

**T1C DIGITAL LINE
TRANSMISSION AND OUTSIDE PLANT DESIGN PROCEDURES
CARRIER ENGINEERING**

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E. T1C Automatic Protection Switch (APS)	11	1.01 This section gives a brief description of the T1C digital line and provides engineering considerations for T1C lines containing up to 250 repeater sections. The engineering required to maintain quality of the longer T1C lines is included, along with new techniques of line protection and maintenance. Improved order-wire and fault-locating facilities are described. Cables, cable operation, and other outside plant considerations are also discussed. A glossary of terms is provided in Part	
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6 of this section. Section 365-250-100 gives a general description of the T1C digital line.

1.02 The reasons for reissuing this section are listed below. Since this reissue is a general revision, no revision arrows have been used to denote significant changes.

- (1) To extend the T1C digital line limits from 50 repeater sections to 250 repeater sections.
- (2) To include bidirectional operation.
- (3) To make reference to the T1C automatic protection switch (APS).
- (4) To include 248-, 249-, and 250-type low power repeaters.
- (5) To clarify the powering considerations and to add calculations for power loop voltage limits.
- (6) To include the 818/819-type apparatus cases.
- (7) To include intercity and outstate trunk (ICOT) cable.
- (8) To include present standard cables and to rate past standard cables either nonstandard limited availability (NSLA) or manufacture discontinued (Mfr Disc).
- (9) To add the J98725AT fault-line powering module to the required test set list.
- (10) To delete information on the test set adapters. The required adapters are contained in the test set sections which are listed in Part 5.
- (11) To update the references in Part 5.
- (12) To update the glossary in Part 6.

1.03 The T1C digital line (Fig. 1) is a digital transmission facility designed to operate at 3.152 Mb/s over paired cable. The T1C digital signal rate is midway between the DS1 digital signal rate (1.544 Mb/s) and the DS2 digital signal rate (6.312 Mb/s) in the digital hierarchy. The T1C digital line uses two exchange-grade cable pairs for transmitting data or 48 pulse code modulation (PCM) encoded voice channels. If D4 channel banks

are not used, a multiplex (M1C) provides an interface between the DS1 digital signal rate and the T1C digital signal rate. Therefore, the T1C digital line can be used for span relief on existing T1 routes. The T1C configurations and circuit designs are modeled on the T1, and the two facilities are compatible in the same cable sheath (see Fig. 1). Refer to Section 855-351-102 for operation with Traffic Service Position System (TSPS) number one.

A. Transmission Medium

1.04 All American Telephone and Telegraph Company (AT&T) standard screened cables manufactured after January 1980 are equipped with maintenance pairs (fault-locate, order-wire, pressure alarm, etc). These standard products include 22-gauge waterproof and air core standard capacitance (.083 $\mu\text{F}/\text{mi}$) cables as well as low capacitance cables, intercity and outstate trunk (ICOT), and metropolitan area trunk (MAT). All 19-gauge screened cables, all 22-gauge pulp insulated screened cables, and all 22-gauge PIC "even-count" screened cables are rated nonstandard limited availability (NSLA). After current stocks are depleted, Western Electric Company, Inc., will no longer retain stocks of NSLA cables. Ultimately, as the need for NSLA cables decreases, the codes will be rated manufacture discontinued (Mfr Disc).

1.05 Table A provides a listing of all past screened cable codes together with the standardization rating, modified cable code (if not Mfr Disc), and the recommended substitute (if Mfr Disc or NSLA). The T1C compatibility information (standard if suitable for full-fill T1C operation, or N/A if compatibility information is not available) is also listed. The present standard cable codes and T1C compatibility, if available, are listed in Table B.

1.06 The maintenance pair color-coding scheme in all the standard cables follows that developed for MAT and ICOT cable. That is, the maintenance pairs have normal PIC color coding that are included in a white-red binder group if the number of maintenance pairs is less than 25. If the number of maintenance pairs is more than 25, half of the pairs will be included on each side of the screen in a white-red or orange-black binder, respectively. In each binder the standard PIC color code beginning with white-blue is used. Typical core diagrams for some of the cable sizes are shown in Fig. 2.

1.07 It is strongly recommended that MAT and ICOT cables be used for digital carrier transmission in lieu of 22-gauge standard capacitance cables. These low capacitance screened cables provide superior digital carrier transmission capabilities. Furthermore, they offer significant facility economics in all but a few isolated instances. The decision to use standard capacitance 22-gauge screened cable should be based upon detailed individual economic studies that prove conclusively that 22-gauge cable is the proper choice.

1.08 The use of layered cable for T1C should be avoided if at all possible. AT&T should be consulted before attempting the use of layered cable for T1C.

1.09 In general, T1C and voice-frequency (VF) facilities (loaded and nonloaded) which are coterminous in the same central offices can share the same cable sheath but *not* the same binder group. When T1C carrier and VF facilities are coterminous, the end sections adjacent to the central office are sufficiently short to mitigate the effect of the central office impulse noise. However, T1C cannot share the same cable sheath with any nonloaded VF facilities which use dc pulse signaling and which are not coterminous with the T1C facilities. An example of the latter is nonloaded subscriber pairs. The subscriber pairs use dc signaling, and the subscriber end is usually not coterminous with the carrier pairs (eg, the subscriber pairs may terminate within an intermediate repeater section). When this situation exists, the off-hook condition at the subscriber set creates an impulse interference which couples into the T1C repeater via crosstalk paths in the cable. This is especially serious when the repeater section is of maximum length. However, loaded subscriber pairs (usually longer than 18 to 20 kft) can share the same cable sheath with T1C. The loaded facilities attenuate the high-frequency components of the off-hook impulse sufficiently to allow loaded subscriber pairs and T1C carrier pairs in the same cable sheath.

B. Operating Modes

1.10 T1C digital lines may be engineered for either bidirectional operation using one cable or unidirectional operation using either one cable or two cables. The three possible configurations are shown in Fig. 3. The decision to provide bidirectional or unidirectional operation should be

based on the circuit requirements and the availability of suitable cables and apparatus cases.

1.11 *Bidirectional Operation:* Several administrative and maintenance improvements can be attained using bidirectional operation. In a bidirectional arrangement, each line is associated with only one repeater slot. This means that if a line repeater is removed only one line is affected (with unidirectional operation, two lines would be interrupted). Patching to maintain service when a repeater is removed is simplified because only one line must be restored. Line powering for a bidirectional line is simplified because office repeater power mates are not required. Each office repeater power loop involves only one line and one repeater slot. Also the initial capital investment is minimized on small cross-section routes, because only one apparatus case (per line repeater location) is required to provide 2-way transmission.

1.12 *Unidirectional Operation:* Unidirectional operation requires the immediate installation of a pair of apparatus cases at each line repeater location, one for each direction of transmission. Each line repeater used in a unidirectional arrangement serves one direction of transmission for two lines. Therefore, if a line repeater is removed, it will affect two lines. Also if one side of a repeater fails, both sides must be patched to maintenance lines before the repeater is removed for repair. This is of small consequence for large installations, but it may be a factor for small initial installations.

1.13 *Two-Cable Operation:* With the exception of the fault-locate, order-wire, etc, pair requirements described in Part 3, full-fill T1C operation is permitted in all two-cable T1C installations using unitized cable with a nominal capacitance of 0.083 $\mu\text{F}/\text{mile}$. However, it should be noted that two-cable operation of T1C in *center units* of 900- and 1100-pair cross-section pulp cable will require a reduction in the maximum repeater spacing. High-loss pairs have been encountered in the center unit of ADA 900-pair and the three center units of ADA 1100 pulp PASP cable used for T1. Laboratory measurements indicate that the average loss of the pairs in these center units is approximately 3 percent higher than the average loss of the pairs in the middle and outer rings. Field and laboratory data are not available for cables with smaller cross sections, but experience indicates that the problem is attendant only to the larger cross-section pulp cables. *It is advised*

that the pairs in the center units of these larger cross-section pulp cables be utilized for fault locating, order wire, and other VF types of applications. If special situations occur where the center units must be used for T1C, the maximum design section lengths **must** be reduced by 3 percent. This does not apply when operating T1C in the center units of Western Electric screened cable.

1.14 One-Cable Operation: In order to ensure that the performance objective for T1C is met for one-cable operation, special spatial separation rules are imposed on the units carrying opposite directions of transmission:

- (1) Since the relative position of the units in the outer and middle rings can vary, selection of T1C units should be restricted to the outer ring.
- (2) In order to satisfy crosstalk margin requirements, at least two units (50 pairs each for 22-gauge cable; 100 pairs each for 24-gauge cable) of separation on the outer ring must be maintained between units carrying opposite directions of T1C transmission or units carrying opposite directions of T1 **and** T1C transmission.

Therefore, the maximum number of T1C lines for one-cable operation on a 900-pair 22-gauge pulp cable is limited to 150. Figure 4 illustrates the cable cross section and unit lay-up for a 900-pair pulp cable. A typical unit selection for 150 T1C lines is also depicted in the cable cross section in Fig. 4.

1.15 For one-cable operation of T1C on an 1100-pair 22-gauge pulp cable, the maximum number of T1C lines is limited to 200. Fifty additional T1 lines can be accommodated if special spatial separation rules are followed. Figure 5 illustrates the cable cross section and unit lay-up for 1100-pair pulp cables. Like the 900-pair cable, selection of the T1C units should be restricted to the outer ring. For one-cable operation of T1C on a 1200-pair 22-gauge pulp cable, the maximum number of T1C lines is 200 or 250, respectively, for 100 and 50 T1 additional lines on the middle ring. The unit

selections for 1200-pair cable are shown in Fig. 6A and 6B. Notice in Fig. 5, 6A, and 6B that:

- (1) For the 1100-pair cable, at least two units of separation on the outer ring must be maintained between units carrying opposite directions of transmission.
- (2) For the 1200-pair cable, when 100 T1 lines are on the middle ring, at least three units of separation on the outer ring must be maintained between units carrying opposite directions of transmission. When 50 T1 lines are on the middle ring, at least two units of separation must be maintained on the outer ring.

For the **additional** T1 lines, the unit selection is restricted to the middle ring as shown in Fig. 5, 6A, and 6B. Since the relative position of the units in the outer and middle ring can vary, the T1 units in the middle ring should be selected to maximize the separation between them and the nearest T1C unit carrying the opposite direction of transmission. This optimization is obtained approximately if the T1 units selected in the middle ring are midway between the extremities of the arc spanned by the units selected for T1C in the outer ring.

1.16 One-cable T1C operation on nonscreened cables with fewer than 900 pairs is not permitted, even though two units (50 pairs each) of separation can be achieved. This is due to the near-end crosstalk (NEXT) constraints of these smaller cables.

1.17 For one-cable operation of T1C on 1500-pair and 1800-pair 24-gauge pulp cable, the unit selection of a T1C and T1 are shown in Fig. 7A and 7B, respectively.

1.18 Interbuilding and intracity trunk cables or subscriber cables sometimes contain facilities for customer loops and therefore have distribution terminals and distribution cable branches. Such trunk cables are not well suited to the application of T1C because they are subject to sheath openings for service connections and rearrangements. Therefore, such trunk cables should **not** be used for T1C applications.

C. Signal Format

1.19 The 3.152-Mb/s T1C digital signal rate can be obtained from a D4 channel bank or formed by multiplexing two asynchronous DS1 signals together and time interleaving them with appropriate framing and control pulses [time division multiplexing (TDM)]. The synchronization process is accomplished by bit stuffing. The T1C line signal is a bipolar, 50-percent duty cycle pulse stream with pulses of 3 volts peak ± 0.3 volts. It has a minimum average pulse density of one out of eight over any interval of 150 symbol periods. The T1C pulse density is controlled to ensure a sufficient number of pulses for accurate timing recovery, while at the same time, limiting pulse density to minimize crosstalk. The line format permits reframing of the D4 channel bank or M1C multiplex in less than 16 milliseconds.

D. Performance Objectives

1.20 T1C engineering rules are derived from a terminal-to-terminal line design objective that at least 95 percent of properly engineered and installed lines will have an error rate less than 10^{-6} . Studies have shown that an appropriate method for engineering long T1C lines is to assign the same error rate objective, 10^{-6} , to each repeater section. The probability of exceeding this error rate is then allocated on a section-by-section basis. As discussed later, 250 properly designed repeater sections are possible.

E. Line Margin

1.21 The T1C line margin, with respect to the objectives of paragraph 1.20, has been calculated for one-cable, two-cable, and screened-cable operation with various fill factors. This margin includes the effects of crosstalk in the cable, timing offset, and misequalization. An additional empirical allotment of margin was made to account for such things as threshold variations and cable imperfections which are difficult to characterize accurately. Thus, no further margin computations are required; merely the use of cables certified for use with T1C. Generally, more available operating margin exists in two-cable operation than in one-cable or screened cable operation.

1.22 One-cable operation does not require availability of a second cable and is compatible with voice-frequency usage. The second cable, when

available, can be used for diversity of one-cable operation. The utilization of pairs for order-wire, pressure alarm, and fault-locate assignment in various cables is shown in Table C. Two-cable operation has greater ultimate capacity in a cable and more margin than one-cable operation. Order-wire, fault-locate, and pressure alarm assignments for two-cable operation are shown in Table D. The economic and engineering tradeoffs must be weighed for each T1C installation to determine the optimum configuration. Screened cable is the ultimate of one-cable operation at full-fill.

2. CENTRAL OFFICE CONSIDERATIONS

A. Terminal Equipment

Office Repeater Bays

2.01 T1C lines terminate at central offices in office repeater bays (ORBs). Six J98725 ORB letter codes (A through F) are used in T1C lines. There are two types of ORB—DSX optional and DSX dedicated. The DSX optional ORB can be used with a DSX-1C or a jack panel mounted in the ORB. The DSX dedicated ORB is always used with a DSX-1C. There are three sizes of DSX optional ORBs (11-foot 6-inch, 9-foot, and 7-foot) and three sizes of DSX dedicated ORBs (11-foot 6-inch, 9-foot, and 7-foot). Jack assignments in the ORB and/or DSX-1C and the apparatus case slot assignments must be consistent; ie, jack 1 to slot 1, etc. Capacities of the ORBs are listed in Table E.

2.02 The ORB provides, in addition to the office repeater shelves, mounting space for the following equipment (see Table E): equalizer plug-in cards, an order-wire and tel set panel, a jack field interface terminal strip, power dissipation units, a fuse and alarm panel with space for fault-locate filters, a quasi-random signal source (QRSS), and series-dropping resistors for -48 volt and $+130$ volt dc distribution. Space is also available on the J98725A, B, and C (DSX optional) bays for mounting a cross-connect panel which provides access for patching and testing the T1C signal. ***This will suffice for up to four adjacent ORBs but larger installations will require one or more DSX-1C cross-connect bays where all patching and testing can be performed.*** In large T1C installations (when DSX-1C cross-connect bays are required), it is advantageous to use the J98725D, E, and F bays

(DSX-dedicated) with their larger repeater capacity per bay (see Table E). The DSX-dedicated bays must be used with DSX-1C equipment. Sections 855-350-105 and 855-350-106 provide explicit guidelines for engineering cross-connect bays for new installations or retrofit, respectively. In this case, the only jacks permitted at the ORB are in the order-wire appearance.

Office Repeaters

2.03 The office repeater consists of a regenerator for the received line signal and a passive through-connecting circuitry for the transmitting side. These repeaters are coded 220-type (standard power) and 250-type (low power). Also available are 220C (standard power) and 250C (low power) for bridging a signal from a working line to a maintenance line. The bridging repeaters are mounted in position 26 on even-numbered ORB shelves. The various codes of T1C office repeaters are shown in Table F.

2.04 A 3-dB pad is included on the incoming line side of the repeater and a 12-dB artificial line is included on the outgoing line side. These pads and artificial lines permit greater flexibility in setting line lengths for end sections and also provide secondary lightning protection. In addition, an automatic line build-out (ALBO) compensates for variations in end-section lengths, including intraoffice cabling from the cable vault to the ORB. An equalizer (see paragraph 2.13) is provided at the repeater output (office side) for cable compensation between the ORB and DSX-1C (Fig. 8).

Multiplex

2.05 The M1C multiplex, as mentioned in paragraph 1.03, provides the interface between the DS1 digital signal rate signals and the T1C (DS1C) digital signal rate. Each M1C *multiplexer-demultiplexer* (muldem) accepts two DS1 digital signal rates and multiplexes them together to form the line digital signal rate discussed in paragraph 1.03. The M1C muldems are mounted in the M1C J98727A, B, or C multiplex bay or J98727E multiplex shelf. The multiplex bay is available in 11-foot 6-inch, 9-foot, or 7-foot arrangements. Capacities of the multiplex bays and single shelf are shown in Table G. In addition to the working muldems, the M1C bay provides space for mounting a standby muldem, a maintenance panel, a fuse and alarm panel, and 71P-type power supplies (each power supply will

serve 16 working muldems). Equalizers (see paragraphs 2.13 and 2.14) are provided to equalize the cable between the M1C and DSX-1C cross-connection on one side and M1C and DSX-1 cross-connection on the other side. (See Fig. 9.) More detailed information on the multiplex bay and multiplex single shelf can be found in Sections 365-604-100 and 365-604-101, respectively.

D4 Channel Bank

2.06 The D4 channel bank is a 48-channel voice-frequency PCM terminal which was developed to provide a more economical access to the T1C facility. In general, the *D4* channel bank could replace two *D3* channel banks and one *M1C* muldem. The D4 channel bank can be used for direct, tandem, toll-connecting, and intertoll trunks. By using higher levels of integration and modern design approaches, the D4 channel bank achieves, relative to D3 channel banks, about a 2:1 reduction in size and power consumption. Improvements in maintenance, power consumption, and reliability are also obtained. The D4 channel bank will directly interface one T1C digital line. D4 channel banks may also be used with a digital cross-connection (DSX-1 or DSX-1C) and digital multiplex equipment (M1C, M12, M13, or MX3). For more detailed information on the D4 channel bank, refer to Section 365-170-100.

B. Interconnecting Facilities

2.07 Interconnecting facilities include the entrance cabling, intraoffice cabling, main distributing frame (MDF), and the cross-connect panel. Unit integrity on T1C routes should be maintained MDF to MDF.

2.08 *Only one direction* of T1C transmission is to be carried in a single tip cable. In addition, the tip cable must be dedicated to T1C with no voice-frequency pairs permitted (reduces effects of switch noise). It should be noted that T1 and T1C can share tip cabling if both are transmitting in the same direction and at the same level.

Note: The following situations will require a 303B2-50 connector: cable counts that result in an odd number of 50-pair binder groups requiring isolation between high and low level signals (eg, one-cable operation on 900-pair cable as shown in Fig. 4; or two-cable operation

on 600-pair cable with 550 pairs devoted to high or low level T1C and 50 pairs maintenance). The 303B2-50 connector has two 50-pair stubs and is described in Section 636-330-100.

2.09 In T1C applications employing fuse cable, the fuse cable should be two gauges smaller than the protected cable; eg, 24-gauge for 22-gauge cable, and 2 feet in length. Fuse cabling is covered in Section 638-205-015.

2.10 The remaining office cabling is 22-gauge ABAM or 600-type cable. Only one direction of T1C transmission can be carried in a single ABAM or 600-type cable sheath. The T1C intraoffice connections and interbay maximum cable lengths are shown in Fig. 10. By following the length restrictions of Fig. 10 and using the appropriate equalizers, signals appearing at the DSX-1C cross-connect panel will be equilevel with a 3-volt peak. Any T1C signals in the same ABAM or 600-type sheath must be equilevel within 3 dB. To ensure equilevel signals, all signals in the same ABAM or 600-type sheath should terminate at the same ORB and in the same section of the MDF. A restriction of 6-dB maximum level difference holds for signals on the tip cable from the MDF to the cable vault. If signals in a tip cable (and at the vault) differ by more than 4 dB but less than 6 dB, the signals must be transmitted in separate units in the entrance and tip cables. If signals in a tip cable (and at the vault) differ by no more than 4 dB, the signals can be transmitted in the same unit in the entrance and tip cables.

2.11 T1C connections to the MDF should be provided in cabling specifically installed for that purpose and connections to the MDF should be made only on the vertical side. This is necessary to minimize exposure to central office noise and to ensure separation of the two directions of transmission. Heat coils are necessary on the MDF when the cable requires protection; otherwise, they should be strapped out because their inadvertent removal would cause a loss of any pair involved. Where protection is not required, the protector blocks should be patched or strapped out, or the engineer may choose to provide ABAM or 600-type cable direct from the cable vault to the ORB, thus conserving valuable MDF space.

2.12 Office wiring for entrance and tip cables and connections between ORB and DSX-1C

are essentially the same as for T1, Section 855-351-101. See Fig. 11.

Intraoffice Cable Equalization

2.13 Equalizers (ORB mounted) are available for equalizing the office cabling between the ORB and DSX-1C or APS. The equalizer codes and their ranges are shown in Table H. When no DSX-1C and APS bay is provided and jack appearances remain on the ORB (DSX optional ORB), the equalizers will be engineered as if there were a DSX-1C located within the bay itself; that is, the equalizer code for 0- to 133-foot cross-connect distances would be used for every repeater in the bay. See paragraph 2.02. This arrangement minimizes flat loss mismatch when the digital lines are looped and provides test set compatibility at the jacks on both bays. Repeater circuit position 26 is equipped with ED-3C555-30, G1 for all applications of the 220C bridging repeater or an ED-3C655-30, G1 for all applications of the 250C bridging repeater.

2.14 Cable equalization between the M1C muldem and the DSX-1C and the M1C and DSX-1 is provided by a single 1012 equalizer network, mounted in the M1C bay or M1C shelf. The various codes and their ranges are listed in Table I. (See Fig. 9.) Cable equalization between the D4 channel bank is provided by a single ED-3C655-30 equalizer mounted in the D4 trunk processing unit. The various codes and ranges are listed in Table J.

2.15 Cable equalization between the APS and the DSX-1C is provided by ED-3C767-30 equalizers. Two of these equalizers are required for each service shelf. The various groups and their ranges are listed in Table K.

Communications Requirements

2.16 An order wire is provided for communication between line repeater locations in a span and between any line repeater location within a span and the ORB and/or DSX-1C at either end of the maintenance span. Order-wire engineering is discussed in Section 855-350-107. The order wire is treated as a subscriber line in one of the maintenance span terminating offices. In this way, the craftperson can dial any number from a line repeater location and call the testboard at either maintenance span terminating office. A network, in series with each order-wire bridge appearance,

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provides better current distribution when more than one handset is connected to the order wire at different locations (see Section 855-350-107).

2.17 The order wire uses a loaded pair and has an appearance at each line repeater apparatus case location in the span as well as on the ORB and/or DSX-1C at each end of the maintenance span. An option is available to provide an order-wire terminal on the outside of the apparatus case, making it unnecessary to open the case to gain access to the order wire. Only one apparatus case requires this option at a line repeater location, since one order wire serves a span, regardless of the number of span lines provided, as long as separate cable routes are not involved. When DSX-1C is used, the order wire will appear on the DSX-1C maintenance panel.

2.18 Spans longer than approximately 12 miles on 22-gauge cable require an order-wire circuit where dc continuity is broken by the addition of dc blocking capacitors. In this way, talking and signaling battery can be supplied at the two ends, each serving half the span. Two pairs (one in and one out) are provided in the stub cable of the line repeater apparatus case for the order wire. Provisions have been made for mounting the blocking capacitors in the apparatus case.

Central Office Communications

2.19 Adequate communications are essential to the proper maintenance and operation of T1C digital lines. In addition to the order wire, all ORB or DSX-1C locations should have access to the switching network to establish contact with other offices when required. Of equal importance is voice contact between maintenance locations within the office to ensure adequate communications among the maintenance staff. When making additions, the intraoffice network should be considered.

Administrative Considerations

2.20 Record keeping methods for the T1C digital line are described in Section 365-000-010. Record cards, forms, and procedures are covered. Another aspect of administration is naming the T1C digital line in accordance with common language requirements, Section 795-450-104.

C. J98725J Express Office Repeater Panel

2.21 The express office repeater panel (EORP) has been developed to reduce the cost and equipment necessary to provide through-office routing on a T1C span. This function is required when a T1C span passes through an intermediate central office other than the span terminating office. Furnishing repeaters at such a location has, in the past, required the use of two office repeater bays. The EORP performs the same function as an apparatus case; however, it is designed to be bay-mounted in a central office location. (See Section 365-250-105.)

2.22 Each EORP is designed to accommodate twenty-five 218- or 248-type line repeaters which regenerate the digital signal. The panel also contains 25 artificial line network printed wiring boards (ED-3C719), one associated with each repeater in the panel. The printed wiring boards contain four 100-ohm artificial line networks, two for the inputs and two for the outputs of each repeater. The insertion loss of these networks is 11.7 dB at 1.576 MHz and maintains a characteristic shape similar to actual cable.

2.23 The purpose of the artificial line networks is to prevent a signal level difference when connecting to cable pairs in an existing cable. The networks also provide additional shaped loss to reduce reflections in extremely short end sections of cable and provide resistance for current limiting the secondary lightning protection.

2.24 Secondary lightning protection is provided as an option on the artificial line printed wiring boards. This option consists of three varistors, one on the input network and two on the output network associated with each regenerator. Primary lightning protection is also optional and consists of a dual gas electron tube connected across each input and output cable pair. If the panel is wired through the MDF where primary protection is already provided, the gas tubes are not required in the panel.

2.25 Each panel contains provision for one fault-locating filter to test the operation of the repeaters during line troubleshooting. The standard fault-locating scheme used for apparatus cases on the T1C digital line is also used for the EORP.

2.26 An optional terminal block (ED-3C723-30) can be installed at the top of the EORP bay to terminate all fault-locate and order-wire pairs within the bay. This block allows the installer to terminate order-wire and fault-locate pairs on the block when the bay is installed so that as future additions are made to the bay it is not necessary to run more pairs.

2.27 Load coils for both the order-wire and fault-locate line may be installed at the panel location on an optional basis. Through-coupling capacitors may also be included to provide dc blocking for the order-wire line when required. The panel contains an optional order-wire appearance to provide access to the order-wire line for maintenance personnel. The bay arrangement for mounting T1C EORPs is as follows:

- 7-foot bay—8 panels (200 repeaters)
- 9-foot bay—10 panels (250 repeaters)
- 11-foot 6-inch bay—14 panels (350 repeaters).

2.28 A typical bay arrangement is specified in ED-3C724. All panel orders will be in groups of two for unidirectional operation or single panels for bidirectional operation.

2.29 Bidirectional or unidirectional T1 repeaters may be installed in the T1C EORP. Type 245A (Mfr Disc) or 245C (unidirectional operation) or 245B (bidirectional operation) adapters must be used when T1 repeaters are employed.

2.30 Power for T1C (or T1) repeaters in the EORP must be provided from the digital line. No option is presently provided to power locally the repeaters in the panel nor to provide power to line repeaters from the panel.

2.31 More detailed information on the description and operation of the T1C EORP can be found in Section 365-250-105.

2.32 Following are two sets of T1C EORP engineering rules. One set of rules (paragraph 2.35) is to be used for engineering T1C EORP installations and the second set of rules (paragraph 2.36) is to be used when engineering T1C express routes where the T1C EORP may be eliminated.

2.33 The set of rules to be used when engineering a T1C EORP installation states that the T1C EORP should be treated as an end section from a transmission and office cabling viewpoint and as a line repeater from an administration and operational viewpoint. Concepts are similar to those for the T1 EORP.

2.34 The second set of engineering rules provides guidance in designing T1C express routes for those applications which do not require an EORP at the express office. The engineering rules themselves form the criteria for determining whether an EORP is required. If an EORP is not required, the express office acts merely as a splice point connecting the two end sections together.

2.35 Following are the T1C EORP engineering rules to be used when designing a T1C EORP installation:

- (1) All T1C end section engineering rules apply [including maximum and minimum repeater spacings (see Table L) and restrictions for sections adjacent to end sections (see Table M)].
- (2) There is no limit (maximum or minimum) on the length of the ABAM, 600-type, and/or tip cables connecting the EORP to the outside plant (as long as the end section repeater spacing limits are not exceeded).
- (3) No voice-frequency circuits are permitted in ABAM, 600-type, or tip cables carrying T1C digital lines.
- (4) Only one direction of T1C transmission is permitted in a tip, 600-type, or ABAM cable.
- (5) The T1C central office engineering rules described in Part 2 of this section apply to the EORP.
- (6) Each shelf in a T1C EORP must be assigned to a particular apparatus case. Mixing of T1C digital lines from different apparatus cases in an EORP panel is not permitted.
- (7) As with the T1 EORP, uniform pair numbering must be retained on each side of the T1C EORP.

- (8) The EORP may be used only at MAT-to-MAT, ICOT-to-ICOT, MAT-to-ICOT, or .083 $\mu\text{F}/\text{mi}$ -to-.083 $\mu\text{F}/\text{mi}$ junctions.

2.36 The following requirements and engineering rules are to be used when designing a T1C express route *without* an EORP at the express office. The requirements and rules are defined for two types of applications:

- T1C express lines only
- T1C express lines plus T1C terminating lines.

T1C Express Lines Only

- (1) In T1C routes (one-cable, two-cable, and screened cable) dedicated to express operation, the T1C EORP is not required as long as the cable length (loss) of the two end sections at the express office does not exceed the T1C engineering rules (repeater spacings) for a T1C intermediate repeater section (see Tables L and M). In a one-cable mode of operation the VF (core) binder groups may terminate at the express office. This "express lines only" rule applies to all types, sizes, and gauges of cables regardless of any mixing thereof at the central office.
- (2) In an "express lines only" route the T1C lines are cross-connected at the MDF at the express office using ABAM or 600-type cable; hence, the express office is merely a cross-connect point for the T1C lines.

T1C Express Lines Plus T1C Terminating Lines

- (1) In many T1C routes, where digital lines coterminous at a central office enter the same sheath with express lines, express office repeaters may not be required if the end sections adjacent to the central office are relatively short. A typical configuration is shown in Fig. 12. Express lines run between apparatus cases B and C, while other lines are coterminous at office A. A route junction is created where lines coterminous at office A enter the same sheath with the express lines. Special engineering considerations arise because of the unequal-level far-end crosstalk (FEXT) exposure created by the junction, and the effect of central office noise which is induced on express lines via VF pairs coterminous at the central office. Adhering to the T1C rule where VF pairs are confined to

separate binder groups from digital lines, unequal level FEXT exposure remains as the controlling factor. The situation thus is reduced to a route junction and is the only instance where a junction is permitted in a T1C cable. Because the unequal level FEXT exposure reduces the total margin against crosstalk, it is necessary that sufficient margin be available initially for the facility configuration involved. This is the case for two-cable operation where ample FEXT margin is available. However, for one-cable operation where the net margin (NEXT plus FEXT) is small (assuming maximum section lengths), it is necessary to contrive a unit selection configuration which will allow the creation of a junction.

