Nov. 6, 1928. 1,690,213

I. G. WILSON

AUTOMATIC SYSTEM FOR TESTING REPEATERS

Filed Dec. 30, 1926 4 Sheets-Sheet 1

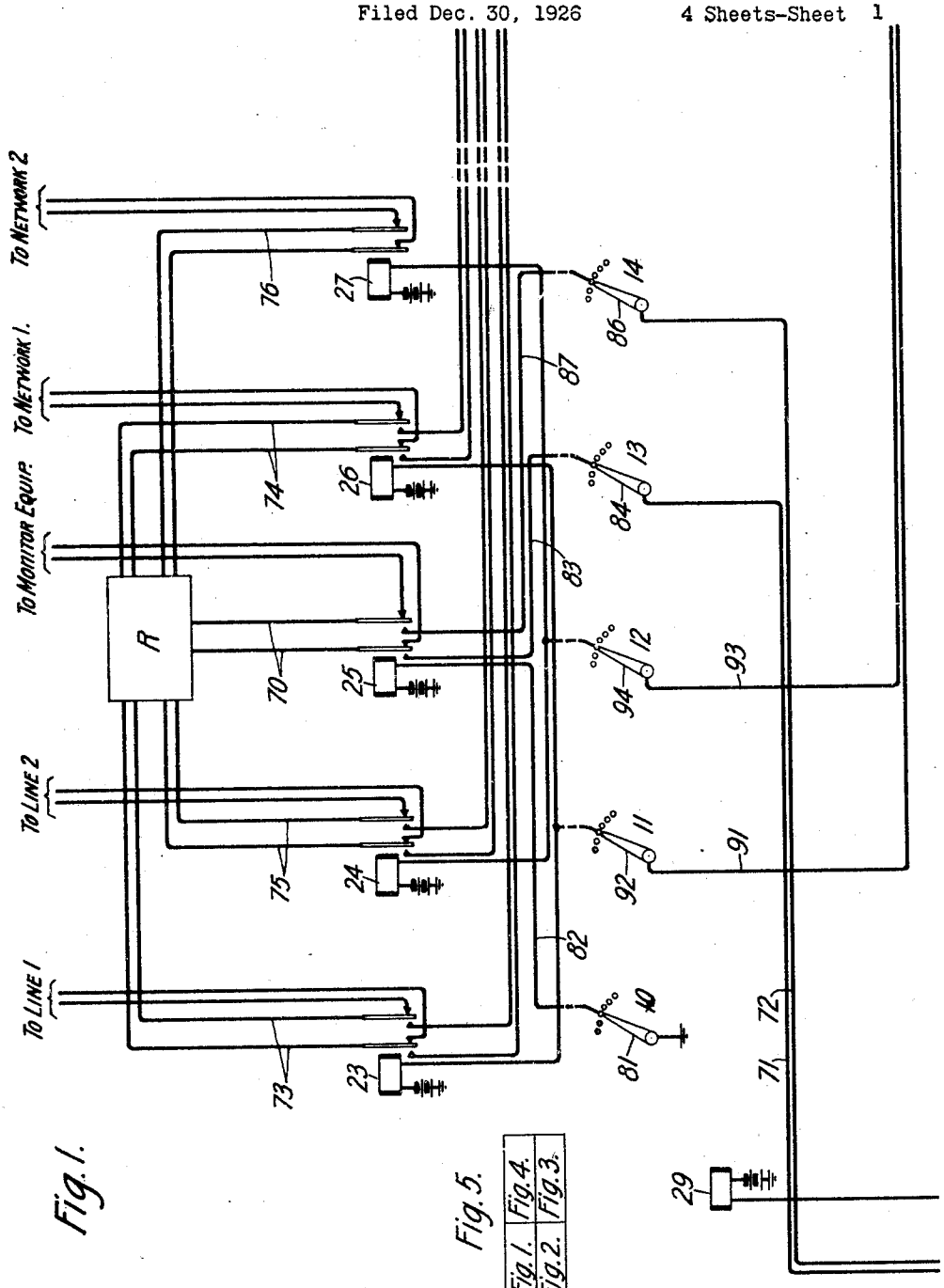


Fig. 1.

Fig. 5.

Fig. 1.	Fig. 4.
Fig. 2.	Fig. 3.

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AUTOMATIC SYSTEM FOR TESTING REPEATERS

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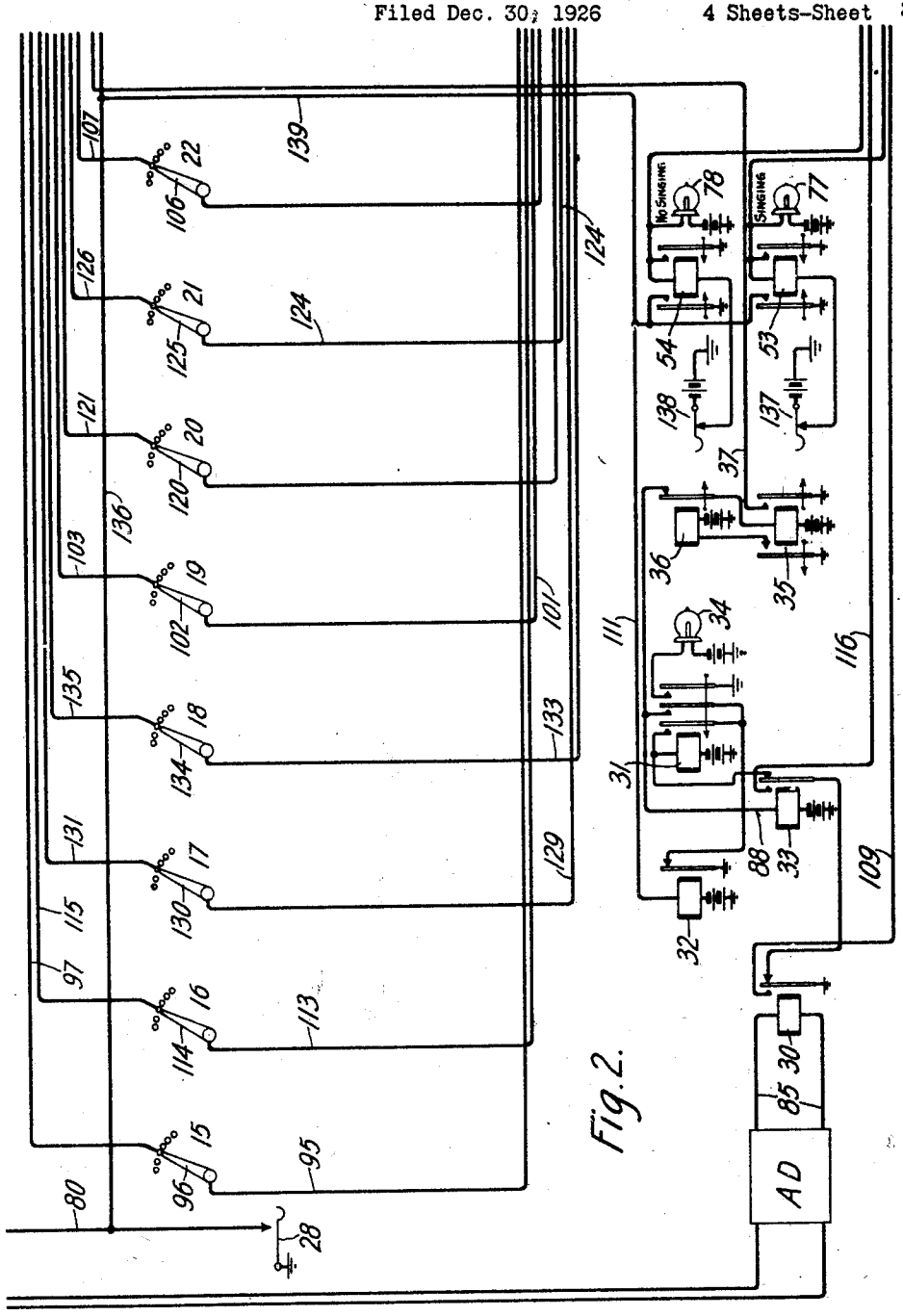


Fig. 2.

