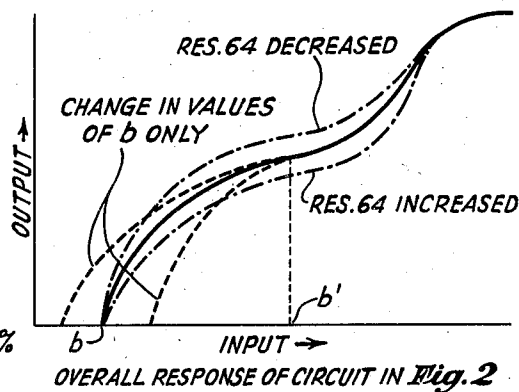


**Fig. 6**

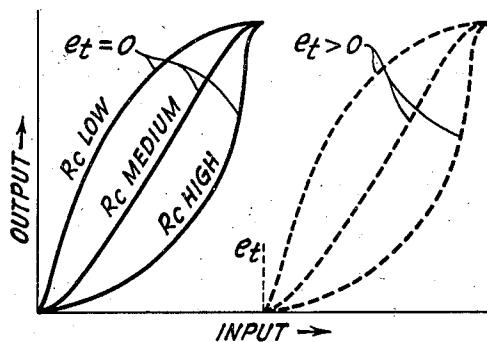
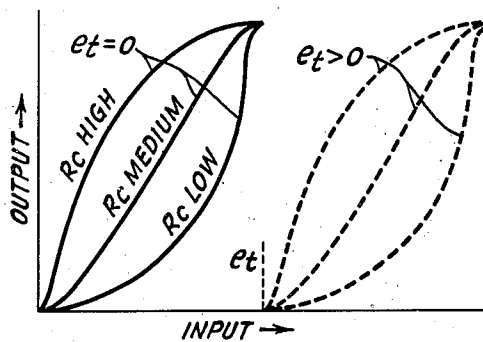


**Fig. 7**



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## UNITED STATES PATENT OFFICE

2,199,192

## COMPENSATION AMPLIFIER SYSTEM

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Application June 8, 1938, Serial No. 212,433

10 Claims. (Cl. 179—171)

This invention relates to an amplifier system wherein it is possible to compensate for undesirable conditions in amplification because of non-linear frequency response or because of non-linear response devices in order that the output from the amplifier may be linear. The system also affords a means whereby peculiarities in the response of an electrical translating apparatus may be compensated for to produce a proper response at the electrical apparatus.

More specifically, the present system is applicable to facsimile recording systems and may be used to amplify signals of variable frequency and amplitude as received from a facsimile scanner with means to compensate for any deficiencies in strength of certain of these signals in order that the recording reproduced at the facsimile receiver may be a more faithful reproduction of the original subject being transmitted.

In facsimile systems it is seldom possible to have all of the parts and elements of the system operate in such a manner as to maintain strict linear amplification and response characteristics. In the recording of true half-tones certain errors are generally present, which, if not compensated for, would produce an undesirable, if not illegible, recording, and to compensate for such errors it is desirable to introduce a corrective or compensation device which may be used to maintain the signals as utilized at the facsimile receiver or translating means at a level which is linear with respect to the light values of the subject being transmitted. It is also desirable that this compensation be variable and controllable so that as various parts of the system are improved the degree of correction can be changed to retain over all straight line amplification characteristics. Furthermore, another reason for maintaining the compensation amplifier system adjustable and variable is to provide a means whereby inherent changes in the response of the system due to use and deterioration which would, without the compensation system, produce errors, may be compensated for by changing the adjustments of the compensation amplifier.

Furthermore, in facsimile systems particularly where a receiver employing the carbon process is utilized such as is shown and described in the patent to Charles J. Young, Reissue #20,152 of October 27, 1936, appropriately responsive means must be introduced in the system to provide a compensation for the non-linear pressure response of the carbon paper used in the receiver. In such an instance, it has been found that a

true linear amplification is not the best condition, because, the amount of carbon which is transferred to the recording paper as a function of the pressure of the printer bar does not vary linearly. It has been found that small changes in signal amplitude, particularly in the low signal levels, do not have the proper effect and are not properly responded to in the carbon paper facsimile process. As a result, it is desirable to provide means whereby the amplitude characteristics of the amplifier increase rapidly with small changes in input at the low-signal level, and gradually change to a lower and lower percentage change in output as the signal level increases. When the proper compensation is provided true half-tones become possible with a carbon paper recorder. When a compensation amplifier system is utilized for the non-linear response of a carbon paper recorder, it is also desirable to have the system adjustable and variable since not all carbon papers respond in the same manner. Accordingly, when a different type of carbon paper is used, or in fact, when different rolls of the same type are used, it may be necessary to adjust the compensation amplifier to maintain proper half-tone recordings in view of changes in the pressure response of the carbon paper being utilized at the particular instant.

