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Southern California Are

BELL SYSTEM PRACTICES
Outside Plant Construction
and Maintenance

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T. P. T. & T. Co.

CABLE MAINTENANCE

CABLE FAILURES - RESTORATION OF FACILITIES

COAXIAL FACILITIES

CONTENTS PAGE

1. GENERAL

1.01 This Section and Section E21.907.3, which are similar, prescribe the methods to be used in restoring coaxial facilities involved in cable failures.

Note: In order to facilitate coordination between the outside plant and central office forces in the restoration of coaxial facilities, paragraphs bearing the same number in E21.907.3 and this Section cover similar instructions. To maintain this parallelism it has been necessary to omit certain paragraph numbers in this Section where the material in the corresponding paragraph in E21.907.3 is covered elsewhere in the "G" series of the Bell System Practices.

1.02 The problem of restoring coaxial facilities differs fundamentally in a number of respects from that involved in the restoration of quadded facilities. Some of the more important of these considerations are discussed briefly below.

1.03 The principal time consuming factors in coaxial restoration work are the measurements to locate the trouble, particularly when it occurs in a power section fed from an unattended main repeater station, and the time to expose the splice or sheath, in the case of buried cables which form the bulk of the coaxial cable mileage in the plant. On the other hand, the actual connecting through of the coaxial facilities themselves at the break is a relatively quick and simple job when the fault is bridged with emergency cable. Also, when some coaxial conductors are unaffected, patches can quickly be made between adjacent "L" auxiliary stations or between a main station and an "L" auxiliary station and working facilities thus restored, even before a final location of the trouble is obtained from these stations.

1.04 It is evident from the above that the speed of restoration of coaxial facilities depends primarily upon taking the proper initial steps prior to the connecting through of the conductors at the break, rather than on the actual splicing work itself. This calls for prompt analysis of conditions and good judgment on the part of those directing the testroom and outside plant activities in determining the preliminary steps to be taken under the particular circumstances. It also calls for close co-operation between the central office and outside plant forces, the latter often being

in a position to make patches and line measurements at unattended main repeater and auxiliary "L" stations before the central offices forces have had time to arrive on the scene.

1.05 These instructions are based on restoring coaxial facilities first by patching between repeater offices, when this is feasible, and second, by bridging the fault temporarily with emergency cable in the quickest and most convenient manner, depending on the conditions at the trouble location. Quadded and paired facilities contained in coaxial cables should be restored in accordance with the methods outlined in Section G74.940.1.

2. COAXIAL FACILITY ARRANGEMENTS - GENERAL INFORMATION

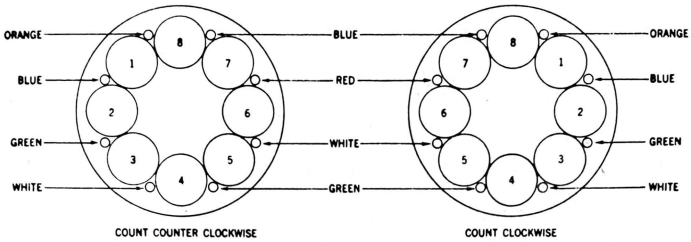
General

2.01 Those who are responsible for directing coaxial cable restoration work should be familiar with the arrangements and operations of coaxial systems, particularly with respect to the power sections extending between main repeater stations. This information is covered in standard instructions. Following is a brief discussion of some of the features of these systems which may be helpful as a reference to all concerned in connection with coaxial cable trouble locations, patching and restoration work in general.

Coaxial Numbering System

2.02 A "coaxial" is a metal tube and a wire centered coaxially therein. The tube is called the outer conductor and the wire, which is insulated from the tube, is called the inner conductor. Numbers are assigned to the individual coaxials during manufacture and they are assembled in the cable accordingly. They are numbered consecutively around the cable beginning with No. 1. Like numbered coaxials must be connected together at splices.

The coaxials can be identified by number by means of the paper insulated pairs or wires located in the outer spaces between the coaxials. Different cable makeups have different color combinations of paper insulated conductors and different numbering schemes. Figure 1 shows the numbering system for a cable containing 8 - .375 inch coaxials.



NUMBERING DIRECTIONS
START AT THE ORANGE MARKER AND NUMBER THE COAXIALS
IN THE DIRECTION OF THE NEARER GREEN WRAPPED INTERSTICE CONDUCTOR

COAXIAL NUMBERING SYSTEM
CABLE CONTAINING 8 .375 INCH COAXIALS
FIGURE 1

"L" Units

2.03 An "L" unit is a coaxial with its associated auxiliary station amplifiers, equalizers, and none, one or several intermediate main repeater stations arranged for one direction of transmission between two main repeater switching stations. It is designated by a number and the names of the switching offices at the ends of the unit. The transmitting office is always the first named office in the designation. Example: "L" Unit 201 between the Meridian and Birmingham switching stations and transmitting in the direction of Birmingham would be designated "201 Meridian-Birmingham."

All "L" units between the same two switching offices are numbered in consecutive sequence beginning with No. 201. Odd numbers (201, 203, etc.) are used for designating "L" units which transmit toward the east or north. Even numbers (202, 204, etc.) are used for designating "L" units with transmit towards the west or south. In the case of units assigned to television the direction of transmission may be reversed. When this is so, the original unit number is retained followed by the letter (R). Thus "L" unit 201 reversed would be "L" Unit 201R.

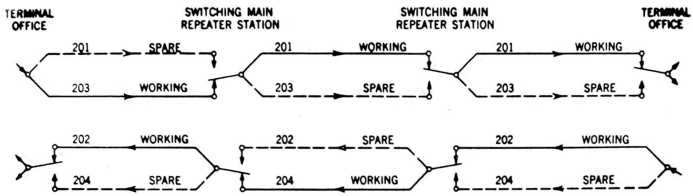
"L" unit numbers are usually associated with corresponding numbered coaxials such as "L" unit 201 and coaxial No. 1. In the case of multiple coaxial cable routes, however, there will be an exception. Thus if the first cable contains 8 coaxials the last numbered unit when assigned will be L208 on coaxial No. 8 but "L" unit 209 will be on coaxial No. 1 in the second cable, etc.