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AUTOMATIC SYSTEM FOR TESTING REPEATERS

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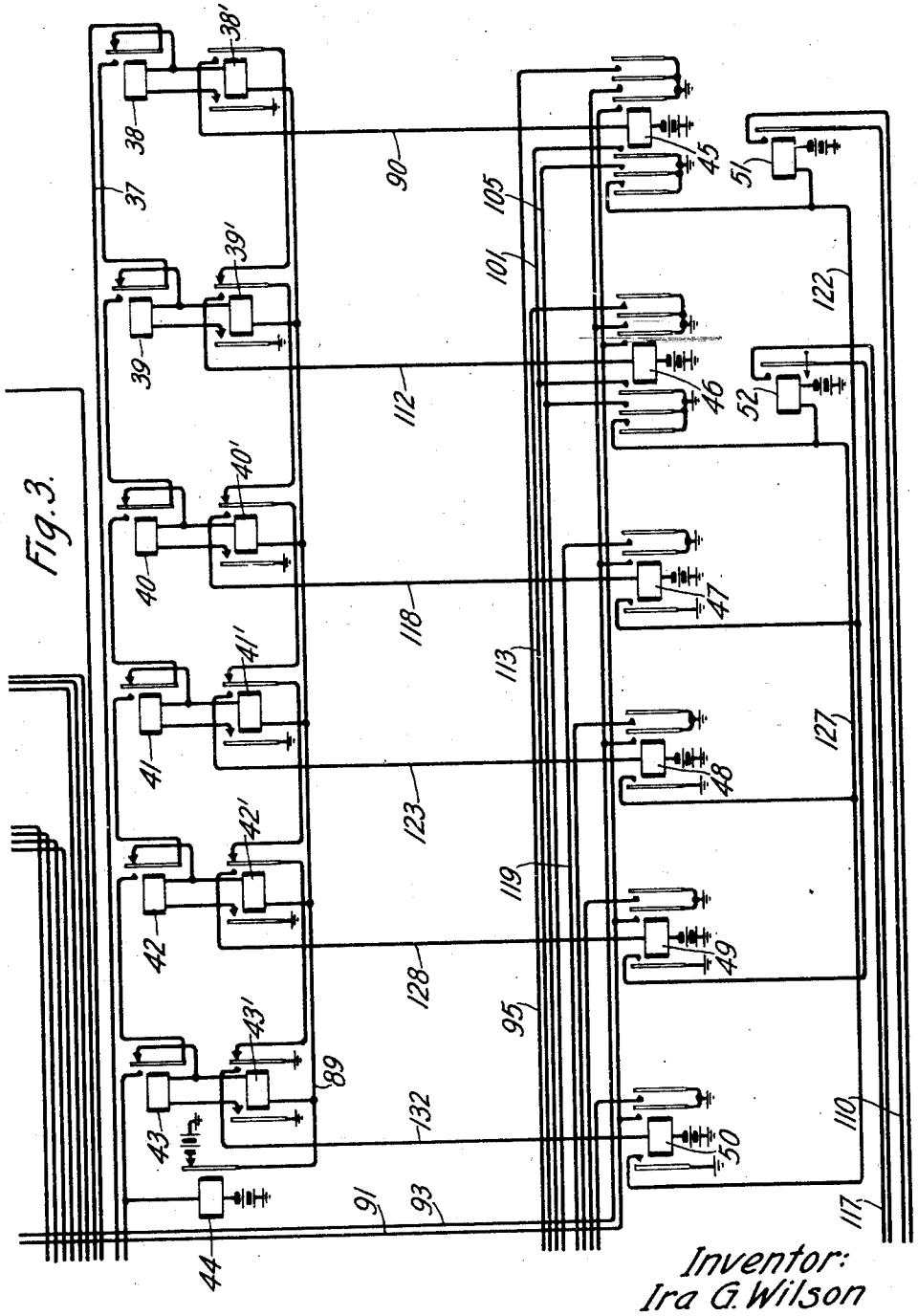


Fig. 3.

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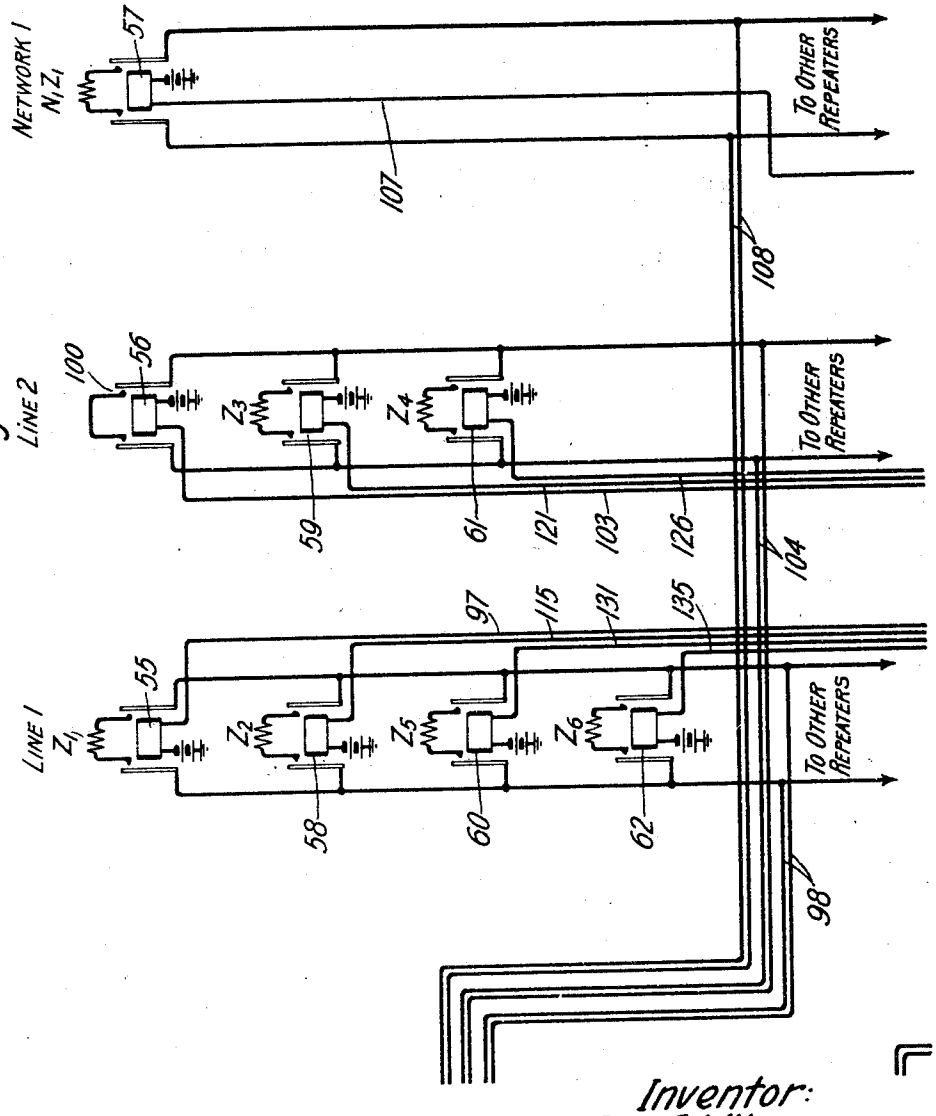
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AUTOMATIC SYSTEM FOR TESTING REPEATERS

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Fig. 4.



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Patented Nov. 6, 1928. 1,690,213

UNITED STATES PATENT OFFICE.

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AUTOMATIC SYSTEM FOR TESTING REPEATERS.

Application filed December 30, 1926. Serial No. 157,902.

This invention relates to automatic testing systems and more particularly to systems for the automatic testing of repeaters and amplifiers.

In the usual repeater circuits used for telephone transmission, two stations distant from one another are interconnected by a transmission line, repeaters being inserted in the line at intermediate stations to amplify the speech currents transmitted over the circuit. These repeaters are usually of the vacuum tube type and have associated therewith balancing networks which simulate the impedances of the lines. Abnormal conditions existing in the repeaters or networks cause reflections on the lines and also produce singing. This singing limits the possible gain of the repeaters and the quality of transmission is impaired. For a more complete description of repeater circuits and their requirements for practical use, reference is made to a paper entitled Telephone repeaters, by Bancroft Gherardi and Frank B. Jewett, in the Proceedings of the American Institute of Electrical Engineers, November, 1919. Various maintenance tests are made by attendants to insure high quality transmission. The equipment for performing these tests is usually in the form of separate testing sets which require manual operation to connect the testing circuits to the repeater. For instance, the unbalanced condition of a repeater may be detected by placing a short circuit across the network of the output line section thereby causing the output hybrid coil to function as a repeating coil. The operator's listening or supervising set is connected to the repeater through a monitoring winding and the gain of the repeater is increased step-by-step until the operator detects singing in the repeater. The gain at the singing point may be observed from the reading of the potentiometers or other means for increasing the repeater gain, and the unbalance between the transmission lines and repeater may then be determined. Such an arrangement is disclosed in W. H. Harden, Patent No. 1,404,288, dated January 24, 1922. In another arrangement, disclosed in C. S. Demarest, Patent No. 1,355,898, issued October 19, 1920, the gain of the repeater is tested by transmitting oscillations from a source associated with the testing circuit to an indicating means either through the repeater or through an auxiliary path. These tests require considerable time and attention, and reduce the line operating time because of the disconnection of the repeater from service.

An object of the present invention is to periodically test repeaters for maintenance purposes with a minimum of manual attention and minimum interruption to normal service.

A more specific object of the invention is to automatically perform a series of routine tests on a repeater to determine the presence of abnormal conditions.

In accordance with the embodiment of the present invention which has been selected for illustration, any one of a number of repeaters may be selected for testing purposes, and if found to be in use, the test is automatically delayed and the testing equipment waits until the repeater is idle. This arrangement consists of suitable monitoring conductors automatically connected to an amplifier-detector which energizes a relay to delay testing on the busy repeater.