This invention therefore relates to a compensation amplifier system in which the slope of the correcting curve may be changed at different pre-set points and may further be changed to have either a positive or negative slope in order that substantially any and all desirable compensation factors may be introduced in the amplifier system to compensate for the non-linear response of one or more parts of the entire transmitting and receiving system.

It is therefore one purpose of the present invention to provide an amplifier system wherein an apparatus having a non-linear response may be so controlled as to produce amplified signals which are linear with respect to the originating variations.

Another advantage of the present system resides in the provision of means whereby various compensations may be introduced in an amplifier system to provide either linear or non-linear amplification response as may be desired under particular circumstances.

Still another advantage of the present invention resides in the provision of an amplifier system wherein the non-linear response of an electrical translating or receiving apparatus may be compensated for by introducing distortions in

the amplifying system whereby the electrical translating or receiving apparatus, in responding to the distorted signals, may be operated with an over-all true linearity.

6 A still further purpose of the present invention resides in the provision of means whereby variations in the pressure response of a carbon paper facsimile receiver may be compensated for to permit the true reproduction of half-tones.

10 Still another advantage of the present invention resides in the provision of means whereby the slope of the correcting curve of the amplifier may be changed and whereby the slope may be set for either positive or negative compensation.

15 Still another advantage of the present invention resides in the provision of means whereby such compensations may be applied to a modulated signal without the necessity of demodulating the signal, correcting the signal and again re-modulating.

20 Still other advantages and purposes of the present invention will become more apparent to those skilled in the art from a reading of the following specification and claims, particularly when considered with the drawings, wherein like figures represent like parts, and wherein:

25 Figure 1 illustrates one form of the present invention, wherein the compensation is introduced after de-modulation of the input signal.

30 Figure 2 illustrates a modification of Figure 1 and another form of the present invention.

35 Figure 3 shows still another form of the invention wherein compensations may be introduced without the necessity of de-modulating the input signal.

40 Figure 4 illustrates various curves showing the possible over-all compensation response of the system shown in Figure 1.

45 Figure 5 shows a possible response curve of the system shown in Figure 2.

50 Figures 6 and 7 illustrate various response curves of the system shown in Figure 3.

Referring now to Figure 1, wherein one form of the present invention is illustrated schematically, the input signal is applied to the primary of transformer 12. This input signal is normally in the form of a modulated tone signal, since ordinarily some scanning tone frequency is applied to the scanning head of a facsimile transmitter. This tone signal is rectified by the discharge tube 14, which comprises a cathode and a pair of anodes, and which operates as a full wave rectifier. The rectified signal is then passed through the filter network which comprises a choke 15 and condensers 16. After the rectified signal has been filtered it represents the envelope of the modulated tone which is applied to the primary transformer 12. The filtered voltage is then applied to a second rectifier tube 18 comprising a cathode and a pair of anodes 19 and 20. This rectifier tube will be referred to as a threshold rectifier and its specific operation will be explained later. The anode 20 is connected to the control electrode of a discharge tube 22, the control electrode being connected to ground by the grid resistor 23, while the anode 19 is connected to the control electrode of discharge tube 25. The control electrode of this tube is connected to ground by way of resistances 26 and 27.

70 For operating the discharge devices a source of potential (not shown) is provided, and is connected to terminals 31 and 32, the latter of which is connected to ground. A series of resistances 27, 28, 29 and 30 are connected between  
75 positive terminal 31 and ground, in order to oper-

ate as a potential divider from which different degrees of positive potential may be made available.

The anode of discharge tube 25 is connected to a point between resistances 29 and 30 by a pair of parallel resistances 34 and 35, each of which operate as potentiometers and are each provided with an adjustable contact 36 and 37 respectively. The anode of discharge tube 22 is connected to the adjustable contact 36 of resistance 34, so that the portion R of the resistance 34 is common to the anode circuits of both tubes 22 and 25.