Coaxial Lines and Switching Arrangements

2.04 Two coaxials with their associated equipment transmitting in opposite directions are required to make up a complete "L" carrier layout. Generally this means that several "L" units must be connected together between terminal offices. This is accomplished at switching main stations and terminals by line switching devices which operate automatically to substitute spare "L" units in case of trouble in the coaxials or the equipment on the working units. Thus in any section there are two units which make up the working line and two which are known as the spare line.

At each terminal and main repeater switching station the two transmitting "L" units are fed in parallel from a hybrid coil. Also at these stations the receiving "L" units are under the control of switching relays so that if an interruption occurs in a working "L" unit, the spare "L" unit is automatically transferred in its place between the two adjacent switching offices, and the faulty working "L" unit then becomes the spare unit in that section.

Depending, therefore, on which contacts are made in each of the several switching circuits, the working line may consist of either of the "L" units transmitting in the same direction in any switching section. This arrangement is shown schematically in Figure 2.

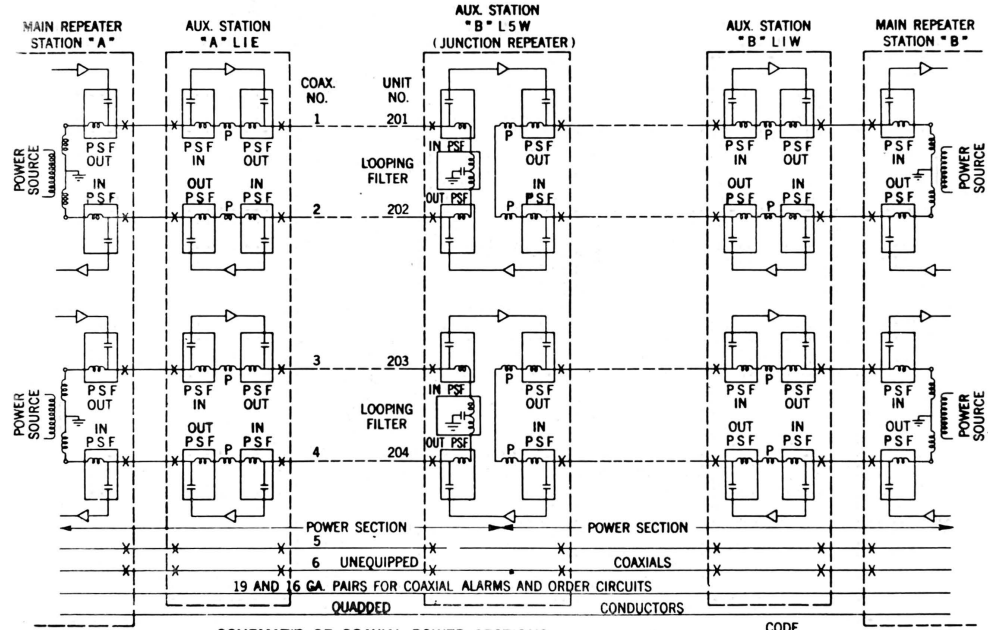


COAXIAL LINE AUTOMATIC SWITCHING ARRANGEMENTS
FIGURE 2

Manual controls are provided at switching stations so that if it is desired to take a working "L" unit out of service for maintenance purposes, the spare "L" unit can be manually switched in its place in that switching section. In the case of unattended main repeater switching stations it will, of course, be necessary to send a man to the station to perform this operation. After the manual switch is completed, the unit will again be restored to automatic operation.

Power Sections

2.05 60 cycle a.c. power to operate the auxiliary repeaters along the line is fed from each terminal office or main repeater station over the inner conductor of an "L" unit to the junction repeater, about halfway between the two main stations, where it loops back over the inner conductor of a second "L" unit transmitting in the opposite direction. Figure 3 shows schematically the power sections between two main stations "A" and "B" providing a working and a spare coaxial line.



SCHEMATIC OF COAXIAL POWER SECTIONS
BETWEEN TWO MAIN REPEATER STATIONS
FIGURE 3

CODE
PSF - POWER SEPARATION FILTER
P - PRIMARY OF POWER TRANSFORMER
▷ - AMPLIFIER
X - COAXIAL PLUG AND JACK CONNECTION

Input and output power separation filters at each auxiliary repeater by-pass the 60 cycle power around the amplifier units and through the primary windings of the power transformers.

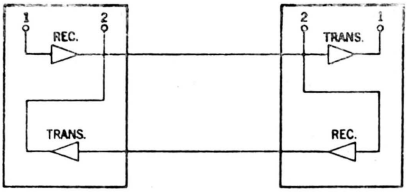
It will be seen from Figure 3 that both power sections loop through the junction repeaters at auxiliary station "B" L5W, but that these repeaters operate from the power section fed from main station "B" only, as indicated by the primary windings of the power transformer. The designation of the junction auxiliary repeater station indicates the station from which the junction repeaters obtain their power.

The power loop carries a closely regulated current of about 450 milliamperes. The voltage across the loop at the main station depends upon the number of auxiliary repeaters fed and may run as high as 2000 volts in long power sections, the voltage reducing along the line due to the resistances of the inner conductors and the equipment at the auxiliary repeater stations.

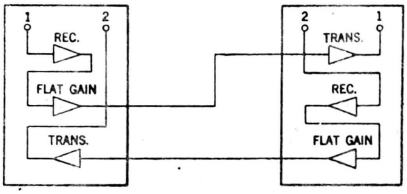
Referring to Figure 3, it will be noted that the working lines at any time might consist of either "L" units 201 or 203 transmitting in one direction and "L" units 202 or 204 transmitting in the opposite direction, depending on the connections made by the switching relays at the main switching stations (see Figure 2). An interruption occurring in only one power loop will, therefore, still leave the two "L" units in the other power loop in operating condition.

Patching Coaxials Between "L" Repeaters

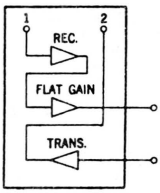
2.06 Each coaxial entering a terminal office or main repeater station is connected to a cable terminal consisting of a single coaxial plug, located at the top of the bay, to which the repeater equipment is patched. Each repeater bay is arranged with two such cable terminals to terminate the two coaxials connecting to the line side of the repeater in that bay, the repeater consisting of a transmitting amplifier and a receiving amplifier. In addition at main switching stations and terminal offices a flat gain amplifier is provided on the output of each receiving amplifier. These arrangements are illustrated in Figure 4.



