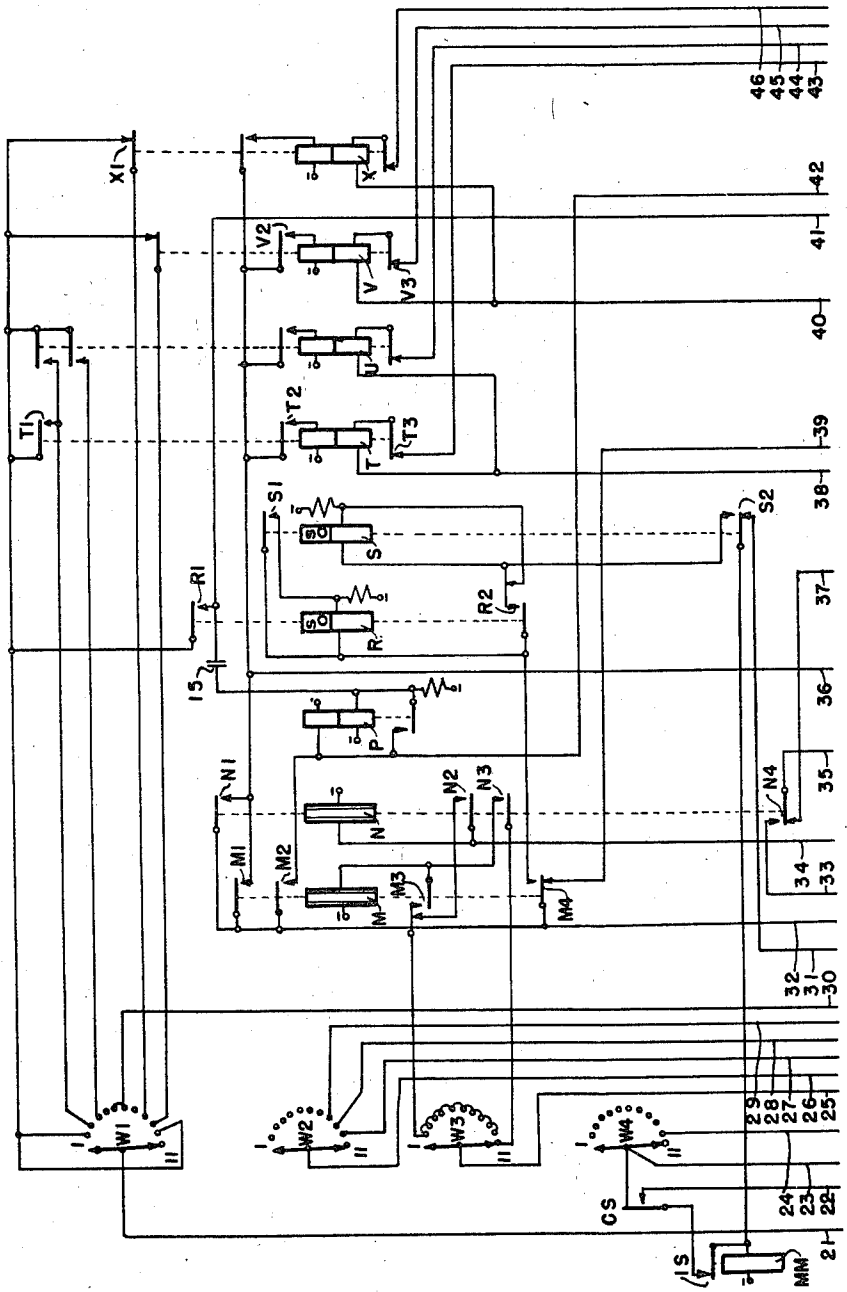
Feb. 18, 1947. F. KESSLER ET AL 2,416,102

