TELEGRAPH REPEATERS

Filed March 29, 1949 8 Sheets-Sheet 1

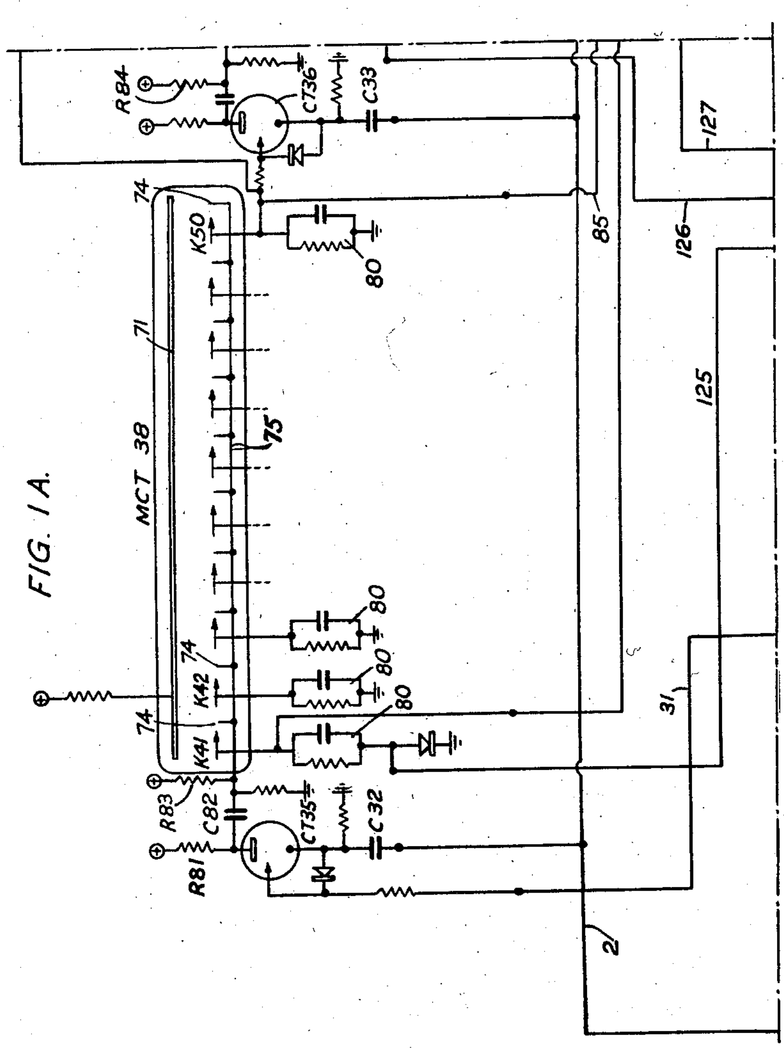

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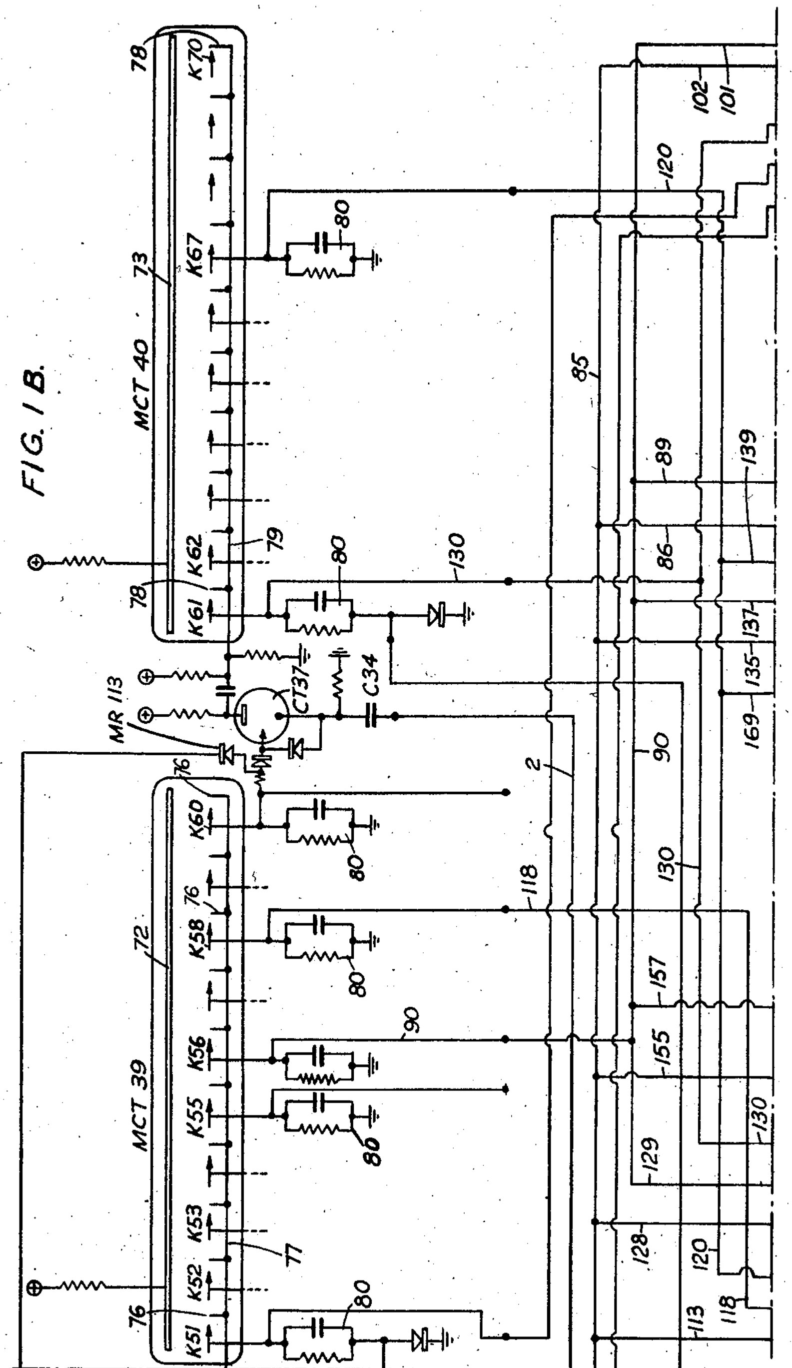
FIG. 1B.



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TELEGRAPH REPEATERS

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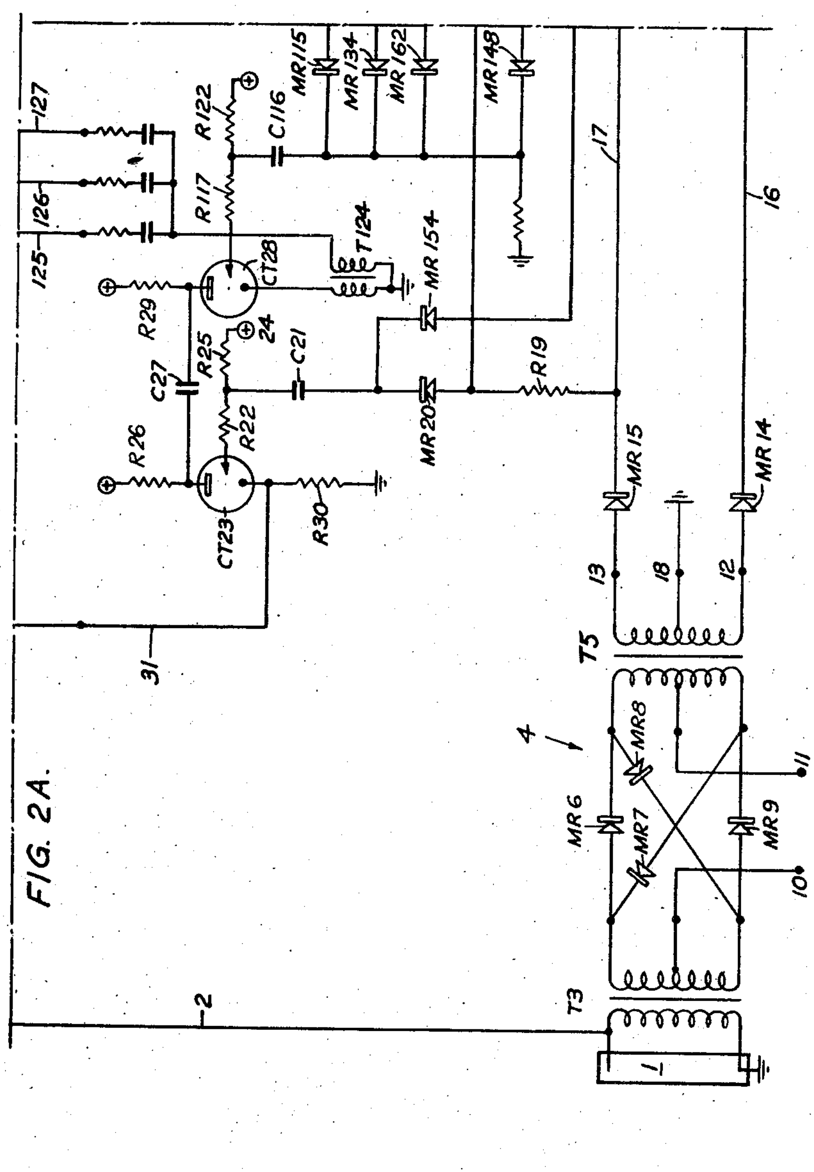

FIG. 2A.