- (2) The restrictions placed on D_B and D_C (Fig. 12) for both two-cable and one-cable operation on pulp-insulated cable (19-, 22-, and 24-gauge underground and aerial) appear in Table N. The restrictions in Table N apply to any size two-cable or one-cable operation, with the stipulation that the A and B lines must be in separate units, where "A" lines are coterminous at the central office, and "B" denotes the express lines.
- (3) In addition to the above stipulation, only certain cable unit selection configurations are allowed for one-cable operation. The allowed configurations for 900-, 1100-, and 1200-pair one-cable operation are shown in Fig. 13, 14, and 15, respectively.
- (4) For 900-pair one-cable operation, the number of T1C "A lines" coterminous at the central office is limited to 50 or less (one unit in each direction) and must be assigned to the units carrying opposite directions of transmission which have the least separation (excluding those carrying T1). The remaining three units (100 T1C pairs and 50 T1 pairs) in each direction can be assigned to express "B lines". Under no circumstances are A and B lines allowed in the same unit.
- (5) The situation is similar for both 1100- and 1200-pair one-cable operation shown in Fig. 14 and 15. The T1C "A lines" coterminous at the central office must be assigned to the units carrying opposite directions of transmission which have the least separation. However, the maximum number of T1C "A lines" allowed is 100 (two units in each direction with least separation). The remaining two to three units (100 to 150 T1C pairs) in each direction can be assigned to

express "B lines". In addition, the units on the inner ring normally reserved for T1 lines should not be used.

(6) Screened cable should not be used in this type of application, since its net margin against crosstalk is not sufficient (assuming maximum length).

(7) The engineering rules in Table N and the cable unit selection configurations in Fig. 13, 14, and 15 also apply when T1 "A lines" are substituted for T1C "A lines" and T1 "B lines" are substituted for T1C "B lines", on a one-for-one basis, with the stipulation that the 7.5-dB artificial line buildout must be employed for the T1 lines coterminous at office A.

(8) The engineering rules in Table N are also applicable when the two end sections have different gauge cables. In this case the length restrictions, D_B and D_C (Fig. 12), under the headings of the appropriate gauges shall apply.

D. ED-2C497-30 DSX-1/DSX-1C Bridging Repeater Panel

2.37 The DSX-1/DSX-1C bridging repeater panel has been developed to provide T1C and T1 bridging repeaters other than those located in slot 26 of the office repeater shelves. The additional bridging repeaters are required when service is transferred to and from maintenance lines and backbone lines. The repeaters may also be used to implement auxiliary maintenance lines when more than one maintenance line is required out of 25 lines. (See SD-99503-01.)

2.38 Each bridging repeater panel is designed to accommodate two 220C or 250C (T1C) or two 221C or 231C (T1) bridging repeaters. The panel is designed to mount on the front or rear of 23-inch unequal flange duct-type or ESS-type framework and to occupy one 2-inch mounting plate space. The ED-2C497-30 panel assembly is intended to be mounted in the DSX-1 or DSX-1C cross-connect bay and to be powered with -48 volts.

2.39 The IN, OUT, and MON jacks for the repeaters appear on the front panel for local patching. The repeaters are separately powered through back contacts on the IN jacks. Remote operation is available through wire wrap terminals at the rear of the panel. The output cable equalizers

are accessible from the rear of the panel, in case the cable length of remote operations requires that they be changed.

2.40 For each repeater, the front panel has two IN jacks, one OUT jack, and two MON jacks. This permits a disabled maintenance span to be replaced first by a backbone line and later by a maintenance line. The two IN jacks are cascaded so that the MON output of the backbone line would be patched to the IN1 jack and replaced later by patching from the maintenance line MON jack to the IN2 jack. The two MON jacks are bridged to the output by separate bridging resistors so that both the backbone line and the maintenance line may be driven simultaneously.

2.41 More detailed information on the description and operation of the DSX-1/DSX-1C bridging repeater panel is available in Section 365-301-103.

E. T1C Automatic Protection Switch (APS)

2.42 The APS is designed to protect up to 144 T1C service lines in modules of 2/48 or 1/24. A 2/48 module protects up to 48 service lines with 2 protection lines. A 1/24 module protects up to 24 service lines with 1 protection line. The 1/24 module can only be used with lines operating in the bidirectional mode. The APS common equipment can handle six 1/24 modules, three 2/48 modules, or any combination of modules as long as the number of service lines does not exceed 144. Further information is contained in Section 365-250-120. APS engineering information will be contained in Section 855-350-109.

3. OUTSIDE PLANT CONSIDERATIONS

A. Outside Plant Equipment

3.01 Apparatus Case: The T1C apparatus case (Fig. 16, 479-type, or Fig. 17, 818/819-type) is similar to the T1 475-type case in capacity and wall-mounting requirements. The T1C case, coded 479A() (unprotected) or 479B() (protected), has two stubs: one for low-level input signals and one for high-level output signals. The T1C case, coded 818()C (unprotected) and 819()C (protected), has two stubs or a quad-screened stub. The quad-screened stub permits bidirectional operation for T1C. Two stubs or quad-screened stubs are used for isolation of the high- and low-level signals to minimize the *NEXT* exposure. Splicing of the

T1C apparatus cases to the cable can be accomplished using either mechanical splice closures or lead-wiped sleeves. Because of the requirement to separate high- and low-level signals which dictates the use of two stubs or quad-screened stubs on the apparatus case, T1C manhole layouts may be more complex and require more care in engineering than for similar T1 situations. Unidirectional operation requires that the T1C apparatus cases be used in pairs for complete 2-way lines; whereas, bidirectional operation using 818/819-type apparatus cases requires only one case at each line repeater location. The high/low signal separation criteria for two-cable operation can best be handled by using two splice cases as shown in Fig. 18. This removes all low-level signals at one splice and reinserts the high-level signals at the next splice.

3.02 More detailed information on the description and use of the T1C apparatus cases is available in Section 640-527-107 (479-type case) or Section 640-525-307 (818/819-type case).

3.03 Line Repeaters: The T1C line repeater performs the following functions: automatic line build out (ALBO), gain, equalization, timing recovery, and regeneration. The 218-type (standard power) and 248-type (low power) repeaters are without lightning protection, which is a feature of the 219-type (standard power) and 249-type (low power). The various codes and options are shown in Table O. Tables L and M contain the maximum and minimum repeater spacings for T1C in a buried (including underground) or aerial environment. They also include the maximum and minimum repeater spacings for intermediate sections as well as end sections on various copper and aluminum cables. A more detailed description of the line repeaters used in T1C digital lines is contained in Section 365-250-101.

3.04 The long distance repeater (218B and D or 219B and D) operates over a loss range between 20 and 54 dB, and the short distance repeater (218A and C or 219A and C) operates between 5.7 and 38.7 dB. All other line repeaters operate over the entire loss range of 5.7 to 54 dB (see Table O). All losses are as measured at 1.576 MHz. These loss ranges include allocations for the effects of temperature variation, route map inaccuracies, repeater circuit variations, and pair-to-pair loss variations. If the selection of a repeater code is based on actual pair loss measurements, scaled to 55°F, then the minimum loss for which a

long code can be selected is 21.7 dB, and the maximum loss is 52.8 dB. Similarly, the short code, based on actual pair loss measurements, can be used for losses from 6.2 to 37.7 dB and the repeaters that cover the entire loss range can be used for losses from 6.2 to 52.8 dB. See Section 103-494-104 for detailed information on pair loss measurements.

3.05 When engineering T1C routes for 22-gauge copper pulp cables in an underground or buried environment, if all section lengths are nominally between 3380 feet and 6100 feet, the range capability of the long distance repeater would compensate for layout inaccuracies and loss variations. In this instance, only the long code would be needed. When engineering end sections, the 12-dB artificial line in the office repeater must be taken into account. This is equivalent to 1500 feet of cable for 22-gauge copper pulp cables, and thus permits use of the long repeater code on end section lengths as short as 1490 feet since the combined loss is equivalent to 2990 feet (see Table L).

3.06 If end sections are shorter than 1490 feet, or intermediate sections are shorter than 3380 feet, the short code repeater must be used. The short code can be used on end sections of 22-gauge copper pulp cable with lengths between 800 and 2990 feet and on intermediate sections with lengths between 1020 and 4320 feet. (Other cables are shown in Tables L and M). Sufficient overlap has been provided in the range capabilities of the two codes so that the engineering and ordering can usually be done from route maps without having to measure the section loss. The difference between the two codes is a pad with shaped loss, which is included in the input circuitry of the short code repeater.

B. Line Engineering Considerations

3.07 As indicated previously, T1C engineering rules are derived from the terminal-to-terminal line design objective that at least 95 percent of properly engineered and installed lines will have an error rate less than 10^{-6} . The probability that a T component (repeater section, span, or terminal-to-terminal section) exceeds this error rate is defined as the design number for that component. The design number for a series connection of components is simply the sum of the design numbers for the constituent components. Various spans in a facility can have different design numbers;

therefore, an administrative record must be kept of these numbers. The fundamental rule is that the terminal-to-terminal design number must not exceed 0.05. Thus the facility is designed on an end-to-end basis rather than by connecting a series of independently designed spans.

3.08 Regenerative sections engineered according to the rules of this Bell System Practice may be assigned the design number values, depending on type of cable and configuration used, as shown in Table P. Although the tabulated design numbers suggest that as many as 1000 such sections may be cascaded for a T1C facility between terminals, for maintainability, T1C line length should be limited to 250 regenerative sections.

3.09 When spans of metropolitan T1, T1D, T1/OS, or T2 are included in tandem with T1C spans, the basic approach is to assign design numbers to each span and verify that the sum of the design numbers on the terminal-to-terminal facility does not exceed 0.05.

3.10 For metropolitan T1 spans the design number to be assigned will depend on three equally important considerations:

- (1) The original engineering design of the repeater sections which make up the span
- (2) The performance history of the span
- (3) The maintenance procedures which will be applied to the candidate span when it is connected in tandem with T1C.

3.11 For the first consideration, original engineering design, the detailed design of each repeater section should be evaluated by the T1C standards. In many cases, metropolitan T1 repeater sections meet these standards and may be assigned a design number of 0.00025. Special situations in metropolitan T1, such as heavily loaded one-cable operation, long apparatus case stubs, route junctions, noisy office environments, or widely spaced apparatus case points, will require special consideration. Design numbers larger than 0.00025 may have to be assigned. If any of the design information required is unobtainable, the section must be assigned a design number not less than 0.001.

3.12 For the second consideration, past performance history and maintenance records should be

consulted to determine whether the original design objective of the span has been achieved; that is, at least 95 percent of the lines must have consistently passed the monthly maintenance tests specified in Section 365-225-500 or Section 365-800-002 (TOP). Provided that the engineering considerations are also met, a span meeting this performance history requirement may be assigned a design number as low as 0.00025 per repeater section. If the span cannot meet this requirement or if no records are available, the minimum design number assignable to each repeater section in the span is 0.001. If the span has shown and continues to show performance well below design objectives (high error rate on more than 5 percent of the span lines and/or frequent outages), the span should not be considered a candidate for extension unless the transmission problems can be identified and removed.

3.13 For the third consideration, maintenance procedures, a clearly defined set of maintenance procedures must exist or be established for a candidate metropolitan span if the span is to be assigned the minimum design number of 0.00025 per repeater section. In the absence of such maintenance procedures, the minimum design number assignable to each repeater section in the candidate span is 0.001.

3.14 Since all three of the above considerations are equally important, the most conservative of the three must always overrule the other two. For example, suppose a 20-foot apparatus case stub in a particular metropolitan repeater section indicates a design number of 0.005. Even if past performance history and maintenance procedures warrant a design number of 0.00025, the larger number, 0.005, must be applied to the repeater section.

3.15 T1/OS engineering rules (Section 855-351-200) are derived from the end-to-end line design objective that at least 95 percent of properly engineered and installed lines will have an error rate less than 10^{-6} . Studies have shown that an appropriate method for engineering long T1 lines is to assign the same error rate objective, 10^{-6} , to each repeater section. The probability of exceeding this error rate is then allocated on a section-by-section basis. For T1/OS, allocate $(100 - 95)$ percent = 5 percent to the system length. Maximum length for T1/OS is 200 properly designed repeater sections; hence, each repeater section shall have a maximum probability of $5 \text{ percent} / 200 = 0.025$ percent of exceeding a 10^{-6} error rate. Therefore, a design

number of 0.00025 should be assigned to each T1/OS span.

3.16 T2 is a medium-haul (up to 500 miles) facility using dedicated LOCAP cable that has been pretested for crosstalk properties. This makes the probability very low that a T2 line has an error rate greater than 10^{-6} . The present guideline for connecting T2 spans in tandem with T1C is to assign a design number of 0.002 per 100 miles of T2 up to a maximum of 0.01 for 500 miles. Present indications are that the design risk on T2 is less than these figures indicate; however, for a medium-haul transmission facility such as T2, these are appropriate values to use in planning.

3.17 For T1D a terminal-to-terminal design number of 0.05 is required. It is assumed that the probability of the terminal-to-terminal error rate exceeding 10^{-6} is equal to the sum of the probabilities of the various repeater section error rates exceeding 10^{-6} . Depending on the type of cable and configuration used, repeater sections engineered according to the T1D engineering rules of Section 855-351-115 may be assigned the design numbers shown in Table Q.

C. Span Engineering Considerations

3.18 There are three types of spans which make up a T1C digital line: powering span, maintenance span, and protection span (Fig. 19). A powering span is the total of all lines between two central offices from the ORB in one office to the ORB in another office, with no intervening office with ORBs. A maintenance span consists of one or more contiguous powering spans which can be fault located from the DSX-1C or ORB (fault-locate pair terminated at both ends). A protection span consists of one or more contiguous maintenance spans for which both ends terminate at an automatic protection switch. When engineering a span, consideration must be given to both the short-term and long-term effects of the particular configuration selected. On a route with rapid growth and large cross section, a two-cable installation provides more capacity and has more margin. On a route with large voice-frequency demand and a slower carrier growth rate, a one-cable T1C installation would provide greater flexibility. However, on a maximum length repeater section it would have somewhat less margin when filled with T1C lines than would a two-cable installation.

3.19 When engineering a span, the following factors must be taken into consideration: cable age, number of times the splice closure has been entered, cable environment, manhole congestion, required capacity, and repeater section lengths. The prime limiting factors that control the engineering of a digital line are cable loss, crosstalk, and central office switching noise. Excessive splice entries will endanger proper operation; therefore, engineering should be done for the next 2 to 5 years and the proper number of pairs installed all at once for that period, with a minimum of 100 pairs per cable per entry, especially with pulp cable.

3.20 Route junctions of T1C cables are not permitted but there may be one instance where a "branch" may be tolerated. This occurs when express pairs are found in the same cable with terminal pairs. This is explained in detail in paragraph 2.36.

D. Repeater Section Engineering

3.21 In a T1C repeater section, the maximum allowable cable loss measured at 1.576 MHz and referred to 55°F is 52.8 dB. **Higher loss pairs cannot be used.** A section of 22-gauge copper pulp insulated cable designed as 6100 feet would have a loss of 48.8 dB (see Table R). Route map inaccuracies have been allotted an additional 1.6 dB, and pair-to-pair loss variations have been allotted 2.4 dB. Adding these losses to the 48.8 dB of a nominal 6100-foot section yields the 52.8-dB limit. **When a mixed cable repeater section is unavoidable, the line repeater selection is dictated by the cable with the greatest loss. Never mix MAT or ICOT cable with other types.**

3.22 To ensure proper performance, the cable should be in good condition, with unit integrity maintained at each splice point. **T1C cannot function properly where wandering and split pairs occur.** If it appears that poor splicing procedures have been followed, all pairs in the cable should be checked. **Detailed instructions for testing and accepting cable pairs are found in Section 855-351-101.** Interstitial pairs cannot be used for T1C transmission. (For an exception, see paragraphs 3.51 and 3.52.) To minimize the effect of office switching noise and near-end, near-end (NE-NE) interaction crosstalk, T1C engineering rules prohibit the use of voice-frequency pairs in binder groups carrying T1C

signals. In one-cable operation the center units are reserved for T1C maintenance and other voice-frequency requirements. For two-cable and screened-cable when all units are used for carrier operation, a method has been developed for placing **nonswitched** voice-frequency maintenance pairs in units carrying T1C signals (see paragraph 3.35).

3.23 The maximum and minimum design length for a T1C repeater section for various cables is shown in Tables L and M. For economic reasons, such as reduced repeater inventory, a better choice for minimum length is 3380 feet on an intermediate section of 22-gauge copper pulp cable. By keeping all section lengths or equivalent loss greater than 3860 feet, only the long distance repeater codes need be stocked. In order to compare the measured cable loss [using the J98725AA pair loss test set (Section 103-494-104)] with an expected loss, the maximum average cable loss at 1.576 MHz is required. This is shown in Table R in dB/kft at 1.576 MHz.

3.24 To limit the effect of central office impulse noise, end sections are limited in length as shown in Tables L and M. This restriction is an actual cable length. A 12-dB artificial line in the office repeater does not affect this restriction. Thus, the loss will be higher than that associated with 4100 feet of cable. Since the office repeater adds the equivalent of 1500 feet of loss, engineering for the long repeater code is facilitated. Engineering end sections between 1490 and 4100 feet would allow use of the long repeater code and also place no restriction on the next repeater section for 22-gauge copper pulp cable. If end sections become too short (less than 2000 feet) the next section must be restricted in length. No section can exceed the combination of 4100 feet plus the length from the end of the section to the span termination in the central office. Only in isolated situations would this place any restriction on intermediate repeater section length.

E. Order-Wire and Fault-Locate Engineering Considerations

Order-Wire Line

3.25 An order-wire line is provided for communication between repeater locations in a span and between any repeater location within a span and the office repeater bay at either end of the maintenance span. The order wire is connected

to a subscriber line in one of the span terminating offices. In this way, any number can be dialed from the line repeater location, and in particular the testboard can be called at either span terminating office. Order wires in binder groups carrying T1C signals must employ the crosstalk suppression filter (described in paragraph 3.36) and cannot be connected to the switched network.

3.26 The order wire uses a loaded pair and has an appearance at each line repeater apparatus case location in the span as well as on the ORB and/or DSX-1C at each end of the maintenance span. An option is available to provide an order-wire terminal on the outside of the apparatus case, making it unnecessary to open the case to gain access to the order wire. Only one apparatus case requires this option at a line repeater location, since one order wire serves a span regardless of the number of span lines provided as long as separate cable routes are not involved.

3.27 Spans longer than approximately 12 miles on 22-gauge cable require an order-wire circuit where dc continuity is broken by the addition of dc blocking capacitors. In this way, talking and signaling battery can be supplied at the two ends, each serving half the span. Two pairs are provided in the input stub [479-type case (Fig. 20)] or output stub [818/819-type case (Fig. 21)] cable of the apparatus case for the order wire. Provisions have been made for mounting the blocking capacitors in the apparatus case. Engineering of the T1C order wire is covered in Section 855-350-107.

Fault-Locate Line

3.28 Arrangements are provided at the DSX-1C or the ORB for detecting faulty repeaters along the digital line. In the event of a digital line failure, alarms associated with the automatic protection switch (APS) and/or the terminals (eg, M1C and D-type channel banks) will be activated. Features have been incorporated to permit maintenance personnel at the terminal offices to determine quickly whether the failure is due to a terminal, APS, or to the digital line.

3.29 If the digital line is at fault and an APS is not provided, the digital line is patched to a backbone line. Measurements using the error detecting set at the DSX-1C or the ORB are then made to determine which maintenance span in the overall facility is in trouble. Service can then be

removed from the backbone line and placed on a maintenanceline. Measurements using the fault-locating set will generally locate the failed repeater or bad section of cable which must be replaced or repaired in the defective line. Slightly marginal lines or lines not sensitive to remote fault locating are further trouble sectionalized with a line bipolar error detector.

3.30 The fault-locating set applies a special test signal to the digital line, and the signal can be adjusted to the frequency of the narrow bandpass filter in a specific repeater apparatus case or ORB. The output of this filter is returned over a fault-locate pair to the ORB or DSX-1C where the test signal was applied. If the proper return signal is received, the repeater is known to be good.

3.31 Each ORB and apparatus case must be equipped with a 1068-, 1114-, or 1115-type filter. The **output** of all repeaters in an apparatus case or shelf pair in an ORB is coupled to the input of the filter. The output of the filter is bridged to the fault-locating pair. A loaded cable pair is used for fault locating. T1C fault-locate system engineering will generally result in different codes of filters in E-W versus W-E apparatus cases at the same repeater location when operating in a unidirectional mode.

3.32 A series of 12 filters, coded 1068, 1114, and 1115, A through M, and 12 filters coded 1068AA through AM are provided. Therefore, in passive fault-locate systems, the repeaters at 12 points can be connected to the same fault-locating pair. When an active fault-locate system is used, two groups of filters (up to a total of 24) can be connected to the same fault-locating pair. However, this involves a planned tip-ring reversal between groups. A separate fault-locating pair must be provided for each string of apparatus cases. If there are more than 12 repeater locations in a maintenance span, an active system should be used or a second fault-locating pair must be provided. An active system requires an ED-2C374 panel or J98725AJ powering module for access and power for the fault-locate pairs. Only one apparatus case at a repeater location should be bridged to the fault-locating pair. For engineering details of the fault-locate system, refer to Section 855-350-104.

3.33 Office repeaters should be included in the fault-locating plan. If an APS is not provided or the failed line is unidirectional, fault location

must be done in the direction of transmission of the digital line. Therefore, it must be done from terminal locations and/or repeater locations containing an ORB or DSX-1C.

Special Considerations for Maintenance Pairs (Fault Locate, Order Wire, Pressure Alarm, etc.)

3.34 As a general rule, the fault-locate, order-wire, and pressure alarm pairs should not share the same binder group with carrier pairs. They should be assigned to units with other VF pairs. For nonscreened one-cable operation, this segregation is easy to implement since the center units cannot be employed for T1C and thus are available for VF and/or fault-locate and order-wire pairs. A similar situation may exist for two-cable operation of T1C on large cross-section cable. The center units of these large cross-section cables may have high-loss pairs and should not be employed for T1C, unless the repeater section lengths have been reduced per paragraph 1.13, or the pairs have been tested satisfactorily. These center unit pairs are adequate for VF, fault-locate, and order-wire use. However, in two-cable operation employing smaller cross-section cables or screened cables where full-fill is desired, a dedicated binder group for fault-locate and order-wire pairs results in inefficient use of the cable. When this situation arises, two alternative solutions exist:

- (1) Use screened cables with extra pairs (odd count). These extra pairs can be used for fault locating and order wire, thus preserving the integrity of the T1C binder groups. **Screened cables do not have high-loss center units.**
- (2) A fault-locate or order-wire pair may share the same binder group with T1C pairs if a special crosstalk suppression filter is incorporated with each fault-locate or order-wire pair. This special filter is discussed in the following paragraphs.

Crosstalk Filter for T1C

3.35 For certain applications of the T1C digital line it is desirable to have the flexibility of operating order-wire, fault-locate, and pressure pairs in the same binder group with the digital lines. As an example, it is very inefficient to dedicate an entire binder group to a single order-wire and fault-locate pair in a small cross-section cable.

Unfortunately, when these pairs are placed in a binder group with digital lines, they act as within-unit tertiaries and become significant contributors of NE-NE interaction crosstalk. To alleviate this problem a filter is needed to isolate the input sides of the pairs from the output. Such a filter is the Delevan BP-3258 inductor assembly. The assembly consists of two inductors, one for each wire in the pair, enclosed in a plastic housing. One assembly is required:

- For each fault-locate, order-wire, and pressure alarm pair sharing a T1C binder group
- At each apparatus case, regardless of where (or if) the fault-locate or order-wire pairs are loaded.

3.36 The Delevan BP-3258 is installed in the *splice case* containing the apparatus case stubs and is spliced into the fault-locate and order-wire pairs either before the pairs loop into the apparatus case stub cable or after they loop out of the stub cable. The order-wire pair loops in and out of the "in" stub (479-type case) or "out" stub (818/819-type case) and the fault-locate pair loops in and out of the "out" stub (479-type case) or "in" stub (818/819-type case). Installation procedures and recommendations are provided in Section 640-527-211 (479-type case) and Section 640-525-307 (818/819-type case). The BP-3258 inductor can be used in all installations where T1C crosstalk suppression filtering is required.

3.37 An alternative exists to the inductor assembly described above for T1C routes using 479 and 819 (protected) and 479 and 818 (unprotected) apparatus cases if the fault-locate and order-wire pairs are loaded in the apparatus case. The alternative utilizes two plug-in networks, coded 4269A and 4270A. These networks combine loading coils and filtering inductors into one plug-in unit. Using this method, loading and filtering are accomplished with one plug-in unit by plugging the proper network into the coil slot of the apparatus case. The 4270A network is for use in the 479 and 819 (protected) apparatus case and the 4269A network is used in the 479 and 818 (unprotected) apparatus case. The 4269A and 4270A networks each consist of two 662 loading coils, four KS-20927, L29 inductors, and a metal faceplate mounted on a printed wiring board and housed in a metal can. Gold-plated fingers on the printed wiring board provide the means of connection in the apparatus

case. The board has provisions for the addition of capacitance buildout of the cable pairs as in the 184A1 and 184B1 coil cases. The two networks are the same except that the 4270A is 1.5 inches longer than the 4269A. This network alternative does not apply to pressure alarm monitoring pairs which must always be filtered using the BP-3258 filter, nor does it apply to fault-locate and order-wire pairs which are not loaded in the apparatus cases. Each BP-3258 filter, 4269A network, and 4270A network adds 2 millihenries inductance and 10 ohms dc resistance to the maintenance pairs which should be considered, particularly in the design of long fault-locate and order-wire lines.

3.38 The use of pairs from binder groups intended for digital line use implies the loss of one or more slots per apparatus case. If filled cable is employed, additional pairs (and occasionally, slots) must be vacated for the apparatus case pressure alarm. Only one pressure alarm pair is needed for the entire cable. This can be an interstitial pair. The filter for the pressure alarm pair must be located in the splice case if no interstitial pair is available. The unused T1C slots propagate throughout the facility (eg, ORB, M1C, etc). In addition to loss of capacity, this arrangement leads to administrative complexities.

3.39 *This special allowance for fault-locate pairs and order-wire pairs sharing the same binder group with T1C does not apply to switched VF pairs.* Switched VF pairs must never share the same binder group with T1C pairs due to the impulse noise they introduce. However, special procedures will allow order-wire dialing by shielding of the order-wire pair between the MDF and the order-wire panel in the ORB or DSX-1C. The shielding requirement applies to any fault-locate and order-wire pair in a binder group or office tip cable. At line repeater locations, dialing transients are suppressed by the application of the BP-3258, 4270A, or 4269A crosstalk filters. These filters must be installed as shown in Fig. 20 or 21, based on the type of apparatus case used and the location of the fault-locate and order-wire pair loading. Figures 20A and 21A illustrate an installation in which the order wire is loaded in the 479- and 818/819-type apparatus cases, respectively, and either a 4269A or 4270A filter is employed. The filter is located on the RW pair and the input side of the order-wire terminal. Figures 20B and 21B illustrate the order wire as loaded externally and a through connection made

in the apparatus case. Then the BP-3258 filter is located in the splice case on the input side of the binder group and order-wire terminal.

T1C Engineering Rules for Use of VF Circuits on MAT and ICOT Cable

3.40 The T1C engineering rules regarding the use of VF pairs within a MAT or ICOT cable multiunit are as follows:

- (1) If the crosstalk suppression filter is employed, only maintenance (fault-locate, order-wire, etc) pairs are permitted within a 25-pair unit carrying T1C digital lines.
- (2) If the crosstalk suppression filter is not employed, VF maintenance pairs are permitted within a **100-pair multiunit** cable carrying T1C as long as the T1C pairs and maintenance pairs are segregated into separate 25-pair units. For example, one 25-pair unit of a multiunit cable may be reserved for maintenance requirements while the remaining three 25-pair units are reserved for T1C pairs.
- (3) No VF pairs, other than the T1C maintenance pairs as described above, are permitted within a 100-pair multiunit carrying T1C digital lines.
- (4) Only nonswitched order wires may be employed in 25-pair units or 100-pair multiunits containing T1C digital lines (except as defined in paragraph 3.39).

Note: These three rules apply only when maintenance pairs are located within the T1C units of a MAT or ICOT cable. The rules are not applicable when dedicated "maintenance pairs" (extra pairs located within each MAT and ICOT cable sheath) are used for maintenance requirements.

F. Determination of One-Cable or Two-Cable Operation

3.41 A major factor in determining whether to use a one- or two-cable T1C configuration on an existing T1 route is the configuration of the existing T1 cable. If T1 is being used in a one-cable mode, the transition to T1C would generally be easier if one-cable operation is continued. T1C can operate with a maximum of 200 lines (see paragraph 1.15) in a one-cable mode using 1100-pair

cable or 250 lines in a 1200-pair cable. In low growth areas where apparatus cases have been installed as needed, there has been a slight initial cost advantage for one-cable T1 operation because only one apparatus case was required at each line repeater location.

3.42 For routes with small cross sections, two-cable or screened-cable operation will generally be required since one-cable T1C operation is not permitted in cables with fewer than 900 pairs. In metropolitan areas, where VF demand dictates installation of new cable in short time intervals, T1C can be economically used in either one- or two-cable configurations. If there is no strong reason for using one-cable operation, then two-cable operation should be used because of the additional margin available in that configuration.

G. Splicing Considerations for One-Cable Operation

3.43 An important factor in engineering T1C is the selection of units for one-cable operation. In order to ensure meeting performance objectives when operating in the one-cable mode, two or three units of separation must be maintained between units carrying opposite directions of transmission. Refer to Fig. 4, 5, and 6. Since the spatial relationship between units of the outer and inner cable rings can vary, T1C one-cable operation is confined to use of the outside units (Fig. 4). However, in some situations additional T1 lines can be added in the middle rings (Fig. 5 and 6).

