

16C1 TELEGRAPH REPEATER AND BALANCED LOOP APPLIQUE TESTS AND ADJUSTMENTS

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1. GENERAL

1.01 This section covers the methods of testing and operating the 16C1 telegraph repeater. It applies to operation over one or two line circuits for all methods of operation for which the repeater is suitable. It is assumed that the line (both lines if neutralizing wire is used) has been tested for continuity, is connected to the repeater and is terminated at the distant end by the equipment assigned to the circuit; also that the relays have been tested and adjusted in accordance with the appropriate B.S.P. sections, and that the LINE, OPN 1, and OPN 2 switches are operated to the positions designated for the type of operation to be used. The LINE switch has three positions, designated 1W, 1W60Ω, and 2W, for 1-wire operation, 1-wire with the 60-cycle

filter connected, and for 2-wire operation (with neutralizing wire), respectively. The positions of the OPN 1 and OPN 2 switches are as follows:

| <u>Polarential</u> | <u>OPN 1</u> | <u>OPN 2</u> |
|----------------------------|--------------|--------------|
| Type A Polar Send | PSA | PS |
| Polar Rec. | PRA | PR |
| Type B Polar Send | PB | PS |
| Polar Rec. | PB | PR |
| <u>Differential Duplex</u> | | |
| <u>Bat. Line</u> | | |
| Norm. Norm. | PB | DX |
| Rev. Norm. | PRA | DX |
| Norm. Rev. | PSA | DX |

Effectiveness of 60Ω Filter and Neutralizing Wire

1.02 When starting service on a 2-wire circuit or one involving the 60-cycle filter, or whenever trouble is suspected, a test of the effectiveness of the neutralizing wire or filter should be made by the following procedure:

- (1) The local 16C1 repeater and the distant repeater or teletypewriter set should be lined up according to the procedures specified for the line and type of operation.
- (2) Arrange for transmission of teletypewriter test signals from the remote terminal and connect the output of the home repeater to suitable transmission measuring equipment. If 1-wire operation with 60-cycle filter is provided, observe the distortion in the received signals while the LINE switch is operated alternately to the 1W and 1W60Ω positions, disregarding any transient distortion produced by operation of the switch. Substantial reduction in any distortion due to 60-cycle line interference should occur with the switch in the latter position.
- (3) If 2-wire operation is provided, observe the distortion in the received signals while the LINE switch is operated

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alternately to the 1W and 2W positions, disregarding any transient distortion produced by operation of the switch. Substantial reduction in the distortion due to all kinds of line interference should occur with the switch in the latter position. Better results should be obtained in the 2W position than in the 1W60 ω position, even though the interference is due to 60-cycle currents.

(4) A rough check for longitudinal balance of a 2-wire system can be made in the absence of line interference and without transmission testing equipment by means of the 163-type test set. Connect the test set as for the duplex balance test described in Paragraphs 2.09 and 2.10. Note the duplex balance of the resistance branch and the timing branch of the No. 1 network against the No. 1 line by observing the reaction of the meter to transmitted steady marking and spacing signals and to slow or fast dots. Readjust the network, if necessary, in order to obtain a high degree of duplex balance. Interchange the connections between the repeater and lines No. 1 and No. 2. Repeat the check of duplex balance, noting the balance of the No. 1 network against the No. 2 line. Similar results (with a high degree of duplex balance in each case) indicates longitudinal balance between the No. 1 and No. 2 lines, including their respective terminations in the remote repeater. Longitudinal balance within the home repeater is indicated (roughly) by a test similar to that just described at the remote repeater.

(5) If the remote termination is a 128B set, interchange the connections between the repeater and lines No. 1 and No. 2 at the remote repeater and repeat the check of duplex balance at the home repeater.

1.03 If a cathode-ray oscilloscope is available, a more accurate method of testing the balance between the two lines is as follows:

(1) At the polar sending end, remove the send relay and with a clip lead connect the No. 1 terminal of the send relay terminal block through 128 ohms to ground. At the polar receiving end, block the send relay to the mark position.

