CARRIER ENGINEERING
SYSTEM APPLICATION
T4M DIGITAL LINE
TRANSMISSION AND OUTSIDE PLANT DESIGN GUIDE

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Printed in U.S.A.

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1. GENERAL

1.01 This section gives a brief description of the T4M digital line and provides specific layout rules for the application of T4M. A general description of the T4M digital line is provided in Section 365-550-100, and detailed equipment descriptions are given in Section 801-523-152. The rules given herein pertain to T4M lines that use 0.375-inch serrated-seam disc insulated coaxial cable and require 30 repeater stations or less. Subsequent issues of this section will detail the rules for longer systems. This section also provides the engineering rules for the wire pairs in the cable sheath that are required for maintenance functions.

1.02 The T4M line is a coaxial digital transmission facility for digital signals at the fourth level (274.176 megabits per second) in the digital hierarchy (see Fig. 1). T4M is intended primarily for high capacity short-haul and metropolitan-area applications for route distances up to 500 miles. It has the capacity of transmitting 4032 two-way voice grade circuits (168 T1 lines) over each pair of coaxial tubes. Other signals such as wideband data can be carried by displacing voice circuits. The T4M line is defined as a separate entity commencing and terminating with and including the span terminating frames in the end offices, but independent of various terminal equipment such as multiplexers and cross-connects that might deliver signals to the line for transmission. The term "line" will be used interchangeably to denote either all the tubes in the cable sheath or a single tube pair. The meaning of the specific usage will be clear from the context of the situation.

1.03 Various cable sizes can be used for T4M including 22-tube cable, 18-tube cable, 12-tube cable, and various composite and smaller size cables containing 0.375-inch coaxial tubes. Up to 14 wire pairs are required in the cable sheath for maintenance functions, 12 of which are required to be 19 or 22 AWG, 0.083 μf/mile wire pairs. T4M may be employed on routes where the cable is buried or placed in ducts. The 22-tube cable may be placed in a 4-inch duct. The 18-tube cable is the largest size sheath that can be placed in a 3-1/2 inch duct. The 18-tube cable provides a capacity of 32,256 two-way circuits with protection (one tube in each direction is used for protection), and the 22-tube cable provides a capacity for 40,320 two-way circuits with protection.

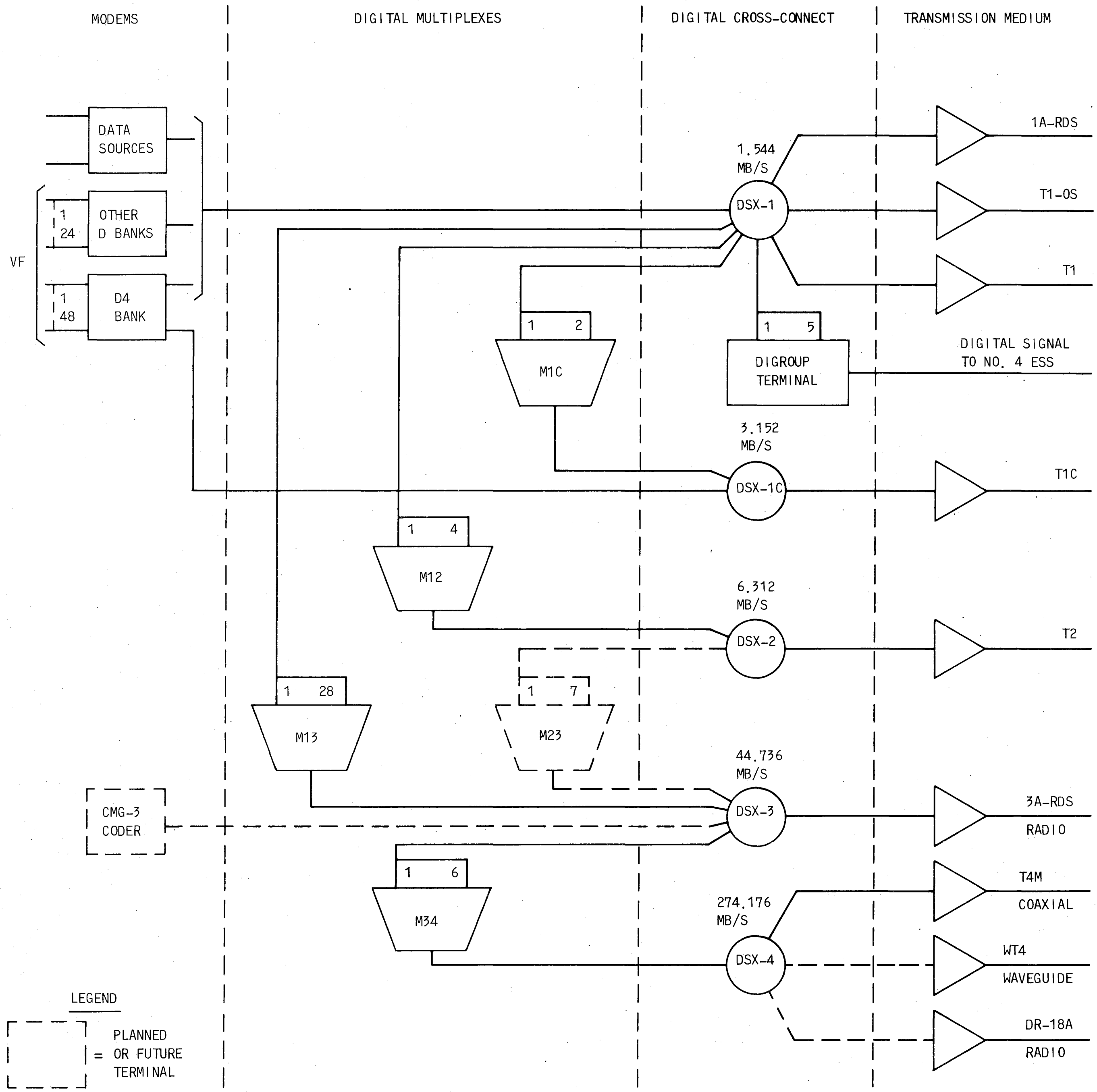


Fig. 1—Digital Hierarchy and Transmission Facilities

1.04 The T4M regenerators are located in repeater stations spaced up to a maximum of approximately 5700 feet apart. (Repeater stations are usually located in manholes.) Powering of the regenerator is accomplished over the center conductor of the coaxial cable from end office constant current power supplies.

1.05 This section provides specific rules which should suffice to cover almost all T4M applications for a given route; however, certain situations may exist where strict adherence to the layout rules given in this section is not possible or desirable. Section 855-353-100 contains the underlying considerations in the generation of the

T4M layout rules and should be consulted when such situations occur.

1.06 The descriptive material and rules presented herein assume the use of 19 AWG, 0.083 μf/mile wire pairs, as found in standard coaxial cable designs, for the maintenance functions. For applications employing cable containing 22 AWG, 0.083 μf/mile wire pairs, where no more than 24 repeater stations are required, consult 5.57 through 5.65.

1.07 L5 and T4M can share coaxial cables and repeater stations. Refer to 5.66 and Section 855-346-100 for more information concerning such joint usage.

1.08 T1 and T4M can share composite cables and repeater stations. Wire-pair utilization for this application is discussed in 5.67 and 5.68.

2. MAINTENANCE FEATURES

2.01 A full complement of protection and maintenance features is available. This includes in-service performance monitoring, automatic protection switching, automatic fault sectionalization, and alarm remoting capability. Wire pairs within the coaxial cable sheath are used for maintenance and order-wire purposes in the T4M line.

2.02 Test equipment designed especially for use with T4M lines comprises five portable units, three of which are intended primarily for central office use and two for general office or line application. The central office sets are the J98721E (21E) Fault Locating Test Set (FLTS), the J98721F (21F) Regenerator Test Set (RTS), and the J98721J (21J) Portable Signal Generator (PSG). The general use test sets are the J98721G (21G) Transmission Test Set (TTS) and the J98721H (21H) Portable Violation Monitoring (PVM) Test Set.

2.03 A T4M line consists of one or more maintenance spans, which under the most favorable conditions can be up to 111 miles in length and may be connected in tandem for a total system length up to 500 miles. Each T4M maintenance span terminates at each end in a span terminating frame (STF) located in a maintenance office. These spans are independent entities for powering, monitoring, protection switching, patching, and fault locating. The line performance within each maintenance span is continuously monitored on an in-service basis. If the error performance of a service line becomes worse than one error in 10^6 bits, the associated service is automatically switched to the protection line (when available) with no loss of service. The system allows up to ten 2-way working T4M lines with one tube for protection in each direction.

2.04 Two other system features, which are planned, are route diversity and ADD/DROP capability. With route diversity, parallel routes of T4M lines in separate cable sheaths which terminate in the same end offices can be protected with a common protection line. The ADD/DROP capability allows intermediate locations to be established on a T4M route for adding or dropping one or more protected 274 megabits per second (Mb/s) signals. These two features will be described in a later issue of this section.

3. TRANSMISSION OBJECTIVES

3.01 The guides for engineering T4M Transmission Systems provided in this section will permit T4M lines with maintenance spans up to 111 miles in length to meet the following objectives for lines up to 500 miles in total length:

(a) An accumulated error rate of better than 10^{-6} for 99 percent of the time.

(b) A service outage due to equipment failures of 0.02 percent, ie, 1.7 hours/year.

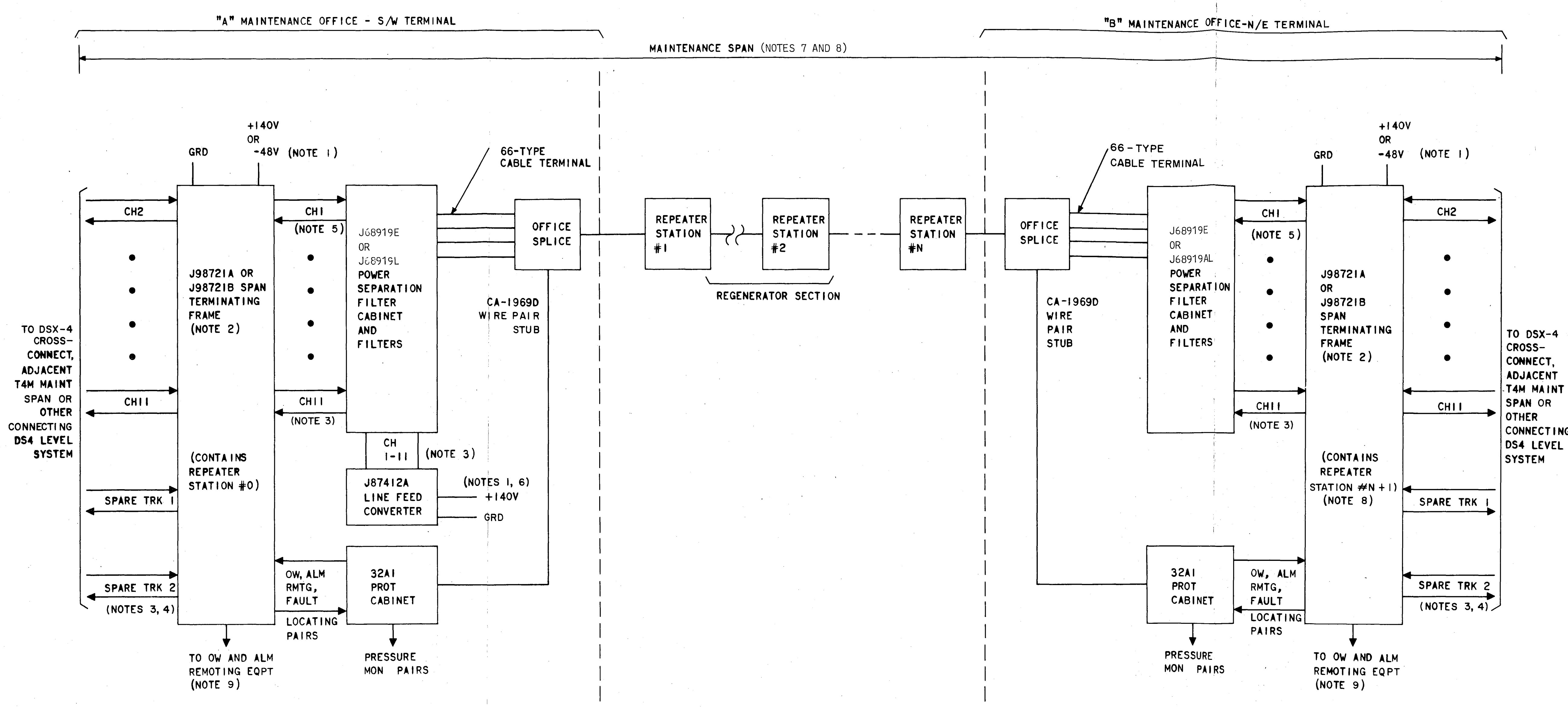
Outage is that percent of time during which service over a given line is interrupted because of unprotected failures.

4. DEFINITIONS

4.01 Figure 2 depicts all equipment and apparatus in a T4M maintenance span up to 31 miles in length. Maintenance spans are coincident with power, protection switching, and fault locating spans. The following paragraphs provide a brief definition and description of the components contained in a maintenance span.

A. Maintenance Office Equipment and Apparatus

4.02 ***Maintenance Office (MO)*** is the end point of a maintenance span, generally located in a central office, and contains equipment



NOTES:

1. MAY BE USED WITH EXISTING +130V PLANT IF EMERGENCY LIMIT GREATER THAN +120V.
2. J98721A STF MAY BE EQUIPPED FOR UP TO SIX 2-WAY CHANNELS. J98721B STF MAY BE EQUIPPED FOR UP TO ELEVEN 2-WAY CHANNELS.
3. 728A USED FOR INTRAOFFICE CABLING.
4. ONLY J98721B STF HAS SECOND OFFICE SPARE TRUNK AVAILABLE FOR RESTORATION.
5. CHANNEL 1 IS PROTECTION LINE; UP TO 1X10 PROTECTION.
6. J87412A LINE FEED CONVERTER IN "A" OR "B" OFFICE.
7. REGENERATOR SECTION LENGTH OF 1.07 MILES ASSUMED.
8. $(N + 1) \leq 29$ (31 MILE MAXIMUM MAINTENANCE SPAN LENGTH WHEN 19 AWG WIRE PAIRS ARE USED FOR MAINTENANCE PURPOSES).
   $(N + 1) \leq 23$ (24.6 MILE MAXIMUM MAINTENANCE SPAN LENGTH WHEN 22 AWG WIRE PAIRS ARE USED FOR MAINTENANCE PURPOSES).
9. ORDER-WIRE AND ALARM REMOTING OPTIONAL.