3.44 Care must be taken to ensure that unit integrity is maintained when splicing cable sections together. Effort should be made to maintain the correct spatial relationship of units in a splice. At the T1C line repeater locations, where high- and low-level signals have a common exposure in a splice closure, the low-level signals should be shielded by foil wrap or metallic tape to provide isolation. (See Fig. 22 and 23.) Low-level signals in any splice within 1000 feet of a line repeater must be shielded (see Note). High- and low-level T1C signals may not be carried in a cable sheath simultaneously unless there is a minimum separation of two or three units between them. This is necessary to keep NEXT exposure at an acceptable level. ***Thus, for one-cable T1C operation, it is necessary that, for each direction of transmission, all low-level T1C signals be removed from the line before any regenerated high-level T1 or T1C signals***

in the same direction are reinserted. (See paragraph 3.01.) For additional information on the apparatus cases, refer to Sections 640-527-107 and 640-527-211 (479-type) or Section 640-525-307 (818/819-type).

Note: Shielding of low-level signals in splices within 1000 feet of an office repeater is **not** required due to the presence of a 12-dB artificial line in the transmit side of all T1C office repeaters. This 12-dB artificial line is equivalent to about 1500 feet of 22-gauge cable. Therefore, any splices, including those in the cable vault, are effectively beyond the critical 1000-foot range of the office repeater.

H. Splicing Considerations for Bidirectional Operation

3.45 Bidirectional operation of T1C is presently limited to a maximum of 400 pairs (8 apparatus cases) if standard mechanical splice closures are used. This limit occurs because of the need to splice all apparatus case stubs to the main cable within a single splice case as shown in Fig. 24A. At present, a 2D splice closure will accommodate one main thru-cable and eight stub cables in grommets. Multiple splice closures, as shown in Fig. 24B, introduce near-end crosstalk (NEXT) and are not allowed.

I. Splicing Considerations for Two-Cable Operation

3.46 Splicing rules for two-cable operation are very similar to those for one-cable operation. Unit integrity must be maintained at all splices. T1C and VF pairs are not allowed in the same unit. (See paragraph 1.13.) If high- and low-level signals appear in the same splice closure, the low-level signals must be shielded with foil or metallic tape. Some common situations involving combined T1C/T1 operations are shown in Fig. 25, 26, and 27. High- and low-level signals cannot appear in the same sheath unless there are two or three units of separation between them. To ensure that this requirement is met, all low-level signals must be taken off the cable before any high-level signals are reinserted. This approach is made easier because the T1C apparatus case has two stubs, one for incoming low-level signals and one for regenerated high-level signals, and there is no inherent length restriction on the stubs. The only length restriction is that on the entire repeater section length. Thus, when splicing the first T1C apparatus cases for two-cable operation, the incoming

signals should be removed from the cables as close as possible to the cable entrance into the manhole. The regenerated signals should be reinserted as close as possible to the cable exit from the manhole. This will provide flexibility for later additions of T1C cases between two original splice access points (see Fig. 18).

3.47 When T1 and T1C digital lines coexist in the same cable, and apparatus cases are spliced in tandem as shown in Fig. 25 and 26, there is the potential for another type of crosstalk exposure. That is, regenerated (high-level) T1C signals could be reinserted into the main sheath prior to regenerating T1 signals in the same direction. The result is a FEXT exposure between high-level T1C signals and low-level T1 signals in the same direction. This is similar to the FEXT exposure presently encountered in T1 digital lines when cascaded splice cases are employed. For example, in Fig. 28 there is an unequal level FEXT exposure between splice case 2 and 3 because high-level regenerated T1C signals are being transmitted in the same direction as low-level unregenerated T1 signals. The existing T1 engineering rules specify that for T1 lines coexisting in the same binder group (within unit) the maximum length allowed for the FEXT exposure is 10 feet (ie, regenerated T1 signals can be inserted into the main sheath 10 feet prior to the point where unregenerated T1 signals are removed from the sheath). For T1 digital lines in adjacent binder groups, the maximum length allowed for the FEXT exposure is 40 feet. For T1 digital lines in nonadjacent binder groups the maximum length allowed for the FEXT exposure is 60 feet (see Section 855-351-101). The preceding engineering rules for T1 are also applicable to T1C when high-level T1C signals coexist with low-level T1 signals in a FEXT exposure as shown in Fig. 28.

3.48 When high- and low-level T1C signals are “stubbed-out” from the main sheath to an auxiliary splice case (which may be in an auxiliary manhole), as shown in Fig. 29, there is a NEXT exposure identical to that found in the main sheath on one-cable operation. In order to minimize that exposure, the T1C engineering rules for one-cable operation must be followed:

- Use a 900- or 1100-pair stub cable and maintain two binder groups of separation between low-level and high-level pairs.

either a looping line repeater or by a looping office repeater. In this configuration each office repeater in a bay represents one complete, independent power loop.

3.62 For unidirectional operation, however, the power loops are more complex as shown in Fig. 32 and 33. Each loop is composed of the same elements as for bidirectional operation, but pairs of loops share the office repeaters at each end. Examination of Fig. 32 and 33 will show that each loop starts at the regulator output of one office repeater (-), goes through one side of each line repeater, through both looping office repeaters (or a looping line repeater), returns through the other side of the same line repeaters, and reaches battery return (+) through the other regulating office repeater. Thus, each power loop passes through all of the office repeaters. The two office repeaters in each office appearing in a power loop are called power mates. Both must be installed to have either power loop complete. For unidirectional operation the J98725A through F office repeater bays (ORBs) are arranged with groups of 4 shelves (50 repeaters) which comprise 25 power mate pairs of 50 two-way lines (see Fig. 35). Power mates appear in shelf positions of the same number separated by one shelf. Shelf numbering starts at the bottom of the ORB and proceeds upwards; thus shelf 1, position 1, and shelf 3, position 1, are power mates as are shelf 5, position 1, and shelf 7, position 1, etc. The lower shelf repeater powers the receive line repeaters and the upper shelf repeater powers the transmit line repeaters. Lower shelf lines transmit and receive through side 1 of the line repeaters while upper shelf lines use side 2.

3.63 This somewhat complex arrangement is necessary with unidirectional line operation to limit the service outages should a repeater fail. Each line repeater involves only the power loop which powers it. Thus a line repeater can be removed and only affect two 1-way transmission paths (for the moment, ignoring the simplex powering of office repeaters). The result is a minimum of patching required in most maintenance and restoral operations. It should be noted, however, that removal of one office repeater in either end of a loop will affect all four 1-way transmission paths since it breaks both power loops of the power mate pair. ***It should also be evident that the same battery voltage must be used to power both repeaters of a power mate***

pair, since each loop starts in one repeater and ends in the other.

Office Repeater Options

3.64 Office repeaters contain two sets of option selectors, one for regulator options (present only on regulating codes) and one for repeater powering options. The regulator option selectors are configured for the particular voltage supplies chosen to power the span (see Table S), while the repeater powering options are chosen to power the office repeater regenerator either from the local -48 volt supply or in series with the simplex line current. Table T summarizes the repeater powering option choices which are accomplished by turning down the indicated screws with all others up two turns. For bidirectional operation the choice of options depends only on whether it is a regulating or looping repeater and whether it is locally or series powered. For unidirectional operation, however, the choice is more complex.

3.65 The two office repeater power mates on one end of a unidirectional loop require different option selections to configure them correctly. When the office repeaters are to be locally powered, the options are B, E, H, and N for the lower shelf power mate and A, F, H, and N for the upper shelf. However, if the office repeaters are to be powered in series with the simplex loop, as recommended, there are two options to choose from for the lower shelf power mate, B, D, and G or C, E, and K. The upper shelf is always A, G, and M when series powered (***the two repeaters of a power mate pair at the same end of the loop should be powered the same, either both locally or both in series***). The reason for the choice between B, D, and G and C, E, and K for the lower shelf and the implications of the choice on power loop calculations will be detailed below.

3.66 The significance of the choice between B, D, and G and C, E, and K can be understood by careful examination of Fig. 32 and 33. The A, G, and M option in the upper shelf repeater always puts that repeater power supply in series with the power loop which powers the receive line repeaters (receive power loop, powered by the regulator in the lower shelf). In the lower shelf repeater, the C, E, and K option puts that repeater power supply also in series with the receive power loop, while the B, D, and G option puts it in the

transmit power loop (powered by the regulator in the upper shelf). From a transmission standpoint, it is desirable to have both office repeaters powered by the receive power loop so that removal of a transmit line repeater, which breaks that power loop, will not rob power from the office repeaters and interrupt receive transmission. This would indicate the use of the C, E, and K option. The B, D, and G option is offered, however, because it minimizes the difference between the transmit and receive loop resistances when series powering is used at one end of a loop and not at the other or when a line repeater looping point is used. This can be important when choosing the office supply voltage since both loops must use the same voltage. The choice between B, D, and G and C, E, and K, therefore, breaks down to whether it is more desirable to minimize the patching required when a line repeater is replaced (C, E, and K) or to minimize the difference between transmit and receive loop resistances (B, D, and G). Table U will clarify this choice. It should be noted that unequal loop resistances will result in different loop voltages between power mates. The combination of B, D, and G at one end of a loop and C, E, and K at the other results in neither of the above benefits and is therefore not recommended.

Battery Voltage Selection

3.67 The procedure for selecting the proper battery voltage to power a loop involves calculating the maximum and minimum total loop resistance, R_{LMAX} and R_{LMIN} . These can be calculated from the cable and repeater resistances using the formula,

$$R_{LMAX} = R_{CMAX} + R_R$$

$$R_{LMIN} = R_{CMIN} + R_R$$

R_R is the total resistance of all repeaters in the loop while R_{CMIN} and R_{CMAX} are the cable resistances at low and high temperature extremes. Cable resistances are determined from the following formulas:

$$R_{CMAX} = \text{Cable Length (kft)} \times R_{MAX} \times [1 + .0022 (T_{MAX} - 68^\circ F)]$$

$$R_{CMIN} = \text{Cable Length (kft)} \times R_{MIN} \times [1 + .0022 (T_{MIN} - 68^\circ F)]$$

Where R_{MAX} and R_{MIN} depend on cable gauge and material and are given in Table V, T_{MAX} and T_{MIN} are the maximum and minimum temperatures which the cable will experience. The total repeater resistance for a loop, R_R , is calculated by adding up the resistance of each repeater in that loop. The suggested way to do this is to sketch out the particular loop as is done in Fig. 31, 32, and 33 to "walk along" each loop, starting at the powering office repeater regulator and stopping at the looping point. The resistance of each repeater walked through (Tables W and X) is added to get the total repeater resistance for the loop, R_R . The resistance of an office repeater will depend on the options used in that repeater (and sometimes the options in its power mate) and whether it is a powering or looping repeater. The resistance of a line repeater depends on whether it is protected or unprotected, whether it is at a through or looping location, and if looping, whether the loop includes the side 1 input or side 1 output. Each repeater in a loop is counted only once, but when a looping line repeater is used, it is counted once in each of the two power loops involved. When a unidirectional line has the same option at both ends or with B, D, and G/A, G, and M at one end and B, E, H, and N/A, F, H, and N at the other, the two power loops are symmetrical and the loop resistance will be the same for both loops (if cable resistances are the same). Use of a looping line repeater, however, results in different resistances for the two loops and each must be calculated separately. In bidirectional lines each loop is the same as all of the others in that span.

3.68 Minimum and maximum cable resistances (R_{CMIN} and R_{CMAX}) are added to R_R to determine minimum and maximum loop resistance (R_{LMIN} and R_{LMAX}), using the formula given previously. Both R_{LMAX} and R_{LMIN} must fall within the range of allowable R_L for the battery voltage used to power the loop (see Table S). When the two loops of a unidirectional power mate pair result in different R_L values, the values for both loops must fall within the range of allowed R_L for a single battery voltage, since the same voltage must be used on both loops. Once a voltage is chosen, the proper regulator options can be determined from Table S. ***A power loop is most efficient and the power dissipated in the ORB is minimized when R_{LMAX} is as close as possible to the maximum R_L allowed for the battery***

voltage used. The lowest battery voltage which will power a loop should always be used.

3.69 When using the J98725J, L2 or L3, express office repeater panel, the EORP is considered the same as a line repeater location for the purposes of calculating loop resistance except for the following consideration. The EORP contains line build-out (LBO) circuits on the repeater inputs and outputs, and the resistance of these must be added to the resistance of the line repeater used. These LBOs add a total of 36 ohms to the through resistance value for the line repeater from Tables W and X or 18 ohms to each of the side 1 in and side 1 out loop resistances.

3.70 Consideration of 60-Hz induced currents must be given when designing standard power (218, 219, and 220 codes) T1C power loops. Low power (248, 249, and 250 codes) loop designs are not affected by induced currents up to 100-mA rms. Standard power loops require a reduced range of allowable loop resistance for more than 10-mA rms and cannot operate with more than 30-mA rms. The reduction of allowable loop resistance for standard power designs with induced currents of 0- to 30-mA rms is shown in Table S and must be applied when choosing the battery voltage to be used to power the span.

ORB Options

3.71 Each ORB must be optioned correctly, depending on which powering options are chosen for the repeaters in that bay. Power dissipation units (PDUs) must be inserted into the shelf at the top of the ORB if 220A-type standard power (or 220AA improved standard power) regulating repeaters are used with battery voltages greater than 48 volts. ED-3C554-30, G1 PDUs are used with J98725A, B, and C bays while ED-3C741-30, G1 are used with J98725D, E, and F bays. Low-power 250A regulating repeaters do not require PDUs, but for safety reasons 292A plug-in adapters should be installed or option P should be wired into the ORB. When 220B or 250B looping office repeaters are used in the ORB for unidirectional operation, option W must be provided in that ORB.

Example Calculation

3.72 An example of a power loop calculation for low-power T1C unidirectional operation shown

in Fig. 36 will be given. Cable resistance will be the same for both loops:

$$R_{CMAX} = \text{Cable Length (kft)} \times R_{MAX} [1 + .0022 (T_{MAX} - 68^{\circ}F)]$$

$$R_{CMIN} = \text{Cable Length (kft)} \times R_{MIN} [1 + .0022 (T_{MIN} - 68^{\circ}F)]$$

$$R_{CMAX} = (3.600 + 5.900 + 6.000 + 5.800) 16.7 [1 + .0022 (100 - 68)]$$

$$= (21.3) 16.7 (1.07) = 381 \text{ ohms}$$

$$R_{CMIN} = (3.600 + 5.900 + 6.000 + 5.800) 16.1 [1 + .0022 (30 - 68)]$$

$$= 21.3 (16.1) (.916) = 314 \text{ ohms.}$$

Repeater resistances will be different, however:

	TRMT LOOP	RCV LOOP
250A (CEK/AGM)	28	394
248A (Thru, X3)	318	318
248A (Loop)	<u>105</u>	<u>1</u>
R _R (Total)	451	713
R _{LMAX} (R _R + R _{CMAX})	832	1094
R _{LMIN} (R _R + R _{CMIN})	765	1027

Since both 765 and 1094 must fit within the range for the battery voltage chosen, the only possibility is 130 volts. Thus, regulator options X and Z would be chosen.

Note: This looping point may not be the optimum looping point. Therefore, calculations may have to be performed a number of times before finding the optimum looping point.

Calculation of Voltage Limits

3.73 In order to provide information for the evaluation of the power loop performance, minimum and maximum values for both line voltage and regulator voltage should be calculated for each

power loop. Line voltage can be calculated from the equations below:

$$V_{LMAX} = R_{LMAX} \times I_L$$

$$V_{LMIN} = R_{LMIN} \times I_L$$

R_{LMAX} and R_{LMIN} are the values for line resistance calculated previously and I_L is the value of line current (60 or 120 mA). Regulator voltage limits are a bit more complex but can be calculated as follows:

$$V_{RMAX} = V_{BMAX} - [(V_{LMIN} + 6.2) + (I_L \times R_x)]$$

$$V_{RMIN} = V_{BMIN} - [(V_{LMAX} + 8.5) + (I_L \times R_x)]$$

Values for V_{BMAX} and V_{BMIN} (office battery voltage limits) and for R_x (miscellaneous bay resistances) are given in Table Y. Once these voltage values are calculated, a record should be made of them on Form E-10604 for use in initial installation testing, periodic maintenance routines, and trouble isolation procedures.

Use of Calculated Limits

3.74 Initial installation and periodic maintenance procedures should require that the power loop measurements be within these limits. If at any time the limits are not met, trouble isolation procedures should be implemented. In new installations, engineering reevaluation may be called for.

3.75 Even though operation within these limits is necessary for a good power loop, it is not, however, sufficient to guarantee that the loop is operating properly. When a power loop problem is suspected because of a transmission failure, one further procedure is useful. Both line voltage and regulator voltage can be measured on all repeaters within a shelf-pair (maximum of 25). The values measured on the suspected line should not deviate more than ± 4 percent from the average of all good lines in the shelf-pair. If there is a significant difference, such problems as a shorted line-repeater power supply diode or a pair-to-ground short may be present. These trouble conditions will often not cause enough shift in voltage measurements to make them fall outside the MIN and MAX limits.

3.76 It should be noted, however, that records of actual measurements made at some time

in the past can be misleading. The operating voltages of lines in a shelf-pair can change significantly with time or temperature, and yet all may still be working properly. Unless trouble is suspected, the only valid requirement is operation within the calculated MIN and MAX values which are valid for all times and temperatures.

4. MAINTENANCE CONSIDERATIONS

4.01 T1C digital lines require standardized procedures for maintenance, which is essentially the same as that for T1 with respect to trouble isolation and fault location [Section 365-271-000 (TOP)]. Apparatus case slot 25 from each span is designated as the maintenance or protection line. Other specific pairs are required to support the pressure alarm, fault-locating, and order-wire needs. Engineering rules for the T1C fault locate and order wire are given in Sections 855-350-104 and 855-350-107.

4.02 It must be kept in mind that voice communications are required between the ORB, DSX-1C, other maintenance locations in the building, and to other central offices. This requirement is the same as for T1 digital lines in Section 855-351-101.

4.03 Seven test sets are required for T1C, six of which can serve both T1 and T1C:

(1) J98725AA Pair Loss Test Set—This battery-powered set measures the loss of a conductor pair at 650 or 1300 kHz, between adjacent line repeater locations, and between the ORB and the first line repeater location. This loss information is taken before repeater installation and is used to select fixed line build-out (LBO) networks in older T1 digital lines and to ensure adequate range in the automatic line build-out (ALBO) network in newer T1 and T1C digital lines. Comparisons from pair to pair allow out-of-limit pairs to be identified for troubleshooting. Connecting adapters allow the set to be used in the ORB as well as in all T1 and T1C apparatus cases. Apparatus case adapters are furnished with the set but ORB adapters must be ordered separately. This set has dc testing capability and should be used when doing pair loss measurements. (See Section 103-494-104.)

(2) J98725AB Manhole Bipolar Violation Detector—This portable, battery-powered set

is used to troubleshoot suspected failed line repeaters, either confirming a remote fault-locating diagnosis or determining the location of a marginal repeater. It also indicates the presence or absence of a valid signal. Its plug-together construction allows its use in either the 466, 468, 475, or 818/819 T1 apparatus cases or the 479 or 818/819 T1C apparatus cases. The set is supplied with adapters in a ruggedized case. (See Section 103-494-101.)

(3) J98725AC Office Bipolar Violation Detector—This is an office test set, powered from the -48 volt dc supply, and is used for in-service performance testing, including an indication of the presence or absence of a valid signal. The violation counter can be stopped after a preset time, up to two hours, with a built-in electronic timer to help isolate marginal lines. The counter counts either violations or violation seconds. (See Section 103-494-100.)

(4) J98725AD Fault-Locate Test Set— This set, powered by the -48 volt office supply, is used to isolate defective repeaters. Bipolar violations are introduced in a variable density bit stream at an audio rate. The audio tone is returned to the office from a line repeater location via a fault-locating filter and a loaded pair in the cable. The transmitter and selective receiver are contained in one package with all tuning fixed by switch positioning. This set has dc testing capability to perform dc tests on the line before attempting actual fault location of a defective repeater. (See Section 103-494-106.)

(5) J98725AJ Fault-Line Powering Module—This portable ac-to-dc converter is used for powering an active fault-locate line and the associated fault-locate test set. The powering module converts 117-volts alternating current to regulated 40- or 118-volts direct current for powering the fault-locate line and -48 volts direct current for powering the fault-locate test set. The powering module also contains a mounting and connection for testing an active fault-locate filter. (See Section 103-494-109.)

(6) J98725AF Quasi-Random Signal Source (QRSS)—This rack-mounted generator consists of two plug-in signal modules, each of which will provide up to 25 outputs of T1 or T1C, depending on the module. These outputs can be used to drive maintenance lines, protection

lines, or backbone lines. They can also be used to provide a test signal for trouble location or to drive idle lines during turnup. (See Section 103-494-105.)

(7) J98725AE Repeater Test Set—This benchtop test set measures the following T1C repeater performance parameters: power drain and leakage, external connector opens or shorts, automatic gain control range, output signal level, fault-locate signal output, and margins on equalization, thresholds, and timing. (See Section 103-494-103.)

4.04 One other test equipment item which may be used with T1C digital lines is the DS1/DS1C/DS2 error rate test set (KS-22331 transmitter and KS-22332 receiver). The transmitter and receiver are powered by 115-volts alternating current. They are operated independently and are contained in separate portable cabinets. The receiver can be used to make in-service bipolar violation measurements. Both the transmitter and receiver can be used to make out-of-service tests to check for bit errors or to perform error-second measurements. Refer to Section 103-493-120 for more detailed information on the DS1/DS1C/DS2 error rate test set.

4.05 The ED-3C584-30, G1 office repeater adapter is used with the J98725AE T1C repeater test set to test T1C office repeaters. It fits into the repeater testing slot of the test set and accommodates one T1C office repeater for testing purposes. The adapter consists of a printed wiring board, connector, wiring, and framework. A switch located on the adapter must be positioned according to the type of office repeater under test (bridging or nonbridging).

5. REFERENCES

5.01 The following drawings pertain to the T1C digital line:

DRAWING	TITLE
SD-3C205-01	218 and 219 T1C Line Repeaters
SD-3C377-01	248 and 249 T1C Line Repeaters
SD-3C252-01	T1C Office Repeater Bay, Application Schematic

		SECTION	TITLE
SD-3C371-01	T1C/T1 Office Repeater Bay (DSX Dedicated) Application Schematic		
		103-494-105	J98725AF T1C/T1 Quasi-Random Signal Source (QRSS)—Description, Operation, and Maintenance
SD-3C253-01	Office Repeaters Type 220 for T1C Digital Line		
SD-3C378-01	250 T1C Office Repeaters	103-494-106	J98725AD T1C/T1 Fault-Locating Test Set—Description and Maintenance
SD-3C254-01	T1C Digital Line Order-Wire Circuit		
SD-3C348-01	T1C/T1 Quasi-Random Signal Source	103-494-109	J98725AJ Fault-Line Powering Module—Description
SD-3C369-01	T1C Express Office Repeater Panel	365-000-010	Central Office Records—Description
		365-170-100	D4 Channel Bank—Description
SD-3C407-01	Office Repeater Type 220AA and 220AB for T1C Digital Line	365-225-500	T1 Digital Line—Routine Maintenance Tests
SD-3C408-01	T1C Digital Line 218AA Through 218AC and 219AA Through 219AC Line Repeaters	365-250-100	T1C Digital Line—General Description
SD-3C442-01	T1C Automatic Protection Switch	365-250-101	T1C Digital Line—Repeater Description
SD-99503-01	Patch and Cross-Connect Interconnection Circuit.	365-250-105	J98725J Express Office Repeater Panel (EORP)—Description, Operation, and Maintenance
5.02	The following Bell System Practices give additional information.	365-250-120	DS1C Automatic Protection Switch—Description
SECTION	TITLE		
103-493-120	DS1/DS1C/DS2 Error Rate Test Set (KS-22331,L1 and KS-22332, L1)—Description, Operation, and Maintenance	365-301-103	DSX-1/DSX-1C Bridging Repeater Panel—Description and Operation
103-494-100	J98725AC Office Bipolar Violation Detector—Description and Maintenance	365-325-100	J98725H Order-Wire Facility—Description
103-494-101	J98725AB T1C/T1 Manhole Bipolar Violation Detector—Description and Maintenance	365-604-100	M1C Digital Multiplex—General Description
103-494-103	J98725AE T1C Line Repeater Test Set—Description, Operation, and Maintenance	365-604-101	M1C Digital Multiplex Single Shelf—General Description
103-494-104	J98725AA Pair Loss Test Set—Description, Operation, and Maintenance	365-800-002	T1 Line—Routine, Acceptance, and Company Order Tasks (TOP)
		638-205-015	Fuse Cable Requirements
		640-525-307	818/819-Type Repeater Cases—Description, Installation, Splicing, and Maintenance

SECTION	TITLE
640-527-107	479-Type Apparatus Case—Description and Installation
640-527-211	479-Type Apparatus Case—Splicing and Maintenance
795-450-104	Digital and Analog Systems (Channel Group or Customer Interface Level)
855-350-104	T1, T1 Outstate, and T1C—Engineering Design, Fault-Locating System
855-350-105	DSX-1, DSX-1C, and DSX-2—New Installation
855-350-106	DSX-1 and DSX-1C Retrofit
855-350-107	T1, T1 Outstate, and T1C—Engineering Design, Order-Wire System Application
855-350-109	DS1/DS1C Engineering Design, Automatic Protection Switch (see Note)
Note: This section may not be available.	
855-351-101	T1 Digital Line—Transmission and Outside Plant Design Procedures
855-351-102	T1 Digital Line—Special Engineering and Design Considerations
855-351-115	T1D Digital Line—Transmission and Outside Plant Design Procedures
855-351-200	T1 Outstate Digital Line—Transmission and Outside Plant Design Procedures.

6. GLOSSARY

6.01 The terms in this glossary are defined relative to their T1C usage.

APPARATUS CASE—This is the housing for 25 T1C repeaters and an associated fault-locating filter.

AUTOMATIC PROTECTION SWITCH

(APS)—The T1C APS protects service by automatically transferring the T1C signal from a bad service line to a good protection line. When the trouble clears, the transmission is switched back to the original line. The switch can be commanded to set up a remote loop after a line has failed.

BIDIRECTIONAL OPERATION

—Repeater operation in which side 1 of the line repeater transmits in one direction and side 2 transmits in the opposite direction. In T1C bidirectional operation is achieved through special splicing arrangements of the apparatus case and/or EORP.

CABLE—The T1 medium is unitized, exchange grade, paired cable.

Two-Cable Operation—This implies that only one direction of transmission is carried in a cable sheath. Thus, two cables are required to provide both directions of transmission.

One-Cable Operation—This implies that both directions of transmission are carried in the same cable sheath.

Entrance Cable—This is the cable which comes into the cable vault from the outside. For T1C, the cable should have the same gauge, insulation, and layout from vault to vault.

Tip Cable—This is 50- or 100-pair cable which runs from the cable vault to the main distributing frame. For T1C this should be 22-gauge only.

Interstitial Pairs—These are extra pairs included in the cable at manufacture. They are between the units and are used to “make good” pairs that are damaged. They are not ordinarily used for T1C transmission but can be used for fault-locate and order-wire pairs.

Tertiary Pairs—These are cable pairs that are spliced through at T1C regeneration points. They provide a crosstalk path and hence are not permitted in the same unit with T1C.

Stub Cable—Two stub cables or a quad-screened stub connect the T1C apparatus case to the main cable. The 2-stub arrangement has 54 pairs. One stub carries the incoming low-level signals and the other carries the high-level regenerated signals. The quad-screened stub consists of four individually screened 25-pair units surrounding an 8-pair core.

CROSS-CONNECTION—The cross-connection provides access for patching and testing the T1C signal. For installations that will never exceed four ORBs, the cross-connection will be panel-mounted in the ORB. For larger installations, a centralized cross-connection must be configured by mounting the cross-connect panels for the various office repeater bays in one or more centralized bay (DSX). Advance planning is required to keep these bays in one continuous lineup.

DESIGN NUMBER—The probability that a T1 component (ie, section, span line, or facility) has an error rate greater than 10^{-6} is defined as the “design number” for that component. The design number for a series connection of components is the sum of the design numbers of those components, and must not exceed 5 percent. A T1C repeater section has a design number of 0.001 percent if properly engineered. Design numbers are also useful in defining rules for connecting T1C in tandem with T1, T1/OS, T1D, and T2.

FEXT (Far-End Crosstalk)—Crosstalk caused by signals transmitted in the same direction as the T1C signal.

MARGIN—This indicates how much the interfering noise power would have to increase, in dB, before the digital line would not meet its performance objective.

MULTIPLEX—The multiplex synchronizes the input signals and then time interleaves information, framing, and control bits into a 3.152 Mb/s signal.

MAINTENANCE SPAN—Consists of one or more contiguous powering spans which the fault-locate line terminates at both ends of the maintenance span.

NEXT (Near-End Crosstalk)—Crosstalk caused by signals transmitted in the opposite direction of the T1C signal.

POWER LOOP—Extends from the powering point (ORB) to the power-looping point.

POWERING SPAN—The total of all lines between two central offices from the ORB in one office to the ORB in another office, with no intervening offices with ORBs.

PROTECTION SPAN—Consists of one or more contiguous maintenance spans which both ends of the protection span terminates with an automatic protection switch.

REGENERATOR—The regenerator automatically builds out the line loss to the maximum allowable loss, equalizes and amplifies the signal, recovers timing, samples the equalized signal, and generates an undistorted replica.

REPEATER—The line repeater houses two regenerators, whereas the office repeater houses only one regenerator.

SECTION—A regenerative section consists of a line plus the associated regenerator and extends from the output of one regenerator to the output of the next regenerator.

SPAN LINE—A span line consists of the tandem connection of a number of sections and is terminated in the office repeater bays at both ends.

