CONFORMANCE TESTING OF SUBSCRIBER CABLES
TEST PROCEDURES, ANALYSIS, AND CATEGORIZATION OF PAIRS

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1. GENERAL

1.01 This section describes the conformance tests that should be performed on completed construction projects prior to closing out the work order or in existing cable facilities, where applicable. The tests and procedures vary, depending on whether the cable is loaded or nonloaded and how many load points are involved. The outside plant engineer (OPE) specifies when the ac and dc conformance tests are required on subscriber cable pairs in newly constructed cable facilities. All pairs shown on the Complement Diagram (E6410) must be tested and the test results recorded and forwarded through the coordinator to the OPE for corrective action and distribution.

1.02 This section has been reissued to:

(1) Incorporate material from Section 330-300-528 into this section.

(2) Eliminate the test procedures and test methods using specific test set equipment.

(3) Include the Cable Pair Analyzer (Model 77) in the test equipment list.

(4) Delete the classification of defective pairs as a Type A (service-affecting) and Type B (service-degrading).

(5) Provide new classification for defective pairs.

Since this reissue is a general revision, no revision arrows have been used to denote the significant changes.

1.03 The tester will generally make tests from the wire center central office (CO) or from remote test points specified by the OPE. It is the responsibility of the tester at the main frame to monitor working pairs before removing the heat coils and replace them when the tests are completed.

Caution: Do not test pairs used as special circuits or as Private Branch Exchange (PBX) trunks.

1.04 A list of typical equipment required to perform conformance tests on subscriber cable pairs is shown in Table A.

1.05 Three forms are required during the testing process. They are Form E6410, Complement Diagram, which is provided by the OPE, and two forms to be prepared by the tester; Form E6413, Test Notes and Form E6414, Test Report.

1.06 Each defective pair must be categorized and summarized by the tester on the Test Report form. Forward the Test Notes and Test Report forms to the coordinator for distribution in accordance with Section 330-300-526.

2. NONLOADED CABLES

2.01 Nonloaded cables can be described as cables up to 18 kilofeet in length, not including bridged tap, and do not require any load points to meet Resistance Design standards.

2.02 The purpose of conformance testing in nonloaded cables is to test for dc-type defects such as opens, shorts, grounds, splits, cable length, insulation resistance, and unbalances. Tests are made with test equipment suitable for nonloaded cables such as those shown in Table A, or equivalent.

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TABLE A

TYPICAL EQUIPMENT USED FOR CONFORMANCE TESTING

ITEMS	NONLOADED	SHORT LOADED	LONG LOADED
AT-8592 "Go/No-Go Test" With Cords as Needed	X	X	X
Handset, Type 1014	X	X	X
Cable Pair Analyzer (Model 77)	X	X	X
Impedance Level Tracer, With Range of 200-4000 Hz, Transmit Level of −20 to +10 dBm, Receive Level of −30 to +20 dBm With Cords as Needed		X	X
Pad of tracing paper for Pencil Copying With Level Tracer		X	X
Artificial Cable Kit, Length as Needed		X	X
Decade Capacitor — 0.001 μf to 0.110 μf		X	X
3C Noise Measuring Set (NMS) or Equivalent		X	X
120G Repeat Coil		X	X
120H Repeat Coil			X
54C or KS-20501 Return Loss Measuring Set or Equivalent			X
Oscillator — 1- and 3-kHz			X
Wheatstone Bridge, KS-14959 or Equivalent			X
Volt-ohmmeter, KS-8455 or Equivalent	X	X	X
Precision Networks — 2 Each as Required 115H; 115AL; 4066A; 4066B; 4066C			X
Optional — Locally Produced or Purchased Switch Box	X	X	X

2.03 The following analysis is used by the tester to interpret the test indications while testing short unloaded cables. Table B is used by the tester to classify the dc-type defects found.