MISCELLANEOUS NOTES:

1. PARTS OF SYSTEM NOT SHOWN:
   A. SPLICING MANHOLES (FOR DUCTED ROUTES)
   B. CABLE PRESSURIZATION
   C. PRESSURE MONITORING
   D. ORDER-WIRE PANELS
   E. OFFICE ALARM CONNECTIONS
2. T4M OPTIONS NOT SHOWN:
   A. ROUTE DIVERSITY
   B. ADD/DROP
3. MAINTENANCE SPANS MAY BE PLACED IN TANDEM FOR SYSTEM LENGTHS TO 500 MILES.

Fig. 2—T4M Maintenance Span (Up to 31 Miles)

to monitor, maintain, administer, and power a T4M line.

4.03 ***Span Terminating Frame (STF)*** is the end point of a T4M maintenance span, located in a maintenance office, and provides the functions of regeneration, line monitoring, protection switching, fault locating, alarming, patching and restoration access, and other maintenance functions.

4.04 ***Line Feed Converter (LFC)*** is located in the maintenance office and provides constant current (835 mA) to power line regenerators.

4.05 ***Power Separation Filter Cabinet (PSFC)*** is located in the maintenance office and contains power separation filters (PSFs) which combine T4M line signals and line power.

4.06 ***Wire Pair Protector Cabinet (WPPC)*** is located in the maintenance office and provides protection against power and lightning surges on cable wire pairs used for T4M maintenance functions.

4.07 ***Office Splice*** is the point in the maintenance office where the line cable is spliced to the coaxial tubes from the PSFC and the wire pairs from the WPPC.

B. Outside Plant Equipment and Apparatus

4.08 ***Repeater Station (RS)*** is generally located in a manhole along the T4M line (each STF also contains an RS) and contains regenerator and maintenance apparatus cases, regenerators and maintenance plug-ins, and order-wire and test appearances.

4.09 ***Splicing Manhole*** is used for pulling and splicing line cable sections between repeater stations in ducted installations (not shown in Fig. 2).

4.10 ***Regenerator Section*** is defined as a regenerator and the cable at its input extending to the output of the previous regenerator.

4.11 ***Auxiliary Station*** is required when more than 30 repeater stations (including those in both office STFs) are required along a T4M route between maintenance offices for powering and repeating of the fault locating and order-wire lines and monitoring of the fault locating wire pairs (not shown in Fig. 2).

4.12 ***Fault Locating Subspan*** includes all equipment and apparatus between two adjacent auxiliary stations, between a maintenance office and an adjacent auxiliary station, or between two maintenance offices without an intervening auxiliary station (as shown in Fig. 2).

4.13 Further information on auxiliary stations and fault locating subspans will be given in a future issue of this section.

5. LAYOUT RULES

5.01 The purpose of this section is to provide the information necessary to plan and engineer a specific T4M route based on current and projected traffic needs. The very large capacity of T4M calls for somewhat longer term planning than existing systems of lower capacity. The fundamental considerations used in the generation of the layout rules are contained in Section 855-353-100. Much of the material in the following paragraphs, which assumes the use of 19 AWG, 0.083 μf/mile wire pairs for maintenance purposes, applies also to 22 AWG, 0.083 μf/mile wire pairs. Paragraphs 5.57 through 5.65 indicate where 22 AWG rules differ from the rules for 19 AWG pairs.

5.02 A T4M route consists of tandem maintenance spans. Each span consists of ducted or buried cable between the maintenance offices with repeater stations at distances up to a maximum of approximately 5700 feet. Somewhat shorter spacings are required for regenerator sections adjacent to maintenance offices to account for office cabling. In addition, splicing manholes are necessary at shorter intervals in ducted routes to allow for pulling continuous sections of cable through the duct. Appropriate codes of regenerators corresponding to the particular regenerator section cable length must be chosen. Maintenance plug-ins must be specified, depending on the regenerator section cable length and also on the particular repeater station location with respect to the maintenance office.

A. Maintenance Spans and Offices

5.03 This section provides rules for maintenance span lengths up to 31 miles (30 repeater stations including those in maintenance offices). Future issues of this section will provide rules to allow for maximum maintenance span lengths of either 47 or 55 miles for lines powered from one end and 111 miles for lines employing double-ended powering. End points of a T4M maintenance span terminate in span terminating frames (STFs) located in maintenance offices. The spans are laid out after the locations of the maintenance offices have been determined.

5.04 A particular maintenance office may house span terminating frames associated with more than one maintenance span. To eliminate confusion, the two span terminating frames associated with a particular maintenance span are designated the S/W terminal and the N/E terminal, depending upon their geographic location. For example, the Epworth maintenance office may house the S/W terminal for the Epworth-Olivesburg maintenance span and the N/E terminal for the Epworth-Brick maintenance span.

B. Cable and Duct Considerations

5.05 Line terminal equipment is designed to permit termination of coaxial cable containing up to 22 tubes. Various cable designs including composite may be used. The specific choice of cable size, however, depends upon growth and routing considerations. The 4-inch duct may accommodate sheaths up to 3.25 inches in diameter, which includes 22-tube cable. The 3-1/2 inch ducts may accommodate sheaths up to 2.75 inches in diameter. The 18-tube cable is the largest full-sized cable that can be placed in 3-1/2 inch ducts. The coaxial tubes are numbered in accordance with Section 632-035-120. Odd-numbered tubes contain transmission in the direction from S/W to N/E; even-numbered tubes contain transmission in the direction from N/E to S/W.

5.06 The cable temperature along a route must lie between 32°F and 100°F. Generally, underground duct temperatures and cable temperatures at burial depths between 3 and 4 feet fall within this range. Occasional hot spots shorter than 100 feet such as that caused by adjacent steam pipes may be tolerated as long as the hot spot does not pose a physical threat to the integrity of the cable (150°F). The temperature within repeater stations must lie between 20°F and 120°F.

5.07 The recommended splice for T4M cable is the K sleeve splice described in Section 632-425-205. (The procedures in that section must be followed exactly.) Each regenerator section must pass the cable acceptance test before it can be used for T4M transmission. This test checks the overall ability of the cable and splices to adequately transmit T4M signals. The test is performed between regenerator manholes with the J98721G (21G) Transmission Test Set (TTS) as described in detail in Section 634-414-201. The test set itself is described in Section 103-486-103. In addition, the cable must pass other tests as denoted in Section 640-540-401. Limits on the number of splices in a regenerator section are given in 5.17. Older type splice sleeves on existing coaxial cables will generally be acceptable for T4M use if the mechanical integrity is sound. Such cables must be tested, however, in accordance with Section 640-540-401.

C. Repeater Station Placement

5.08 The selection of repeater station locations is determined next. Repeater stations are numbered sequentially starting at the S/W terminal with the S/W terminal containing repeater station number 0. The number designations are used to simplify the wire-pair engineering discussed in 5.41 and for fault-locating identification discussed in 5.45.

5.09 Regenerator equalization is designed to compensate for the electrical impairments resulting from signal transmission through a coaxial tube. Because the tubes are stranded in a helical fashion within the cable, the actual tube length is longer than the sheath length of a cable. Also, the difference between tube length and sheath length varies among cables containing different numbers of coaxial tubes. For these reasons, the maximum distance between line regenerators depends on the specific code of cable being used.

5.10 The following paragraphs describe suitable manhole arrangements. The first and most direct approach is to establish an in-line manhole directly in the path of the cable route. Such a manhole would contain everything associated with cable splicing and all other repeater station apparatus.

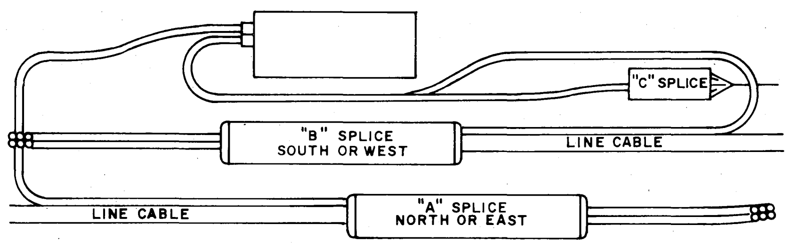
5.11 The second approach is useful in systems in which existing duct and manholes are to be used for the cable route. In this case, it may not be possible to use existing manholes as in-line manholes and accommodate all necessary repeater station apparatus because of crowded conditions. Therefore, new auxiliary manholes may have to be established adjacent to the existing manholes. The existing manhole is used to splice into the line cable. Connection is then made between the line cable splice in the existing manhole and the repeater station apparatus in the auxiliary manhole by means of a short duct run. A typical manhole configuration is shown in Fig. 3. Details of manhole arrangements are contained in Section 640-540-230.

Regenerator Section Cable Length

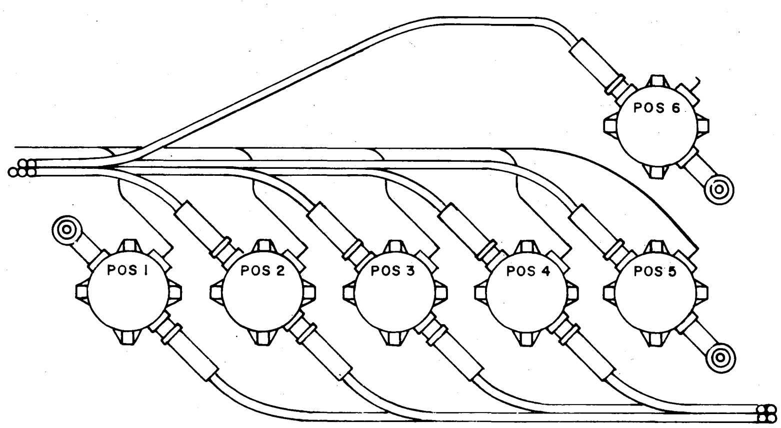
5.12 For regenerator sections between two adjacent outside plant repeater stations, the regenerator section cable length, L_{RS}, is defined to be the physical cable sheath distance between the furthermost apparatus cases in adjacent repeater stations. For regenerator sections adjacent to maintenance offices, the regenerator section cable length, L_{RS}, is defined to be the sum of the equivalent office distance between the STF and the office splice and the physical cable sheath distance from the office splice to the furthermost apparatus case in the adjacent repeater station. Table A shows the maximum value of L_{RS}, denoted L_{RSmax}, for various cable designs. These distances allow for normally expected variations in cable temperature, copper conductivity, cable stranding, and other factors and include an allowance of ±1 percent for cable route map inaccuracies. The application of Table A to regenerator sections either adjacent to or not adjacent to maintenance offices is described in the following paragraphs.

Placement of Repeater Stations Not Adjacent to Maintenance Offices

5.13 The path between two adjacent outside plant repeater stations is depicted in Fig. 4. The particular two apparatus cases, shown in the respective repeater stations, contain regenerators



TYPICAL CABLING WALL



TYPICAL APPARATUS WALL

Fig. 3—Typical T4M Regenerator Manhole Arrangement (Shown for Coax-22)

TABLE A

MAXIMUM REGENERATOR SECTION CABLE LENGTH

CABLE TYPE	NUMBER OF TUBES	MINIMUM DUCT SIZE (INCHES)	MAXIMUM REGENERATOR SECTION CABLE LENGTH ($L_{RS\ Max}$)
CA-1983	4	3-1/2	5780
CA-3209	6	3-1/2	5757
CA-3020, CA-9002	8	3-1/2	5719
CA-3226	12	3-1/2	5672
CA-3242	18	3-1/2	5755
CA-3225	22	4	5718

associated with the same T4M channels. Distances are measured to the 66-type terminal ends, ie, the point where the 66-type terminals bolt onto the respective apparatus cases. When two adjacent repeater stations in manholes are engineered according to layouts contained in Section 640-540-230, the maximum allowable manhole center-to-manhole center distance may be determined by subtracting 65 feet from the distances given in Table A. The manhole layout in Section 640-540-230 has been arranged so that apparatus case-to-apparatus case distances are approximately the same for all T4M channels. Note that for situations where the repeater station is located in an auxiliary manhole (rather than an in-line manhole), the distance between the auxiliary manhole and the main cable route must be accounted for. In nonstandard manhole configurations, the specific manhole racking in both repeater stations should be accounted for so that the longest total path length between apparatus cases containing the same T4M channels is less than or equal to the distance given in Table A for the specific cable type used. Repeater station placement is unrestricted for distances below the maximum.

Placement of Repeater Stations Adjacent to Maintenance Offices

5.14 Figure 5 shows the signal path from the span terminating frame in the maintenance office to the apparatus case in the repeater station adjacent to the maintenance office. The path in the maintenance office from the span terminating frame to the office splice consists of two sections: 728A solid dielectric cable between the T4M span terminating frame terminal strip and the power separation filter cabinet of length L_A feet (L_A constrained to be less than 500 feet) and 0.375-inch air dielcctric cable between the power separation filter cabinet and the office splice of length L_B feet. The latter consists of the 66-type terminal stub length and a section of air dielectric cable spliced to it, if required. The wire pairs are spliced in with the tubes at the office splice. A splice may also be present in the cable vault. Length L_C is the physical cable sheath distance from the office splice to the furthermost apparatus case in the adjacent repeater station. The cable in the section of length L_C is thus the particular outside plant cable used for this regenerator section. The equivalent office distance (EOD) is defined as follows:

$$EOD = 3.55\ L_A + L_B + 140 \text{ feet.}$$

This formula accounts for all maintenance office losses shown in Fig. 5, ie, losses in the span terminating frames, losses in the power separation filter itself as well as its cabling, losses in cabling lengths L_A and L_B, and other miscellaneous loss factors. It represents the equivalent cable electrical distance between the office transmitting regenerator output (or office receiving regenerator input) in the span terminating frame to the office splice. Thus, for regenerator sections adjacent to maintenance

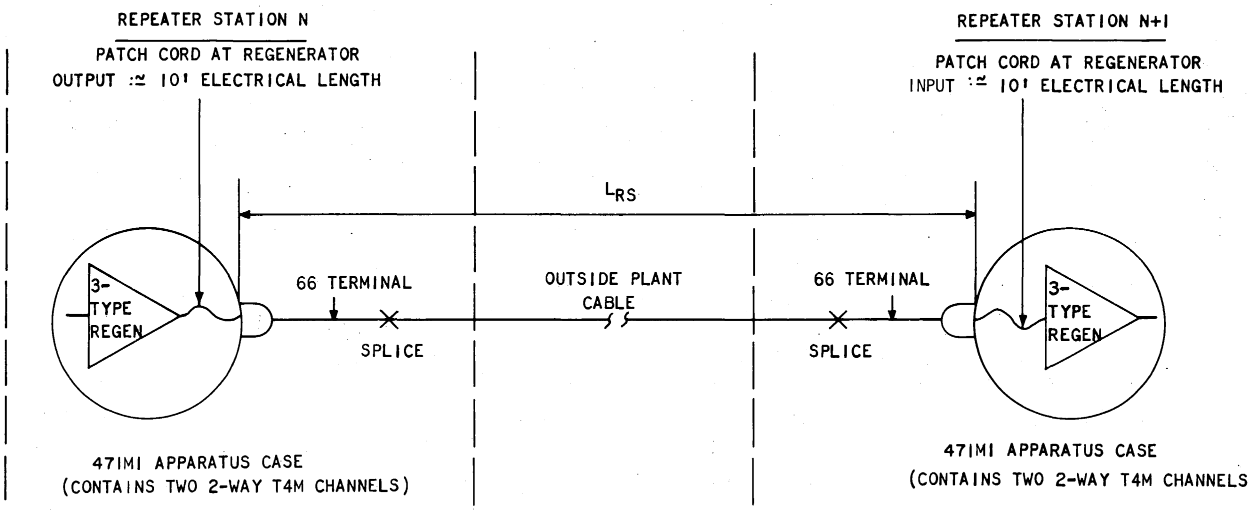


Fig. 4—Definition of Regenerator Section Cable Length, L_{RS}, for Regenerator Sections Between Two Adjacent Outside Plant Repeater Stations

offices, the regenerator section cable length is given by the following formula:

$$L_{RS} = EOD + L_C \text{ feet.}$$

L_{RS} is unrestricted for distances less than the maximum length specified in Table A.