TABLE A
PAST STANDARD SCREENED CABLE

	EXISTING CABLE CODE	NEW CABLE CODE (EFF. JAN. 1, 1980)	STANDARDIZATION RATING (EFF. JAN. 1, 1980)	RECOMMENDED SUBSTITUTE (IF MFR DISC OR NSLA)	T1C COMPATIBILITY INFORMATION
PULP SCREENED CABLE	BDAC-300	—	Mfr Disc	—	N/A
	BDAC-400	—	Mfr Disc	—	N/A
	BDAC-600	—	Mfr Disc	—	N/A
	BDAC-900	—	Mfr Disc	—	Standard
	BDAC-1200	—	Mfr Disc	—	Standard
	BDAH-300	—	Mfr Disc	—	N/A
	BDAH-400	—	Mfr Disc	—	N/A
	BDAH-600	—	Mfr Disc	—	N/A
	BDAH-900	—	Mfr Disc	—	Standard
	BDAH-1200	—	Mfr Disc	—	Standard
	KDAC-600	KDAC-600	NSLA	MCMC-616	Standard
	KDAC-900	KDAC-900	NSLA	MCMC-922	Standard
KDAC-1200	KDAC-1200	NSLA	MCRC-1228	Standard	
KDAH-600	KDAC-600	NSLA	MCMH-616	Standard	
KDAH-900	KDAH-900	NSLA	MCMH-922	Standard	
KDAH-1200	KDAH-1200	NSLA	MCRH-1228	Standard	
WATERPROOF COPPER PIC SCREENED CABLE	BJAW-16	—	Mfr Disc	—	N/A
	BJAW-25	KJAW-25	NSLA	KJAW-28	N/A
	BJAW-50	KJAW-50	NSLA	KJAW-54	N/A
	BJAW-100	—	Mfr Disc	—	N/A
	BJAW-150	—	Mfr Disc	—	N/A
	BJAW-200	—	Mfr Disc	—	N/A
	BJAW-300	—	Mfr Disc	—	N/A
	BJAW-600	—	Mfr Disc	—	N/A
	CA-6076-W-100	KJAW-100	NSLA	KJAW-106	Standard
	CA-6076-W-150	KJAW-150	NSLA	KJAW-158	Standard
	CA-6076-W-200	KJAW-200	NSLA	KJAW-210	Standard
	CA-6076-W-300	KJAW-300	NSLA	KJAW-314	Standard
	CA-6076-W-400	KJAW-400	NSLA	KJAW-418	Standard
	CA-6076-W-600	KJAW-600	NSLA	KJAW-616	Standard
	BLAW-16	—	Mfr Disc	—	N/A
	BLAW-25	KLAW-25	Mfr Disc	KJAW-28	N/A
	BLAW-50	KLAW-50	NSLA	KLAW-54	N/A
	BLAW-100	—	Mfr Disc	—	N/A
BLAW-150	—	Mfr Disc	—	N/A	
BLAW-200	—	Mfr Disc	—	N/A	
BLAW-300	—	Mfr Disc	—	N/A	
BLAW-600	—	Mfr Disc	—	N/A	

TABLE A (Contd)
PAST STANDARD SCREENED CABLE

	EXISTING CABLE CODE	NEW CABLE CODE (EFF. JAN. 1, 1980)	STANDARDIZATION RATING (EFF. JAN. 1, 1980)	RECOMMENDED SUBSTITUTE (IF MFR DISC OR NSLA)	T1C COMPATIBILITY INFORMATION
WATERPROOF COPPER PIC SCREENED CABLE (Contd)	KLAW-100	KLAW-100	NSLA	KLAW-106	Standard
	KLAW-150	KLAW-150	NSLA	KLAW-158	Standard
	KLAW-200	KLAW-200	NSLA	KLAW-210	Standard
	KLAW-300	KLAW-300	NSLA	KLAW-314	Standard
	KLAW-400	KLAW-400	NSLA	KLAW-418	Standard
	KLAW-600	KLAW-600	NSLA	KLAW-616	Standard
	BJBW-16	—	Mfr Disc	Substitute	N/A
	BJBW-25	—	Mfr Disc	T-2 LOCAP	N/A
	BJBW-50	—	Mfr Disc	Cable	N/A
	BJBW-100	—	Mfr Disc	—	N/A
	BJBW-150	—	Mfr Disc	—	N/A
	BJBW-200	—	Mfr Disc	—	N/A
	BJBW-300	—	Mfr Disc	—	N/A
	BLBW-16	—	Mfr Disc	Substitute	N/A
	BLBW-25	—	Mfr Disc	T-2 LOCAP	N/A
	BLBW-50	KLBW-50	NSLA	Cable	N/A
	BLBW-100	KLBW-100	NSLA	—	N/A
	BLBW-150	KLBW-150	NSLA	—	N/A
BLBW-200	KLBW-200	NSLA	—	N/A	
BLBW-300	KLBW-300	NSLA	—	N/A	
AIR CORE COPPER PIC SCREENED CABLE	CA-6033-H, 50	—	Mfr Disc	—	N/A
	CA-6034-H, 50	—	Mfr Disc	—	N/A
	CA-6034-H, 100	—	Mfr Disc	—	N/A
	CA-6077-H, 100	KHAH-100	NSLA	KHAH-106	Standard
	CA-6077-H, 150	KHAH-150	NSLA	KHAH-158	Standard
	CA-6077-H, 200	KHAH-200	NSLA	KHAH-210	Standard
	CA-6077-H, 300	KHAH-300	NSLA	KHAH-314	Standard
	CA-6077-H, 400	KHAH-400	NSLA	KHAH-418	Standard
	CA-6077-H, 600	KHAH-600	NSLA	KHAH-616	Standard
	CA-6077-G, 100	KHAG-100	NSLA	KHAG-106	Standard
	CA-6077-G, 150	KHAG-150	NSLA	KHAG-158	Standard
	CA-6077-G, 200	KHAG-200	NSLA	KHAG-210	Standard
	CA-6077-G, 300	KHAG-300	NSLA	KHAG-314	Standard
	CA-6077-G, 400	KHAG-400	NSLA	KHAG-418	Standard
	CA-6077-G, 600	KHAG-600	NSLA	KHAG-616	Standard

TABLE A (Contd)
PAST STANDARD SCREENED CABLE

	EXISTING CABLE CODE	NEW CABLE CODE (EFF. JAN. 1, 1980)	STANDARDIZATION RATING (EFF. JAN. 1, 1980)	RECOMMENDED SUBSTITUTE (IF MFR DISC OR NSLA)	T1C COMPATIBILITY INFORMATION
WATERPROOF ALUMINUM SCREENED CABLE	BLCW-50	—	Mfr Disc	—	N/A
	BLCW-100	—	Mfr Disc	—	N/A
	BLCW-150	—	Mfr Disc	—	N/A
	BLCW-200	—	Mfr Disc	—	N/A
	BLCW-300	—	Mfr Disc	—	N/A
	BLDW-50	—	MS*	KLDW-54	N/A
	BLDW-100	—	MS*	KLDW-106	N/A
	BLDW-150	—	MS*	KLDW-158	N/A
	BLDW-200	—	MS*	KLDW-210	N/A
	BLDW-300	—	MS*	KLDW-314	N/A
	BLDW-400	—	MS*	KLDW-418	N/A
	BLDW-600	—	MS*	KLDW-616	N/A

* All aluminum cable was "Manufacture Suspended" as of October 1, 1977, due to significant decreases in the price of copper. Aluminum cable manufactured prior to that date is not suitable for full-fill T1C operation at maximum repeater spacings. Should aluminum cable manufacture be resumed in the future, system standard cable will be coded as above, will include service pairs, and will be suitable for full-fill T1C operation.

TABLE B

PRESENT STANDARD SCREENED CABLE

CABLE TYPE	CABLE CODE (NOTE 1)	TYPE CAPACITANCE	T1C COMPATIBILITY
ICOT (Air Core)	MCMC-54	Low	Standard
	MCMC-106	Low	Standard
	MCMC-158	Low	Standard
	MCMC-210	Low	Standard
	MCMC-314	Low	Standard
	MCMC-418	Low	Standard
	MCMC-616	Low	Standard
	MCMC-922	Low	Standard
	MCMH-54	Low	Standard
	MCMH-106	Low	Standard
	MCMH-158	Low	Standard
	MCMH-210	Low	Standard
	MCMH-314	Low	Standard
	MCMH-418	Low	Standard
	MCMH-616	Low	Standard
	MCMH-922	Low	Standard
MAT (Air Core)	MCRC-412	Low	Standard
	MCRC-616	Low	Standard
	MCRC-1024	Low	Standard
	MCRC-1228	Low	Standard
	MCRC-1432	Low	Standard
	MCRC-1840	Low	Standard
	MCRH-412	Low	Standard
	MCRH-616	Low	Standard
	MCRH-1024	Low	Standard
	MCRH-1228	Low	Standard
	MCRH-1432	Low	Standard
	MCRH-1840	Low	Standard
PIC (Air Core)	KHAG-28	Standard	N/A
	KHAG-54	Standard	N/A
	KHAG-106	Standard	Standard
	KHAG-158	Standard	Standard
	KHAG-210	Standard	Standard
	KHAG-314	Standard	Standard
	KHAG-418	Standard	Standard
	KHAG-616	Standard	Standard

Note 1: All ASP sheathed cables are also available with UM protection with the exception of MLMW-922.

TABLE B (Contd)

PRESENT STANDARD SCREENED CABLE

CABLE TYPE	CABLE CODE (NOTE 1)	TYPE CAPACITANCE	T1C COMPATIBILITY
PIC (Air Core)	KHAH-28	Standard	N/A
	KHAH-54	Standard	N/A
	KHAH-106	Standard	Standard
	KHAH-158	Standard	Standard
	KHAH-210	Standard	Standard
	KHAH-314	Standard	Standard
	KHAH-418	Standard	Standard
	KHAH-616	Standard	Standard
ICOT (Filled)	MLMW-54	Low (ICOT)	Standard
	MLMW-106	Low (ICOT)	Standard
	MLMW-158	Low (ICOT)	Standard
	MLMW-210	Low (ICOT)	Standard
	MLMW-314	Low (ICOT)	Standard
	MLMW-418	Low (ICOT)	Standard
	MLMW-616	Low (ICOT)	Standard
	MLMW-922	Low (ICOT)	Standard
PIC (Filled)	KJAW-28	Standard	N/A
	KJAW-54	Standard	N/A
	KJAW-106	Standard	Standard
	KJAW-158	Standard	Standard
	KJAW-210	Standard	Standard
	KJAW-314	Standard	Standard
	KJAW-418	Standard	Standard
	KJAW-616	Standard	Standard
DEPIC (Filled)	KLAW-54	Standard	N/A
	KLAW-106	Standard	Standard
	KLAW-158	Standard	Standard
	KLAW-210	Standard	Standard
	KLAW-314	Standard	Standard
	KLAW-418	Standard	Standard
	KLAW-616	Standard	Standard

Note 1: All ASP sheathed cables are also available with UM protection with the exception of MLMW-922.

TABLE C
ORDER-WIRE, PRESSURE ALARM, AND FAULT-LOCATE
PAIR ASSIGNMENT FOR ONE-CABLE OPERATION

PRESENT STANDARD SCREENED CABLE						
CABLE SIZE	PAIR ASSIGNMENT					
	ORDER WIRE	PRESSURE ALARM	FAULT LOCATE			
LOW CAPACITANCE (MAT) CABLE						
412	T1	T10	01 Case-T2 02 Case-T3 03 Case-T4 04 Case-T5		05 Case-T6 06 Case-T7 07 Case-T8 08 Case-T9	
616	T1	T14	01 Case-T2 02 Case-T3 03 Case-T4 04 Case-T5 05 Case-T6 06 Case-T7		07 Case-T8 08 Case-T9 09 Case-T10 10 Case-T11 11 Case-T12 12 Case-T13	
1024	T1	T22	01 Case-T2 02 Case-T3 03 Case-T4 04 Case-T5 05 Case-T6 06 Case-T7 07 Case-T8 08 Case-T9 09 Case-T10 10 Case-T11		11 Case-T12 12 Case-T13 13 Case-T14 14 Case-T15 15 Case-T16 16 Case-T17 17 Case-T18 18 Case-T19 19 Case-T20 20 Case-T21	
1228	T1	T14	W-R BINDER GROUP		BL-O BINDER GROUP	
			01 Case-T2 02 Case-T3 03 Case-T4 04 Case-T5 05 Case-T6 06 Case-T7	07 Case-T8 08 Case-T9 09 Case-T10 10 Case-T11 11 Case-T12 12 Case-T13	13 Case-T27 14 Case-T28 15 Case-T29 16 Case-T30 17 Case-T31 18 Case-T32	19 Case-T33 20 Case-T34 21 Case-T35 22 Case-T36 23 Case-T37 24 Case-T38
1432	T1	T16	01 Case-T2 02 Case-T3 03 Case-T4 04 Case-T5 05 Case-T6 06 Case-T7 07 Case-T8	08 Case-T9 09 Case-T10 10 Case-T11 11 Case-T12 12 Case-T13 13 Case-T14 14 Case-T15	15 Case-T27 16 Case-T28 17 Case-T29 18 Case-T30 19 Case-T31 20 Case-T32 21 Case-T33	22 Case-T34 23 Case-T35 24 Case-T36 25 Case-T37 26 Case-T38 27 Case-T39 28 Case-T40
1840	T1	T20	01 Case-T2 02 Case-T3 03 Case-T4 04 Case-T5	10 Case-T11 11 Case-T12 12 Case-T13 13 Case-T14	19 Case-T27 20 Case-T28 21 Case-T29 22 Case-T30	28 Case-T36 29 Case-T37 30 Case-T38 31 Case-T39

TABLE C (Contd)

ORDER-WIRE, PRESSURE ALARM, AND FAULT-LOCATE
PAIR ASSIGNMENT FOR ONE-CABLE OPERATION

PRESENT STANDARD SCREENED CABLE						
CABLE SIZE	PAIR ASSIGNMENT					
	ORDER WIRE	PRESSURE ALARM	FAULT LOCATE			
LOW CAPACITANCE (MAT) CABLE (Contd)						
1840	T1	T20	W-R BINDER GROUP		BL-O BINDER GROUP	
			05 Case-T6	14 Case-T15	23 Case-T31	32 Case-T40
			06 Case-T7	15 Case-T16	24 Case-T32	33 Case-T41
			07 Case-T8	16 Case-T17	25 Case-T33	34 Case-T42
			08 Case-T9	17 Case-T18	26 Case-T34	35 Case-T43
			09 Case-T10	18 Case-T19	27 Case-T35	36 Case-T44
LOW CAPACITANCE (ICOT) CABLE						
54	T1	T3	01 Case-T2			
106	T1	T4	01 Case-T2		02 Case-T3	
158	T1	T5	01 Case-T2 02 Case-T3		03 Case-T4	
210	T1	T6	01 Case-T2 02 Case-T3		03 Case-T4 04 Case-T5	
314	T1	T8	01 Case-T2 02 Case-T3 03 Case-T4		04 Case-T5 05 Case-T6 06 Case-T7	
418	T1	T10	01 Case-T2 02 Case-T3 03 Case-T4 04 Case-T5		05 Case-T6 06 Case-T7 07 Case-T8 08 Case-T9	
616	T1	T14	01 Case-T2 02 Case-T3 03 Case-T4 04 Case-T5 05 Case-T6 06 Case-T7		07 Case-T8 08 Case-T9 09 Case-T10 10 Case-T11 11 Case-T12 12 Case-T13	
922	T1	T20	01 Case-T2 02 Case-T3 03 Case-T4 04 Case-T5 05 Case-T6 06 Case-T7 07 Case-T8 08 Case-T9 09 Case-T10		10 Case-T11 11 Case-T12 12 Case-T13 13 Case-T14 14 Case-T15 15 Case-T16 16 Case-T17 17 Case-T18 18 Case-T19	

TABLE C (Contd)

ORDER-WIRE, PRESSURE ALARM, AND FAULT-LOCATE
PAIR ASSIGNMENT FOR ONE-CABLE OPERATION

PRESENT STANDARD SCREENED CABLE				
CABLE SIZE	PAIR ASSIGNMENT			
	ORDER WIRE	PRESSURE ALARM	FAULT LOCATE	
STANDARD CAPACITANCE CABLE				
106	T1	T4	01 Case-T2	02 Case-T3
158	T1	T5	01 Case-T2 02 Case-T3	03 Case-T4
210	T1	T6	01 Case-T2 02 Case-T3	03 Case-T4 04 Case-T5
314	T1	T8	01 Case-T2 02 Case-T3 03 Case-T4	04 Case-T5 05 Case-T6 06 Case-T7
418	T1	T10	01 Case-T2 02 Case-T3 03 Case-T4 04 Case-T5	05 Case-T6 06 Case-T7 07 Case-T8 08 Case-T9
616	T1	T14	01 Case-T2 02 Case-T3 03 Case-T4 04 Case-T5 05 Case-T6 06 Case-T7	07 Case-T8 08 Case-T9 09 Case-T10 10 Case-T11 11 Case-T12 12 Case-T13
PAST STANDARD NONSCREENED CABLE				
CABLE SIZE	PAIR ASSIGNMENT			
	ORDER WIRE	PRESSURE ALARM	FAULT LOCATE	
STANDARD CAPACITANCE CABLE				
900	50	49	01 Case-001 02 Case-002 03 Case-003 04 Case-004	05 Case-005 06 Case-006 07 Case-007 08 Case-008
1100	50	49	01 Case-001 02 Case-002 03 Case-003 04 Case-004 05 Case-005 06 Case-006	05 Case-005 06 Case-006 07 Case-007 08 Case-008 09 Case-009 10 Case-010

TABLE C (Contd)

ORDER-WIRE, PRESSURE ALARM, AND FAULT-LOCATE
PAIR ASSIGNMENT FOR ONE-CABLE OPERATION

PAST STANDARD NONSCREENED CABLE				
CABLE SIZE	PAIR ASSIGNMENT			
	ORDER WIRE	PRESSURE ALARM	FAULT LOCATE	
STANDARD CAPACITANCE CABLE				
1200	1200	1187	01 Case-1199 02 Case-1198 03 Case-1197 04 Case-1196 05 Case-1195 06 Case-1194	07 Case-1193 08 Case-1192 09 Case-1191 10 Case-1190 11 Case-1189 12 Case-1188
PAST STANDARD SCREENED CABLE				
CABLE SIZE	PAIR ASSIGNMENT			
	ORDER WIRE	PRESSURE ALARM	FAULT LOCATE	
STANDARD CAPACITANCE CABLE				
100	100	50	01 Case-49	02 Case-99
150	150	75	01 Case-49 02 Case-74	03 Case-148
200	200	100	01 Case-199 02 Case-99	03 Case-198 04 Case-98
300	300	150	01 Case-299 02 Case-149 03 Case-298	04 Case-148 05 Case-297 06 Case-147
400	400	200	01 Case-399 02 Case-199 03 Case-398 04 Case-198	05 Case-397 06 Case-197 07 Case-396 08 Case-196
600	600	300	01 Case-599 02 Case-299 03 Case-598 04 Case-298 05 Case-597 06 Case-297	07 Case-596 08 Case-296 09 Case-595 10 Case-295 11 Case-594 12 Case-294

TABLE C (Contd)

ORDER-WIRE, PRESSURE ALARM, AND FAULT-LOCATE
PAIR ASSIGNMENT FOR ONE-CABLE OPERATION

PAST STANDARD SCREENED CABLE				
CABLE SIZE	PAIR ASSIGNMENT			
	ORDER WIRE	PRESSURE ALARM	FAULT LOCATE	
STANDARD CAPACITANCE CABLE				
900	900	450	01 Case-899 02 Case-429 03 Case-898 04 Case-448 05 Case-897 06 Case-447 07 Case-896 08 Case-446 09 Case-895	10 Case-445 11 Case-894 12 Case-444 13 Case-893 14 Case-443 15 Case-892 16 Case-442 17 Case-891 18 Case-441

TABLE D

ORDER-WIRE, PRESSURE ALARM, AND FAULT-LOCATE
PAIR ASSIGNMENT FOR TWO-CABLE OPERATION

PAST STANDARD CABLE E-W DIRECTION*				
CABLE SIZE	PAIR ASSIGNMENT			
	ORDER WIRE	PRESSURE ALARM	FAULT LOCATE	
100	100	74	01 Case-75	03 Case-174
200	200	173	01 Case-175 02 Case-199	03 Case-174 04 Case-198
300	300	272	01 Case-275 02 Case-299 03 Case-274	04 Case-298 05 Case-273 06 Case-297
400	400	371	01 Case-375 02 Case-399 03 Case-374 04 Case-398	05 Case-373 06 Case-397 07 Case-372 08 Case-396
600	600	569	01 Case-575 02 Case-599 03 Case-574 04 Case-598 05 Case-573 06 Case-597	07 Case-572 08 Case-596 09 Case-571 10 Case-595 11 Case-570 12 Case-594
900	900	866	01 Case-875 02 Case-899 03 Case-874 04 Case-898 05 Case-873 06 Case-897 07 Case-872 08 Case-896 09 Case-871	10 Case-895 11 Case-870 12 Case-894 13 Case-869 14 Case-893 15 Case-868 16 Case-892 17 Case-867 18 Case-891
1100	1100	1064	01 Case-1075 02 Case-1099 03 Case-1074 04 Case-1098 05 Case-1073 06 Case-1097 07 Case-1072 08 Case-1096 09 Case-1071 10 Case-1095 11 Case-1070	12 Case-1094 13 Case-1069 14 Case-1093 15 Case-1068 16 Case-1092 17 Case-1067 18 Case-1091 19 Case-1066 20 Case-1090 21 Case-1065 22 Case-1089

* W-E direction cable should have same numbering plan.

TABLE E

CAPACITIES OF T1C/T1 OFFICE REPEATER BAYS

UNITS/MODULES	T1C/T1 DSX OPTIONAL ORB			T1C/T1 DSX DEDICATED ORB		
	J98725A	J98725B	J98725C	J98725D	J98725E	J98725F
	11'6" BAY	9' BAY	7' BAY	11'6" BAY	9' BAY	7' BAY
Office Repeaters	96	48	48	144	96	72
Maintenance Repeaters	4	2	2	6	4	3
Bridging Repeaters	4	2	2	6	4	3
Equalizer Modules	104	52	52	6*	4*	3*
Equalizer Cards	Not Used	Not Used	Not Used	12†	8†	6†
Jack & Cross-Connect Panel	1	1	1	Not Used	Not Used	Not Used
Fuse, Alarm, & Fault Locate	1	1	1	Not Used	Not Used	Not Used
Fuse & Alarm Panel	Not Used	Not Used	Not Used	1	1	1
Fault Locate Panel	Not Used	Not Used	Not Used	1	1	1
Power Dissipation Units	8	4	4	12†	8†	6†
Order Wire & Tel Set Panel	1	1	1	1	1	1
TCAS Plug-In	Not Used	Not Used	Not Used	12	8	6

* Used at bridging repeater position.

† 13 equalizers per card.

TABLE F
T1C OFFICE REPEATERS

REPEATER CODE	TYPE	NOMINAL LOOP CURRENT	CABLE LOSS RANGE (dB) (NOTE)
220A	Current Regulating	120 mA	4.0 to 37.0
220B	Current Looping	120 mA	4.0 to 37.0
220C	Bridging	—	—
220AA	Current Regulating	120 mA	4.0 to 37.0
220AB	Current Looping	120 mA	4.0 to 37.0
250A	Current Regulating	60 mA	4.0 to 37.0
250B	Current Looping	60 mA	4.0 to 37.0
250C	Bridging	—	—

Note: The cable loss range indicates the range of cable loss over which office repeaters will operate. The cable loss is measured at 1.576 MHz. This range covers cable lengths from 800 to 4100 feet.

TABLE G
CAPACITIES OF M1C MULTIPLEX BAYS
AND SINGLE SHELF

CODE	SIZE FT	MULDEMS	
		WORKING	STANDBY
J98727A	11'6"	48	1
J98727B	9'0"	36	1
J98727C	7'0"	24	1
J98727E	0'9"	3	0

TABLE H

T1C/T1 ORB-MOUNTED EQUALIZERS (NOTE 1)

EQUALIZER			OFFICE RPTR CODES	ORB CODES J98725	DSX-1C REQ D	OFFICE CABLE LENGTH (FEET)
ED CODE	GROUP	QTY REQ D				
3C555-30	1	1 Per RPTR	220-TYPE (Note 2)	A, B, & C	No	0 to 133 133 to 267 267 to 400
	2					
	3					
3C655-30	1	1 Per RPTR	250-TYPE (Note 2)	A, B, & C	No	0 to 133 133 to 267 267 to 400 400 to 533 533 to 655
	2					
	3					
	4					
	5					
3C744-30 (Note 3)	1	1 Per RPTR Shelf	220A and B	D, E, & F	Yes	0 to 133 133 to 267 267 to 400
	2					
	3					
3C555-30	1	1 Per RPTR	220C	D, E, & F	Yes	—
3C767-30 (Note 3)	1	1 Per RPTR Shelf	250A and B	D, E, & F	Yes	0 to 133 133 to 267 267 to 400 400 to 533 533 to 655
	2					
	3					
	4					
	5					
3C655-30	1	1 Per RPTR	250C	D, E, & F	Yes	—

Note 1: At cable length transition point use equalizer for the shorter length. (*Do not overequalize.*)

Note 2: Position 26 (bridging repeater) is equipped with a Group 1 equalizer for all cable lengths.

Note 3: Thirteen equalizers per card.

TABLE I

M1C MOUNTED EQUALIZER NETWORKS (NOTE)

CABLE LENGTH M1C TO DSX-1C IN FEET	CABLE LENGTH M1C TO DSX-1 IN FEET		
	0 TO 150	150 TO 450	450 TO 655
0 to 133	1012 AA	1012 AB	1012 AC
133 to 267	1012 BA	1012 BB	1012 BC
267 to 400	1012 CA	1012 CB	1012 CC

Note: At cable length transition point use equalizer for the shorter length. (*Do not overequalize.*)

TABLE J

D4 CHANNEL BANK MOUNTED EQUALIZERS (NOTE)

EQUALIZER	GROUP	CABLE LENGTH (FEET)
ED-3C655-30	1	0 to 133
	2	133 to 267
	3	267 to 400
	4	400 to 533
	5	533 to 655

Note: At cable length transition point use equalizer for shorter length (*Do not overequalize.*)

TABLE K

APS MOUNTED EQUALIZERS (NOTE 1)

EQUALIZER (NOTE 2)	GROUP	CABLE LENGTH IN FEET TO DSX-1C
3C767-30	1	0 to 133
	2	133 to 267
	3	267 to 400
	4	400 to 533
	5	533 to 655

Note 1: At cable length transition point use equalizer for shorter length. (*Do not overequalize.*)

Note 2: Thirteen equalizers per card.

TABLE L
T1C REPEATER SPACING

			INTERMEDIATE SECTION				END SECTION (NOTE 1)			
			MAX (NOTE 3)		MIN		MAX (NOTE 3)		MIN (NOTE 3)	
TYPE CABLE	CODE	GA	UNDER-GROUND FT	AERIAL FT	UNDER-GROUND FT	AERIAL FT	UNDER-GROUND FT	AERIAL FT	UNDER-GROUND FT	AERIAL FT
Cu Pulp	ADB	19	7,970	7,850	1,330	1,570	5,360	5,290	1,020	1,200
	ADA	22	6,100	5,950	1,020	1,170	4,100	4,010	800	890
	ADM	24	4,970	4,870	840	960	3,350	3,280	700	770
Cu PIC (air core)	BHB	19	9,880	9,500	1,580	1,680	6,670	6,420	1,190	1,270
	BHA	22	7,190	6,910	1,120	1,200	4,900	4,700	850	900
	BKM	24	5,720	5,500	910	970	3,900	3,750	720	750
Cu PIC (filled)	AJB	19	12,280	11,940	1,810	1,890	8,240	8,020	1,370	1,430
	AJA	22	8,700	8,390	1,260	1,330	5,900	5,690	930	980
	AJM	24	6,930	6,650	1,010	1,070	4,720	4,530	770	810
Cu DEPIC	ALB	19	10,830	10,450	1,600	1,690	7,290	7,040	1,210	1,280
	ALA	22	7,720	7,430	1,110	1,170	5,250	5,060	840	880
	ALM	24	6,220	5,980	900	950	4,240	4,070	710	740
Al DEPIC	ALC	17	10,740	10,290	1,620	1,730	7,230	6,940	1,220	1,310
	ALD	20	7,700	7,400	1,110	1,180	5,240	5,040	840	890
Al PIC (air core)	AH DU	20	7,190	6,710	1,120	1,200	4,900	4,700	850	900
MAT	MCR	25	6,340	6,090	1,840	1,970	4,320	4,150	800	850
ICOT (air core)	MCM	24	9,300	8,910	2,210	2,370	6,290	6,030	1,000	1,050
ICOT (filled)	MLM	24	8,760	8,440	2,080	2,210	5,930	5,720	950	1,000

Note 1: Includes office cabling (22-gauge copper PIC, 600-type or ABAM, < 200 feet).

Note 2: For back-to-back operation (ORB to ORB) the distance is 0 feet.

Note 3: If the line is to be used initially for T1, the maximum section lengths cannot exceed those specified in Section 855-351-101.