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TELEGRAPH REPEATERS

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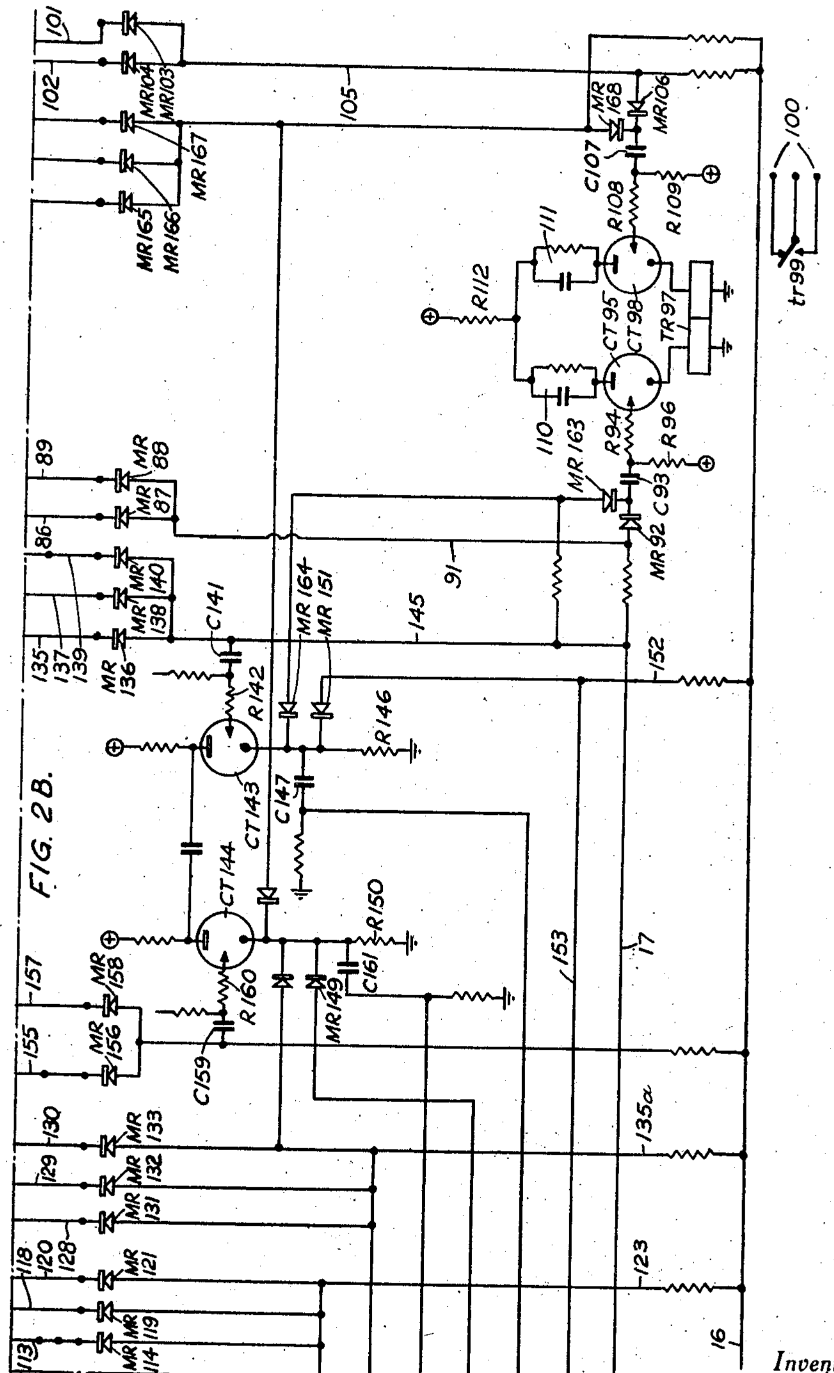

FIG. 2B.

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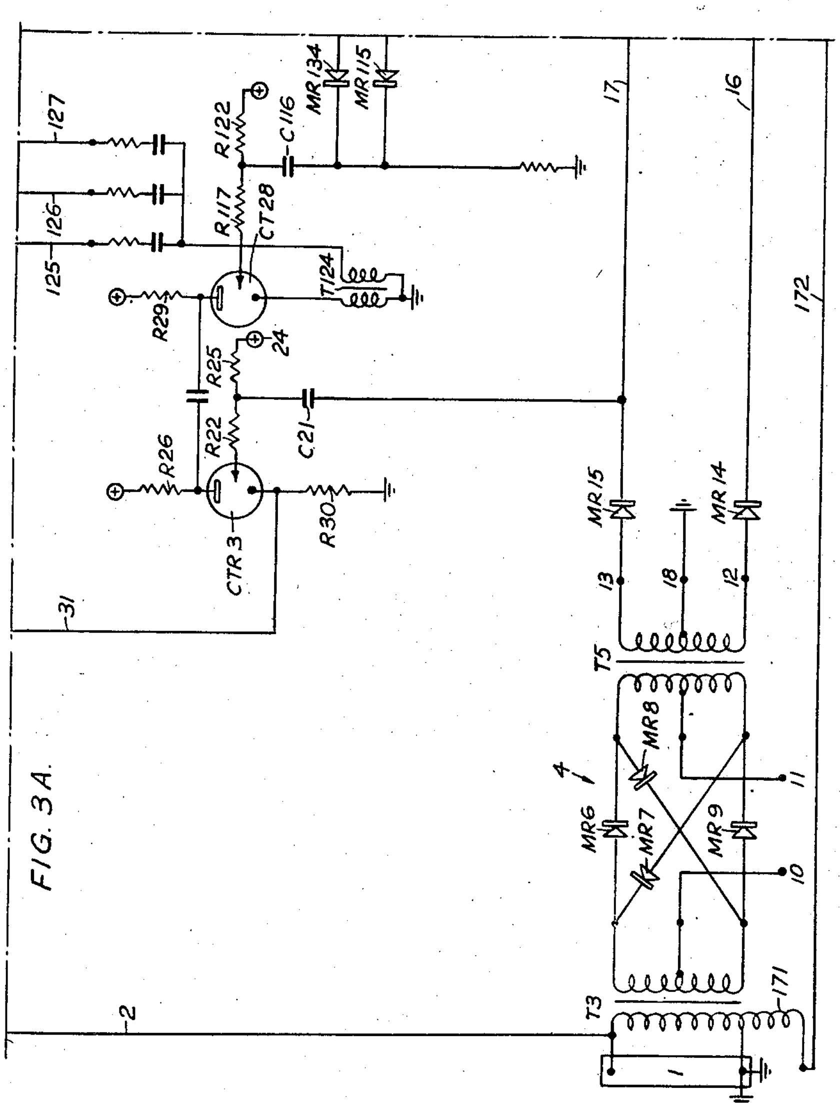

FIG. 3A.