The invention also comprises a combination of apparatus for setting up various test conditions to operate signaling devices if abnormal conditions are present in the apparatus under test and to actuate indicating means to denote the trouble. In this combination, certain groups of test impedance networks are connected in proper sequence to the repeater in place of the transmission lines and associated networks. In a particular group of impedances associated with the repeater, the values are such as to produce singing on the test repeater if above the maximum limit of gain adjustment and the singing caused by this condition operates a signaling device to indicate the high gain condition present in the repeater. If such an abnormal condition is found, testing on the selected repeater is automatically stopped and an alarm given. To determine if the repeater is operating below the prescribed maximum gain limit, another group of impedances is automatically connected to the repeater which causes singing if the repeater is functioning above the prescribed minimum limits, that is, if the operation of the repeater in this respect is satisfactory. However, if singing does not occur under this condition another signaling

device is automatically operated to call the operator's attention to the low gain condition of the repeater. If the latter abnormal condition exists, testing is again discontinued automatically. Other routine tests are made automatically in a given order to determine whether the balance between the line and network of a selected repeater is within prescribed maximum and minimum limits of unbalance. The various gain and unbalance tests are made on a selected repeater in sequence and if the repeater is operating within the prescribed limits the same tests are automatically applied to successively selected repeaters.

The repeater is selected by a selector switch arrangement which is connected to a series of relays which operate to disconnect either one of the lines or networks from the repeater and to substitute therefor suitable test networks for testing the repeater. A control relay operates pulsing relays to transmit pulses to a bank of sequence relays which, in turn, control the operation of test selecting relays which are interconnected through the test selector switches to energize the test relays. The test relays connect certain test networks of predetermined values of impedances in proper sequence in place normally connected to the lines and networks of the repeater under test through the disconnect relays associated with the repeater.

A feature of the invention relates to the determination of abnormal conditions present in the repeater, which for normal operation should function between certain maximum and minimum gain or unbalance limits, and indicating to the attendant when the gain or unbalance is outside the range as determined by the predetermined limits.

Another feature of the invention relates to the operation of the routine tests from a point remote from the repeaters, such as a central office, whereby a single testing equipment may be utilized to test all the repeaters located in a given area.

Another feature of the invention relates to means for automatically indicating to an attendant that a particular repeater is being tested so that this particular repeater will not be connected in service during the test.

A more detailed description of the invention follows, and is illustrated in the accompanying drawings in which,

Fig. 1 illustrates a repeater to be tested having associated therewith a number of disconnect relays connected to the repeater selector switches,

Fig. 2 shows the circuit connections of control and indicating relays and a series of test selector switches in the system of the invention,

Fig. 3 illustrates the sequence relays which operate the test selecting relays associated with the test selector switches of Fig. 2,

Fig. 4 shows the circuit connections of test relays and associated test networks to be connected to the repeater for the various tests and

Fig. 5 is a diagram showing the order in which the various figures of the drawings should be arranged to illustrate the complete system.

General description.

Referring to the drawings, the automatic routine testing of repeaters in sequence is initiated by closing the key 28, for an instant, to energize the stepping magnet 29, which is normally deenergized, to step the repeater selector switches 10 to 14 inclusive and test selector switches 15 to 22 inclusive, to the positions for testing the first repeater. These selector switches are mounted on a common shaft so that the brushes will always be on corresponding contacts. When the routine tests on the first repeater are completed the switches are automatically advanced to apply the same tests to the next repeater. For a more complete disclosure of the type of repeater to which this invention is applicable, reference is made to W. H. Harden, Patent No. 1,404,288, dated January 24, 1922. Assuming the third repeater designated R is selected for testing, the advancement of the repeater selector switches to position 3 energizes relay 25 through repeater selector switch 10, to disconnect the monitoring conductors 70 from the monitoring equipment located at the repeater station and to connect conductors 70 to switches 13 and 14. Attached to switches 13 and 14 are conductors 71 and 72 respectively, which are connected to an amplifier detector AD (see Fig. 2) having a relay 30 in its output circuit. If the repeater R is busy, current will be induced in the monitoring conductors 70 by the voice currents transmitted over the line and relay 30 will be operated to delay testing on the busy repeater. When the repeater becomes idle, relay 30 will release its armature and control relay 31 will operate. The control relay 31 is slow operating so that a normal pause in the conversation being repeated on the line will not cause this relay to operate. When relay 31 operates, a locking circuit is established through the armature of relay 32. Relay 33 is also operated. A signal lamp 34 is also illuminated by the operation of control relay 31 to indicate that a repeater is being tested.

Routine gain tests.

The operation of control relay 31 also starts the pulsing relays 35 and 36 to operating and releasing thereby sending out a series of pulses over conductor 37 to the sequence relays (see Fig. 3). The first pulse causes the operation of sequence relays 38'

and 38, test selecting relay 45, and relay 51 to apply the first test to the repeater R. Relays 23 and 26 are energized by the operation of test selecting relay 45 through its inner right hand contact and selector switch 11, to disconnect conductors 73 from the transmission line 1 and conductors 74 from the associated balancing network for line 1. Relays 24 and 27 are also energized through selector 12 and the intermediate right hand contact of test selecting relay 45, to disconnect conductors 75 from the transmission line 2 and conductors 76 from the associated balancing network for line 2. The operation of relay 45 also energizes test relay 55 (see Fig. 4) through test selector switch 15 and the outer right hand contact of relay 45. The operation of relay 55 places the test network Z_1 in circuit with conductors 73 through conductors 98. Network Z_1 is thus connected to the repeater R in place of line 1. Test relay 56 is energized through test selector switch 19 and the inner left hand contact of relay 45 to place a short circuit on conductors 75 of repeater R in place of line 2. Test relay 57 is operated through test selector switch 22 and the intermediate left hand contact of relay 45 to place test network $N_1 Z_1$ in circuit with conductors 74 in place of the the normally associated balancing network for line 1. The operation of relay 27 leaves conductors 76 open circuited by the disconnection of the normally associated balancing network for line 2.

The test networks Z_1 and N_1Z_1 substituted for line 1 and its associated balancing net work are of such values and the condition set up for the repeater is such that if the repeater R is operating below the prescribed maximum limit of transmission gain, no singing will be produced. However, if this condition produces singing, due to a gain higher than the maximum limit, relay 30 will be energized, thereby operating signal relay 53 (see Fig. 2) through the front contacts of relays 51 and 30 and the lamp 77 will be illuminated to indicate the high gain condition of the repeater R. The operation of signal relay 53 causes the operation of relay 32, thereby causing the release of control relay 31, relay 32, and the non-operation of the pulsing relays 35 and 36. Further testing is automatically discontinued on the selected repeater. The operation of signal relay 53 also closes a circuit to energize relay 44, thereby removing grounded battery from the sequence relays 38 and 38′. The release of these relays causes test selecting relay 45 to deenergize and the testing condition applied to the repeater R will be discontinued by the release of the test relays 55, 56 and 57. At the same time stepping magnet 29 is energized through the left-hand armature and contact of signal relay 53 and conductors 139, 136 and 80. The stepping magnet 29, however, does not advance the selector switches to the next terminal until a break key 137 associated with signal relay 53 is operated to release the locking circuit for this relay. When the stepping magnet 29 is deenergized it advances the brushes of the selector switches to the next terminal and the first test is applied to the repeater connected to the fourth terminal of the selector switches. The abnormal repeater may be removed from service and the trouble indicated by the testing equipment rectified.

If the first test is within limits, the next pulse sent over conductor 37 causes the operation of sequence relays 39′ and 39 in a manner similar to the operation of relays 38′ and 38, test selecting relay 46 and relay 52. The operation of sequence relay 39′ opens the circuit for test selecting relay 45 through the right-hand armature and back contact of relay 39′, thereby releasing all the relays set up for the previous test combination.

The operation of relay 46 energizes relays 23 and 26 through repeater selector switch 11 and the inner right-hand contact of relay 46, and relays 24 and 27 through repeater selector switch 12 and the intermediate right-hand contact of relay 46, for a purpose similar to that described in connection with the first test. At the same time test relay 58 is caused to operate through test selector switch 16 and the outer right-hand contact of relay 46, to place the test network Z_2 on conductors 73. Test relays 56 and 57 are again energized through selector switches 19 and 22 and the left-hand inner and intermediate contacts of relay 46 respectively, to set up the same conditions on conductors 75 and 76 as described heretofore. The values of the substituted networks Z_2 and N_1Z_1 are such as to produce singing in the repeater R, if the repeater is operating above the prescribed minimum limit of gain.

However, if no singing is produced by the above condition, indicating a low gain, signal relay 54 will be operated through the front contacts of relays 52 and 33, thereby lighting signal lamp 78, to indicate that the transmission gain is below the minimum limit. The operation of relay 54 also energizes relay 32 to automatically discontinue testing on the abnormal repeater and all the relays set up for the test are released through the energization of relay 44. Stepping magnet 29 is also energized. The locking circuit for signal relay 54 may be broken by operating break key 138 to return the testing equipment to normal condition and cause the brushes of the selector switches to be advanced to the next terminal by deenergizing magnet 29. The above tests indicate whether or not the repeater R is op-

erating within the prescribed limits of gain.

Routine unbalance tests.