5.15 When the repeater station adjacent to the maintenance office conforms to the layouts given in Section 640-540-230, L_{RS} can be determined using the quantity L^*_C, which is the physical distance from the office splice to the adjacent manhole center as measured directly from a route map. In this case L_{RS} is given by the following formula:

$$L_{RS} = EOD + L^*_C + 40 \text{ feet.}$$

The maximum value of L_{RS} is given in Table A, and these distances include an allowance of ±1 percent for route map inaccuracies. For nonstandard manhole configurations, use the following relation for L_{RS}:

$$L_{RS} = EOD + L_C \text{ feet.}$$

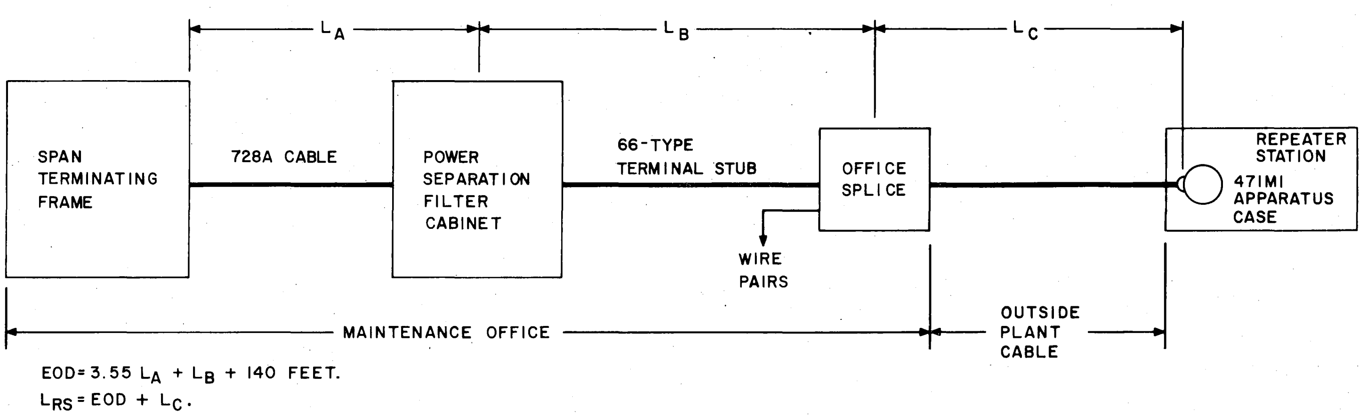


Fig. 5—T4M Maintenance Office to Repeater Station Signal Path

In this case, the specific manhole racking should be accounted for so that the maximum value of L_{RS} measured to the furthermost apparatus case is less than or equal to the distance given in Table A. Repeater station placement is unrestricted for distances below the maximum.

D. Placement of Splicing Manhole

5.16 In ducted routes, splicing manholes are necessary between repeater stations because a practical limit exists for pulling a continuous cable section through a duct. In addition, the amount of continuous cable that can be ordered on a reel is limited to distances shorter than most regenerator sections. The maximum distance a continuous length of cable may be pulled through a duct is a function of cable type, duct size, and the number and severity of bends in the route. Guidelines for placing coaxial cable in ducts are given in Section 628-200-210.

5.17 Because a splice in the cable represents a potential transmission impairment, a limit of 30 splices in a regenerator section is necessary, including splices to 66-type terminals in the manholes. Hence, 28 splicing manholes per regenerator section are permitted. A limit of 20 splices is imposed for regenerator sections adjacent to maintenance offices for the path from office splice to apparatus case, including the office splice. Refer to Section 855-353-100 for regenerator sections where these limits are exceeded. Except for the limit on the number of splices, there are no restrictions due to transmission on placing of splicing manholes.

E. Placement of Auxiliary Stations

5.18 The wire pairs of a coaxial cable in a specific route associated with a T4M line must make an auxiliary station appearance at specific intervals within a T4M maintenance span. This appearance of the wire pairs at the auxiliary station is for powering and repeating of the fault locating and order-wire lines. Auxiliary stations must be placed after every 30 repeater stations (including those located in maintenance offices). Detailed rules for auxiliary stations will be furnished in a later issue of this section.

F. Powering Limitations

5.19 In a T4M route layout, it is necessary to check each maintenance span to ensure that the planned single- or double-ended powering arrangement for the span will be adequate.

Let n = the number of repeater stations (not including those located in span terminating frames) that are along the route.

Let d = the total cable sheath distance along the route in miles.

Single-Ended Powering

5.20 The maintenance span may be powered from a single end using the J87412A Line Feed Converter (LFC) as long as 5.0d + 16.8n is less than 960. If this number exceeds 960, a system layout containing fewer repeater stations should be attempted, or shorter maintenance spans must be established. For an average regenerator spacing of 1.07 miles, a maintenance span up to 47 miles in length can be powered with the J87412A LFC. For a maintenance span not longer than 31 miles, and using 28 or less line regenerators, the maximum voltage developed by the line feed converter will be 626 volts.

5.21 Table B shows the maximum power span length (d_{max}) as a function of the number of repeater stations in the outside plant when the J87412A LFC is used to power the line.

Double-Ended Powering

5.22 Specific rules for extending the powering span capabilities up to 111 miles using a double-ended powering configuration will be included in future issues of this section.

G. Maintenance Office Equipment

5.23 A reasonable goal in laying out a T4M maintenance office is to maximize the distance to the first repeater station. To do this, the equipment should be placed according to the following priorities:

1. The span terminating frame should be as close as possible to the power separation filter cabinet.

2. The power separation filter cabinet should be placed as close as possible to the office cable splice. Since 66-type terminal stubs do not normally exceed 45 feet, a 45-foot

TABLE B

MAXIMUM POWER SPAN LENGTH AS A FUNCTION OF THE NUMBER OF REPEATER STATIONS – J87412A LFC

NUMBER OF REPEATER STATIONS (NOT INCL THOSE IN STFs) n	MAXIMUM POWER SPAN LENGTH IN MILES d_{max}
1–43	1.07(n+1); 47 miles for n=43
44	44.1
45	40.8
46	37.4

or less cable distance to the splice is desirable.

3. The distance from the power separation filter cabinet to the line feed converter has relatively little bearing on the objective of maximizing the distance to the first repeater station; therefore, minimizing this distance should have the lowest priority. However, this distance should be kept short since the high voltage leads must be run in conduit.

5.24 The T4M maintenance office environment must have the following properties:

1. Temperature between 40°F and 100°F. Short term variations, which are not more than 72 consecutive hours and not more than 15 days in one year, must be between 32°F and 120°F.

2. Relative humidity between 20 percent and 50 percent. Short term variations (see above) must be between 20 percent and 80 percent.

3. Availability of -48 volt or +140 volt dc battery for the span terminating frame. Availability of +140 volt dc battery for line feed converters for single-ended and double-ended powered lines. In general, the use of existing +130 volt battery as a substitute for +140 volt battery is acceptable as long as the lower emergency voltage limit for the +130 volt battery plant ***is greater than +120 volts at the T4M equipment power input terminals.*** The requirements for battery voltage variations at the T4M equipment power input terminals are shown in Table C.

Span Terminating Frame

5.25 The span terminating frame consists of one bay (J98721A) if six or less (including protection) 2-way lines are used. If more than six 2-way lines are used, a 2-bay frame (J98721B) is required.

5.26 The span terminating frame must be within 165 cable feet of the DSX-4 cross-connect. For maintenance offices where demultiplexing is not required and where tandem T4M maintenance spans come together, it is possible to connect STFs together without a DSX-4, if desired, to allow a maximum distance between STFs of 400 cable feet. The 728A interconnecting cable is used in either case. The 728A solid dielectric cable may be run in troughs with bend radii not less than 7 inches. The span terminating frame may be powered from -48 volt or +140 volt office battery. A minimum system requires about 320 watts of battery power for one working and one protection line. Up to nine additional lines require approximately 85 watts per line.

TABLE C

OFFICE BATTERY VOLTAGE VARIATIONS
AT EQUIPMENT INPUT TERMINALS

NOMINAL BATTERY (VOLTS)	NORMAL VOLTAGE RANGE (VOLTS)	EMERGENCY LIMITS (VOLTS)
−48	46—50	42.75—53
+130	125—135	120—140
+140	147—152	120—154

Power Separation Filter Cabinet

5.27 The J68919E Power Separation Filter Cabinet (PSFC) contains a maximum of 22 J68919AF Power Separation Filters, two for each 2-way T4M line. Equivalently, 11 J68919AW Power Separation Filters may be used in conjunction with the J68919L or J68919E Power Separation Filter Cabinets. The maximum cable distance between the PSFC and the office splice is normally 45 feet if 66-type cable stubs are used exclusively. This distance can be extended by splicing in sections of 2- or 4-unit line cable or by special order of extended length 66-type cable stubs. Bend radii for 66-type stubs mounted on top of the PSFC are limited to 18 inches. There is a distance limitation between the span terminating frame and the power separation filter cabinet of 500 feet when 728A cable is used. After the power separation filter cabinet location is determined, it is strongly recommended that the span terminating frame be kept close to the power separation filter cabinet to avoid reducing the distance to the first outside repeater station excessively.

Line Feed Converters

5.28 The line feed converters for single-ended powering are powered from +140 volt office battery (or +130 volt). See Table C. The battery current drain, I_{in}, for the J87412A Line Feed Converter is given by this formula:

$$I_{in} = V_{out}/0.6\ V_{in} + 1.25 \text{ amperes.}$$

V_{in} is the battery voltage at the line feed converter terminals, and V_{out} is the line-to-ground voltage delivered to the T4M line at a constant current of 835 mA. The LFC output voltage, V_{out} (from line to ground), is given by the relation:

$$V_{out} = 5.0d + 16.8n \text{ volts.}$$

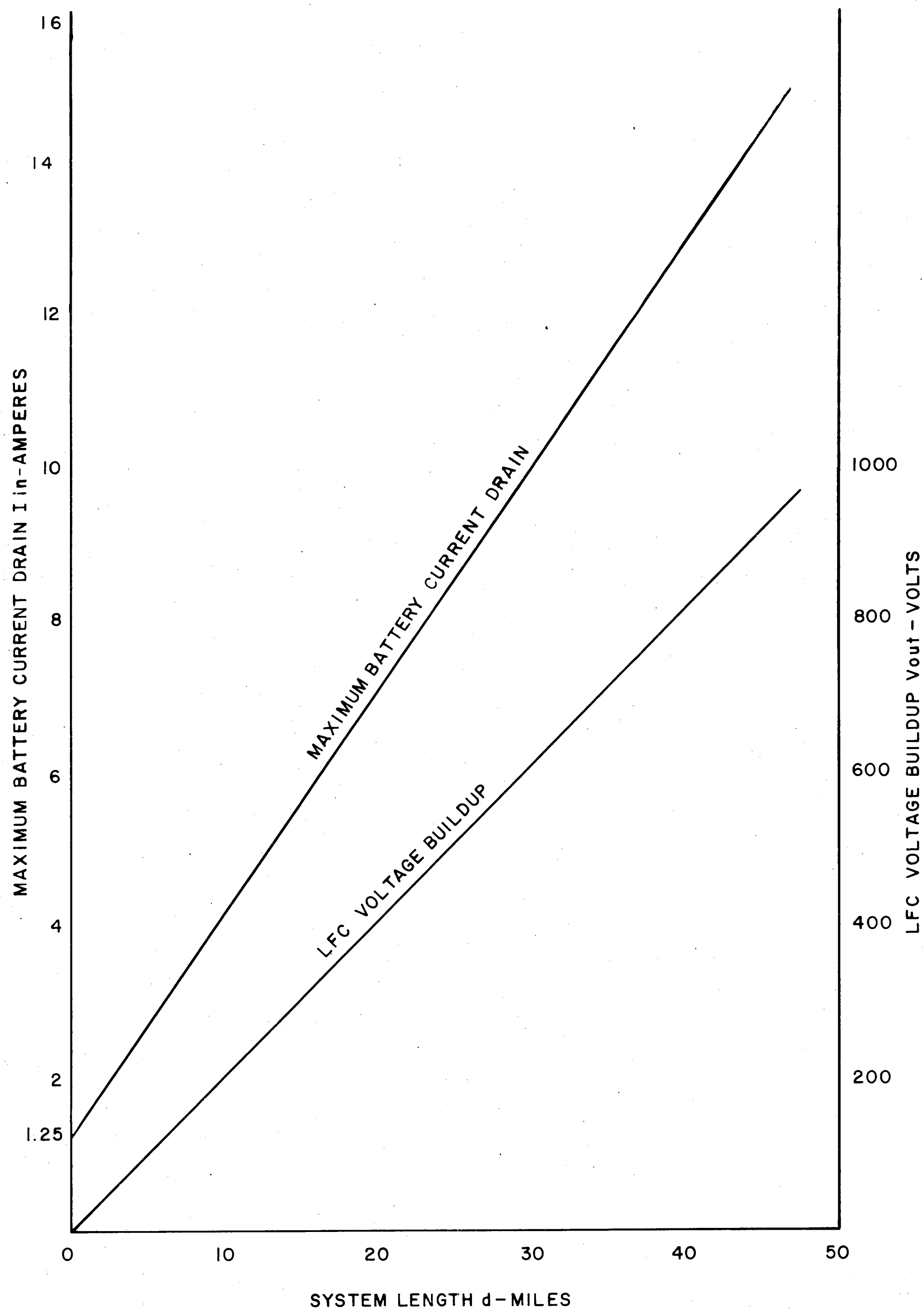
Figure 6 shows the approximate current drain and voltage buildup for a single converter for various length lines assuming a 1.07-mile regenerator spacing and a +140 volt office battery furnishing 120 volts (see Table C).