2.04 ***Length Error***—Length errors may be due to the physical length being different than that shown on the Complement Diagram or to record errors. The indication can be that the pair is either longer or shorter than shown on the Complement Diagram but, in either case, it is not the responsibility of the tester to investigate the source of the error. The OPE will attempt to determine the cause of the discrepancy by referring to records or other source documents. A shorter length usually is due to an incomplete splice. A longer length is usually the result of unknown bridged taps or incomplete plant records. Consult Table B on classification of cable pairs with length errors.

2.05 ***Low Resistance***—When tests indicate low resistance between the tip and ring of the pair, ie, a short circuit, low resistance between the tip and ring and ground, or a ground. Short circuits and/or grounds should be measured and categorized in accordance with Table B.

2.06 ***Capacitance Unbalance***—The three main causes of a capacitance unbalance (CAP UNBAL) are:

(a) ***Opens***—If one of the conductors is open, it will have less capacitance to ground than its mate.

(b) ***Crosses***—If one side of a pair is crossed with another conductor, it will indicate a higher capacitance to ground than its mate.

TABLE B

CLASSIFICATION OF DC DEFECTS

TEST INDICATION	PAIR STATUS
LENGTH:	
• Less than 10% longer or shorter than length shown on complement diagram.	Good
• More than 10% shorter or longer than length shown on complement diagram.	Defective
LOW R:	
• Short — >900,000 ohms*	Good
• Ground — >400,000 ohms*	Good
CAP UNBAL: Any measurable amount	Defective
CO BATT: $\geq$ 14 volts	Defective
HIGH VOLTAGE: > 50 volts ac or dc	Defective

* These values are intended to be a broad transmission performance indicator of the severity of the defect and may be adjusted for local conditions to be consistent with local settings of the Line Status Verifier (LSV) and the Line Insulation Test (LIT). If no specific local conditions exist, the values noted above should be used to categorize pairs as good or defective. Future issues of this Bell System Practice will attempt to distinguish between quality construction and quality transmission — the former criteria being more stringent by a factor of 10 for newly constructed plant.

(c) ***Party Lines***—If the pair under test is a working party line, its ringers to ground will cause a capacitance unbalance. This may be verified by checking the records. If the tester verifies that the pair is a working party line, it should be eliminated as a defect from the test report.

Using Table B, a CAP UNBAL is found to be classified as a defective cable pair.

2.07 ***CO Battery***—If the tests show a 14-volt or greater CO battery (CO BATT), it is an indication of a pair crossed with a working pair. The tester must make an effort to determine which pairs are crossed. Using Table B, the tester will classify the pair as defective on the Test Report (E6414).

2.08 ***High Voltage***—When tests show 50 volts of ac or dc volts on the line, it is an indication that foreign voltages are present on the cable pair. Using caution, the tester should measure the voltage. In cases of high voltage (over 50 volts), the tester must immediately notify the network switching supervisor and the repair service bureau so the necessary safety precautions may be taken to prevent employee injury. Using Table B, the tester must classify the cable pair with the high voltage level as defective.

3. SHORT LOADED CABLES

3.01 Short loaded cables can be defined as cables with loading requirements of up to six load points to meet Resistance Design standards.

3.02 The purpose of conformance testing in short loaded cables is to test cable pairs to identify the dc-type defects and determine loading irregularities while performing the ac-type tests. Table A provides a list of typical test equipment used for testing short loaded cables.

3.03 The tester must use Table B to classify the cable pairs based on test indications while performing the dc-type tests. Table C provides the classification of cable pairs based on ac-type test indications.

TABLE C

CLASSIFICATION OF SHORT LOADED CABLE PAIRS

TEST INDICATION	PAIR STATUS
DC TESTS:	See Table B
AC TESTS:	
• Pairs With Good Impedance Traces:	
— Noise (CO) $\leq$ 20 dBrnc	Good
$>$ 20 dBrnc	Defective
• Pairs With Irregular Impedance Traces or Pair Analyzer:	
— Diagnosed as a missing or double load coil:	Defective
— Diagnosed as bridged tap between loads or loaded bridged tap:	Defective
— All other spacing and/or length faults exceeding ± 250 feet:	Defective
— Noise (CO) $\leq$ 20 dBrnc	Good
$>$ 20 dBrnc	Defective

3.04 Figure 1 is a flowchart showing the interrelation of the dc and ac test results and how to categorize the short loaded cable pairs based on the test results. If a cable pair is classified as a ***defective*** pair after the dc-type tests are made, it is not necessary to make the ac-type tests. If a cable pair is classified as a ***good*** pair after the dc-type tests, the tester must perform ac-type tests to determine which cable pairs are good or defective.