Assuming that the repeater R is operating within the prescribed gain limits, the next pulse sent over conductor 37 operates sequence relay 40', which causes the operation of sequence relay 40, test selecting relay 47 and relay 51. The operation of relay 40' opens the circuit for test selecting relay 46 thereby releasing all the test and test selecting relays set up for the previous combination. The operation of relay 47 causes relays 24 and 27 to operate through selector switch 12 and the inner right-hand contact of relay 47, to disconnect conductors 75 from line 2 and conductors 76 from the network for line 2. Relay 59 is also energized through test selector switch 20 and the outer right-hand contact of relay 47, to connect the test network Z_3 to the conductors 75 through conductors 104 and the front contacts of relay 24, in place of line 2. During this test line 1 remains normal, that is. line 1 and its associated network are connected to the repeater R with the impedance Z_3 substituted for line 2 and the balancing network for line 2 disconnected from the repeater through the operation of disconnect relay 27. The impedance of the test network Z_3 is of such value and the conditions set up with respect to the connections to the repeater R are such that if the balance between line 1 and its associated network is above the limit of minimum unbalance, nothing will happen and the next test is applied to repeater R. However, if an unbalanced condition is present, either in the hybrid coil associated with line 1 or the balancing network of line 1, singing will be produced. Current in the monitoring conductors 70, caused by this singing is amplified and rectified by the amplifier detector AD to energize relay 30. Signal relay 53 will be energized through the front contacts of relays 30 and 51, and the lamp 77 will be illuminated, to indicate the unbalance of the repeater is above the maximum limit. The operation of relay 53 again discontinues the test by operating relay 32, causing the release of all the relays set up for this unbalance test by operating relay 44 and the selector switches are advanced to the next repeater in a manner hereinbefore described.

If the repeater R is within normal operating limits the next pulse operates sequence relay 41', which causes the operation of sequence relay 41, test selecting relay 48, and relay 52. This test is substantially the same as the previous test except that test relay 61 is energized through test selector switch 21 and the outer right-hand contact of relay 48, to connect the test network Z_4 to conductors 75 in place of line 2. The conditions set up by this test will induce singing in the repeater R if the balance between line 1 and its associated network is above the prescribed minimum limit of unbalance. Non-singing of the repeater causes the operation of signal relay 54 and lamp 78 will be illuminated, to indicate the unbalance is below the minimum limit. Relay 32 is again operated to discontinue testing and all the relays set up for this test are released by the operation of relay 44, in a manner heretofore described. The testing system is again returned to normal by the operation of break key 138 to deenergize relay 54.

If the balance between line 1 and its associated network is within the prescribed limits the next pulse operates sequence relay 42', which causes the operation of sequence relay 42, test selecting relay 49 and relay 51. Relay 42'opens the circuit for test selecting relay 48 thereby releasing all the relays energized in the previous test. The operation of relay 49 energizes relays 23 and 26 to disconnect conductors 73 from line 1 and conductors 74 from the balancing network for line 1. At the same time test relay 60 is energized through test selector switch 17 to connect the test network Z_5 to conductors 73 in place of line 1. In this test, line 2 remains normal, that is; line 2 and its associated balancing network are connected to the repeater with the impedance Z_5 substituted for line 1 and the network for line 1 disconnected from the repeater. The impedance of network Z_5 is of such a value that singing does not occur if the balance between line 2 and its assocated network is above the prescribed minimum limit. Now, if singing occurs indicating an unbalanced condition above the maximum limit caused by the hybrid coil associated with line 2 or the network of line 2, signal relay 53 will be energized through relays 30 and 51 and the lamp 77 will be illuminated to indicate the unbalanced condition. The operation of relay 53 again discontinues the test through the operation of relay 32 and releases all the relays set up for this test by the operation of relay 44.

Assuming that no abnormal conditions are present in the repeater R, another pulse is sent over the conductor 37 to energize sequence relay 43' which locks up through sequence relay 43, operates test selector relay 50 and relay 52 and releases all the relays energized in the previous test by opening the circuit for test selecting relay 49. The operation of relay 50 energizes relays 23 and 26 and substantially the same conditions are set up for this test as in the last test except that relay 62 is energized through test selector switch 18 to connect the test network Z_6 to conductors 73 in place of line 1. This condition will cause singing in the repeater if the repeater is below the maximum limit, and nothing further will happen. If the re-

peater does not sing under these conditions, indicating that the unbalance is above the maximum limit, signal relay 54 will be energized to illuminate the lamp 78 and indicate the trouble in the repeater. This completes the series of tests on the individual repeater and assuming no abnormal conditions exist in repeater R, the final pulse operates relay 44 which restores all the sequence relays to normal, relay 32 to cause the release of control relay 32, and also operates the stepping magnet 29 to advance the selector switches 10 to 22 inclusive to the next repeater to be tested.

This arrangement performs automatically a series of routine tests on the repeaters of a group in sequence and automatically indicates when a repeater is not operating within prescribed limits. When abnormal conditions are present in the repeater such as when the gain is above or below the maximum and minimum limit prescribed for the particular repeater or unbalances are present in the hybrid coils or networks, alarms will be given indicating the trouble and the abnormal repeater may be removed from service. The testing equipment is restored to normal by the attendant operating the break key associated with either signal relay and the routine tests are applied to the next repeater. Since the tests are made continuously, circuit equivalents may be more closely maintained.

Detailed description.

Let it be assumed that a plurality of repeaters are located at an intermediate repeater station between two terminal stations and that the repeater testing equipment is located at one of the terminal stations. It is also assumed that an automatic routine test is to be made on the third repeater having its disconnect relays 23 to 27 inclusive, connected to the third terminal of the repeater selector switches 10 to 14 inclusive. The operation of key 28 closes a circuit which is normally open, from ground, conductor 80, winding of magnet 29 to grounded battery. This circuit energizes stepping magnet 29. When key 28 is released, the deenergization of relay 29 causes the advance of the brushes of the repeater selector switches 10 to 14 inclusive and test selector switches 15 to 22 inclusive to the first repeater to be tested. When the routine tests have been applied to this repeater and no abnormal condition has been located in the first repeater, stepping magnet 29 is automatically energized and the test are applied to the next repeater. If an abnormal condition is encountered in the repeater being tested, all tests are automatically stopped, and it will be necessary for the operator to press the starting key 28 again in order that the tests may go on. When the brush 81 is advanced to the third terminal of switch 10 and energizing circuit is established for disconnect relay 25, from ground, brush 81, terminal of switch 10, conductor 82, winding of relay 25, to grounded battery. The operation of relay 25 draws up its armatures to disconnect the station monitoring equipment from the monitoring conductors 70 of repeater R and to connect the amplifier detector AD (see Fig. 2) to the monitoring conductors 70. One side of this circuit extends through the inner armature and front contact of relay 25, conductor 83, terminal of repeater selector switch 13, brush 84, conductor 71, to one input terminal of amplifier detector AD. The return circuit is completed over conductor 72, brush 86, third terminal of repeater selector switch 14, conductor 87 and outer armature and front contact of relay 25. If the repeater R is busy, the voice currents transmitted over the line will induce corresponding currents in the monitoring conductors 70 of the repeater, and these currents will be transmitted to the amplifier detector AD which will cause relay 30 to operate over conductors 85 connected to the output circuit of the amplifier detector. When relay 30 is energized it draws up its armature and removes ground from the test controlling circuit and thereby delays testing on a busy repeater R. Testing on the repeater R which is selected for test is discontinued until the repeater is idle. This arrangement automatically monitors on a repeater to be tested to determine whether the repeater is busy or idle.

When the repeater R becomes idle, relay 30 is deenergized and the test controlling circuit is established for the operation of relay 31. This relay is of the slow operating type to prevent the operation thereof during a pause in the conversation being repeated. The circuit for this relay may be traced from ground, armature and back contact of relay 30, armature and back contact of relay 33, winding of relay 31 to grounded battery. The operation of the control relay 31 completes a locking circuit through its inner armature and contact and the armature and contact of relay 32 to ground. A signal circuit is also completed from ground, outer armature and contact of relay 31, lamp 34 to grounded battery. The illumination of lamp 34 indicates that a repeater is being tested so that the repeater attendant will not connect it in service during the test. The pulsing circuit is also established over the middle armature and contact of control relay 31 and relay 33 is energized over conductor 88, to open the original energizing circuit for control relay 31 which is now locked. This circuit may be traced from ground, armature and contact of relay 32, middle armature and contact of re-

lay 31, conductor 88, winding of relay 33 to grounded battery. Relay 33 is also energized to prepare a partial circuit for the alarm circuit to be hereinafter described.

Routine gain tests.