Office Splice

5.29 The office splice is the junction between outside plant cable and the 66-type terminal stubs which connect to the power separation filter cabinet and where the maintenance wire pairs are separated. The rules associated with the splice are detailed in 5.07. The vault splice case is wall racked in the cable vault. Connection to the line cable for all wire pairs is through the 32A1 protector cabinet which is wall mounted. A description of this cabinet is contained in Section 636-250-101. The unit may be equipped with protectors for up to 156 wire pairs. The CA-1969D cable is used to connect the office splice to the 32A1 protector cabinet. ABAM cable is used to connect the office equipment to the 32A1 protector cabinet. Interconnection arrangements at the 32A1 protector cabinet are given in SD-99610-01.

H. Regenerator Code Selection

5.30 The following two types of regenerators are used in T4M lines: the 3-type regenerator for outside plant use for installation in the regenerator apparatus case (471M1) and the 4-type regenerator for office use in the span terminating frame. The 3-type regenerator is available in four codes: 3A, 3B, 3C, and 3D. A particular code is chosen to



Iin = Vout/0.6Vin + 1.25 Amperes
Where Vin = 120 Volts

Vout = 5.0d + 16.8n Volts
Where n = Number Of Line Regenerators For 1.07 Mile Spacing

Fig. 6—J87412A LFC Approximate Input Currents and Output Voltages as a Function of Power Span Length

match the regenerator section cable length. The 4-type regenerator is available in five codes: 4A, 4B, 4C, 4D, and 4E. The 4A, 4B, 4C, and 4D regenerators are the receiving office regenerators (receiving direction is defined as outside plant toward office). A particular code is chosen to match the electrical length of the regenerator section adjacent to the office. The 4E regenerator is the transmitting office regenerator.

5.31 Table D indicates the code selection for regenerators terminating a regenerator section as a function of the associated regenerator section cable length L_{RS} as defined in 5.12. Note again that the 4E transmitting regenerator is used in the span terminating frame for signals transmitted from the span terminating frame in the direction toward the outside plant. Note also that Table D allows for the ±1 percent uncertainty in L_{RS}. This uncertainty can be increased for lengths away from the code breakpoints as long as the actual value of L_{RS} can be guaranteed not to be more than one percent outside of the range covered by a given regenerator code.

Regenerator Sections Not Adjacent to Maintenance Offices

5.32 For regenerator sections not adjacent to a maintenance office and where the manholes at both ends conform to the layouts given in Section 640-540-230, add 65 feet to the manhole center-to-manhole center route map distance. The resulting sheath distance is used in Table D to determine the correct regenerator code.

5.33 For regenerator sections not adjacent to a maintenance office and for which the manholes at one or both ends are in nonstandard configurations, determine the maximum apparatus case-to-apparatus case distance, including racking in both manholes. The resulting sheath distance is used to determine the correct regenerator code from Table D.

Regenerator Sections Adjacent to Maintenance Offices

5.34 For regenerator sections adjacent to a maintenance office where the adjacent outside plant repeater station conforms to the layouts given in Section 640-540-230, determine L_{RS} from the following formula:

$$L_{RS} = EOD + L^*_C + 40 \text{ feet.}$$

EOD is the equivalent office distance defined in 5.14, and L^*_C is the physical cable sheath distance measured from the office splice to the manhole center. The resulting value of L_{RS} is used in Table D to determine the correct regenerator code for

TABLE D

LINE AND OFFICE REGENERATOR CODE SELECTION
(L_{RS}, REGENERATOR SECTION CABLE LENGTH IN FEET)

CABLE TYPE	NUMBER OF TUBES IN LINE CABLE	REGENERATOR APPARATUS CODE	REGENERATOR APPARATUS CODE	REGENERATOR APPARATUS CODE	REGENERATOR APPARATUS CODE
		3A (LINE) 4A (OFFICE)	3B (LINE) 4B (OFFICE)	3C (LINE) 4C (OFFICE)	3D (LINE) 4D (OFFICE)
CA-1983	4	0 to 1868	1868 to 3470	3470 to 4785	4785 to 5780
CA-3209	6	0 to 1861	1861 to 3456	3456 to 4766	4766 to 5757
CA-3020, 9002	8	0 to 1849	1849 to 3433	3433 to 4735	4735 to 5719
CA-3226	12	0 to 1834	1834 to 3406	3406 to 4697	4697 to 5672
CA-3242	18	0 to 1860	1860 to 3455	3455 to 4764	4764 to 5755
CA-3225	22	0 to 1848	1848 to 3433	3433 to 4734	4734 to 5718

Note: The transmitting office regenerator in the STF is always a 4E code.

3-type regenerators in the manholes and for 4-type regenerators in the STF.

5.35 Where the adjacent outside plant repeater station is in a nonstandard configuration, determine L_{RS} from this formula:

$$L_{RS} = EOD + L_C \text{ feet.}$$

L_C is the physical cable sheath distance measured to the furthermost apparatus case, including racking in the manhole. Use the resulting value of L_{RS} to determine the correct regenerator code from Table D for 3-type regenerators in the manholes and 4-type receiving regenerators in the span terminating frame.

I. Maintenance Wire Pairs

5.36 As part of the T4M digital line, up to 14 wire pairs are reserved for maintenance purposes. The specific wire-pair usage is given in Table E. Pair interconnection within the repeater stations can be found in Section 640-540-230, at the office splice in Section 640-010-015, and at the 32A1 protector cabinet in SD-99610-01. The rules given in the following paragraphs require that all wire pairs, except those for pressure monitoring, be 19 AWG pairs having nominal 0.083 μf/mile capacitance. For route lengths containing no more than 30 repeater stations in total (including the repeater stations in the maintenance offices), only two pairs will be required for fault locating, so that the maximum number of wire pairs used for maintenance purposes in this case is 11. Standard equipment arrangements, however, provide for all 14 pairs. Much of the following material applies also when 22 AWG, 0.083 μf/mile wire pairs are employed for maintenance purposes. Paragraphs 5.57 through 5.65 indicate where 22 AWG rules differ from the rules for 19 AWG pairs.

5.37 Figure 7 shows a simplified diagram of the end-to-end path traversed by the wire pairs. All maintenance wire pairs, except those required for pressure monitoring, are conditioned in the J98721A or J98721B STFs and the 472H1 maintenance apparatus case. The two wire pairs reserved for cable pressure monitoring are simply spliced continuously throughout the length of the cable and require no conditioning. Local options such as transferring responsibility for cable pressure at arbitrary boundaries along the route must be implemented as required. ABAM cable connects the STF to the 32A1 protector cabinet. The wire pairs in ABAM cable are 22 AWG and thus cause a slight, but tolerable error in buildout.

TABLE E

T4M WIRE PAIRS REQUIREMENTS

FUNCTION	NUMBER OF PAIRS
Fault Locating	2 + 1 additional for each additional fault locating subspan up to a maximum of five pairs total.
Order Wire	Up to five to allow for two 4-wire and one 2-wire order wire as desired.
Pressure Monitoring	Up to two.
Alarm Remoting	Up to two.

5.38 The 32A1 protector cabinet is the wire pairs interface between outside plant and the office. It has sufficient capacity to terminate the wire pairs from a maximum of three coax cables. On the outside plant side of the cabinet, a CA-1969D, 19 AWG, 0.083 μf/mile cable connects the cabinet to the office splice. The cable must be equipped with a lead sheath and a gas pressure dam. In the repeater stations, the cable wire pairs are spliced through and conditioned in the 472H1 maintenance apparatus case. The case also contains a protector block; pressure contactor or transducer, as selected by local option; and fault locating electronics. Connection from the 472H1 case to the 471M1 regenerator apparatus case is made through the "C" splice to pick up fault locating signals. The "C" splice also provides an optional order-wire connection usually brought up to the manhole collar. An appearance for a 2-wire order-wire circuit is provided on the 472H1 case.

5.39 In Fig. 7, we note that the convention adopted for transmission direction is consistent with the L-carrier systems. That is, the "B" splice in a repeater station faces toward the S/W maintenance office and the "A" splice faces toward the N/E maintenance office. In addition, traffic on odd-numbered tubes in the cable is regenerated in the N/E direction from the "B" to the "A" splice in the repeater station. Conversely, traffic on the even-numbered tubes is regenerated in the S/W

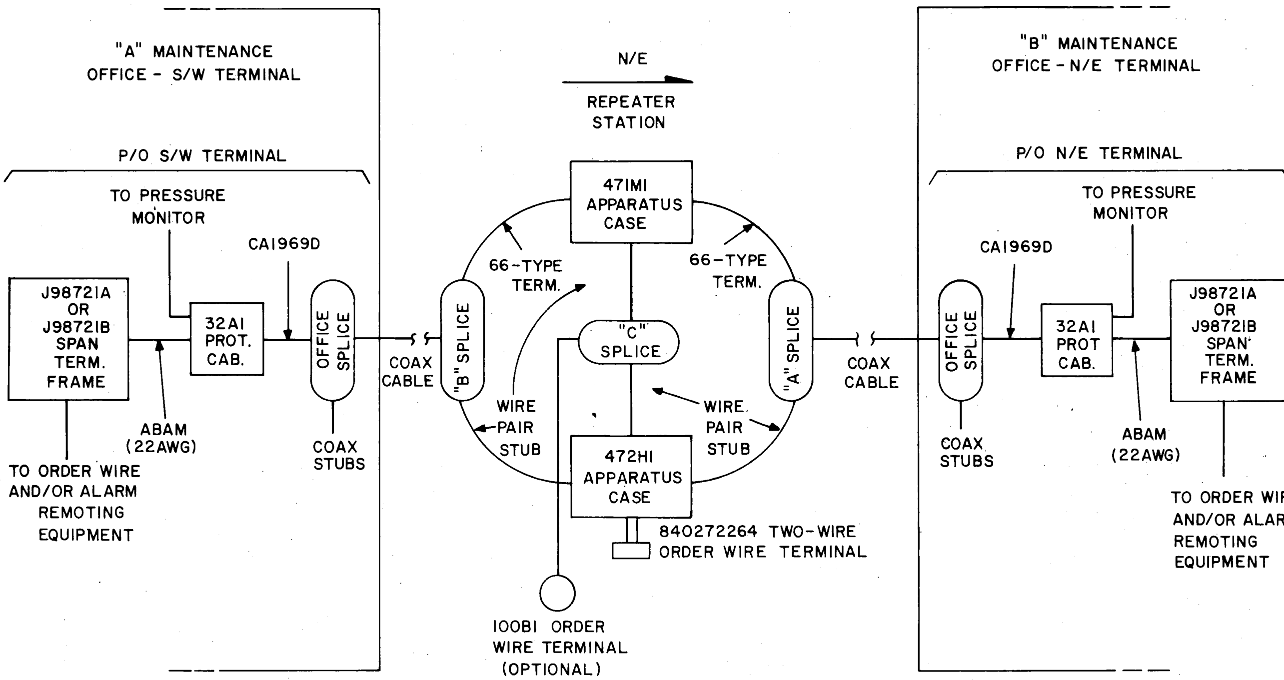


Fig. 7—End-to-End T4M Maintenance Wire Pairs Path—Simplified Diagram

direction from the "A" to "B" splice. Specific rules and options for the T4M maintenance pairs are described in the following paragraphs.

Line Buildout and Loading of Wire Pairs

5.40 The T4M line uses H88 loading on the fault locating and order-wire pairs and H44 loading on the alarm remoting pairs. The load coils are factory installed in every 472H1 apparatus case. At the maintenance office, a plug-in card equipped with the required load coils must be placed in the maintenance shelf of the span terminating frame. H88 loading requires 6000 feet spacing between load coils. Since 472H1 apparatus cases are located in repeater stations, regenerator spacing sets the physical separation of load coils in the range of 0 to 5700 feet, except possibly for sections adjacent to maintenance offices where the wire pairs path in the office is different than the coaxial path and may exceed 5700 feet total for the regenerator section. For proper audio frequency transmission on the fault locating, order-wire, and alarm remoting wire pairs, it is necessary that build-out networks be placed in 472H1 apparatus cases located in repeater stations along the route and in the STF to increase the electrical length of the pairs to 6000 feet. To build out the wire pairs between the repeater stations, two networks selected from 16 coded networks are equivalently connected in cascade in the regenerator section. These networks approximate 19 AWG, 0.083 μf/mile wire pairs in multiples of 200 feet. Used in pairs with approximately half of the buildout at each end of the regenerator section, any cable length can be built out to 6000 ±100 feet.

5.41 The arrangement of build-out cards is depicted in Fig. 8. Recall that traffic in the odd-numbered tubes flows from the S/W office to the N/E office, corresponding to flow from the "B" to the "A" splice in the manhole. Taking the signal flow on odd-numbered tubes as the defining direction, a repeater station numbering scheme can be established with number 0 assigned to the S/W office. Repeater stations are numbered consecutively in the N/E direction within a maintenance span. Such spans begin and end at STFs in maintenance offices. Table F lists the build-out network codes, their build-out length, and wire pairs and sheath lengths for various cable designs, within which the paired networks should be used. The distance ℓ_w is defined as the length of the wire pairs path. For sections not adjacent to maintenance offices, the wire pairs path extends between adjacent 472H1 cases. For sections adjacent to maintenance offices, the wire pairs path extends between the STF terminal strip and the 472H1 case. The distance ℓ_w is required to be accurate to within ±2 percent.

Regenerator Sections Not Adjacent to Maintenance Offices—Standard Manhole Layout

5.42 For regenerator sections not adjacent to maintenance offices and where the outside plant repeater stations conform to the layouts in Section 640-540-230, it is sufficient to use $\ell_w = L_{RS}$. (L_{RS} is the regenerator section cable length used in 5.32 for regenerator code selection.) This length is entered in Table F for the given outside plant cable type to select the appropriate build-out card codes. For example, to build out pairs between repeater stations 9 and 10, which contain standard manhole layouts and where L_{RS} equals 5362 feet of coax-22, a KG4 plug-in is installed in the BOC 1 slot of the 472H1 apparatus case in repeater station 9; and KG5 is installed in the BOC 2 slot in the 472H1 apparatus case in repeater station 10. An example of build-out card assignment is given in Part 6 of this section.