TABLE M
RESTRICTIONS FOR SECTIONS ADJACENT TO END SECTION

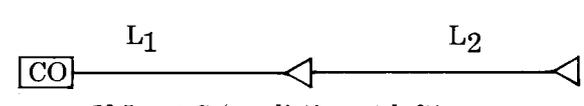
TYPE CABLE	CODE	GA	S		RESTRICTION
			UNDER-GROUND FT	AERIAL FT	
Cu Pulp	ADB	19	2,610	2,560	<p>END ADJACENT</p>  <p>If $L_1 < S$ (see listing at left) then it is required that: $L_2 < L_1 +$ (end section maximum)</p>
	ADA	22	2,000	1,940	
	ADM	24	1,620	1,590	
Cu PIC (air core)	BHB	19	3,210	3,080	
	BHA	22	2,290	2,210	
	BKM	24	1,820	1,750	
Cu PIC (filled)	AJB	19	4,040	3,920	
	AJA	22	2,800	2,700	
	AJM	24	2,210	2,120	
Cu DEPIC	ALB	19	3,540	3,410	
	ALA	22	2,470	2,370	
	ALM	24	1,980	1,910	
Al DEPIC	ALC	17	3,510	3,350	
	ALD	20	2,460	2,360	
Al PIC (air core)	AH DU	25	2,290	2,210	
MAT	MCR	25	2,020	1,940	
ICOT (air core)	MCM	24	3,010	2,880	
ICOT (filled)	MLM	24	2,830	2,720	

TABLE N
MAXIMUM END SECTION LENGTHS
ONE-CABLE AND TWO-CABLE (PULP)

CABLE LOCATION	D _B			D _C		
	19 GA (FT)	22 GA (FT)	24 GA (FT)	19 GA (FT)	22 GA (FT)	24 GA (FT)
UNDERGROUND	3620	2840	2375	4000	3000	2000
AERIAL	3560	2770	2330	4000	3000	2000

TABLE O
T1C LINE REPEATERS

REPEATER CODE	LINE POWER TYPE	POWER OPTION	CABLE TYPE	MAXIMUM LOSS RANGE (db) (NOTE 1)	APPARATUS CASE (NOTE 2)	OPERATION TYPE
218A 218B 218C 218D 218E 218F 218G	120 mA	Through Through Looped Looped Through Looped (Note 3)	Pulp (short code) Pulp (long code) Pulp (short code) Pulp (long code) DEPIC & PIC DEPIC & PIC MAT & ICOT	5.7 to 38.7 20.0 to 54.0 5.7 to 38.7 20.0 to 54.0 5.7 to 54.0 5.7 to 54.0 10.0 to 54.0	479-type or 818A1C or 818C1C Unprotected	Unidirectional
218AA 218AB 218AC	120 mA	(Note 3) (Note 3) (Note 3)	Pulp DEPIC & PIC MAT & ICOT	9.0 to 54.0 9.0 to 54.0 9.0 to 54.0	479-type or 818A1C, C1C, or A2C Unprotected	Unidirectional
219A 219B 219C 219D 219E 219F 219G	120 mA	Through Through Looped Looped Through Looped (Note 3)	Pulp (short code) Pulp (long code) Pulp (short code) Pulp (long code) DEPIC & PIC DEPIC & PIC MAT & ICOT	5.7 to 38.7 20.0 to 54.0 5.7 to 38.7 20.0 to 54.0 5.7 to 54.0 5.7 to 54.0 10.0 to 54.0	479-type or 819A1C, B1C, or C1C Protected	Unidirectional
219AA 219AB 219AC	120 mA	(Note 3) (Note 3) (Note 3)	Pulp DEPIC & PIC MAT & ICOT	9.0 to 54.0 9.0 to 54.0 9.0 to 54.0	479-type or 819A1C, B1C, C1C, A2C, or B2C Protected	Unidirectional
248A 248B 248C	60 mA	(Note 3) (Note 3) (Note 3)	Pulp DEPIC & PIC MAT & ICOT	9.0 to 54.0 9.0 to 54.0 9.0 to 54.0	479-type or 818A1C, C1C, or A2C Unprotected	Unidirectional
248BA 248BB 248BC	60 mA	(Note 3) (Note 3) (Note 3)	Pulp DEPIC & PIC MAT & ICOT	9.0 to 54.0 9.0 to 54.0 9.0 to 54.0	818A2C Unprotected	Bidirectional
249A 249B 249C	60 mA	(Note 3) (Note 3) (Note 3)	Pulp DEPIC & PIC MAT & ICOT	9.0 to 54.0 9.0 to 54.0 9.0 to 54.0	479-type or 819A1C, B1C, C1C, A2C, or B2C Protected	Unidirectional
249BA 249BB 249BC	60 mA	(Note 3) (Note 3) (Note 3)	Pulp DEPIC & PIC MAT & ICOT	9.0 to 54.0 9.0 to 54.0 9.0 to 54.0	819A2C or B2C Protected	Bidirectional

Note 1: The loss range indicates the range of cable loss over which the line repeaters will operate. This loss is the cable loss as measured at 1.576 MHz.

Note 2: Apparatus cases with single fault-locate wiring are 818A1C and C1C and 819A1C, B1C, and C1C. Apparatus cases with dual fault-locate wiring are 818A2C and 819A2C and B2C.

Note 3: Option plugs on repeaters are used to select through or looped power configuration.

TABLE P

T1C DESIGN NUMBER ASSIGNMENT

CABLE AND CONFIGURATION	DESIGN NUMBER
Large Pulp Single Cable, 3 Units Separation or Two-Cable or Screened MAT Cable All at Maximum Loss	0.00005
Large Pulp Single Cable, 2 Units Separation or Screened Pulp Cable or Screened PIC Cable All at Maximum Loss	0.001
Large Pulp Single Cable, 2 Units Separation or Screened Pulp Cable or Screened PIC Cable All 1 dB Short Spaced	0.0005
Large Pulp Single Cable, 2 Units Separation or Screened Pulp Cable or Screened PIC Cable All 2 dB Short Spaced	0.00025

TABLE Q

T1D DESIGN NUMBER ASSIGNMENT

CABLE AND CONFIGURATION	DESIGN NUMBER
Large Unscreened Pulp Single Cable, Maximum Capacity	0.001
Screened Cable, PIC and Pulp	0.00025

TABLE R
ENGINEERING LOSS AT 1.576 MHZ

CABLE TYPE		CABLE CODE	MAXIMUM AVERAGE CABLE LOSS (dB/Kft)@ 55° F	TEMPERATURE COEFFICIENT (dB/Kft)/10° F
Pulp	19 ga	ADB	6.2	See Note
	22 ga	ADA, CDA	8.0	
	24 ga	ADM, CDM	9.7	
PIC (air Core)	19 ga	BHB, KHB	4.8	0.048
	22 ga	BHA, DHA, KHA	6.6	0.066
	24 ga	BKM, DKM, KHM	8.3	0.081
PIC (filled)	19 ga	AJB, KJB	4.0	0.027
	22 ga	AJA, KJA	5.6	0.049
	24 ga	AJM, KJM	7.0	0.069
DEPIC	19 ga	ALB, KLB	4.5	0.039
	22 ga	ALA, KLA	6.3	0.059
	24 ga	ALM, KLM	7.8	0.075
ALUM	17 ga	ALC	4.5	0.048
DEPIC	20 ga	ALD	6.3	0.061
MAT	25 ga	MCR	7.4	0.075
ICOT	24 ga	MCM	5.2	0.055

Note: Because the loss of PULP cable is nonlinear with temperature, a temperature coefficient cannot be provided. However, the loss per kft at 72° F, 100° F, and 140° F is as follows:

CABLE CODE	LOSS/Kft		
	72° F	100° F	140° F
ADB	6.2	6.3	6.4
ADA, CDA	8.1	8.2	8.4
ADM, CDM	9.8	10.0	10.2

TABLE S

LOOP POWERING FOR T1C LINES

POWERING VOLTAGE	SUPPLIES REQUIRED	REGULATOR OPTIONS	ALLOWABLE R_L , STANDARD POWER (120 mA) T1C LINE WITH INDUCED AC CURRENT AS INDICATED			ALLOWABLE R_L , LOW POWER (60 mA) T1C LINE
			0 TO 10 mA	10 TO 20 mA	20 TO 30 mA	
48V	-48*	W, Z, V †	0 to 266 Ω	0 to 220 Ω	0 to 180 Ω	0 to 550 Ω
130V	+130 *	X, Z	220 to 822 Ω	0 to 620 Ω	0 to 540 Ω	0 to 1740 Ω
178V	+130, -48	W, Z	586 to 1187 Ω	460 to 1060 Ω	340 to 950 Ω	800 to 2460 Ω
260V	+130, -130	W, Y	1100 to 1853 Ω	1100 to 1680 Ω	1100 to 1610 Ω	2190 to 3760 Ω

* When -48V only is selected, replace fuse F201 (+) with a dummy fuse (open circuit).
When +130V only is selected, replace fuse F202 (-) with a dummy fuse.

† When V option is selected, turn screw fully down; otherwise, two turns up.

TABLE T
 REPEATER POWERING OPTIONS

		LOCAL POWERING	SERIES POWERING
BIDIRECTIONAL	REGULATING REPEATER	BEHN	CEK
OPERATION	LOOPING REPEATER	HJN	DK
UNIDIRECTIONAL	LOWER POWER MATE (RECEIVE LOOP) REGULATING OR LOOP	BEHN	BDG OR CEK
OPERATION	UPPER POWER MATE (TRANSMIT LOOP) REGULATING OR LOOP	AFHN	AGM

TABLE U

TRANSMISSION LOSS FOR POWER LOOP FAILURES
IN UNIDIRECTIONAL OPERATION (NOTE)

POWERING OFFICE OPTIONS	LOOPING POINT OPTIONS	RCV LOOP FAILURE*				TRMT LOOP FAILURE*			
		LOWER SHELF		UPPER SHELF		LOWER SHELF		UPPER SHELF	
(LOWER/UPPER)	(LOWER/UPPER)	TRMT	RCV	TRMT	RCV	TRMT	RCV	TRMT	RCV
BEHN/AFHN	Line Repeater		X		X	X		X	
BEHW/AFHN	BEHN/AFHN		X		X	X		X	
BDG/AGM	Line Repeater		X		X	X	X	X	
CEK/AGM	Line Repeater		X		X	X		X	
BDG/AGM	BEHN/AFHN		X		X	X	X	X	
CEK/AGM	BEHN/AFHN		X		X	X		X	
BEHN/AFHN	BDG/AGM	X	X		X	X		X	
BEHN/AFHN	CEK/AGM		X		X	X		X	
BDG/AGM	BDG/AGM	X	X		X	X	X	X	
CEK/AGM	CEK/AGM		X		X	X		X	

Note: X Indicates end-to-end transmission lost with the indicated power loop failure.

* Failure of regulator or removal of a line repeater, RCV and TRMT relative to powering office.

TABLE V

CABLE RESISTANCES

WIRE GAUGE		OHMS/KFT OF SPAN	
COPPER	ALUMINUM	R _{MIN}	R _{MAX}
19	17	8.0	8.3
22	20	16.1	16.7
24		25.6	26.5
25		32.4	33.5
26		40.8	42.2

TABLE W
T1C STANDARD POWER (120 mA)
REPEATER RESISTANCES

REPEATER	UNIDIRECTIONAL LINE OFFICE REPEATER OPTIONS AND RESISTANCES					LINE REPEATER OPTIONS AND RESISTANCES		
	BDG	CEK	(AGM/BDG)	(AGM/CEK)	BEHN OR AFHN	THRU	LOOP, SIDE 1 OUTPUT	LOOP, SIDE 1 OUTPUT
220A or AA	125	222	125	28	28			
220B or AB	125	28	125	222	28			
218-TYPE						94	93	1
219-TYPE						106	99	7

TABLE X

T1C LOW POWER REPEATER (60 mA)

REPEATER RESISTANCES

REPEATER	UNIDIRECTIONAL LINE, OFFICE REPEATER OPTIONS AND RESISTANCES					BIDIRECTIONAL LINE, OFFICE REPEATER OPTIONS AND RESISTANCES				LINE REPEATER OPTIONS AND RESISTANCES		
	BDG	CEK	AGM/BDG	AGM/CEK	BEHN OR AFHN	CEK	BEHN	DK	HJN	THRU	LOOP, SIDE 1 INPUT	LOOP, SIDE 1 OUTPUT
250A	211	394	211	28	28	211	28					
250B	211	28	211	394	28			201	18			
248-TYPE										106	105	1
249-TYPE										118	111	7

TABLE Y

OFFICE BATTERY LIMITS AND MISCELLANEOUS BAY RESISTANCES

POWERING VOLTAGE	V _B MAX (V)	V _B MIN (V)	R _X (Ω)
48 V	50	45	10
130 V	135	125	120
178 V	185	170	130
260 V	270	250	130

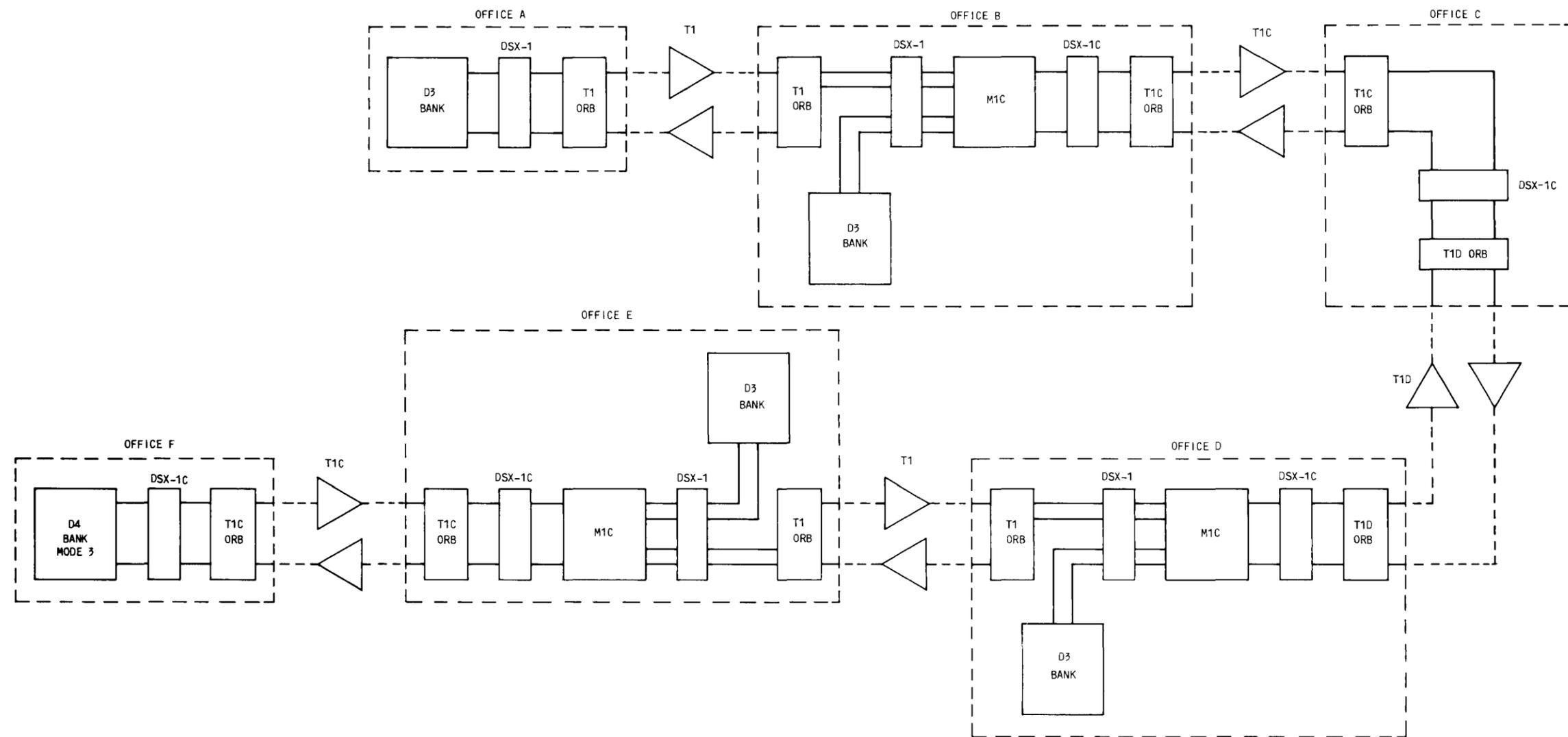
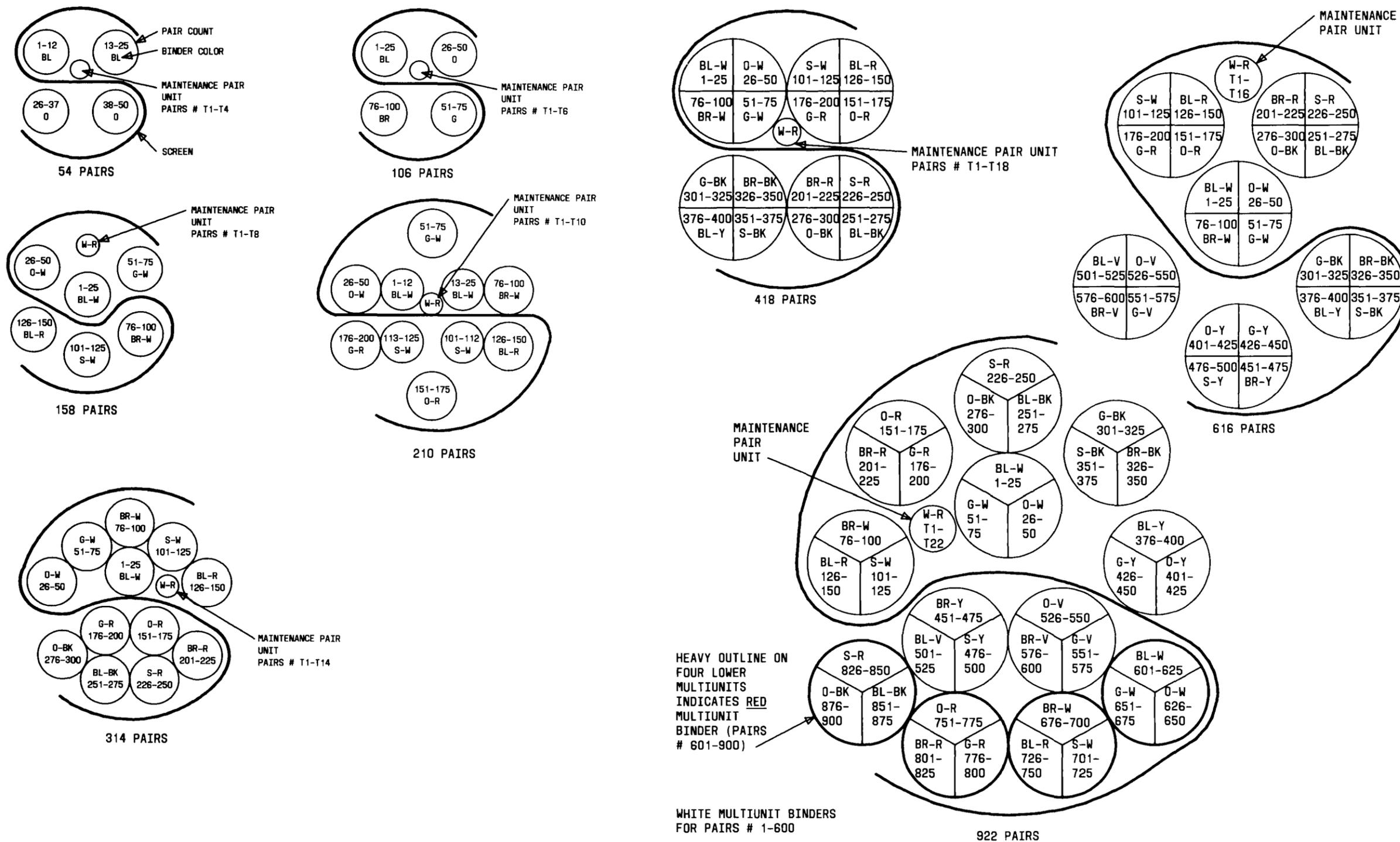


Fig. 1—T1/T1C/T1D Block Diagram



V = VIOLET

Fig. 2—Typical Core Diagrams for Screened Cable

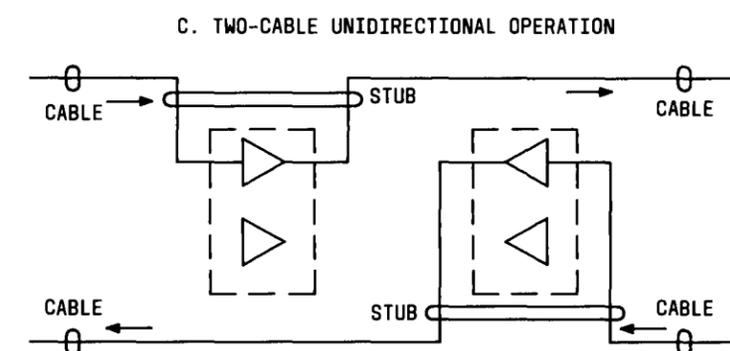
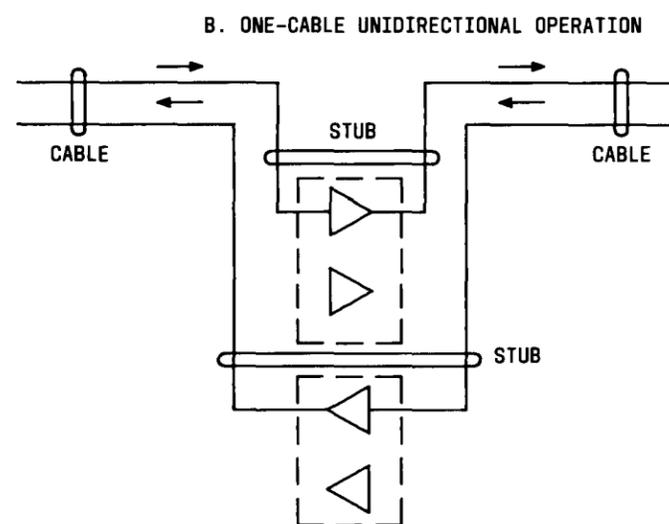
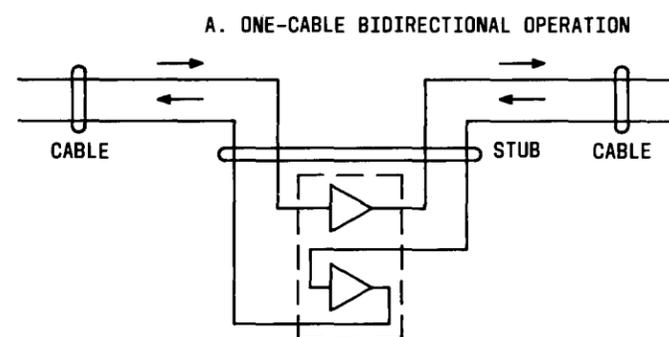


Fig. 3—Bidirectional and Unidirectional Operation
(Apparatus Cases Shown Dashed)

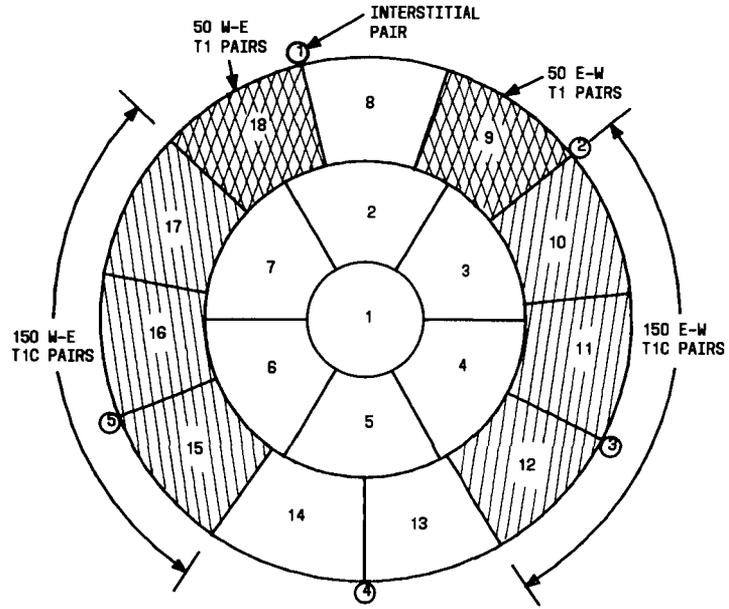


Fig. 4—Unit Selection for One-Cable Operation With 150 T1C Lines and 50 T1 Lines on 900-Pair Pulp Cable

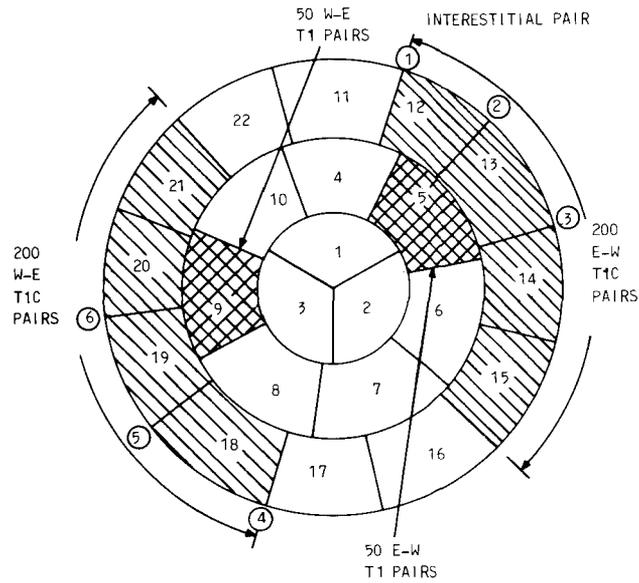
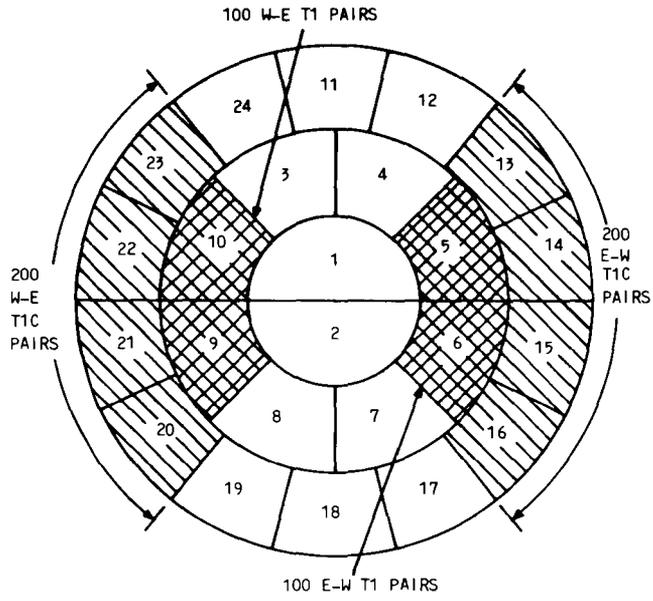
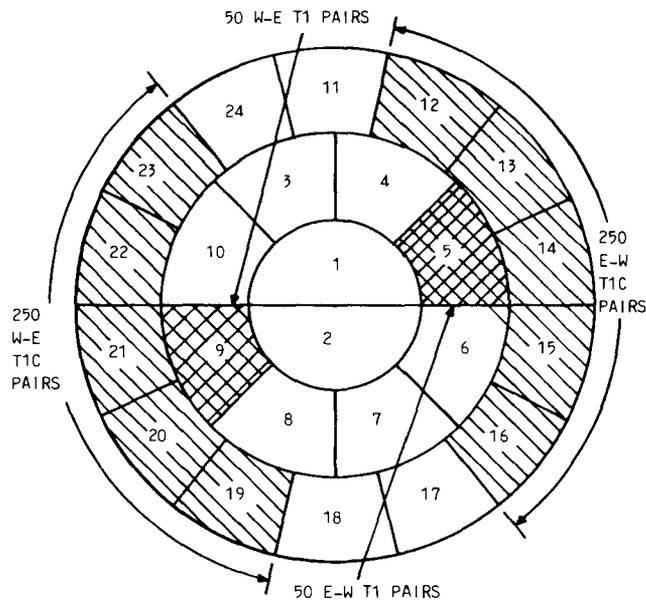


Fig. 5—Unit Selection for One-Cable Operation With 200 T1C Lines and 50 T1 Lines on 1100-Pair Cable

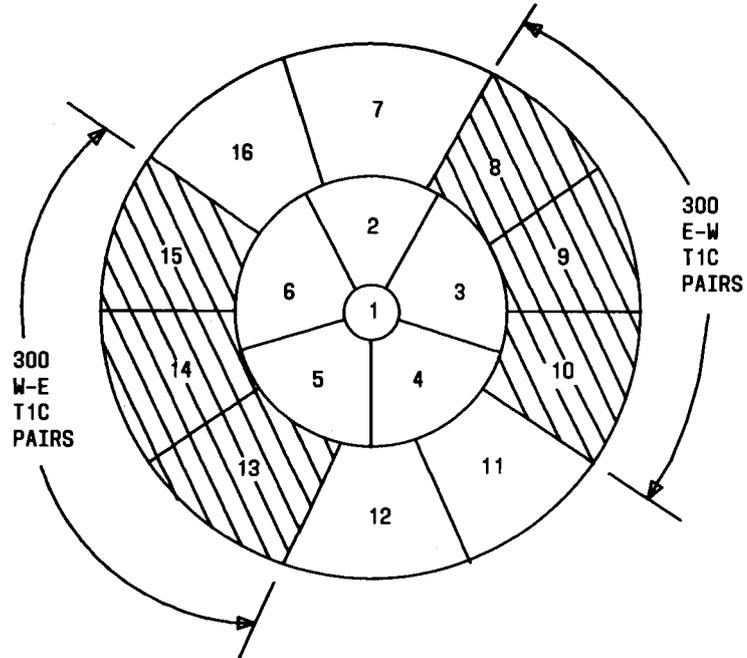


A. 200 T1C LINES AND 100 T1 LINES

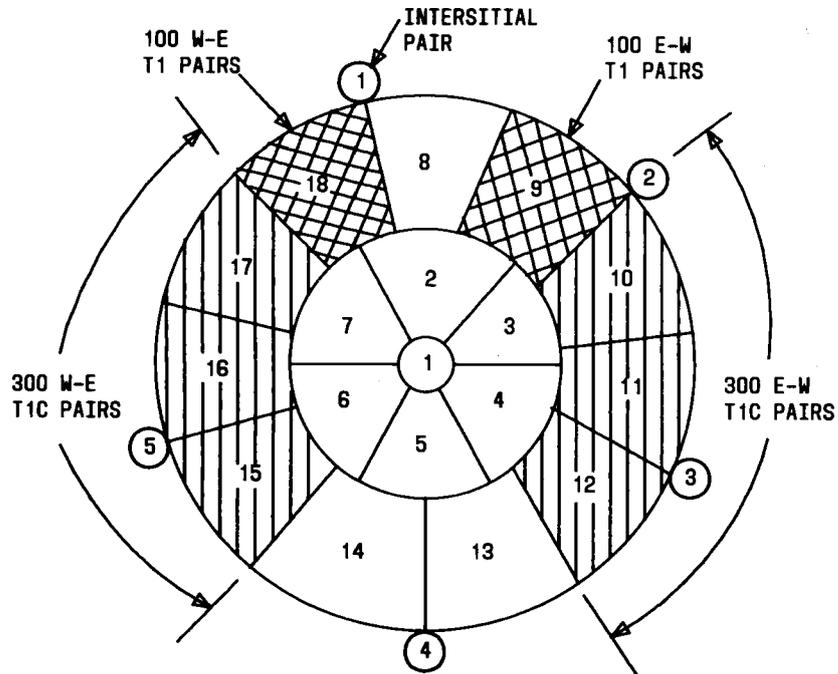


B. 250 T1C LINES AND 50 T1 LINES

Fig. 6—Unit Selection for One-Cable Operation on 1200-Pair Cable



A. 300 T1C LINES ON 1500 PAIR CABLE



B. 300 TIC LINES AND 100 T1 LINES ON 1800 PAIR CABLE

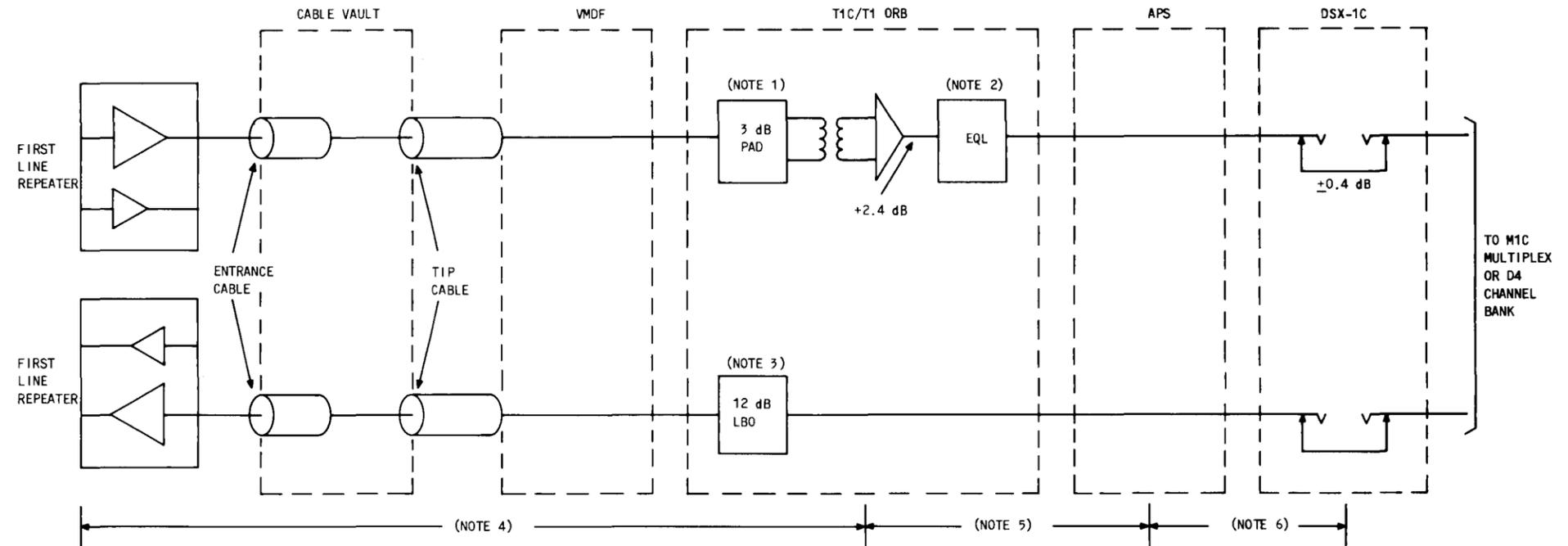
Fig. 7—Unit Selection for One-Cable Operation on 1500- and 1800-Pair Pulp Cable