The operation of control relay 31 establishes a circuit for the pulsing relays 35 and 36. The circuit for these relays may be traced from ground, armature and contact of relay 32, middle armature and contact of control relay 31, armature and contact of relay 36, winding of relay 35 to grounded battery. Relay 35 will be energized to draw up its right and left hand armatures and thereby establish an energizing circuit for pulsing relay 36 from ground, left hand armature and contact of relay 35, winding of relay 36 to grounded battery. The operation of relay 36 opens the energizing circuit of relay 35 and the deenergization of relay 35 causes in turn the deenergization of relay 36, at which time the original circuit conditions are established and the cycle is repeated. These relays are of the slow releasing type. For each successive operation of relay 35 a pulse will be transmitted over conductor 37 to operate the sequence or counting relays 38 to 43 inclusive. The first pulse sent over conductor 37 energizes relay 38′ over a circuit which may be traced from ground, right-hand armature and contact of relay 35, conductor 37, armature and back contact of relay 38, winding of relay 38′, conductor 89, armature and contact of relay 44 to grounded battery. The operation of sequence relay 38′ prepares a locking circuit for itself in series with sequence relay 38. Relay 38, however, is not energized at this time since it is shunted at the right-hand armature and contact of pulsing relay 35. When relay 35 deenergizes it permits sequence relays 38 and 38′ to lock up in series with each other. This locking circuit may be traced from ground, left-hand armature and contact of relay 38′, windings of relays 38 and 38′, conductor 89, armature and contact of relay 44, to grounded battery. Relay 38′ establishes a circuit for test selecting relay 45 from ground, right-hand armature and back contact of relay 43′, right-hand armature and back contact of relay 42′, right-hand armature and back contact of relay 41′, right-hand armature and back contact of relay 40′, right-hand armature and back contact of relay 39′, right-hand armature and contact of relay 38′, conductor 90, winding of relay 45, to grounded battery. When test selecting relay 45 operates a circuit is established to energize relays 23 and 26, associated with the repeater R, to disconnect conductors 73 from the incoming line 1 and conductors 74 from the balancing network for incoming line 1. This circuit may be traced from ground, inner right-hand armature and contact of relay 45, conductor 91, brush 92, terminal of repeater selector switch 11, and then over a divided path, one branch going through the winding of relay 23 to grounded battery, and the other branch through the winding of relay 26 to grounded battery. At the same time, a circuit is established to disconnect conductors 75 from outgoing line 2 and conductors 76 from the balancing network for outgoing line 2. This circuit may be traced from ground, middle right-hand armature and contact of relay 45, conductor 93, brush 94, terminal of selector switch 12 and then over a divided path, one branch going through the winding of relay 24 to grounded battery, and the other branch through the winding of relay 27 to grounded battery. The repeater R is now disconnected from its associated transmission lines and networks and the first test is to be made on the repeater.

In Fig. 4 is shown a bank of test networks having associated therewith test relays for substituting different values of impedances for the transmission lines and balancing networks of the repeater to be tested. It will be noted that the test networks Z_1, Z_2, Z_5 and Z_6 are individual to line 1, short-circuit connection 100, test networks Z_3 and Z_4 are individual to line 2, and the test network N_1 Z_1 is individual to the balancing network for line 1. Furthermore, it is to be noted that a single bank of test networks is provided and these networks may be multipled to a large number of repeaters to be tested.

Test relay 55 is energized by the operation of test selecting relay 45, to connect the test network Z_1 to conductors 73. The energizing circuit for relay 55 may be traced from ground, outer right-hand armature and contact of relay 45, conductor 95, brush 96, third terminal of test selector switch 15, conductor 97, winding of relay 55 to grounded battery. When relay 55 is energized a circuit is completed through its right and left hand armatures and contacts to connect the test network Z_1 to conductors 73, over conductors 98 and the closed armatures and front contacts of relay 23. Test relay 56 is operated to substitute the short-circuit connection 100 in place of line 2. The energizing circuit for relay 56 may be traced from ground, inner left-hand armature and contact of relay 45, conductor 101, brush 102, terminal of test selector switch 19, conductor 103, winding of relay 56 to grounded battery. When relay 56 operates a short-circuit is established for conductors 75 of repeater R over conductors 104 and the closed armatures and front contacts of relay 24. Test relay 57 is also operated to connect the test network N_1 Z_1 to conductors 74 of the repeater. An energizing circuit for relay 57 may be traced from ground, middle left-hand armature and contact of relay 45, conductor 105, brush 106,

terminal of test selector switch 22, conductor 107, winding of relay 57 to grounded battery. The operation of relay 57 establishes a circuit for the network N_1 Z_1 thtrough the closed armature, and contacts of relay 57, conductors 108 and the closed armatures and front contacts of relay 26. Relay 51 is also energized over a circuit, from ground, outer left-hand armature and contact of relay 45, winding of relay 51 to grounded battery. The operation of relay 51 forms a partial circuit for the alarm circuit to be hereinafter described.

The conditions for the first test are now set up for the repeater R, with the test network Z_1 substituted for line 1 of the repeater, the test network N_1 Z_1 substituted for the balancing network of line 1, the short-circuit connection 100 substituted for line 2 and the balancing network for line 2 disconnected from the repeater R. The impedances of the test networks Z_1 and N_1 Z_1 are of such values and the other connections of the circuit are such that if the repeater is below the prescribed maximum limit of gain, no singing will take place and a second pulse will be sent over the conductor 37 to energize sequence relay 39′, for setting up the next gain test.

Let us assume, however, that under the test conditions set up by the operation of relay 45 the repeater sings due to the amplification being above the maximum limit prescribed. The singing will cause current to be transmitted over the monitoring conductors 70 to the amplifier detector AD, thereby energizing relay 30 which draws up its armature to place ground on conductor 109 to operate signal relay 53, over a circuit which may be traced from ground, armature and front contact of relay 30, conductor 109, armature and contact of operated relay 51, conductor 110, winding of relay 53, to grounded battery. The operation of relay 53 closes an alarm circuit, from ground, through its right-hand armature and contact and lamp 77 to grounded battery, thereby indicating to the test attendant that the gain of the repeater R is above the maximum operating limit. Relay 53 also closes a circuit for the operation of relays 32 and 44, from ground, left-hand armature and contact of relay 53, and then over a divided path, the branch for relay 32 including conductor 111 and winding of relay 32 to grounded battery, and the branch for relay 44 including conductor 139 and winding of relay 44 to grounded battery. The operation of relay 32 discontinues the test, since control relay 31 will be deenergized by the opening of its locking circuit through the armature and contact of relay 32. The operation of relay 44 removes grounded battery from the sequence relays 38 and 38′. Relay 38′, upon deenergization releases test selecting relay 45, thereby causing the release of relay 51, test relays 55, 56 and 57, and disconnect relays 23, 24, 26 and 27. At the same time stepping magnet 29 is energized over a circuit which may be traced from ground, left-hand armature and contact of signal relay 53, conductors 139, 136 and 80, winding of stepping magnet 29, to grounded battery. Signal relay 53 still remains energized due to the locking circuit formed through its right-hand armature and contact. After the test attendant has informed the repeater attendant of the abnormal gain condition of repeater R, a break key 137, associated with the signal relay 53, may be operated to disconnect battery from the signal relay 53. Upon the release of signal relay 53, lamp 77 is extinguished, relays 32 and 44 are deenergized, and the brushes of the selector switches 10 to 22 inclusive, are advanced to the next terminal when magnet 29 is deenergized. The testing equipment has now returned to normal condition except that the brushes of the repeater selector switches 10 to 14 inclusive and the brushes of the test selector switches 15 to 22 inclusive are connected to the repeater associated with the fourth terminal of these switches, to apply the routine tests to the fourth repeater.

Referring back now to a previous condition and assuming that the first gain test applied to the repeater R, connected to the third terminals of the selector switches found the repeater operating below the prescribed maximum limit of gain, and a second pulse is sent over conductor 37 to energize sequence relay 39′. The energizing circuit for relay 39′ may be traced from ground, right-hand armature and contact of relay 35, conductor 37, armature and front contact of relay 38 which is locked in operated position, armature and back contact of relay 39, winding of relay 39′, conductor 89, and armature and contact of relay 44 to grounded battery. The energization of sequence relay 39′ pulls up its right and left-hand armatures. The circuit for test selecting relay 45 is opened at the right-hand armature and back contact of relay 39′. When relay 45 releases, the circuits established over conductors 91, 93, 95, 101 and 105 are opened causing the release of disconnect relays 23, 26, 24 and 27, and test relays 55, 56 and 57. Relay 51 is also deenergized by the removal of the ground connection through the outer left-hand armature and contact of relay 45.

When relay 39′ is operated an energizing circuit is prepared for relay 39 from ground, left-hand armature and contact of relay 39′, windings of relay 39 and relay 39′, to establish a locking circuit for these relays when pulsing relay 35 releases. A circuit is also established for the energization of test se-

lecting relay 46, from ground, right-hand armature and back contact of relay 43′, right-hand armature and back contact of relay 42′, right-hand armature and back contact of relay 41′, right-hand armature and back contact of relay 40′, right-hand armature and front contact of operated relay 38′, conductor 112, winding of relay 46 to grounded battery. When relay 46 operates, a circuit is completed over its inner right-hand armature and contact, conductor 91, brush 92, and terminal of repeater selector switch 11, to again energize disconnect relays 23 and 26 in the same manner as described in connection with the first gain test. A circuit is also completed over the middle right-hand armature and contact of relay 46, conductor 93, brush 94, terminal of repeater selector switch 12, to energize disconnect relays 24 and 27 for disconnecting line 2 and its associated balancing network from the repeater R. Relay 52 is energized over a circuit from ground, outer left-hand armature and contact of relay 46, winding of relay 52, to grounded battery. This relay is operated to form a partial circuit for the alarm circuit to be hereinafter described.