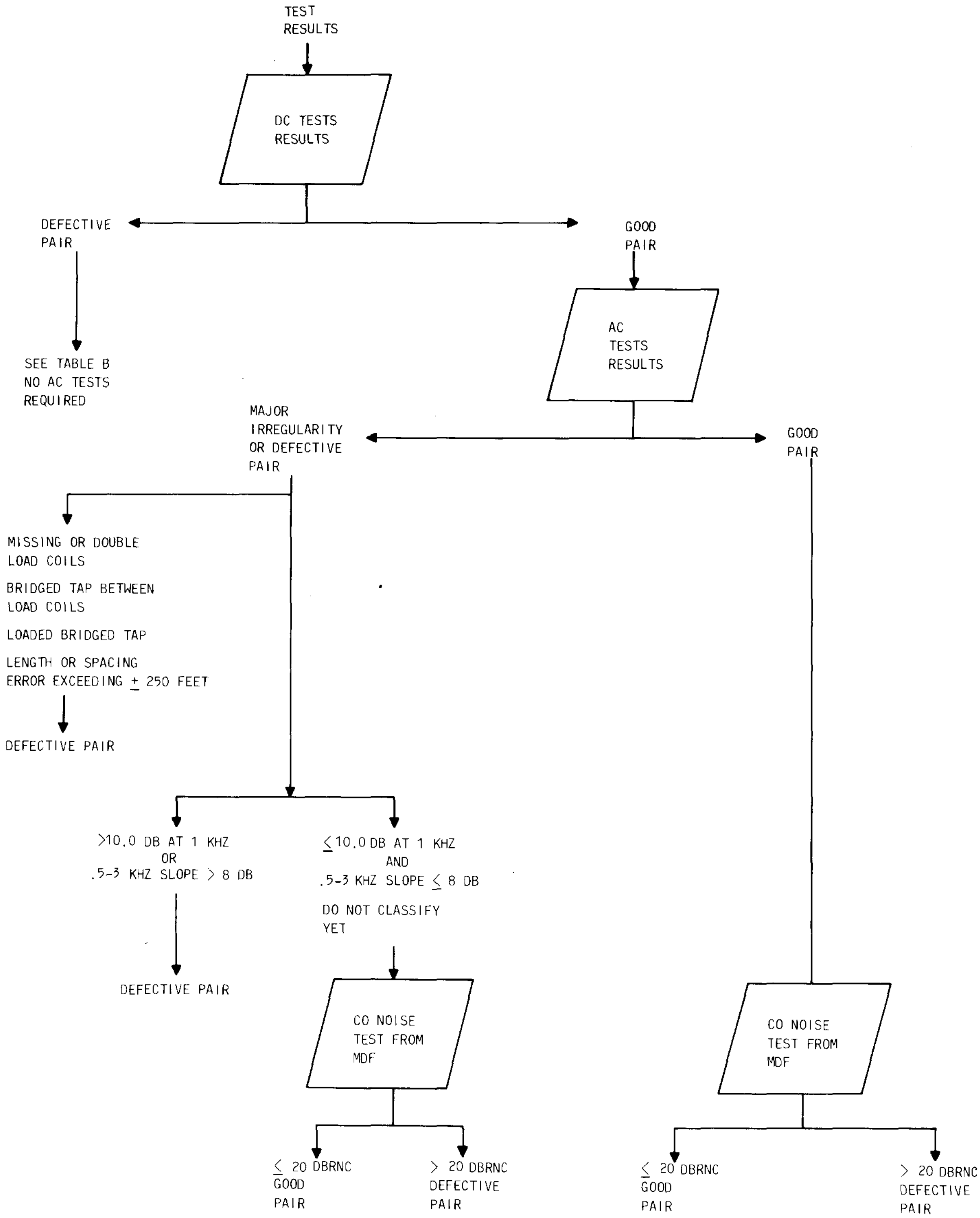

Fig. 1—Flowchart for Short Loaded Cables

4. LONG LOADED CABLES

4.01 Long loaded cables are identified as cables with loading requirements of more than six load points to meet Resistance Design standards.