For the purpose of again modulating the signal, a pair of tubes 39 and 40 are provided, and to provide a source of carrier frequency an oscillator tube 42 is also provided. The tube 42 and its immediately associated circuit comprises a standard oscillator, the oscillations being present in the primary of transformer 43. The secondary of the transformer 43 is connected in push-pull to the first control electrodes of discharge tubes 39 and 40. The anodes of discharge tubes 39 and 40 are connected to the end terminals of the primary of the output transformer 44, the secondary of which is connected to the output terminals 45 and 46. The screen or #2 grids of the discharge tubes 39 and 40 are connected together and are in turn connected to the source of positive potential and to the midpoint of the primary winding of transformer 44. The suppressor or #3 grids of discharge tubes 39 and 40 are connected together and are in turn connected to the adjustable point 37 of the resistance 35. When the carrier frequency, which originates at the oscillator 42, is applied to the control electrodes (#1 grids) of the discharge tubes 39 and 40, an output will be present in the secondary of transformer 44 of amplified carrier frequency. The intensity of the carrier frequency in the output depends upon the potential of the #3 grids, this potential being determined by the voltage drop across that portion of the resistance 35 between the contact 37 and the point between resistances 29 and 30. Under a condition of zero input signal, the discharge tubes 22 and 25 draw sufficient current through their common plate resistor that the modulator discharge tubes 39 and 40 are biased to cut-off. The output from the rectifier 14 is applied between the cathode of rectifier 18 and an adjustable contact 33 along resistance 28.

To simplify the explanation of the operation of the system, the voltage drop which appears across the resistance 27 will be designated as the voltage  $e$ , while the voltage drop across that portion of the resistance 28 between the adjustable contact 33 and the cathode of discharge tube 25 will be designated as the voltage  $e'$ . It will be noticed therefore that the potential of the anode 19 of tube 18 is negative with respect to its cathode by an amount equal to the voltage  $e'$ . Furthermore, the anode 20 is negative with respect to the cathode by an amount equal to the sum of voltages  $e$  and  $e'$ . Therefore, the rectified signal, as it appears at the output of the filter circuit, must rise above the value  $e'$  before the anode 19 of tube 18 will be supplied with any current. At this signal level, and above, there will be anode current flowing through the resistance 26. The presence of the current flowing through resistance 26 produces a potential drop which drives the control electrode of discharge tube 25 in a negative direction, tending to reduce it to cut-off. This reduces the amount of anode cur-  
75

rent which flows through tube 25 and accordingly reduces the negative bias of the modulator tubes 39 and 40, permitting carrier frequency to be transferred therethrough by an amount determined by the level of the rectified voltage applied to the cathode of tube 18 and the contact 33 of resistance 28. Even when the tube 25 is driven to complete cut-off there is still a voltage present at the resistance R (a portion of resistance 34) due to the presence of anode current in discharge tube 22 which is not at cut-off. The circuit constants are so arranged that the signal level which is sufficient to produce cut-off at tube 25 is just sufficient to overcome the negative bias of the anode 20 of tube 18 which, as stated before, is equivalent to the sum of the voltages  $e$  and  $e'$ . The anode 20 of tube 18 is then supplied with current and produces a potential drop across resistance 23, which potential drop is in turn applied to the control electrode of discharge tube 22. This voltage acts negatively on the control electrode and tends to drive the tube toward cut-off, thereby reducing the anode current in tube 22 and accordingly further reducing the negative bias on the modulator tubes 39 and 40. When maximum input signal is present, both of the anodes 19 and 20 of the tube 18 draw current, and tube 22 as well as tube 25 is biased to cut-off. Under these circumstances the modulator tubes 39 and 40 will be operated at maximum output and a maximum intensity of carrier frequency will be present at the output terminals 45 and 46. The output of the modulator tube is therefore varied in amplitude between zero and a maximum in accordance with the intensity of the input signal as applied to the discharge tube 18.

Even though the output of the modulator tubes ranges from a minimum to a maximum in accordance with the rectified signal present at the output of the filter circuit, this relationship is not linear unless the parameters of the system are set for such operation. Normally, for carbon paper recording the tube 25 is set for high current and high gain so that small signal increases above the threshold voltage value  $e'$  give large changes in modulator output. At the point where this tube is biased to cut-off and tube 22 assumes control, the relationship changes since the tube 22 is set for low gain and low current with the result that the signal must increase a larger amount to produce a change in the output of the modulator tubes 39 and 40. A curve of the overall operation of the system when so adjusted is shown in Figure 4 and is marked R-low.

By changing the value of the resistance R the shape of the response curve may be changed as shown in Figure 4. If the resistance is made high, then an operation opposite to that which is present when the resistance is made low may be accomplished so that the signal output from the compensating amplifier will change little during the operation of tube 25, the change increasing rapidly up to a maximum value during the subsequent operation of the tube 22. If it is desired that the compensating amplifier operate substantially linearly, then some average or intermediate value of the resistance R may be used as indicated by the curve marked R-medium in Figure 4.