The test relay 58 is energized over a circuit, from ground, outer right-hand armature and contact of relay 46, conductor 113, brush 114, terminal of test selector switch 16, conductor 115, winding of relay 58 to grounded battery. The operation of relay 58 connects the test network Z_2 to the conductors 73 in place of line 1, over conductors 98, and the armatures and front contacts of operated relay 23. Relay 56 is again energized to substitute the short circuit connection 100 in place of line 2, over a circuit from ground, inner left-hand armature and contact of relay 46, conductor 101, brush 102, terminal of test selector switch 19, conductor 103, and winding of relay 56 to grounded battery. The short-circuit connection 100 is connected across the outgoing conductors 75 of the repeater by the conductors 104 and the armatures and front contacts of operated relay 24. Relay 57 is energized over a circuit from ground, middle left-hand armature and contact of relay 46, conductor 105, brush 106, terminal of test selector switch 22, conductor 107, and winding of relay 57 to grounded battery. The operation of relay 57 closes a circuit through its armatures and contacts and connects test network N_1 Z_1 across conductors 74, through conductors 108, and the armatures and front contacts of operated relay 26, thereby substituting the test network N_1 Z_1 for the balancing network for line 1.

The second gain test is now applied to the repeater R, with the test network Z_2 connected to the input conductors 73 of the repeater, the test network N_1 Z_1 substituted for the balancing network for line 1, the short-circuit connection 100 connected across the output conductors 75 of the repeater, and the balancing network for line 2 disconnected from the repeater by the operation of relay 27. The conditions set up for this test and the impedances of the test networks are of such values that singing will be produced in the repeater R if the repeater is operating above the prescribed minimum limit. If singing is produced indicating that the repeater is within the prescribed limits of gain, relay 30 will be energized due to current being transmitted to the amplifier detector AD. Signal relay 54, with which the lamp 78 is associated, is prevented from being energized by the opening, at the armature and front contact of relay 30, of an otherwise completed energizing circuit extending through the armature and front contact of relay 33, conductor 116, armature and front contact of relay 52, conductor 117, and winding of relay 54 to grounded battery. Under these conditions the next pulse sent over conductor 37 will energize sequence relay 40′ to apply the subsequent balance test to the repeater R.

However, when the conditions set up in connection with the second gain test on the repeater R do not produce singing, indicating that the gain is lower than the minimum limit, the energizing circuit for signal relay 54, previously traced, is completed at the armature and back contact of relay 30. The operation of signal relay 54 closes a locking circuit, from ground, through its right-hand armature and contact, and at the same time closes a circuit for the lamp 78, from ground, right-hand armature and contact of relay 54, signal lamp 78 to grounded battery. The illumination of lamp 78, indicates to the test attendant that the repeater is operating below the minimum gain limit. Further testing on the repeater R is discontinued by the operation of relay 32, which is energized over a circuit from ground, left-hand armature and contact of relay 54, conductor 111, relay 32 to grounded battery. This relay causes the release of relay 31, due to the interruption of its locking circuit. The repeater attendant will be informed as to the low gain condition of the repeater R, so that the attendant may rectify the abnormal condition of the repeater. Relay 44 and stepping magnet 29 will be energized through the left-hand armature and contact of signal relay 54 over circuits similar to those described in connection with signal relay 53. The locking circuit for relay 54 may be broken by operating key 138.

Again referring back to the next preceding condition and assuming that the previous tests applied to the repeater R, disclosed no abnormal conditions in the repeater, the third pulse sent over the conductor 37 will energize sequence relay 40′, over a circuit

which may be traced from ground, right-hand armature and contact of relay 35, conductor 37, armature and front contact of relay 38, armature and front contact of relay 39, armature and back contact of relay 40, winding of relay 40′, conductor 89, armature and contact of relay 44, to grounded battery. When relay 40′ operates it draws up both its armatures. An energizing circuit is prepared at the left-hand armature and contact for sequence relay 40, which, however, does not operate immediately, due to the shunt circuit established by the grounded armature of pulsing relay 35. As soon as relay 35 releases, a locking circuit is established for sequence relays 40 and 40′ from ground, left-hand armature and contact of relay 40′, windings of relays 40 and 40′ in series, and conductor 89 to grounded battery through the armature and contact of relay 44. When the right-hand armature of relay 40′ moves to its front contact the energizing circuit for test selecting relay 46 is broken, at the back contact. Test selecting relay 46 is thereupon deenergized and the disconnect relays 23, 24, 26 and 27 are deenergized to connect the respective conductors to the normally connected lines and balancing networks of the repeater R. At the same time test relays 56, 57 and 58 are deenergized to open the circuits for the test networks. This completes the gain tests on the repeater R.

Unbalance tests for line 1.

The operation of sequence relay 40′ establishes at its right-hand armature and front contact an energizing circuit for the test selecting relay 47. This circuit may be traced from ground, right-hand armature and back contact of relay 43′, right-hand armature and back contact of relay 42′, right-hand armature and back contact of relay 41′, right-hand armature and front contact of relay 40′, conductor 118, and winding of relay 47 to grounded battery. The operation of relay 47 completes a circuit from ground, inner right-hand armature and contact of relay 47, conductor 93, brush 94, and terminal of selector switch 12, to again energize relays 24 and 27. The energization of relays 24 and 27 as before disconnect respectively conductors 75 from line 2 and conductors 76 from the balancing network for line 2. Test relay 59 is energized over a circuit from ground, outer right-hand armature and contact of relay 47, conductor 119, brush 120, third terminal of selector switch 20, conductor 121, winding of test relay 59, to grounded battery. When the armatures and contacts of relay 59 are closed the test network Z_3 is connected to conductors 75 of the repeater R over conductors 104, and the front contacts and armatures of relay 24. Relay 51 is energized over a circuit which may be traced from ground, left-hand armature and contact of relay 47, conductor 122, and winding of relay 51, to grounded battery, to prepare a partial circuit for the signaling circuit to be hereinafter described.

The repeater R is now in condition for the third routine test or first unbalance test in which line 1 and its associated network are normally connected to the repeater R, test network Z_3 is substituted for line 2, and the associated network for line 2 is disconnected from the repeater. The impedance of the test network Z_3 is so chosen that, if the balance between the line and network of the repeater is below the prescribed maximum limit of unbalance, singing will not take place and no current will be induced in the monitoring conductor 70 to energize the relay 30. The next pulse sent over conductor 37 will therefore energize sequence relay 41′, to initiate the fourth routine test on the repeater R.

However, if singing is produced in the repeater, indicating that the unbalance is above the maximum limit, relay 30 will be energized over conductors 71 and 72 in a manner hereinbefore described and an energizing circuit will be completed for signaling relay 53. This circuit may be traced from ground, armature and front contact of relay 30, conductor 109, armature and contact of operated relay 51, conductor 110, and winding of signaling relay 53 to grounded battery. The operation of relay 53 again lights the signal lamp 77 and at the same time discontinues further testing on the repeater by operating relay 32. The repeater attendant will again be informed of the high unbalance of the repeater and the repeater may be disconnected from service for adjustments. Relay 44 is again energized, in a manner hereinbefore described, to return the operated sequence relays to normal position thereby releasing the relays set up for the previous test. Stepping magnet 29 is energized to advance the brushes of the selector switches to the next terminal when the magnet is deenergized. Signal relay 53 which still remains energized, due to its locking circuit, may be released by operating key 137. Upon the operation of key 137 stepping magnet 29 is released and advances the brushes to the next terminal.

But returning once more to a previous condition and assuming that the third test applied to the repeater R indicates that the repeater is operating within the prescribed limits of unbalance, the next pulse operates relay 41′, over a circuit which may be traced from ground, right-hand armature and contact of pulsing relay 35, conductor 37, armature and front contact of sequence relay 38, armature and front contact of sequence relay 39, armature and front contact of

sequence relay 40, armature and back contact of relay 41, winding of sequence relay 41′, and conductor 89, to grounded battery through the armature and contact of relay 44.

When sequence relay 41′ operates, the circuit for test selecting relay 47 is opened at the right-hand armature and back contact of relay 41′, thereby deenergizing all the relays set up for the previous test. A circuit is also formed through the right-hand armature and front contact of relay 41′ for the energization of test selecting relay 48. This circuit may be traced from ground, right-hand armature and back contact of relay 43′, right-hand armature and back contact of relay 42′, right-hand armature and front contact of relay 41′, conductor 123, and winding of relay 48 to grounded battery. A circuit is also prepared for the operation of sequence relay 41 from ground, left-hand armature and contact of relay 41′, windings of relay 41 and 41′ in series, conductor 89, armature and contact of relay 44 to grounded battery, but relay 41 does not operate until the short circuit is removed by the deenergization of pulsing relay 35. At the operation of relay 41 a locking circuit for itself and sequence relay 41′ in series is formed. When test selecting relay 48 operates a circuit is completed from ground, inner right-hand armature and contact of relay 48, conductor 93, brush 94, and terminal of repeater selector switch 12, to operate disconnect relays 24 and 27, thereby disconnecting conductors 75 from line 2, and conductors 76 from the associated balancing network for line 2. A circuit is also completed for the energization of test relay 61, from ground, outer right-hand armature and contact of relay 48, conductor 124, brush 125, terminal of test selector switch 21, conductor 126, winding of relay 61, to grounded battery. Test relay 61 completes a circuit through both its armatures and contacts, to connect the test network Z_4 across conductors 75, over conductors 104 and the front contacts and armatures of relay 24. Relay 52 is also energized over a circuit from ground, left-hand armature and contact of relay 48, conductor 127, and winding of relay 52 to grounded battery. The operation of relay 52 again forms a partial circuit for the operation of signal relay 54 hereinafter to be described.