NOTES:

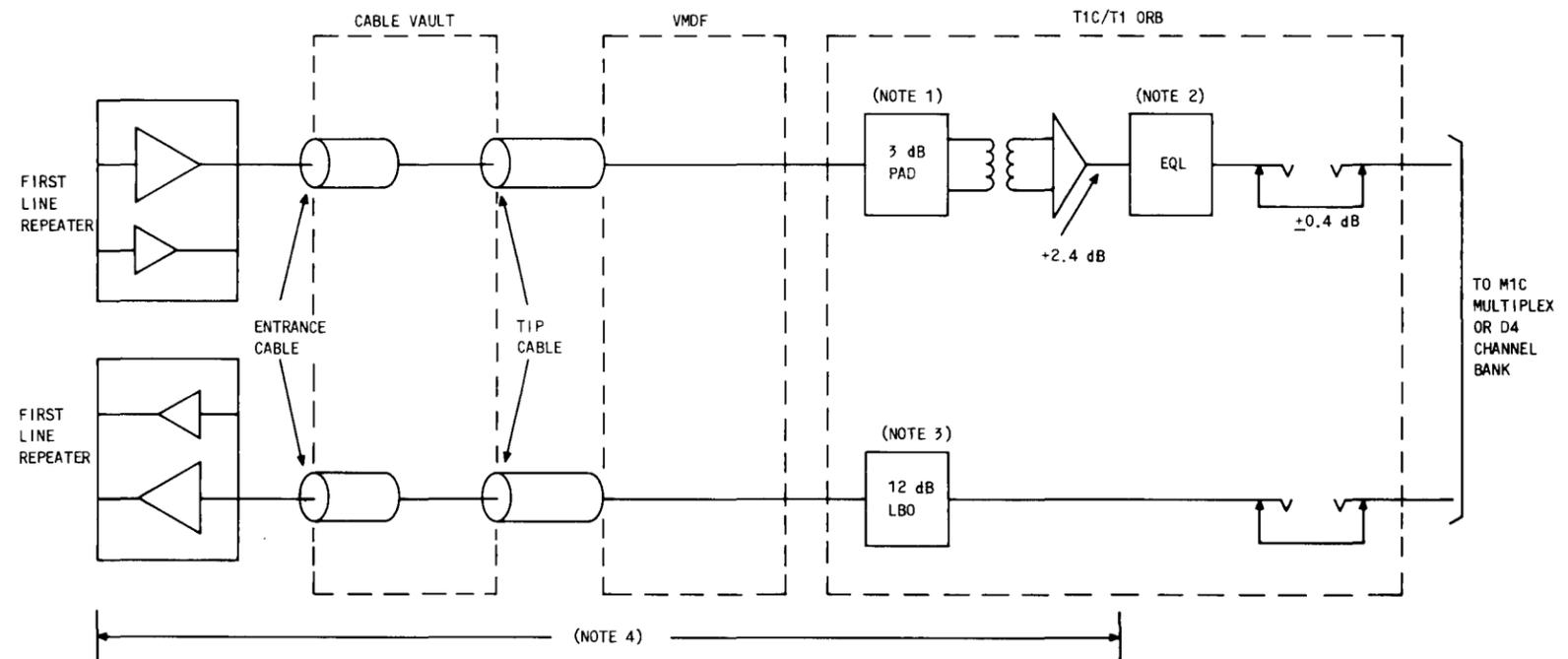
1. FIXED 3-dB PAD USED TO IMPROVE RETURN LOSS AND PROVIDE SECONDARY LIGHTNING PROTECTION.
2. EQUALIZER SELECTED TO GIVE ± 0.4 dB AT CROSS-CONNECT.
3. LINE BUILD-OUT EQUIVALENT TO 1500 FEET OF 22-GAUGE PULP INSULATED CABLE.
4. INCLUDES ALL CABLING BETWEEN THE LINE REPEATER AND THE OFFICE REPEATER WITH MAXIMUM AND MINIMUM LENGTH AS FOLLOWS:

CABLE TYPE BETWEEN VMDF AND FIRST LINE REPEATER			END SECTION LENGTH			
TYPE CABLE	CODE	GA	MAXIMUM		MINIMUM	
			UNDER-GROUND FT	AERIAL FT	UNDER-GROUND FT	AERIAL FT
CU PULP	ADB	19	5,360	5,290	1,020	1,200
	ADA	22	4,100	4,010	800	890
	ADM	24	3,350	3,280	700	770
CU PIC (AIR CORE)	BHB	19	6,670	6,420	1,190	1,270
	BHA	22	4,900	4,700	850	900
	BHM	24	3,900	3,750	720	750
CU PIC (FILLED)	AJB	19	8,240	8,020	1,370	1,430
	AJA	22	5,900	5,690	930	980
	AJM	24	4,720	4,530	770	810
CU DEPIC	ALB	19	7,290	7,040	1,210	1,280
	ALA	22	5,250	5,060	840	880
	ALM	24	4,240	4,070	710	740
AL DEPIC	ALC	17	7,230	6,940	1,220	1,310
	ALD	20	5,240	5,040	840	890
AL PIC (AIR CORE)	AHDU	20	4,900	4,700	850	900
MAT	CA-6045	25	4,320	4,150	800	850
ICOT (AIR CORE)	MCM	24	6,290	6,030	1,000	1,050
ICOT (FILLED)	MLM	24	5,930	5,720	950	1,000

5. MAXIMUM 400 FEET IF 220-TYPE REPEATERS ARE USED OR 655 FEET IF 250-TYPE REPEATERS ARE USED.
6. MAXIMUM 655 FEET USING 22-GAUGE ABAM OR 600-TYPE CABLE.



A. T1C/T1 DSX DEDICATED ORB



B. T1C/T1 DSX OPTIONAL ORB

Fig. 8—Typical End Section

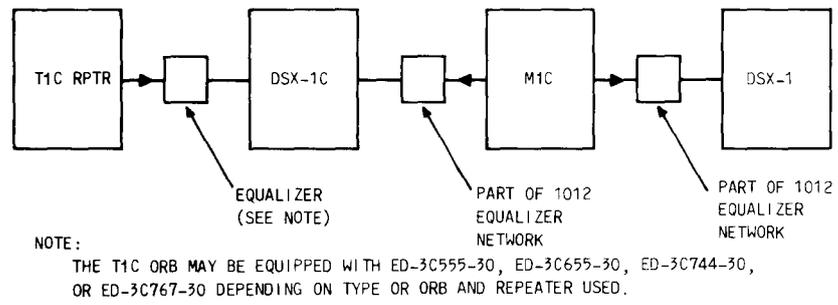
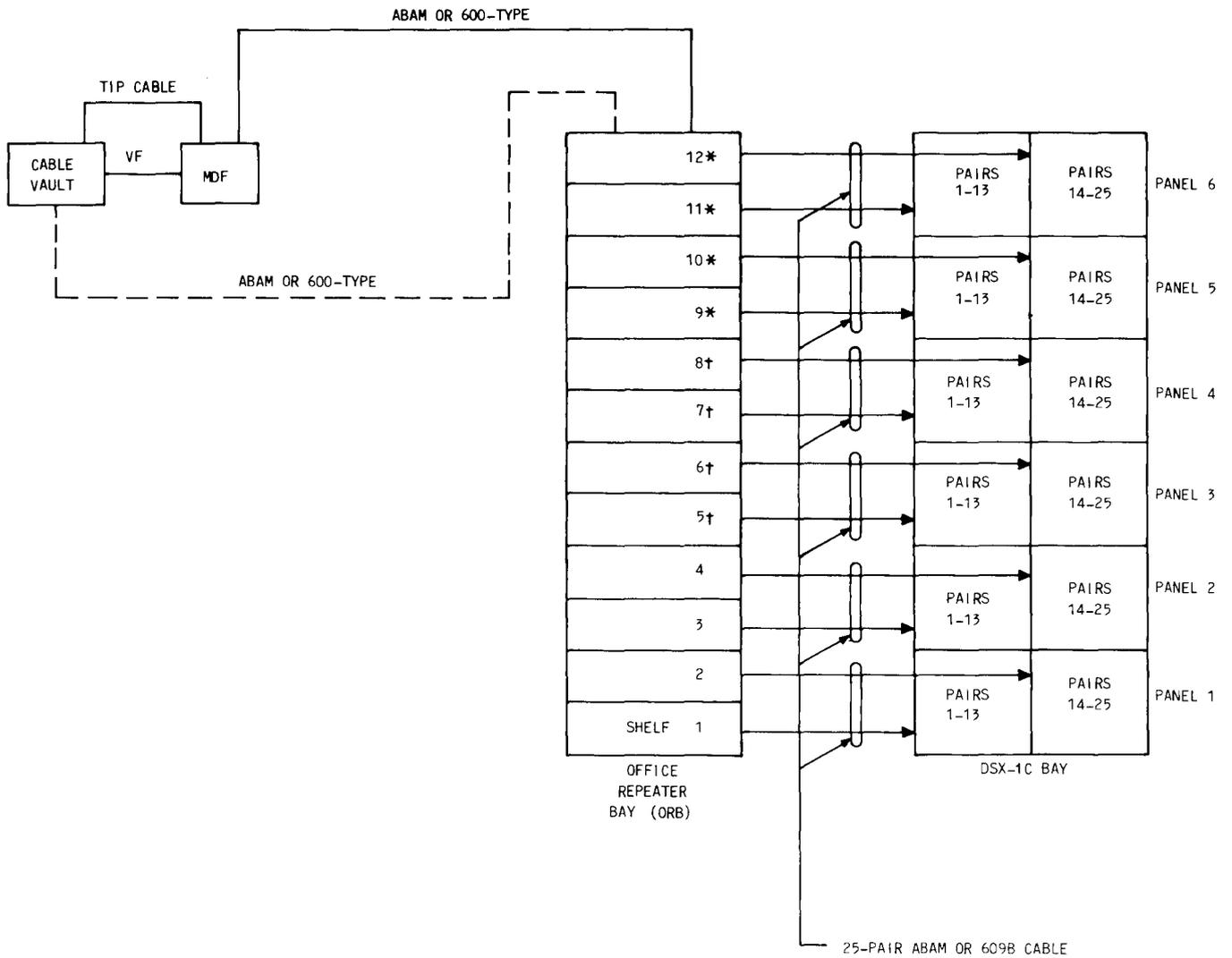