(2) Make a varley measurement of the local telegraph repeater and of the lines terminated in the distant repeater. Investigate any unbalance greater than 10 ohms by repeating the varley measurement with the lines grounded at various points. (In exceptional cases, a greater unbalance may not indicate a trouble, because of manufacturing variations in equipment; for instance, the two windings of a 158A retardation coil may differ 5 ohms.)

(3) Connect the Y axis of the oscilloscope to line 1, the ground post to ground, and turn the synchronous signal selector to External. Adjust the Y-axis gain to make the peak vertical trace, due to interference, span two large divisions.

(4) Without disturbing the Y-axis gain, change the connection of the Y axis from line 1 to the corresponding point of line 2.

(5) If the peak vertical trace is not the same as that of Step (3), thus indicating that the magnitudes of the interference are different in the two wires, repeat (3) and (4) and investigate the cause of the difference by grounding the two wires at various points.

(6) If the magnitudes of the interference in the two lines are the same, check the relative phases by connecting line 1 to the X axis and adjusting the X-axis gains to cause the resulting figure to slant about 45°. If there is no phase difference, this figure is a straight line. Phase difference causes it to be a circle or ellipse. The departure from a straight line which is tolerable depends on the magnitude of the interference, and so no limits can be given.

2. DESCRIPTION OF TESTS AND ADJUSTMENTS

Additional Apparatus Required

2.01 The following apparatus will be required in making some of the tests:

163A1 or 163A2 Test Unit (Balanced Loop Applique)
163F1 Test Unit (114-Type Coupling Unit)
165C Plug (dummy) or equivalent open plug
118-Type Transmission Measuring Equipment or
161A1 Telegraph Station Test Set
100A Test Distributor (at subscriber station)

(A) Loop Current Adjustment

2.02 With balanced loop applique, adjust the loop currents of the sending and receiving loops in accordance with Table 1 below by turning the rheostats by means of the screwdriver. Turning the loop rheostat in a clockwise direction decreases the resistance of the loop circuit and increases the current.

Table 1

| <u>Sum of 1130V Battery Voltages</u> | <u>Loop Current</u> |
|--|---------------------|
| 270 | 65 ma |
| 260 | 62.5 " |
| 250 | 60 " |

With 114-Type Coupling Unit - No Adjustment

(B) Type B Polar Potential - Polar Sending

L Pad Switch

2.03 Operate the L PAD switch to a position designated with the resistance value indicated in the following table, within the CX BAL OUT sector if the line is not equipped with composite sets, or within the CX BAL IN sector if the line is equipped with composite sets.

| <u>Line Res. External to the Terminal Repeaters*</u> | <u>Res. Setting of L PAD Switch</u> |
|--|---|
| Under 400 ohms | 450 |
| 400-800 ohms | 300 |
| 800-1200 ohms | 150 |
| Over 1200 ohms | 0 |

* The measured or computed resistance from testboard-to-testboard or from testboard to line terminal of a 128B2 set including entrance cables and composite or simplex coils.

APEX Switch

2.04 Operate the APEX switch to a position appropriate to the line resistance and remote terminal equipment. Use the switch settings covered in the table below when the remote terminal is a 16C1 or 16B1 repeater and resistances of the entrance cables at the two terminals differ by less than 100 ohms. Decrease switch settings by 200 ohms when entrance cable resistance at the polar sending terminal exceeds that at the polar receiving terminal by 100 ohms or more. Increase switch

settings by 200 ohms when entrance cable resistance at the polar receiving terminal exceeds that at the polar sending terminal by 100 ohms or more.

| <u>Line Res. between Terminal Repts.</u> | <u>APEX Switch Setting</u> |
|--|--------------------------------|
| Under 600 ohms | 800 |
| 600-1000 ohms | 1000 |
| 1000-1200 ohms | 1200 |
| 1200-1400 ohms | 1400 |
| 1400-1650 ohms (Max.) | 1600 |

2.05 Operate the APEX switch as indicated in the table below when the remote terminal is a 128B2 teletypewriter subscriber set. Modify the switch settings for unequal entrance cable resistances at the two terminals as described in Paragraph 2.04 above.

| <u>Line Res. between Rept. and Sub. Set</u> | <u>APEX Switch Setting</u> |
|---|--------------------------------|
| Under 600 ohms | 600 |
| 600-1200 ohms | 800 |
| 1200-1400 ohms | 1000 |
| 1400-1650 ohms (Max.) | 1200 |

2.06 Line up the repeater for Type B polar potential polar sending transmission by adjusting duplex balance, bias current and equalization if required. This line-up should preferably be made when there is no leakage on the line. If it is necessary to line up the system when leakage is present on the line, proceed in the same way as described below, and check the need for later readjustment as described in Paragraph 3.01.

