

**T1D DIGITAL LINE
SYSTEM APPLICATION
TRANSMISSION AND OUTSIDE PLANT DESIGN PROCEDURES
CARRIER ENGINEERING**

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1. GENERAL

1.01 This section gives a brief description of the T1D digital line and provides engineering considerations for the application of T1D to existing exchange area installations. A glossary of terms is provided in Part 7 of this section. Section 365-280-100 gives a general description of the T1D digital line.

1.02 This section is being reissued for the following reasons:

- (1) Expand Part 2E on the T1C Automatic Protection Switch.
- (2) Add the Digital Carrier Operation, Planning, and Engineering (DCOPE) Computer Program, Part 2G.
- (3) Clarify Part 3 on Fault-Locate Filter.

Revision arrows are used to emphasize the more significant changes.

1.03 The T1D digital line (Fig. 1 and Fig. 34 Page 74) is a 48-channel, 3.152 Mb/s transmission line and is utilized where T1C cannot be used because of near-end crosstalk (NEXT) limitations. The T1D augments T1C by increasing the capacity of single cable installations employing large pulp cables and very small screened cables. The primary application will be with the large pulp cables. Although dual cable and large screened cable operations of T1D are not precluded, the economic advantage of T1C will favor T1C for these applications. ♦The format of the T1D signals (duobinary) transmitted down the line alleviate the NEXT problem encountered in T1C. The T1C transmits bipolar signals supplied by multiplex or channel bank equipment. The T1D office repeater converts the bipolar signals to a duobinary format before they are transmitted. The office repeater also contains circuits to convert the received duobinary signals back to bipolar. The growth application of T1D utilizes existing T1C office repeater bays, T1C crosstalk controlled apparatus cases, express office repeater panels, cross-connect bays, and digital channel bank or M1C or M1C-A multiplex equipment. The retrofit application of T1D utilizes T1 apparatus cases and office repeater bays. ♦

A. Transmission Medium

1.04 The T1D is intended for use on screened or nonscreened pulp and polyethylene-insulated

conductor (PIC) cable for exchange area use in routes having up to 50 sections (including T1 and T1C sections). ♦For T1D growth, a route with screened cable can have up to 200 repeater sections. ♦ Full-fill T1D is only possible on screened cables. In general, the following applies:

- (a) Some binder groups previously not used in cables can now be used to carry T1D.
- (b) Initially T1D is restricted to 19-, 22-, and 24-gauge copper and 17- and 20-gauge aluminum exchange-grade cable with unit type construction of 150 or more pairs in a single cable mode. Layered, MAT® cables, and ICOT* cables are not permitted.
- (c) T1D and T1, being nearly crosstalk equivalent, are compatible in the same sheath; however, they are not fully compatible with T1C.
- (d) Underground, buried, and aerial installations are permitted for T1D.

1.05 The T1D and loaded voice frequency (VF) facilities using either dc pulse signaling or multi-frequency (MF) signaling techniques can share the same cable sheath (but not the same binder group). Loaded facilities sufficiently attenuate high frequency components of dc spikes so that "roll off" of the spike edges occurs.

1.06 The T1D cannot share the same cable sheath with any nonloaded VF facilities (trunks, subscriber lines, private lines, etc) which are not coterminous in the same central offices with the T1D spans, and which use dc pulse signaling techniques (dial pulse, revertive pulse, etc) or services (dc telegraph, alarm industry, etc) which induce sharp dc transient (spike) characteristics.

1.07 In general, it is recommended that subscriber lines, whether loaded or nonloaded, not share the same cable sheath with any T-Carrier facilities.

1.08 ♦The T1D line can be constructed to use the following modes of cable-repeater operation:

- (a) New T1D Line
 - (1) Screened cable operation
 - (2) One cable using bidirectional operation.

* Trademark of Western Electric

(b) T1 Line Retrofitted to T1D Line

- (1) Screened cable operation
- (2) One cable using bidirectional operation
- (3) One cable using unidirectional operation
- (4) Two cables using unidirectional operation.

1.09 The new T1D will not generally be used in the 2-cable mode because of the economic advantage of using T1C.♦

B. Operating Modes

1.10 **Single-Cable T1D Operation** (See Glossary Definition, Part 7): The superior NEXT performance of T1D will permit full-fill operation on all existing screened pulp and PIC cables with maximum loss repeater sections. On large size non-screened pulp cables, unit selection is necessary in order to meet the 3-dB margin standard for NEXT. In Table A the section design numbers for maximum capacity single-cable operation are given. In Table B the capacities for single-cable operation of various combinations of T1, T1C, and T1D on 600, 900, 1100, and 1200 pair 22-gauge, and 1500 and 1800 pair 24-gauge pulp cable are tabulated. Also, 152 through 455 pair 19-gauge pulp cable may be used. The T1D is engineered in blocks of 50 span lines for unidirectional operation and blocks of 25 for bidirectional operation. (See Fig. 2 through 12.) Maintenance pairs (order wire, fault locating, and pressure alarm pairs) are normally assigned to units carrying VF service. (See Table C.) The maximum spacing for T1D intermediate sections for pulp cable is the same as for T1C. However, the maximum spacing for intermediate sections for PIC and DEPIC cable is somewhat less than for T1C. The minimum spacing for T1D intermediate sections for all types of cables is somewhat greater than for T1C. (See Table D.) The restrictions for sections adjacent to end sections are shown in Table E.

C. Signal Format

1.11 The T1D duobinary code is a 3-level signal with a signal rate of 3.152 Mb/s. The T1D line signal uses 3-volt rectangular 100-percent duty cycle pulses in comparison to the 3-volt rectangular bipolar 50-percent duty cycle pulses comprising the T1C line signal. (See Fig. 13.)

D. Performance Objectives

1.12 The probability that a digital system component (ie; repeater section, span, or terminal-to-terminal system) has an error rate greater than 10^{-6} is defined as the design number for that component. For T1D, a terminal-to-terminal system design number of 0.05 is required:

$$\text{Prob (Error Rate} \geq (10^{-6}) \leq 0.05$$

It is assumed that the probability of the terminal-to-terminal system error rate exceeding 10^{-6} is equal to the sum of the probabilities of the various repeater section error rates exceeding 10^{-6} . Thus, the terminal-to-terminal design number is equal to the sum of the design numbers for the constituent repeater sections. The fundamental rule is that the terminal-to-terminal design number must not exceed 0.05. Depending on the type of cable and configuration used, repeater sections engineered according to the T1D engineering rules may be assigned the design numbers shown in Table A. ♦Screened cable♦ route lengths should be limited to 200 repeater sections to facilitate maintenance.

1.13 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 365-272-000 (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.

E. System Margin

1.14 The T1D margin against crosstalk with respect to the performance objectives has been calculated for large nonscreened and small screened cable operation. This margin includes the effects of crosstalk in the cable and repeater impairments (ie,

misequalization, mistiming, aging, reflections, repeater circuitry, etc). No further margin computations are required, merely the use of cables certified for use with T1D. The utilization of maintenance pairs in various cables is shown in Table C.

2. CENTRAL OFFICE ENGINEERING

A. Terminal Equipment

2.01 Repeaters: The T1D spans terminate at central offices (COs) in office repeaters mounted in an office repeater bay (ORB). The capacities of ORBs J98725A, B, C, D, E, F, and J98710J, K, and L are shown in Table F. ♦The office repeater consists of a transmit and receive regenerator. These repeaters provide line current regulation and line current looping. They may be powered locally or in series with the line. ♦The repeaters are coded 260A, B, C, and D for the J98725() ORB and 286A, B, C, and D for the T1 J98710() ORB. The fault locate information is taken off at a point before the descrambler. The receive regenerator accepts a duobinary signal from the line, descrambles it, and converts it into a bipolar signal. On the transmit side after regenerating, the bipolar signal is converted to unipolar, scrambled, and then converted to a duobinary format suitable for transmission on the span line. Also available in the ORB are facilities for bridging a signal from a working line to a maintenance line. See Fig. 14 for a block diagram of the office repeater. Office and line repeater codes are shown in Tables G and H.

2.02 The J98725A, B, and C ORB provides, in addition to the office repeater shelves, mounting space for the following equipment: 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 power distribution to the repeater positions. Space is also available on J98725A, B, and C, and J98710() bays for mounting a jack panel which provides access for patching and testing the T1D spans. ***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 done.*** In large T1D installations (when DSX-1C cross-connect bays are required) it is advantageous to use J98725D or E bays (DSX-dedicated) with their larger repeater capacity per bay. The DSX-dedicated bays must be used with

DSX-1C equipment. Sections 855-350-105 and 855-350-106 give 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 panel. A 0-dB or 12-dB artificial line is included on the outgoing line side of each T1D office repeater. These pads permit greater flexibility in setting line lengths for end sections. In addition, an automatic line buildout (ALBO) on the receive side of the office repeater compensates for variations in end section lengths, including intraoffice cabling from the cable vault to the ORB. ♦The 7.5 dB artificial line option in the office repeater should be used only when the cable loss of the end section is less than 15.5 dB at 772 kHz. (The artificial line loss is 7.5 dB at 772 kHz and 12 dB at 1.576 MHz.) When the cable loss is greater than 15.5 dB, the 0 dB artificial line option should be used. ♦An equalizer (see paragraph 2.11) is provided at the receive output (office side) for cable compensation between the ORB and DSX-1C. (See Fig. 15.)

Multiplex

2.03 The M1C or M1C-A multiplex, as mentioned in paragraph 1.03, provides the interface between the DS1 level signals and the T1C (DS1C level) signal. Each M1C muldem accepts two DS1 signals and multiplexes them to form the ♦T1C interface♦ signal. The M1C muldems are mounted in the M1C J98727A, B, C, or E multiplex bay as shown in Table I. 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 (paragraphs 2.11 and 2.12) are provided to equalize the cable between the M1C and DSX-1C on one side and M1C and DSX-1 on the other side (Fig. 16).

D4 Channel Bank

2.04 The D4 channel bank is a 48-channel VF pulse code modulation (PCM) terminal which was developed to provide a more economical access to the T1C line facility. In general, the D4 terminal could replace two D3-type 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, D4 achieves, relative to D3, about a 2:1 reduction in size and power consumption. Improvements in maintenance, power consumption, and reli-

ability are also obtained. The bank will directly interface one T1D line. The D4 may also be used with digital cross-connect equipment (DSX-1, DSX-1C) and digital multiplex equipment (M1C, M1C-A, M12, M13 or MX3). [See Section 365-170-000 (TOP).]

B. Interconnecting Facilities

2.05 Interconnecting facilities include the entrance cabling, intraoffice cabling, main distributing frame (MDF), and the cross-connect panel. Unit integrity on T1D should be maintained MDF-to-MDF.

2.06 *Only one direction* of T1D transmission is to be carried in a single tip cable. In addition, the tip cable must be dedicated to T1D with no voice frequency pairs permitted (reduces effects of switch noise). It should be noted that T1, T1C, and T1D can share tip cabling if all 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. The 303B2-50 connector has two 50-pair stubs and is described in Section 636-330-100.

2.07 In T1D 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.

2.08 The remaining office cabling is 22-gauge ABAM or 600-type cable. Only one direction of T1D transmission can be carried in a single cable sheath. The T1D intraoffice connections and interbay maximum cable lengths are shown in Fig. 35 Page 75. By following the length restrictions of Fig. 35 and using the appropriate equalizers, signals appearing at the DSX-1C will be equilevel with a 3-volt peak. Any T1D signals in the same cable sheath must be equilevel within 3 dB. To ensure equilevel signals, all signals in the same cable 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.