Fig. 9—T1C Equalizer Arrangement for Outputs to DSX



— — — INDICATES POSSIBLE DIRECT CONNECTION WHEN NO PROTECTION REQUIRED

† 11 FOOT, 6 INCH BAY ONLY

* 11 FOOT, 6 INCH DSX-DEDICATED BAY ONLY

Fig. 11—TIC Line Office Wiring

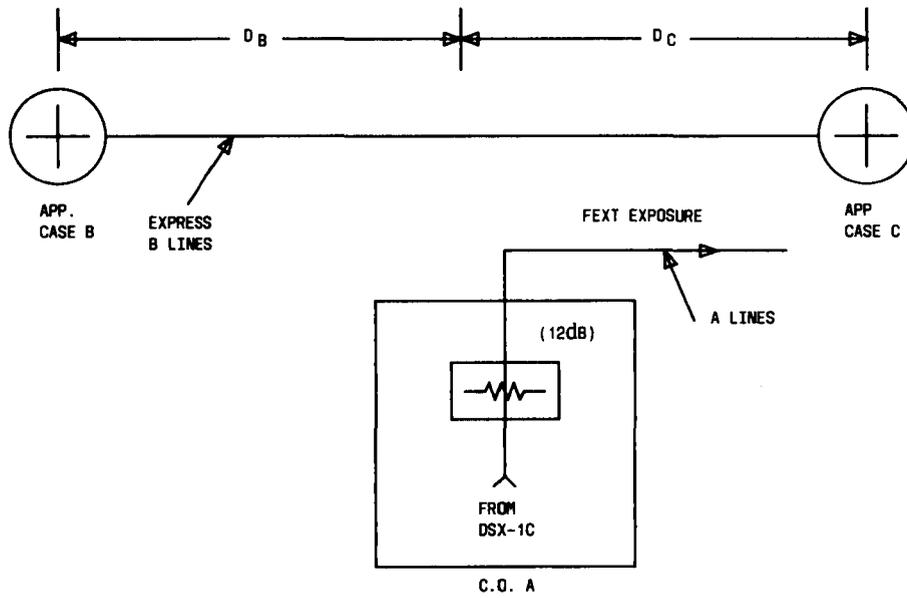


Fig. 12—T1C Express Lines Plus T1C Terminating Lines

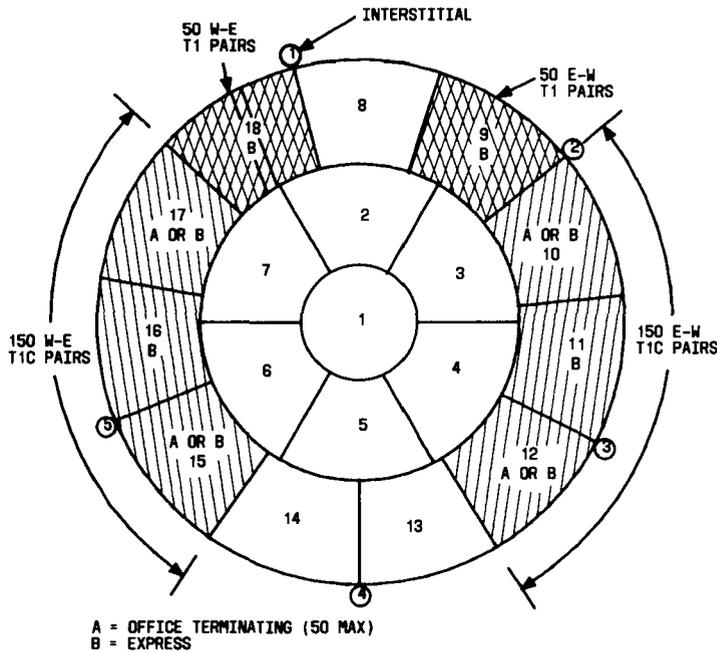


Fig. 13—Unit Selection for One-Cable Operation With EORP, 900-Pair Cable

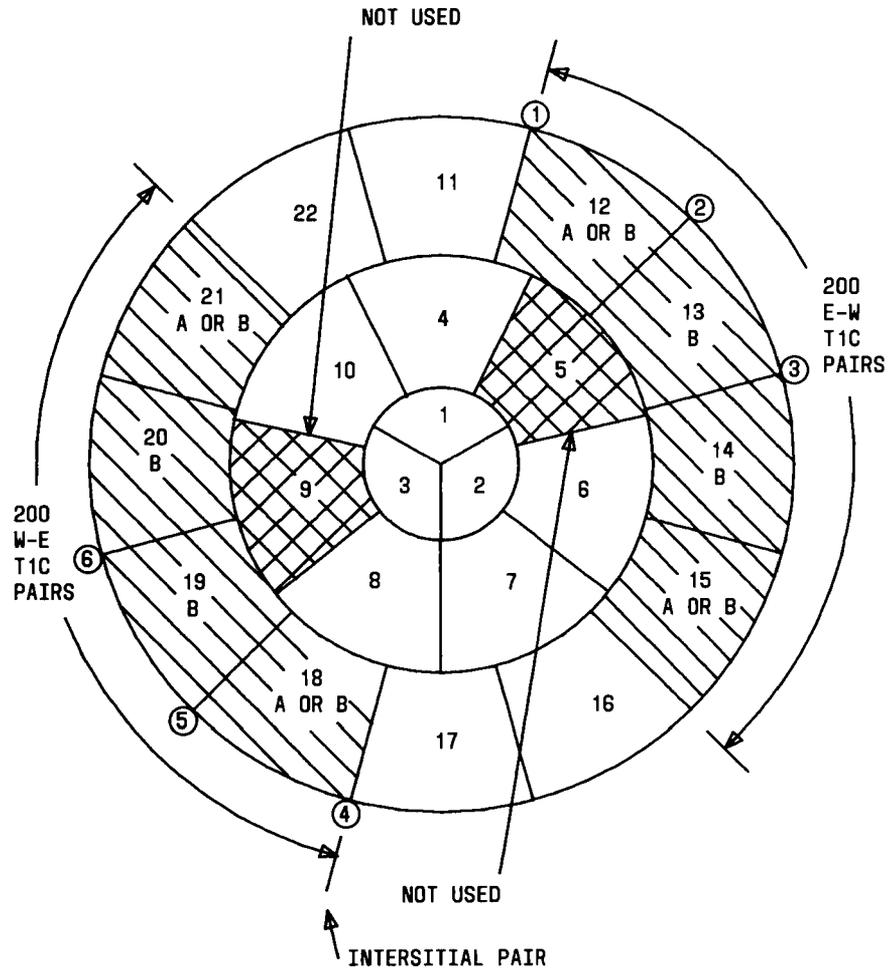


Fig. 14—Unit Selection for One-Cable Operation With EORP, 1100-Pair Cable

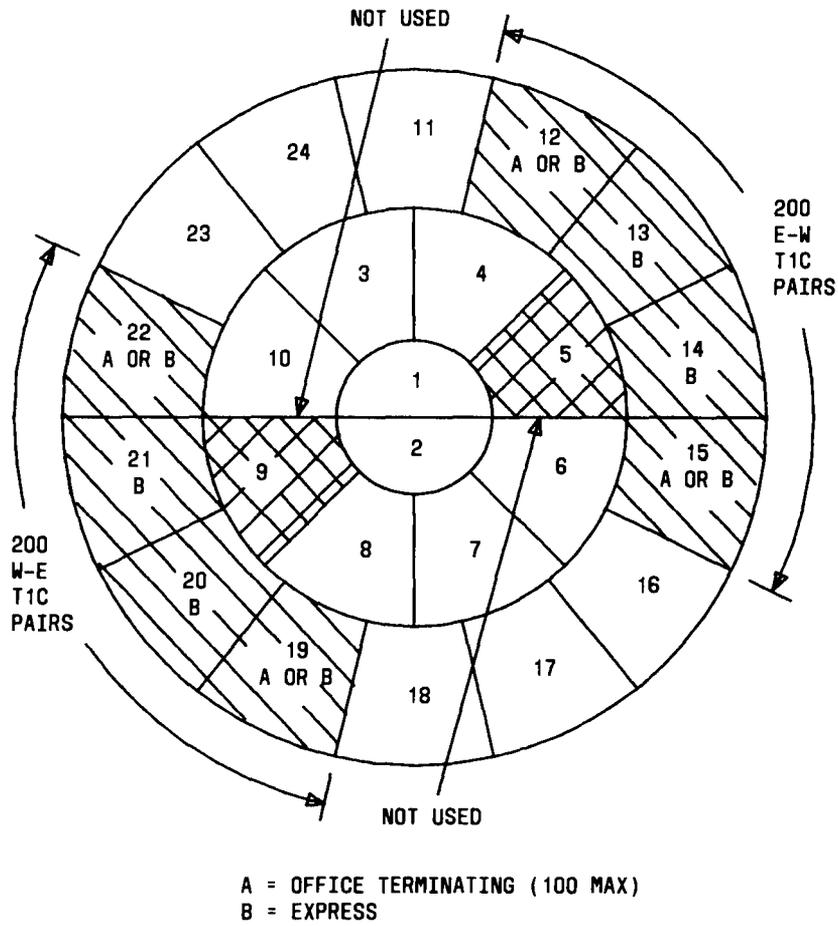


Fig. 15—Unit Selection for One-Cable Operation With EORP, 1200-Pair Cable

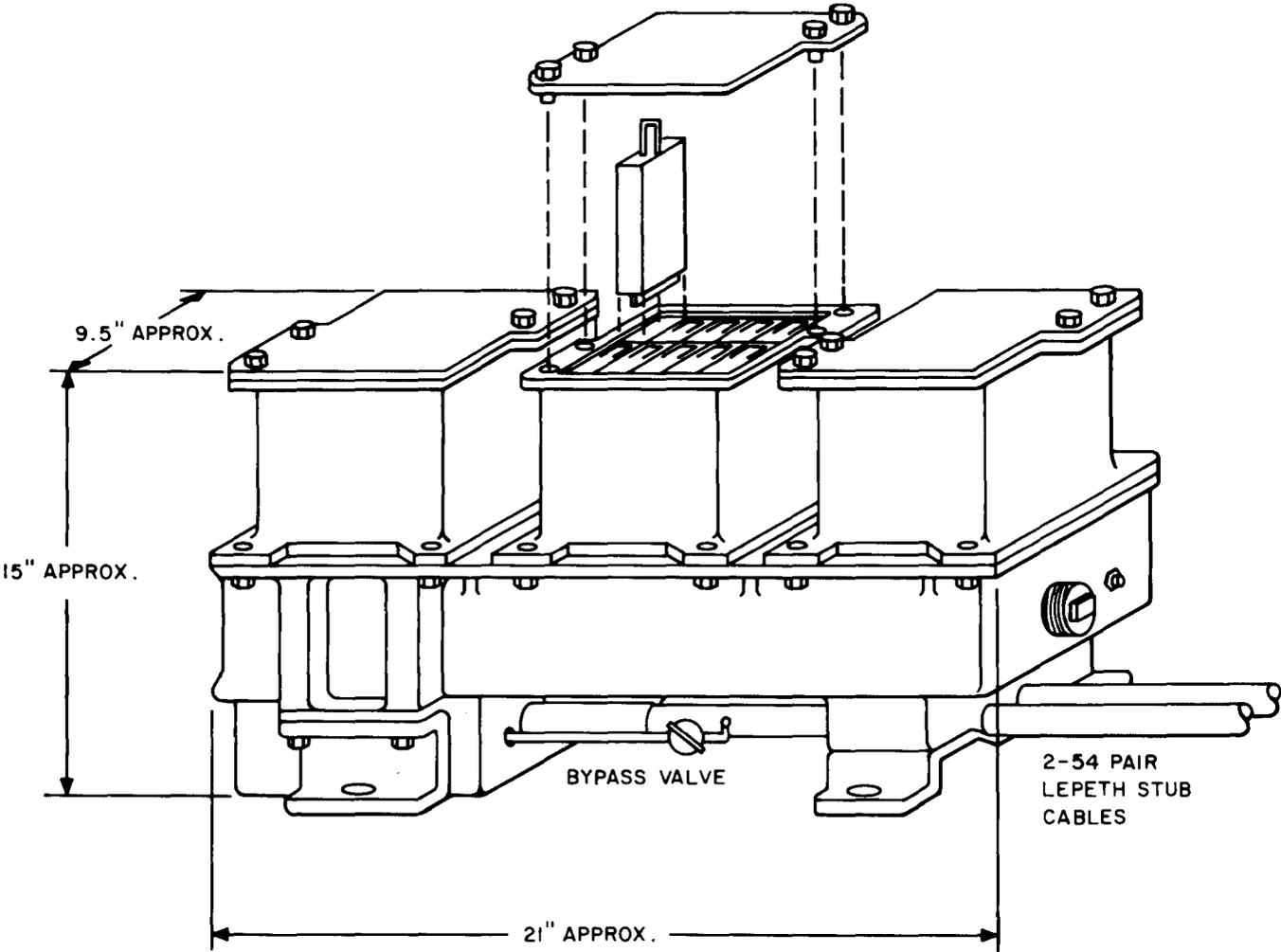


Fig. 16—479-Type Apparatus Case

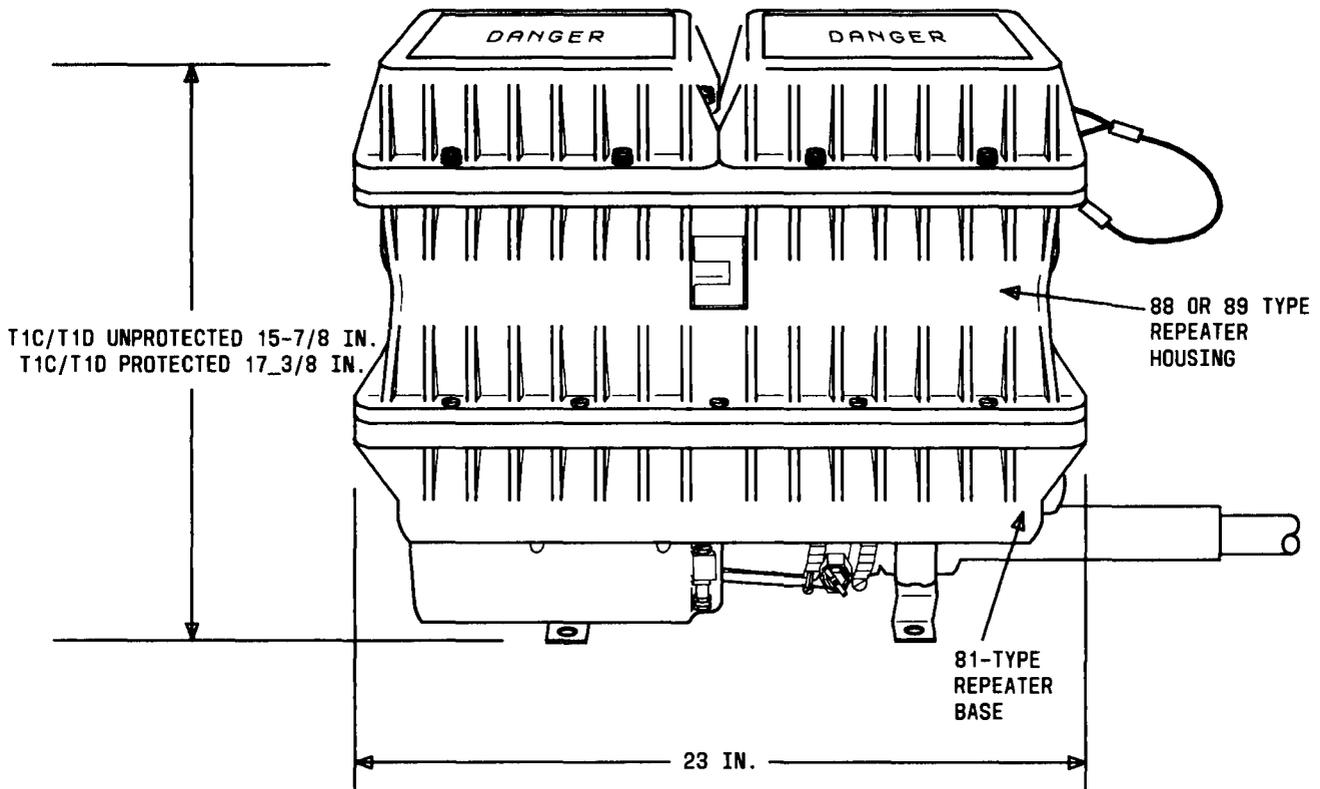


Fig. 17—818/819-Type Apparatus Case

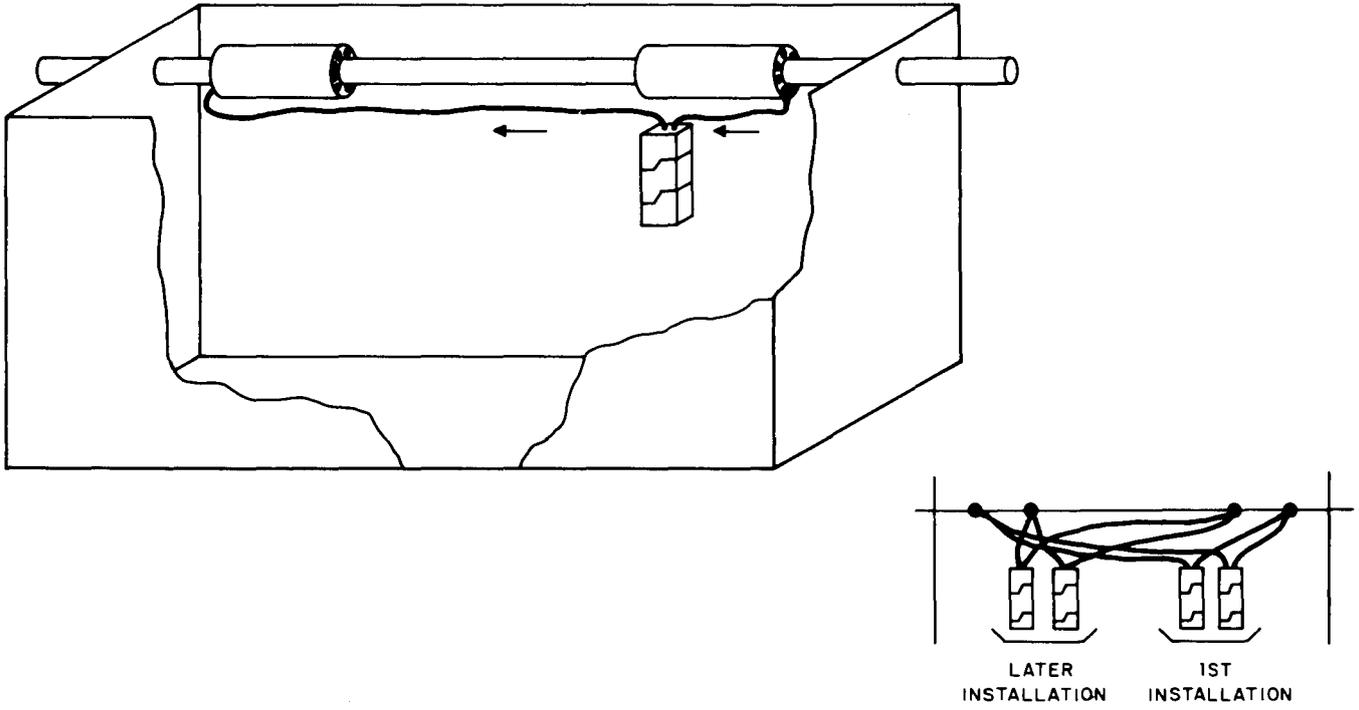
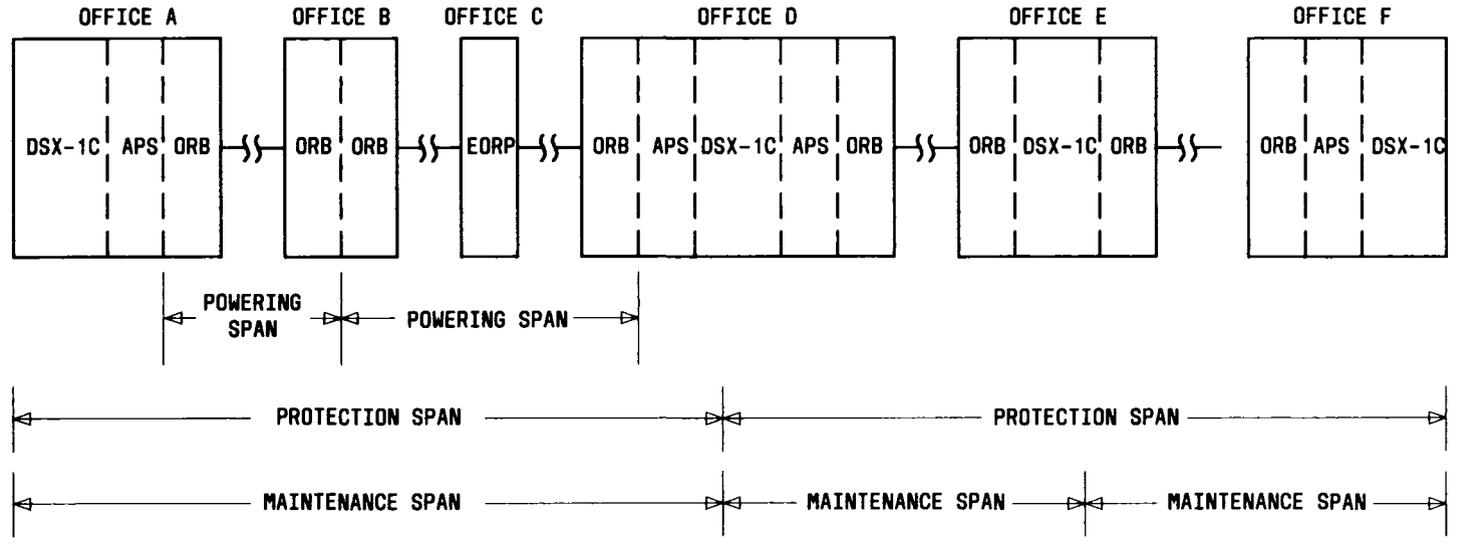
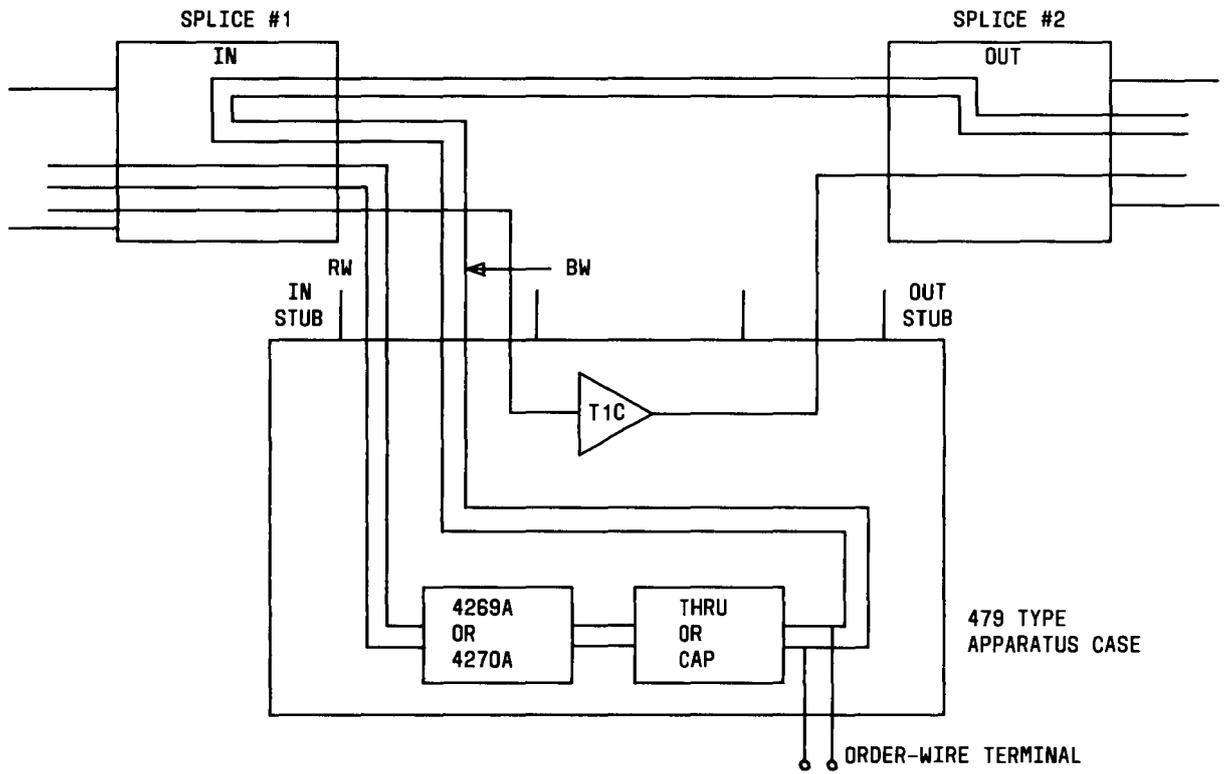


Fig. 18—Splice Access for TIC Apparatus Case

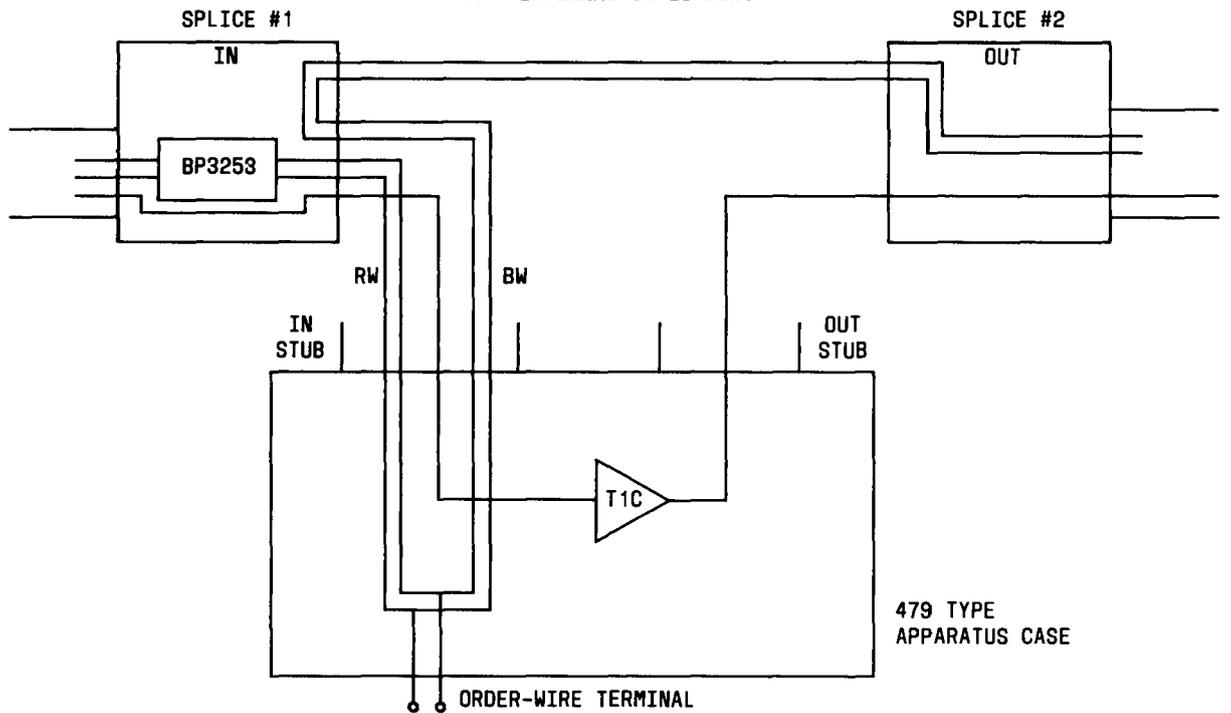


NOTES:
OFFICES NOT EQUIPPED WITH APS MAY OR MAY NOT BE EQUIPPED WITH DSX-1C.
OFFICES EQUIPPED WITH APS MUST BE EQUIPPED WITH DSX-1C.

Fig. 19—Span Concept



A - INTERNAL OW LOADING



B - EXTERNAL OW LOADING

Fig. 20—Crosstalk Filter Installation of Order-Wire Pair in T1C Binder Group (479-Type Apparatus Case)

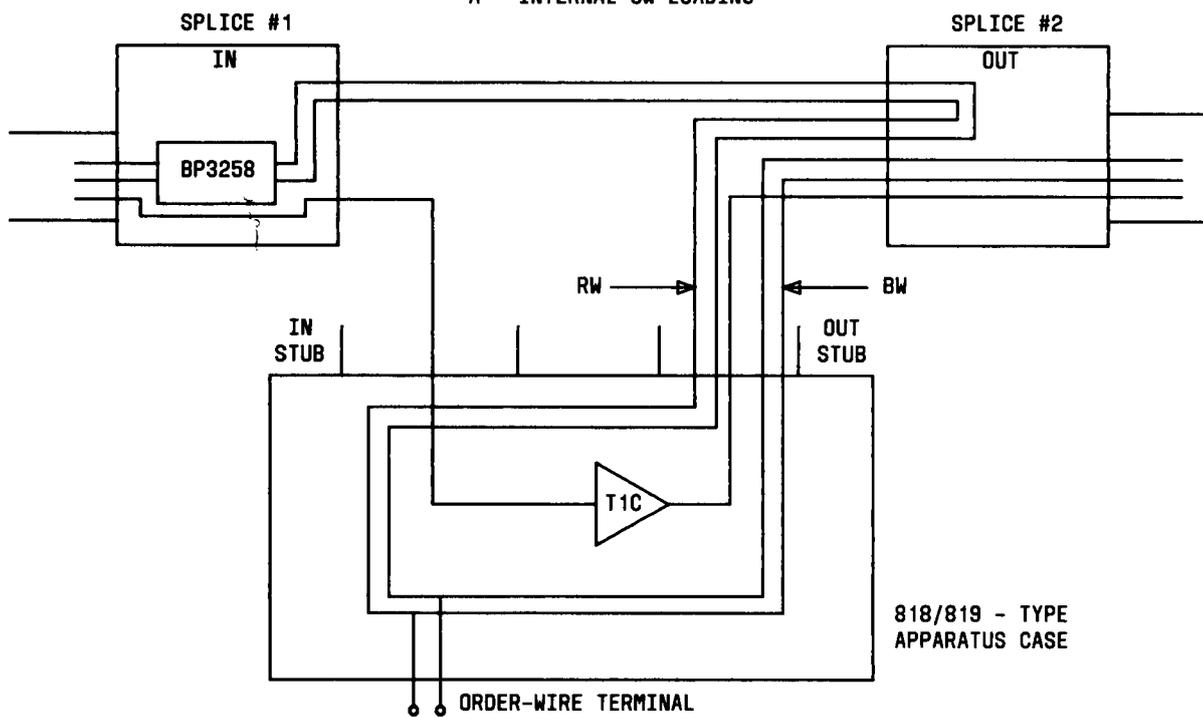
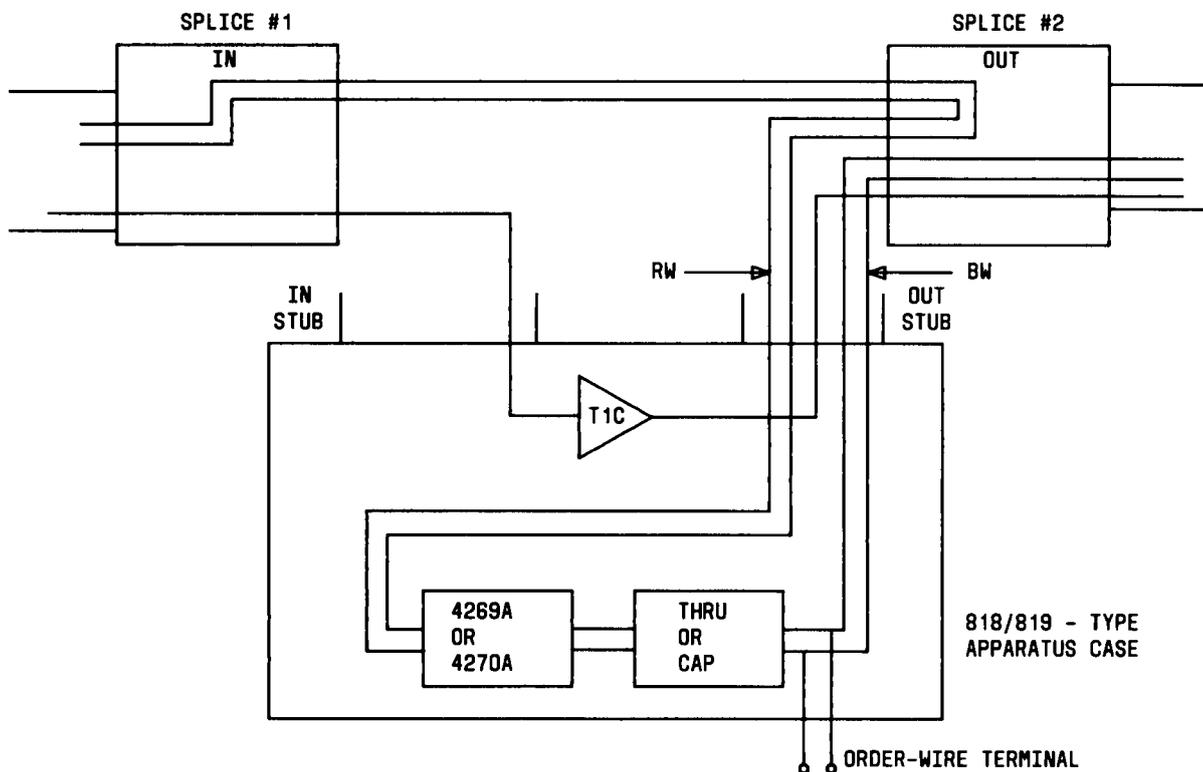


Fig. 21—Crosstalk Filter Installation of Order-Wire Pair in T1C Binder Group (818/819-Type Apparatus Case)

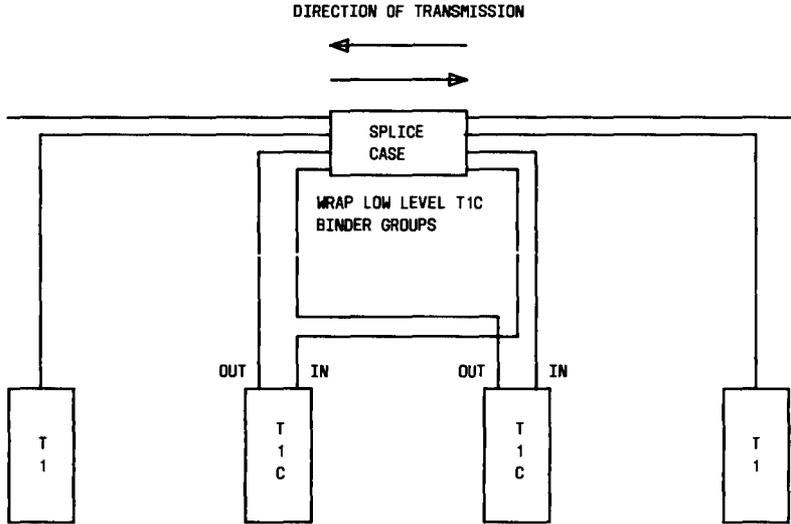


Fig. 22—Shielding Low-Level Signals in One-Cable Operation

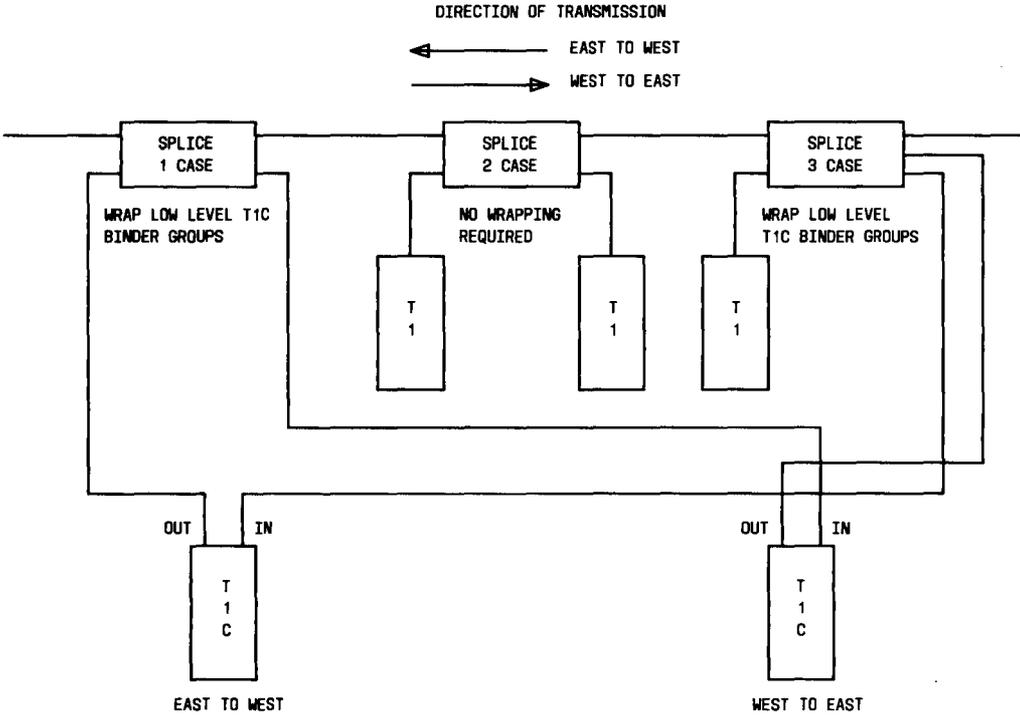
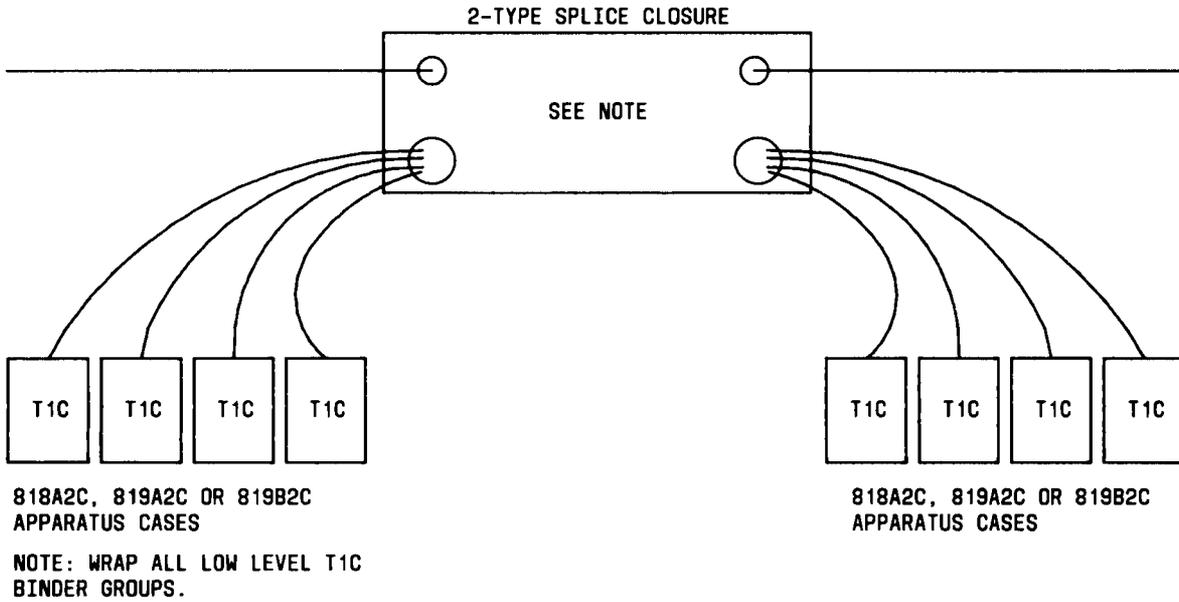
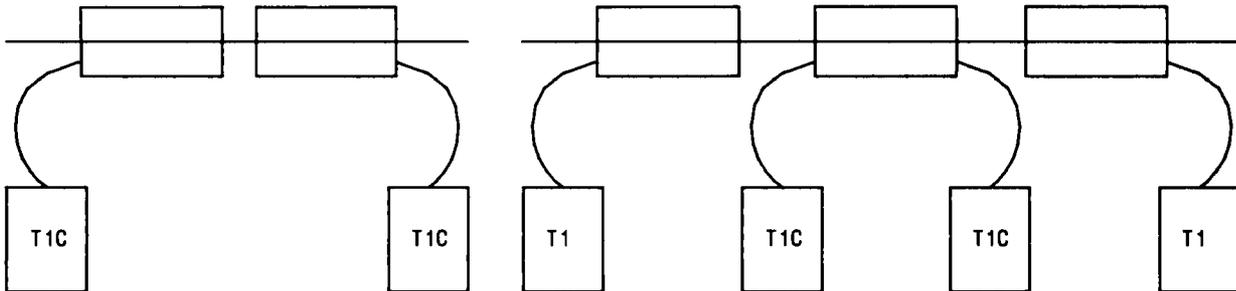