2.07 Make preliminary or estimated settings of the network and equalizer controls if information on which to base such settings is available. Otherwise it is suggested that the controls be centered. This is to reduce the amount of hunting required in reaching final adjustment at both terminals. If it is not intended to employ equalization, operate the EQL rheostat to the OFF position. The BIAS rheostat may be set in the extreme clockwise position for the convenience of holding the local receiving circuit in a marking condition.

Balance

2.08 Connect the meter of the 163-type test set in the BAL 1 jack. Connect the telegraph key of the test set in the MON jack if a coupling unit is used for local termination, or in the S LOOP jack of the associated balanced loop applique if such equipment is being used for local termination of the repeater.

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The balanced loop applique, if provided, should be conditioned for half-duplex operation during the use of the test set for line-up and communication over the line.

2.09 While opening and closing the telegraph key slowly, adjust the BAL RES rheostat so that the same steady reading of the meter is obtained in both positions of the telegraph key. This provides for duplex balance with respect to direct currents. If line interference is present care must be used to distinguish between any disturbance of the meter due to the interference and the steady change in reading which follows the input signal condition when resistance unbalance is present.

2.10 Adjust the timing branch of the network by means of the C BAL switch and the TIM RES rheostat so that the kicks of the meter which accompany operation of the telegraph key are reduced to a minimum. Rough adjustment can be made during the transmission of slow dots. Try several positions of the C BAL switch in two or three mf steps, and find the best setting of the TIM RES rheostat for each of the C BAL switch positions. Retaining the combination which appeared best, refine the balance by successive readjustment of the C BAL switch and the TIM RES rheostat while sending trains of rapid dots. If the change in meter deflection due to transmitted signals can not be reduced to a small amplitude by adjustment of the timing branch, change the composite set balancing elements of the network by operating the L PAD switch into the opposite sector from that adopted in the preliminary setup. Readjust the BAL RES and the timing branch as described above. Retain whichever combination of L PAD switch position and timing branch adjustment gives the best balance. Care must be used throughout the process to distinguish meter reactions due to the transmitted signals from those which may be caused by line interference.

Bias Current Adjustment

2.11 Procedure:

- (1) Insert the meter plug of the 163-type test unit in the BAL 1 jack.
- (2) Obtain from the polar receiving repeater or set at the distant end of the line a steady spacing signal and record the meter indication.
- (3) Insert the meter plug into the BIAS jack and adjust the BIAS rheostat by means of the screwdriver until the meter reading is the same but opposite in direction

to that recorded in (2). This adjustment is only approximate but permits communication over the circuit. (If signals can not be received in test (4) below, it may be due to earth potential difference; a better value for this initial setting, then, is the algebraic difference between the indications for a steady mark and space.)

(4) Make a more accurate adjustment of the bias current as follows. Obtain from the distant station unbiased miscellaneous test signals. Measure the bias in these signals by means of a 118-type transmission measuring set or by means of the orientation range of a monitoring teletypewriter. Remove the bias by adjusting the bias current. From a subscriber's station, if there is no transmitter-distributor, obtain a repeated O signal from a 100A test distributor or a repeated R signal from a locked-in teletypewriter. The 118-type set indicates one-half of the actual bias for the O signal and 1.5 times the bias for the R signal. Recheck the bias current adjustment after each change in setting of the home equalizer.