INTERMEDIATE NON-SWITCHING MAIN STATION



INTERMEDIATE SWITCHING MAIN STATION



TERMINAL OFFICE

REPEATER BAY ARRANGEMENTS.
INTERMEDIATE MAIN AND TERMINAL OFFICES
FIGURE 4

At auxiliary stations, the equipment for one repeater for both directions of transmission is mounted in a steel apparatus case. Two coaxials from each direction are brought into the repeater case through a single cable terminal and terminate in 4 coaxial plugs.

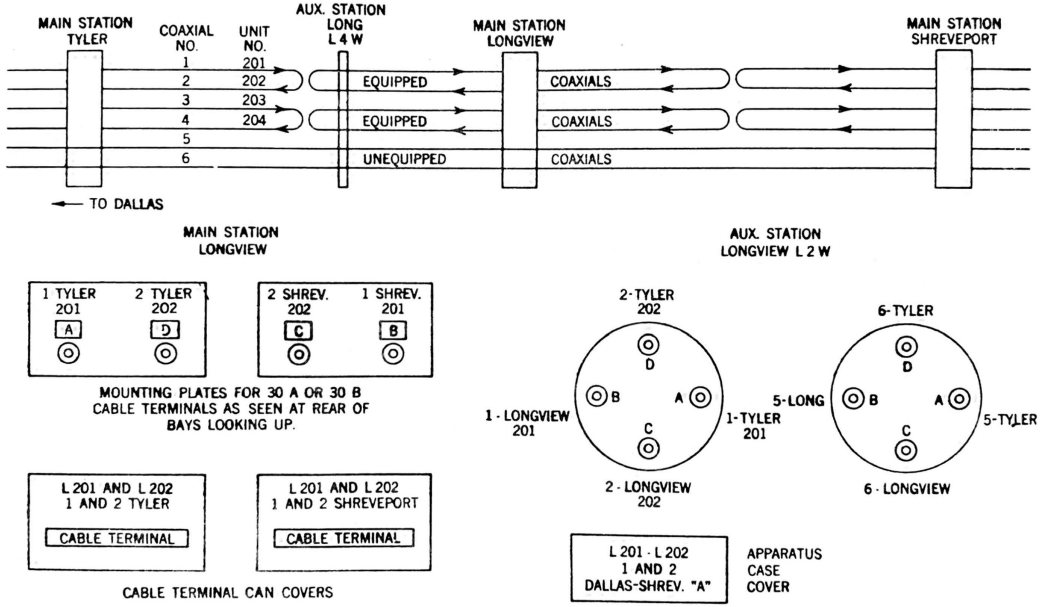
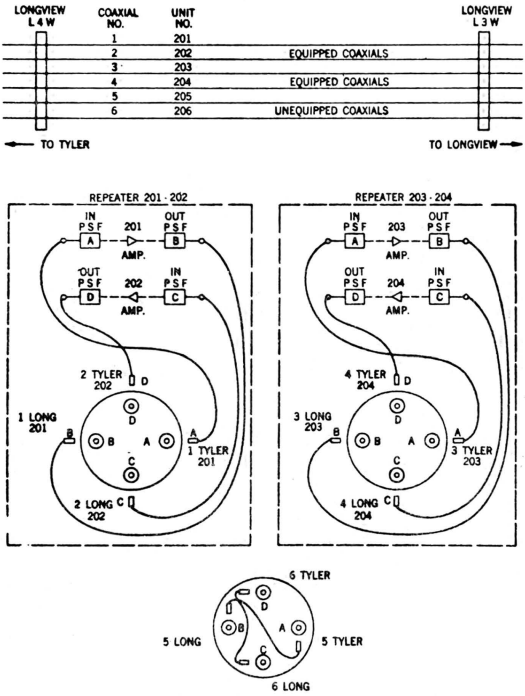


Figure 5 shows schematically the arrangements and designations of the cable terminals at main and auxiliary repeater stations.

DESIGNATIONS AT CABLE TERMINALS-MAIN AND AUXILIARY REPEATER STATIONS
FIGURE 5

Flexible cords, permanently connected to the input and output power separation filters of the repeaters, terminate in coaxial jacks which are plugged into the coaxial plugs at the cable terminals. A schematic of the patching arrangement at an auxiliary station with 4 equipped coaxials, providing a working and spare line, and 2 unequipped coaxials, is shown in Figure 6.



PATCHING ARRANGEMENTS BETWEEN COAXIAL REPEATERS AND CABLE TERMINALS - AUXILIARY REPEATER STATION

FIGURE 6

The unequipped coaxials are patched through at the cable terminal with short patch cords in order to retain continuity between attended main stations for testing purposes.

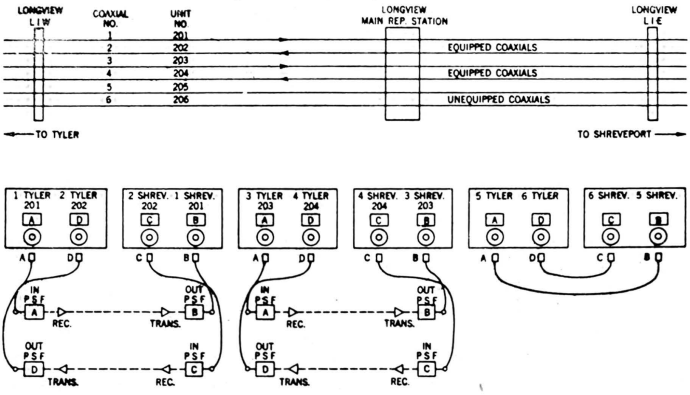
At some locations additional equipment is mounted in apparatus cases. This added equipment may be a power loading panel and a line building-out panel. The patching arrangement for such locations are not illustrated here.

In the case of a partial cable failure, as many "L" units as possible are made good in the faulty section between two auxiliary stations by disconnecting the repeater panel cords from the defective coaxials at each auxiliary station and plugging them into good coaxials at the cable terminals.

