CIRCUIT DESCRIPTION
SWITCHING SYSTEMS DEVELOPMENT DEPARTMENT

CD-96144-01
Issue 2-D
Appendix 3-D
Dwg. Issue 9-D

COMMON SYSTEMS
LOCAL TEST DESK NO. 12A, 12B, OR 12C
WHEATSTONE BRIDGE TEST CIRCUIT
WITH KS-3011 WHEATSTONE BRIDGE
ARRANGED FOR OPEN LOCATION TESTS
MODIFICATION TO PROVIDE 3 VARLEY TESTS

CHANGES

D. DESCRIPTION OF CIRCUIT CHANGES

D.1 In Figure L, leads designated M and N from the Test Cord Circuit to the contact springs of the (VMB) key are reversed to bring this drawing into agreement with the manufacturing drawings.

All other headings, no change.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT. 2325-FHP-EWO-LN

COMMON SYSTEMS
LOCAL TEST DESK NO. 12A, 12B, OR 12C
WHEATSTONE BRIDGE TEST CIRCUIT
WITH KS-3011 WHEATSTONE BRIDGE
ARRANGED FOR OPEN LOCATION TESTS
MODIFICATION TO PROVIDE 3 VARLEY TESTS

CHANGES

B. CHANGES IN APPARATUS

B.1	Superseded	Superseded By
	Rel. G82 (T)	Rel. G80 (T)

D. DESCRIPTION OF CIRCUIT CHANGES

D.1 The use of relay G82 is rated "Mfr. Disc." to show realistic rating for obsolescent apparatus.

All other headings, no change.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT. 2352-LLB-PWS-EB

COMMON SYSTEMS
LOCAL TEST DESK NOS. 12A, 12B OR 12C
WHEATSTONE BRIDGE TEST CIRCUIT
WITH KS-3011 WHEATSTONE BRIDGE
ARRANGED FOR OPEN LOCATION TESTS
MODIFICATION TO PROVIDE 3 VARLEY TESTS

CHANGES

D. DESCRIPTION OF CIRCUIT CHANGES

D.1 Reversed designation of "M" and "N" leads in figure L. "M" lead now is on swinger of (VMB) key.

All other headings, no change.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT. 2352-LLB-PWS-AK

COMMON SYSTEMS
LOCAL TEST DESK NO. 12A, 12B, OR 12C
WHEATSTONE BRIDGE TEST CIRCUIT
WITH KS-3011 WHEATSTONE BRIDGE
ARRANGED FOR OPEN LOCATION TESTS
MODIFICATION TO PROVIDE 3 VARLEY TESTS

CHANGES

A. CHANGED AND ADDED FUNCTIONS

A.1 Provisions for voltmeter bridge testing and for making automatic varley-3 tests are added.

B. CHANGES IN APPARATUS

B.1 Added

Figure J
2 - U75 relays, (R)&(RC1)
1 - U541 relay, (RC)
1 - Y241 relay, (RL)
1 - Y267 relay, (RP)
2 - Y127 relays,(RT)&(RT1)
2 - 13D resistance lamps, (C)&(D)

Figure L
1 - 19LA resistance, (K)
1 - 101ED resistance (L) - "J" option

B.2

Superseded	Superseded by
A1TW key - "R" option	A1AAM key - "Q" option
110 plug	310 plug

D. DESCRIPTION OF CIRCUIT CHANGES

D.1 Figure J is added and Figure H which was formerly part of Figure 1 is designated.

D.2 Figure L is added and Figure K which was formerly part of Figure 1 is designated.

D.3 "N" option is added superseding "M" option. "M" option was formerly not designated.

D.4 "Q" option is added superseding "R" option. "R" option was formerly not designated.

D.5 "K" and "J" options are added.

D.6 Notes 109, 110 and 111 are added.

D.7 Circuit drawing ES-20629-01 is added in the Circuits Modified table.

D.8 References to Figures H, J, K and L and options "R", "Q", "N", "M", "K" and "J" are added in the Options Used table.

All other headings under Changes, no change.