It will be noticed that changes in the value of the resistance R materially affect the response characteristics of the compensation amplifier as indicated by the curves shown in Figure 4, but it will also be noticed that the minimum and maximum amplitudes of the carrier frequency in the

output remain substantially constant. This is particularly advantageous since no adjustments other than the setting of the adjustable contact 36 on the resistance 34 are necessary to control the response of the compensation amplifier.

Such an amplifier, as may be evident from an inspection of the curves shown in Figure 4, may also be used as a "compressor" or "expander". If the value of the resistance R is low, then the amplifier will operate as a "compressor" and may be used, for instance, for making master phonograph records. When the recording is played back through the amplifier with the value of the resistance R set high, the amplifier will act as an "expander" so that the output from the amplifier will have the same original tone and volume values which were impressed upon the recording system. The circuit is particularly adaptable for such use in view of the fact that it operates instantaneously on each wave rather than on an average volume as in the case of the present phonograph "expanders".

Referring now to Figure 2 wherein is shown a modified circuit for accomplishing the purposes set forth above. This circuit is similar to that shown and described in connection with Figure 1, but differs therefrom in that the modulator tubes are controlled in a different manner. In this figure the modulated input signal is applied to the transformer primary 12, the output of which is connected to a double diode rectifier 14. A threshold double diode rectifier tube 50 is provided having a cathode 51 and a pair of anodes 52 and 53. The cathode 51 of the threshold rectifier 50 is connected to one terminal of the output from the rectifier tube 14 and the anodes 52 and 53 are connected to the control electrodes of two separate electron discharge tubes 55 and 56 respectively. The discharge tube 56 includes a cathode, a control electrode and an anode, whereas the discharge tube 55 is of the pentode type including a suppressor grid and a screen grid.

For applying proper operating potentials to the electrodes of the various tubes, a source of current is applied to the terminals 31 and 32, the latter of which is connected to ground. A plurality of resistances 60, 61 and 62, which operate as a potentiometer, are connected in series between the terminal 31 and ground. The anodes 57 and 58 of the discharge tubes 55 and 56 are connected to the potentiometer at a point between resistances 61 and 62, resistances 64 and 65, respectively, being included in these connections. The control electrode of discharge tube 56 is connected to the cathode thereof by way of a resistance 67 and is also connected to the anode 53 of the threshold rectifier 50. The cathode is connected to an adjustable point 59 along the resistance 60. The cathode of the rectifier tube 14 (which forms the other output terminal for the rectified signal input) is connected to an adjustable point 63 on the resistance 60, positive with respect to the point at which the cathode of the discharge tube 56 is connected.

The anode 52 of the threshold rectifier 50 is connected to the control electrode of the discharge tube 55, which in turn is connected to the cathode of that tube by way of a resistor 68. The cathode of the tube 55 is connected to an adjustable point 70 along the resistance 60.

An oscillation generator including the tube 42 is provided for supplying a carrier frequency, which carrier frequency is to be modulated in accordance with the intensity of the input signal. This oscillator is conventional in design and cor-

responds to the oscillator shown and described in connection with Figure 1. For coupling the carrier frequency oscillator to the modulator tubes 72 and 73 a transformer 74 is provided.

5 The modulator tubes 72 and 73 include a cathode, a control electrode, a screen or #2 grid, a suppressor or #3 grid and an anode. The cathodes are connected together and are in turn connected to a point between the resistances 61 and 62 of

10 the potentiometer. In order that the carrier frequency may be applied to the tubes the ends of the secondary of transformer 74 are connected to the control electrodes of these tubes. The screen or #2 grids of the modulator tubes are

15 connected together and are connected to the midpoint of the primary of the output transformer 44. These grids are also connected to the positive terminal 31 in order that they may be maintained positive with respect to their associated cathodes.

20 The anodes of the modulators 72 and 73 are connected to the end terminals of the primary of transformer 44 so that the modulated carrier current which appears in the anode circuits of these tubes may be utilized by connecting to the

25 secondary of the output transformer.

The modulator tubes 72 and 73 are controlled by impressing signal or voltage variations upon the control electrodes and upon the suppressor or #3 grids. The midpoint of the secondary of

30 transformer 74 is therefore connected to the anode 57 of tube 55 so that the control electrodes will be affected by the current drawn by the tube 55 while the suppressor or #3 grids of the modulator tubes are connected together and are in

35 turn connected to an adjustable point 75 along the anode resistor 65 of tube 56. Current which is drawn by the tube 56 will therefore produce a potential drop along resistance 65 to control the potential of the suppressor electrodes of the modulator tubes 72 and 73, and the degree of this

40 control may be adjusted by varying the position of the adjustable contact 75 along the resistor 65.