IMPULSE TESTING APPARATUS

Filed Jan. 8, 1945 2 Sheets-Sheet 1

FIG. 1



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IMPULSE TESTING APPARATUS

Filed Jan. 8, 1945 2 Sheets-Sheet 2

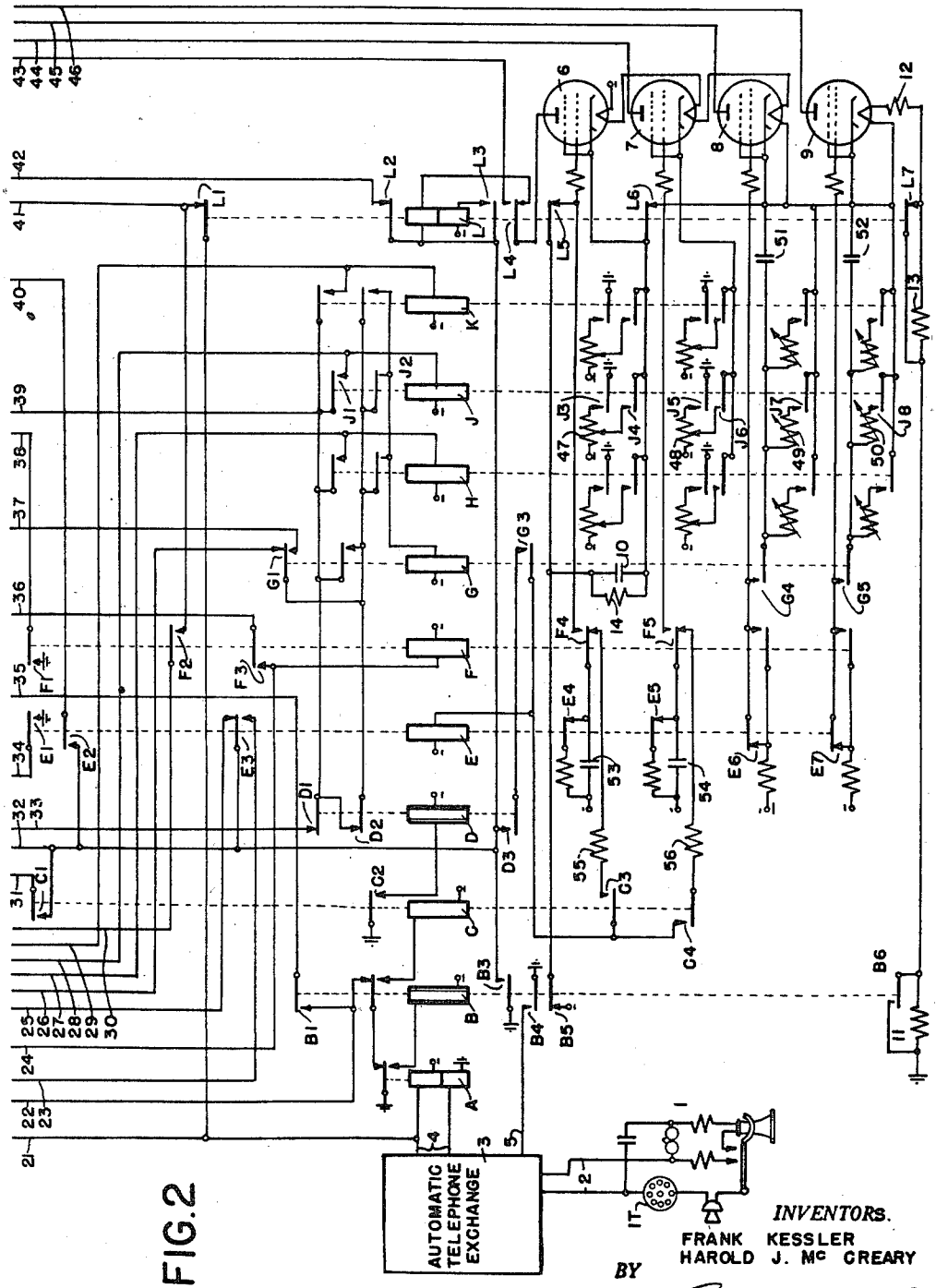


FIG. 2

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Patented Feb. 18, 1947 2,416,102

UNITED STATES PATENT OFFICE

2,416,102

IMPULSE TESTING APPARATUS

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Application January 8, 1945, Serial No. 571,782

13 Claims. (Cl. 179—175.2)

1

The present invention relates in general to apparatus for testing the operation of an impulsing contact and in particular to apparatus for remotely testing the operation of an impulse transmitter located at a subscriber substation of an automatic telephone system.