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TELEGRAPH REPEATERS

Filed March 29, 1949 8 Sheets-Sheet 6

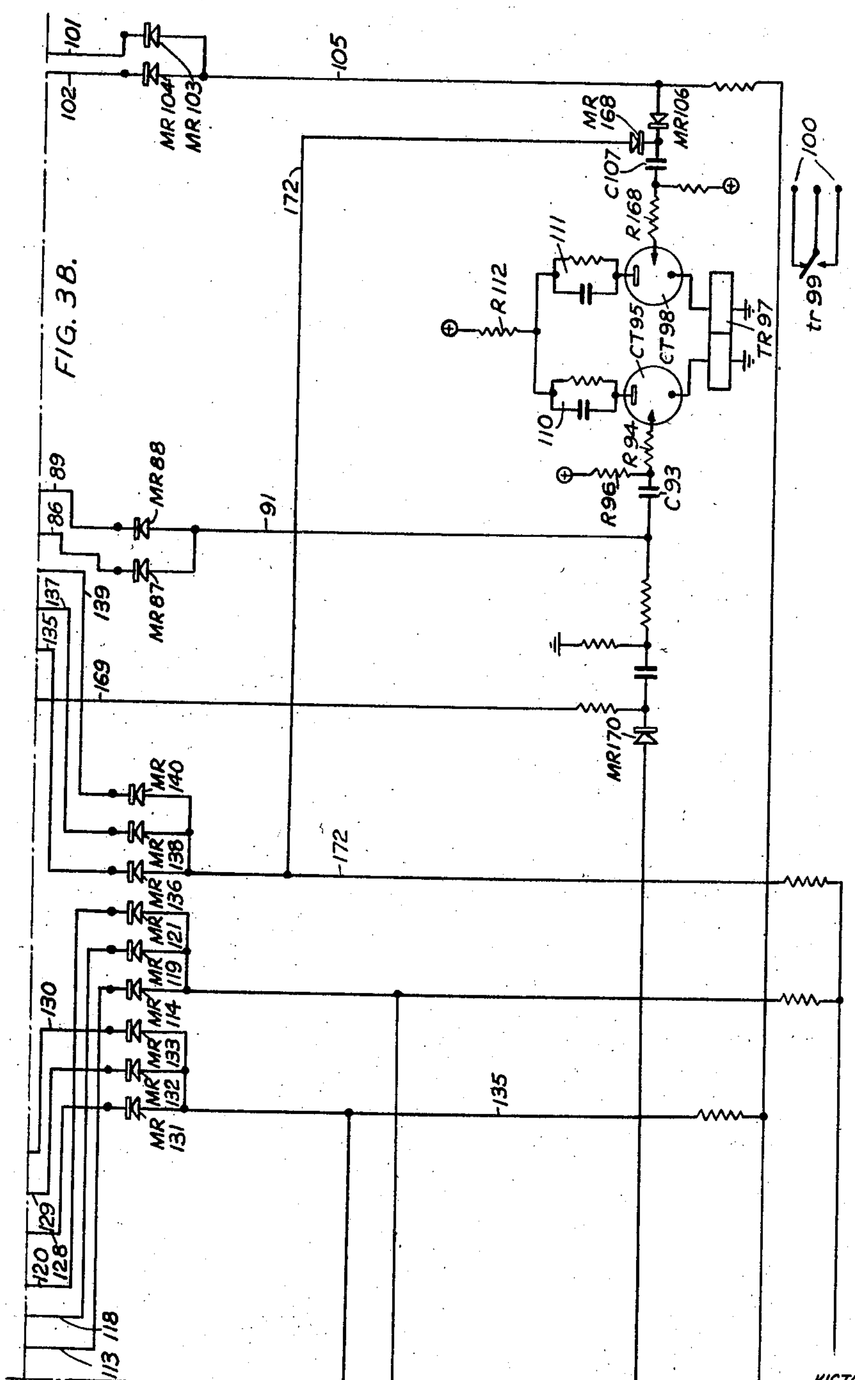

FIG. 3B.

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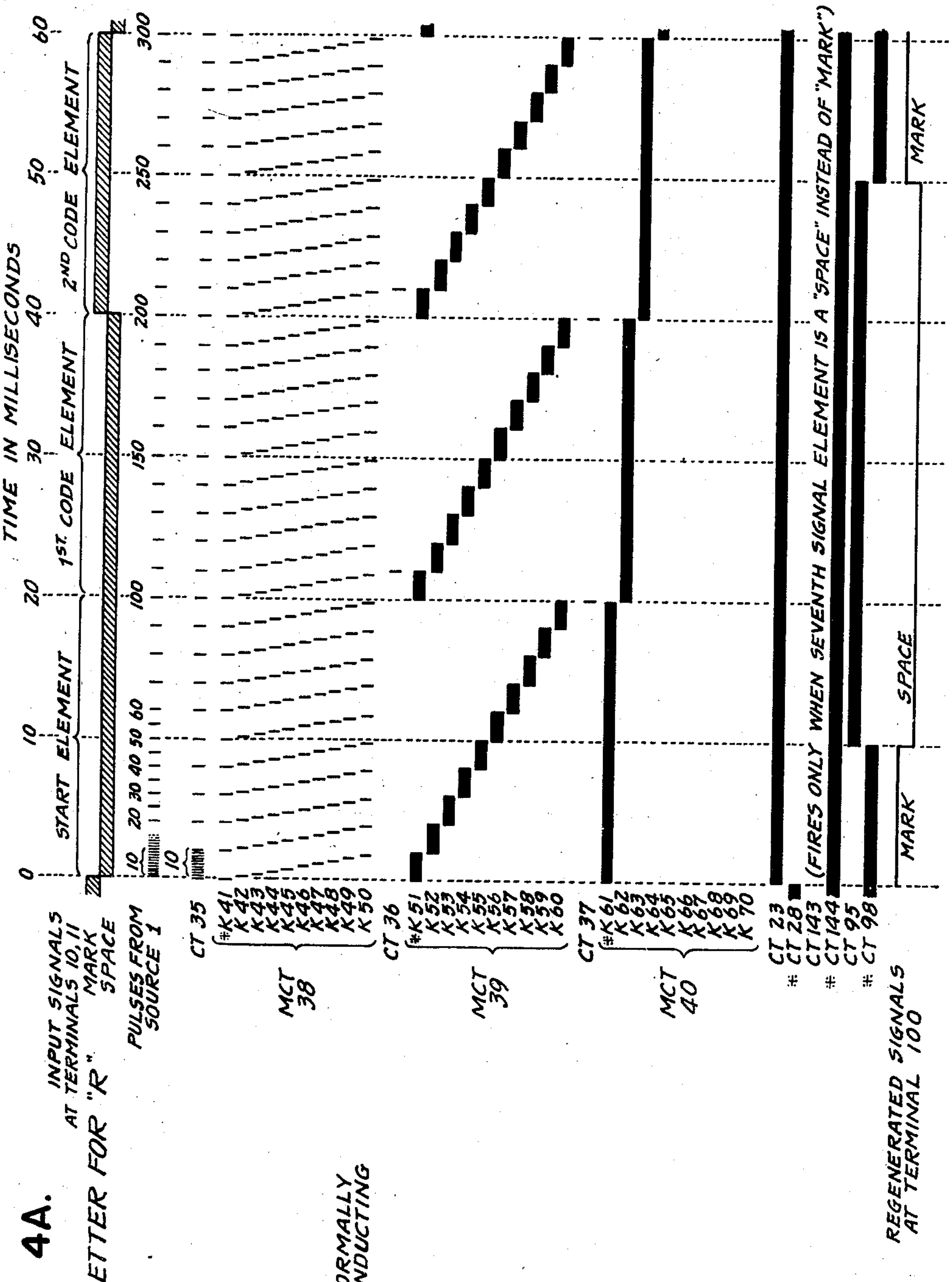

FIG. 4A.