For example, referring to Figure 6, if all coaxials between Longview L3W and L4W were in trouble except 1 and 5, a working line could be obtained by making good L unit 202 over Coaxial 5 in place of Coaxial 2. The patch required at Longview L4W would be to disconnect patch cord C from 2 Longview at the cable terminal of Repeater 201-202 and plug it, with the help of an intermediate extension patch cord, into 5 Longview at the spare cable terminal. Similarly at Longview L3W, patch cord D would be disconnected from 2 Tyler at the cable terminal of Repeater 201-202 and plugged into 5 Tyler at the spare cable terminal, also using an intermediate extension patch cord.

A fault occurring on one coaxial of a power loop will usually affect the power on both coaxial units comprising the loop and interrupt the high frequency line. For example, if, in Figure 6 all coaxials failed except 1 and 3, all four of the "L" units would usually be in trouble. To make good a working line, Coaxial 3 would be patched in place of Coaxial 2 at the two auxiliary stations thus restoring "L" units 201 and 202.

Figure 7 shows the patching arrangement between the repeater bay equipment and the cable terminals at the top of the bays at an intermediate main repeater station.



PATCHING ARRANGEMENTS BETWEEN COAXIAL REPEATERS AND CABLE TERMINALS - MAIN INTERMEDIATE REPEATER STATION
FIGURE 7

Coaxials are patched between a main station and an auxiliary station in the same general manner as between two auxiliary stations as explained above.

Trouble Alarms

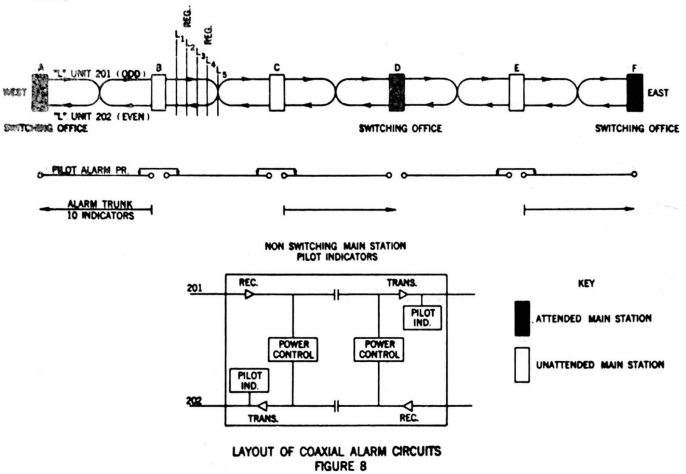
2.07 When equipment trouble occurs at a main repeater station or when cable or equipment trouble occurs in the power section fed by that office, affecting the transmission of a coaxial line, various alarms operate in that station and possibly also in other main stations. A proper interpretation of these alarms and the readings of the meters on the power control panel and pilot alarm panels will usually indicate whether the trouble is in the cable or in the equipment.

A trunk alarm circuit is provided for each unattended main repeater station to the nearest attended office. When alarms of various kinds operate at the unattended station, they are transmitted over this alarm trunk to the attended office where they appear on 10 separate lamp indicators. Since a number of different alarms may be grouped on one lamp and the readings of the meters on the power control panel would not be known at the attended office, it is, therefore, frequently not possible to determine if the trouble is in the equipment at the main station or in one of the power sections, or on which side of the unattended office it is located. This is particularly true for some types of troubles affecting transmission in two directions. A man must be dispatched to the unattended station to diagnose the trouble, determine the section affected and make the necessary measurements.

Complete instructions regarding the interpretation of alarms and meter readings are beyond the scope of these instructions. However, the following discussion may be found helpful to the forces who are engaged in handling this work.

A pilot alarm pair is provided for each pair of "L" units whose inner conductors comprise a power loop. This pilot alarm pair is made continuous between attended offices. In general, when the pilot frequency (2064 Kc) at a regulated auxiliary repeater station falls below or exceeds a certain level in either direction of transmission, the pilot alarm pair is shorted at that point and an alarm operates at the ends of the pilot alarm circuit. (Regulated repeaters occur, in general, at every other auxiliary repeater point.)

Figure 8 shows the layout of a pair of "L" units involving a number of attended and unattended main stations with associated alarm circuits.



LAYOUT OF COAXIAL ALARM CIRCUITS
FIGURE 8

Following is a brief outline of the alarms which are received at the various stations when certain equipment or cable troubles occur and the deductions which can be made from them to assist in determining the location of the trouble. All of these troubles are assumed to occur in the East power section of central office "B" which is an unattended main station.

(a) High or Low gain occurs on "L" Unit 201 at a regulated auxiliary repeater (L2). High or low gain is assumed automatically compensated for at next regulated repeater (L4). The pilot alarm pair is shorted at L2 and alarms are received at "A" and "D." Transmission remains normal over the system. Both "A" and "D" make resistance measurements on the pilot alarm pair both of which locate the trouble at L2.

(b) Same as (a) above except that it requires two regulated repeaters to restore the gain. The pilot alarm pair is shorted at L2 and L4 and alarms are received at "A" and "D." Transmission probably will remain

normal over the "L" unit. "A" measures to L2 and "D" measures to L4. By manipulating the bridge current, it is possible to tell if the trouble is on "L" unit 201 or 202. Since it is found that the trouble is on 201, the first offender and probably the one causing the trouble would be L2, or possibly L1.

(c) The amplifier at L2 on "L" Unit 201 fails.
This caused the "L" unit to fail. If L201 is the working unit at the time of trouble an immediate switch to L203 takes place at "D" accompanied by "line switch" alarm. If L201 is the spare unit the "spare failure" alarm operates at "D." In addition a "pilot level" alarm is received over the alarm trunk from "C." Since no alarm is received from Station "B" it is evident that the trouble located between "B" and "C".

The pilot alarm pair is shorted at L2 and at all other regulated "L" stations toward "D." Pilot alarms are received at both "A" and "D." "A" measures to L2 and "D" measures to his first regulated "L" point toward "A." This located the trouble at L2, or possibly L1. Station "D" identifies the unit in trouble by observing the position of his line switch.

(d) Coaxial for "L" Unit 201 grounded or open or coaxials for both "L" units 201 and 202 open between L2 and L3.
Any one of these troubles causes both "L" units 201 and 202 to fail. Service is immediately switched to spare "L" units at "A" and "D." The power section East of "B" is unbalanced or open and the power is automatically dropped to practically zero.