Regenerator Sections Adjacent to Maintenance Offices—Standard Manhole Layout

5.43 For regenerator sections adjacent to maintenance offices, where the adjacent outside plant

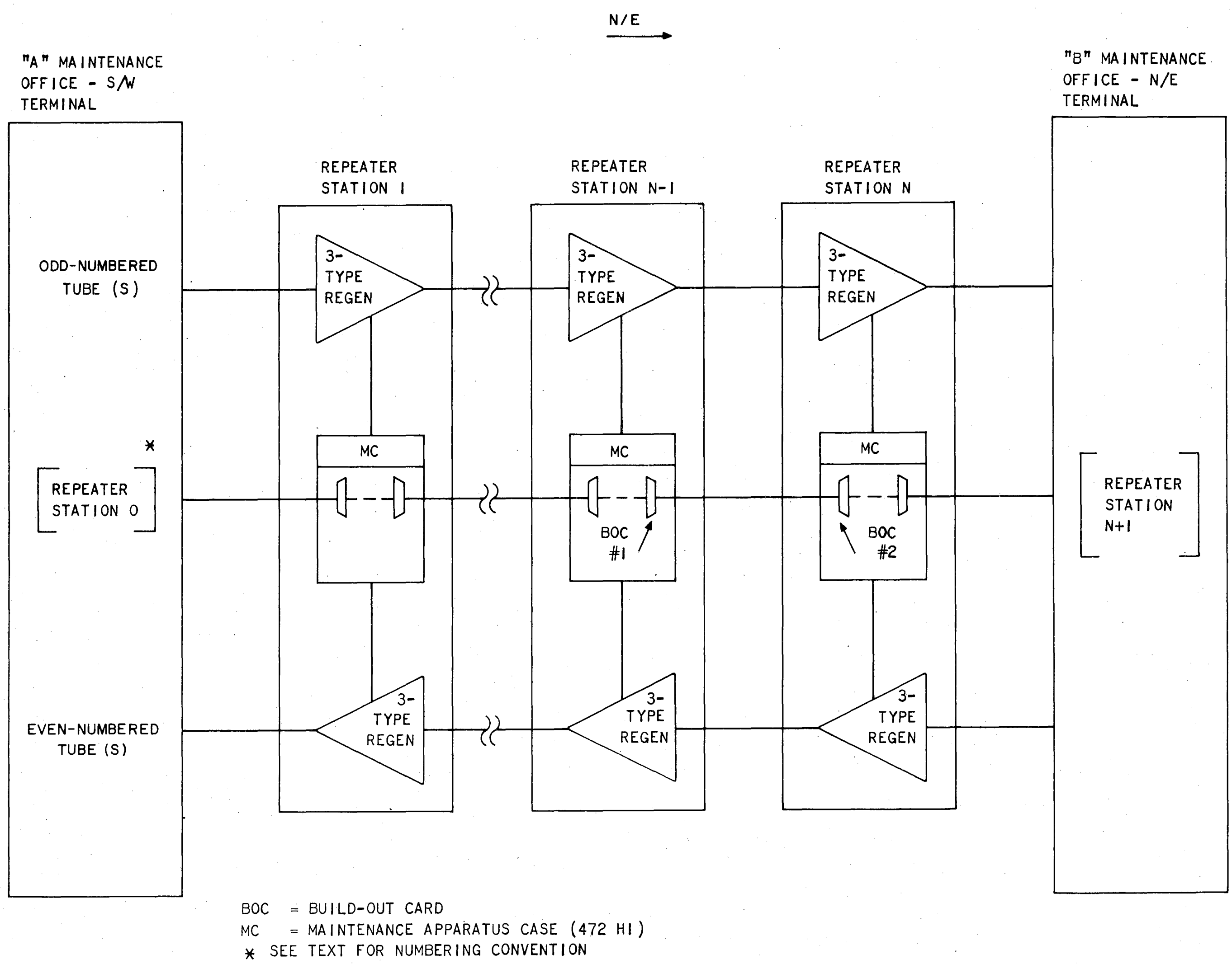


Fig. 8—Number Assignments for Buildouts

repeater station conforms to the layouts in Section 640-540-230, it is sufficient to use:

$$\ell_w = \ell_1 + \ell_2 + L^*_C + 40 \text{ feet.}$$

Refer to Fig. 9. ℓ_1 is the length of ABAM cable between the J98721A or J98721B STF and the 32A1 protector cabinet; ℓ_2 is the length of CA-1969D cable between the 32A1 protector cabinet and office splice; and L^*_C is the distance between the office splice and the adjacent manhole center. Table F is then entered in the column corresponding to the given cable type used in the outside plant for the calculated value of ℓ_w.

Nonstandard Manhole Layouts

5.44 For nonstandard manhole layouts, determine ℓ_w by calculating the wire-pair distance to the 472H1 apparatus case with cable racking accounted for. Specifically, for sections not adjacent to maintenance offices, ℓ_w is the distance between 472H1 apparatus cases in adjacent repeater stations. For sections adjacent to maintenance offices, use:

$\ell_w = \ell_1 + \ell_2 +$ office splice to 472H1 apparatus case distance,

where the various lengths are as shown in Fig. 9.

Fault Locating System

5.45 The fault locating system extends from span terminating frame to span terminating frame but not beyond. It is divided into subspans, each containing up to 30 repeater stations, including those contained in the maintenance offices. The system uses the audio tone technique to locate a faulty regenerator span with a fault locating wire pair dedicated to each direction of T4M signal transmission. All regenerators in a particular repeater station use the same audio frequency for one direction of transmission. The returned audio output for all of these regenerators is combined through an active bandpass filter (address identifier) and amplified before bridging onto the fault locating line. A maximum of 30 filters is assigned to the repeater stations in a subspan. The filters are assigned in alphabetical order from the transmitting end. This means a specific repeater station may have two different frequencies associated with it, one for each direction of transmission.

5.46 Every repeater station in the outside plant contains two maintenance units. Each maintenance unit is equipped with a 1094-type fault locating filter. Maintenance unit 1 serves the odd-numbered regenerators (signal transmission direction toward N/E maintenance office) while maintenance unit 2 serves the even-numbered regenerators (signal transmission direction toward S/W maintenance office).

5.47 There are also two maintenance units in each span terminating frame. In this case maintenance unit 1 is always associated with transmitting regenerators and is equipped with a 1094A filter. Maintenance unit 2 is always associated with receiving regenerators and is equipped with a filter code which depends on span length.

5.48 Table G lists the 1094-type filter assignment for a maximum length system of 30 repeater stations. For spans shorter than 30 repeater stations, the filter codes are dropped in sequence beginning with 1094AK. The filter codes are assigned consecutively starting with the STF. An example of filter assignment for a system with 26 repeater stations is discussed in Part 6 of this section.

5.49 Maintenance circuits in repeater stations in both the span terminating frame and in the outside plant are powered from a fault locating power converter located in the span terminating frame. To complete the powering circuit, a loop-back option must be exercised in a maintenance apparatus case near midspan. Hence, two power loops are formed, each including the outside plant repeater stations and the repeater station in the maintenance office. The repeater station in which the loop-back option is exercised is included in the power loop originating in the S/W maintenance office. The number of repeater stations (including those contained in the maintenance office) in any power loop must be greater than or equal to two but less than 16. Special arrangements are required for power loops containing fewer than two repeater stations. Details of the wiring option are given in Section 640-540-230. The repeater station in which the option is exercised should be noted in the "Remarks" column of the worksheet as discussed in Part 6 of this section.

Order Wire

5.50 Several order-wire alternatives are available for T4M use. The General Purpose Order

TABLE F

T4M BUILD-OUT NETWORKS FOR 19 AWG, 0.083 μF/MILE WIRE PAIRS

BUILD-OUT NETWORKS		BUILD-OUT LENGTH*	WIRE-PAIR LENGTH*†		CA-3020, CA-9002 8-TUBE COMPOSITE SPAN SHEATH LENGTHS*†		CA-3226 COAX-12 SPAN SHEATH LENGTHS*†		CA-3242 COAX-18 SPAN SHEATH LENGTHS*†		CA-3225 COAX-22 SPAN SHEATH LENGTHS*†	
BUILD-OUT CARD #1 RPTR STA N	BUILD-OUT CARD #2 RPTR STA N+1		MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
KG 3	KG 3	0	5900	6100	5900	6100	5760	5960	5845	6045	5810	6010
KG 3	KG 4	200	5700	5900	5700	5900	5560	5760	5650	5845	5615	5810
KG 4	KG 4	400	5500	5700	5500	5700	5370	5560	5450	5650	5420	5615
KG 4	KG 5	600	5300	5500	5300	5500	5175	5370	5250	5450	5220	5420
KG 5	KG 5	800	5100	5300	5100	5300	4980	5175	5055	5250	5025	5220
KG 5	KG 6	1000	4900	5100	4900	5100	4785	4980	4855	5055	4825	5025
KG 6	KG 6	1200	4700	4900	4700	4900	4590	4785	4660	4855	4630	4825
KG 6	KG 7	1400	4500	4700	4500	4700	4395	4590	4460	4660	4435	4630
KG 7	KG 7	1600	4300	4500	4300	4500	4200	4395	4260	4460	4235	4435
KG 7	KG 8	1800	4100	4300	4100	4300	4005	4200	4065	4260	4040	4235
KG 8	KG 8	2000	3900	4100	3900	4100	3810	4005	3865	4065	3840	4040
KG 8	KG 9	2200	3700	3900	3700	3900	3615	3810	3665	3865	3645	3840
KG 9	KG 9	2400	3500	3700	3500	3700	3420	3615	3470	3665	3450	3645
KG 9	KG 10	2600	3300	3500	3300	3500	3225	3420	3270	3470	3250	3450
KG 10	KG 10	2800	3100	3300	3100	3300	3030	3225	3070	3270	3055	3250
KG 10	KG 11	3000	2900	3100	2900	3100	2830	3030	2875	3070	2855	3055
KG 11	KG 11	3200	2700	2900	2700	2900	2635	2830	2675	2875	2660	2855
KG 11	KG 12	3400	2500	2700	2500	2700	2440	2635	2475	2675	2465	2660
KG 12	KG 12	3600	2300	2500	2300	2500	2245	2440	2280	2475	2265	2465
KG 12	KG 13	3800	2100	2300	2100	2300	2050	2245	2080	2280	2070	2265
KG 13	KG 13	4000	1900	2100	1900	2100	1855	2050	1885	2080	1870	2070
KG 13	KG 14	4200	1700	1900	1700	1900	1660	1855	1685	1885	1675	1870
KG 14	KG 14	4400	1500	1700	1500	1700	1465	1660	1485	1685	1480	1675
KG 14	KG 15	4600	1300	1500	1300	1500	1270	1465	1290	1485	1280	1480
KG 15	KG 15	4800	1100	1300	1100	1300	1075	1270	1090	1290	1085	1280
KG 15	KG 16	5000	900	1100	900	1100	880	1075	890	1090	885	1085
KG 16	KG 16	5200	700	900	700	900	685	880	695	890	690	885
KG 16	KG 17	5400	500	700	500	700	490	685	495	695	495	690
KG 17	KG 17	5600	300	500	300	500	295	490	295	495	295	495
KG 17	KG 18	5800	100	300	100	300	100	295	100	295	100	295
KG 18	KG 18	6000	0	100	0	100	0	100	0	100	0	100

* Measured in feet.

† Length corresponds to ℓ_w (see 5.41).

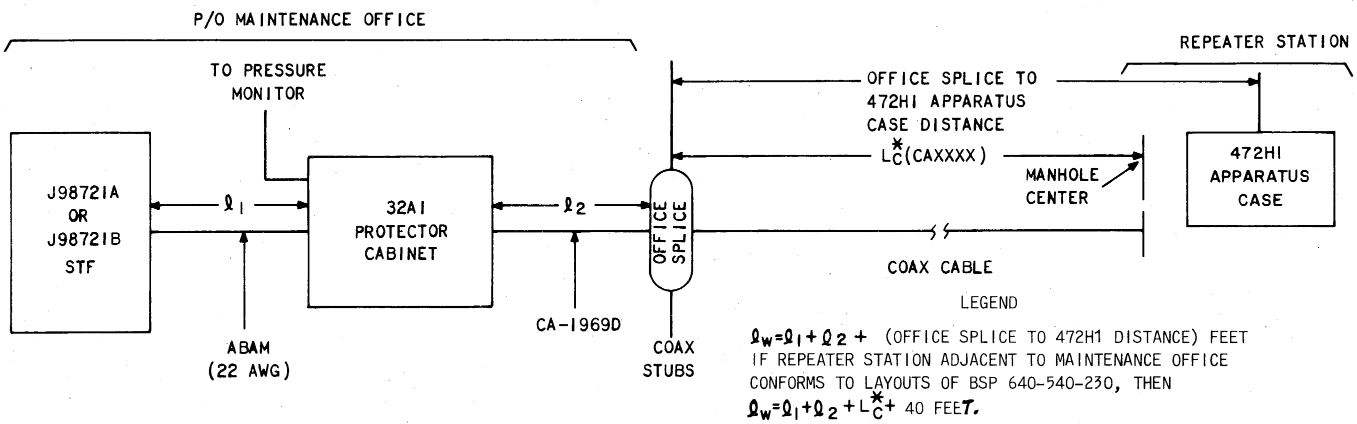


Fig. 9—Wire Pairs From STF to Adjacent Repeater Station

TABLE G

FAULT LOCATING FILTER SEQUENCE FOR 19 AWG, 0.083 μF/MILE WIRE PAIRS

FAULT LOCATE FILTER CODE	FREQUENCY (HZ)	FAULT LOCATE FILTER CODE	FREQUENCY (HZ)
1094A	2982.8	1094S	1829.6
1094B	2913.8	1094T	1767.6
1094C	2847.8	1094U	1651.9
1094D	2784.8	1094W	1531.3
1094E	2724.5	1094Y	1470.5
1094F	2666.8	1094AA	1411.1
1094G	2548.1	1094AB	1350.6
1094H	2487.6	1094AC	1229.2
1094J	2313.9	1094AD	1169.8
1094K	2247.8	1094AE	1050.7
1094L	2192.9	1094AF	929.6
1094M	2133.5	1094AG	870.5
1094N	2063.5	1094AH	810.0
1094P	1948.5	1094AJ	750.1
1094R	1890.0	1094AK	630.0

Wire or SS3 Order Wire may be used with two of the available wire pairs to provide maintenance office-to-maintenance office communication. Wire-pair buildout and loading are in the 472H1 apparatus case. However, no access to this order wire is provided at repeater stations. Another alternative uses the General Purpose Order Wire or SS3 Order Wire and two additional wire pairs in the cable sheath to provide maintenance office-to-maintenance office, maintenance office-to-repeater station, and repeater station-to-repeater station communication. Access to the order wire in the repeater stations is provided via a 100B1-4 cable terminal which may be mounted on the manhole collar. The 100C communications set is used at the manhole collar. The third alternative uses the T1-type 2-wire, order-wire equipment and uses the final pair of the five pairs that are reserved for order-wire use. In this option, repeater station access is gained by using an order-wire terminal mounted on the 472H1 apparatus case. An order-wire appearance is also available at the J87412A LFC. Any combination of the alternatives can be used. Interconnection information for each of the order-wire alternatives is provided in SD-99610-01.