The operation of the switching equipment of an automatic telephone exchange depends upon both the speed and the impulse ratio of the impulse it receives from the transmitter at a subscriber substation. Heretofore, automatic testing apparatus has been provided to test the speed of operation of the impulse transmitter without the intervention of an operator but the assistance of a test operator at the exchange has been required to perform an impulse ratio test.

It is an object of the invention, therefore, to provide an automatic means operative under the control of the impulse transmitter at a subscriber substation to perform an impulse ratio test on impulses received therefrom.

A further object of the invention is to provide a means for simultaneously measuring the speed and impulse ratio of an impulsing contact.

Still another object is to provide a means operative from the subscriber's substation for selecting the limits between which the impulse transmitter thereat is to be tested.

A feature of the invention is the provision, in a testing apparatus of the above described type, of means for verifying that the proper number of impulses required to perform a test are received.

It is believed that a complete understanding of the invention may be had by reference to the following description taken in conjunction with the accompanying drawings comprising Figures 1 and 2, which taken together form a complete schematic diagram of the testing apparatus.

It is contemplated that the testing apparatus may be made an integral part of a conventional telephone exchange or that it may be made as a separate portable unit which may be connected to the exchange switching equipment as required. To this end the apparatus is made as complete in itself as possible. The only connections which need be made to the regular exchange equipment are two connections to the exchange battery and three connections to the bank contacts of a selector through which the testing unit may be reached by the exchange switching equipment. The three connections to the selector include two line leads over which the subscriber loop is extended and the private, or holding lead, over which the switch train is held under the control of the subscriber loop circuit. The line leads terminate in an impulsing relay which is preferably of the same type

2

and has the same impulsing characteristics as the corresponding line relays in the switching equipment. Contacts of this impulsing relay are arranged to control a group of relays and a rotary swtch to perform the desired tests in response to operation of the impulsing relay by the transmitter at a subscriber substation. The first series of operations of the impulsing relay causes the apparatus to select the desired limits between which the test is to be made. A succeeding series of a predetermined number of operations of the impulsing relay causes simultaneous tests to be made which determine whether the speed and impulse ratio are within the selected limits. The apparatus then returns a coded tone signal to the subscriber substation indicative of the results of the test and also indicative of whether the required predetermined number of impulses were received. The actual measurement of the speed and impulse ratio is performed by a series of condenser-resistor networks and associated gaseous discharge tubes. The speed measurement is accomplished by causing a pair of initially charged condensers to be partially discharged during the time that the predetermined number of operations of the impulsing relay takes place. The charge which remains on these condensers is then an indication of the total duration of the series of impulses. The remaining charge is measured by two gaseous discharge tubes and relays controlled by these tubes are operated in accordance with whether the remaining charge is within the previously selected limits. The impulse ratio measurement is accomplished by a further pair of initially discharged condensers which are partially charged during the break periods of the received series of impulses. The charge which these condensers receive is then an indication of the total duration of the break periods of the series of impulses. This charge is measured by a further pair of gaseous discharge tubes and relays controlled by these tubes are operated in accordance with whether the charge is within predetermined limits. The relays controlled by the gaseous discharge tubes prepare marking circuits to the banks of the rotary switch from a tone generator. The rotary switch is then operated to successively connect the subscriber line to the several marking circuits and thereby causes a coded tone signal to be returned to the subscriber substation indicative of the results of the speed and impulse ratio test.

Referring now to the drawings, a subscriber substation 1 is shown connected via line 2 to an automatic telephone exchange 3. By dialing an appropriate number over line 2 from the subscriber substation, line 2 may be extended by means of the exchange switching equipment to line 4. The usual impulse transmitter IT transforming a part