Failure of the power interrupts the pilot frequency on "L" Unit 201 at all "L" stations East of "B" and on "L" Unit 202 at all "L" stations West of L5 so that shorts are placed on the pilot alarm pair at every regulated auxiliary station between "A" and "D." Measurements from both of these stations, will therefore, give a location at the first adjacent regulator "L" point. The pilot alarm pair is, therefore, useless for locating the trouble.

"C" and "D" get alarms showing that no pilot frequency is being received on Unit 201. The alarm at "C" is transmitted over the alarm trunk to "D" indicating the condition at "C."

At "B," the power control panel being at minimum voltage, three alarms appear and are transmitted over the alarm trunk to "A." These alarms show

(1) One or both power control panels in lowest limiting voltage condition (the lamp which carries this indication is also used to show 24-volt and 130-volt discharge fuse operation and 130-volt rectifier-inverter failure.)

(2) The loss of pilots on "L" Unit 201 due to above loss of power.

(3) The loss of pilots on "L" Unit 202 due to above loss of power.

Figure 8 shows the connections of the pilot indicators on the output side of the transmitting amplifier of each "L" unit, at a nonswitching main repeater office. It is evident that the pilot indicators will be affected when power is lost on either side of the power feed station, and no deductions as to the side in trouble can be made. Also, the power control alarm received from "B" would apply to either of the two power control panels normally feeding power to Units 201 and 202. It will not be known, therefore, from the alarm indications whether there is cable trouble East or West of "B" or whether the trouble is within Station "B." However, since only the one alarm indication has been received from Station "C" it can be concluded that a man should be dispatched to "B."

The maintenance man when he arrives will note the condition of the power control panel feeding the East power section and will proceed to make measurements on the East coaxial conductors, locating the trouble between L2 and L3.

(e) Coaxials for "L" Units 201 and 202 grounded at the same location

(1) The grounds are located between "B" and a point just beyond "L1." "L" Units 201 and 202 will fail and an automatic switch to the spare line will take place at "A" and "D." The voltage probably will automatically reduce to a minimum value at the limiting range of the regulating apparatus and a power control alarm at "B" will be transmitted over the alarm trunk to "A."

The various alarm indications will be identical to those in (d) above and a man would be dispatched to "B."

(2) The grounds are located between a point just beyond "L1," and "L5." The units will fail as before and cause a switch to the spare line at "A" and "D." The power in the section will remain on but the voltage will be automatically adjusted downward to keep the current in the loop at normal value.

All auxiliary stations in the East power loop East of the trouble will be without power but power will be intact on the line equipment at "B" and at all auxiliary stations between "B" and the trouble.

Pilot alarms over the pilot alarm pair will be received at "A" and "D" from all regulated auxiliary stations East of the trouble on Unit 201 and from L5 and points West on Unit 202.

Loss of pilot frequencies on Unit 201 at "C" and on Unit 202 at "B" will be indicated over the alarm trunk to "D" and "A" respectively. No power control alarm will be received from "B" (except a possible momentary alarm while the automatic current adjustment is being made.)

As in the previous case, measurements on the pilot alarm pair will be of no value. However, the single indication of "odd" pilot alarm from "C" received at "D" and the "even" alarm from "B" received at "A" do permit the conclusion that the trouble is between "B" and "C" and men will have to be dispatched to both of those stations.

The only indication which the maintenance man at "B" will note may be a line voltage reading below normal. Both coaxials will be tested at "B" and "C" and the grounds will be discovered in the East power section at "B."

3. PRECAUTIONS REQUIRED DUE TO POWER VOLTAGES

3.01 Because of the method used to supply power to the intermediate repeaters, dangerously high voltages may exist between the two inner conductors of a power loop or from either conductor to ground. To protect personnel and testing apparatus, it is imperative that power be removed from the loop before it is opened at main or auxiliary stations and before any test connections to it are made; likewise before any work is done on coaxials in the cable at a splice or sheath opening.

3.02 Extreme care must be exercised before opening a loop to make sure that it is the idle loop, in order to avoid danger to personnel, to the continuity of service on working "L" units, or to the equipment. Any person who may make connections to or any changes in the power loops should be thoroughly familiar with the system of numbering used for designating the coaxials.

3.03 When trouble on a power loop is indicated and it is desired to make preliminary voltmeter and Wheatstone bridge measurements at the main station feeding power to the loop, the precautions and general methods of removing power and making the coaxial conductors available for test, as covered in Bell System Practices Section E34.579, should be followed. Care should be taken to see that the proper Power Disconnect and Restoration card is filled out and placed on the power control panel and that this card is removed when work is completed and the power restored.

3.04 Before making tests on coaxials between auxiliary repeater stations and between auxiliary and main stations, or before working on coaxials in the cable, power on the coaxials involved must be first turned off at the main station, or both main stations if a junction repeater is involved, and the section isolated by disconnecting the flexible leads between the adjacent repeaters and the cable terminals. Upon opening the cable, the coaxials to be worked on can be identified by means of the numbering plan, as explained in Paragraph 2.02 and verified by using the 79-type test set, which is described in Section G50.213.4. The above procedures are covered in detail in Section G74.440, "Coaxial Cable Maintenance - Precautions," and anyone working on a coaxial cable should be thoroughly familiar with these instructions.

4. TEMPORARY CABLE RESTORATION USING FLEXIBLE COAXIAL CABLE

4.01-4.12 See Section G50.445.1 for instructions on the temporary restoration of coaxial facilities by the use of flexible coaxial cable.

Transmission Data

4.13 For either .27 inch or .375 inch coaxials, it can be stated in general, that an excess loss up to 2db inserted in a coaxial between two "L" amplifiers will be compensated for automatically in the repeaters. If the excess loss is between 2 db and 5 db, it can usually be compensated by gain adjustments made at the adjacent "L" repeaters without appreciably degrading transmission. If the excess loss exceeds 5 db, the above gain adjustments will usually not take care of the situation and progressively more serious transmission impairment will result.