In order to assist in the explanation of the operation of this system it will be assumed that

45 the potential which appears between the adjustable contacts 63 and 59 along the resistor 60 be designated as the voltage  $b$ , whereas the voltage which appears between the adjustable contacts 63 and 70 will be designated as  $b'$ . Since the

50 cathode of the rectifier 14 is connected to the adjustable contact 63, it may be seen, therefore, that the anode 53 of the threshold rectifier 50 is negative with respect to its cathode 51 by an amount equal to the voltage  $b$ . Similarly, the

55 anode 52 of the threshold rectifier 50 is negative with respect to its cathode 51 by an amount equal to the voltage  $b'$ .

Modulated tone signals applied to the transformer 12 are rectified by the rectifier 14 and

60 appear as a varying direct current voltage at the output of this tube. This direct current voltage is impressed upon the cathode 51 of the threshold rectifier 50 and upon the resistance 60 at the adjustable point 63. When the rectified voltage

65 is less than the voltage  $b$ , no current will be passed by the threshold rectifier 50, but when the rectified signal exceeds the voltage  $b$ , then current will be drawn by the anode 53 of the threshold rectifier. This permits current to flow

70 through the resistor 67 which tends to drive the discharge tube 55 toward cut-off. This reduction in the anode current of tube 56 reduces the negative bias of the suppressor or #3 grids of the modulator tubes with the result that there is

75 an increase in the carrier frequency passed by

these tubes. As the rectified input signal increases in potential, the discharge tube 55 is gradually driven to cut-off, with the result that more and more carrier frequency is passed by the modulator tubes. The position of the adjustable

5 contact 70 is so set that at about the instant that the tube 56 is driven to complete cut-off, the rectified signal input voltage is sufficient to overcome the voltage  $b'$ , which results in anode current being drawn by the anode 52 of the threshold

10 rectifier 50. Current then begins to flow through the resistance 68 which tends to drive the discharge tube 55 toward cut-off. This reduces the current drawn by the discharge tube 53 and accordingly the voltage applied to the control elec-

15 trodes of the modulator tubes 72 and 73 is changed tending to further increase the amount of carrier current passed by these tubes. Further increases in the rectified signal input causes corresponding increases in the amount of carrier

20 frequency passed by the modulator tubes 72 and 73 until a saturation or maximum limit is reached.

In view of the fact that the tubes 55 and 56 are different in structure and have different op-

25 erating characteristics, the relationship of the current passed by the modulator tubes and the rectified potential as supplied by the rectifier 14 is different during the time periods that the

30 tubes 55 and 56 are controlling the operation of the tubes 72 and 73. The operation of the compensating amplifier is best shown by referring to Figure 5 wherein curves of the response of the amplifier are illustrated. No output from the

35 amplifier is present until the input signal has reached a value corresponding to the potential  $b$ . At this point the tube 56 assumes control of the modulator tubes and the relationship between the input and output of the amplifier system may be indicated by that portion of the curve shown

40 between the points  $b$  and  $b'$  along the abscissae of the curve. At the point represented by the input voltage  $b'$ , and for any greater voltage, the tube 55 assumes control of the modulator tubes

45 72 and 73 and the relationship of this control is indicated by the remainder of the curve. This over-all relationship is shown by the solid line curve of Figure 5. If it is desired that the compensating amplifier respond to a higher or lower

50 initial input voltage, then the adjustable point 53 may be moved along the resistance 60 and the effect of such an adjustment is illustrated by the dotted curves shown in Figure 5. Such an

55 adjustment, of course, determines the point at which the anode 53 of the threshold rectifier 50 is supplied with current, and also the point at which the modulator begins to be affected by the input signal. The over-all shape of the response

60 curve may also be varied as indicated by the dot-and-dash curves shown in the figure by controlling the amount of the resistance contained in the anode circuit of the tube 55, which resistance is preferably made adjustable.

From the above it may be seen that various

65 shapes of response curves may be produced and it may further be seen that changes in the over-all response characteristics of the compensating amplifier do not affect the minimum or maximum

70 output from the modulator tubes, but only the intermediate values thereof. The minimum output of the modulator may, however, be controlled by varying the position of the adjustable contact 75 along the resistance 65, so that varying de-

75 grees of minimum carrier signal frequency may

be present in the output of the amplifier when no signal input is impressed upon the system.

The shape of the curves shown in Figure 5 corresponds quite favorably with the curve necessary to produce proper halftones in facsimile recordings, such a response being capable of compensating for non-linear responses of all of the elements of the complete facsimile system. When the compensating amplifier responds in a manner similar to that shown by the curves in Figure 5, an over-all linear relationship from the scanner head to and including the printer at the receiving station, is possible.