Equalizer Adjustment

2.12 Procedure:

- (1) At offices with Nos. 2 and 9B service boards, connect a 161A1 telegraph station test set to the 16C1 repeater by the following patches, which will be described in more detail in Bell System Practices concerning these service boards. Patch from the LEG jack associated with the 16C1 repeater through a leg patch cord, a second leg patch cord, a trunk to the facility position, and a trunk from the facility position to the equipment aisle. Terminate the first leg patch cord in a spare hub potentiometer.
- (2) Before making equalization tests in these service board offices, determine by local test that the transmission through the trunk between the service and facility positions is satisfactory.
- (3) If the distant terminal of the line is in a telegraph repeater station, follow procedure (4), below; if it terminates in a subscriber's office, follow procedures (5) to (9).
- (4) Obtain from the distant station test sentence signals with 20 per cent switched bias impressed on them by means

of a 119C telegraph signal biasing set. Adjust the EQL resistance for minimum distortion indication of a 118-type telegraph transmission measuring set. If the 119C set is not available at the distant station, test first with signals biased 20 per cent steady marking, then 20 per cent steady spacing, by means of a 119A or B set, and set the EQL resistance half-way between the two settings determined. If a 118-type set is not available, a 161A1 telegraph station test set may be used; follow procedures (6) to (9), testing with unit mark biased 20 per cent spacing and Letters biased 20 per cent marking in addition to the other test signals specified.

(5) If there is a transmitter-distributor at the subscriber station, follow procedure (4) above, but test with unbiased signals.

(6) If there is no transmitter-distributor, obtain the following signals in turn over the circuit from a 100A test distributor, or equivalent, at the distant terminal:

Unit mark, Blank, T, O, M, V, and Letters, at the speed at which the circuit is to operate. Each signal should be repeated a sufficient number of times for a measurement to be made, before starting the next signal.

(7) Measure the received signals by means of a 161A1 or 118-type transmission measuring set, and subtract, algebraically, the distortions of the O signal from that of the other signals. (The indicated distortion of the O signal is very nearly the circuit bias, one-half the bias in the 118-type set.)

(8) Adjust the EQL rheostat to make the largest of the differences obtained as in (5) a minimum. With no equalizer, the difference is apt to be a maximum for the signals biased 20 per cent, but when the circuit is equalized, the maximum difference may be found in another signal. For more detailed information, see Bell System Practices concerning the 161A1 set. The following example illustrates test results which might be obtained before and after equalization:

| | <u>Blank</u> | <u>T</u> | <u>O</u> | <u>M</u> | <u>V</u> | <u>Letters</u> |
|---------------------|--------------|----------|----------|----------|----------|----------------|
| Before equalization | 12 | 9 | 2 | 1 | -6 | -11 |
| After " | 6 | 4 | 2 | 1 | -4 | - 3 |
| Corrected for bias | 4 | 2 | 0 | -1 | -6 | - 5 |

(9) If a test distributor is not available, teletypewriter keyboard signals may be used for equalizing, provided the calibration error is small as determined by the procedure in another section. They should not be used without prior calibration.

2.13 After the adjustments described above have been made at both terminals of the system, recheck the adjustment of each control in turn in order to make minor corrections which may be necessary due to the change in the remote terminal. Recheck the resistance and timing branches of the network after each change at the remote terminal, until the desired degree of duplex balance is obtained at both terminals, with line currents within the prescribed limits.

(C) Type B Polarential - Polar Receiving

2.14 Line up the repeater for Type B polarential polar receiving operation by adjusting duplex balance and equalization if required.

(1) Operate the L PAD switch as described in Paragraph 2.03 and adjust the balance per 2.08 to 2.10.

(2) Recheck the duplex balance of the repeater after any change in the adjustment of the APEX switch or major change in the balancing network at the remote polar sending repeater.

(3) If equalization is required proceed as described in Paragraph 2.12, except that any small duplex unbalance at the remote terminal due to a change in equalizer setting from the initial value, may be disregarded. A recheck should be made, however, of the final bias current adjustment at the remote polar sending terminal. If it is not intended to employ equalization, operate the EQL rheostat to the OFF position. The APEX switch and BIAS rheostat are disabled by the OPN 2 switch and may be disregarded.