of the subscriber telephone may be employed for this purpose or, if it is so far out of adjustment as to preclude proper operation of the exchange switching equipment, a separate impulse transmitter such as is usually carried by telephone maintenance men may be used. When the subscriber loop is extended to line 4 a circuit is completed to relay A which operates and closes a circuit to relay B. Relay B operates, at contacts B4 grounds lead 5 to hold the switching equipment in the exchange through which the subscriber loop is extended, at contacts B3 connects ground or plus battery to the anode of tube 6 through the upper winding of relay L, at contacts B5 disconnects negative battery from condenser 10, and at contacts B6 short-circuits resistor 11. The heaters of tubes 6, 7, 8 and 9 are connected in series with each other and with resistors 11 and 12. These resistors are of such a value that the heater current is below its normal value so as to substantially prolong the life of the tubes and yet so as not to require an undue length of time for the cathodes of the tubes to reach their normal operating temperature when the heater current is increased to normal. Resistor 11 preferably has a value such that the heater current will be greater than normal when it is short-circuited by contacts B6 so as to accelerate the warming up operation. The heater current is returned to normal when the short circuit is removed from resistor 13 by relay L as will be described presently. The lower end of condenser 10 is connected through contacts L6 to the junction point between the heaters of tubes 8 and 9. This condenser is, therefore, normally charged to the potential existing across the series connected heaters of tubes 6, 7 and 8. When contacts B5 open this charging circuit condenser 10 discharges through resistor 14. The lower end of condenser 10 is also connected to the cathode of tube 6 and the upper end of condenser 10 is connected to a grid of tube 6 through contacts L5. The value of resistor 14 is so chosen that the potential impressed between the grid and cathode of tube 6 by condenser 10 remains above the striking potential for a length of time sufficient to insure that the cathodes of all of the tubes have reached their normal operating temperatures. During this interval a circuit is completed from contacts B3, through contacts L2, and over lead 42 to the upper winding of relay P. Relay P is arranged to complete a circuit to its lower winding when it operates. Its two windings are connected differentially which causes it to vibrate its armature at a rapid rate and thus produce an audio frequency voltage across its lower winding. This alternating tone voltage is conveyed through condenser 15, lead 41, and contacts L1 to line 4 which is connected via the exchange switch train to the subscriber line 2. When condenser 10 has discharged sufficiently, tube 6 strikes and energizes relay L. Relay L operates, disconnects line 4 from the tone source at contacts L1 to inform the test man that the equipment is ready for use, opens the circuit to the tone generating relay P at contacts L2, closes a locking circuit to its lower winding at contacts L3, transfers the anode of tube 6 from the upper winding of relay P to lead 43 at contacts L4, disconnects condenser 10 from the grid of tube 6 at contacts L5, disconnects the cathode of tube 6 from filament of tube 8 at contacts L6 and removes the short circuit from resistor 13 at contacts L7. Tube 6 deionizes.

The testing unit is now prepared for use. The

test man at the subscriber station is informed of this fact by the cessation of the tone and he, therefore, proceeds to dial an appropriate digit to select the limits between which he desires to test the impulsing device at the subscriber station. In the present instance three sets of limits have been provided, any one of which may be selected by dialing "8," "9" or "0." Assuming that the test man dials a "9," relay A will be momentarily released nine times in succession. Each time that relay A restores it completes a circuit to relay C which is thus momentarily operated nine times in succession. Each time that relay C operates it closes a circuit to the motor magnet MM of the rotary switch from ground at contacts B3, through contacts C1, over lead 31, and through contacts S2 to MM. Motor magnet MM advances the rotary switch wipers one step each time that it restores. A circuit is also completed to relay D by contact C2 of relay C while relay C is operated. Relay D is rendered slow to release by a copper sleeve on its core and thus remains operated during the series of impulses. Relay B is similarly made slow to release so that it remains operated even though its circuit is interrupted by relay A during dialing. At the conclusion of the series of impulses the wipers W1 to W4 of the rotary switch will be resting on the ninth set of bank contacts. Relay D restores shortly after the series of impulses is completed and closes a circuit to relay J from ground at contacts B3, over lead 32, through contacts M4, over lead 39, through contacts D2 and G1, over lead 26, through the ninth bank contacts of wiper W2 to lead 28 and thence to relay J. Relay J operates, closes its locking circuit over lead 39 at contacts J1, closes a circuit to relay G at contacts J2 from ground over lead 39 and through contacts D2, energizes potentiometers 47 and 48 at contacts J3 and J5 respectively, connects the cathodes of tubes 6 and 7 to the adjustable taps on potentiometers 47 and 48 at contacts J4 and J6 respectively, and connects adjustable resistors 49 and 50 in multiple with condensers 51 and 52 at contacts J7 and J8 respectively. Relay G operates, at contacts G1 extends ground over lead 37, through contacts N4, over lead 35, through contacts B1, over lead 22, through the rotary switch cam springs CS and interrupter springs IS to the motor magnet MM, causing the motor magnet to operate self-interrupting to drive the wipers to the eleventh step where the cam springs CS open to stop further rotation of the wipers. The operation of relay G also completed charging circuits to condensers 51 and 52 through contacts E6 and E7 and contacts G4 and G5 respectively. The outer sides of condensers 51 and 52 are connected to the junction points between the filaments of tubes 8 and 9. These two condensers therefor become charged to a potential equal to that across the series connected filaments of tubes 6, 7 and 8.