4.14 The following table gives the transmission losses for regular and emergency cable at 2 megacycles:

	Loss in db per 100 ft.
P2BE Cord	.33 db
RG6/U Flexible Coaxial Cable	.40 db
CA-1282 Flexible Coaxial Cable	.33 db
.27 inch coaxial Cable	.15 db
.375 inch Coaxial Cable	.10 db

The length of RG6/U wire spanning a section of .27 inch coaxial which will cause an excess loss of 5 db is therefore

$$X\,\frac{(.40-.15)}{100} = 5 \qquad X = 2000 \text{ ft.}$$

Similarly, for a .375 inch coaxial

$$X\,\frac{(.40-.10)}{1000} = 5 \qquad X - 1660 \text{ ft.}$$

4.15 The following table based on the above data, gives the approximate effect of various lengths of flexible coaxial cable inserted in .27 inch and .375 inch coaxials.

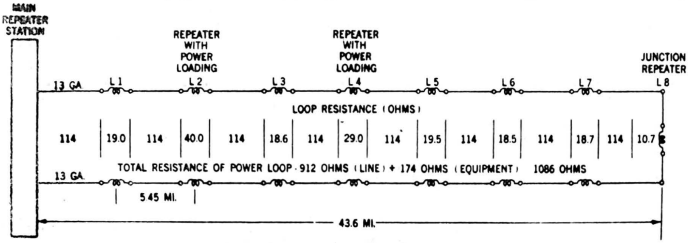
Excess Loss	Effect on Transmission	Max. Feet of Flexible Coaxial Cable			
		.27 Inch Coaxial		.375 inch Coaxial	
		RG6/U	CA-1282 or P2BE Cord	RG6/U	CA-1282 or P2BE Cord
0 to 2 db	Automatically compensated	800	1110	660	870
2db to 5db	Compensated by adjustments	2000	2770	1660	2170
5db to 7.5 db	Probable maximum degrading desirable after adjustments	2000	4170	2500	3260

4.16 Actually, the effect on transmission due to the insertion of emergency cable varies with the distance from the nearest main switching station or terminal office. For example, if an excess loss of 5 db is inserted at a point where there are 2 or more regulated auxiliary stations between the point of insertion and the nearest main switching station or terminal office, no transmission adjustments will normally be required. The margin of gain in the regulated points will restore the pilot levels and equalization slope. If, however, there are less than two regulated points between the point of insertion and the nearest main switching station or terminal office, the excess loss may be compensated by level changes at the two auxiliary stations adjacent to the break. The level of the 2064 Kc pilot transmitting toward the break should be increased by 3 or 4 db by adjusting the regulator or manual gain unit. If the station receiving from the direction of the break is a manual gain unit point, the manual gain unit should be replaced temporarily with two 103-C regulators.

5. FAULT LOCATION MEASUREMENTS - GENERAL

5.01 When trouble is indicated in a coaxial cable power section, the first step is to remove the power from the defective loop or loops at the main station in accordance with standard instructions and test the inner conductors of the coaxials for grounds and opens. Preliminary location measurements are then made from the main station over the coaxial power loop using the Wheatstone Bridge. These preliminary tests are covered in Bell System Practices Section E31.014. They do not require the sending of personnel to the end of the power loop at the junction repeater.

5.02 Each auxiliary repeater adds a certain amount of series resistance and capacitance to ground to the power loop due to the power separation filters and power supply transformers and, in some cases, power loading coils and building out networks.



GENERAL INFORMATION

	.27 IN. COAXIALS	.375 COAXIALS
NOMINAL AUXILIARY REPEATER STATION SPACING	5.45 MI.	7.9 MI.
MAIN REPEATER STATION SPACING MAXIMUM	90 MI.	150 MI.
SIZE OF INNER CONDUCTOR	13 GA.	10 GA.
RESISTANCE OF INNER CONDUCTOR PER MILE	10.50 OHMS	5.25 OHMS

LOOP RESISTANCE OF INNER CONDUCTOR AND AUXILIARY STATION EQUIPMENT IN A TYPICAL POWER LOOP .27 IN. COAXIALS
FIGURE 10

Figure 10 shows the conductor and equipment resistances in a typical power loop of a cable containing .27 inch coaxials. It will be noted that the lumped resistances in the equipment at the auxiliary stations comprise in this case about 16% of the total resistance of the loop. Temperature changes in the equipment, resulting in resistance changes, may, therefore, have a considerable effect on the accuracy of preliminary measurements made from a main station, since an error of one ohm is equivalent to about 500 feet for a 72 mil conductor (.27 inch coaxial) and about 1000 feet for a 100.3 mil conductor (.375 inch coaxial). For this reason, even when the actual resistance of the equipment at each auxiliary station is known, preliminary measurements made from a main station over a power loop are in many cases not sufficiently accurate to warrant opening the cable at the indicated location. They serve primarily to determine between which two auxiliary stations the trouble locates. A precision measurement using portable testing apparatus is then made on the bare coaxials between the two auxiliary stations. This procedure is preferred to the more complicated and less accurate precision measurements made from the main station as described in Bell System Practices Section E31.014.

5.03 Standard fault location methods can be used for any spare unequipped coaxials which are patched through at auxiliary or main repeater stations in accordance with Section E21.913 or for any other conductors which are continuous between main repeater stations. In this connection tests indicate that the standard testboard KS-3011 Wheatstone Bridge will accurately measure unbalances as small as one ohm in a 12,000 ohm loop.

5.04 When a coaxial is crushed, it sometimes happens that the insulation of the inner conductor breaks down and it grounds when the normal power voltage is applied, but it tests clear when subjected to the 150 volt testing battery. For use in such cases, a high voltage Wheatstone Bridge is available, (90A Test Set) having a power pack capable of delivering a line current through the fault of about 10 milliamperes, at a voltage up to about 3000. The description and method of using this bridge is described in Section G50.250.1.

5.05 Small hairlike copper slivers may at times short circuit the inner and outer coaxial conductors. When such is the case, it may be possible to burn out the sliver with the 94A or D-175572 test sets (sliver burners). The operation of these sets is described in Section G50.244.7.

6. PRELIMINARY LOCATION MEASUREMENTS

6.01 When service on one or more "L" units in a power section is interrupted, the trouble is first diagnosed by means of the alarms and meter readings as equipment trouble at the main station, or trouble in the cable or auxiliary repeaters in the power loop. If cable trouble is indicated, power is first removed from the power loop or loops which are in trouble and a voltmeter test is made on the coaxials as covered in Bell System Practices Section E31.014 to determine if the inner conductors are grounded or open. If such is the case, preliminary measurements are then made with the Wheatstone Bridge, as covered in the above B.S.P. Section, which should locate the trouble between two auxiliary stations.