1. PURPOSE OF CIRCUIT

1.1 This circuit is designed to provide testing facilities for the local test desk No. 12 for the location of faults in cables. By connecting the two Wheatstone Bridge cords to an associated test trunk circuit, this circuit is made ready for test. The operation of various keys determines the class of tests to be made in conjunction with a Wheatstone Bridge provided in this circuit. The circuit is also arranged to permit its association with other circuits for voltmeter testing, talking and ringing.

2. WORKING LIMITS

2.1 The maximum power consumption of any spool of the Wheatstone Bridge is 1 watt.

2.2 (L) relay - Figure 4

Max.Ext.Loop Res. - 3455 ohms
Min.Ins.Res. - 15000 ohms

3. FUNCTIONS

3.01 A Wheatstone bridge with a reflecting mirror scale is provided for locating faults in cable.

3.02 Test cords $\binom{WB}{B}$ and $\binom{WB}{G}$ are provided for Wheatstone Bridge testing.

3.03 With the (VM) voltmeter key operated the primary and secondary test circuit is connected for the purpose of making voltmeter tests.

3.04 The $\binom{TALK}{G.PR}$ talking good pair key provides means for cutting in the telephone circuit of the primary and secondary test circuit for talking on the good pair of the test trunk.

3.05 With the (L) loop key operated, ground is removed from the testing battery and the side of the battery normally grounded is connected to the tip side.

3.06 With the (G) ground key operated the tip of the test cord is grounded for making tests for earth potential or Wheatstone bridge measurements.

3.07 The (REV) reverse key provides means for reversing the tip and ring of the

test cord with respect to the Wheatstone bridge.

3.08 The interchange key (X) provides means for splitting the two test cords by reversing the test pairs.

3.09 The selecting key (TG TG) (TG TB) (TB RB) (RG RB) (RG RG) (RB TB) is provided to shift the connection of the terminals on the Wheatstone bridge with respect to the conductors of the two test pairs.

3.10 The test battery key, (20 V), (100 V), (200 V) permits the use of different testing voltages for Wheatstone bridge testing.

3.11 The class of test key (LOOP), (MURRAY), (VARLEY) provides means for making Loop, Murray and Varley measurements with the Wheatstone bridge.

3.12 The (OL) open location key provides means for making an open location test on the line or trunk in trouble, and a signal will be given by lighting the (OL) lamp if this lamp is equipped.

3.13 Provides for the use of either 4 cycle or 20 cycle AC for open location measurements.

3.14 Provides for making non-grounded capacity tests on open location testing.

3.15 The (PS) phase shift key provides means for shifting the phase relation of the two alternating currents which are applied to the Wheatstone bridge circuit when open locations tests are made.

3.16 The class of test key (V1), (V2) and (V3) in Figure H provide means for making the Varley 1, Varley 2 and Varley 3 measurements and also for making Murray tests.

3.17 The scale lamp of the Wheatstone bridge is lighted and the field coil is energized when the Wheatstone bridge test cords are plugged into the test trunk and the (VM) key is normal.

3.18 Provides for talking on the good or bad pair of the test trunk.

3.19 Provides for ringing on the good or bad pair of the test trunk.

3.20 Provides for making single wire resistance measurements.

3.21 Provides for making insulation resistance measurements.

3.22 The class of test keys (V1), (V2) and (V3) of Figure J provide means for making Varley 1, Varley 2 and automatic Varley 3 measurements and also for making Murray tests.

3.23 The (XL) key provides means for making Varley measurements for crosses.

3.24 The (±MDF) key is provided for signalling the main frame by applying ringing current simultaneously to both good and bad pairs of the test trunk.

3.25 The (VMB) key is provided for making a voltmeter bridge test. This makes a bridge test over the tip and ring using the voltmeter as the galvanometer and fixed resistances of 300 ohms as the two arms of the bridge.

3.26 The (VMS) key provides a low scale condition on the voltmeter to permit a more accurate reading voltmeter bridge test.