2.09 The T1D 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 CO noise and to ensure separation of the two directions of transmission. Where protection is not required, the protector blocks should be patched or strapped out because their inadvertent removal would cause a loss of any pair involved. The engineer may choose to provide ABAM or 600-type cable direct from the cable vault to the ORB, thus conserving valuable distributing frame space.

2.10 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. 17.)

Intraoffice Cable Equalization

2.11 Equalizers (ORB or repeater mounted) are available for equalizing the office cabling between the ORB and DSX-1C. For all 260 and 286C, D, and E repeaters, the equalizer codes and their ranges are shown in Table J. When no DSX-1C bay is provided and jack appearances remain on the repeater bay, 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 (paragraph 2.02). This arrangement minimizes flat loss mismatch when systems are looped and provides test set compatibility at the jacks on both bays. In J98725 ORB, repeater circuit position 26 is equipped with ED-3C655-31, G6 for all applications of the 250C bridging repeater, since all signals on the office side of the ORB are T1C format in the T1D System.

2.12 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. The various codes and their ranges are listed in Table K. (See Fig. 16.)

Communications Requirements

2.13 An order wire 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 span. Order-

wire engineering is discussed in Section 855-350-107. The order wire is treated as a subscriber line in one of the span terminating offices. In this way, the craft person can dial any number from the manhole repeater location and call the testboard at either span terminating office. A network, in series with each order-wire bridge appearance, provides better current distribution when more than one handset is connected to the order wire at different locations.

2.14 The order wire uses a loaded pair and has an appearance in each repeater apparatus case in the span as well as on the ORB or DSX at each end of the 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 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 also appear on its maintenance panel.

2.15 ♦When order-wire panel J98725H is used, the maximum working length of this order wire is 40 miles when 22-gauge cable and 96 volts are used or 20 miles when 22-gauge cable and 48 volts are used. Order-wire panel J98710E can only be used for 20 miles with 48 volts. When used with a central office at each end, spans up to 20 or 10 miles can be serviced by using a blocking capacitor in the center of the span and an order-wire circuit at each end. For those situations where the order wire shares a binder group, a suppression filter is installed to prevent interference with voice communications on digital transmission from interaction crosstalk.♦

Central Office Communications

2.16 Adequate communications are essential to the proper maintenance and operation of a T1D line. 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

2.17 Record keeping methods for all CO equipment are found in Section 365-000-010. Record

cards, forms, and procedures are covered. Another aspect of administration is naming the T1D line in accordance with common language requirements, Section 795-450-104.

C. J98725J Express Office Repeater Panel (EORP)

2.18 The express office repeater panel (EORP) has been developed to reduce the cost and equipment necessary to provide through-office routing. This function is required when a span passes through an intermediate CO other than the span terminating office. The EORP performs a function similar to a manhole apparatus case; however, it is designed to be bay-mounted in a CO location. (See EORP application schematic SD-3C369-01.)

2.19 Each EORP is designed to accommodate 25 258- and/or 259-type line repeaters which regenerate the digital signal. The panel also contains 25 artificial line network printed wiring boards (ED-7C320), 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 networks provide at least 12 dB insertion loss at 1.576 MHz for the inputs and outputs of the repeaters and maintain the characteristics of actual cable.♦

2.20 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.

2.21 Secondary lightning protection is provided as an option on the artificial line printed wiring boards. 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.

2.22 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 T1D line is also used for the EORP.

2.23 An optional terminal block (ED-3C723-30) can be installed at the top of the 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.

2.24 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 T1D 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)

2.25 A typical bay arrangement is specified in ED-3C724.

2.26 The EORP J98725J can be used for T1D and T1C unidirectional modes. The minimum installation is two panels (50 repeaters) with a span capability of 50 lines. Bidirectional T1D and T1C applications can be accomplished by special splicing arrangements to the EORP. The minimum span capability in a bidirectional mode is 25 lines, one panel of 25 repeaters.

2.27 Power for T1D repeaters in the EORP must be provided from the repeatered line. No option is provided to power locally the repeaters in the panel or to provide power to line repeaters from the panel.

2.28 When a T1 line, which is being retrofitted to a T1D line, contains a J98710U Express Office Repeater Panel, this EORP must be replaced by a J98725J EORP in order to accommodate the T1D retrofit repeaters.

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

2.30 Following are two sets of EORP engineering rules. One set of rules is to be used for engineering EORP installations and the second set of rules is to be used when engineering T1D express routes where the EORP may be eliminated.

2.31 The set of rules to be used when engineering a T1D EORP installation states that the

EORP should be treated as an end section from a transmission and office cabling viewpoint and as a manhole repeater from an administration and operational viewpoint. Concepts are similar to those for the T1/T1C EORP installation.

2.32 The second set of engineering rules provides guidance in designing T1D 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.

2.33 Following are the EORP engineering rules to be used when designing a T1D EORP installation:

1. All T1D end section engineering rules apply [including maximum and minimum repeater spacings (Table D)].
2. There is no limit (maximum or minimum) on the length of the ABAM or 600-type and/or tip cables connecting the EORP to the outside plant (as long as the end ABAM or 600-type and/or tip cables and the end section repeater spacing limits are not exceeded).
3. No voice frequency circuits are permitted in ABAM, 600-type, or tip cables carrying T1D lines.
4. Only one direction of T1D transmission is permitted in a tip, ABAM, or 600-type cable.
5. The T1D CO engineering rules described in Part 2 of this section apply to the EORP.
6. Each shelf in an EORP must be assigned to a particular apparatus case. Mixing of T1D 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 J98725J EORP.

2.34 The following requirements and engineering rules are to be used when designing a T1D express route *without* the EORP at the express office:

1. In T1D routes where nonscreened cable is dedicated to express operation, the J98725J EORP

is not required as long as the cable length (loss) of the two end sections at the express office does not exceed the T1D engineering rules (repeater spacings) for a T1D intermediate repeater section. In a 1-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 CO.

2. In an "express lines only" route, the T1D lines are cross connected at the MDF of the express office using ABAM or 600-type cable; hence, the express office is merely a cross-connect point for the T1D lines.

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

2.35 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 standby terminals or 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 Schematic SD-99503-1.)

2.36 Each bridging repeater panel is designed to accommodate two 220C (T1C), two 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 DSX-1/DSX-1C panel assembly is intended to be mounted in the DSX-1 or DSX-1C cross-connect bay and to be powered with -48 volts.

2.37 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 shelf. The output cable equalizers are accessible from the rear of the shelf in case the cable length of remote operations require that they be changed.

2.38 For each repeater, the front panel has two IN jacks, one OUT jack, and two MON jacks. This permits a disabled span to be replaced first by a back-

bone 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 span maintenance line may be driven simultaneously.

2.39 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)

2.40 The APS is designed to protect up to 144 T1D service lines using protection to service line ratios of 1/24 and 2/48. 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. When T1D lines are protected by the APS, a line affected by trouble is switched to a protection line and the line in trouble is taken out of service for repair. This switch is fast enough to maintain a call in progress (no bank alarms) for most single failures.

2.41 The T1C APS is designed with signal levels that are compatible with DSX-1C and the J98725 (new installation or retrofit) or the J98710 (retrofit) ORB. The T1D fault-locate scheme requires that a single jack access panel be added between the APS and the T1D ORB. That panel provides the necessary dc continuity from the fault-locating input jack to the T1D ORB. Figure 18 illustrates how an APS is positioned in a T1D system. The design of the T1C APS requires APS equipment on both ends of the facility to be protected. Refer to sections 365-250-120 and 855-350-109 for specific information regarding the use of the APS to protect T1D span lines.♦

F. Central Office Switching Noise Considerations

2.42 The maximum cable length of an end section is limited as shown in Table D. End section cable length is measured from the ORB to the first line repeater, and therefore includes ABAM or 600-type intraoffice cable, tip cable, entrance cable, line cable, and apparatus case stub. The length restriction is necessary to limit the effect of central office impulse noise arising from switched voice pairs. By limiting the length to 4100 feet, as for 22-gauge copper pulp cable, the minimum signal-to-noise ratio at the

office repeater is 16 dB greater than it would be with a 6100-foot section.

2.43 Voice pairs are not allowed in units carrying T1D signals except for nonswitched maintenance pairs (paragraphs 3.27 through 3.31). This absence of voice pairs increases the impulse noise loss by 10 to 12 dB. Also, tip cables carrying T1D signals from the cable vault to the MDF and ABAM or 600-type cables carrying T1D signals from the MDF to the ORB must be dedicated to T1 and/or T1D Carrier. The use of a dedicated cable eliminates a significant exposure to switching noise and near-end crosstalk which would otherwise occur in the tip and ABAM or 600-type cables.

2.44 Engineering the cabling as discussed allows end section lengths up to 4100 feet for 22-gauge copper pulp cable. Although end section lengths as short as 800 feet are allowed, the sections should be engineered to be between 2000 and 4100 feet where possible. End section lengths shorter than 2000 feet would place a length restriction on the adjacent repeater section which can be no more than 4100 feet plus the length of the end section.

G. Powering Considerations

2.45 Powering of T1D line repeaters is accomplished by sending a constant dc current over the cable pairs in a simplex manner. Office battery voltage is applied to the cable pairs through a constant current regulator in the office repeater. At each repeater location the simplex current is passed through zener diodes to develop the power supply voltage for that repeater. The voltage drop for 258-, 281-, and 288-type repeaters is 11.2V; for 259-, 285-, and 289-type repeaters it is 12.7V; and for 260- or 286-type repeaters the drop is 23.0V. These repeaters operate with a simplex current of 120 ± 4 mA. The T1D office repeaters provide for the use of office battery supplies of -48V, +130V, and -130V. Combinations of these voltages can be used to derive total supply voltages of 48, 130, 178, or 260 volts. In order to minimize power dissipation in the ORB, it is desirable to use the lowest possible supply voltage which will properly power the span. Typical T1D simplex power loops are shown in Fig. 19, 20, and 21. In Fig. 19 the loop is completed (looped back) at a manhole repeater location. This is accomplished by selecting the "looping" instead of a "thru" option on the line repeater at that manhole. All other manholes would have the "thru" option selected. When a looping line repeater

is used, it actually completes two power loops at once—one looking towards each office. Each of these power loops must be treated separately when performing the calculations given in the following paragraphs. A power loop can also be looped at the far end office by installing looping office repeater codes as shown in Fig. 20.

(a) Powering of the regenerator circuits in office repeaters can be accomplished in either of two ways. The repeater can be "locally powered" from the -48V office battery and be independent of the simplex loop, or it can be "series powered" by the simplex loop in the same manner as line repeaters. **Local powering puts an extra load on the -48V supply and significantly increases the power dissipated in the office repeater bay and should be avoided if possible.** It does allow a slightly longer power loop, however, and will be necessary in a limited number of applications.