Fig. 23—One-Cable Operation With Three Splice Cases



A - SPLICING FOR T1C BIDIRECTIONAL OPERATION



B - SPLICING ARRANGEMENTS DISALLOWED FOR T1C BIDIRECTIONAL OPERATION

Fig. 24—Splicing Considerations for Bidirectional Operation

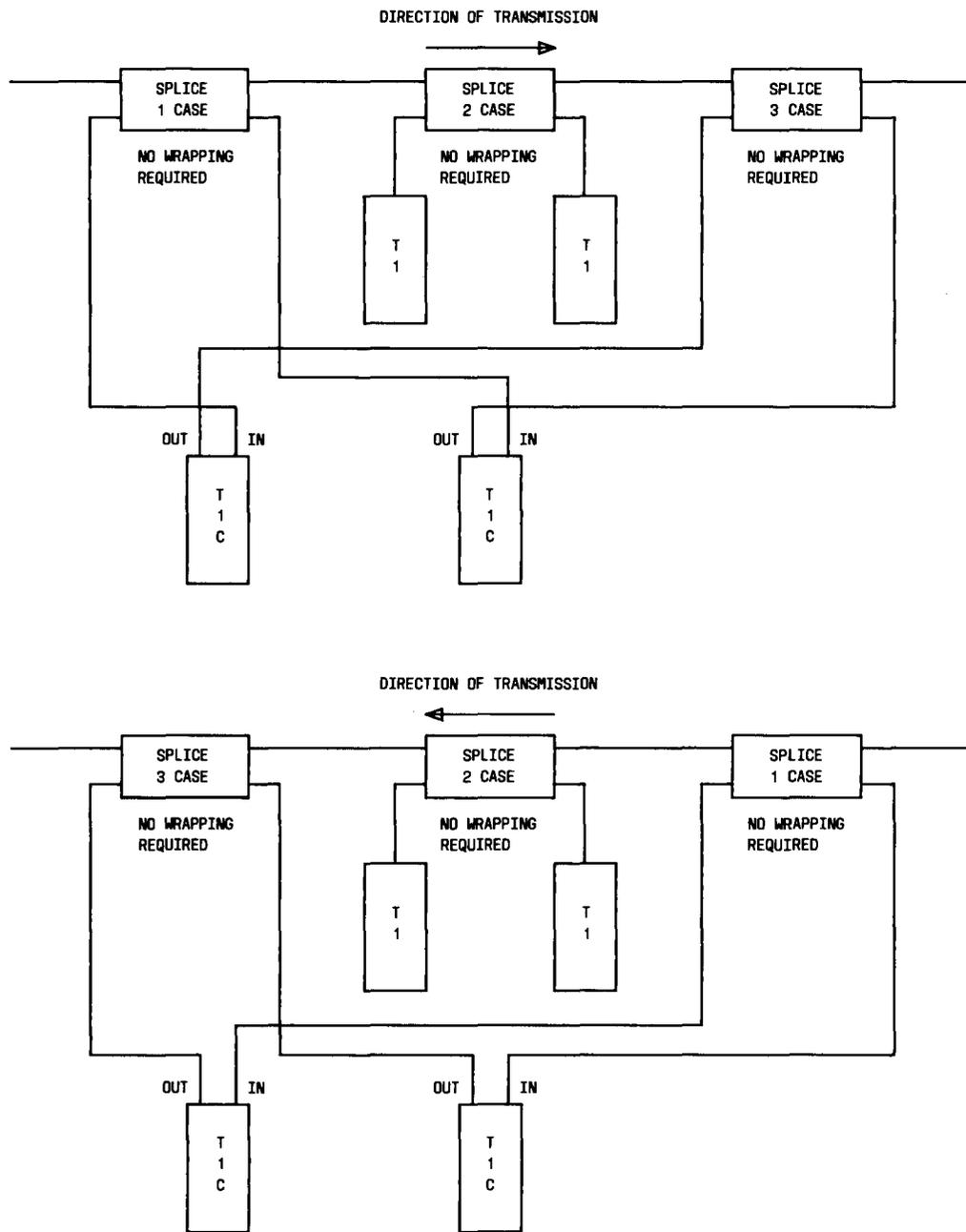


Fig. 25—Two-Cable Operation With Three Splice Cases Each Cable

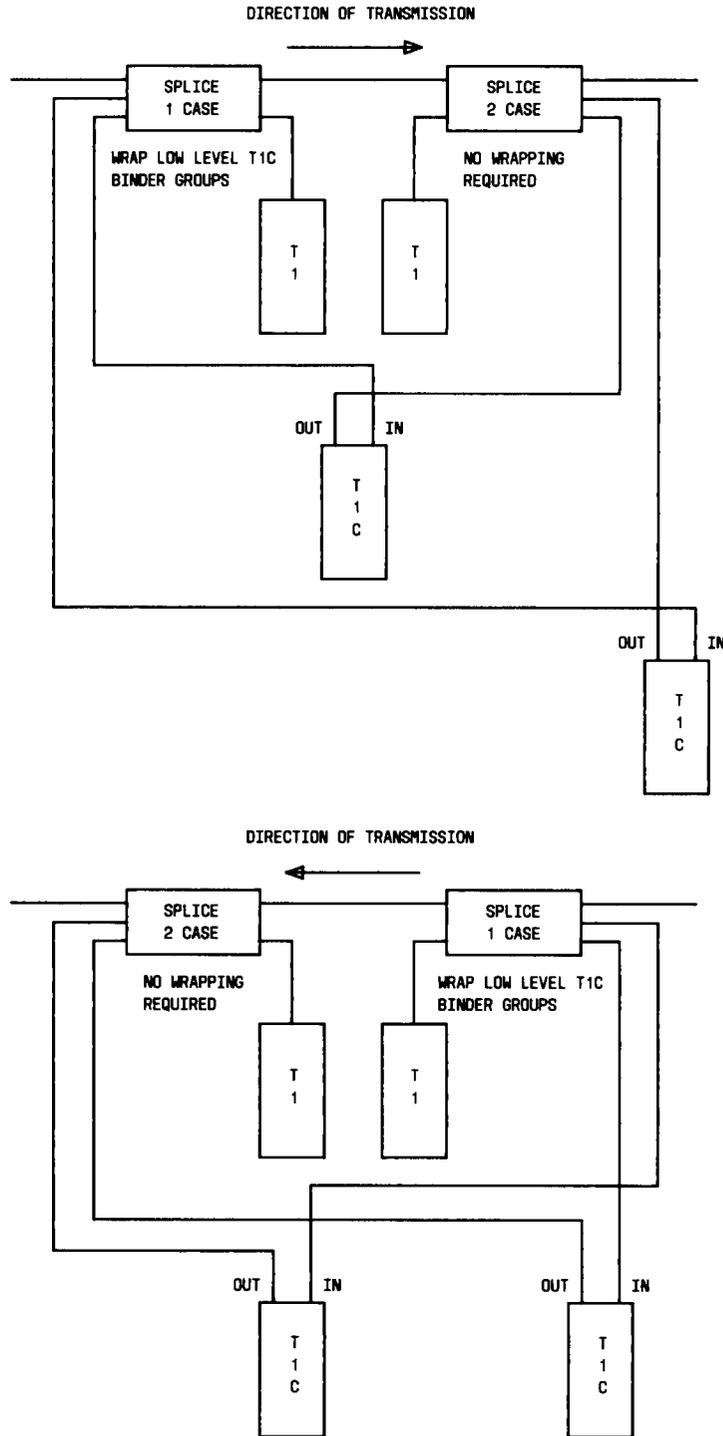


Fig. 26—Two-Cable Operation With Two Splice Cases Each Cable

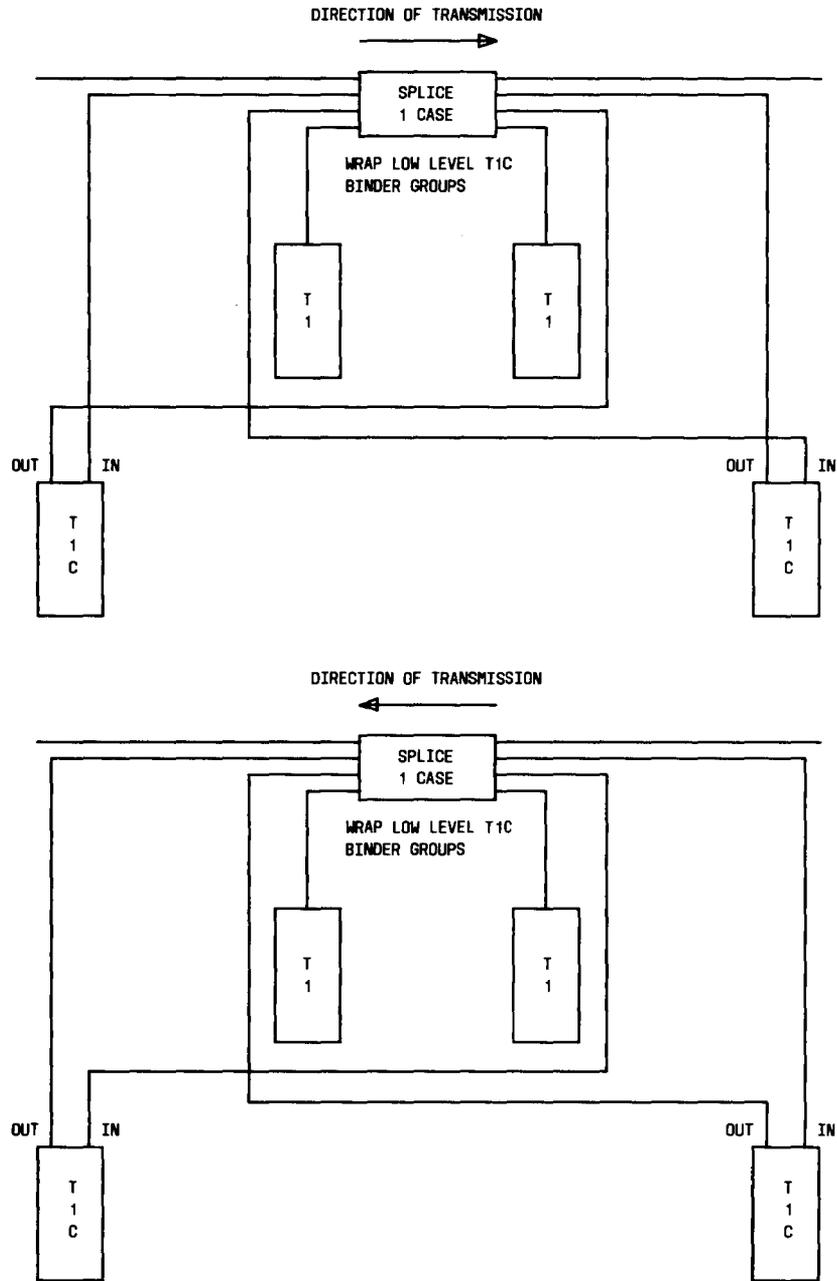


Fig. 27—Two-Cable Operation With One Splice Case Each Cable

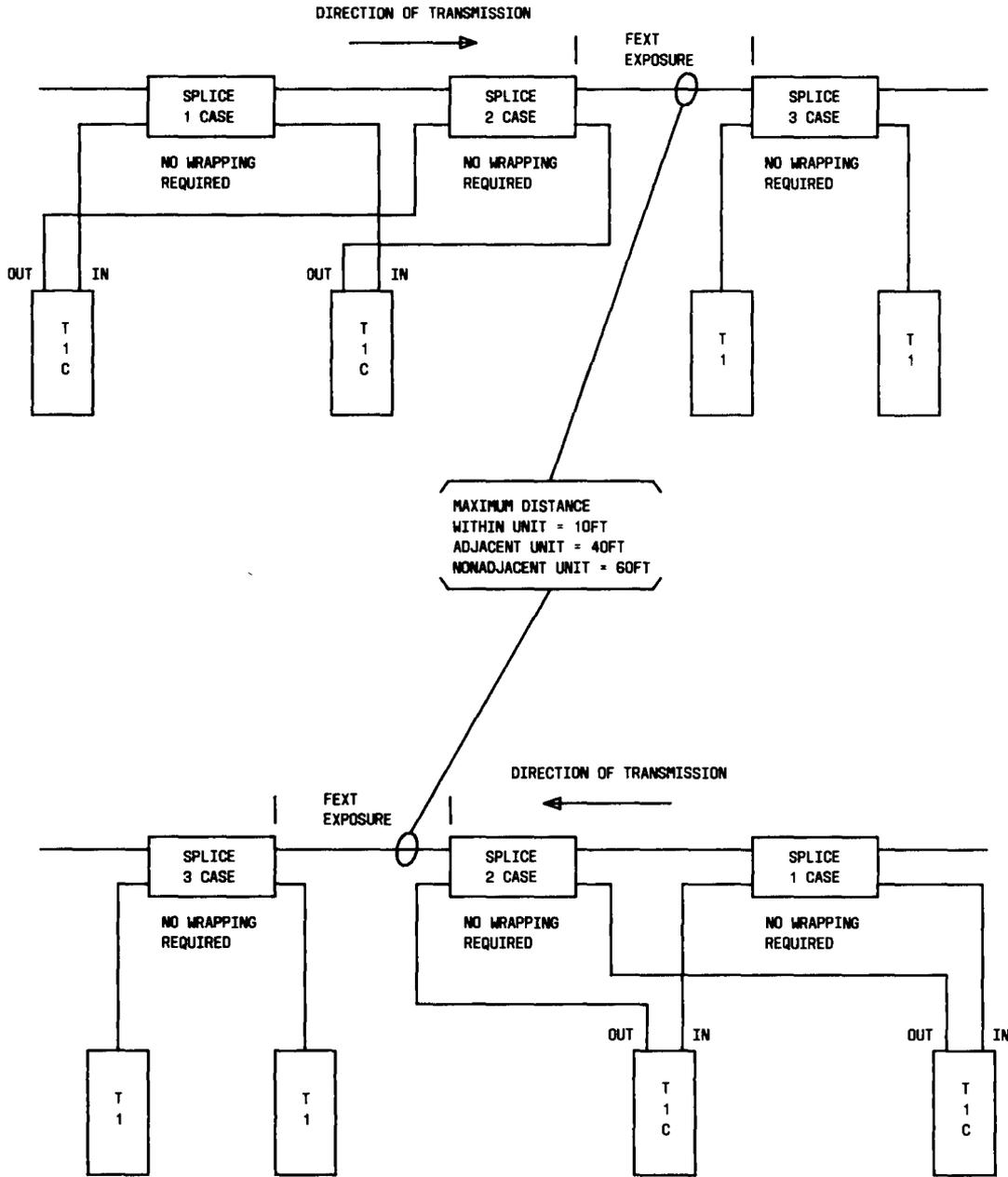


Fig. 28—Two-Cable Operation With Three Splice Cases Each Cable, T1 FEXT Exposure

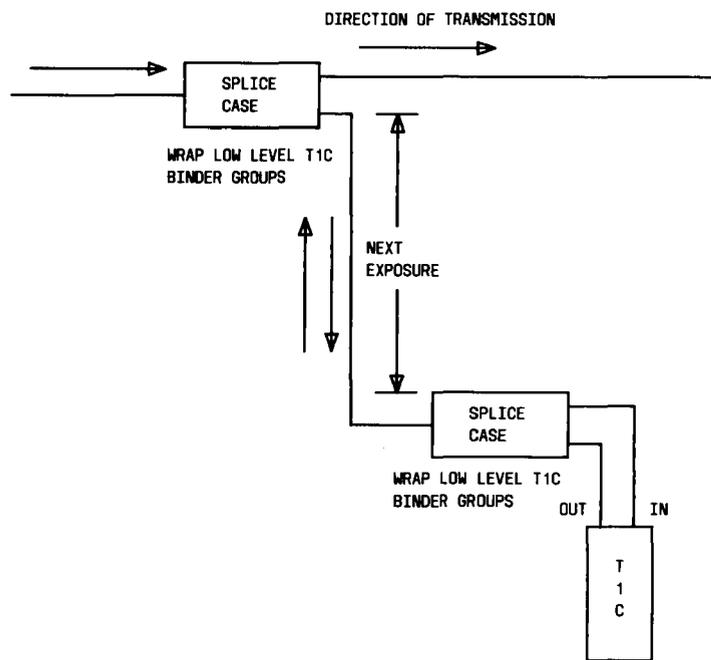
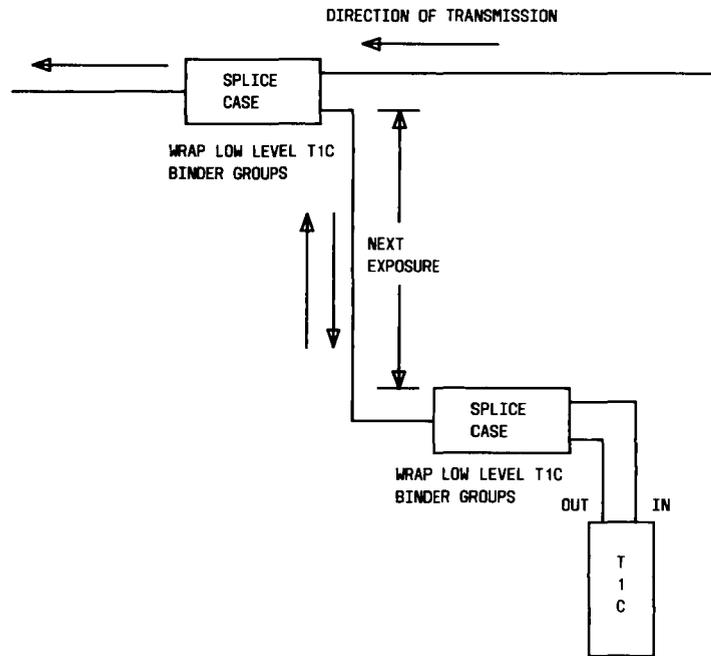


Fig. 29—Two-Cable Operation, NEXT Exposure

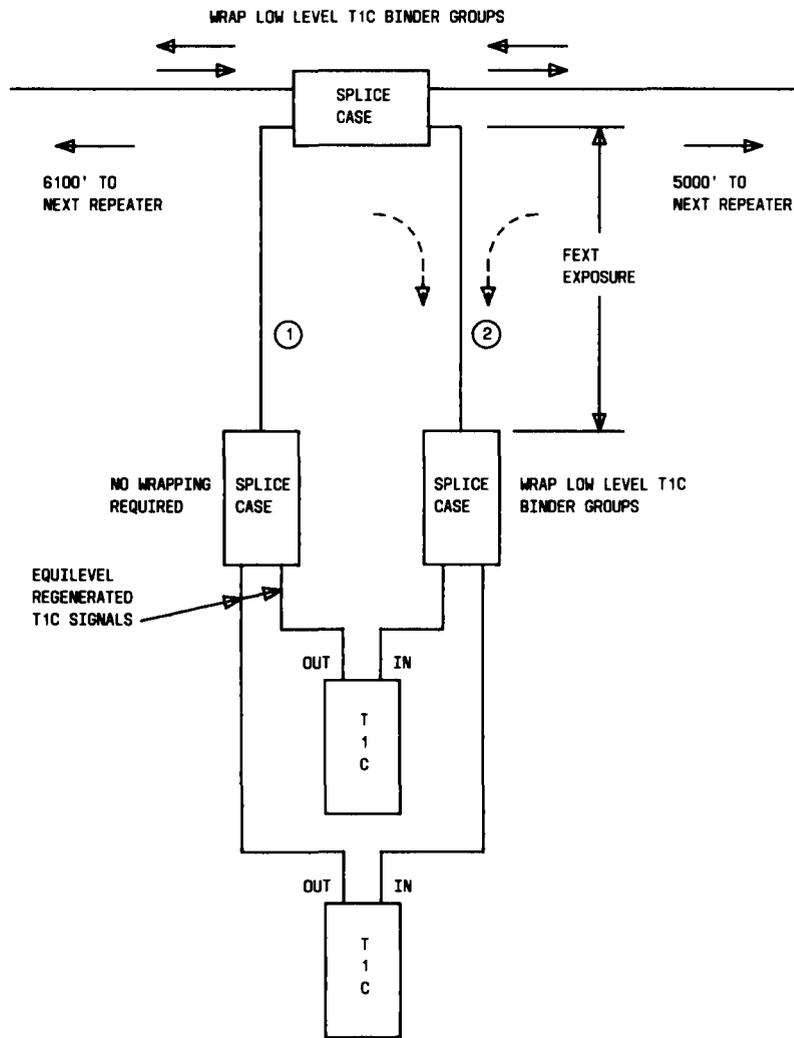
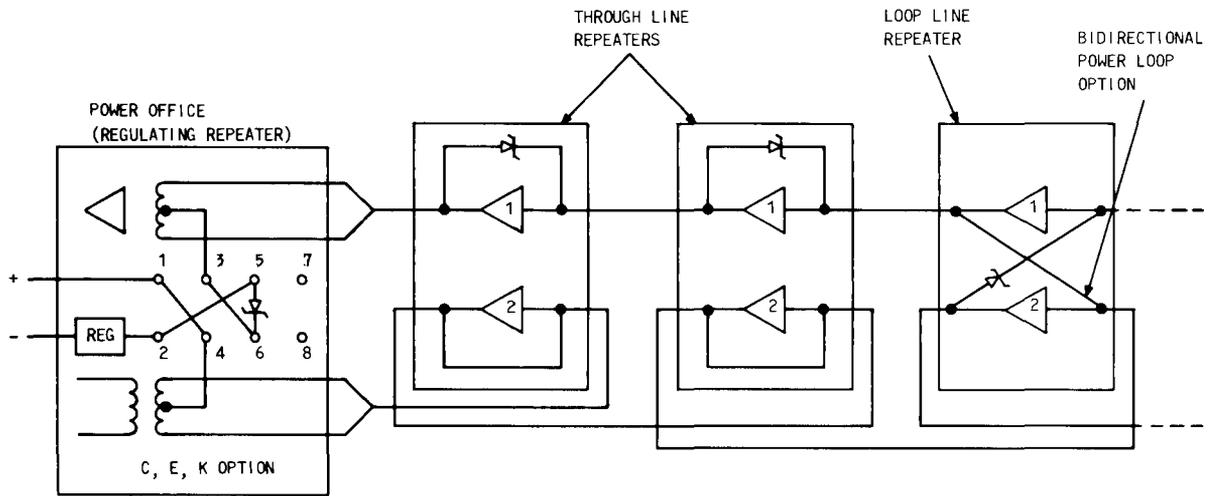


Fig. 30—One-Cable Operation, Differing Low-Level Signals



NOTE:
 T1C BIDIRECTIONAL OPERATION IS ACHIEVED
 THROUGH SPECIAL SPLICING ARRANGEMENTS

Fig. 31—T1C Bidirectional Power Loop

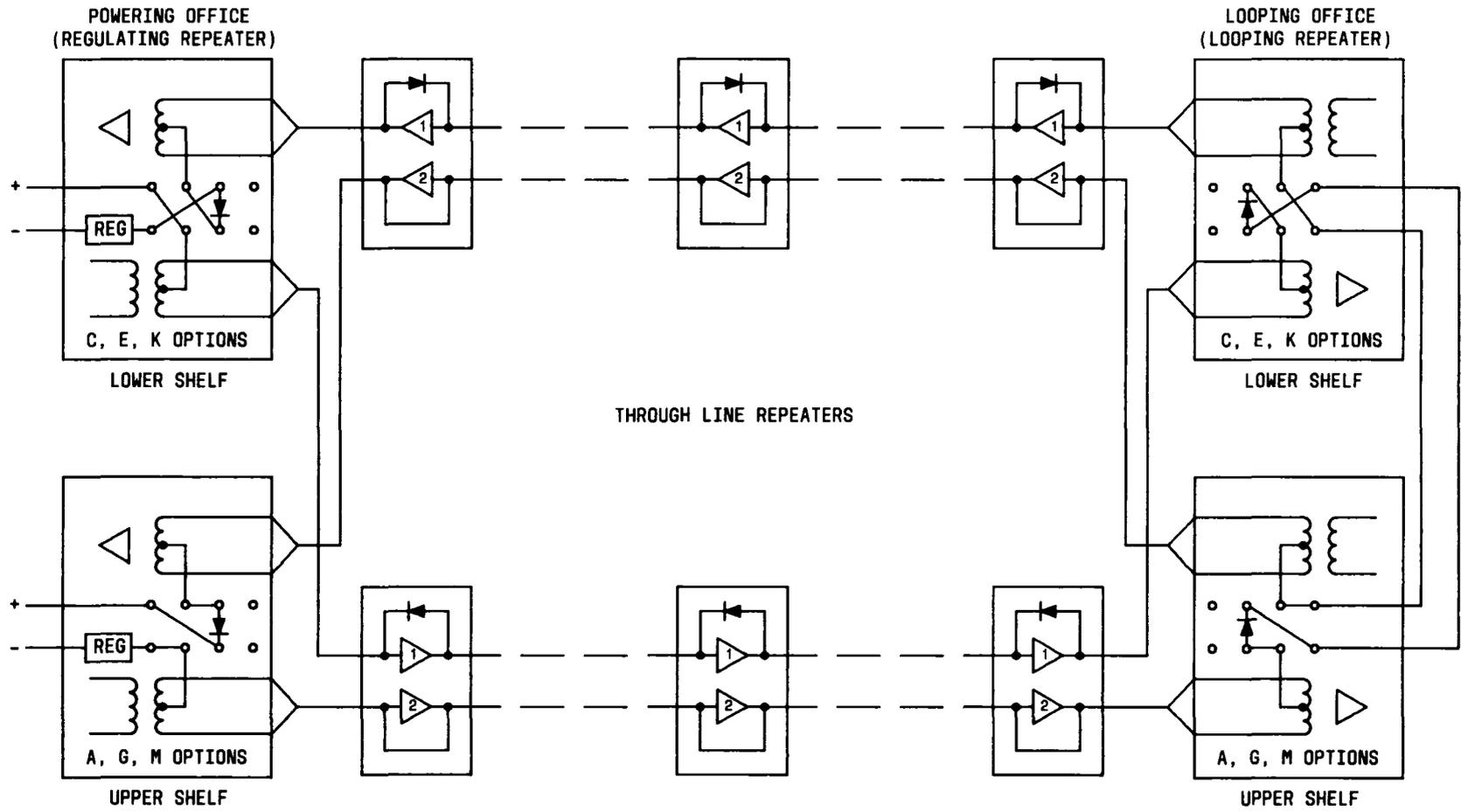


Fig. 32—Unidirectional Power Loop (C, E, K and A, G, M Options)

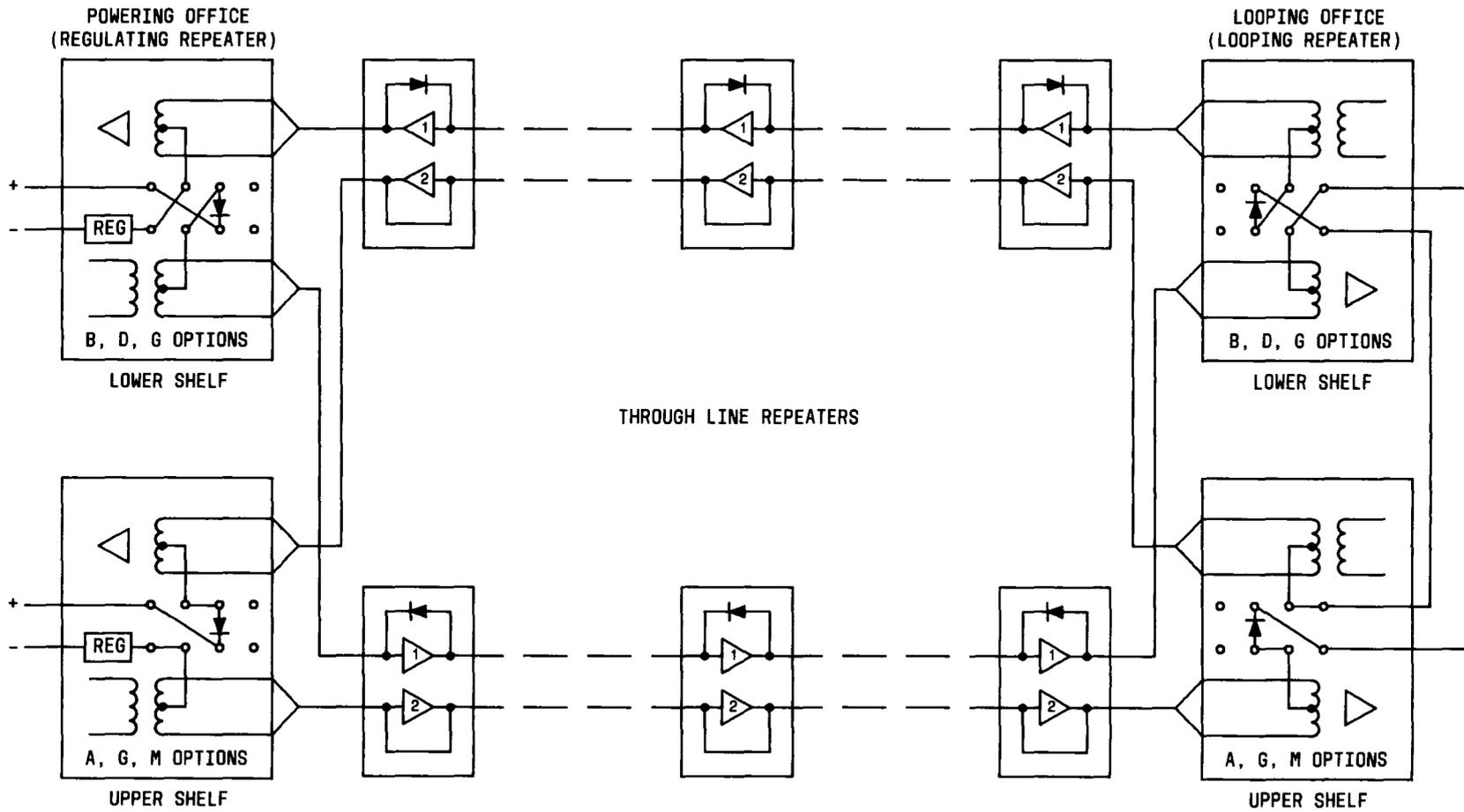


Fig. 33—Unidirectional Power Loop (B, D, G and A, G, M Options)



Initial Power Loop Information

Order No.	T _____ Powering Span	Office A	Office B
Engineered By	Telephone No.	Date Issued	New <input type="checkbox"/> Change <input type="checkbox"/>
Line Repeater <input type="checkbox"/> Bidirectional Operation <input type="checkbox"/> Unidirectional		Looping Point	Line Current

Office A		Office B	
Battery Voltage		Battery Voltage	
Bay Number		Bay Number	
Shelf Numbers		Shelf Number	
Office Repeater		Office Repeater	
Office Repeater Powered		Office Repeater Powered	

Repeater Options

Upper Shelf	Upper Shelf
Lower Shelf	Lower Shelf

Line Voltage

Min	Engr	Max	Meas	Min	Engr	Max	Meas
-----	------	-----	------	-----	------	-----	------

Regulator Voltage

Min	Engr	Max	Meas	Min	Engr	Max	Meas
-----	------	-----	------	-----	------	-----	------

Technician	Telephone No.	Date Implemented
Supervisor		

E-10604
Code B
(2-80)

Fig. 34—Form E-10604, Initial Power Loop Information

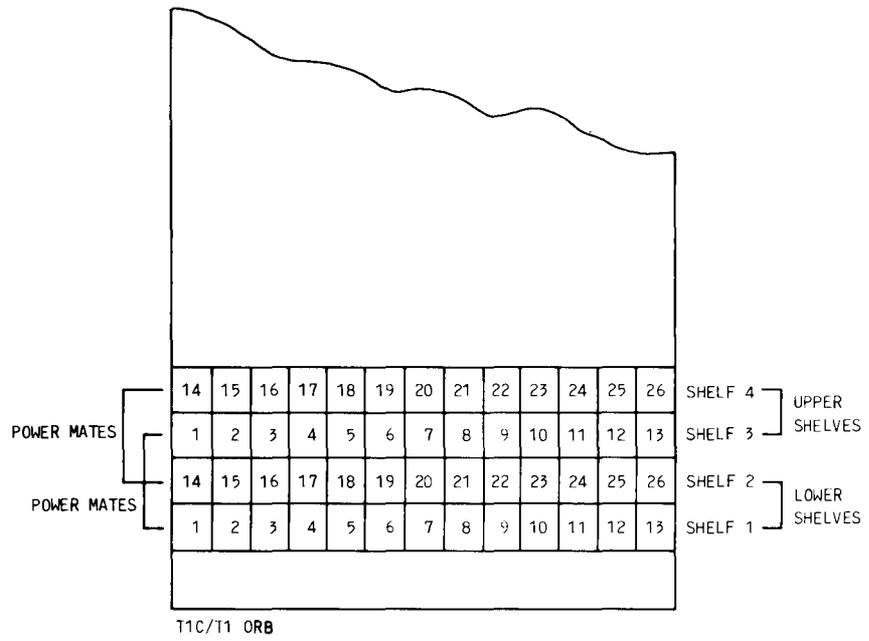


Fig. 35—Unidirectional Operation ORB Layout

22 GA. CU. PULP CABLE, BURIED (30-100 F)

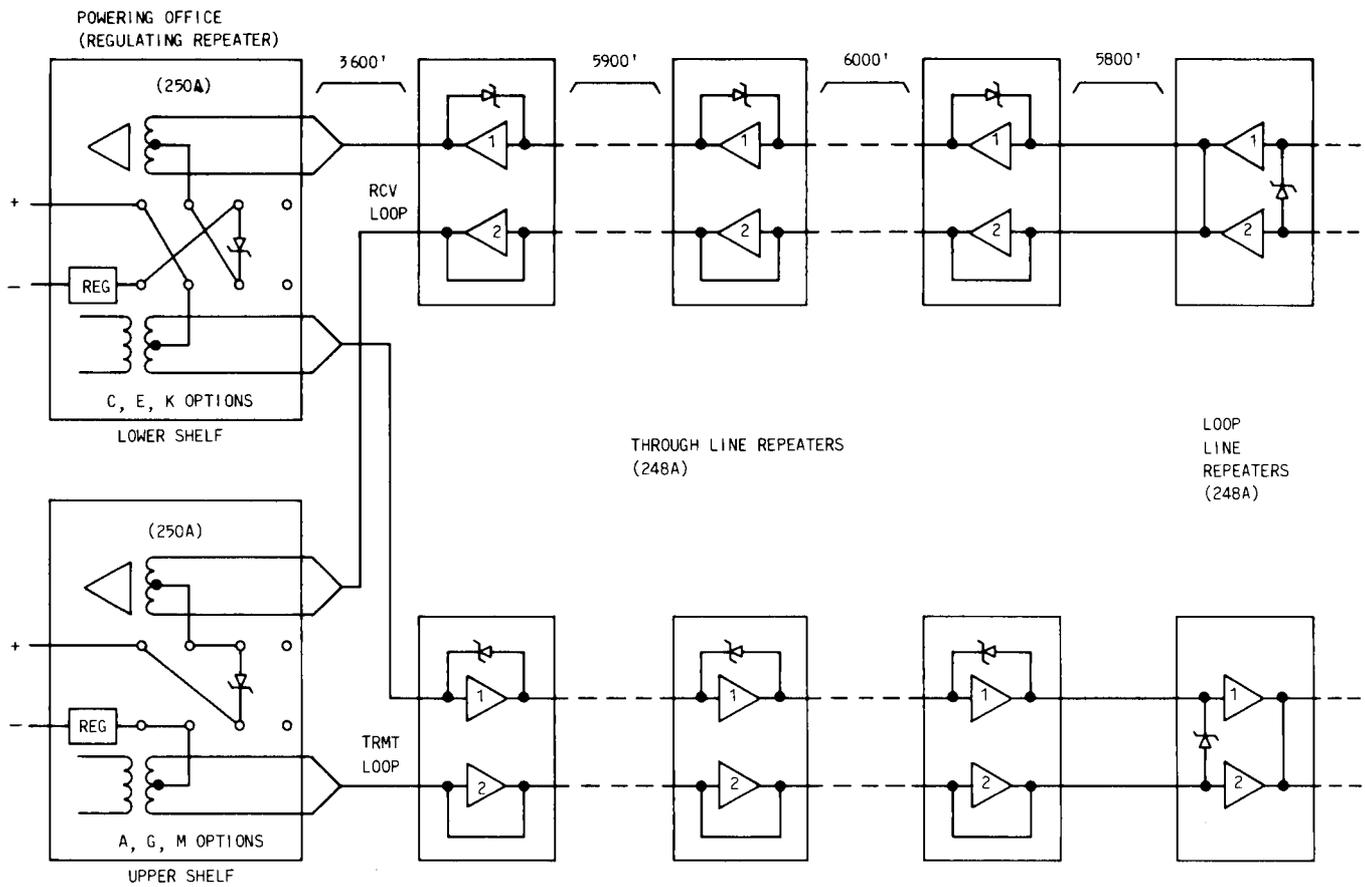


Fig. 36—Example Power Loop