5.51 The General Purpose Order Wire is described in Section 201-646-101, and the SS3 Order Wire is described in Section 982-328-100. The General Purpose Order Wire and SS3 Order Wire require transmission levels -16 dB transmitting and +7 dB receiving. To achieve these levels, 44V4 repeaters are required at maintenance offices and possibly at auxiliary stations. The engineering of voice-frequency facilities with 44V4 repeaters is covered in Section 852-307-100.

5.52 The T1 order-wire equipment is described in Section 365-320-100. The option using the T1 order-wire equipment has the limitation that talk battery may be supplied from an office for a maximum of 12 miles on 19-gauge facilities. The addition of a dc blocking capacitor (437QA) may be used to break dc continuity at midspan. The blocking capacitor may be mounted in the 472H1 apparatus case. By using a blocking capacitor, the length of the 2-wire order-wire spans is limited to 24 miles. The location of blocking capacitors should be noted in the "Remarks" column of the worksheet as discussed in Part 6 of this section. In general, the blocking capacitor will be located in the same 472H1 case in which the power loop-back option for the fault locating line is exercised, but such correspondence is not a requirement. The SS3 Order Wire, the General Purpose Order Wire, and the T1 order-wire equipment are miscellaneously mounted in maintenance offices with jack access provided at the span terminating frame.

5.53 In addition to the above order wires which are associated specifically with the T4M line facility, a digital network order wire (DNOW) may be established as an express circuit between maintenance offices. In addition to appearances on the T4M span terminating frames, appearances are provided on the associated multiplex and cross-connect equipment. Normally, the DNOW is established on loaded wire pairs separate from the T4M cable although the 4-wire loaded pairs within the T4M cable may be used. Further information on the DNOW is provided in SD-1G288-01.

Cable Pressurization and Monitoring

5.54 Although cable pressurization equipment is not provided as part of the T4M line, it is necessary to monitor the pressure of the T4M cable to detect sheath breaks. Two wire pairs within the cable have been reserved for transmitting monitoring information back to the offices. Provision is made for mounting up to two N pressure contactors (AT8679) or up to two D pressure transducers (AT8405) in the 472H1 apparatus case. The D pressure transducer arrangement uses two wire pairs, one for telemetry and one for control, while the N pressure contactor requires only one of the two pairs reserved for pressure monitoring. The type of equipment used in the maintenance offices to monitor the pressure must be chosen so that excessive noise is not caused on the maintenance pairs. The 32A1 protector cabinet in each maintenance office provides access to the pairs.

J. Alarm System

5.55 Alarm provisions include major and minor bay lamp indications with arrangements to provide major and minor indications to central office alarm systems. Optional arrangements are provided to remote alarm and status indications via E-type telemetry or a similar system. Remote operation of certain switching, lock-in, and lock-out features, provided with the protection switching circuit, may be provided for span terminating frames via an E-type telemetry system.

K. T4M Route Layout Worksheets, Forms E-6561A and E-6561B

5.56 A T4M Route Layout Worksheet (for cables having 19 AWG maintenance wire pairs), Form E-6561A (see Fig. 10), is provided for maintenance spans containing no more than 30 repeater stations and employing 19 AWG, 0.083 μf/mile wire pairs. A T4M Route Layout Worksheet (for cables having 22 AWG maintenance wire pairs), Form E-6561B (see Fig. 11), is provided for maintenance spans containing no more than 24 repeater stations and employing 22 AWG, 0.083 μf/mile wire pairs. These worksheets provide for repeater station location and numbering (including those at the maintenance offices); the cable type in the various regenerator sections; regenerator section cable length; wire-pair path length; regenerator, build-out, and maintenance unit fault locating filter codes; and fault locating power loop-back and dc blocking capacitor location. In addition, the worksheets contain a brief synopsis of the layout rules for the most common situations encountered in route design. The use of these worksheets will be illustrated in connection with the example given in Part 6 of this section.

L. Operation With 22 AWG, 0.083 μf/Mile Maintenance Wire Pairs

5.57 The rules given herein pertain to T4M lines which employ 22 AWG, 0.083 μf/mile maintenance wire pairs and require 24 repeater stations or less including those in the maintenance offices (24.6 miles maximum). For such routes, only two wire pairs are required for fault locating so that the maximum number of wire pairs used for maintenance purposes is 11. Standard equipment arrangements, however, provide for all 14 wire pairs, the utilization of which is the same as for the 19 AWG case as shown in Table E. Subsequent issues of this section will contain the rules for longer systems.

5.58 Although 22 AWG wire pairs are used in the outside plant cable, a CA-1969D, 19 AWG, 0.083 μf/mile cable connects the 32A1 protector cabinet to the office splice. This causes a slight, but tolerable error in buildout.

5.59 The previous paragraphs on 19 AWG, 0.083 μf/mile wire pairs use generally apply to 22 AWG, 0.083 μf/mile wire pairs. The differences are noted in the following paragraphs.

5.60 The procedure for choosing build-out cards is the same as in 5.40 through 5.44 except that Table H lists the build-out network codes for 22 AWG, 0.083 μf/mile wire pairs. Note that for the 707 pair CA-1983 design, the code choice depends on the pair layers in which the maintenance pairs are located. Hence, the maintenance pairs (except those for pressure monitoring) must, for a given regenerator section, all be contained within one of the groupings of pair layers indicated in Table H. If pair availability is restricted, the particular pair layer group in which all the maintenance pairs are contained need not be the same for all regenerator sections in a given route.

5.61 Fault locating subspans contain up to 24 repeater stations including those contained in the maintenance offices. A maximum of 24 filters is assigned to the repeater stations in a subspan.

5.62 The procedure for choosing 1094-type fault locating filters is the same as in 5.45 through 5.48 except that Table I lists the 1094-type filter assignments for a maximum length system of 24 repeater stations. Maintenance unit 1 in the span terminating frame is always associated with transmitting regenerators and is equipped with a 1094A filter. Maintenance unit 2 in the span terminating frame is always associated with receiving regenerators and is equipped with a filter code which depends on span lengths. The filters are assigned consecutively starting from the transmitting end STF (for each direction of transmission), so that the sequence is 1094A, 1094AL,....1094BN. For spans shorter than 24 repeater stations, the filter codes are dropped in sequence beginning with 1094BN.

5.63 The number of repeater stations (including the one contained in the maintenance office) in any power loop must be greater than or equal to two but less than 12. Special arrangements are required for power loops containing fewer than two repeater stations.

5.64 The order-wire options available for use with 22 AWG, 0.083 μf/mile wire pairs are the same as for the 19 AWG, 0.083 μf/mile wire pairs, except that the T1 order-wire equipment has the limitation that talk battery may be supplied for a maximum of 7 miles. A dc blocking capacitor (437QA) can be used to break continuity at midspan, thus increasing the length of the 2-wire order-wire spans to 14 miles.

5.65 Figure 11 (Form E-6561B) shows the T4M Route Layout Worksheet for maintenance spans containing no more than 24 repeater stations and employing 22 AWG, 0.083 μf/mile wire pairs. Enter the pair layer(s) in which the maintenance pairs are contained in the "Remarks" column of the worksheet.

E-6561A

T4M ROUTE LAYOUT WORKSHEET (FOR CABLES HAVING 19 AWG MAINTENANCE PAIRS)

REPEATER STATION DATA (NOTE 1)

REMARKS (NOTE 2)	RS	LOCATION	MU FILTER MU1	MU FILTER MU2	REGENERATOR N/E (ODD TUBES)	REGENERATOR S/W (EVEN TUBES)	BUILD-OUT CARD (NOTE 3) BOC 1	BUILD-OUT CARD (NOTE 3) BOC 2	RS
	0	MAINTENANCE OFFICE A(S/W)	1094A	1094 ___	4E	4 ___	KG ___		0
	1		1094B	1094 ___	3 ___	3 ___	KG ___	KG ___	1
	2		1094C	1094 ___	3 ___	3 ___	KG ___	KG ___	2
	3		1094D	1094 ___	3 ___	3 ___	KG ___	KG ___	3
	4		1094E	1094 ___	3 ___	3 ___	KG ___	KG ___	4
	5		1094F	1094 ___	3 ___	3 ___	KG ___	KG ___	5
	6		1094G	1094 ___	3 ___	3 ___	KG ___	KG ___	6
	7		1094H	1094 ___	3 ___	3 ___	KG ___	KG ___	7
	8		1094J	1094 ___	3 ___	3 ___	KG ___	KG ___	8
	9		1094K	1094 ___	3 ___	3 ___	KG ___	KG ___	9
	10		1094L	1094 ___	3 ___	3 ___	KG ___	KG ___	10
	11		1094M	1094 ___	3 ___	3 ___	KG ___	KG ___	11
	12		1094N	1094 ___	3 ___	3 ___	KG ___	KG ___	12
	13		1094P	1094 ___	3 ___	3 ___	KG ___	KG ___	13
	14		1094R	1094 ___	3 ___	3 ___	KG ___	KG ___	14
	15		1094S	1094 ___	3 ___	3 ___	KG ___	KG ___	15
	16		1094T	1094 ___	3 ___	3 ___	KG ___	KG ___	16
	17		1094U	1094 ___	3 ___	3 ___	KG ___	KG ___	17
	18		1094W	1094 ___	3 ___	3 ___	KG ___	KG ___	18
	19		1094Y	1094 ___	3 ___	3 ___	KG ___	KG ___	19
	20		1094AA	1094 ___	3 ___	3 ___	KG ___	KG ___	20
	21		1094AB	1094 ___	3 ___	3 ___	KG ___	KG ___	21
	22		1094AC	1094 ___	3 ___	3 ___	KG ___	KG ___	22
	23		1094AD	1094 ___	3 ___	3 ___	KG ___	KG ___	23
	24		1094AE	1094 ___	3 ___	3 ___	KG ___	KG ___	24
	25		1094AF	1094 ___	3 ___	3 ___	KG ___	KG ___	25
	26		1094AG	1094 ___	3 ___	3 ___	KG ___	KG ___	26
	27		1094AH	1094 ___	3 ___	3 ___	KG ___	KG ___	27
	28		1094AJ	1094 ___	3 ___	3 ___	KG ___	KG ___	28
	___	MAINTENANCE OFFICE B(N/E) (NOTE 5)	1094A	1094 ___	4 ___	4E		KG ___	___

CABLE SECTION DATA

L_{RS}/ℓ_w (NOTE 4)	CABLE TYPE	REMARKS
(NOTE 6)		ℓ_w = ___
(NOTE 6)		ℓ_w = ___

BELL SYSTEM PRACTICE 855-353-101

NOTES:

1. CHOOSE CODES FOR MU FILTER, REGENERATOR, AND BOC FROM TABLES IN PART 5.
2. ENTER LOCATION(S) OF F.L. POWER LOOPBACK AND OW DC BLOCKING CAPACITOR BELOW.
3. ENTER PAIR OF BOC CODES DETERMINED IN BOC TABLE, FOR GIVEN VALUE OF ℓ_w, IN PAIR OF BOXES CONNECTED BY ARROWS.
4. EXCEPT AS NOTED IN PART 5, L_{RS} = MH CENTER TO MH CENTER DISTANCE +65 FEET AND $\ell_w = L_{RS}$. IF ℓ_w IS NOT EQUAL TO L_{RS}, ENTER ℓ_w IN REMARKS COLUMN.
5. ENTER RS NUMBER FOR MO B NEXT IN SEQUENCE FOLLOWING FINAL OUTSIDE PLANT RS NUMBER.
6. CALCULATE L_{RS} AND ℓ_w FOR SECTIONS ADJACENT TO MO'S FROM FOLLOWING TABLE:

	L_A	L_B	EOD (a)	L_{RS} (b)	ℓ_1	ℓ_2	ℓ_w (c)
MO A							
MO B							

(a) EOD = 3.55 L_A + L_B + 140 FEET.
(b) EXCEPT AS NOTED IN PART 5, L_{RS} = EOD + OFFICE SPLICE TO MH CENTER DISTANCE + 40 FEET.
(c) EXCEPT AS NOTED IN PART 5, ℓ_w = OFFICE SPLICE TO MH CENTER DISTANCE + ℓ_1 + ℓ_2 + 40 FEET.