The fourth routine test is now applied to the repeater R and the conditions of the repeater are as follows: Line 1 and its associated balancing network are normally connected to the repeater, with the test network Z_4 substituted for line 2 and the associated balancing network for line 2 disconnected from the repeater. This test is also an unbalance test to determine if the unbalance of the repeater is below the minimum limit, it being often desirable to determine if the actual value of balance has changed from a value indicated by a previous test, even though the test indicates the balance condition to be satisfactory, to determine the margin of safety. If the balance between line 1 and its associated network is above the prescribed minimum limits, singing will be produced and relay 30 will be energized by the induced currents in monitoring conductors 70 passing to the amplifier detector AD. When relay 30 is energized it draws up its armature to the front contact, and no signal will be given. The next pulse sent over conductor 37 will energize sequence relay 42′, to get up the fifth test for balance of line 2.

However, if the fourth test condition applied to the repeater R does not produce singing in the repeater, a signaling circuit will be formed from ground, armature and back contact of relay 30, armature and front contact of relay 33, conductor 116, armature and contact of operated relay 52, conductor 117, winding of signal relay 54, to grounded battery. The operation of relay 54 again forms a locking circuit through its right-hand armature and contact and lights the signal lamp 78, to indicate that the unbalance of the repeater R is below the minimum limit. The test will again be discontinued through the closing of a circuit for relay 32, from ground, left-hand armature and contact of relay 54, conductor 111, and winding of relay 32 to grounded battery. Control relay 31 is again released through the removal of the ground connection of relay 32. When the signal lamp 78 lights the test attendant will notify the repeater attendant of the low unbalance in the repeater R and the trouble may be remedied. Upon the operation of signal relay 54, relay 44 is energized to release the operated sequence relays and cause the release of selecting relay 48, thereby disconnecting the test connections set up for the previous test. Stepping magnet 29 is again energized to prepare the advance of the selector brushes to the next position. The locking circuit for signal relay 54 may be broken by operating key 138 whereupon stepping magnet 29 is deenergized and the brushes of the selector switches are advanced to the next terminal.

Unbalance tests for line 2.

Once again going back to a previous condition, let us assume that the fourth routine test applied to the repeater R determines that the repeater is operating within the normal limits of unbalance and that accordingly another pulse has been sent over conductor 37 to energize sequence relay 42′ as stated. The energizing circuit for relay 42′ may be traced from ground, right-hand armature and contact of relay 35, conductor 37, armature and front contact of relay 38,

armature and front contact of relay 39, armature and front contact of relay 40, armature and front contact of relay 41, armature and back contact of relay 42, winding of relay 42′, conductor 89, and armature and contact of relay 44 to grounded battery. The operation of sequence relay 42′ prepares a circuit for itself in series with sequence relay 42 through its left-hand armature and contact. Relay 42, however, is not energized until relay 35 releases. At the same time the energizing circuit for test selecting relay 48 is opened at the right-hand armature and back contact of relay 42′ whereupon all the relays set up for the previous test are deenergized. A circuit is also completed for the energization of test selecting relay 49, from ground, right-hand armature and back contact of relay 43′, right-hand armature and front contact of relay 42′, conductor 128, and winding of test selecting relay 49, to grounded battery. When test selecting relay 49 operates a circuit is closed for the energization of disconnect relays 23 and 26, from ground, inner right-hand armature and contact of relay 49, conductor 91, brush 92, terminal of repeater selector switch 11, and then over the divided path to the windings of relays 23 and 26 to grounded battery. The operation of these relays disconnects conductors 73 from line 1 and conductors 74 from the associated network for line 1. A circuit is also closed for the energization of test relay 60, from ground, outer right-hand armature and contact of test selecting relay 49, conductor 129, brush 130, terminal of selector switch 17, conductor 131, and winding of relay 60 to grounded battery. Upon energization relay 60 draws up its armatures to connect test network Z_5 to conductors 73 by way of conductors 98 and the front contacts and armatures of operated relay 23. Relay 51 is energized through the operation of test selecting relay 49 over a circuit which may be traced from ground, left-hand armature and contact of relay 49, conductor 122, and winding of relay 51 to grounded battery. The operation of relay 51 prepares a partial circuit for the energization of signal relay 53 which will be hereinafter described.

The circuit connections for the fifth routine test on the repeater R are now set up and the conditions of the test are as follows: The test network Z_5 is connected across the conductors 73 in place of line 1; the balancing network for line 1 is disconnected from the repeater; and line 2 and its associated balancing network are connected to the repeater R in the usual way. If the unbalance in the repeater is below the prescribed maximum limit, the next test will be applied to the repeater.

However, if the unbalance in the repeater R is above the prescribed maximum limit, singing will take place in the repeater, whereupon current in the monitoring conductors 70 will be transmitted to the amplifier detector AD over conductors 71 and 72. Relay 30 will be energized and draw up its armature, closing a circuit through its front contact for the energization of relay 53 from ground, conductor 109, armature and contact of operated relay 51, conductor 110, and winding of relay 53 to grounded battery. The operation of relay 53 again lights the signal lamp 77, and also stops the test by completing an energizing circuit for relay 32 through its left-hand armature and contact, which in turn removes the ground connection from the control relay 31. The test attendant again informs the repeater attendant that the unbalance condition of the repeater is above the maximum limit, and the repeater attendant will disconnect the repeater from service, to locate the unbalance and remedy the defect. Operation of signal relay 53 again releases all the relays as hereinbefore described. Key 137 may be operated to release the locking circuit for relay 53 and deenergized magnet 29 to advance the selector brushes to the next terminal.

If the repeater R is operating below the prescribed maximum limit of unbalance, the conditions set up with the fifth test will not produce singing and the next pulse will operate sequence relay 43′ over a circuit from ground, right-hand armature and contact of relay 35, conductor 37, each of the armatures and front contacts of the preceding operated sequence relays, the armature and back contact of sequence relay 43, winding of relay 43′, conductor 89 and armature and contact of relay 44, to grounded battery. The operation of relay 43′ forms a locking circuit for itself in series with the winding of relay 43 through its left-hand armature and contact. The energizing circuit for test relay 49 is opened by the operation of the right-hand armature of relay 43′ and all the relays set up for the previous test combination are deenergized. At the same time test selecting relay 50 is energized over a circuit from ground, right-hand armature and front contact of relay 43′, conductor 132 and winding of relay 50, to grounded battery. The operation of relay 50 again closes a circuit for disconnect relays 23 and 26 from ground, inner right-hand armature and contact of relay 50, conductor 91, brush 92, terminal of repeater selector switch 11, and then over a divided path to the windings of relays 23 and 26 to grounded battery. The operation of these relays disconnect conductors 73 from line 1 and conductors 74 from the balance network for line 1. Test relay 62 is energized over a circuit from ground, outer right-hand armature and contact of relay 50,

conductor 133, brush 134, terminal of test selector switch 18, conductor 135 and winding of relay 62 to grounded battery. When relay 62 is energized the test network Z_6 is connected across conductors 73 by way of conductors 98 and the front contacts and armatures of relay 23. Relay 52 is also energized over a circuit which may be traced from ground, left-hand armature and contact of relay 50, conductor 127 and winding of relay 52 to grounded battery. The operation of this relay prepares a partial circuit for the energization of signaling relay 54.

This is the last test to be applied to the repeater R and the conditions set up for this test are as follows: The test network Z_6 is substituted for line 1; the associated balancing network for line 1 is disconnected from the repeater; and line 2 and its associated balancing network are connected to the repeater in the usual manner. The value of the impedance of the test network Z_6 and the other circuit connections are so chosen as to cause singing in the repeater R if the repeater is operating below the minimum unbalance limit. When singing occurs, relay 30 is energized, and no signal is given. The next pulse sent over conductor 37 energizes relay 44, to remove the battery and ground connection from all the sequence relays previously set up and they return to normal condition. The deenergization of relay 43' releases relay 50, thereby releasing all the relays set up in the previous test combination. At the same time a pulse will be sent over conductor 136 and conductor 80 to energize stepping magnet 29 which advances the brushes of selector switches 10 to 14 inclusive and the test selector switches 15 to 22 inclusive to the next terminal of each switch when it deenergizes, preparatory to testing the next repeater. Relay 32 is also energized by the last pulse over conductors 139 and 111. When relay 32 operates, relay 31 is released, thereby discontinuing the sending of further impulses, and then when pulsing relay 35 is deenergized stepping magnet 29 is released to advance the brushes to the next terminal.

However, if the unbalance of the repeater is below the minimum limit under the conditions described in connection with the last test, the repeater will not sing and an energizing circuit for signal relay 54 will be formed from ground, armature and back contact of relay 30, armature and front contact of relay 33, conductor 116, armature and contact of operated relay 52, conductor 117 and winding of relay 54 to grounded battery. Relay 54 will again cause the illumination of signal lamp 78 and the discontinuation of the test through the operation of relay 32. Lamp 78 gives a visual indication that the unbalance of the repeater R is below the prescribed minimum limit. The abnormal repeater may be removed for the adjustment of the unbalance. Signal relay 54 again is released by operating key 138.