4.02 The purpose of conformance testing these long loaded cables is to identify the dc-type defects, determine the loading irregularities, and measure noise, insertion loss, and cable resistance and return loss in ac-type tests. Table A provides a list of typical test equipment used for testing long loaded cables.

4.03 The tester uses Table B for classification of dc-type defects and Table C to classify the ac-type defects based on test indications and results. After the long loaded cable pairs have been tested for the dc-type defects, tests are made to measure return loss, insertion loss, noise levels, and cable resistance.

4.04 ***Return Loss***—In long loaded subscriber cable, structural echo return loss is an excellent measure of uniformity of the cable gauging and regularity of the load spacing. The better these are, the better the return loss. In the absence of any manufacturing variations or construction errors, the measured return loss values for individual pairs will be in close agreement with each other, and their mean (average) also will be in close agreement with the Universal Cable Circuit Analysis Program (UNICCAP) calculated value. The measured return loss will be severely reduced by placing a load coil at the wrong point, connecting it the wrong way, or omitting it entirely. Minor deviations in load spacing also will reduce measured return loss, but to a lesser degree. The nearer the loading fault to the point of measurement, the greater the reduction in measured return loss. Deviations from the UNICCAP calculated value also can occur in well-constructed plant. These deviations generally result from changes in the capacitance or other properties of the cable due to normal manufacturing variations. Typically, the measured values are found to follow the well-known, bell-shaped (normal) distribution (Fig. 2). As with other faults, manufacturing variations have a greater effect on cables for which high return loss is otherwise expected and less effect when low return loss is expected.

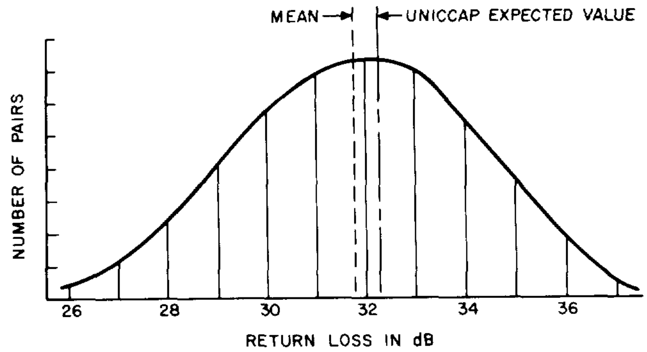

Fig. 2—Return Loss in dB

4.05 Table D shows the OPE the range of structural echo return loss values (dB) that can be expected as a result of manufacturing variations, principally capacitance. The upper chart shows the variations when the first three load sections of the facility consist of pulp cable that was placed in reel lengths less than 1000 feet. The same chart is applicable when the first three load sections are constructed of PIC cable. The lower chart is used when the first three full sections are constructed of pulp cable and placed in reel lengths in excess of 1000 feet. Note that the variations are greater in the lower chart. To find the variation that can be expected for the facility under test, read down the left-hand column (UNICCAP CALCULATED VALUE) in the appropriate chart until you come to the value nearest the one calculated. The UNICCAP calculated value is shown on the right-hand side of Form E6410. Move to the right and find the column which represents the gauge of the facility under test. In mixed gauge cables, use the column of the most predominant gauge within the first three sections. Read the minimum and mean values that you can expect when return loss testing. If the UNICCAP calculated value for the facility under test is not one of the whole numbers shown in the left-hand column, interpolate the numbers shown in the gauge columns to more accurately determine the appropriate minimum and mean value.