(D) Type A Polarential - Polar Sending

2.15 Line up the repeater for Type A polarential polar sending transmission by adjusting line current, duplex balance, bias current, and equalization, if required.

(1) Operate the L PAD switch as described in Paragraph 2.03.

(2) Make preliminary or estimated settings of the apex, network, and equalizer controls if information on which to base

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such settings is available. Otherwise it is suggested that the controls be centered. This is to reduce the amount of hunting required in reaching final adjustment at both terminals. If it is not intended to employ equalization, operate the EQL rheostat to the OFF position. The BIAS rheostat may be set in the extreme clockwise position for the convenience of holding the local receiving circuit in a marking condition.

(3) Connect the meter of the 163-type test set in the LINE jack. Connect the key of the test set in the MON jack if a coupling unit is used for local termination, or in the S LOOP jack of the associated balanced loop applique if such equipment is being used for local termination of the repeater. The balanced loop applique, if used, should be conditioned for half-duplex operation during use of the test set for line-up and communication over the line.

(4) Adjust the APEX switch so that the current read in the LINE jack is $30 + 3$ ma when a marking signal is being transmitted to the line. Readjustment of the APEX switch may be required later after other adjustments in the home and distant repeaters have been made.

(5) Adjust the balance as described in Paragraphs 2.08 to 2.11, inclusive.

(6) Adjust the bias current and equalization (if required) as described in Paragraphs 2.11 and 2.12.

(7) After initial adjustments have been made at the distant terminal, recheck controls per Paragraph 2.14.

(E) Type A Polarential - Polar Receiving

2.16 Line up the repeater for Type A polarential polar receiving operation by adjusting duplex balance and equalization if required.

(1) Operate the L PAD switch as described in Paragraph 2.03.

(2) Adjust the balance rheostat as described in Paragraphs 2.08 to 2.11, inclusive.

(3) If equalization is required proceed as described in Paragraph 2.12.

(4) The APEX switch and BIAS rheostat are disabled by the OPN 2 switch and may be disregarded.

(5) After initial adjustments have been made at the distant terminal, recheck controls per Paragraph 2.13.

(F) Differential Duplex

2.17 Line up the repeater for differential duplex transmission by adjusting line current, duplex balance and equalization if required.

(1) Operate the L PAD switch to position 0 in the CX BAL OUT sector if the line is not equipped with composite sets, or to position 0 in the CX BAL IN sector if the line is equipped with composite sets. The line pads are short-circuited by the OPN 2 switch. On some non-composited lines, a better balance may be obtained by use of the CX BAL IN sector.

(2) Make preliminary or estimated settings of the apex, network, and equalizer controls if information on which to base such settings is available. Otherwise it is suggested that the controls be centered. This is to reduce the amount of hunting required in reaching final adjustment at both terminals. If it is not intended to employ equalization, operate the EQL rheostat to the OFF position. The BIAS rheostat is disabled by the OPN 2 switch and may be disregarded.

(3) Connect the meter of the 163-type test set in the LINE jack. Connect the key and sounder of the test set in the MON jack if a coupling unit is used for local termination, or in the S LOOP jack of the associated balanced loop applique if such equipment is being used. The balanced loop applique, if used, should be conditioned for half-duplex operation during use of the test set for line-up and communication over the line.

(4) Adjust the APEX switch so that a difference of $65 + 5$ ma is obtained between the meter readings taken in the LINE jack when marking and spacing signals are transmitted by the telegraph key of the test unit. Readings on the opposite side of zero should be added to obtain the algebraic difference. Readjustment of the APEX switch may be required later after other adjustments in the home and distant repeaters have been made; also when the line is dry if the initial adjustment is made under leaky conditions. The final adjustment should result in apex resistances at the two terminals of the system which are the same or not more than 100 to 200 ohms

different when 16B1 or 16C1 repeaters are used at both terminals. If there is no line leakage or earth potential the current read in the LINE jack should be close to zero when the batteries at the two terminals oppose each other, that is, when the terminal of a "normal" system is sending a mark against a received mark, or when the terminal of a system with reversed battery and line is sending a space against a received mark.