In the circuits shown in Figures 1 and 2 it will be noticed that demodulation of the modulated tone signal input is necessary, the output from the compensating amplifier being again modulated in order that the signals may be subsequently transmitted. There are instances, however, when such demodulation and subsequent modulation is objectionable and under such conditions a circuit such as that shown in Figure 3 may be used, the circuit operating as a compensating amplifier for a modulated signal which is not demodulated or rectified.

The system shown in Figure 3 comprises an input transformer 81 to the primary of which is connected the modulated input signal which may be derived from the scanning head of a facsimile transmitter. A pair of threshold tubes T-1 and T-2 are used, each of which includes a cathode and a pair of anodes. These tubes operate in push-pull, and to each one of the tubes are connected separate amplifier tubes which have different operation characteristics. For applying appropriate potentials to the electrodes of all of the tubes, a source of current is provided, and is connected to terminals 84 and 85, the latter of which is connected to ground. A plurality of resistances 87, 88 and 89 are connected between the positive terminal 84 and ground so as to act as a potentiometer from which different potentials may be derived.

The secondary of the input transformer 81 is provided with a center tap which is connected to an adjustable contact 91 on the resistance 88 while the ends of the secondary of the transformer are connected to the cathodes of discharge tubes T-1 and T-2.

As stated above, tube T-1 includes a pair of anodes 93 and 94, the latter of which is connected to ground by way of resistance 95, the resistance operating as a load resistance for the anode 94 and as a grid resistance for the discharge tube T-3. Similarly, discharge tube T-2 includes a pair of anodes 96 and 97, the latter of which is connected to ground by way of resistance 98. In view of the fact that the anodes 94 and 97 of tubes T-1 and T-2 are connected to ground, while the cathodes of these tubes (that is, the mid-point of the secondary of transformer 81) are connected to the adjustable contact 91 on resistance 88, it may be seen that the anodes 94 and 97 are negative with respect to their cathodes by an amount equal to the potential of the adjustable contact 91.

The anode 93 of tube T-1 is connected to a point between resistances 87 and 88 by resistance 101 while the anode 96 of tube T-2 is connected to the same point by resistance 102. The anodes 93 and 96 are also connected to the control electrodes of discharge tubes T-5 and T-6 respectively. The cathodes of tubes T-3 and T-4 are connected to ground, while the cathodes of tubes T-5 and T-6 are connected to a point

between resistances 87 and 88. The anodes of tubes T-5 and T-6 are maintained positive with respect to their cathodes by connecting the anodes to the positive terminal 84 through resistances 104 and 105 respectively, while the anodes of tubes T-3 and T-4 are maintained positive by reason of the fact that these anodes are connected to adjustable contacts along the resistances 104 and 105. That portion of the resistances 104 and 105 which is connected between the adjustable contacts and the positive terminal 84 will be designated as  $R_c$  as indicated in the drawings.

The output from the compensating amplifier is derived from the potential drops along resistances 104 and 105 and is applied to the primary of an output transformer 107 by a capacity coupling through condensers 108. From the secondary of the transformer 107 may, therefore, be derived the compensated and amplified modulated signal which was impressed upon the input transformer 81.

For the purpose of explaining the operation of the system, the potential drop along resistance 87 will be designated as voltage  $e_c$  while the potential drop along that portion of resistance 88 between the adjustable contact 91 and the junction of resistances 88 and 87, will be designated as  $e_t$ . The anodes 94 and 97 are, therefore, negative with respect to their cathodes by a voltage equivalent to the sum of the voltages  $e_c$  and  $e_t$ . Also, since the anodes 93 and 96 of the discharge tubes T-1 and T-2 are connected to a point between resistances 87 and 88, these anodes will be negative with respect to the cathodes by an amount equal to the voltage  $e_t$ . Inasmuch as this voltage is less than the combined voltages  $e_t$  and  $e_c$ , it is only necessary for the input signal to be of an amplitude equivalent to the voltage  $e_t$  to permit current to flow to the anodes 93 and 96. Any signal in excess of the voltage  $e_t$  will therefore permit passage of current through the resistances 101 and 102 to control the operation of tubes T-5 and T-6. No current will be supplied to the anodes 94 and 97 until the input signal has at least reached an amount equivalent to the sum of the voltages  $e_t$  and  $e_c$ . At this time current will be supplied through the resistances 95 and 98 of the discharge tubes T-3 and T-4 so that a control of these tubes will then be initiated. In view of the different characteristics of tubes T-3 and T-4 as compared to tubes T-5 and T-6, different overall amplification responses will be present depending upon the strength of the input signal. Furthermore, the combined effects of the tubes T-3 through T-6 depend upon the value of the resistances  $R_c$ , this resistance being common to the anodes of all of these tubes.