4.06 Knowing the UNICCAP calculated value and the minimum and mean for the return loss, analyze the test results and categorize the pairs as either good, defective, or in need of further investigation. A large number of pairs might have measured return loss values below the minimum in Table D if the cable capacitance variation is greater than was assumed in deriving the tables. Therefore, the test results must be analyzed in total before individual pairs can be evaluated. To do this, the measured results must be examined and/or plotted to observe their distribution.

TABLE D

RANGE OF (STRUCTURAL ECHO) RETURN LOSS VALUES (dB)
DUE TO MANUFACTURING VARIATIONS

ALL PIC/PULP (≤1000-FT REEL LENGTHS)								
UNICCAP CALCULATED VALUE	GAUGES							
	19		22		24		26	
	MIN	MEAN	MIN	MEAN	MIN	MEAN	MIN	MEAN
25	22.6	24.8	22.9	24.8	23.1	24.9	23.0	24.9
28	24.8	27.6	25.1	27.7	25.7	27.6	25.5	27.6
30	26.0	29.0	26.6	29.6	27.2	29.4	27.1	29.4
32	27.4	30.4	27.9	31.1	28.6	31.0	28.8	31.2
34	28.2	31.8	29.1	32.4	29.9	32.5	30.4	33.0
36	29.0	32.8	30.1	33.5	31.1	33.7	32.0	34.9
PULP (>1000-FT REEL LENGTHS)								
UNICCAP CALCULATED VALUE	GAUGES							
	19		22		24		26	
	MIN	MEAN	MIN	MEAN	MIN	MEAN	MIN	MEAN
25	21.2	24.4	21.6	24.4	22.0	24.6	22.0	24.8
28	22.8	26.6	23.4	26.8	24.2	27.0	24.2	27.3
30	23.8	27.6	24.5	28.1	25.5	28.5	25.7	28.7
32	24.6	28.4	25.3	29.3	26.7	29.7	27.0	30.0
34	25.0	29.0	26.0	30.2	27.7	30.9	28.2	31.0
36	25.6	29.6	26.7	30.9	28.4	31.9	29.2	31.9

4.07 The curve of Fig. 2 represents test results with a normal distribution. The curve is drawn by plotting the number of pairs with a specific return loss reading vertically above that return loss value. Instrument readings should be rounded to the nearest whole number when plotting. Connecting the tops of the vertical lines will produce the distribution curve. If the curve rises smoothly to a single peak and then drops off smoothly, the curve represents a normal distribution and indicates that the pairs are all similarly constructed, differing among themselves in return loss only because of normal manufacturing variations.

4.08 The numerical average of the test results should be close to the means given in Table D. If not, it means that the facility under test has properties other than specified on the Complement Diagrams, ie, capacitance, load spacing, temperature, etc. As long as the distribution is smooth, it is not important that the mean from Table D does not coincide exactly with the average of the measurements. If the average is more than 3 dB below the mean and the distribution is normal, it means there is a construction defect common to all the pairs, ie, a missing load coil, spacing error, etc. All pairs should be investigated further with the level tracer.

4.09 The minimum values in Table D represent the points below which no more than 10 percent of the measured values are expected to fall when there are no construction errors. If the average of the measured values is somewhat less than the mean from Table D, the minimum also should be adjusted downward, but by a lesser amount. As long as the curve is smooth and only about 10 percent of the pairs are below the minimum or adjusted minimum, it may be assumed there are no major loading faults. If more than 10 percent fall below the adjusted minimum, those pairs need further investigation. Even when less than 10 percent fail to meet the minimum, a few pairs may fall more than 3 dB below the minimum, and these should be investigated further.

4.10 To summarize; for smooth distribution, investigate all pairs with the level tracer when the average falls more than 3 dB below the mean from Table D, those pairs below the adjusted minimum when they constitute more than 10 percent of the pairs, and pairs more than 3 dB below the adjusted minimum when less than 10 percent fall below the adjusted minimum. After investigating the pairs with the level tracer, categorize them per paragraph 4.11.