The test man now dials an "0" causing relay A to release and operate relay C ten times in succession. Relay D again operates the first time that relay C operates and remains operated throughout the series of impulses. The operation of relay D closes a circuit to relay E from ground at contacts B3, through contacts D3 and G3. Charging circuits to condensers 53 and 54 are also completed by relay D through the last traced circuit and through contacts C3 and C4, and through resistances 55 and 56, respectively. Relay E operates, removes the shunting resistors from condensers 53 and 54 at contacts E4 and E5,

opens the charging circuits to condensers 51 and 52 at contacts E6 and E7 respectively, and closes a circuit to relay N over lead 34 at contacts E1. Relay N operates. Condensers 51 and 52 discharge continuously through resistances 49 and 50 during the entire series of impulses. Condensers 53 and 54 charge through resistances 55 and 56 only during the intervals when relay C is operated during the series. Relay C is adjusted to faithfully repeat the impulses it receives from relay A so that the total length of time that the charging circuits are closed to condensers 53 and 54 corresponds to the summation of the restored intervals of relay A. Therefore, at the end of the series of impulses, the charge on condensers 53 and 54 is a measure of the total duration of the break periods of the received series of impulses; and the charge on condensers 51 and 52 is a measure of the total duration of the received series of impulses. During the reception of the series of impulses the rotary switch is advanced ten steps by the motor magnet MM which is operated by contacts C1 over the previously traced circuit. When the rotary switch reaches the tenth step a circuit is completed to relay F from ground at contacts B3, through contacts E3, over lead 23, and through the tenth bank contact of wiper W4 to lead 24 thence to relay F. Relay F operates, closes its locking circuit through contacts F3, over lead 36, through contacts N1, and over lead 32 to ground at contacts B3; transfers condensers 53 and 54 from their charging circuits to the grids of tubes 6 and 7 at contacts F4 and F5; and recloses the charging circuits to condensers 51 and 52. Resistors 49 and 50 are preset so that if the duration of the series of impulses is within the required limits condenser 51 will have been discharged sufficiently to permit tube 8 to strike, but condenser 52 will not have discharged sufficiently to permit tube 9 to strike, prior to the operation of relay F. If the dial at the subscriber's station is too fast, condenser 51 will not discharge sufficiently to permit tube 8 to strike. If the dial is too slow, condensers 51 and 52 will discharge sufficiently to permit both tubes 8 and 9 to strike. When relay F operates condensers 51 and 52 are immediately recharged, but if either tube 8 or both tubes 8 and 9 have struck they will remain ionized since the grid loses control once the discharge has been initiated in the tubes. Assuming that the dial speed is within the selected limits, tube 8 fires and its anode current flows over lead 45, through contacts V3 and the lower winding of relay V, over lead 40 and through contacts E2 to ground at contacts B3. Relay V operates; opens a marking circuit to the W1 bank contacts of the rotary switch; closes a locking circuit to its upper winding through contacts V2, N1, and over lead 32 to ground at contacts B3; and opens the anode circuit of tube 8 at contacts V3 causing it to be deionized. When condensers 53 and 54 are transferred to the grids of tubes 6 and 7 by the operation of relay F, the potentials between the grids and cathodes of these tubes is equal to the potential across the corresponding condenser less the voltage between negative battery and the taps on the associated potentiometers 47 and 48. The taps on these potentiometers are preset so that for normal impulse speeds tube 6 will fire and tube 7 will not fire if the impulse ratio of the received impulses lies between two predetermined limits. If the impulse ratio lies outside of these limits either both tubes or neither tube will fire depending upon whether the ratio is high or low. Inasmuch as the charge on condensers 53 and 54 is a function of the impulse speed as well as a function of the impulse ratio an exact determination of the limits between which the impulse ratio lies will not be obtained unless the speed is normal. Therefore, if the test shows that the dial speed is normal the impulse ratio test may be depended upon. If the test shows that the dial speed is high or low the impulse ratio test may be disregarded until the dial has been adjusted to operate at normal speed. Assuming that the impulse ratio was within the predetermined limits; tube 6 strikes and its anode current flows through contacts L4, over lead 43, through contacts T3 and the lower winding of relay T, and over lead 38 to ground at contacts F1. Relay T operates, closes a marking circuit to the W1 bank contacts of the rotary switch, closes its locking circuit at contacts T2 over the circuit previously traced for relay V, and opens the anode circuit for tube 6 at contacts T3 causing it to be deionized. This completes the registration of the results of the test, the next step being the return of a coded tone signal to the test man indicative of the results of the test.