(b) Transmission design will usually determine the office and manhole locations and cable types and lengths used in a line. With these parameters fixed, one office in a span is chosen as the powering (regulating) office and a looping point is chosen either at the other office or in a manhole. Office repeater powering options are chosen based on efficiency considerations. At this point it is possible to calculate the equivalent resistance of the power loop and select the proper battery supply voltage. Depending on the results obtained, it may be desirable to move the looping point or change the options chosen and recalculate the required supply voltage to optimize efficiency or to consider special limitations such as available battery supplies, unmanned office, or diversity of looping points. It is possible to go through several iterations of the above procedure before arriving at an optimum configuration. Figure 22 illustrates a 1- or 2-cable span line for a 21-mile span. This span line will require power from both ends which will be looped at a selected repeater somewhere in the span. The location of the looping repeater is governed by several factors, including the voltages available at either end and the criteria set forth in the power notes in Schematics SD-3C252-01, SD-3C371-01, or SD-97080-02.

2.46 Power Loop Structure: The simplest power loop structure is the bidirectional operation (Fig. 19). It is composed of a current regulator,

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repeater power supply zener diodes, cables, and a return path to the battery supply. The regulating office repeater provides both the current regulator and battery return path, while the loop is made continuous by 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.

2.47 In unidirectional operation, however, the power loops are more complex as shown in Fig. 20. Each loop is composed of the same elements as for a bidirectional operation system, but pairs of loops share the office repeater at each end. Examination of Fig. 20 will show that each loop starts at the regulator output of one office repeater (-), passes 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 and both must be installed to have either power loop complete. The ORBs are arranged with groups of four shelves (50 repeaters) which comprise 25 power mate pairs or 50 2-way lines (Fig. 23). Power mates appear in shelf positions of the same number separated by one shelf. Shelf numbering starts at the bottom of the bay 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. This somewhat complex arrangement is necessary with unidirectional line repeaters to limit the service outages due to repeater failure. 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.***

2.48 ♦**DCOPE/T-PWR Applications:** As an aid in designing T1D power loops, a computer pro-

gram has been developed to compute the required power design parameters from known circuit data input. This subprogram called T-Carrier Power Loop Calculations (T-PWR) is part of the application package Digital Carrier Operation, Planning and Engineering (DCOPE) which is a program in the **Engineering Planning Analysis System (EPLANS)**. Using the T-PWR program, an engineer can determine the powering arrangement and select the looping point for powering T-Carrier line repeaters between two COs. The T-PWR program benefits include:

- (a) Listing the optional looping point for a span
- (b) Calculating the minimum voltage(s) required to power a span
- (c) Providing more efficient and effective use of battery voltage
- (d) Reducing the capital expenditure needed for power plant facilities
- (e) Reducing time and effort involved in power loop calculations. The program calculates and prints the minimal power requirement (either 48 or 130 volts) for every possible looping point in the span. In addition, on an optional basis, the theoretical maximum and minimum line and regulator voltages are calculated and printed for each looping point in all spans except those powered by STAs.

2.49 The T-PWR program can handle any non-WE user-selected systems with similar powering arrangements. The program requires a data base containing T-Carrier parameters. The data base consists of two sets of tables. Standard tables are stored in the same system as T-PWR program and contain data on standard WE T-Carrier systems. User tables are stored in the user's disk file and contain data on the general trade Digital Carrier Systems as selected by the operating company.

2.50 Ordering information for DCOPE (T-PWR) package can be obtained from the EPLANS coordinator. General information and references for using DCOPE for specific designs are given in the DCOPE program application handbook, PA-1N160-01. This document describes how DCOPE provides the data necessary for a given span. The power calculations include maximum and minimum total loop

resistance (R_{LMAX} and R_{LMIN}), required voltage (48 or 130 volts), and specific repeater power options (CEK, AGM, etc).♦

2.51 Office Repeater Options: 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 (Table L), while the repeater powering options are chosen to power the office repeater regenerator either from the local -48V supply or in series with the simplex line current. Table M summarizes the repeater powering option choices which are accomplished by turning down the indicated screws with all others up two turns. The choice of options depends on whether it is a regulating or looping repeater and whether it is locally or series powered. In unidirectional lines, however, the two office repeater power mates on one end of a loop require different option selections to configure them correctly. When the office repeaters are to be locally powered, the options are BEHN for the lower shelf power mate and AFHN for the upper shelf. However, if the office repeaters are to be powered in series with the simplex loop, as is recommended, the options are BDG for the lower shelf power mate and AGM for the upper shelf. **The two repeaters of a power mate pair at the same end of a span should be powered the same, either both locally or both in series.**

2.52 The T1D office repeaters employ active circuitry in both transmit and receive signal paths. Therefore, if power to the repeater is lost, both directions of transmission will require patching for restoral. In unidirectional operation, if the office repeaters are series powered, loss of the simplex loop current will rob power from both line repeaters in one direction and the office repeater of one line, with a total of three patches required for restoral. When local powering is used, only two patches are necessary to restore a failed loop. These considerations are important when restoral of lost service is necessary.

2.53 Battery Voltage Selection: 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,

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

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

where R_{MAX} and R_{MIN} depend on cable gauge and material and are given in Table N and 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 the particular loops as is done in Fig. 19 and 21 and 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 (from Table O) 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 whether it is a powering or looping repeater. Line repeater resistance depends on whether it is protected or unprotected, whether it is a through or looping location, and, if looping, whether the loop includes the zener diodes path (side 1 input) or the low impedance path (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 BDG/AGM at one end and BEHN/AFHN at the other, the two power loops of the power mate pair are symmetrical and the loop resistance will be the same for both (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 operation each loop is the same as all of the others in that span. Refer to Table O.

2.54 Minimum and maximum cable resistance (R_{CMIN} and R_{CMAX}) is 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 M). 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 al-

lowed 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 M. 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. When using the express office repeater panel (J98725J), it is considered the same as a manhole for the purposes of calculating loop resistance except for the following consideration. The EORP contains line buildout (LBO) circuits on the repeater inputs and outputs and the resistance of these must be added to the resistance of the line repeater used. The T1D LBOs add a total of 28 ohms to the thru resistance value for the line repeater from Table O or 14 ohms to each of the zener loop (side 1 in) and low Z (side 1 out) loop resistances.

2.55 ORB Options: 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 regulating repeaters are used with battery voltages greater than 48V. The ED-3C554-30, G1 PDUs are used with J98725A, B, and C bays; ED-3C741-30 G1s are used with D and E bays. When looping office repeaters are used in the ORB, option W for J98725 bays or option YY for J98710 bays must be provided in that bay if the lines are unidirectional. In addition, in J98710 bays the Q, R, S, and Z options must be selected per Table M.

2.56 Example Calculation: An example of a power loop calculation for the unidirectional T1D line shown in Fig. 21 follows. Cable resistance will be the same for both loops.

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

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

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

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

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

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

Repeater resistances will be different, however:

	XMIT LOOP	REC LOOP
260A (BDG/AGM)	207	207
258A (Thru, X3)	288	288
258A (Loop)	95	1
R_R (Total)	590	496
R_{LMAX} (= $R_R + R_{C_{MAX}}$)	971	877
R_{LMIN} (= $R_R + R_{C_{MIN}}$)	904	810

Since both 810 and 971 must fit within the range for the battery voltage chosen, the only possibility is 178V. Thus, regulator options W and Z would be chosen. Note that 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. Power options and information should be shown on the Span Line Record. (See Section 365-000-010.)

2.57 Calculation of Voltage Limits: 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 (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 M. 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 (See Fig. 24).

2.58 Use of Calculated Limits: 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 required.

2.59 Even though operation within these limits is necessary for a good power loop, it is not 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 not often cause enough shift in voltage measurements to make them fall outside the MIN and MAX limits.

2.60 It should be noted 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.

3. GROWTH APPLICATION

A. Outside Plant Equipment

3.01 Apparatus Cases (Fig. 25 through 29):

Only 479-type or T1C versions of 818/819-type apparatus cases can be used for T1D growth applications. The extremely good crosstalk performance of these cases is achieved by using either two stubs or a quad-screened stub to isolate the low-level input signals from the high-level output signals, and by controlling the internal wiring in these cases. The

479-type case has two stubs, whereas the 818/819-type case can be obtained with either two stubs or a quad-screened stub. Both cases can house up to 25 T1D repeaters and an associated fault-locate filter. Order-wire and pressure contactors are available. An order-wire terminal is provided on an option basis. ♦Figures 30 and 31 show the stub cable binder group arrangement for unidirectional and bidirectional splicing of the repeater cases. Splicing of the 479-type apparatus cases to the cable is implemented by using either mechanical splice closures or lead-wiped sleeves. The 818/819-type cases use mechanical splice closures. Where low-level T1C signals appear in the same splice closure with high-level T1D signals within 500 feet of the repeater site, these splices must be shielded. This is accomplished by wrapping the low-level T1C pairs in the splice closure with foil wrap. At present only the 818/819 apparatus case with a quad-screened stub cable or the 818C2C/819C2C apparatus case with dual-screened stub cable is recommended for use for bidirectional operation. ♦The repeater cases for T1C and T1D must be spliced for either unidirectional or bidirectional operation.

3.02 Line Repeaters: The T1D line repeater performs the following functions: automatic line buildout (ALBO), gain, equalization, timing recovery, DC restoration, and regeneration. The 258-type repeaters are without lightning protection, which is a feature of the 259-types. The above repeater codes will cover the 12-54 dB equalization range (ie, no long and short repeater codes are required). All losses are measured at 1.576 MHz which includes allowances for cable pair loss deviations, route map inaccuracies, and temperature variations (paragraph 3.08).

3.03 The T1D line repeater operates at a nominal line current of 120 mA (paragraph 2.45). Power options for ♦“thru” or “looping” (unidirectional or bidirectional operation) ♦powering are provided. Table E contains restrictions for sections adjacent to end sections. See Section 365-280-101, T1D Repeater Description.

3.04 ♦Fault-Locate Filter: The 1068-type passive fault-locate filter and the 1114-type active fault-locate filter are used for T1D. Both types are coded A through M or AA through AM. Either single- or double-letter passive fault-locate filter codes and **only** double-letter active fault-locate filter codes may be used for T1D. Double-letter filter codes denote the most recent designs and are preferred for new installations. ♦

B. Line Engineering Considerations

3.05 Since T1D will be used mainly to increase the capacity of existing large size pulp cables which carry T1 or T1C lines, engineering considerations which deal with the longer term effects of line configurations are important. For example, if the capacity of a large size pulp cable is initially increased by placing T1 in binder groups previously unused, the line design should not preclude the possibility of placing T1D on these same binder groups at some later date. In general, T1D engineering guidelines should be implemented during the initial construction if conversion to T1D at some later date is contemplated.

3.06 In addition, T1D should not be utilized for those situations where 48-channel operation is required and the crosstalk margins are sufficient to allow T1C operation. Because of the increased cost and complexity of the T1D repeater and increased power consumption, application of T1D should be reserved for those situations where the NEXT limitations preclude the use of T1C.

3.07 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 CO 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.

C. Repeater Section Engineering

3.08 Table D contains the maximum and minimum repeater spacings for T1D intermediate and end sections in a buried (including underground) or aerial environment for several popular copper cables. The spacings are based on the assumption that the T1D lines are loss-limited (not crosstalk-limited). That is, the maximum and minimum spacings for the intermediate sections correspond to the maximum (54 dB, pulp and 50.2 dB, PIC) and minimum (12 dB) cable loss which the T1D line repeater can equalize, respectively. Similarly, the maximum and minimum spacings for the end sections correspond to the maximum (37 dB) and minimum (4.3 dB) cable loss which the T1D office repeater can equalize, respectively.