4.11 If the facility has construction deviations, the distribution curve will look something like the curve in Fig. 3 or 4. The pairs in the lower lobe of a curve, as in Fig. 3, must be tested with the level tracer since they differ significantly from the main group. For distributions similar to Fig. 4, the distinction is more subtle and the numerical criterion of more than 10 percent of the pairs below the minimum should be used to determine the need for further testing with the level tracer. In dealing with cases like Fig. 4, do not adjust the minimum as was suggested in paragraph 4.08 for smooth distributions. The irregular curve of Fig. 4 may be due to minor deviations or deviations near the far end of the facility loop.

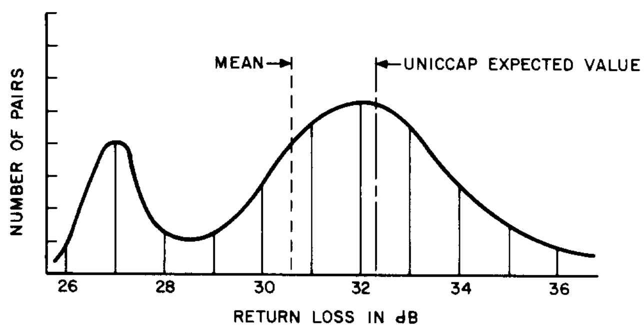

Fig. 3—Return Loss in dB

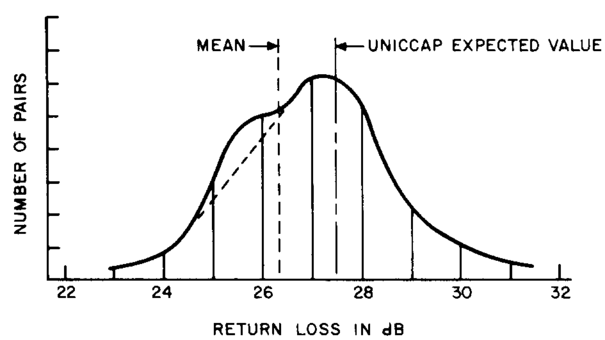

Fig. 4—Return Loss in dB

4.12 When a group of pairs meets one of the criteria described in paragraphs 4.06 through 4.10, is in the lower lobe of a distribution like Fig. 3, or is among the 10 percent or more below the minimum for distributions like Fig. 4, they should be tested with a level tracer. Pairs which exhibit irregular impedance curves are defective pairs and should be categorized per the criteria in Table E. Those pairs with low values of measured return loss but good level traces and no other known fault should be categorized as good. If major construction deviations are found within the groups that are investigated with the level tracer, all other pairs should be examined with the level tracer so that pairs with the same fault can be included in the corrective action. Using the level tracer can be time-consuming, and the testing effort described above may be excessive. The following approach can result in the identification of virtually all faults without 100-percent level tracer testing.

(a) When level tracer testing is called for because the distribution curve is smooth but the average falls no more than 3 dB below the mean from Table D, test a few pairs with the level tracer and try to identify the problem. The likelihood is that all of the pairs have the same defect since the distribution is normal.

(b) For distribution curves like Fig. 3, additional testing is called for if defective pairs are found in the initial group of pairs tested with the level tracer. The defects are almost all within the lower lobe or 1 or 2 dB above the dividing line. For example, in Fig. 3 the dividing line is at about 29 dB. Therefore, test all pairs with return loss values up to and including 31 dB with the level tracer.

(c) For distribution curves like Fig. 4, 100-percent testing is called for if defective pairs are found in the initial group tested with the level tracer. Most of the additional defective pairs, if any, will be below the mean from Table D. Therefore, first test all pairs with return loss below the minimum and those up to 1 dB above the minimum. Next, test all pairs with return loss from 1 to 2 dB above the minimum, etc. When two successive groups have yielded no defective pairs, level tracer testing can stop.