Shortly after the operation of relay F, relay D restores, opens the circuit to relay E at contacts D3, and completes a homing circuit to the motor magnet MM of the rotary switch from ground at contacts B3, over lead 32, through contacts M4, over lead 39, through contacts D1, over lead 33, through contacts N4, over lead 35, through contacts B1, over lead 22, and through cam springs CS and interrupter springs IS to MM. The motor magnet MM operates self-interrupting to drive the wipers of the rotary switch until cam springs CS open on the eleventh step. During this homing operation relay E restores, short-circuits condensers 53 and 54 through low resistances, and opens the operating circuit to relay N at contacts E1. Relay N remains locked through its contacts N2, contacts M3, wiper W3, over lead 25, and through contacts E3 to ground at contacts B3. When wiper W3 reaches the eleventh step this locking circuit is opened and a circuit is completed to relay M from the eleventh bank contact of wiper W3 and through contacts N3. Relay M operates, opens a further point in the locking circuit for relay N and prepares its own locking circuit to the first ten bank contacts of wiper W3 at contacts M3, closes a multiple circuit across contacts N1 at contacts M1, closes a circuit to the tone generating relay P at contacts M2, and closes a circuit to the interrupter relays R and S and opens the locking circuits to relays G and J at contacts M4. Relays G and J restore. Relay P begins to generate a tone voltage. Relay R operates and closes a circuit to relay S at contacts R2. Relay S operates, short-circuits relay R at contacts S1, and closes a circuit to motor magnet MM at contacts S2 in multiple with itself. Motor magnet MM operates. Relay R restores, opens the circuits to relay S and MM and short-circuits relay S at contacts R2. Motor magnet MM restores and advances the rotary switch wipers to the first set of bank contacts. Wiper W3 completes the locking circuit to relay M through contacts M3. Relay N restores. Relays M and N are both made slow to release by means of copper sleeves on their cores to enable them to remain operated during the time it takes relays R and S to operate. Relays R and S are made slow to operate and slow to release by means of copper slugs on the armature ends of their cores to regulate the speed at which they operate. Relays R and S continue to pulse

During a portion of the time that the wiper W3 rests on bank contact 1, a circuit is completed from the lower winding of relay P, through condenser 15, contacts R1, wiper W1, over lead 21 to line 4, and thence to the subscriber line 2 over the exchange switch train; thus returning a splash of tone to the subscriber telephone. Each time that relay S operates, a circuit is completed to the motor magnet MM causing it to operate, and each time that relay R restores it opens the circuit to the motor magnet MM causing it to restore and advance the wipers one step. While the wipers are resting on the second step another splash of tone is returned to the subscriber telephone, during the interval when relay R is operated, over a circuit similar to that previously traced except that it now includes contacts T1. A long splash of tone is returned when the wiper W1 rests on bank contacts 5 and 6 because these contacts are multipled and the tone circuit is not interrupted by relay R. This circuit may be traced from condenser 15, over lead 41, through contacts F2, and over lead 3 to bank contacts 5 and 6. This circuit is taken through contacts of relay F so that the presence of the long splash of tone serves to verify to the test man that the digit "0" was correctly received by the testing apparatus. Two more short splashes of tone are returned when the wipers rest on the eighth and the tenth bank contacts. The first circuit includes contacts X1 and R1 and the second includes only R1. Thus the tone signal received by the test man consists of two short splashes of tone followed by a long tone signal and then two more short splashes of tone. When the rotary switch is advanced to the eleventh step the locking circuit to relay M is opened by wiper W3. Relay M restores, opens the locking circuits to relays F, T, and V at contacts M1, opens the circuit to the tone generating relay P at contacts M2, and opens the circuit to the interrupter relays R and S at contacts M4. Relays F, T, and V restore. All relays are now restored to normal except relays A, B, and L which remain operated until the subscriber loop circuit is opened by the restoration of the receiver on the hookswitch of the telephone at the subscriber station.