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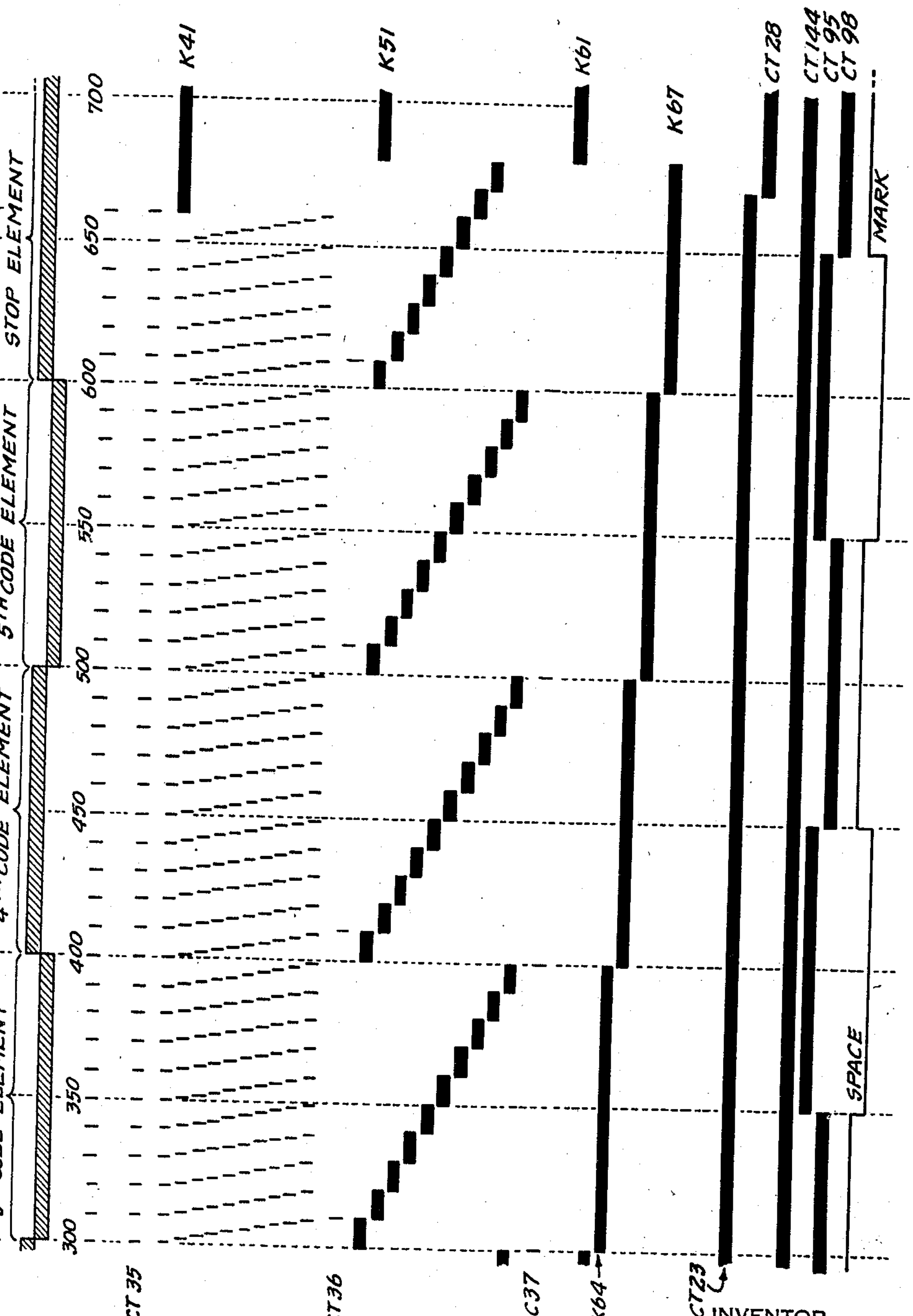

FIG 4B.

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TELEGRAPH REPEATERS

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Application March 29, 1949, Serial No. 84,104

Claims priority, application Great Britain April 1, 1948

8 Claims. (Cl. 178—70)

This invention relates to regenerative repeaters for start-stop printing telegraph signal combinations.

A start-stop printing telegraph signal combination consists of a code combination of an equal number of code elements transmitted successively, each code element consisting (as transmitted) of one or other of two different conditions, usually denoted "marking" and "spacing," persisting throughout the duration of the element. The duration of each code element is the same. The number of code elements is usually five or six and the code combination is immediately preceded by a start element of spacing condition and of duration equal to that of one of the code elements and is immediately succeeded by a stop element of marking condition. The nominal duration of the stop element is usually either equal to that of a code element, in which case the system is said to work (when a five-element code combination is used) on a seven-unit basis, or one and a half times that of a code element in which case the system (when a five element code combination is used) is said to work on a seven and a half unit basis.

Distortion in the line or other transmission medium alters the times of change-over between marking and spacing conditions and the function of a regenerative repeater is to respond to distorted signals and in response to retransmit signals in which each element is of the proper duration. For this purpose, and to ensure the proper response to signals that have suffered a large amount of distortion, the condition of the received signal in the line, or other transmission medium, is scrutinised substantially at the middle of each element period, and an element of the condition thus determined commences to be transmitted and is extended to its full duration. The regenerated and retransmitted signals thus lag behind the received signals by an interval equal to half a signal element period.

The object of the present invention is to provide a regenerative repeater for start-stop signal combinations.

Electronic regenerative repeaters are known in which vacuum tube means are used for timing the signal element periods, for scrutinising the incoming signals and for determining the transmission of the regenerated signals.

It is one object of the present invention to perform these functions by means of cold cathode gas-filled tubes and thus minimise the power drain and simplify the circuits of such regenerative repeaters.

According to one feature of this invention, there is provided a regenerative repeater for start-stop printing telegraph signal combinations comprising a chain of cold cathode gas discharge gaps each formed between a cathode and an anode, means for rendering these gaps conducting sequentially to time the intervals occupied by the elements of a signal combination, means under the joint control of said chain and the received signal operative at the middle of each signal element period to condition a transmitter circuit to cause said circuit to transmit a signal element of the same kind as that received and means to cause said transmitter circuit to remain in that condition until again reconditioned.

Preferably, the invention makes use of a source of pulses of repetition period short compared with the duration of a signal element. The receipt of a start element of a signal causes pulses from said source to be applied to the chain to cause the gaps to become conducting sequentially. A counting circuit or time-base circuit constituted by the chain of gaps is thus set into operation after the commencement of the start element with the very minimum of delay, this delay being at its maximum the repetition period of the pulses. The principle of starting a counting circuit at any instant or with a very brief delay is sometimes referred to as a "ratchet start" but hitherto a continuously operating source of pulses of very short repetition period has not been used for this purpose.

When signals are being received over a transmission circuit which includes a radio path, atmospheric or other interference may cause space condition to be delivered to the regenerator momentarily and thus simulate the commencement of a start element. A similar condition may occur owing to momentary interruptions of a line transmission circuit or momentary failure of power supply at any point. If a momentary spacing condition is received with regenerator circuits hitherto known, the circuits that control the timing of the scrutinising of the received signals will be set into operation but when the condition of the received signals is scrutinised in the middle of the start element period, the condition will be found to be marking and no start element will be sent forward regenerated. The regenerator, however, continues its cycle and a real signal which commences to be received during such cycle may be missed or mis-read.

In order to avoid such a state of affairs, the present invention provides a regenerative repeater for start-stop printing telegraph signal combinations comprising a time base for timing and counting the elements of a signal combination, means dependent on the commencement of a received start element for rendering said time base operative, means for examining the incoming signal condition at a time subsequent to said commencement and not later than the lapse of half a signal element period and means operative upon said condition received being then marking to render said time base inoperative and to restore the regenerator to initial condition.

The present invention is applicable, as will be clear from the above, to regenerative repeaters for regenerating signal combinations in which the stop period is equal in duration to one element period or to one-and-a-half element periods. If, however, the stop period is only equal to the one element period, special difficulties arise. If, in the received signals, the mark-space transits constituting the commencement of the start element are mistimed, corresponding errors appear in the durations of the stop periods. If these result in a stop period being shortened so as to be of much shorter duration than one element, a difficulty arises that further distortion of the stop period is likely to occur in subsequent transmission through a telegraph channel of limited speed. This distortion is likely further to reduce the length of stop periods at each new regeneration. If the stop period becomes reduced to as little as half an element period, it may be beyond the capacity of the transmission channel to retransmit the stop element at all. It is, nevertheless, essential in the regenerator, to allow for some shortening of the stop period to avoid cumulative errors in the case in which the source of signals is running slightly faster than the regenerator.

It has been found that a shortening, by one-quarter of an element period, of the period during which the stop condition is regenerated is adequate to cover normal differences of speed. The accurate transmission of a stop condition which is only three-quarters of an element period long is not beyond the capacity of the average transmission path.

Furthermore, when the maximum distortion does not exceed 50%, the occurrence of a stop period shorter than three-quarters of the normal length indicates a high degree of probability that the transit to a start condition which terminates the stop periods has been advanced by distortion. Accordingly, the delay in the instants when scrutiny of the received elements takes place which follows from delaying starting the counting train until a time corresponding to six and three-quarters element periods has elapsed since the previous transit to a start condition gives a high degree of probability that the scanning instants will approach more nearly to the ideal timing.

When telegraph signals are being repeatedly regenerated, as in the case of a long line, the full benefit of this feature of limiting the extent to which the regenerated stop period may be curtailed will not be realised if the minimum character lengths are not equal to a high degree of accuracy.