3.27 Provides a means for making Murray and Varley loop tests with the voltmeter bridge conditions.

4. CONNECTING CIRCUITS

4.1 Test Trunk Circuit - Frame End - Arranged for Manual Varley-3 Test - SD-90403-01.

4.2 Test Trunk Circuit - Frame End - Arranged for Automatic Varley-3 Test - SD-95545-01.

4.3 Primary and Secondary Test Circuit- ES-10370-01, ES-254581, ES-261158 or ES-20629-01.

4.4 Telephone Circuit - ES-359281, ES-358038 or ES-254583.

4.5 Primary Ringing Circuit - ES-359627, ES-239467, ES-20672-01 or ES-254600.

4.6 Four Cycle Interrupter Circuit - SD-95301-01.

DESCRIPTION OF OPERATION

5. INCOMING CALLS

When the repairman's or the frameman's telephone set is connected across the "TG" and "RG" leads of Figure 4, the (L) relay operates over the loop and lights the trunk lamp. The call is answered by plugging the (WB G) cord into the good pair jack and operating the (TALK G PR) key. This opens the cut-off springs on the jack thus disconnecting the ground and the (L) relay from the line. The (L) relay releases and retires the trunk lamp. A talking path to the telephone set in the test desk is provided through the (WB) repeating coil and transmitter battery is supplied to the testman through the windings of the (T) relay. When the (WB B) cord is plugged into the

other jack of the test trunk, relay (WB) operates, providing the (VM) key is normal. The (WB) relay operated, (a) removes ground from the negative side of the 20 volt battery and connects this battery to the voltage key, (b) energizes the field coil and lights the lamp in the Wheatstone bridge and (c) connects battery to the (MURRAY) key through the voltage key. The plugging up of the two cords, therefore automatically connects this circuit for test with the Wheatstone bridge.

6. VOLTMETER BRIDGE TEST

A voltmeter bridge key (VMB), in Figure L, is provided to establish a Murray Wheatstone Bridge with the voltmeter of the primary and secondary test cord circuit as the galvanometer. Two resistances of 300 ohms each form the fixed arms of this bridge. Ordinarily the 100 volt test battery is used in connection with the 24 volt scale of the voltmeter using the 1000 ohm winding of the meter. However, if the primary and secondary test circuit is equipped with a KS-13724 voltmeter, it is necessary to provide "J" option since the KS-13724 meter has no 1000 ohm winding. "J" option connects a 1053 ohm shunt across the 20000 ohm winding of the meter thus providing a circuit equivalent to the 1000 ohm winding. In connection with voltmeter bridge testing a sensitive scale key designated (VMS) is provided which is effective only when the (VMB) key is operated. This key cuts in a very sensitive winding of the voltmeter to obtain a greater deflection of the meter needle when required. The (VMS) key is non-locking and should be used only when the needle deflection is 5 or less scale divisions with the (VMS) key normal. This test is used to determine the proper settings of the (X) and selecting keys when Wheatstone Bridge Varley measurements are to be made. Settings of the (X) and selecting keys are tried, as will be described later, until a balance or the smallest deflection is obtained on the voltmeter. A reverse deflection of the meter needle on any setting can be off-set by operating the (REV) key. When a balance or near balance is obtained, it indicates that the correct connections of the test circuit tip and ring have been established with respect to the good and bad test pairs as required by the connections made by the repairman at the distant end. The (VMB) key is then restored to normal and the testman can proceed with Wheatstone Bridge Varley measurements.

7. WHEATSTONE BRIDGE MEASUREMENTS

7.1 Wheatstone Bridge

This instrument is of the reflecting mirror type, the illumination for the mirror being received from the scale lamp, reflecting itself as a single line upon the scale. If the image does not appear as a single line the filament of the lamp can be aligned by removing the cover from the bridge and loosening the adjustment screws which hold the lamp. When the testing circuit is normal, the image of the lamp should fall on zero, and a zero adjustment screw is provided on top near the rear of the bridge. Normally 20 volts testing battery is connected to the bridge and all preliminary balances should be made with this test battery. Shunt keys are provided as part of the Wheatstone bridge and are designated (1), (0.1), (0.01) and (0.001). These keys determine the sensitivity of the galvanometer when making a balance. A deflection to the left indicates not enough resistance in the "R" resistance arm of the Wheatstone bridge and a deflection to the right indicates too much resistance in this arm.