Since the equipment is now in exactly the same condition as it was prior to the test, it should be apparent that the test may be repeated by re-operating the impulse transmitter at the subscriber substation. If desired, the digits "8" and "0," or "9" and "0," may be dialed the second time in place of "9" and "0" in order to change the limits between which the tests are made. If no further tests are required the test man restores the receiver on the hookswitch causing the subscriber loop circuit to be opened. When the subscriber's loop circuit is opened relay A restores and opens the circuit to relay B which restores and removes ground from the holding lead 5 at contacts B4 to release the exchange switch train, and opens the locking circuit to relay L at contacts B3. Relay L restores.

In the event that the impulse ratio of the received impulses was too high both tubes 6 and 7 would have fired causing the operation of both relays T and U. Bank contacts 1, 2, and 3 of wiper W1 would then be connected to the tone source through contacts R1 causing three short splashes of tone to be returned to the test man before the long tone signal. If the impulse ratio was too low neither tube 6 nor 7 would have fired and consequently neither relay T nor U would have been operated. Thus only one short splash of tone would be sent before the long tone signal. In a similar manner, if the dial speed was too high neither tube 8 nor 9 would fire causing both relays V and X to remain normal, or if the dial speed was too low both tubes 8 and 9 would fire causing both relays V and X to operate. Thus three splashes of tone following the long tone signal, indicating a fast dial; or one splash of tone following the long tone signal, indicating a slow dial, would be returned to the test man.

It is oftentimes desirable to have different adjustment margins for different dials depending upon the type of line with which they are used. Thus a wide margin may be permissible for a local subscriber dial, an intermediate margin may be required for dials which are used with short trunks or heavily loaded party lines, while a narrow margin may be necessary for dials which are used with inter-office trunks. Provision for testing with any one of three margins is provided by arranging the testing apparatus so that any one of the three relays H, J, or K may be operated when the test man dials the first digit after seizing the testing equipment. In the previous discussion it was assumed that "9" was dialed which caused the operation of relay J. It should be apparent from the preceding description that if the first digit had been "8" or "0" instead of "9," either relay K or H would have been operated in place of relay J. The operations are identical to those previously described except that slightly different valued resistors are substituted for resistors 49 and 50, and potentiometers with a slightly different adjustment of the tap are substituted for potentiometers 47 and 48. All of these resistors and potentiometers are adjustable so that the impulse ratio and speed limits for any of the three sets of margins can be varied as desired. These resistors and potentiometers may be initially adjusted by operating relay A with impulses of known characteristics, as from a varying machine, and adjusting the various controls until the desired results are obtained.

It should be understood that numerous modifications in the details of the circuit arrangements may be resorted to without departing from the scope of the invention as defined in the subjoined claims.

What is claimed is:

1. In a telephone system, a subscriber substation including a transmitter operative to transmit impulses, apparatus operative to test the impulse ratio of a transmitter, means controlled by initial operation of said transmitter for associating it with said apparatus, means in said apparatus controlled by further operation of said transmitter for operating said apparatus, and means controlled by said apparatus for automatically transmitting a signal to said subscriber substation indicative of the tested impulse ratio of said transmitter.

2. In a telephone system, a subscriber substation including a transmitter operative to transmit impulses, apparatus operative to test both the impulse ratio and the impulsing speed of a transmitter, means controlled by initial operation of said transmitter for associating it with said apparatus, means in said apparatus controlled by further operation of said transmitter for operating said apparatus, and means controlled by said apparatus in testing the ratio for transmitting a signal to said subscriber substation indicative of the tested impulse ratio and impulsing speed of said transmitter.

3. In a signaling system, a device operative to

transmit impulses, a plurality of testing means each having a set of limits individual thereto, means controlled by an operation of said device for selecting one of said plurality of testing means, and means responsive to further operation of said device for operating said selected testing means to determine whether the impulsing speed of said device lies within the limits associated with the selected testing means.