According to another feature of the present invention, there is provided a regenerative repeater for start-stop printing telegraph signal combinations of which each stop element nominally occupies one signal element period comprising means dependent upon the commencement of a received start element for rendering a time base circuit operative to time a signal combination, and means to cause said time base to become again dependent upon the commencement of a received start element after the lapse of a period after said first mentioned commencement less than the nominal period of a full signal combination by a period between 0.1 and 0.4 of an element period.

The choice of a minimum character length, in the case of 5-unit code combinations, lying between 6.6 and 6.9 element periods and preferably 6.75 element periods offers considerable advantages provided that all the regenerators used in a telegraph circuit yield identical minimum character lengths. As accuracy is as essential in timing the fractional part of the stop period as it is in timing the elements of the character, the timing of the duration of a character is preferably, therefore, placed under the control of a source of pulses of repetition period short compared with the duration of a signal element.

The invention will be better understood from the following description of one embodiment thereof taken in conjunction with the accompanying drawings, in which:

Fig. 1 consisting of Figs. 1A and 1B, and Fig. 2 consisting of Figs. 2A, 2B taken together represent a single circuit diagram of a rengerator. Fig. 1B being placed to the right of Fig. 1A and Figs. 2A and 2B being placed below Figs. 1A and 1B respectively.

Fig. 3 consisting of Figs. 3A and 3B, is a modification of that part of the circuit shown in Figs. 2A and 2B. Figs. 3A and 3B should accordingly replace Figs. 2A and 2B below Figs. 1A and 1B to form a single circuit diagram.

Fig. 4 consisting of Figs. 4A and 4B is a timing chart showing the operating sequence of the various electrodes of the multi-cathode tubes and various control tubes shown in Figs. 1A and 1B. Fig. 4B should be placed to the right of Fig. 4A.

The regenerative repeater shown in Figs. 1 and 2 uses a continuously-running source **1** of pulses of a short repetition period. These pulses may be derived from an oscillator operating at 5,000 cycles per second so that the pulses are delivered at 0.2 millisecond intervals. Pulses from the source **1** are delivered as negative-going pulses to the conductor **2** and are thus delivered to various points in the circuit of Fig. 1 which will be referred to hereafter. They are also delivered over a transformer T3 to a balanced modulator generally designated by the reference numeral **4**. The balanced modulator comprises the secondary of transformer T3, the primary of a second transformer T5, and four rectifiers, MR6, MR7, MR8 and MR9. The incoming telegraph signals are applied through terminals **10** and **11** between the mid-point of the secondary winding of transformer T3 and the mid-point of the primary of transformer T5. The primary of the transformer T3, the rectifiers and transformer windings forming the balanced modulator are so connected that when the incoming line is in the rest condition, that is, with a mark condition applied to terminals **10** and **11**, positive pulses appear on terminal **12** of the secondary of transformer T5 and negative pulses on terminal **13**, whereas when a spacing condition is applied to terminals **10** and **11**, positive pulses appear on terminal **13** and negative pulses on terminal **12**. Terminals **12** and **13** are connected over rectifiers MR14 and MR15 respectively to mark lead **16** and space lead **17** respectively. It will be seen that the rectifiers MR14 and MR15 suppress negative-going pulses so that when marking conditions are applied to terminals **10** and **11**, positive-going pulses appear on mark lead **16** and when spacing conditions are applied to terminals **10** and **11**, positive going pulses appear on the space lead **17**. The balanced modulator **4** is of known type but is employed in an unusual way to reverse the polarity of the pulses appearing on terminals **12** and **13** in accordance with the reversals of the received signal conditions which reversals are of course of a much lower frequency than that corresponding to the pulse repetition rate. The regenerator being described is intended for operation with a five-unit code and signal elements of 20 milliseconds duration corresponding to a signalling speed of 50 bauds.

It should be noted that the mid-point of the secondary of transformer T5 is connected to ground at **18**.

The change from the rest condition (mark) to space condition in the signals received on terminals **10** and **11** causes positive pulses to appear in the space lead **17**. This lead is connected over resistance R19, rectifier MR20, condenser C21 and resistance R22 to the control electrode of a three-electrode cold cathode tube CT23. A source of bias potential **24** is connected to the control electrode of the tube CT23 over a resistance R25 and the resistance R22 but is insufficient normally to render this tube conducting. The anode of the tube CT23 is connected to a suitable source of potential through a resistance R26 and also is connected over a condenser C27 to the anode of a similar tube CT28, the anode of which is connected to a suitable source of potential over resistance R29.

The potential from the source **24** and the resistances R22 and R25 and the anode potential of the tube CT23 are so arranged that the first pulse applied to the control electrode thereof, causes the tube to become conducting. Normally tube CT28 is conducting and the connections between the anodes of the two tubes CT23 and CT28 cause CT28 to be made non-conducting when tube CT23 becomes conducting. It is to be noted that the tube CT23 becomes conducting within a maximum limit of time of 0.2 milliseconds after the change over from mark to space, since this is the maximum time that can elapse after the change over before a pulse is applied to the control electrode of the tube.

When tube CT23 becomes conducting, current flows through the resistance R30 connected between its cathode and earth. The upper end of the resistance therefore becomes positive and positive potential is thus applied over conductor **31** to a counting circuit, Fig. 1A. The function of this counting circuit is to count the pulses from the pulse source **1** and thereby to time the signal element periods and the period occupied by a signal combination. The appearance of positive potential on the conductor **31** starts this counting circuit into operation as will be explained hereinafter. The pulses from the source **1** that are to be counted are applied over a conductor 2 and condensers C32, C33 and C34 respectively, to the cathodes of cold cathode tubes CT35, CT36 and CT37. The counting operation is performed by three multi-cathode tubes MCT38, MCT39 and MCT40. Each of these tubes MCT38, MCT39 and MCT40 is of the type described in the co-pending application of G. H. Hough, filed September 27, 1949, and bearing Serial No. 118,055. In tube MCT38, ten cathodes K41 to K50 are arranged in circular formation so that cathode K50 is adjacent to cathode K41, though for purposes of circuit description, the cathodes are shown arranged in line. Similarly, tube MCT39 is provided with ten cathodes K51 to K60 and tube MCT40 with the ten cathodes K61 to K70. Although the cathodes are arranged in a circle, the ionisation coupling from one gap is greater in the direction of the array from cathode K41 to K50 than in the other and similarly in the other two tubes. Tube MCT38 is provided with an anode 71 and tubes MCT39 and MCT40 are provided with anodes 72 and 73, respectively. Between each adjacent pair of cathodes in a tube there is a transfer electrode. All the transfer electrodes in tube MCT38 are denoted by the same reference numeral 74 and are connected in common to a conductor 75. The right-hand transfer electrode 74 of the tube MCT38 is positioned between the cathode K50 and the cathode K41 as above stated.

Similarly, transfer electrodes 76 are connected between the various cathodes K51 to K60 in tube MCT39 and are all connected to a common lead 77. Likewise, in tube MCT40 transfer electrodes 78 are provided between the various cathodes K61 and K70 and are connected to a common lead 79. The various cathodes K41 to K50, K51 to K60 and K61 to K70 are each separately connected to ground over separate time constant circuits each denoted by the reference numeral 80. Each time constant circuit 80 consists of a resistance and a condenser in parallel and the time constant thereof is greater than the duration of each of the pulses from the source 1 (Fig. 2A). In order not to unduly complicate the circuit diagram only some of the time constant circuits 80 have been shown. The operating sequence of the several cathodes K may be readily followed as this description proceeds with the aid of the timing chart shown in Fig. 4.

As previously stated, when the tube CT23 is made conducting a positive potential appears on the conductor 31 and is applied to a control electrode of the three element gas filled cold cathode tube CT35. Pulses from the source 1 are applied over conductor 2 and condenser C32 to the cathode of the tube CT35. This results in the tube CT35 becoming immediately conducting, and the passage of current through the resistance R81 connected in the anode circuit of the tube. This results in the application of a positive potential through condenser C82, over the conductor 75 to the transfer electrodes 74 of the tube MCT38. Initially, the gap between the cathode K41 and the anode 71 of this tube is conducting and the application of potential to that transfer electrode 74 which is between the cathodes K41 and K42 results in the transfer of the discharge from the gap between cathode K41 and anode 71 to one across the gap between the cathode K42 and the anode 71. The discharge between the cathode K41 and the anode 71 is at the same extinguished.