The spacings in Table D include allowances for cable manufacture variations, temperature variations, pair loss deviations, and route map inaccuracies. In addition, the **spacing** for end sections **includes** an allowance for 200 feet of ABAM or 600 cable. If actual pair loss measurements are made, the maximum allowable pair loss for intermediate sections using 22-gauge pulp insulated cable in an underground environment is 52.7 dB at 1.576 MHz and 55°F, and the minimum allowable pair loss is 13 dB. For end sections, the corresponding maximum and minimum allowable pair losses are 36 dB and 4.7 dB, respectively, at 1.576 MHz and 55°F. The corresponding maximum and minimum allowable pair loss for other types of cables (PIC and DEPIC) are approximately 48.2 dB and 12.5 dB, respectively. A section consisting of 6100 feet of 22-gauge copper pulp insulated cable would have a maximum average loss of 48.8 dB (Table P).

3.09 Because CO noise dominates over cable crosstalk at the input to the office repeater, end sections must be restricted in length (loss). This effectively increases the signal-to-noise ratio sufficiently to meet the 10^{-6} error rate objective at the office repeater. Both T1 and T1C engineering rules restrict the maximum end section spacing to approximately 67 percent of the maximum intermediate section spacing for this purpose. With this spacing, the signal-to-noise ratio for T1 is sufficient to allow switched VF pairs in the same unit with T1 carrier pairs. If we take T1 as a bench mark for central office noise performance and assume that the gain-bandwidth product of the office repeater is a good measure of the sensitivity to CO noise, we find that T1D is about 12 dB more sensitive to CO noise than T1.

3.10 This is approximately the increase in NEXT isolation that is realized for systems located in adjacent units in comparison to systems located in the same unit. Thus, the 12-dB increased sensitivity of T1D to CO noise will be neutralized if switched VF pairs are restricted to units which are adjacent (or remote) to those carrying T1D lines. Hence, the CO noise performance for T1D is comparable to that for T1 if the maximum end section spacing is restricted to approximately 67 to 73 percent of the maximum intermediate section spacing (Table D) and switched VF pairs are restricted to units which are adjacent or remote to those carrying T1D lines. (An exception is the switched order wire pair which may appear in the same binder group with carrier pairs if special precautions are observed.)

3.11 The presence of 60-Hz (ac) induced currents can degrade the performance of digital lines.

However, due to the design of the T1D repeaters, moderate levels of 60 Hz induced currents will not cause a problem in the performance of the T1D digital lines.◆

3.12 As in the case for T1C, nonswitched VF maintenance pairs are allowed in the same units with ◆growth◆ T1D carrier pairs if the special crosstalk filters developed for T1C are employed to minimize the effect of near-end-near-end-interaction crosstalk (NENEIXT). If the end section length is less than S in Table E, the section adjacent to the end section will also be exposed to CO noise, and must be restricted in length. The general engineering guideline is that the length of the section adjacent to the end section cannot exceed the sum of the actual end section length and the maximum allowable end section length (Table E).

3.13 The usual precautions pertaining to maintaining unit integrity at splices and avoiding wandering and split pairs should be taken. Interstitial pairs can be used to replace faulty T1D pairs if the proper spatial separation rules are observed. The interstitial pair should be chosen so that it is close to the parent unit to which the faulty pair belongs or so that it is separated by at least one unit on the periphery from units carrying opposite directions of transmission.

3.14 In addition to engineering T1D carrier pairs, the fault-locate and order-wire pairs must be properly engineered in order to meet standard VF noise requirements. This includes the observance of maximum loss limits to ensure adequate signal-to-noise ratios and the proper spacing of loading coils in order to obtain the desired transmission characteristic.

3.15 All route junctions with unequal-level signals in adjacent or remote cable units will be allowed for screened cable operation of T1D. Because the creation of a route junction degrades the crosstalk performance, sufficient NEXT and FEXT margins must exist initially. This is the situation which exists for screened cable operation of T1D since the NEXT is almost negligible. For unscreened single-cable operation of T1D with maximum capacity, NEXT is limiting, thus prohibiting the creation of route junctions.

D. Cable Utilization Resulting from Spacing/ Separation Trade-Offs

3.16 By trading off repeater spacing and/or binder group separation, the use of T1D on some

smaller size unscreened pulp and PIC/DEPIC cables can be achieved. The following equation is used to find the maximum section design loss, L_d , at 772 kHz and 55°F:

$$◆L_d = (m - \sigma - 37.0 - 10 \log n) / f_T$$

Where m and σ are the mean and standard deviation, respectively, of the NEXT pair-to-pair coupling loss distribution at 772 kHz

Where n is the number of T1D systems ultimately expected, and

Where f_T is a conversion factor for temperature.

Values for m , σ and f_T can be found in Section 855-351-101.◆

E. Order-Wire and Fault-Locate Engineering Considerations

Order Wire

3.17 An order wire is provided for communication between repeater locations in a span and between any repeater location within a span and the ORB at either end of the 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 test board can be called at either span terminating office. Order wire in binder groups carrying T1D signals must employ the crosstalk suppression filter (described in paragraph 3.27) and cannot be connected to the switched network. The order wire uses a loaded pair and has an appearance in each line apparatus case location in the span as well as on the ORB and/or DSX-1C at each end of the 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.

3.18 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 are provided in the

input stub (479-type) or output stub (818/819-type) cable of the line repeater apparatus case for the order wire. Provisions have been made for mounting the blocking capacitors in the apparatus case. Design of the T1D order wire is covered in Section 855-350-107.

Fault Locate Line

3.19 Arrangements are provided in the DSX-1C or the CO repeater bay for locating faulty repeaters along the line. In the event of a repeatered line failure, alarms associated with the terminals (eg, M1C, M1C-A, and D-type channel banks) will be activated. Features have been incorporated in the terminals to permit maintenance personnel at the terminal offices to determine quickly whether the failure is due to a terminal or to the line.

3.20 If the line is at fault, the system is patched to a backbone line. Measurements using the error detecting set at the DSX-1C or the ORBs are then made to determine which span in the overall facility is in trouble. Service can then be removed from the backbone line and placed on a maintenance line. Measurements using the fault-locate set will generally locate the failed repeater or bad section of cable which must be replaced or repaired in the defective line. Slightly marginal systems or systems not sensitive to remote fault locating are further trouble sectionalized with a manhole violation detector.

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

3.22 Each 479- or 818/819-type apparatus case must be equipped with a 1068- type or 1114- double-letter filter. The output of all repeaters in an apparatus case is coupled to the input of the filter. The output of the filter is bridged to the fault-locate pair. A loaded cable pair is used to fault-locate. Noise and length of the fault-locate pair may affect the fault locating signal. The T1D fault-locate system engineering for unidirectional operation will generally result in different codes of filters in E-W versus W-E apparatus cases in the same manhole. However, when T1D is operated in a bidirectional mode, the

E-W and W-E regenerators are housed in the same apparatus case.

3.23 Providing a complement of 12 filters permits a series of 12 apparatus cases, EORPs, or ORBs to be fault located. However, only one apparatus case, EORP or ORB at a repeater location should be bridged to the fault-locate pair. Longer maintenance spans can be fault located by repeating the series of fault-locate filters and using a second fault-locate pair or by designing an active fault-locate system. It is recommended that an active fault-locate system be designed for longer maintenance spans. 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-locate line. However, this involves a planned T-R reversal between groups. Since loop-back fault locating is not allowed for T1D, no split fault-locate scheme is available for bidirectional T1D. Refer to Section 855-350-104 for details concerning fault locating.

3.24 Office repeaters should be included in the fault-locate plan. Fault location must be done in the direction of transmission of the repeatered line. Therefore, it must be done from terminal locations and/or repeater locations containing an ORB or DSX. For further details refer to Section 855-350-104.

3.25 The T1D repeater test equipment is described in Part 5 of this section.

Special Considerations for Fault-Locate, Order Wire, and Pressure Alarm Pairs

3.26 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 non-screened 1-cable operation, this segregation is easy to implement since the center units cannot be employed for T1D and thus are available for VF and/or fault-locate and order-wire pairs. The center units of large cross-section cables may have high-loss pairs and should not be employed for T1D unless the repeater section lengths have been reduced or the pairs have been tested satisfactorily. These center unit pairs are adequate for VF, fault locate, and order-wire use. **Screened cables do not have high-loss center units.** A fault-locate or order-wire pair may share the same binder group with T1D 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 T1D

3.27 For certain applications of the T1D Carrier

System, it is desirable to have the flexibility of operating order-wire, fault-locate, and pressure contactor pairs in the same binder group with carrier. As an example, it is 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 carrier, they act as within-unit tertiaries and become significant contributors of NENEIXT. 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 filter is required:

- For each fault-locate, order-wire, and gas pressure monitor pair sharing a T1D binder group
- At each apparatus case, regardless of where (or whether) the maintenance pairs are loaded.

3.28 The Delevan BP-3258 is installed in the *splice case* containing the apparatus case stubs and is spliced into the maintenance pair either before the pair loops into the apparatus case stub cable or after it loops out of the stub cable. The order-wire pair loops in and out of the "in" stub (479-type case) and the "out" stub (818/819-type). The fault locate pair loops in and out of the "out" stub (479-type case) and "in" stub (818/819 type case). Installation procedures and recommendations are provided in Sections 640-527-211 and 640-525-307. The BP-3258 inductor can be used in all installations where T1D crosstalk suppression filtering is required, including unprotected (479A and 818) and protected (479B and 819) T1D routes and on nonloaded maintenance pairs.

3.29 An alternative exists to the inductor assembly described above for T1D routes using 479A2, 479B, 479B2, and 800-type 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 protected apparatus cases and the 4269A network is used in unprotected apparatus cases. No network is available for the 479A1 apparatus case which was replaced by the 479A2 (MD). 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 (PWB) 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 gas pressure 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.

3.30 The use of pairs from binder groups intended for carrier 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. When air core cable is employed, 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 T1D slots propagate throughout the facility (eg, ORB, M1C, etc). In addition to loss of capacity, this arrangement leads to administrative complexities.

3.31 *This special allowance for fault-locate pairs and order-wire pairs sharing the same binder group with T1D does not apply to switched VF pairs.* Switched VF pairs must never share the same binder group with T1D 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 maintenance pair in a carrier binder group or office tip cable. At 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. 32A or B (479-type apparatus case) or Fig. 33 (818/819-type apparatus case). Figure 32B illustrates an installation in which the order wire is loaded in the apparatus case 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. Figure 32B illustrates 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.

F. Splicing Considerations for 1-Cable Operation

3.32 The T1D is restricted to 19-, 22-, or 24-gauge copper, and 17- or 20-gauge aluminum screened or nonscreened PIC and pulp-insulated cable with unit type construction (layered cable is not permitted). The MAT cables and ICOT cables are not permitted. Underground, buried, and aerial installations are permitted. Two-cable operation of T1D has been ruled out for economic reasons. (The T1C will usually prove more economical.)

3.33 An important factor in engineering T1D is the selection of units for 1-cable operation. The T1D is engineered in blocks of 50 span lines for unidirectional operation and blocks of 25 for bidirectional operation. Refer to Fig. 2 through 12.