Fig. 10—T4M Route Layout Worksheet (for Cables Having 19 AWG Maintenance Wire Pairs), Form E-6561A

E-6561B

T4M ROUTE LAYOUT WORKSHEET (FOR CABLES HAVING 22 AWG MAINTENANCE PAIRS)

BELL SYSTEM PRACTICE 855-353-101

REPEATER STATION DATA (NOTE 1)

REMARKS (NOTE 2)	RS	LOCATION	MU FILTER MU1	MU FILTER MU2	REGENERATOR N/E (ODD TUBES)	REGENERATOR S/W (EVEN TUBES)	BUILD-OUT CARD (NOTE 3) BOC 1	BUILD-OUT CARD (NOTE 3) BOC 2	RS
	0	MAINTENANCE OFFICE A(S/W)	1094A	1094 ____	4E	4 ____	KG ____		0
	1		1094AL	1094 ____	3 ____	3 ____	KG ____	KG ____	1
	2		1094AM	1094 ____	3 ____	3 ____	KG ____	KG ____	2
	3		1094AN	1094 ____	3 ____	3 ____	KG ____	KG ____	3
	4		1094AP	1094 ____	3 ____	3 ____	KG ____	KG ____	4
	5		1094AR	1094 ____	3 ____	3 ____	KG ____	KG ____	5
	6		1094AS	1094 ____	3 ____	3 ____	KG ____	KG ____	6
	7		1094AT	1094 ____	3 ____	3 ____	KG ____	KG ____	7
	8		1094AU	1094 ____	3 ____	3 ____	KG ____	KG ____	8
	9		1094AW	1094 ____	3 ____	3 ____	KG ____	KG ____	9
	10		1094AY	1094 ____	3 ____	3 ____	KG ____	KG ____	10
	11		1094BA	1094 ____	3 ____	3 ____	KG ____	KG ____	11
	12		1094BB	1094 ____	3 ____	3 ____	KG ____	KG ____	12
	13		1094BC	1094 ____	3 ____	3 ____	KG ____	KG ____	13
	14		1094BD	1094 ____	3 ____	3 ____	KG ____	KG ____	14
	15		1094BE	1094 ____	3 ____	3 ____	KG ____	KG ____	15
	16		1094BF	1094 ____	3 ____	3 ____	KG ____	KG ____	16
	17		1094BG	1094 ____	3 ____	3 ____	KG ____	KG ____	17
	18		1094BH	1094 ____	3 ____	3 ____	KG ____	KG ____	18
	19		1094BJ	1094 ____	3 ____	3 ____	KG ____	KG ____	19
	20		1094BK	1094 ____	3 ____	3 ____	KG ____	KG ____	20
	21		1094BL	1094 ____	3 ____	3 ____	KG ____	KG ____	21
	22		1094BM	1094 ____	3 ____	3 ____	KG ____	KG ____	22
	____	MAINTENANCE OFFICE B(N/E) (NOTE 5)	1094A	1094 ____	4 ____	4E		KG ____	____

CABLE SECTION DATA

L_{RS} / ℓ_w (NOTE 4)	CABLE TYPE	REMARKS (NOTE 7)
(NOTE 6)		ℓ_w = ____
(NOTE 6)		ℓ_w = ____

NOTES:

1. CHOOSE CODES FOR MU FILTER, REGENERATOR, AND BOC FROM TABLES IN PART 5.
2. ENTER LOCATION(S) OF F.L. POWER LOOPBACK AND OW DC BLOCKING CAPACITOR BELOW.
3. ENTER PAIR OF BOC CODES DETERMINED IN BOC TABLE, FOR GIVEN VALUE OF ℓ_w, IN PAIR OF BOXES CONNECTED BY ARROWS.
4. EXCEPT AS NOTED IN PART 5, L_{RS} = MH CENTER TO MH CENTER DISTANCE +65 FEET AND $\ell_w = L_{RS}$. IF ℓ_w IS NOT EQUAL TO L_{RS}, ENTER ℓ_w IN REMARKS COLUMN.
5. ENTER RS NUMBER FOR MO B NEXT IN SEQUENCE FOLLOWING FINAL OUTSIDE PLANT RS NUMBER.
6. CALCULATE L_{RS} AND ℓ_w FOR SECTIONS ADJACENT TO MO'S FROM FOLLOWING TABLE:

	L_A	L_B	EOD (a)	L_{RS} (b)	ℓ_1	ℓ_2	ℓ_w (c)
MO A							
MO B							

(a) EOD = 3.55 L_A + L_B +140 FEET.

(b) EXCEPT AS NOTED IN PART 5, L_{RS} = EOD + OFFICE SPLICE TO MH CENTER DISTANCE + 40 FEET.

(c) EXCEPT AS NOTED IN PART 5, ℓ_w = OFFICE SPLICE TO MH CENTER DISTANCE + ℓ_1 + ℓ_2 + 40 FEET.

7. ENTER PAIR LAYER(S) FOR MAINTENANCE PAIRS IN REMARKS COLUMN.

Fig. 11—T4M Route Layout Worksheet (for Cables Having 22 AWG Maintenance Wire Pairs), Form E-6561B

TABLE H

T4M BUILD-OUT NETWORKS FOR 22 AWG, 0.083 μF/MILE WIRE PAIRS

BUILD-OUT NETWORKS		BUILD-OUT LENGTH*	WIRE-PAIR LENGTH*†		SPAN SHEATH LENGTH*†									
					CA-1983, 4-TUBE COMPOSITE WITH 707 PAIRS OF 22 GAUGE‡								CA-1983, 4-TUBE COMPOSITE WITH 202 PAIRS 22 GA	
BUILD-OUT CARD #1 RPTR STA N	BUILD-OUT CARD #2 RPTR STA N+1				2ND, 3RD, 4TH, AND 5TH LAYERS§		6TH AND 7TH LAYERS§		8TH AND 9TH LAYERS§		10TH AND 11TH LAYERS§			
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
KG 3	KG 3	0	5900	6100	5845	6045	5805	6005	5780	5975	5750	5945	5835	6035
KG 3	KG 25	200	5700	5900	5650	5845	5610	5805	5585	5780	5555	5750	5640	5835
KG 25	KG 25	400	5500	5700	5450	5650	5415	5610	5385	5585	5360	5555	5440	5640
KG 25	KG 26	600	5300	5500	5255	5450	5215	5415	5190	5385	5165	5360	5240	5440
KG 26	KG 26	800	5100	5300	5055	5255	5020	5215	4995	5190	4970	5165	5045	5240
KG 26	KG 27	1000	4900	5100	4855	5055	4825	5020	4800	4995	4775	4970	4845	5045
KG 27	KG 27	1200	4700	4900	4660	4855	4625	4825	4605	4800	4580	4775	4650	4845
KG 27	KG 28	1400	4500	4700	4460	4660	4430	4625	4405	4605	4385	4580	4450	4650
KG 28	KG 28	1600	4300	4500	4260	4460	4230	4430	4210	4405	4190	4385	4255	4450
KG 28	KG 29	1800	4100	4300	4065	4260	4035	4230	4015	4210	3995	4190	4055	4255
KG 29	KG 29	2000	3900	4100	3865	4065	3840	4035	3820	4015	3800	3995	3860	4055
KG 29	KG 30	2200	3700	3900	3665	3865	3640	3840	3625	3820	3605	3800	3660	3860
KG 30	KG 30	2400	3500	3700	3470	3665	3445	3640	3430	3625	3410	3605	3460	3660
KG 30	KG 31	2600	3300	3500	3270	3470	3250	3445	3230	3430	3215	3410	3265	3460
KG 31	KG 31	2800	3100	3300	3070	3270	3050	3250	3035	3230	3020	3215	3065	3265
KG 31	KG 32	3000	2900	3100	2875	3070	2855	3050	2840	3035	2825	3020	2870	3065
KG 32	KG 32	3200	2700	2900	2675	2875	2655	2855	2645	2840	2630	2825	2670	2870
KG 32	KG 33	3400	2500	2700	2480	2675	2460	2655	2450	2645	2435	2630	2475	2670
KG 33	KG 33	3600	2300	2500	2280	2480	2265	2460	2255	2450	2240	2435	2275	2475
KG 33	KG 34	3800	2100	2300	2080	2280	2065	2265	2055	2255	2045	2240	2075	2275
KG 34	KG 34	4000	1900	2100	1885	2080	1870	2065	1860	2055	1850	2045	1880	2075
KG 34	KG 35	4200	1700	1900	1685	1885	1675	1870	1665	1860	1655	1850	1680	1880
KG 35	KG 35	4400	1500	1700	1485	1685	1475	1675	1470	1665	1460	1655	1485	1680
KG 35	KG 36	4600	1300	1500	1290	1485	1280	1475	1275	1470	1265	1460	1285	1485
KG 36	KG 36	4800	1100	1300	1090	1290	1085	1280	1075	1275	1070	1265	1090	1285
KG 36	KG 37	5000	900	1100	890	1090	885	1085	880	1075	875	1070	890	1090
KG 37	KG 37	5200	700	900	695	890	690	885	685	880	680	875	690	890
KG 37	KG 38	5400	500	700	495	695	490	690	490	685	485	680	495	690
KG 38	KG 38	5600	300	500	295	495	295	490	295	490	290	485	295	495
KG 38	KG 39	5800	100	300	100	295	100	295	100	295	95	290	100	295
KG 39	KG 39	6000	0	100	0	100	0	100	0	100	0	95	0	100

* Measured in feet.

† Length corresponds to ℓ_w (see 5.41).

‡ All maintenance pairs (except those for pressure monitoring) must be located within the same pair layer group.

§ Cable layer from CA drawing (coaxial tubes are in first layer and wire pairs start with the second layer).

TABLE I

FAULT LOCATING FILTER SEQUENCE FOR 22 AWG, 0.083 μF/MILE WIRE PAIRS

22 AWG FAULT LOCATING FILTER CODES	FREQUENCY (Hz)
1094A	2982.8
1094AL	2913.8
1094AM	2847.8
1094AN	2784.8
1094AP	2724.5
1094AR	2666.8
1094AS	2548.1
1094AT	2487.6
1094AU	2313.9
1094AW	2247.8
1094AY	2192.9
1094BA	2133.5
1094BB	2063.5
1094BC	1948.5
1094BD	1890.0
1094BE	1829.6
1094BF	1767.6
1094BG	1651.9
1094BH	1531.3
1094BJ	1470.5
1094BK	1411.1
1094BL	1350.6
1094BM	1229.2
1094BN	1169.8

M. Joint L5/T4M Operation

5.66 L5 and T4M can share coaxial cables and repeater stations. Existing manholes on an L5 route can be shared for joint L5/T4M operation if repeater station spacing is consistent with T4M requirements. The two systems are treated as distinct entities at the repeater stations. If T4M repeater station requirements are not satisfied, auxiliary manholes must be established. Section 855-346-100 provides more information concerning joint usage. Manhole layout information for joint L5/T4M routes is contained in Section 640-400-190. The layouts of Section 640-400-190 are such that T4M spacing and regenerator selection rules which apply to Section 640-540-250 apply also to Section 640-400-190.

N. Joint T1/T4M Operation

5.67 T1 and T4M can share composite cables and repeater stations. Existing manholes on a T1 route can be shared for joint T1/T4M operation if repeater station spacing is consistent with T4M requirements. The two systems are treated as distinct entities at the repeater stations. If T4M repeater station requirements are not satisfied, or if space does not permit, auxiliary manholes must be established.

5.68 If T1 and T4M maintenance pairs are located in nonadjacent pair groups or layers, the T1 and T4M Fault Locating Systems may be operated simultaneously. If, however, T1 and T4M maintenance pairs must be located in the same or adjacent pair groups or layers, an analysis of crosstalk interference coupling between the T1 fault locating pairs and the T4M maintenance pairs will be required to determine whether the T1 line can be fault located at the same time a T4M line is being fault located. A T1 line can, however, always be fault located, in this case, when the T4M Fault Locating System is not in service.

6. EXAMPLE OF LAYOUT PROCEDURE

6.01 The following is an example of a T4M line laid out in accordance with the engineering guides in this section. The cable will be 22-tube CA-3225 placed in ducts and the length of the system will be 24 miles. These requirements suggest the following characteristics for the line:

1. The line can be powered from a single end with the J87412A LFC because the length is 24 miles, and it is expected that ≤43 repeater stations will be used.
2. Because it is expected that the number of repeater stations (including the end offices) will not exceed 30, auxiliary stations will not be required (CA-3225 contains 19 AWG, 0.083 μf/mile wire pairs).
3. A 4-inch duct must be used; a 3-1/2 inch duct will not accommodate 22-tube cable.

6.02 Assume that after consideration of possible splicing manhole and repeater station sites, the route shown in Fig. 12 is the most attractive and has been chosen. The span terminates in maintenance offices A and B and passes through the cable vault of a central office location at repeater station 10. It is planned to power the line single ended from office A. Transmission in the N/E direction is from office A to office B. Regenerator section distances would, if indicated in Fig. 12, be manhole center-to-manhole center determined from a route map drawn to ±1 percent accuracy. Regenerator section distances adjacent to RS10 would include vault cable runs and appropriate racking. Distances for regenerator sections adjacent to the maintenance offices correspond to the physical distances between the office splices and the adjacent manhole centers.

A. Coaxials-Calculation of L_{RS}

6.03 First, the regenerator section cable lengths, L_{RS}, are calculated. Assuming duct and manhole temperature ranges are acceptable, the proper placement of repeater stations is checked according to the requirements given in 5.13, 5.14, and 5.15.

Regenerator Sections Not Adjacent to Maintenance Offices

6.04 Except for the regenerator sections adjacent to RS10 and the regenerator section between RS24 and RS25, the regenerator section cable lengths are calculated by simply adding 65 feet (see 5.13) to all the manhole center-to-manhole center route map distances. For the nonstandard situations indicated, the detailed racking should be investigated to determine the correct values of L_{RS} (apparatus case-to-apparatus case distance). Filled in Form E-6561A, shown in Fig. 13, tabulates all the calculated values of L_{RS}.

Regenerator Sections Adjacent to Maintenance Offices

6.05 Distances in maintenance offices A and B are as follows:

		OFFICE A	OFFICE B
L_A	(Cable distance between STF and PSFC)	300 feet	330 feet
L_B	(Cable distance between PSFC and office splice)	93* feet	30 feet

*93 feet may be obtained with a 66-type terminal with a 45-foot stub spliced to a 48-foot section of a 4-tube cable.

The equivalent office distance, EOD, and L_{RS} are now calculated with the aid of Form E-6561A:

Office A:

$$EOD = 3.55\ L_A + L_B + 140 \text{ feet}$$

$$= 3.55 \times 300 + 93 + 140$$

$$= 1298 \text{ feet.}$$

Office B:

$$EOD = 3.55 \times 330 + 30 + 140$$

$$= 1342 \text{ feet.}$$

The repeater station adjacent to maintenance office A conforms to the layout given in Section 640-540-230 so that from 5.15:

$$L_{RS} = EOD + L^*_C + 40 \text{ feet}$$

$$= 1298 + 3143 + 40$$

$$= 4481 \text{ feet.}$$

For the repeater station adjacent to office B, Fig. 12 indicates that a nonstandard layout is used. It is determined that 50 feet must be added to the route map distance (office splice to manhole center) shown to obtain the office splice to furthest 471M1 apparatus case distance. Hence, the regenerator section cable length is given by:

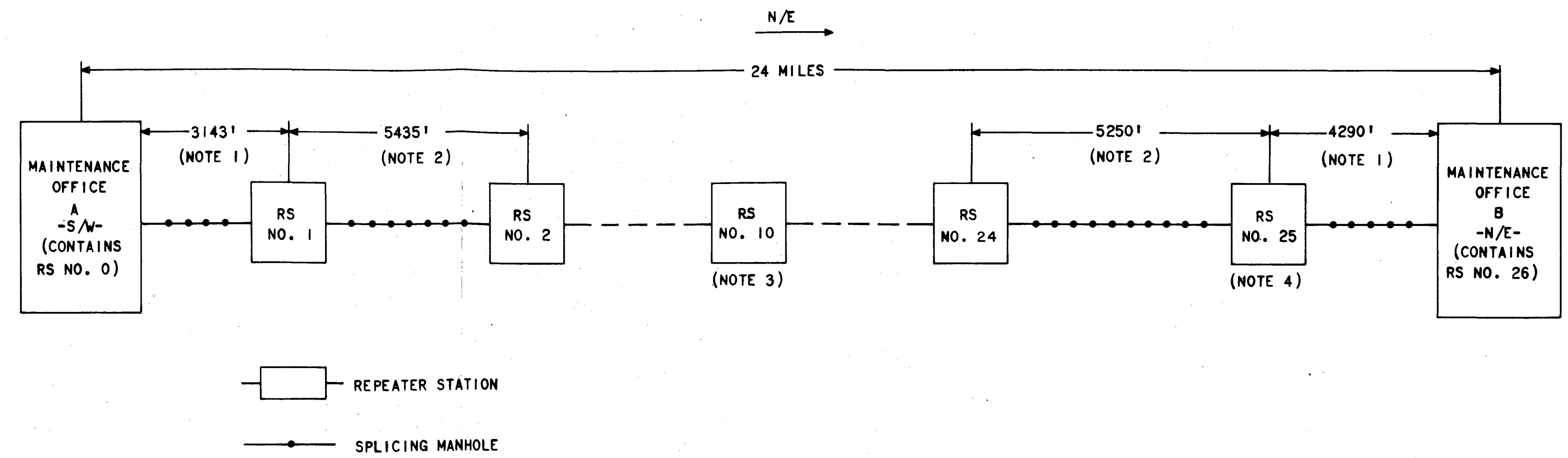
$$L_{RS} = EOD + L_C$$

$$= EOD + L^*_C + 50 \text{ feet}$$

$$= 1342 \times 4290 + 50$$

$$= 5682 \text{ feet.}$$

L_{RS} is now entered on the form (Fig. 13). Note that none of the regenerator section cable lengths exceed 5718 feet so that from Table A, the repeater station sites are acceptable. Note further, however, that the section adjacent to office B is only 35 feet below the maximum permitted distance. Hence, it would be wise to check the cable paths and racking in this regenerator section to ensure that the distances used in the calculation will not cause the maximum allowable distance to be exceeded by more than 1 percent.