7.2 Loop Resistance Measurement

With the (Murray) and (Varley) loop keys normal, a condition is set up for making loop measurements over the so-called good pair. In order to make a loop test, the distant end of the pair must be short-circuited or closed through the repairman's telephone set. If the approximate resistance of the loop is not known, the preliminary balance should be obtained with the "A" and "B" arms equal, that is, the "multiplied by" dial at one. If a more accurate measurement is desired or if a balance cannot be obtained with equal ratio arms the ratio should be adjusted by the "multiplied by" dial. The following table indicates the approximate setting of the dial for measuring certain values of resistance.

Resistance being measured	Multiplier on Ratio Dial
Less than 10 ohms	.001
10 to 100 ohms	.01
100 to 1000 ohms	.1
1000 to 10000 ohms	1.
10000 to 100000 ohms	10.
100000 to 1000000 ohms	100.
Over 1000000	1000.

When the Wheatstone bridge has been brought to a balance the resistance of the external circuit may be calculated by the formula L = XR. Where "L" is the loop resistance of the circuit under test, "R" the value of resistance in the rheostat arm, "R" and "X" is the multiplier at which the "multiply by" dial is set.

7.3 Metallic Varley Loop Measurement (V1)

With the (Varley) key operated, a circuit condition is set up to make the

metallic Varley loop measurement with the (V1) key normal. This measurement which is known as the Varley loop is made with the positive side of the battery applied to the loop at the repairman's telephone set over a third wire which eliminates earth potential. The balance of the bridge is obtained in the same manner as previously described for the loop resistance test and from this may be calculated the resistance of the faulty wire from the central office to the repairman.

7.4 Grounded Varley Measurements (V2)

With the (V2) and (Varley) keys operated and the (GL) key normal a grounded Varley measurement may be made similar to the metallic Varley measurement just made. In this case, the positive side of the battery is grounded which for ground location means that the battery is applied to the loop at the fault. This is known as the Varley 2 measurement and from this may be calculated the resistance from the fault to the repairman and from the fault to the central office.

Single wire resistance measurements may be determined by means of a Varley test in conjunction with a loop test. To do this the loop resistance is first measured and then both wires are connected to ground at the distant end and a Varley test made.

7.5 Metallic Manual Varley Measurement (V3)

With the (V3) key (Fig. H) operated together with the (Varley) key, another metallic Varley measurement may be made with provision for applying the positive side of the test battery to the bad wire at the main distributing frame, in the central office where the test trunk is connected, to the cable under test. This arrangement provides for making a loop measurement which in conjunction with the loop measurements previously made may be used to calculate the location of the fault so as to eliminate the resistance of the test trunk from the test desk to the central office. The connection from battery to the bad wire at the main distributing frame is accomplished manually.

7.6 Metallic Automatic Varley Measurement (V3)

With the (V3) key (Fig. J) operated together with the (Varley) key, another metallic Varley measurement may be made with provision for applying the positive side of test battery to the bad wire at the main distributing frame, in the central office where the test trunk is connected to the cable tested. This arrangement provides for making a loop measurement which in conjunction with the measurements previously made may be used to calculate the location of the fault so as to eliminate the resistance of the test trunk from the test desk to the central office. The connection of battery to the bad wire at the main distributing frame is accomplished automatically by the operation of the (V3) key. When this key is operated ground is closed to operate relay (RT). (RT) operates (RT1). (RT1) operates (RP). (RP) operates (RL) from ground through contacts of the (V3) key and operates relay (R). Relay (R) connects ringing current to the so-called good pair. Relay (RL) in operating releases (RT). (RT) releases (RT1). (RT1) releases (R) but relay (RL) remains locked through normally made contacts of (RP). Relay (RL) in releasing removes ringing current from the good pair. At the same time that this impulse of ringing current is being sent out over the good pair, battery of a certain polarity, as determined by the setting of the selecting keys and X key which will be described later, is connected to the so-called bad pair. This combination causes the distant frame end test trunk to function to make the desired connections at the distant end of the test trunk. When the test is completed the (V3) key is restored. The (V3) key restored to normal causes another impulse of ringing current to be sent out which brings about the disconnection of these leads automatically at the main distributing frame at the distant office.