These events take place during the duration of the pulse that causes the tube CT23 to become conducting, the pulse length, 40 or 50 microseconds, being adjusted to be sufficient for this purpose. It is to be understood that the tube CT35 can only become conducting when a positive potential is applied over conductor 31 coincidentally with a negative pulse over conductor 2. Upon the cessation of the pulse applied over conductor 2 the tube CT35 becomes extinguished. Whilst the bias on the conductor 31 persists, the tube CT35 becomes conducting on each pulse applied over conductor 2 and therefore applies a pulse, positive going in this case, to a transfer electrode 74 of the tube MCT38. The positive pulse thus applied is sufficient in conjunction with the bias applied over the resistor R83 to cause the transfer of the discharge in MCT38 from one cathode to the next in the direction from left to right in the drawing. On the ninth pulse over the conductor 2 the discharge is transferred to cathode K50 and on the 10th pulse, a discharge reappears on cathode K41.

After the disappearance of the ninth pulse and whilst the cathode K50 is still discharging, the potential at the upper end of the time constant circuit 80 connected to cathode K50 rises sufficiently to apply a positive potential to the control electrode of tube CT36. The result is that when the tenth pulse is applied over conductor 2 and thus over condenser C33 to the cathode of tube CT36, this tube becomes conducting and acts to cause the application of a positive potential to conductor 77, which is added to the potential of the bias source applied over resistance R84 and so causes the discharge in the gap between cathode K51 and anode 72 to be transferred to the gap between the next cathode K52 and the anode. At the same time the effect of the same pulse applied through the tube CT35 to conductor 75 causes the discharge to be transferred from cathode K50 of tube MCT38 to the next cathode in the circle, namely, K41. The nineteenth pulse over conductor 2 causes cathode K50 to discharge and the twentieth pulse causes cathodes K41 and K53 to discharge. The fiftieth pulse causes cathodes K41 and K56 to discharge. Each time that cathode K50 discharges and when the pulse that has caused the discharge has died away the current between the anode 71 of tube MCT38 and cathode K50 flows to earth through the time constant circuit 80 connected to that cathode. This causes a potential to be applied to rectifier MR87 over conductor 85 and conductor 86. Similarly when a discharge occurs between cathode K56 and anode 72 of tube MCT39, a potential is applied to rectifier MR88 over conductors 90 and 89. The other terminals of the rectifiers are connected together and over a resistance to the wire 17. The connections of the cathodes K50 and K56 respectively, to the rectifiers MR87 and MR88 and the connection including the junction point of the other terminals of these rectifiers constitute a gate circuit as described and claimed in the co-pending application Serial No. 90,326, filed April 29, 1949, the effect of which is that when a discharge passes to one of these two cathodes only, the potential impressed upon the junction point between the rectifiers MR87 and MR88 by the pulse over lead 17 is low, because a path is found to earth over the circuit 80 of the other cathode, but when a discharge is passing from both cathodes, an appreciable positive potential is impressed upon this point from the lead 17, because flow of current will be blocked by the bias on the other side of the rectifiers. It will be noted that the first time that such a positive potential is impressed on this point is after the forty-ninth pulse. This potential is impressed over conductor 17 and over rectifier MR92 onto condenser C93, the other side of which is connected over a resistance R94 to the trigger electrode of a three element cold cathode tube CT95. This trigger electrode is connected over resistances R94 and R96 to a source of bias potential insufficient to trigger the tube. When a pulse arrives from terminal 13 over space lead 17, that is, on the next occurrence of a pulse from the pulse source 1, the potential of the trigger electrode of tube CT95 is raised sufficiently to cause a discharge in that tube. Thus if the condition of the incoming signal applied to terminals 10, 11 is still spacing, tube CT95 will be rendered conducting on the fiftieth pulse and current will flow through the space winding of a telegraph relay TR97, which winding is connected between the cathode of tube CT95 and earth. The tube CT95 together with another like tube CT98 and their circuit connections form a transmitter circuit, CT95 being the space tube and CT98 the mark tube. The cathode of tube CT98 is connected to earth through the mark winding of the telegraph relay TR97, which at its contacts *tr*99 transmits the regenerated signals to the outgoing line **100**.

It will be noted that the conductors **90** and **85**, in addition to being connected to conductors **89** and **86** are also connected through conductors **101** and **102** respectively and rectifiers MR103 and MR104 to a conductor **105** which is connected over rectifier MR106, condenser C107 and resistance R108 to the trigger electrode of tube CT98. Mark lead **16** is also connected to conductor **105**. Tube CT98 is initially conducting and thus the bias impressed over conductor **105** from the cathodes K50 and K56, after the forty-ninth pulse, has no immediate effect, since its function is to prevent the lowering of the potential on the trigger electrode of tube CT98 when positive pulses appear over lead **16**. Tubes CT95 and CT98 are connected through individual time constant circuits **110** and **111** and a common resistance R112 to a common source of anode potential. The consequence of this connection is, that when CT95 becomes conducting, CT98 is made non-conducting and current ceases to flow through the mark winding of relay TR97. As current through tube CT95 flows through the space winding of that relay, the contacts *tr*99 of the relay change over and the signal transmitted over the outgoing line **100** changes from mark to space and this is the commencement of the retransmission of the incoming signal.

It will be noted that this change over occurs on the receipt on the fiftieth pulse from the source **1** and therefore is approximately ten milliseconds after the commencement of the received space element. It will be noted that cathodes K50 and K56 will not be discharging simultaneously again until the occurrence of the hundred-and-forty-ninth pulse and that therefore bias potentials sufficient to trigger either one of the tubes CT95 and CT98 will not be impressed upon the trigger electrode of one of these tubes until the occurrence of the hundred-and-fiftieth pulse, that is, until after the lapse of a further period of twenty milliseconds which is just before the middle point of the next signal element, the first code element of the signal combination. At this instant either tube CT98 will be triggered or tube CT95 will remain conducting according as the hundred-and-fiftieth pulse appears on mark lead **16** or on space lead **17**, that is, according to whether the incoming signal condition on terminals **10** and **11** is mark or space. The transmitter circuit will accordingly be conditioned in accordance with the incoming signalling condition at that instant to transmit a regenerated signal element, and will remain so conditioned for 20 milliseconds.

This conditioning of the transmitter circuit will recur at intervals of 20 milliseconds and all the code elements of the incoming signal will be scrutinised at approximately the middle of the corresponding signal element and like signal elements will be regenerated and retransmitted. Finally the stop element will be scrutinised at 130 milliseconds after the commencement of the start element of the incoming signal and since a mark condition, denoting the stop element of the signal combination will then be applied to terminals **10** and **11**, tube CT98 will be triggered to cause contacts *tr*99 of relay TR97 to transmit a marking condition to the outgoing line **100**.

The function of tube MCT38 is to count all the pulses from conductor **2**, tube MCT39 to count every 10th pulse and the function of tube MCT40 is to count every 100th pulse. It has previously been pointed out that a pulse is transferred from one cathode to the other of tube MCT39 when a bias potential is impressed on the trigger electrode of tube CT36 from cathode K50. Inasmuch as cathode K60 when it commences to discharge remains discharging during 10 pulse periods it is essential that a bias potential shall not be impressed on the trigger electrode of tube CT37 during the whole of this period as otherwise tube MCT40 would count each pulse applied to it from the pulse generator **1** over conductor **2** and condenser C34 during those ten pulse periods. Accordingly a rectifier MR113 is connected between the cathode K50 of tube MCT38 and the cathode K60 of tube MCT39. This rectifier MR113 shunts the potential derived from the current flowing from cathode K60 of tube MCT39 through its own time constant circuit **80** to earth by a path through the time constant circuit **80** associated with cathode K50 of tube MCT38 to earth. Whilst cathode K50 is discharging, however, rectifier MR113 is blocked and the potential derived from cathode K60 when it is discharging is applied to the trigger electrode of tube CT37 which is therefore rendered conducting by a pulse received from pulse generator **1** over conductor **2**. Thus a pulse is only passed over conductor **79** to the transfer electrode **78** of tube MCT40 when both cathodes K50 and cathodes K60 are simultaneously discharging. Thus every hundredth pulse causes the discharge in tube MCT40 to be transferred from the cathode which is then discharging to the next cathode. The cathode K61 is normally discharging and on the first impulse passed to conductor **79** the next cathode K62 discharges. This occurs after the hundredth pulse applied to conductor **2** from the source **1** and each hundredth pulse is passed on in like manner to cause successive cathodes of the tube MCT40 to discharge. The successive gaps in the tube MCT40 will therefore discharge or be rendered conducting at 20 millisecond intervals.