This completes the routine tests on the repeater R and the stepping of the brushes to the succeeding terminals of the switches initiates the same cycle of tests for the next repeater.

While the above specific description relates to a particular embodiment and operation of the routine testing of repeaters it is apparent that various modifications may be made in the testing system and other routine tests may be applied to repeaters and amplifiers within the scope of this invention and is only to be limited by the appended claims.

What is claimed is:

1. In a system for automatically testing repeaters, testing equipment, means for connecting said equipment to a repeater to be tested, and means under the control of said equipment and automatically responsive to an abnormal condition in the repeater under test for indicating said condition.

2. In a system for automatically testing repeaters, a plurality of repeaters, testing equipment, switching means for associating said repeaters individually with said testing equipment and means under the control of said switching means and automatically responsive to the operation thereof for selecting said repeaters for test in sequence.

3. In a system for automatically testing repeaters, testing equipment comprising a plurality of elements, different ones of said elements being used for different types of tests, and means for automatically connecting said elements to a repeater in a given order for testing the gain and impedance unbalance of the repeater.

4. In a system for automatically testing repeaters, a repeater which is to operate between predetermined maximum and minimum limits of gain, testing equipment, means for connecting said equipment to the repeater to be tested, and means under the control of said testing equipment and automatically responsive to a gain condition in said repeater outside said limits for causing an indication thereof.

5. In a system for automatically testing repeaters, a repeater in which the allowable unbalance for satisfactory operation is between certain predetermined values, means for testing the unbalance of said repeater, and indicating means under the control of said testing means and automatically responsive to an unbalanced condition in said repeater outside the range of said predetermined values.

6. In a system for automatically testing repeaters, testing equipment comprising a

plurality of testing elements, different ones of said elements being adapted for applying different types of tests to a repeater to be tested, a switching means, and means under the control of said switching means and automatically responsive to the operation thereof for connecting the proper elements to said repeater to be tested and applying a plurality of different tests thereto in sequence.

7. In a system for automatically testing a repeater, testing equipment comprising monitoring means and test control means, means for automatically connecting said monitoring means to said repeater to determine if said repeater is idle, and means under the control of said monitoring means to establish an energizing circuit for said test control means, said test control means being inoperative if said repeater is idle only for an interval corresponding to a normal pause in the transmission being repeated.

8. In a system for automatically testing a repeater, a repeater having associated therewith a transmission line, means automatically disconnecting said repeater from said transmission line, means to connect an impedance of predetermined value to said repeater in place of said transmission line, and signaling means operated by said repeater if said repeater is in an abnormal condition.

9. In a system for automatically testing repeaters, means for selecting a repeater for test, means controlled by the selected repeater if busy to delay the test until said repeater is idle, means operative when the selected repeater is idle to perform a given test of said repeater, and indicating means operative when said test determines said repeater to be in an abnormal condition.

10. In a system for automatically testing repeaters, means for selecting a repeater for test, means controlled by the repeater if busy to delay the test until said repeater is idle, control means operative when the selected repeater is idle to set up a given testing condition on said repeater, signaling means operated by said repeater when said given testing condition determines an abnormal condition, and means operated by said signaling means to release said control means when an abnormal condition is discovered to discontinue testing on said repeater.

11. In a system for automatically testing repeaters, means for selecting a repeater for test, means controlled by the repeater if busy to delay the test until said repeater is idle, control means operative when said repeater is idle to set up a given testing condition on said repeater, indicating means operated by said repeater when said given testing condition produces an abnormal condition in the repeater, means to disconnect said given testing condition from said repeater, and means operative to automatically apply the same test to another repeater.

12. In a system for automatically testing repeaters, switching means for selecting each of a group of repeaters in sequence, and test control means for setting up proper testing conditions for the selected repeater if idle, said control means being inoperative if said repeater is idle only for an interval of duration corresponding to a normal pause in transmission through said selected repeater.

13. In a system for automatically testing repeaters, a control element, switching means under the control of said element and automatically responsive to the operation thereof for selecting each of a group of repeaters in sequence, testing equipment comprising a plurality of test selecting devices, and test control means controlled by said switching means and responsive to the operation thereof to connect said test selecting devices to the selected repeater, and to energize them in sequence to apply various test conditions to said selected repeater.

14. In a system for automatically testing repeaters, switching means for selecting each of a group of repeaters in sequence, means operated by the selected repeater to delay testing if the repeater is busy, test selecting devices, and test control means operative when said selected repeater is idle to energize said test selecting devices in sequence to apply various test conditions to said selected repeater.

15. In a system for automatically testing repeaters, a control element, switching means under the control of said element and automatically responsive to the operation thereof for selecting each of a group of repeaters in sequence, testing equipment comprising test selecting devices and test networks having predetermined values of impedances, test control means under the control of said control element and automatically responsive to the operation thereof to energize said test selecting devices to automatically connect different groups of said test networks to said selected repeater in a given order, and means under the control of the connected networks and automatically responsive to an abnormal condition in the gain and impedance unbalance of said repeater to give an indication thereof.

16. In a system for automatically testing repeaters, a plurality of repeaters, transmission lines and line balancing networks associated with each repeater, a control element, switching means under the control of said element and automatically responsive to the operation thereof to select each of said repeaters in sequence, testing equipment com-

prising a plurality of test networks, means automatically responsive to the selection of a given repeater to disconnect said repeater from one of said lines and its balancing networks, and to substitute one of said test networks for the transmission line disconnected from the repeater, and means under the control of the substituted network and automatically responsive to an unbalance condition in said repeater to give an indication thereof.

17. In a system for testing repeaters, a plurality of repeaters, transmission lines and networks associated with each repeater, switching means for automatically selecting each of said repeaters in sequence, test selecting devices, control means for energizing said devices to disconnect said repeater from one of said transmission lines, means operated by said devices to substitute an impedance of a predetermined value in place of said disconnected line, means operated to disconnect said repeater from the network associated with the line having the substitute impedance, and means operated by said repeater to indicate the unbalance between the other transmission line and its associated network.

18. In a system for automatically testing the gain of a repeater, a repeater which is to operate between maximum and minimum limits of gain, switching means for automatically selecting said repeater, test selecting relays, a control relay operative when said repeater is idle to energize said test selecting relays, test networks, means to substitute one of said test networks for the incoming line of said repeater, means to substitute another test network for the balancing network of said incoming line, means to short-circuit the outgoing line of said repeater, the test condition set up being such that if said repeater is above the predetermined maximum limit of gain singing will take place, and means operated by said singing condition to indicate that the gain is higher than the predetermined maximum limit.

19. In a system for automatically testing repeaters, a repeater having an incoming line, an outgoing line and balancing networks for each of said lines, disconnecting means associated with said repeater and each of said lines and networks, means for automatically selecting a repeater for test, control means energized when said repeater becomes idle, pulsing means energized by said control means to operate a series of sequence relays, testing selecting relays operated by said sequence relays, test networks individual to said incoming line, test networks individual to said outgoing line, a test net work individual to one of said balancing networks, and means operated by said test selecting relays to successively connect said test networks in place of the respective lines and one of said balancing networks.

20. In a system for automatically testing repeaters, a repeater having an incoming line, an outgoing line, balancing networks for each of said lines, disconnecting means associated with said repeater and each of said lines and networks, means for automatically selecting a repeater for test, control means energized when said repeater becomes idle, pulsing means energized by said control means to operate a series of sequence relays, testing selecting relays operated by said sequence relays, test networks individual to said incoming line, test networks individual to said outgoing line, a test network individual to one of said balancing networks, means to connect certain of said test networks to said repeater through said disconnecting means, and means operated by said repeater to indicate an abnormal condition when said test networks are connected to the repeater.

21. In a system for automatically testing repeaters, a repeater having associated therewith transmission lines and networks, switching means automatically selecting said repeater to be tested, means operated by said switching means to disconnect the transmission lines and networks from said repeater, control means, pulsing means energized by said control means, progressively operated means energized by said pulsing means, test selecting means operated by said progressively operated means, a plurality of different test networks, relays associated with said test networks, switching means connecting said test selecting means to said relays, and circuit connections substituting certain of said test networks for said transmission lines and one of said networks.

22. In a system for automatically testing repeaters, a repeater having associated therewith transmission lines and networks, switching means automatically selecting said repeater to be tested, means operated by said switching means to disconnect the transmission lines and networks from said repeater, means to institute a series of tests of said repeater, test selecting relays operated by said means, a plurality of test networks of different values, a relay associated with each of said networks, and switching means individual to said relays, certain of said switching means being selected by said test selecting means to energize said relays and connect said test networks with said repeater.

23. In a system for automatically testing repeaters, switching means to automatically select a repeater for test, means operated by said switching means to connect a monitoring winding of said selected repeater to said switching means, and monitoring means automatically operated by said repeater to delay testing if said repeater is busy.

24. In a system for automatically testing repeaters, switching means automatically selecting a repeater for test, testing equipment, means for connecting said testing equipment to the selected repeater, a control relay for controlling the testing of said selected repeater, and a visual indicator operatively connected to said control relay to automatically indicate to an operator when the repeater is being tested.

In witness whereof, I hereunto subscribe my name this 29th day of December A. D., 1926.

IRA G. WILSON.