3.34 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. The T1D, like T1 and T1C, requires the existence of cable unit (binder group) integrity in all units carrying T1D signals. ♦Random unit splicing on maximum length sections would result in unacceptable crosstalk performance.♦

3.35 Defective VF pairs in the middle ring binder group cable splice sections may have been "made good" by using interstitial pairs. The possibility of applying T1D in the middle ring creates the possibility of "wandering pairs." A wandering pair situation exists when a middle ring binder group pair carrying any VF or an opposite direction of a T-Carrier System appears in a binder group carrying T1D. Wandering pairs are not allowed in cables supporting any T-Carrier Systems.

3.36 In all cases, an interstitial pair closest to, but in no case on the opposite side of the cable

from, a binder group with a defective pair should be used to "make-good" the pair. If the random utilization of interstitial pairs occurred to repair defective pairs, T1D use on middle ring binder groups in cables already supporting T1 and/or T1C will only be allowed provided that:

- (a) Cable splice sections using interstitial pairs on a random basis are not within ♦500♦ feet of a repeater location, or
- (b) All "made-good" pairs using interstitial pairs on the opposite side of the cable and within ♦500♦ feet of a repeater location are respliced to good interstitial pairs on the same side.

Proper records of all splicing activity should be kept to allow future determination of splicing arrangements.

3.37 A potential source of NEXT exists where high- and low-level signals coexist in splice closures located near a repeater site. ♦When T1D and T1C signals coexist in splice closures located within 500 feet from a line repeater site, the T1C low-level signals must be shielded (with foil wrap) from the high-level T1D signals. Shielding of T1C low-level signals in splices within 500 feet of an office repeater is not required if T1D office repeaters (with a 12 dB transmitting line buildout) are used. However, when only T1D or T1D and T1 signals coexist in splice closures located within 500 feet from a repeater site, shielding of the low-level signals is not required.♦

3.38 It is often necessary to splice a number of apparatus cases to the main cable at nearby points because of the mechanical limitations of splice closures in accommodating a large number of case stubs at one point. In the short cable segments between splice cases, unequal-level FEXT exposures (called incidental junctions) are created. For T1D, the crosstalk margin precludes any within-unit incidental junctions. However, adjacent-unit incidental junctions with maximum exposure lengths of 40 feet (for 22-gauge pulp cable) are allowed for T1D. Alternatively stated, all within-unit low-level T1D signals must be removed from the main cable prior to the point where any of the within-unit high-level T1D signals are reinserted into the main cable. And, all adjacent-unit low-level T1D signals must be removed from the main cable at a point not exceeding 40 feet after the point where any of the adjacent-unit high-level T1D signals are reinserted.

3.39 These restrictions also apply when T1 and T1D signals coexist in the same sheath. How-

ever, when T1D and T1C signals coexist in the same sheath, no within-unit or adjacent-unit incidental junctions are permitted. That is, all low-level T1D and T1C signals must be removed from the main cable prior to the point where high-level T1D and T1C signals are reinserted.

3.40 An incidental junction (unequal-level FEXT exposure) also occurs when T1D is operated bidirectionally, the adjacent repeater sections have different losses (lengths), and the apparatus case has an unscreened stub. With this situation, pairs with unequal signal levels appear in the input stub of the apparatus case, creating an unequal-level FEXT exposure which is a function of the difference in signal levels. For this reason, it is recommended that the 818/819-type apparatus cases with a quad-screened stub be used for bidirectional operation of T1D. With the quad-screened stub, the unequal-level signals are shielded from each other, thus mitigating the effect of the unequal-level FEXT exposure. The dual-stub 479-type case and the dual-stub 818/819-type case should be used for unidirectional operation of T1D where the preceding type of incidental junction is nonexistent. For additional information on 479-type apparatus cases, refer to Sections 640-527-107 and 640-527-211. For 818/819-type apparatus cases, refer to Section 640-525-307.

G. Use of Interstitial Pairs in a Cable for T1D

3.41 Interstitial pairs, which can be used to replace faulty or high-loss pairs, are located in interstices on the periphery of the cable core. For the 900-pair pulp cable, five interstitial pairs are located in five equidistant interstices in this manner (Fig. 3). For the 1100-pair pulp cable, six interstitial pairs are available and are grouped in threes (triplets) approximately diametrically across the cable core (Fig. 4). In order to ensure that the crosstalk performances for 1-cable operation of T1C are not degraded, the selection of interstitial pairs as replacements must adhere to special spatial separation rules. The interstitial pair should be chosen so that it is close to the parent unit to which the faulty pair belongs or is separated by at least two units on the periphery from units carrying opposite directions of transmission. For example, in Fig. 3 for the 900-pair cable, interstitial pairs 1 and 5 could be used to replace faulty pairs in the W-E units. Likewise, interstitial pairs 1 and 3 could be used to replace faulty pairs in the E-W units. Interstitial pair 4, shown midway between W-E and E-W units, could not be used since only one unit of

separation exists between it and the units carrying the opposite direction of transmission.

3.42 For the 1100-pair cable shown in Fig. 4, interstitial pairs 1, 2, and 3 could be used to replace faulty pairs in the E-W units; while interstitial pairs 4, 5, and 6 could be used to replace faulty pairs in the W-E units.

4. RETROFIT APPLICATION

A. General

4.01 In a retrofit mode, T1D can double the channel capacity of existing T1 plant facilities equipped with 466-, 468-, or 475-type (noncrosstalk controlled) apparatus cases. This allows the deferral of plant addition due to the extended life (higher capacity) of the existing plant. The hardware developed for retrofit applications of T1D consists of 16 codes of line repeaters and 5 codes of office repeaters. These repeaters are simply repackagings of the basic T1D repeaters for retrofit in 466-, 468-, or 475-type cases and J98725 or J98710 ORB.

B. Hardware Description

4.02 The T1D repeater codes have been developed for installation in 466-, 468-, and 475-type apparatus cases with PIC or pulp type cables. The 281- and 285-types used in the 466 and 468 cases, respectively, are the same width and height as the 201- and 205-type T1 repeaters used in these cases. The 288 and 289 types used in the 475-type case have the same cross section as the 208- and 209-type T1 repeaters they replace, but are slightly longer. A new, deep cover has been designed to allow the use of these codes in the 475-type cases. Each 475-type apparatus case must be equipped with a 1068- or 1114-type bandpass filter for fault locating. Except for the 468C6 apparatus case, each 466/468-type case must be equipped with a 598-type filter. The 468C6 case must be equipped with a 1068- or 1114-type filter. In addition, a new T1D office repeater code (the 286-type) has been developed that is mechanically compatible with the J98710 ORB that houses the 206- or 236-type T1 office repeater. Line powering, power looping, extended cross connect package (EXCP), and non-EXCP type office repeaters have been designed. The T1C-type bridging repeater has also been designed in the 206 or 236 size to allow bridging and patching of DS1C signals in the J98710 ORB. The new repeater codes are electrically identical to the previ-

ous T1D line and office repeaters. (See Tables G and H.)

4.03 The new KS-22424 T1D fault location and repeater test set and the KS-22423 T1D manhole violation detector are electrically compatible with the new T1D repeaters. Where required, as in repeater testing and line error detection, new codes of adapters are shown in Table Q.

C. Engineering Rules and Application Guidelines

4.04 The retrofit application of T1D, while involving a repackaging of T1D hardware, predominantly involves the provision of a different set of engineering rules which take into account the limitations of the environment in which it is deployed; ie, noncrosstalk-controlled apparatus cases.

4.05 The engineering rules for retrofit application of T1D consist of a set of administered and engineered restrictions. The administered restrictions are those items which require no calculations but do involve the inspection of the existing plant records for compliance. The considerations involving VF sharing, end-section engineering, binder group integrity, route junctions, incidental junctions, and shielding of splices are identical to growth T1D transmission line design. Table R summarizes these restrictions and compares them to T1.

4.06 Retrofit T1D is intended for application only where the cable crosstalk (ie, FEXT and NEXT) is negligible relative to the 466-, 468-, 475-type apparatus case crosstalk (ACXT). This condition is satisfied for dual-cable and screened-cable operation where the combined contribution of both FEXT and NEXT is negligible relative to ACXT. However, in order to satisfy this condition for single-cable operation, there must be **at least** one 50-pair, 22-gauge unit of separation between the pairs carrying the opposite directions of transmission, or the following relationship must be satisfied:

$$\diamond m - \sigma - 10 \log n \geq 69.0$$

Where m and σ are the mean and standard deviation, respectively, of the NEXT pair-to-pair coupling loss distribution at 772 kHz. See Section 855-351-101 and \blacklozenge

Where n is the number of systems in the cable units carrying opposite directions of transmission which have the least separation.

4.07 The engineered restrictions for retrofit application T1D are designed to guarantee the performance objective. Specifically, 95 percent of all T1D systems consisting of 50 regenerative sections must operate with an error rate no greater than one error in 10^6 bits. In order to maintain this level of performance, a tabulation of section losses of the span in question must be examined.

D. Intermediate Repeater Section Engineering

4.08 Spacing \blacklozenge (ACXT/Loss-Limited): The maximum and minimum intermediate repeater spacings for T1D given in Table D shall also apply for retrofit T1D. The maximum spacings are based on the assumption that the T1D systems are loss and ACXT limited (ie, the maximum loss allowable due to ACXT is the same as the maximum loss that the repeater can equalize.) \blacklozenge For retrofit application in the T1 plant, these spacings must be compatible with the T1 spacings given in Section 855-351-101. If the three percent route error allocation for the T1D spacings is removed, the maximum intermediate T1D spacings are equal to or greater than the T1 spacings in Section 855-351-101. (The T1 spacings do not include an allocation for route error.) For example, consider the maximum intermediate repeater spacings for buried, 22-gauge, pulp-insulated cable (ADA). The maximum T1D spacing is 6280 feet (6100×1.03) as compared to 6200 feet for T1.

4.09 However, due to the different methods used in determining the minimum intermediate repeater spacings for T1 and T1D, the minimum intermediate T1D spacings in Table D are somewhat longer than the corresponding minimum spacings for T1. Using buried, 22-gauge, pulp cable as an example, the minimum intermediate spacing for T1D is 2000 feet (2060×0.97) as compared to 1440 feet (7.5 dB minimum loss) at 5.2 dB/kft for T1. (The T1 does not publish minimum spacings, but uses 7.5 dB as a minimum section loss.) Because of this discrepancy between T1D and T1 minimum spacings, Table D should always be consulted when T1 sections are being retrofitted for T1D.

4.10 60 Hz Induced Currents: \blacklozenge Due to the design of the T1D retrofit repeaters, moderate levels of 60 Hz induced currents will not degrade the performance of the T1D digital lines. \blacklozenge

4.11 VF Maintenance Pairs: For retrofit T1D, the VF maintenance pairs (order wire, fault

locate, etc) will be allowed in the same units with T1D carrier pairs without the special crosstalk filters normally required to minimize the effect of near-end-near-end interaction crosstalk (NENEIXT). For retrofit T1D systems, the contribution of NENEIXT is negligible in the presence of apparatus case crosstalk (ACXT). This is consistent with the existing T1 practice which allows VF maintenance pairs in the unit with T1 carrier pairs.

4.12 Route Junctions: Existing T1 repeater sections with route junctions can be retrofitted with T1D if the unequal-level signals appear in adjacent units. The contribution of the unequal-level adjacent-unit FEXT for the worst case junction is negligible in the presence of ACXT. Under no circumstances can sections having within-unit junctions be retrofitted with T1D.