- (5) Balance the repeater in accordance with 2.08 to 2.12.
- (6) The distant repeater attendant should follow the same procedure as above after which a rebalance should be made.
- (7) Readjust the equalizers as covered in 2.12. For differential duplex operation best results may in some cases be obtained when the equalizers are not used. (EQL in OFF position.)
- (8) Repeat (6) and (7).
- (9) If the system is to be used for full-duplex service, final adjustment of the duplex balance may be made on the basis of telegraph transmission tests. For this purpose, arrange for transmission of test teletypewriter signals by the remote repeater, and for connection of the local repeater to distortion measuring equipment. Connect a local source of signals to the input of the repeater, and adjust the balancing network for minimum increase in distortion in the received signals when outgoing signals are transmitted simultaneously. Test dots or other signals may be used for this test.

3. SERVICE ADJUSTMENTS

Type B Polarential

3.01 Experience in service may indicate the need for refinement of the initial adjustments made. Do not readjust the polar receiving terminal unless a complete new systems line-up is to be made. Small amounts of bias received at the polar sending terminal when there is no line leakage may be corrected by readjustment of the biasing current. There will always be some swing in bias (in the differential direction of transmission) with changing conditions of line leakage, since exact compensation is possible for only one specific condition of leakage. The need for a change in line-up is indicated by a predominance of one sign of bias over the range of conditions

of line leakage. Such an offset in the compensation characteristic may be due to unusual distribution and amounts of entrance cable, or to the fact that initial line-up was made under wet weather conditions. If the predominant tendency is toward marking bias, decrease the APEX switch setting one step, or if the predominant tendency is toward spacing bias, increase the APEX switch setting one step. Such a change may be made at any time, but for best performance it should be followed up by recheck of duplex balance at both terminals and bias current at the polar sending terminal when there is no line leakage. If there is a frequently recurring or normal condition of line leakage, exact self-compensation for that specific condition can be obtained by setting the APEX switch at such a value as to reduce the received bias to zero. This direct approach can be used, however, only when it is known that other causes of bias are absent, including duplex unbalance in the dry line condition, or abnormal battery voltages at either terminal. Any change of more than one step in the APEX switch setting should be followed up by recheck of duplex balance (of the resistance branch) at both terminals and bias current at the polar sending terminal during dry line conditions.

Type A Polarential

3.02 Experience in service may indicate the need for refinement of the initial adjustments. Do not readjust the polar receiving terminal unless a complete new systems line-up is to be made. Small or temporary corrections of bias received at the polar sending terminal can be made by readjustment of the biasing current. Bias changes with line resistance may be experienced on long lines because the apex resistance, adjusted to obtain specified line current, is too low for correct self-compensation. This condition can be identified by a change toward spacing bias when the line resistance becomes higher than at the time of line-up, and a change toward marking when the line resistance decreases. If such swings exceed a few per cent, make a new systems line-up, preferably at a time when the line resistance is near the average value expected in service. Increase the polar sending APEX switch setting to a value equal to 400 ohms plus the combined resistance of the line and the line pads at both terminals. (Up to the maximum value of 2000 ohms provided by the APEX switch.) This will improve the self-compensation, but may result in slight impairment of the transmission in the polar direction. In most cases the latter effect will be of no consequence, since transmission in the polar direction is considerably better than in the differential direction.

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Differential Duplex

3.03 Readjust the repeater as experience in service indicates the need. Generally such readjustment will be limited to the duplex balance. The BAL RES rheostat can be used to trim the bias out of the received signals when half-duplex service is provided. It must be readjusted whenever the line resistance changes appreciably. Only wide swings in line impedance will necessitate any other adjustments in half-duplex systems, and if required, these should be made by following the complete line-up procedure in Paragraph 2.17.

With full-duplex systems a larger amount of attention will be required, depending on the performance expected. Readjustment of the timing branch as well as the resistance branch of the network will probably be necessary as line conditions change. APEX switch settings should be changed only when a wide swing in line resistance takes the total line current outside limits, and then a complete new line-up will be necessary. A recheck of the resistance balance at half-duplex terminals, or of both resistance and timing branches at full-duplex terminals, should be made after each change in adjustment at the remote terminal.