In Figures 6 and 7 are shown various curves indicating the response of the system illustrated in Figure 3 and further illustrating the type of response that may be accomplished by using such a system. The instant at which the anodes 93 and 94 are supplied with current depends upon the value of the voltage  $e_t$ , which may be regulated by moving the contact 91 along the resistance 88. If this voltage is increased then the threshold operating voltage of the tubes T-1 and T-2 is altered so that, as indicated by Figures 6 and 7, the curves may be caused to be shifted horizontally along the input axis of the curves. Accordingly, as the voltage  $e_t$  is increased, a greater initial input voltage is necessary before the tubes T-3 and T-4 are controlled or are

supplied with a control voltage from the anodes 93 and 96 of tubes T—1 and T—2.

In Figure 6, the curves indicate the response possible when the gain or amplification of tubes T—5 and T—6 is greater than that of tubes T—3 and T—4. In this case, if the resistance  $R_c$  is low, then large changes in the output from the amplifier will be present when small low voltage changes are applied to the system, whereas, if the resistance  $R_c$  is made high, the compensating amplifier will be less responsive to low voltage changes of input whereas large changes in the output of the amplifier will be present when higher voltage changes are impressed upon the system.

In Figure 7 is shown a similar family of curves in which the gain of tubes T—5 and T—6 is less than the gain of tubes T—3 and T—4. When this situation exists then the value of the resistance  $R_c$  will affect the operation of the compensating amplifier in a manner opposite to the effect which exists as explained above in connection with Figure 6. In other words, when the resistance  $R_c$  is low, then the greatest response is attained when high voltage variations are present at the input whereas when the resistance  $R_c$  is high, the greatest percentage effect upon the output of the compensating amplifier is present during low voltage changes of input, that is, when the input voltage has increased just above the threshold value as determined by the value of the voltage  $e_t$ .

In Figures 6 and 7 it will be seen that the maximum and minimum signal output from the amplifier remain substantially constant regardless of the value of the resistance  $R_c$  or the value of the voltage  $e_t$ . For this reason changes in the response of the compensating amplifier may be brought about by simply adjusting the value of the resistance  $R_c$ , and the instant at which the compensating amplifier begins to operate may be determined solely by adjusting the position of the contact 91 along the resistance 88. When either the resistance  $R_c$  or the voltage  $e_t$  or both are adjusted no further adjustments to maintain the same minimum or maximum output from the compensating amplifier are necessary.

It will also be noticed that the compensating amplifier as shown in Figure 3 (which operates on a modulated wave without demodulation of the wave) may be used as a "compressor" or "expander" as explained above in connection with Figure 1, by simply varying the amount of the resistance  $R_c$ .

From the above description of the present invention, it may be seen that the over-all operation of a facsimile system may be greatly improved by using any one of the described circuits, since with each it is possible to compensate for the non-linear operating characteristics of all of the elements in a facsimile transmitting and receiving system. In instances where the non-linear response of the various elements of the complete system remain substantially constant the compensation amplifier is preferably located on the facsimile transmitter, with the result that adequate compensation will have been inserted in the transmitted signal before it is received at the facsimile receiver. When such compensated signals are received and utilized to produce a facsimile recording, an over-all operation is produced which is desirable and which will result in the production of facsimile recordings which compare very favorably with the original subject matter. In the transmission of photographs or

subject matter wherein a high degree of fidelity half-tone transmission is necessary, the compensating amplifiers shown are particularly advantageous since by using such amplifiers the half-tones are more faithfully reproduced and resemble the transmitted subject much more closely than has heretofore been possible.

Various modifications of the systems shown and described herein are possible, without departing from the spirit and scope of the invention described herein, and it is desired that any and all of such modifications be considered within the purview of the present invention except as limited by the hereinafter appended claims.

I claim:

1. An amplifying system comprising an electron discharge device having a cathode and a pair of anodes, circuit means for normally maintaining said anodes negative with respect to said cathode by different amounts, means for applying a single signal source of variable potential between said anodes and said cathode whereby said anodes will be supplied with current when the intensity of the signal potential variations exceed the negative bias of the respective anodes, thermionic discharge means associated with each anode circuit, each of the thermionic discharge means having different operating characteristics, means whereby said thermionic discharge means will respond to the presence of and amount of current in the associated anode circuit, and means for combining the outputs from said thermionic discharge means.

2. An amplifying system comprising a pair of unidirectional current paths, potential biasing means for opposing the flow of current through said paths the degree of the potential bias being different for the two paths, means for applying a single variable potential signal source to said paths whereby current may flow through said paths when their respective bias potentials are overcome by the signal potential, a pair of electron discharge devices each including at least a cathode, a control electrode and an anode, and each having different operating characteristics, means for controlling said discharge devices in accordance with the presence and amount of current in the current paths, and a common output circuit connected to said anodes.