7.7 Location of Crosses by Varley Tests

If the fault to be tested is a cross instead of a ground condition as previously determined by the voltmeter test then the cross location key (XL) will be operated and the tests described above for locating grounds may be duplicated. The operation of the cross location key removes the ground from the positive side of battery and connects the positive battery to the other bad wire. It may sometimes be desirable to make a cross location on the same basis as a ground location and this may be accomplished by operating the ground key (G) which will ground the tip side of the test circuit.

7.8 Open Location Tests

The location of an open in a cable pair is made by obtaining a balance of the capacity of the leads of the open pair to ground with the capacity of a fixed condenser. To make these tests the (OL) (MURRAY) and (G) keys should be operated and the ratio dial on the Wheatstone bridge should be set to "M-1000". This transfers the field coil and also the bridge circuit to a source of alternating current, connects the (A) condenser and the "r" rheostat into the bridge circuit, and grounds the "ST" lead to start the four-

cycle interrupter or to operate the (A) relay, Fig. 2. If a four-cycle interrupter is used, the (OL) lamp will light when the interrupter is associated with the position. Alternating current for making open location measurements is obtained either from a four-cycle interrupter or from the ringing machine. The four-cycle interrupter furnishes one source of 24-volt AC potential and two sources of 100-volts AC potential each of four cycles per second. The two sources of 100-volts AC are 90° out of phase with each other and the 24-volt AC is approximately in phase with one of the 100-volt AC potentials. The 24 volts AC is supplied to the field coil of the galvanometer and the 100 volts potential is supplied to the bridge either from leads 1 and 2 if the phase shift key (PS) is normal or from leads 3 and 4 if the (PS) key is operated.

If 20-cycle AC from the ringing machine is used for making the open location measurements, the operation of the (A) relay as mentioned above connects 20 cycles to the field coil of the bridge through the (J) resistance and supplies 20 cycles to the bridge through the 77A repeating coil and the (G) and (H) resistances. The operation of the (PS) key shifts the phase of the a-c. by short-circuiting the (G) and (H) resistances.

With the phase shift key (PS) normal, a balance should be obtained by adjusting the "R" arm of the bridge and the phase shift key should then be operated and a balance again obtained, this time by adjusting the "r" rheostat. This operation should be repeated until a change in phase by the operation and release of the (PS) key has no effect. When a balance is obtained as described above, the resistance of the "R" arm of the bridge is practically proportional to the capacity between the wire under test and ground. The "r" arm serves to balance the resistance component of the line and therefore does not enter into the calculations. Non-grounded capacity tests to determine the capacity between wires may be made in the same manner without the operation of the (G) key. This method is used to locate split pairs in cables.

7.9 Murray Loop Tests

Murray loop tests corresponding to the Varley loop tests may be made by operating the (Murray) key instead of the (Varley) key. The operation of the (Murray) key transfers the galvanometer connections from terminal (J) to terminal (T). The "multiplied by" dial of the bridge is set to the "M-1000" point so that the "A" arm is 1,000 ohms. The other ratio arm under this condition consists of the variable resistance arm which is used in the Varley loop measurements. The (V1), (V2), (V3) key is used to determine the battery condition for the Murray tests exactly the same as for the Varley tests. The balance of the galvanometer is obtained for the Murray loop test in exactly the same manner as for the Varley test. Having obtained a balance with the (Murray) key operated, the location of the fault may be calculated. The location of the crosses by the Murray loop test may be obtained in the same manner as for the location of crosses by the Varley loop method.

Single wire resistance measurements may be made as stated in paragraph 7.4 except that Murray tests are substituted for Varley tests.

8. MISCELLANEOUS FEATURES

8.1 Talking

A talking key (TALK G. PR.) is provided directly associated with the tip and ring of the so-called good pair so that the tester may talk with the repairman whose telephone set is bridged across the good pair at the distant test point. When the talking key is operated, 48 volt talking battery is connected to the tip and ring through the repeating coil which enables the repairman at the distant point to talk. The desk man may instruct the repairman to shift connections as required.