6.02 If difficulty is found in obtaining a satisfactory preliminary trouble location over the power loops, it may be possible in some cases to make check tests over spare unequipped coaxials or other conductors in the cables. In any case, the condition of all spare coaxials should be determined since the maximum use

should be made of all good coaxials by patching them between auxiliary stations to restore working lines.

6.03 If trouble occurs at an unattended main station or in the power sections fed by that station, alarms from that station will be received at the nearest attended office. As described in Paragraph 2.07, it will frequently not be possible to determine from these alarms whether the trouble is in the main station equipment or whether it is in one of the power sections fed by the station. Central office forces should be dispatched at once to the unattended main station to make the trouble analysis and preliminary tests covered in Paragraph 6.01 above, unless the trouble is clearly shown to be due only to equipment. If possible, at least three men should be sent so that in case of trouble in a power section, one will be available at the main station and two for dispatching to the auxiliary stations on each side of the trouble location.

6.04 In some cases when long distances are involved, a section cableman who has been trained in making preliminary location measurements from main stations, may be close to the unattended office, and considerable time may be saved if he can be contacted and directed by the attended office to make these tests prior to the arrival of the central office forces.

6.05 In the case of alarms received from an unattended main station, there may be spare unequipped coaxials or other conductors which are in trouble due to the same cause in the cables extending between two attended stations. It may be feasible to make measurements over such conductors between the two attended offices as a further check on the location of the trouble.

7. PATCHING COAXIALS AND PATROLLING LINE

7.01 If the preliminary measurements indicate that some good coaxials are available, the first consideration is to patch them between the two auxiliary stations adjacent to the trouble so as to make good the maximum number of working lines. A craftsman should be stationed at the power looping station to assist in testing transmission paths in the event amplifiers fail when service is restored. Patching between auxiliary stations or between a main and an auxiliary station is discussed in Paragraph 2.06 above.

7.02 Central office men with portable testing apparatus should be dispatched immediately to each of the auxiliary stations. On arrival, they should, if possible, get in touch with the main station and with each other over the "L" station order wire or cablemen's talking circuit. The faulty coaxials and any good coaxials not in use on working lines should be disconnected at the cable terminals and tested with the voltmeter for grounds and opens. The patches should then be made and the main repeater station advised.

7.03 If it is evident, due to the shortage of available central office people, the distance involved or other factors, that one or more trained section cablemen are in a position to make the patches in appreciably less time than would be taken by the central office people, consideration should be given to assigning them temporarily to this job pending the arrival of the central office forces. Otherwise, as soon as the trouble is located between two auxiliary stations or, in the latter case, as soon as the central office forces arrive at the auxiliary stations or the patching is completed, the section cablemen should patrol the cable in the vicinity of the trouble location to search for visible signs of the trouble.

7.04 The two most common causes of serious trouble in buried or underground cable is damage due to foreign workmen, which can usually be seen, particularly in the case of buried cables, or lightning which is frequently not evident from an inspection along the route. The nature of the trouble and conditions at the time of the trouble, may however, give some clue as to the cause. Upon completing his patrol, the cableman should immediately call the main station from a cable talking terminal or get in touch with one of the auxiliary stations and report the conditions found.

8. PRECISE LOCATION MEASUREMENTS

8.01 As soon as all possible patching has been completed between the two auxiliary stations, trouble location measurements should be made from both auxiliary stations over the bare coaxials using a portable Wheatstone Bridge.

8.02 If central office forces have not yet arrived to make these tests and a trained section cableman with the necessary testing apparatus is available, it may be advisable to have the latter start the measurements, but not until after the patrol of the cable between the two auxiliary stations has been completed and no trouble found.

9. TEMPORARY CLEARANCE OF TROUBLE FOUND BY INSPECTION

9.01 If the location of the trouble is found visually by the section cableman during his patrol, he should advise the testboard of the location, preliminary manpower requirements, tools and testing equipment needed. The cable should be immediately exposed at the point of damage and the sheath removed for a sufficient length to effect repairs.

9.02 Arrangements should be made with the testboard to put tone on the cableman's talking circuit or, if desired, the cableman can place tone on it himself at a near-by cable talking terminal. As soon as the cable is opened, he should establish communication with the main repeater station and the auxiliary stations. He should then identify any working coaxials in accordance with standard instructions and repair those which are damaged or make them good by means of short lengths of flexible coaxial cable, whichever is quicker.

9.03 Central office people should remain at the auxiliary stations until released by the control testboard.

10. TEMPORARY CLEARANCE OF TROUBLE BASED ON PRECISE LOCATION MEASUREMENTS - UNDERGROUND CABLE SECTION

10.01 Upon completing the patrol of the cable, including gas pressure readings, and finding no evidence of the trouble, the section cableman should report to the nearest auxiliary station or call in from a cable talking terminal for the final trouble location.

10.02 If any of the inner coaxial conductors are grounded or if there are grounds which measure at the same location on other conductors in the cable, tone should be bridged between the conductor and ground at an "L" station and an exploring coil should be used at the manholes on either side of the trouble location. When the two splices between which the trouble locates have been definitely determined, they should both be opened simultaneously if sufficient forces are available. In case there are no grounds, or an exploring coil is not available, the two splices on each side of the trouble location should be opened.

10.03 The cableman's talking circuit should be identified as covered in Paragraph 9.02 above and communication established between the splices and the main and auxiliary stations. If either the cableman's talking circuit or the local order wire are in trouble, the circuits in trouble should be made good by laying twist on the ground between the two manholes.

10.04 Assuming that the power is turned down on the coaxials in trouble and that these coaxials have been opened at the terminals in the auxiliary stations on each side of the trouble, identification should be made at each open splice as follows:

(a) Short the inner conductor to the outer conductor at one station using a D-160114 cord.

(b) Apply tone between the inner and outer conductor at the other station using a 20C or 76-type test set.

(c) Identify the coaxial at each splice by listening for the tone with a 79-type test set connected to a 107A amplifier.

As each coaxial in trouble is identified, open it at the splice in accordance with standard instructions and bridge the defective section between manholes with flexible coaxial cable as outlined in Part 4 of these instructions and Section G50.445.1.