E. Central Office—End Section Engineering

4.13 Repeater Spacing: The maximum and minimum end section spacings for T1D given in Table D shall also apply for retrofit T1D. The maximum end section spacings for T1D are slightly shorter than the corresponding spacings for T1. For buried, 22-gauge, pulp cable, the maximum end section spacing for T1D is 4220 feet (4100×1.03) as compared to 4420 feet ($4.420 \times 5.2 \text{ dB/kft} = 23 \text{ dB maximum}$) for T1.

4.14 The minimum end section spacings for T1D are also more conservative (longer) than the corresponding spacings for T1. Whereas the minimum end section spacing for T1D on 22-gauge, pulp cable is 780 feet (800×0.97), the corresponding minimum for T1 is 0 feet. Because of these discrepancies, Table D should always be consulted when T1 sections are being retrofitted for T1D.

4.15 Short End Sections: The length restriction imposed on the first intermediate T1 repeater section adjacent to the end section when the end section is very short is also sufficient for T1D.

4.16 Artificial Line Option: In order to eliminate the crosstalk contribution of the apparatus case (ACXT) located at the first manhole out from the CO, the total loss of the end section (cable plus the artificial line) in the transmit direction must be less than or equal to $\nabla 3 \text{ dB}$ (at 772 kHz). This in turn means that the 7.5 dB (at 772 kHz) artificial lines option in the office repeater should be used only

when the cable loss of the end section is less than 15.5 dB (23 - 7.5). (The artificial line loss is 12 dB at 1.576 MHz and 7.5 dB at 772 kHz.) \blacklozenge When the cable loss is greater than 15.5 dB, the 0 dB artificial line option should be used.

4.17 Switched VF Pairs: As in the case of growth T1D, switched VF pairs are restricted to units in the main and entrance cables which are adjacent (or remote) to those carrying retrofit T1D systems. Switched VF pairs are not allowed in the same tip cable with T1D pairs. This ensures that the required error rate performance objective at the office repeater will be satisfied in the presence of CO noise. This is more restrictive than the corresponding T1 rules which allow switched VF pairs in the same cable unit carrying T1 systems and allow switched VF in tip cables with T1 pairs. Thus, all cable units and tip cables designated for retrofit T1D systems must be cleared of switched VF pairs.

4.18 Intraoffice Cabling: The T1C engineering rules for maximum cable lengths and equalization between D-type channel banks, DSX-1C cross-connect bays, M1C multiplexes, and T1C/T1 office repeater bays will apply for retrofit T1D.

4.19 Since the far-end crosstalk (FEXT) performance for T1D is comparable to that of T1, the existing T1 intraoffice cable arrangements with any unequal-level FEXT exposures are acceptable for retrofit T1D.

4.20 Only one direction of T1D transmission is allowed in a single tip cable. T1D can share the same tip cable with T1 and T1C pairs if all are transmitting in the same direction and at the same level.

4.21 Cable Types, Configurations: Retrofit T1D can be considered for use on all existing T1 cable configurations (single, dual, screened) using 19-, 22-, and 24-gauge, copper pulp and PIC cable, and 17- and 20-gauge aluminum PIC cable. The application of retrofit T1D on MAT[®] cable, ICOT* cable, and 26-gauge, copper pulp and PIC cable is not allowed.

4.22 Apparatus Cases: Retrofit T1D repeaters (281, 285, 288, 289) are intended for use on those routes with 466-, 468-, or 475-type apparatus cases. *They cannot be used in T1 versions of the 800-type apparatus case (ie, 818A1, 819A1).*

4.23 Incidental Junctions: As in the case of the growth application of T1D, only adjacent-unit incidental junctions with a maximum exposure length of 40 feet are allowed. This is more restrictive than the corresponding T1 rules which, in addition to the adjacent-unit incidental junctions, also allow within-unit incidental junctions with a maximum exposure length of 10 feet. The splicing arrangements for repeater sections being considered for retrofit should be examined for within-unit type incidental junctions.

4.24 Shielding of Splices: For retrofit application of T1D, shielding of the low-level signals in splice closures located within 500 feet of the repeater site is *not* required.

4.25 Span Qualifications: Any T1 facility that has been engineered to satisfy T1 rules can be retrofitted with T1D with no additional loss restrictions.

5. MAINTENANCE CONSIDERATIONS

5.01 The T1D Carrier digital lines require standardized procedures for maintaining the system (essentially the same as those for T1/T1C with respect to trouble isolation and fault location). One apparatus case slot from each span must be designated as the maintenance line. In installations using J98725() ORB, this can be slot 1 or 25. When J98710() ORB is used, it must be slot 25. Other specific pairs are required to support the gas alarm, fault locating, and order-wire needs. Engineering rules for the T1D fault locate and order-wire are given in Sections 855-350-104 and 855-350-107.

5.02 Voice communications are required between the ORB and the DSX-1C, other maintenance locations in the building, and to other COs. This requirement is the same as for T1 Carrier in Section 855-351-101.

5.03 Except for two newly designed test sets, existing sets used for T1C will also serve T1D. The new sets are a combined fault location and repeater test set and a manhole violation detector test set.

(a) **Pair Loss Test Set (J98725AA):** This battery powered set measures the loss of a conductor pair at 650 or 1300 kHz, between adjacent manholes, and between the ORB and the first repeater location. Comparisons from pair-to-pair

allow out-of-limits pairs to be identified for troubleshooting. Connecting adapters allow the set to be used in the ORB as well as in all T1, T1C, and T1D 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.)

(b) **T1D Manhole Bipolar Violation Detector (KS-22423):** This portable, battery-powered set is used to troubleshoot suspected failed line repeaters, either confirming a remote fault-locate diagnosis or determining the location of a marginal repeater. It also indicates the presence or absence of a valid signal. (See Section 103-494-108.)

(c) **T1C/T1 Office Bipolar Violation Detector (J98725AC):** This is an office test set, powered from the -48 volt 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 2 hours, with a built-in electronic timer to help isolate marginal systems. The counter counts either violations or violation seconds. (See Section 103-494-100.)

(d) **T1D Fault-Location and Repeater Test Set (KS-22424):** This set, powered by 117 volts ac, is used to isolate defective repeaters to a specific section and manhole. This set produces a special bipolar signal at a 3.152 megabit rate. This signal, after going through the T1C to T1D converter in the T1D office repeater, will produce a T1D type signal for fault locating. The audio tone is returned to the office from a manhole via a fault-locate filter in the manhole 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 fault-locate line before attempting actual fault location of a defective repeater. This set will also perform preinstallation tests on all codes of T1D line and office repeaters. (See Section 103-494-107 and Section 365-272-000 Task Oriented Practices, (TOP).)

(e) **Fault Line Powering Module (J98725AJ):** This portable ac-to-dc converter is used for powering an active fault-locate line. The powering module converts 117 volts ac to

regulated 40 or 118 volts dc for powering the fault-locate line. The powering module also contains a mounting and connection for testing an active fault locate filter. (See Section 103-494-109.)

(f) **DS1 Error Rate Test Set (KS-20775):**

The receiver can synchronize to the DS1 quasi-random word from the generator at a remote point. The generator provides a quasi-random bipolar DS1 signal and errors are detected either by a bit-by-bit comparison or as bipolar violations. This set is required for M1C maintenance and can be used for turning up new lines or testing lines in trouble. (See Section 103-493-109.) The error rate test set (KS-22331 transmitter and KS-22332 receiver) may be used for DS1, DS1C, and DS2 signal rates. (See Section 103-493-120.)

(g) **Quasi-Random Signal Source (J98725AF):** 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 or backbone lines. They can be used to provide a test signal for trouble routines or to drive idle lines during line turn-up. (See Section 103-494-105.)

6. REFERENCES

6.01 The following APS drawings pertain to T1D repeaters.

APS-578085 258A T1D Line Repeater
 APS-578086 258B T1D Line Repeater
 APS-578087 281A T1D Line Repeater
 APS-578088 281B T1D Line Repeater
 APS-578089 281C T1D Line Repeater
 APS-578090 281D T1D Line Repeater
 APS-578091 286E T1D Bridging Repeater
 APS-578093 259A T1D Line Repeater
 APS-578094 259B T1D Line Repeater
 APS-578095 285A T1D Line Repeater
 APS-578096 285B T1D Line Repeater

APS-578097 285C T1D Line Repeater

APS-578098 285D T1D Line Repeater

APS-578101 through 104 260A,B,C,&D T1D Office Repeater

APS-578105 through 108 286A,B,C,&D T1D Office Repeater

APS-578448 through 51 288A,B,C,&D T1D Office Repeater

APS-578452 through 55 289A,B,C,&D T1D Office Repeater

6.02 The following drawings are of typical connecting circuits for the T1D Carrier digital line:

DRAWING	TITLE
SD-3C369-01	J98725J Express Office Repeater Panel, Application Schematic
SD-1A158-01	ESS No. 1, Office Alarm Circuit
SD-1A210-01	ESS No. 1, Remote Master Scanner, Applique Circuit
SD-1C599-01	M1C Digital Multiplexer
SD-25671-01	No. 5 CSBR Alarm Circuit
SD-31551-01	S × S No. 1 or 350A Audible Alarm Circuit
SD-31573-01	S × S No. 350A Pilot Lamp and Power Alarm Lamp Circuits
SD-32145-01	S × S No. 356A Alarm Circuit
SD-3C252-01	T1C Office Repeater Bay, Application Schematic
SD-3C371-01	T1C/T1 ORB DSX—Dedicated
SD-3C254-01	Digital Line Order-Wire Circuit
SD-3C304-01	D4 Application Schematic
SD-90614-01	Audible Alarm and Pilot Lamp Circuit
SD-95063-01	Audible and Visual Alarm Circuit

SECTION 855-351-115

DRAWING	TITLE	SECTION	TITLE
SD-95075-01	Audible and Visual Alarm Circuit	365-170-000	D4 Channel Bank (TOP)
SD-95143-01	Voice-Frequency Alarm and Order-Wire Signaling Circuit	365-225-500	Routine Maintenance Tests—T1
SD-96188-01	Audible and Visual Alarm Circuit	365-250-105	J98725J Express Office Repeater Panel (EORP), Description, Operation, and Maintenance
SD-97080-02	T1 Application Schematic	365-250-120	DS1C Automatic Protection Switch—Description
6.03 The following Bell System Practices are referred to in this section:			
SECTION	TITLE	SECTION	TITLE
103-493-109	KS-20775, L1 and L2 Error Rate Test Set—Description and Operation	365-271-000	T1C Digital Line (TOP)
103-493-120	DS1/DS1C/DS2 Error Rate Test Set (KS-22331, L1 and KS-22332, L1)	365-272-000	T1D Digital Line (TOP)
103-494-100	J98725AC Office Bipolar Violation Detector—Description and Maintenance	365-280-100	T1D Digital Line—General Description
103-494-104	J98725AA Pair Loss Test Set—Description, Operation, and Maintenance	365-280-101	Repeater Description
103-494-105	J98725AF T1C/T1 Quasi-Random Signal Source (QRSS), Description, Operation, and Maintenance	365-301-103	DSX-1/DSX-1C Bridging Repeater Panel—Description and Operation
103-494-107	KS-22424 T1D Test Set—(Fault Locating and Repeater)—Description and Maintenance	365-325-100	J98725H Order-Wire Facility—Description
103-494-108	KS-22423 T1D Test Set (Manhole Violation Detector)—Description and Maintenance—Transmission and Equipment	365-672-000	M1C Digital Multiplex (TOP)
103-494-109	J98725AJ Fault Line Powering Module—Description—Digital Transmission Systems	636-330-100	303-Type Connectors—Description, Installation, and Marking
365-000-010	Terminal and Repeated Line Central Office Record Cards	638-205-015	Fuse Cable Requirements
		640-525-107	475-Type Apparatus Case—Description and Installation
		640-525-210	466- and 468-Type Apparatus Case—Splicing and Maintenance
		640-525-307	818-/819-Type Repeater Cases, Description, Installation, Splicing, and Maintenance, T1, T1C, T1D, and T1/OS Carrier Systems
		640-527-107	479-Type Apparatus Case—Description and Installation
		640-527-211	479-Type Apparatus Case—Splicing and Maintenance