8.2 Voltmeter Testing and Ringing

In order to permit the association of the primary and secondary test circuit with this circuit for voltmeter testing, talking and ringing, the (VM) and (L) keys are provided. The (VM) key operated, transfers the Wheatstone bridge cord circuit from the Wheatstone bridge to the voltmeter in the primary and secondary test circuit and also prevents the operation of the (WB) relay. This prevents any possible interference from the Wheatstone bridge circuit during voltmeter testing. The loop key (L) operated, removes the ground from the testing battery and connects the side of the battery which is normally grounded at the key to the tip side of the voltmeter test circuit. This will provide a testing circuit with the primary and secondary test circuit, independent of ground which may be used in measuring foreign potential across bonds in a cable plant, measuring insulation resistances where ground is present on the line or cable being measured and for making ballistic capacity tests.

8.3 Ringing Key

A ringing key is provided to enable the tester to signal the main frameman at the distant central office. This is

accomplished by sending ringing current simultaneously on both test pairs. The ringing key (±MDF) when operated connects ringing current to the bad pair through contacts of relay (RC1). By means of a timing arrangement ringing current will be applied to the good and bad pairs simultaneously and remove from the bad pair slightly before the removal of ringing current from the good pair. In addition the bad pair is not closed through until a time interval after ringing current is removed from the good pair. This circuit arrangement is to prevent a false Varley 3 set up when signaling the MDF. This ringing is provided so that the tester may signal the main frame man at the distant central office in order to have him disconnect or shift the connection of the test trunk as the tester may desire.

3.4 Selecting Key

The $\begin{pmatrix}TG\ TG\\TB\ RB\end{pmatrix}$ $\begin{pmatrix}TG\ TB\\RG\ RB\end{pmatrix}$ $\begin{pmatrix}RG\ RG\\RB\ TB\end{pmatrix}$ key provides means for shifting the connection of the terminals in the Wheatstone bridge circuit with respect to the conductors of the two test pairs. These connections are as follows:- The normal designation of this key is: (TG/RG,TB/RB) when operated in one direction it is designated (RG/RB,RG/TB) and when operated in the other direction, it is designated (TG/TB,TG/RB). These letter designations represent the tip of the good pair (TG), ring of the good pair (RG), tip of the bad pair (TB), and ring of the bad pair (RB). In addition to the above, the left-hand designations indicate the order in which the tip and ring leads from the Wheatstone bridge circuit are connected to the particular leads of the test trunk when the (X) key is normal. The right-hand designation indicates the corresponding connections when the (X) key is operated. In other words, with the above key and the (X) key both normal, the tip and ring leads from the Wheatstone bridge circuit will be connected to the tip and ring of the good pair, respectively. With this key normal and the (X) key operated, the tip and ring leads are connected to the tip and ring of the bad pair respectively as indicated by the right-hand designations. When this key is operated to the position designated (TG/TB,TG/RB) the tip and ring will be connected to the tip of the good and the tip of the bad, respectively, and with the (X) key operated, the tip connection does not change, but the ring will be connected to the ring of the bad pair. When this key is operated to the position designated (RG/RB,RG/TB), the tip and ring will be connected to the ring of the good pair and the ring of the bad pair, respectively, and with the (X) key also operated, the tip connection does not change but the ring will be connected to the tip of the bad pair. In addition to this combination of connections, a reversing key (REV) is provided to reverse the "T" and "R" leads from the Wheatstone bridge and a ground key (G) is provided to connect ground to the tip test lead of the Wheatstone bridge.

3.5 Testing Battery Potential

The testing battery for the Wheatstone bridge measurements is normally 20 volts but the provision is made by means of the 100 volt key or the 200 volt key to connect the potentials to the Wheatstone bridge through fixed resistances which guard against injury to the bridge in case of maximum unbalance. The 200 volt testing battery is used particularly for obtaining measurements of a variable fault as the higher voltage tends to hold the faulty connection more stable.