10.05 Some types of trouble on coaxials such as shorts between the inner and outer conductors will not pass tone between the open splices and identification must be made by sending tone from each station adjacent to the trouble.

10.06 After the working coaxials are temporarily restored with the emergency cable, permanent repairs can be made in the most practicable manner.

11. TEMPORARY CLEARANCE OF TROUBLE BASED ON PRECISE LOCATION MEASUREMENTS - BURIED CABLE SECTION

11.01 In the case of a buried cable section if the trouble is not found on patrol, pits should be dug and the cable sheath exposed simultaneously at two points a sufficient distance on each side of the measured location to insure that the trouble is located between the two points. This procedure will restore service with the minimum delay in the average case. Additional forces should

be obtained, if possible, to assist in this work. Assuming a reasonably accurate location, these points should be at least 150 feet on each side of the measured location if a ground is involved and at least 250 feet on each side if an open is involved.

11.02 If the cable has an outside layer of conductors, it is difficult to obtain sufficient slack in a buried section to work properly on the coaxials when a sheath opening is made. Therefore, it is generally best to expose the sheath at a splice in such cables, even if this results in a greater length between openings than the above limits require. In this connection, the effect of long lengths of flexible coaxial cable, as explained in Part 4, should be taken into consideration when deciding upon the best points to expose the sheath.

If the cable does not have an outside layer of conductors and it is decided to restore service on the coaxials by patching around the trouble, it may be preferable to open the cable sheath rather than a sleeve.

11.03 As soon as the sheath or sleeve is exposed, the location of the trouble between the two points should be verified with the exploring coil before opening the cable, if any grounds are involved. In the case of a nonsplice point with tape armored cable, it may be necessary to strip off the tape for a short distance before the tone can be heard in the coil.

11.04 The procedure is then the same as in the case of underground cable, Part 10 above. The flexible coaxial cable should be adequately protected where it crosses roads and other places where it is liable to be damaged.

11.05 To make permanent repairs, Varley measurements are made from the two openings over the defective length and the cable is exposed at the new trouble location which should be within a few feet of the actual trouble. In the case of a ground, the exact location is found with the exploring coil, the sheath opened at that point and repairs made. In the case of an open, it will be necessary to make continuity tests and additional open location measurements and sheath openings until the trouble is finally found. For short distances (splice lengths) accurate location measurements can be made with a 2A capacity bridge and 11A oscillator. The portable bridge test set is satisfactory for measuring the usual types of d.c. faults in cable conductors, including opens between auxiliary repeater stations.

12. ORGANIZATION

12.01 A District Office representative should be present at the scene of the trouble to direct activities, see that sufficient forces, material, testing apparatus, etc. are on the job and coordinate the work of the outside forces and the central office people at the auxiliary and main repeater stations.

12.02 The office in whose testing territory the trouble locates will naturally control the direct restoration activities from a testboard standpoint. However, when coaxial systems are interrupted and power turned off and on in various sections, there may be amplifier failures in both the power section in trouble and also in other power sections. This may result in additional equipment failures after the physical restoration of the coaxials is completed and power is turned on. It is, therefore, important that supervisors at both the unit control and system control offices who are thoroughly familiar with the coaxial system be kept informed of conditions all along the line, plot this information as it is received and direct the moves of personnel at various offices, the frogging of coaxials, etc. so that overall restoration is accomplished in the shortest possible time.

13. TESTING EQUIPMENT

13.01 The following portable testing equipment should be available for testing coaxials between "L" auxiliary repeater stations or between main and auxiliary stations.

(a) Testing tone (76-type test set)
(b) Voltmeter (or Volt-ohmmeter)
(c) 45 volt dry battery
(d) Coaxial patch cords for use in auxiliary stations
(e) Wheatstone bridge or portable bridge test set which includes testing battery, bridge, voltmeter and open location feature.

13.02 For work on the cables, section cablemen should be equipped with

(a) 75A test set (exploring coil and amplifier)
(b) 107A amplifier
(c) 79-type test set
(d) 513A tool (probe)

13.03 When the inner conductor is open, the 2A capacity bridge and 11A oscillator or Portable Bridge Test Set should be used for precise location measurements over short distances between sheath or splice openings, as discussed in Paragraph 11.05.

13.04 In special cases, a "sliver burner" or high voltage Wheatstone Bridge may be required, as covered in Part 5.

13.05 A compact and convenient portable test set for this work, which can be made up locally, has recently been developed, known as the Portable Bridge Test Set. This set contains a voltmeter, 167 volt testing battery, Wheatstone bridge, and a 4 cycle interrupter for open location measurements.

14. PROVISION OF EMERGENCY CABLE

14.01 Emergency lengths of P2BE, RG6/U or CA-1282 flexible cable equipped with couplings should be provided at convenient locations for making emergency repairs. A length (usually 400-600 ft.) of emergency cable carried on a light reel weighs about 50 pounds, which is about the maximum a man can conveniently carry and pay out along the ground. It appears, therefore, that the lengths to be stored should not, in general, exceed 600 feet and that a number of these lengths should be coupled together when it is desired to span a greater distance. When a cable is excavated and repaired at the point of damage, 50 foot lengths would appear convenient to effect emergency restoration where a considerable area of sheath is damaged. If the damage is localized, 1 ft. patch cords may be used to advantage in restoring the coaxials since cords of this length can be temporarily wrapped up with the splice.

14.02 It is suggested that the following amount of emergency cable terminated with coaxial jacks and plugs be provided for each equipped coaxial to take care of average conditions:

(a) Each Cable Sectionman

1 - 50 foot length of emergency cable
1 - 5 foot patch cord
2 - 479-type jacks

(b) At Main Stations about Every 150 Miles along Underground or Buried Cable Routes

Sufficient reel lengths (400-600 ft.) to span the maximum distance between splices.

1 - 5 foot patch cord (or other suitable length to permit patching from spare terminals to working terminals in the auxiliary stations)
2 - 479-type jacks

14.03 Reference should be made to Plant Memorandum X10.45 for the type, quantity, and location of emergency stocks in this area.

15. STORAGE OF COAXIAL CORDS

15.01 See Section G50.445.1 for information on the storage of flexible coaxial cords.