3. An amplifying system comprising a pair of unidirectional current paths, potential biasing means for opposing the flow of current through said paths the degree of the potential bias being different for the two paths, means for applying a single variable potential signal source to said paths whereby current may flow through said paths when their respective bias potentials are overcome by the signal potential, a pair of electron discharge devices each including at least a cathode, a control electrode and an anode, and each having a different control response, means for controlling said discharge devices in accordance with the presence and amount of current in the current paths, means for suppressing or accentuating the control response of said devices, and a common output circuit connected to said anodes.

4. An amplifying system comprising a plurality of unidirectional current paths, means for applying a different adjustable potential bias to each path to oppose current flow therethrough, means for applying a single variable potential signal source to said paths whereby current may flow through said paths when their respective bias potentials are overcome by the signal potential,

an electron discharge device associated with each current path and responsive to the presence and amount of current passed by the associated path, each of said discharge devices having different operating characteristics, means for controlling the degree of response of said devices, and means for combining the outputs from said discharge devices.

5. An amplifying system comprising a plurality of unidirectional current paths, means for applying a different potential bias to each path to oppose current flow therethrough, means for applying a single variable potential signal source to said paths whereby current may flow through said paths when their respective bias potentials are overcome by the signal potential, an electron discharge device associated with each current path and responsive to the presence and amount of current passed by the associated path, each of said discharge devices having different operating characteristics, means for controlling the degree of response of said devices, means for varying the potential bias applied to each current path, and means for combining the outputs from said discharge devices.

6. An amplifying system comprising a plurality of unidirectional current paths, means for applying a different potential bias to each path to oppose current flow therethrough, means for applying a single variable potential signal source to said paths whereby current may flow through said paths when their respective bias potentials are overcome by the signal potential, an electron discharge device associated with each current path and responsive to the amount of current passed by the associated current path, each of said devices including at least a cathode, a control electrode and an anode and each having a different response characteristic, a source of carrier frequency, means for modulating the carrier frequency, and output circuit means including the anode of each electron discharge device for controlling said modulation means.

7. An amplifying system comprising a plurality of unidirectional current paths, means for applying a different potential bias to each path to oppose current flow therethrough, means for applying a single variable potential signal source to said paths whereby current may flow through said paths when their respective bias potentials are overcome by the signal potential, an electron discharge device associated with each current path and responsive to the amount of current passed by the associated current path, each of said devices including at least a cathode, a control electrode and an anode and each having a different response characteristic, a source of carrier frequency, means for modulating the carrier frequency, means for varying the potential bias applied to each current path, and output circuit means including the anode of each electron dis-

charge device for controlling said modulating means.

8. An amplifying system comprising a plurality of unidirectional current paths, means for applying a different potential bias to each path to oppose current flow therethrough, means for applying a variable potential signal source to said paths whereby current may flow through said paths when their respective bias potentials are overcome by the signal potential, an electron discharge device associated with each current path and responsive to the amount of current passed by the associated current path, each of said devices including an anode and each having a different response characteristic, a source of carrier frequency, means for modulating the carrier frequency, and circuit means including the anode of each electron discharge device for controlling said modulating means.

9. A compensating amplifier system for a modulated signal comprising a pair of unidirectional current paths, means for applying a different potential bias to each path to oppose current flow therethrough, means for demodulating the signal to produce a potential variation, means for applying the potential variation to said paths whereby current may flow through said paths when the potential variations exceed their respective bias potentials, an electron discharge device associated with each current path and responsive to the amount of current in the associated path, each of said devices including an anode and each having a different response characteristic, a source of carrier frequency, means for modulating the carrier frequency, and circuit means including the anodes of said discharge devices for controlling said modulating means.

10. An amplifying system comprising a pair of thermionic discharge means each including a cathode and a pair of anodes, means for normally maintaining one anode of each discharge means negative with respect to its cathode by a certain amount, means for normally maintaining the other anode of each discharge means negative with respect to its cathode by another amount, means for applying a signal source of variable potential between said anodes and said cathodes whereby said anodes will be supplied with current when the signal potential variations exceed the negative bias of the respective anodes, a pair of thermionic discharge tubes connected respectively to said one anode in each discharge means, a second pair of thermionic discharge tubes connected respectively to said other anode in each discharge means, each of said pairs of tubes having different characteristics and each tube responsive to the presence and amount of current in the associated anode circuit, and means for combining the outputs from all of the discharge tubes.

MAURICE ARTZT.