The purpose of the tube MCT40 is to measure out the length of a signal combination. It is assumed in the present description that the system is working on a seven unit basis so that the stop element of a signal combination as originally transmitted is equal to the length of one of the code elements. As stated above, it is important to measure the minimum length of a signal combination to a high degree of accuracy and in the embodiment of the invention being described the minimum character length is set at 6.6 element periods, that is to say, a period of 132 milliseconds. Accordingly in the circuit shown in Figs. 1 and 2 a time of 132 milliseconds is measured and the time base or counting circuit of Fig. 1 is then restored automatically to its normal condition in which it is again dependent upon the commencement of a received start element.

After the 132 milliseconds cathodes K50, K58 and K67 will be simultaneously discharging for the first time and potential will be passed from cathode K50 over a conductor **85** to be applied to rectifier MR114. At the same time potential is impressed from cathode K58 over conductor **118** to rectifier MR119. Potential is also impressed from cathode **67** over line **120** to rectifier MR121. The other sides of these rectifiers are connected together and to lead **16** over a resistance and this point of juncture is connected to the trigger electrode of tube CT28 through rectifier MR115, condenser C116, and resistor R117. The connections from the cathode K50, K58 and K67 through the rectifiers MR114, MR119 and MR121 constitute a gate circuit of the kind above referred to, the effect of which is that a potential is not applied to the trigger electrode of the tube CT28 until all three cathodes are discharging. A bias potential is applied to the trigger electrode of the tube CT28 through the resistance R122 but this is not sufficient to trigger the tube. The mark lead **16**, as stated above, is connected over conductor **123** to the rectifier MR115 and on the occurrence of the next pulse on the mark lead the tube CT28 is triggered. This causes the tube CT23 to extinguish and thus cuts off the source of pulses from the counting circuit by removing the bias from the trigger electrode of CT35. In the absence of this path the tube CT35 is unable to pass on pulses from the conductor **2** to trigger tube MCT38, and the counting process comes to an end. The negative pulse induced in the secondary winding of the transformer T124 is applied over condenser resistance combinations to the conductors **125**, **126** and **127** and thus to the cathodes K41, K51 and K61 respectively, thus bringing these cathodes into the discharging condition ready to commence another count. The gaps that were conducting in the tubes MCT38, MCT39 and MCT40 are extinguished owing to the action of the common anode resistance of each tube in well known manner.

The whole circuit is thus restored to the initial condition in which tubes CT28 and CT98 are conducting and cathodes K41, K51 and K61 are discharging. Since tube CT98 is conducting, current is passing through the mark winding of relay TR97 and contacts *tr*99 transmit a mark condition to the outgoing line **100**. If now a new incoming signal combination commences with a transit to the space condition and the counting circuit is again set into operation, the tube CT98 will remain conducting for a further period of 10 milliseconds thus ensuring the transmission of a minimum stop element of 16 milliseconds duration. It is to be understood that the conductors **113**, **118** and **120** may be connected to other cathodes of the tubes MCT38, MCT39 and MCT40 respectively if a different minimum stop timing is required.

Another facility which is referred to earlier in the specification is the suppression of a false start. This is provided as previously explained to prevent a momentary space condition delivered to the regenerator simulating the receipt of a start element. This facility is provided by examining the start element at some time less than or equal to 10 milliseconds after the initiation of the count to see whether the line condition is still at space and, if it has returned to mark, the count is stopped and the circuit restored to normal. At 10 milliseconds after the commencement of the count the cathodes K50, K56 and K61 are discharging and this combination does not recur during the remainder of the signal combination.

Cathode K50 is connected through conductors **85** and **128**, rectifier MR131 to a common point to which cathode K56 is connected over conductors **90** and **129** and rectifier MR132 and to which cathode K61 is connected over conductor **130** and rectifier MR133, this common point being connected over rectifier MR134 and to the trigger electrode of tube CT28. If the coincidence of the bias applied from all three cathodes also coincides with a positive pulse on the mark lead **16**, which is connected through a resistance to the common point above referred to over conductor **135***a*, the result will be that the tube CT28 will be triggered in exactly the same way as described above for the minimum stop facility and produce the same result, namely, stopping the count and restoring the multi-cathode tubes to normal rest condition.

For many applications it is now necessary that a regenerator shall be able faithfully to retransmit a signal consisting of a long application of spacing condition to the line. Such signals are required in connection with supervisory equipment associated with printing telegraph exchange systems and are used to indicate that the transmission over a particular circuit is completed and that the circuit can be released and reconnected to form a part of another through connection.

It can be seen that in the arrangements described above the condition of the incoming line is examined at or after the expiration of a 130 milliseconds from the start. If the seventh signal element is a space and not a mark, as it would normally be at the end of a signal combination, it is to be presumed that a long spacing condition is being transmitted. At this time, cathodes K50, K55 and K67 are discharging. Cathode K50 is connected over conductors **85** and **135**, rectifier MR136 to a common point to which cathode K55 is connected over conductors **90** and **137** and rectifier MR138 and cathode K67 is connected over conductors **120** and **139** and rectifier MR140. This common point is connected over condenser C141 and resistance R142 to the trigger electrode of a tube CT143. CT143 is one of a pair of tubes CT143 and CT144 of which CT144 is normally triggered. Space lead **17** is connected over conductor **145** to the common point of rectifiers MR136, MR138 and MR140 and if, therefore, there is a positive pulse on space lead **17** at the moment when the bias potential is applied to these rectifiers from the cathodes K50, K55 and K67, tube CT143 will be triggered. The firing of tube CT143 extinguishes tube CT144. The triggering of tube CT143 causes a rise of potential to occur over resistance R146 and this is applied over condenser C147, rectifier MR148, condenser C116, resistance R117 to the trigger electrode of tube CT28 which is therefore triggered and extinguishes tube CT23. The extinguishing of tube CT23 restores the counting circuit to normal as previously described. When tube CT144 is extinguished the positive pulses which are appearing on space lead **17** are short circuited to earth over resistance R19 and rectifier MR149 and resistance R150.

Before tube CT144 is extinguished a potential drop across R150 blocked rectifier MR149 and rendered the short circuit ineffective. On the other hand, rectifier MR151 is now blocked by the potential developed across resistance R146, since tube CT143 is conducting, so that any positive pulses which appear on the mark lead **16** will pass over conductor **152**, conductor **153**, rectifier MR154, condenser C21, resistance R22 to the trigger electrode of tube CT23. Consequently, when a mark condition is restored on the incoming line after the long space supervisory signal, tube CT23 is fired by the first positive pulse on the mark lead **16** and thus starts the counting circuit into operation. The process continues for a period of 10 milliseconds until cathodes K50 and K56 are together discharging, whereupon potential is impressed from cathode K50 over conductors **85** and **155** to rectifier MR156, at the same time as potential is impressed from cathode K56 over conductors **90** and **157** to rectifier MR158. These rectifiers are connected through condenser C159 and resistance R160 to the trigger electrode of tube CT144. The potential from mark lead **16** triggers tube CT144 and extinguishes tube CT143. The consequential rise of potential across resistance R150 passes a pulse of potential through condenser C161, rectifier MR162, condenser C116 and resistance R117 to the trigger electrode of tube CT28 and thus triggers this tube to restore the whole regenerator to normal as previously described. The 10 millisecond delay before the coincidence occurs on cathodes K50 and K56 is added to the transmitted long space condition and replaces the 10 milliseconds lost at the commencement.

Rectifiers MR163 and MR164 on the one hand and rectifiers MR165, MR166, MR167 and MR168 on the other ensure that the space and mark tubes CT95 and CT98 respectively are supplied with a continuous train of pulses when the incoming line is resting in space or mark condition. This is not an essential feature but has been included to preclude any danger of the tube which should be discharging becoming extinguished during any transient condition. Such failure might otherwise result in the regenerator going out of service.