4. In a signaling system, an impulse transmitting device, a plurality of testing means each having a set of limits individual thereto, means controlled by an operation of said device for selecting one of said plurality of testing means, and means responsive to further operation of said device for operating said selected testing means to determine whether the impulse ratio of said device lies within the limits associated with the selected testing means.

5. In a telephone system, a subscriber substation including a transmitter operative to transmit impulses, apparatus operative to test the impulse ratio and impulse speed of said transmitter in response to the receipt of a predetermined number of impulses therefrom, means controlled by operation of said transmitter for operating said apparatus, and means controlled by said apparatus for transmitting a coded signal to said subscriber substation indicative of the tested impulse ratio and impulse speed of said transmitter, said means also operated automatically to transmit a supervisory signal as a part of said coded signal to said subscriber indicative of proper operation of said apparatus in response to the operation of said apparatus.

6. In a system for measuring time intervals, a pair of condensers, means for charging said condensers during a variable time interval, a pair of thermionic tubes each being arranged to compare the charge on one of said condensers with a reference potential, and means responsive at times to the operation of one of said tubes and at other times to the operation or nonoperation of both of said tubes for indicating the duration of the variable time interval.

7. In a system for measuring time intervals, a pair of condensers, means for altering the charge on said condensers at a predetermined rate during a variable time interval, a pair of thermionic tubes each being arranged to be controlled by the charge on one of said condensers, and means controlled by said tubes for indicating the duration of the variable time interval, said last means responsive at times to the operation of one of said tubes and at other times to the operation or nonoperation of both of said tubes for the purpose specified.

8. In a system for testing the impulse ratio of an interrupting device, a testing circuit including a pair of condensers, means for altering the charges on said condensers during a portion of each of a predetermined number of impulses, a pair of thermionic tubes each being arranged to be controlled by the final charge accumulated on one of said condensers by said predetermined number of impulses, and means controlled by said tubes for indicating the ratio between said portion and the whole impulse.

9. In a system for testing the impulse ratio of an interrupting device, a testing circuit including a pair of condensers, means for altering the charges on said condensers during a portion of each of a predetermined number of impulses, a pair of thermionic tubes each being arranged to compare the final charge accumulated on one of said condensers by said predetermined number of impulses with a reference potential, and means controlled by said tubes for indicating the ratio between said portion and the whole impulse.

10. In a system as claimed in claim 9 in which said last means indicates whether the tested impulse ratio lies between two limits, means for changing the value of the reference potential to alter the value of said limits.

11. In a system for testing the impulsing speed of an interrupting device, a testing circuit including a pair of condensers, means for altering the charges on said condensers for the duration of a predetermined number of impulses, a pair of thermionic tubes each being arranged to be controlled by the final charge on one of said condensers, and means responsive at times to the operation of one of said tubes and at other times to the operation or nonoperation of both of said tubes for indicating the tested impulsing speed.

12. In a system as claimed in claim 11 in which said last means indicates whether the tested impulsing speed lies between two limits, means for changing the rates at which the charges on said condensers are altered to change the value of said limits.

13. In a system of electrical measurement in which it is desired to determine whether an element has characteristics which lie within, or on either side of two limiting values, a pair of condensers having charge and discharge circuits, a pair of grid-controlled tubes having input and output circuits, a plurality of pairs of circuits, each pair effective to apply different biasing potentials to said tubes to render one of said tubes effective to strike at a higher input than the other of said tubes to establish different upper and lower limits for each of said pair of circuits connected thereto, means controlled by said element for selecting any one of said plurality of pairs of circuits, means for causing said condensers to be charged an amount proportional to the characteristics of the element being tested, means for alternately placing said condensers in the charge and discharge circuits, said discharge circuits connected to the input circuits of said tubes, said discharge circuits ineffective to strike the tubes if the charge on the condensers representing said element characteristics is less than the lower limit of the pair of circuits selected, said discharge circuits effective to strike one of said tubes if the charge on said condensers is within the limits of the selected pair of circuits, and said discharge circuits effective to strike both of said tubes if said charge on said condensers is greater than the limits of the selected pair of circuits, and means in the output circuits of said tubes for indicating the relation of said characteristics with regard to the limits of said selected pair of circuits.

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