SECTION	TITLE
760-100-084	T1, T1/OS, T1C, and T2—Digital Carrier Terminal Office Planning Building Engineering
855-350-104	T1, T1 Outstate, T1C, and T1D Fault-Locate System Engineering Design
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, T1C, T1D, and T2—Order-Wire System Engineering Design
855-350-109	T1C Automatic Protection Switch—Design Consideration, Digital Transmission Systems
855-351-101	Transmission and Outside Plant Design Procedures—T1 Digital Line
855-351-102	T1 Digital Line Special Engineering and Design Considerations
865-201-100	T-Carrier Administration System (TCAS)—Overall Engineering Considerations

7. GLOSSARY

The terms in this glossary are defined relative to their T1D usage.

Apparatus Case—This is the housing for 25 T1D repeaters and an associated fault locating filter. The 479- or 818/819-type apparatus cases are approximately 15 inches high by 23 inches wide. The 466/468-type cases are approximately 40 inches high by 11 inches diameter. The 475-type case is approximately 20 inches high by 9 inches wide.

Automatic Protection Switch (APS)—The DS1C APS protects service by automatically transferring the T1D 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 commandeered to set up a remote loop after a line has failed. All this is done without affecting service.

Bidirectional—Repeater operation in which signals from both directions of transmission are regenerated in the same repeater. The IN stubs of the repeater case are spliced half to one direction of low level signals and half to the other direction.

Cable—The T1D transmission medium is exchange grade, paired 19-, 22-, or 24-gauge copper cable possessing unit construction.

Two-Cable Operation—Two cables are required to provide both directions of transmission—one cable for each direction. The T1D will generally not be used in the 2-cable mode because of the economic advantage of using T1C.

One-Cable Operation—This implies both directions of transmission are carried in the same sheath. Either one direction of transmission can appear in an apparatus case (unidirectional mode) or both directions can appear (bidirectional mode).

Screened Cable Operation—Screened cables are single cables possessing a bisecting metallic screen which controls the amount of cable crosstalk. All existing screened cables will support "full-fill" T1D operation; ie, all the pairs on one side of the cable carry one direction of transmission while the other direction of transmission travels over the pairs on the other side of the screen. Note that more economical "full-fill" T1C operation can be achieved on 100-600 pair extended wrap (120°) screened cables and MAT cables.

Entrance Cable—This is the cable which comes into the cable vault from the outside. For T1D, 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 T1D this should be 22-gauge copper 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 T1D transmission but can be used for fault locating and order-wire pairs.

Tertiary Pairs—These are cable pairs that are spliced through at T1D regeneration points. They provide a crosstalk path and hence are not permitted in the same unit with T1D.

Dual Stub Cable—Two stub cables connect the 479-type apparatus case to the main cable (optional on 818/819-type case). Each stub has 54 pairs. One stub carries the incoming low-level signals and the other carries the high-level regenerated signals. For bidirectional operation, one stub cable of 108 pairs carries both directions of transmission in separate shielded binder groups.

Cross-Connect—The DSX-1C cross-connect provides access for patching and testing the T1D signal. For installations that will never exceed four ORBs, it will be panel-mounted in the ORB. For larger installations, a centralized cross-connect must be configured by mounting the cross-connect panels for the various office repeater bays in one or more centralized bay (DSX-1C). Advance planning is required to keep these bays in one continuous lineup.

Design Number—The probability that a T1D component 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. Design numbers are useful in defining rules for connecting T1D in tandem with T1C, T2, and metropolitan T1 and T1/OS.

Duobinary Code—A three level code consisting of “plus one” and “minus one” pulses and a “zero”. Changes in polarity in the code occur only when an odd number of “zeros” intervene between two pulse positions. An even number of “zeros” between two pulse positions will result in the second pulse having the same polarity as the first.

Facility—T1D facility consists of the tandem connection of a number of spans, and is terminated in M1C multiplex, D4 channel banks, or T1C lines at DSX-1C panels at each end.

FEXT (Far-End Crosstalk)—Crosstalk caused by signals transmitted in the same direction as the T1D signal.

Framing—Periodic pulse patterns are time interleaved with the information bits to provide synchronization at the demultiplexer. By modifying the

framing pattern, status information can be fed back to the remote terminal location.

Junction—A junction is formed where lines from two or more systems enter a sheath at different levels.

Margin—This indicates how much the interfering noise power would have to increase, in dB, before a T1D repeater section would not meet its performance objective of a 10^{-6} error rate.

Multiplexer—The multiplexer synchronizes the input signals and then time interleaves information, framing, and control bits into a 3.152 Mb/s DS-1C signal.

NEXT (Near-End Crosstalk)—Crosstalk caused by signals transmitted in the opposite direction of the T1D signal.

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, Office—The office repeater contains circuitry for signal conditioning, bipolar to duobinary format conversion, code violation detection and transferral, and line current regulation for both directions on one T1D line.

Repeater, Line—The line repeater houses two regenerators, both of which transmit in the same direction. Depending on the splicing arrangements used, a line repeater can provide regeneration for one direction of transmission for two T1D systems (unidirectional) or two directions of transmission for one T1D system (bidirectional).

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 or DSX bays at both ends.

Unidirectional—Repeater operation in which all regenerators in a repeater case transmit in the same direction. All pairs in the IN binder group stubs of

the repeater case are spliced to low level pairs in the main transmitting in the same direction.

TABLE A**T1D DESIGN NUMBERS**

MODE	SECTION DESIGN NUMBER
Large Nonscreened Pulp Single-Cable, Maximum Capacity	0.001
Screened Cable, PIC and Pulp	0.00025

TABLE B

**TYPICAL BINDER GROUP UTILIZATION SCHEMES FOR
VARIOUS COMBINATIONS OF T1, T1C, AND T1D
ON 600, 900, 1100, AND 1200 ADA-TYPE CABLES
AND 1500 AND 1800 ADM-TYPE CABLES**

CABLE SIZE (PAIRS)	REFERENCE FIGURE	T1		T1C	T1D		EQUIVALENT DIGROUP (24 CHANNELS) CAPACITY
		OUTER RING (PAIRS)	MIDDLE RING (PAIRS)	OUTER RING (PAIRS) (NOTE)	OUTER RING (PAIRS)	MIDDLE RING (PAIRS)	
600	2A	300	—	—	—	—	150
600	2B	—	—	—	300	—	300
900	2C	400	200	—	—	—	300
900	2D	100	—	300	—	—	350
900	3A	—	—	300	100	—	400
900	3B	400	—	—	—	200	400
900	3C	—	—	—	400	200	600
900	3D	—	—	200	200	200	600
1100	4A	500	200	—	—	—	350
1100	4B	300	200	200	—	—	450
1100	4C	500	—	—	—	200	450
1100	4D	—	100	400	—	—	450
1100	5A	—	—	—	500	200	700
1100	5B			300	200	200	700
1100	5C			400	—	100	500
1200	6A	—	200	400	—	—	500
1200	6B	—	100	500	—	—	550
1200	6C	600	200	—	—	—	400
1200	6D	—	—	500	—	100	600
1200	7A	400	200	200	—	—	500
1200	7B	600	—	—	—	200	500

Note: T1C cannot be used on binder groups in the middle ring.

TABLE B (Contd)

**TYPICAL BINDER GROUP UTILIZATION SCHEMES FOR
VARIOUS COMBINATIONS OF T1, T1C, AND T1D
ON 600, 900, 1100, AND 1200 ADA-TYPE CABLES
AND 1500 AND 1800 ADM-TYPE CABLES**

CABLE SIZE (PAIRS)	REFERENCE FIGURE	T1		T1C	T1D		EQUIVALENT DIGROUP (24 CHANNELS) CAPACITY
		OUTER RING (PAIRS)	MIDDLE RING (PAIRS)	*OUTER RING (PAIRS) (NOTE)	OUTER RING (PAIRS)	MIDDLE RING (PAIRS)	
1200	7C	—	—	400	200	200	800
1200	7D	—	—	—	600	200	800
1500	8A	800	200	—	—	—	500
1500	8B	—	—	600	—	—	600
1500	8C	—	—	400	400	200	1000
1500	8D	—	—	—	800	200	1000
1800	9A	800	400	—	—	—	600
1800	9B	200	—	600	—	—	700
1800	9C	—	—	600	200	—	800
1800	9D	800	—	—	—	400	800
1800	10A	—	—	—	800	400	1200
1800	10B	—	—	400	400	400	1200

Note: T1C cannot be used on binder groups in the middle ring.

TABLE C

STANDARD MAINTENANCE PAIR ASSIGNMENT
FOR 1-CABLE OPERATION

CABLE SIZE	PAIR ASSIGNMENT		
	ORDER WIRE	GAS ALARM	FAULT WIRE
900	50	49	Case 01 through 012 Pair 001 through 012
1100	50	49	Case 01 through 014 Pair 001 through 014
1200	50	49	Case 01 through 016 Pair 001 through 016
1500	50	49	Case 01 through 020 Pair 001 through 020
1800	50	49	Case 01 through 024 Pair 001 through 024

TABLE D
T1D REPEATER SPACING

CABLE TYPE	CODE	GA	INTERMEDIATE SECTION				END SECTION (NOTE)			
			MAX		MIN		MAX		MIN	
			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	2,710	3,180	5,360	5,290	1,020	1,200
	ADA	22	6,100	5,950	2,060	2,360	4,100	4,010	800	890
	ADM	24	4,970	4,870	1,680	1,940	3,350	3,280	700	770
CU PIC (air core)	BHB	19	9,310	8,980	3,310	3,530	6,670	6,420	1,190	1,270
	BHA*	22	6,700	6,470	2,350	2,510	4,900	4,700	850	900
	BKM	24	5,320	5,140	1,900	2,020	3,900	3,750	720	750
CU PIC (filled)	AJB	19	10,980	10,710	3,800	3,960	8,240	8,020	1,370	1,430
	AJA†	22	7,900	7,650	2,630	2,780	5,900	5,690	930	980
	AJM	24	6,300	6,080	2,110	2,240	4,720	4,530	770	810
CU DEPIC	ALB	19	9,890	9,590	3,360	3,540	7,290	7,040	1,210	1,280
	ALA‡	22	7,170	6,940	2,320	2,450	5,250	5,060	840	880
	ALM	24	5,730	5,530	1,870	1,980	4,240	4,070	710	740
AL DEPIC	ALC	17	9,800	9,430	3,390	3,630	7,230	6,940	1,220	1,310
	ALD	20	7,150	6,900	2,320	2,460	5,240	5,040	840	890

Note: Includes office cabling (22-gauge copper PIC (ABAM), ≤200 ft.)