Fig. 3 shows a modification of Fig. 2 whereby a further facility may be provided, namely, enforced stop insertion. The system described up to now provides that each character received shall terminate with a seventh element of mark condition forming the stop element period and this is regenerated and retransmitted, but measured off to a definite length if desired. In certain circumstances distortion may occur to such a degree that the stop period is lost altogether or is displaced in time and there is therefore a danger that no stop element will be sent forward. This is more likely to occur when the circuit includes a radio link on which fading is occurring. Figure 3 shows a circuit which is arranged so that the regenerator operates automatically to commence to transmit a stop condition 120 milliseconds after it first commences to retransmit the start element irrespective of the condition of the incoming line. In the following description Fig. 3 forms a single circuit diagram with certain of the connections from Fig. 1. Insofar as the elements of Fig. 3 are the same as those of Fig. 2 and perform the same function they are designated with the same reference numerals. It is clear, however, that when the enforced stop insertion facility is provided it is inconsistent with the provisions for the precise measurement of the duration of a signal combination that have been previously described and is also inconsistent with the facility of transmitting a long space signal and accordingly the circuits of Fig. 3 are simplified by omitting those parts of Fig. 2 that are required for those facilities. It is to be understood that the circumstances in which it is required to provide the enforced stop insertion facility are not those in which it is required to transmit a long space.

The circuit of Fig. 3 accordingly operates similarly to that of Fig. 2 in its response to the commencement of a start signal and starts up the counting circuit of Fig. 1 in the same manner. In the same manner as in Fig. 2 bias potential is impressed upon both the space lead **17** and the mark lead **16** and therefore on the control electrodes of the tubes **CT95** and **CT98** at 10 milliseconds after the commencement of the incoming start element and at a period of 20 milliseconds thereafter, and the transmitter circuit constituted by tubes **CT95** and **CT98** acts in exactly the same manner as the similar transmitter circuit in Fig. 2 to retransmit the regenerated signal elements.

At the end of 120 milliseconds cathode **K67** of tube **MCT40** commences to discharge for the first time and a positive potential is applied from its cathode over conductor **120**, Fig. 1 to conductor **169**. Between the terminal **13** of transformer **T5** and the point of connection of conductor **169** to the space lead **17** there is a rectifier **MR170** so arranged that it becomes of high resistance when the potential is applied to it over the conductor **169**. This prevents pulses from the space lead being applied to the trigger of the space tube **CT95** which therefore cannot be rendered conducting from then onwards. In Fig. 3 the primary winding of transformer **T3** is provided with an additional winding **171** and thus positive pulses from this winding go into a conductor **172** by means of which they are applied over rectifier **MR168** to the trigger electrode of tube **CT98** provided there is a potential on conductor **105** which is impressed thereon by the coincidence circuit previously described formed by rectifiers **MR104** and **MR103** from the cathode circuits of **K50** and **K56**. This coincidence occurs 10 milliseconds after the cathode **K67** has commenced to discharge, that is, 130 milliseconds from the commencement of the count which is immediately at the end of the transmission of the sixth element of the retransmitted signal. The transmission of a mark period therefore always follows the transmission of the code elements of a signal. After a further six milliseconds, that is, after 136 milliseconds from the commencement of the count, cathodes **K50**, **K58** and **K67** will be simultaneously discharging for the first time and the simultaneous occurence of potentials impressed over conductor **113** upon rectifier **MR114**, over conductor **118** upon rectifier **MR119** and over conductor **120** upon rectifier **MR121** will permit a potential to be impressed over rectifier **MR115**, condenser **C116** and resistance **R117** on to the trigger electrode of tube **CT28**, whereupon this tube will be triggered and the count will be brought to an end and the counting circuit restored to normal condition in the manner previously described with reference to Fig. 2. There will therefore be a compulsory insertion of a stop period of at least 16 milliseconds.

Whilst the principles of the invention have been described in connection with a specific embodiment intended for operation with five unit code combinations and for a speed of 50 bauds it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of the invention. The following are some, but not all of the modifications that may be made.

Thus a counting circuit could be used constituted by well known "counting chains" of cold cathode gas discharge gaps in which each discharge gap is contained in an individual tube, and the circuit connections ensure that the tubes become conducting one at a time in turn, the striking of each tube extinguishing the previous tube in the chain. It is, however, even in this case not necessary to use a number of tubes equal to the number of pulses to be counted, since the tubes can, in known manner, be arranged in separate sets to count units, tens, hundreds etc. pulses or on any other scale of notation.

Furthermore, although a counting circuit has been described in which use is made of multi-gap discharge tubes of the kind described in the copending application Serial No. 118,055, referred to above it will be clear that, by the use of the appropriate circuit connections described in copending application of D. S. Ridler, Serial No. 100,462, filed June 10, 1949, earlier types of multi-gap cold cathode discharge tubes may be employed.

It is also to be noted that, instead of the three multi-gap tubes counting pulses on the decimal scale of notation, a binary counting chain could be used. Thus the pulse generator **1** could supply 6,400 pulses per second and these could be applied (through a gate circuit as described herein) to a binary counter consisting of successive pairs of cold cathode tubes as described in the U. S. Patent No. 2,576,099, issued on November 27, 1951 to Frederick Harry Bray, George Clifford Hartley and Desmond Sydney Ridler. Each pair of tubes halves the frequency so that the reduction from 6,400 pulses per second to 100 pulses per second (the pulse period of which measures the 20 m. s. element periods) can be effected by six pairs of tubes and the necessary bias for carrying out operations after periods which are not multiples of 20 milliseconds can be obtained from a combination of several tubes in the binary chain.

Although the regenerator described uses a contact making relay to effect the re-transmission of signals it is clear that this re-transmission could be effected by connecting the line wires to appropriate points in the transmitter circuit constituted by the pair of tubes **CT95** and **CT98**.

What is claimed is:

1. Regenerative repeater for start-stop printing telegraph signal combinations comprising a chain of cold cathode gas discharge gaps, each formed between a cathode and an anode, means for rendering said gaps conducting sequentially to time the intervals occupied by the elements of a signal combination, a transmitter circuit, means under the joint control of said chain and the received signals operative at the middle of each signal element period to condition said transmitter circuit to cause said circuit to transmit a signal element of the same kind as that received and means to cause said transmitter circuit to remain in that condition until again reconditioned.

2. Regenerative repeater as claimed in claim 1, comprising a source of pulses of repetition period short compared with the duration of a signal element and means operative upon the receipt of the start element of a signal combination to cause pulses from said source to be applied to said chain to cause said gaps to become conducting sequentially.

3. Regenerative repeater as claimed in claim 2 in which said chain of gas discharge gaps is divided into a plurality of sets, the gaps in one set being rendered conducting one at a time in turn on the application thereto of successive pulses from said source and the gaps in an-

other set being rendered conducting one at a time in turn on the occurrence of a conductive condition across a given one of said first set of gaps.

4. Regenerative repeater as claimed in claim 1 in which said chain of gas discharge gaps comprises one or more sets of gaps, each set being contained within a single envelope and in which the means for rendering the gaps conducting sequentially comprises auxiliary electrodes, one adjacent each gap.

5. Regenerative repeater as claimed in claim 4 in which each gap of any one of said sets of gaps is formed between an individual cathode and an anode common to the set.

6. Regenerative repeater as claimed in claim 1, comprising a source of pulses of repetition period short compared with the duration of a signal element, means operative upon the receipt of the start element of a signal combination to cause pulses from said source to be applied to said chain to cause said gaps to become conducting sequentially, and means operative only upon the joint occurrence of a conducting condition in each of a plurality of gaps in different sets of said gaps to condition said transmitter circuit.

7. Regenerative repeater for start-stop printing telegraph signal combinations comprising a normally operating source of pulses of repetition period short compared with the duration of an element of a signal combination, a counting circuit means operative upon the receipt of a start element of a signal to cause pulses from said source to be applied to said counting circuit for counting said pulses, means controlled by said counting circuit for scrutinising the received signals after a number of pulse periods equal to half a signal element period after the said commencement and at times equal to the number of pulse periods in a signal element period thereafter, a transmitting circuit, means controlled by the condition of the incoming signals at said times to condition said transmitter circuit to transmit a signal element of the same kind as that received at the respective times, and means to cause said transmitter circuit to remain in that condition until again reconditioned.

8. Regenerative repeater for start-stop printing telegraph signal combinations comprising a normally operating source of pulses of repetition period short compared with the duration of an element of a signal combination, a transmitter circuit, means dependent upon the condition of the incoming signals to cause said pulses to be applied to one or another point of said transmitter circuit, a counting circuit, means operative upon the receipt of a start element of a signal to cause pulses from said source to be applied to said counting circuit for counting said pulses, means controlled by said counting circuit for applying a bias potential to both said points of said transmitter circuit at the middle of each signal element period from said receipt of a start element and means operative jointly by the pulses and said bias potential at one of said points in said transmitter circuit to cause the transmission of one or another signalling condition during a signal element period.

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