NOTES:
1. OFFICE SPLICE TO MANHOLE CENTER DISTANCE.
2. MANHOLE CENTER-MANHOLE CENTER DISTANCES FOR LOCATIONS IN MANHOLES.
3. RS NO. 10 IS RACKED IN A NONSTANDARD FASHION IN A CABLE VAULT.
4. RS NO. 25 IS RACKED IN A NONSTANDARD FASHION IN A MANHOLE.

Fig. 12—Example of T4M Route Layout

E-6561A

T4M ROUTE LAYOUT WORKSHEET (FOR CABLES HAVING 19 AWG MAINTENANCE PAIRS)

BELL SYSTEM PRACTICE 855-353-101

REPEATER STATION DATA (NOTE 1)

REMARKS (NOTE 2)	RS	LOCATION	MU FILTER MU1	MU FILTER MU2	REGENERATOR N/E (ODD TUBES)	REGENERATOR S/W (EVEN TUBES)	BUILD-OUT CARD (NOTE 3) BOC 1	BUILD-OUT CARD (NOTE 3) BOC 2	RS
	0	MAINTENANCE OFFICE A(S/W) Epworth - San Rd.	1094A	1094 AG	4E	4 C	KG 9		0
	1	John St. & Ira Blvd	1094B	1094 AF	3 C	3 D	KG 4	KG 9	1
	2	Jack St.	1094C	1094 AE	3 D	3 D	KG 4	KG 4	2
	3	Patricia Ave.	1094D	1094 AD	3 D	3 D	KG 4	KG 5	3
	4	Warren Ave.	1094E	1094 AC	3 D	3 D	KG 4	KG 5	4
	5	John St. & Williams Ave.	1094F	1094 AB	3 D	3 D	KG 4	KG 5	5
	6	Chu St. & Edward Ave.	1094G	1094 AA	3 D	3 D	KG 4	KG 5	6
	7	Walter St. & Roberts Rd.	1094H	1094 Y	3 D	3 D	KG 4	KG 4	7
	8	Walter St. & Gary St.	1094J	1094 W	3 D	3 D	KG 4	KG 4	8
	9	Ismail Ave. & Lee St.	1094K	1094 U	3 D	3 C	KG 6	KG 5	9
cable vault	10	Nancy St. C.O.	1094L	1094 T	3 C	3 D	KG 4	KG 7	10
	11	Nancy St. & Toms Rd.	1094M	1094 S	3 D	3 D	KG 4	KG 5	11
Power loopback & DC blocking cap.	12	Philip Ave.	1094N	1094 R	3 D	3 D	KG 5	KG 4	12
	13	Darryl Ave.	1094P	1094 P	3 D	3 A	KG 14	KG 5	13
	14	Richards Rd.	1094R	1094 N	3 A	3 C	KG 9	KG 14	14
	15	Josephs St.	1094S	1094 M	3 C	3 D	KG 4	KG 9	15
	16	Nancy St. & Fang Ave.	1094T	1094 L	3 D	3 D	KG 4	KG 5	16
	17	Felicia St. & Donald Ave.	1094U	1094 K	3 D	3 D	KG 3	KG 5	17
	18	Alan Ave. & Harold St.	1094W	1094 J	3 D	3 D	KG 4	KG 4	18
	19	Fredrick St.	1094Y	1094 H	3 D	3 B	KG 11	KG 4	19
	20	Henry Ave.	1094AA	1094 G	3 B	3 D	KG 4	KG 12	20
	21	Alan Ave. & David St.	1094AB	1094 F	3 D	3 D	KG 4	KG 5	21
	22	Raymond Blvd & Jules Pl.	1094AC	1094 E	3 D	3 D	KG 5	KG 4	22
	23	Abraham St.	1094AD	1094 D	3 D	3 D	KG 4	KG 5	23
	24	Stanley Rd.	1094AE	1094 C	3 D	3 D	KG 4	KG 5	24
Nonstandard Racking	25	Raymond Blvd & Albert St.	1094AF	1094 B	3 D	3 D	KG 6	KG 5	25
	26	Olivesburg - Marc St.	1094AG	1094	3	3	KG	KG	26
	27		1094AH	1094	3	3	KG	KG	27
	28		1094AJ	1094	3	3	KG	KG	28
	—	MAINTENANCE OFFICE B(N/E) (NOTE 5)	1094A	1094 AG	4 D	4E		KG 6	26

CABLE SECTION DATA

L_{RS}/ℓ_w (NOTE 4)	CABLE TYPE	REMARKS
(NOTE 6) 4481	CA-3225	ℓ_w = 3453
5500		
5350		
5404		
5298		
5401		
5500		
5602		
5391		
4604		
5300		
5592		
5196		
1651		
3500		
5300		
5252		
5701		
5497		
2500		
5402		
5500		
5205		
5289		
5302	CA-3225	
5682 (NOTE 6)	CA-3225	ℓ_w = 4635

NOTES:

1. CHOOSE CODES FORMU FILTER, REGENERATOR, AND BOC FROM TABLES IN PART 5.
2. ENTER LOCATION(S OF F.L. POWER LOOPBACK AND OW DC BLOCKING CAPACITOR BELOW.
3. ENTER PAIR OF BO CODES DETERMINED IN BOC TABLE, FOR GIVEN VALUE OF ℓ_w, IN PAIR O BOXES CONNECTED BY ARROWS.
4. EXCEPT AS NOTED N PART 5, L_{RS} = MH CENTER TO MH CENTER DISTANCE +65 FEET AND ℓ_w= L_{RS}. IF ℓ_w IS NOT EQUAL TO L_{RS}, ENTER ℓ_w IN REMARKS COLUMN.
5. ENTER RS NUMBERFOR MO B NEXT IN SEQUENCE FOLLOWING FINAL OUTSIDE PLANT RSNUMBER.
6. CALCULATE L_{RS} AD ℓ_w FOR SECTIONS ADJACENT TO MO'S FROM FOLLOWING TABLE:

	L_A	L_B	EOD[(a)]	L_{RS}[(b)]	ℓ_1	ℓ_2	ℓ_w[(c)]
MO A	300	93	1298	4481	220	50	3453
MO B	330	30	1342	5682	250	45	4635

(a) EOD =3.55 L_A + L_B +140 FEET.
(b) EXCEP AS NOTED IN PART 5, L_{RS} = EOD + OFFICE SPLICE TO MH :ENTER DISTANCE + 40 FEET.
(c) EXCEP AS NOTED IN PART 5, ℓ_w = OFFICE SPLICE TO MH CETER DISTANCE + ℓ_1 + ℓ_2 + 40 FEET.

Fig. 13—Example of T4M Route Layout Worksheet, Form E-6561A, Filled In

Number of Splices

6.06 Next, the number of cable splices between repeater stations is checked to ensure conformity with the rules given in 5.17. For example, the regenerator section between repeater stations number 24 and number 25 contains ten splicing manholes. Assuming an additional splice to the 66-type terminals within each repeater station, this section thus contains 12 splices in the transmission path and is acceptable. Similarily, it is observed that seven splices including the office splice occur in the regenerator section between RS25 and maintenance office B, and thus this cable section is also acceptable.

Calculation of Line Voltage and LFC Current Drain

6.07 The maximum voltage buildup in the J87412A LFC is determined from the relation of V_{out} given in 5.28 with d = 24 miles and n = 25. Hence,

$$V_{out} = 5.0d + 16.8n = 5.0 \times 24 + 16.8 \times 25$$

$$= 540V,$$

which is of course less than the maximum of 960V.

The maximum current drain, I_{in}, given in 5.28 is determined for a +130V battery plant as follows:

$$I_{in} = V_{out}/0.6\ V_{in} + 1.25$$

$$= 540/(0.6)\ (120) + 1.25 = 8.75 \text{ amperes.}$$

A value of +120V is used for V_{in} in the maximum current calculation, since in Table C this is the lower limit shown for a +130V plant suitable for powering the T4M line. The nominal current, calculated for V_{in} equals +130V, is 8.17 amperes for this example.

Choice of Regenerator Codes

6.08 L_{RS} and the number of splices have been determined for all regenerator sections, as well as the maximum line voltage buildup. Since all of these are acceptable, the regenerator codes can be determined using Table D. As an example, for the regenerator section adjacent to maintenance office A, L_{RS} = 4481 feet so that the regenerator transmitting toward the N/E (B) maintenance office in RS1 is a 3C. In office A, the receiving regenerator is a 4C and, as always, the transmitting regenerator is a 4E. The regenerator codes are entered in the form (Fig. 13) as shown.

B. Wire Pairs—Calculation of ℓ_w

Regenerator Sections Not Adjacent to Maintenance Offices

6.09 Except for regenerator sections adjacent to RS10 and the regenerator section between RS24 and RS25, the values of L_{RS} determined for the various regenerator sections can be used for ℓ_w to determine the wire-pair build-out card codes (see 5.42). For the regenerator sections adjacent to RS10 and between RS24 and RS25, the values of L_{RS} are within ±2 percent of the distances measured to the 472H1 case so that, from 5.41, the values of L_{RS} tabulated in the form (Fig. 13) for these sections may also be used for ℓ_w to determine the build-out codes.

Regenerator Sections Adjacent to Maintenance Offices

6.10 Distances in maintenance offices A and B are as follows:

		OFFICE A	OFFICE B
ℓ_1	(length of ABAM from STF to 32A1)	220 feet	250 feet
ℓ_2	(length of CA-1969D cable from 32A1 to office splice)	50 feet	45 feet

With the aid of Form E-6561A, ℓ_w is calculated for the section adjacent to office A,

$$\ell_w = \ell_1 + \ell_2 + L^*_C + 40 \text{ feet}$$

$$= 220 + 50 + 3143 + 40 = 3453 \text{ feet.}$$

For the section adjacent to office B, it is determined that 50 feet must be added to the office splice to manhole center distance to account for the nonstandard racking of RS25. This 50 feet accounts for the distance from the manhole center to the 472H1 case.

$\ell_w = \ell_1 + \ell_2$ + office splice to 472H1 apparatus case distance

$= \ell_1 + \ell_2 + L^*_C + 50$ feet

$= 250 + 45 + 4290 + 50 = 4635$ feet.

The wire pairs distances, where the distances differ from L_{RS}, are recorded in the "Remarks" column of the form (Fig. 13) as shown.

Choice of Build-Out Cards

6.11 The build-out cards are selected in pairs from Table F (also see Fig. 8) based on the values of ℓ_w. For example, the value of ℓ_w between RS1 and RS2 is 5500 feet. Enter Table F at column entitled coax 22 lengths and find minimum and maximum lengths which bracket 5500 feet. Move left to find BOC 1 for RS1 and BOC 2 for RS2, ie, KG4 for both. Enter these on the form (Fig. 13). Note that the pair correspondence is shown by arrows.

Choice of Fault Locating Filters

6.12 As indicated in 5.45 and 5.48, different codes of 1094-type filters must be chosen to provide the unique fault locating frequencies for the various repeater stations. Beginning with the N/E direction of transmission at office A, MU1 is assigned a 1094A filter; at RS1, a 1094B filter; and at RS25, a 1094AF filter. At maintenance office B, MU1 is associated with the S/W direction of transmission and is assigned a 1094A filter; however, MU2 is associated with the N/E direction of transmission and is assigned the next, or 1094AG filter. MU2 in RS25 is assigned a 1094B, RS24 a 1094C, RS1 a 1094AF, and maintenance office A a 1094AG. This information is entered on the form (Fig. 13).

Choice of Fault Locate Power Loop-Back Point

6.13 As indicated in 5.49, a fault locate power loop-back option must be exercised in a 472H1 maintenance case near midspan. Since the maintenance span is 24 miles in length, a repeater station is chosen which is close to 12 miles from either maintenance office as the location. RS12 is chosen as the power loop-back point rather than RS13 (26/2 = 13) since it is closer to the length midpoint. Enter this choice in the "Remarks" column adjacent to RS12 in the form (Fig. 13).

Choice of DC Blocking Capacitor Location

6.14 As indicated in 5.52, dc blocking capacitors (437QA) must be provided in the wire pair used for the 2-wire order wire to allow for lengths up to approximately 24 miles. The maximum distance from the maintenance office is limited to approximately 12 miles. In the example chosen, the dc blocking location is chosen to be coincident with the power loop-back point. Enter this choice in the "Remarks" column adjacent to RS12 in the form (Fig. 13). Note that the wire-pair distance between maintenance office B and the power loop-back point is somewhat greater than 12 miles, and therefore presents a borderline condition for operation of the 2-wire order wire.

7. EQUIPMENT AND APPARATUS

7.01 A detailed list of equipment and apparatus is found in the J98721 specification as listed in Section 801-523-152. Manhole layout and equipping is covered in Section 640-540-230. The T4M interconnection schematic is SD-99610-01.