4.13 ***Noise***—Long subscriber loops are particularly susceptible to noise because of their greater exposure to power line influences. A well-constructed cable facility can withstand these influences and provide noise-free service. A measure of how well the cable has been constructed is its balance.

$$\text{Balance} = \text{Ng} - \text{Nm}$$

Poorly made splices can cause a pair to be unbalanced. Pairs having a good balance ">60 dB," but high Ng ">90 dBrnc" readings often indicate that there is an open in the cable sheath. An important consideration in accepting noise levels on long loops exceeding 20 dBrnc is that the loop must be well-balanced. The noise values that categorize cable pairs are shown in Table E.

TABLE E

CLASSIFICATION OF NOISE TEST RESULTS

READING	PAIR STATUS	
Nm	≤ 20 dBrnc	Good
	>20 dBrnc	Defective
Ng	≤ 85 dBrnc	Good
	>85 dBrnc	Defective
Balance	≥ 60 dB	Good
	<60 dB	Defective

4.14 ***Loop Resistance***—The expected loop resistance to the test point is a function of the wire gauge, length, load coil resistance, and an assumed design temperature of 68°F. It is usual to make a rough correction for cable temperature and then allow a certain tolerance to care for uncertainties. An acceptable range for expected loop resistance is from 7 percent below to 10 percent above the temperature corrected expected value. This is best illustrated by an example.

(a) Expected value of loop resistance (R) = 1000 ohms.

(b) Estimated cable temperature (T) = 88°F.

(c) Temperature correction = 0.0022 × (T - 68) × R = 0.0022 × (88 - 68) × 1000 = 44 ohms.

(d) Corrected expected value = 1044 ohms.

(e) 7% × 1044 = 73 ohms.

(f) 10% × 1044 = 104 ohms.

(g) Acceptable range is (d - e) to (d + f) = 971 to 1148 ohms.

4.15 Table F should be used to categorize the loop resistance test results.

TABLE F

CLASSIFICATION OF LOOP RESISTANCE TEST RESULTS

LOOP RESISTANCE	PAIR STATUS
From −7% to +10% of temperature corrected expected value.	Good
Beyond −7% and + 10% of temperature corrected expected value.	Defective

4.16 ***Loss***—If the expected values for resistance and return loss are obtained, the 1-kHz insertion loss should be within ±1 dB of the UNICCAP expected value. To categorize a cable pair based on insertion loss test results, use Table G. Insertion loss readings at 1 kHz are always required, but 3-kHz readings are only required when return loss measurements cannot be taken because the closest test point is beyond the optimum range of from 3 to 6 kilofeet after the last load coil. In those cases, the insertion loss at 3 kHz will give some clue as to the structural correctness of the facility. Refer to Section 852-200-102 for a study of the effects of missing load coils and illegal bridged tap on insertion loss. In general, when the difference between the 1- and 3-kHz readings is more than 8 dB, a structural problem exists. The greater the difference, the more likelihood there is of a severe problem, such as a missing load coil or a large illegal bridged tap.

> ***Note:*** The OPE has the responsibility for identifying and correcting any cable record discrepancies and issuing the routine work order to correct any loading irregularities or other design defects. This should be done on any cable pair that meets the criteria of usability but does not meet criteria comparing cable makeup and test results. The record corrections or changes should then match the test results and cable makeup so the known physical dimensions of the cable are reflected and recorded.

TABLE G

CLASSIFICATION OF INSERTION LOSS TEST RESULTS

INSERTION LOSS	PAIR STATUS
At 1 kHz: ± 1.5 dB of expected value and $\leq$ 10.0 dB and 1- to 3-kHz slope $\leq$8 dB	Good
>1.5 dB beyond the expected value and > 10.0 dB or 1- to 3-kHz slope >8 dB	Defective

4.17 To determine the overall classification of a long loaded cable pair, its total performance in each of the five tests must be reviewed. A pair must meet or exceed the criteria of all five tests to be categorized as good. If the pair has been identified as having a defect in any one of the tests, it must be categorized as a defective pair. A combination of good and defective evaluation will also cause the pair to be categorized as a defective pair.

4.18 When all tests are completed, results analyzed, and defects categorized using the criteria in Parts 2 through 4, the tester should forward all Test Notes and Test Report forms to the coordinator so the analysis can be verified and the Test Report distributed.