* CA-6077 has the same cable loss and repeater spacing characteristics.

† CA-6076 has the same cable loss and repeater spacing characteristics.

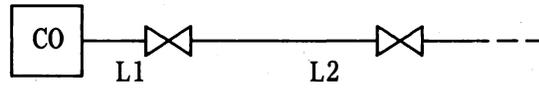
‡ KLAW has the same cable loss and repeater spacing characteristics.

TABLE E

RESTRICTIONS FOR INTERMEDIATE SECTIONS
ADJACENT TO END SECTIONS

TYPE CABLE	CODE	GAUGE	S	
			UNDER- GROUND FT	AERIAL FT
CU Pulp	ADB	19	2610	2560
	ADA	22	2000	1940
	ADM	24	1620	1590
CU PIC (air core)	BHB	19	2640	2560
	BHA	22	1800	1770
	BKM	24	1420	1390
CU PIC (filled)	AJB	19	2740	2690
	AJA	22	2000	1960
	AJM	24	1580	1550
CU DEPIC	ALB	19	2600	2550
	ALA	22	1920	1880
	ALM	24	1490	1460
AL DEPIC	ALC	17	2570	2490
	ALD	20	1910	1860

S = End section length threshold below which a restriction on the length of adjacent intermediate section is required
 L1 = Actual end section length
 L2 = Adjacent intermediate section length



If $L1 < S$
 then it is required that:
 $L2 < L1 + \text{Maximum end section length allowed (See Table D)}$

TABLE F

CAPACITIES OF T1, T1C/T1 OFFICE REPEATER BAYS

BAY CODE	HEIGHT	SHELVES	REPEATERS		
			WORKING	MAINTENANCE	BRIDGING
J98725A	11' 6"	8	96	4	4
J98725B	9' 0"	4	48	2	2
J98725C	7' 0"	4	48	2	2
J98725D*	11' 6"	12	144	6	6
J98725E*	9' 0"	8	96	4	4
J98725F*	7' 0"	6	72	3	3
J98710J	11' 6"	6	72	3	3
J98710K	9' 0"	4	48	2	2
J98710L	7' 0"	4	48	2	2

* T1C/T1 ORB, DSX-dedicated.

TABLE G

T1D OFFICE REPEATER CODES

OFFICE REPEATER CODES	OFFICE REPEATER BAYS	LINE POWERING	TRANSMIT LBO	APPLICATION (NOTE)
260A	J98725()	Regulating	12 dB	6V OUT
260B	J98725()	Looping	12 dB	6V OUT
260C	J98725()	Regulating	0 dB	6V OUT
260D	J98725()	Looping	0 dB	6V OUT
250C	J98725()	—	—	T1C Bridging*
286A	J98710()	Regulating	0/12 dB	3V OUT Jacks
286B	J98710()	Looping	0/12 dB	3V OUT Jacks
286C	J98710()	Regulating	0/12 dB	6V OUT
286D	J98710()	Looping	0/12 dB	6V OUT
286E	J98710()	—	—	T1C Bridging*

Note: All office repeaters can function in either unidirectional or bidirectional mode on PIC, PULP, or DEPIC copper cables.

* The 250C and 286E are bridging repeaters used for the T1C format office signals in a T1D installation.

♦TABLE H♦

T1D LINE REPEATER CODES

LINE REPEATER CODES (NOTE)	PROTECTION	CABLE TYPE	APPARATUS CASE	MODE
258A 258B	No No	PULP PIC/DEPIC	479A/818C	UNI/BI*
259A 259B	Yes Yes	PULP PIC/DEPIC	479B/819C	UNI/BI*
281A 281B 281C 281D	No	PULP PULP PIC/DEPIC PIC/DEPIC	466 Type	UNI BI UNI BI
285A 285B 285C 285D	Yes	PULP PULP PIC/DEPIC PIC/DEPIC	468 Type	UNI BI UNI BI
288A 288B 288C 288D	No	PULP PULP PIC/DEPIC PIC/DEPIC	475A 475F 475F2	UNI BI UNI BI
289A 289B 289C 289D	Yes		475B 475G 475G2	UNI BI UNI BI

Note: All line repeaters can function in either a thru or loop powering mode.

* 258 and 259 line repeaters can function in either unidirectional or bidirectional mode by splicing arrangements.

TABLE I

CAPACITIES OF M1C MULTIPLEX BAYS

BAY CODE	HEIGHT	MULDEMS	
		WORKING	MAINTENANCE
J98727A	11' 6"	48	1
J98727B	9' 0"	36	1
J98727C	7' 0"	24	1
J98727E	0' 9"	3	0

♦ TABLE J ♦

OFFICE REPEATER BAY MOUNTED EQUALIZERS (NOTE 1)

EQUALIZER			OFFICE REPEATER CODES	OFFICE REPEATER BAY CODES	DSX-1C REQD	OFFICE CABLE LENGTH FEET
ED-CODE	GROUP	QTY REQD				
3C655-31 (Note 2)	6	1 Per Repeater	260-Type	J98725A, B, &C	No	0-133
	2					133-267
	3		286-C & D	J98710J, K & L	No	267-400
	4					400-533
	5					533-655
3C767-30 (Note 3)	1	1Per Repeater Shelf	260-A & B	J98725D & E	Yes	0-133
	2					133-267
	3					267-400
	4					400-533
	5					533-655
3C655-31	6	1 Per Repeater	250C, 286E	J98725D & E or J98710J, K, & L	Yes	—

Note 1: At cable length transition point, use equalizer for the shorter length. **Do not over equalize.**

Note 2: 286A & B and 286E repeaters provide fixed equalization for 0 to 133 feet and do not require equalizers.

Note 3: 13 equalizers per card.

TABLE K
M1C MOUNTED EQUALIZER NETWORKS
(1012 TYPE)

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

TABLE L
REPEATER POWERING OPTIONS

OPERATION	REPEATER	LOCAL POWERING	SERIES POWERING
BIDIRECTIONAL	Regulating	BEHN	CEK
	Looping	HJN	DK
UNIDIRECTIONAL	Lower Power Mate (Receive Loop) Regulate Or Loop	BEHN	BDG
	Upper Power Mate (Transmit Loop) Regulate Or Loop	AFHN	AGM

TABLE M

LOOP POWERING FOR T1D REPEATERS

REPEATER TYPE	POWERING VOLTAGE	SUPPLIES REQUIRED (NOTE 1)	REGULATOR OPTIONS (NOTES 2 and 3)	ALLOWABLE R_L FOR A 120 mA T1D LINE	OFFICE BATTERY LIMITS AND MISCELLANEOUS BAY RESISTANCE			ORB OPTIONS
					V_{BMAX}	V_{BMIN}	(RX Ω)	
260	48V	-48	W, Z, V	0-266 Ω	50	45	10	J98725() (Note 4)
	130V	+130	X, Z	0-822 Ω	135	125	120	W
	178V	+130, -48	W, Z	370-1187 Ω	185	170	130	
	260V	+130, -130	W, Y	1100-1853 Ω	270	250	130	
286	48V	-48	Y	0-267	50	45	10	J98710() (Note 4) and R, S, and YY
	130V	+130	Z, R	53-912	135	125	10	Z, S, and YY
	178V	+130, -48	Z	431-1265	185	170	20	R, S, and YY
	260V	+130, -130	Z	1010-1800	270	250	130	Q and YY

Note 1: When -48V only is selected, replace (+) fuse with a dummy fuse (open circuit). When +130V only is selected, replace (-) fuse with a dummy fuse.

Note 2: When V or R option is selected, turn screw fully down; otherwise, two turns up.

Note 3: Do not confuse the 260A **regulator option "W"** for powering voltage selection with the J98725 **ORB option "W"** for providing the unidirectional system power looping function when 260B repeaters are used.

Note 4: In a unidirectional system **"W" option** for J98725() ORB and **"YY" option** for J98710 () ORB required when looping office repeaters are employed.

TABLE N
MAXIMUM AND MINIMUM CABLE RESISTANCE
COEFFICIENTS

WIRE GAUGE Cu	OHMS PER 1000 FT OF SPAN LINE	
	'MAX	'MIN
19	8.3	8.0
22	16.7	16.1
24	26.5	25.6

TABLE O
EFFECTIVE RESISTANCES FOR T1D REPEATERS

UNIDIRECTIONAL OPERATION OFFICE REPEATER			BIDIRECTIONAL OPERATION OFFICE REPEATER				UNIDIRECTIONAL OR BIDIRECTIONAL OPERATION LINE REPEATER		
REPEATER	OPTIONS		CEK	BEHN	DK	HJN	THRU	ZENER LOOP	LOW Z LOOP
	AGM OR BDG	BEHN OR AFHN							
286A, C 260A, C	207	15	207	15					
286B, D 260B, D	207	15			197	5			
281, 288 & 258-Type							97	97	4
285, 289 & 259-Type							108	108	15

TABLE P

T1D INSERTION LOSS
MEASURED AT 1.576 MHZ IN DB PER KFT

CABLE TYPE		CABLE CODE	MAXIMUM AVERAGE CABLE PAIR LOSS (DB/KFT)		
			55°F	100°F	140°F
Cu Pulp	19 Ga	ADB	6.2	6.3	6.4
	22 Ga	ADA	8.0	8.2	8.4
	24 Ga	ADM	9.7	10.0	10.2
Cu PIC (air-core)	19 Ga	BHB	4.8	5.0	5.2
	22 Ga	BHA	6.6	6.9	7.2
	24 Ga	BKM	8.3	8.7	9.0
Cu PIC (filled)	19 Ga	AJB	4.0	4.1	4.2
	22 Ga	AJA	5.6	5.8	6.0
	24 Ga	AJM	7.0	7.3	7.6
Cu DEPIC	19 Ga	ALB	4.5	4.7	4.9
	22 Ga	ALA	6.3	6.6	6.8
	24 Ga	ALM	7.8	8.1	8.5
AL DEPIC	17 Ga	ALC	4.5	4.7	4.9
	20 Ga	ALD	6.3	6.6	6.8

TABLE Q

T1D REPEATERS/ADAPTERS

REPEATER (TYPE)	APPARATUS CASE (TYPE)	ORB	PROBE KS-22423 TEST SET	ADAPTER KS-22424 TEST SET
<u>Line Repeaters</u>				
258/259	479 and 818/819		L5	L5
288/289	475		L6	L8
281/285	466/468		L7	L7
<u>Office Repeaters</u>				
260		J98725()		L6
286		J98710()		None Required

◆ TABLE R ◆

ADMINISTERED RESTRICTIONS FOR T1D

WITHIN UNIT	T1D	T1
Switched VF Sharing	No	Yes
Maintenance Pairs	Yes*	Yes
Binder Group Integrity	Yes	Yes
Route Junction	No	Yes
Incidental Junctions	No	10 Ft
Shielded Splices	No	No
ADJACENT UNIT		
Route Junction	Yes	Yes
Incidental Junction	40 Ft	40 Ft

*Growth T1D requires crosstalk filters.

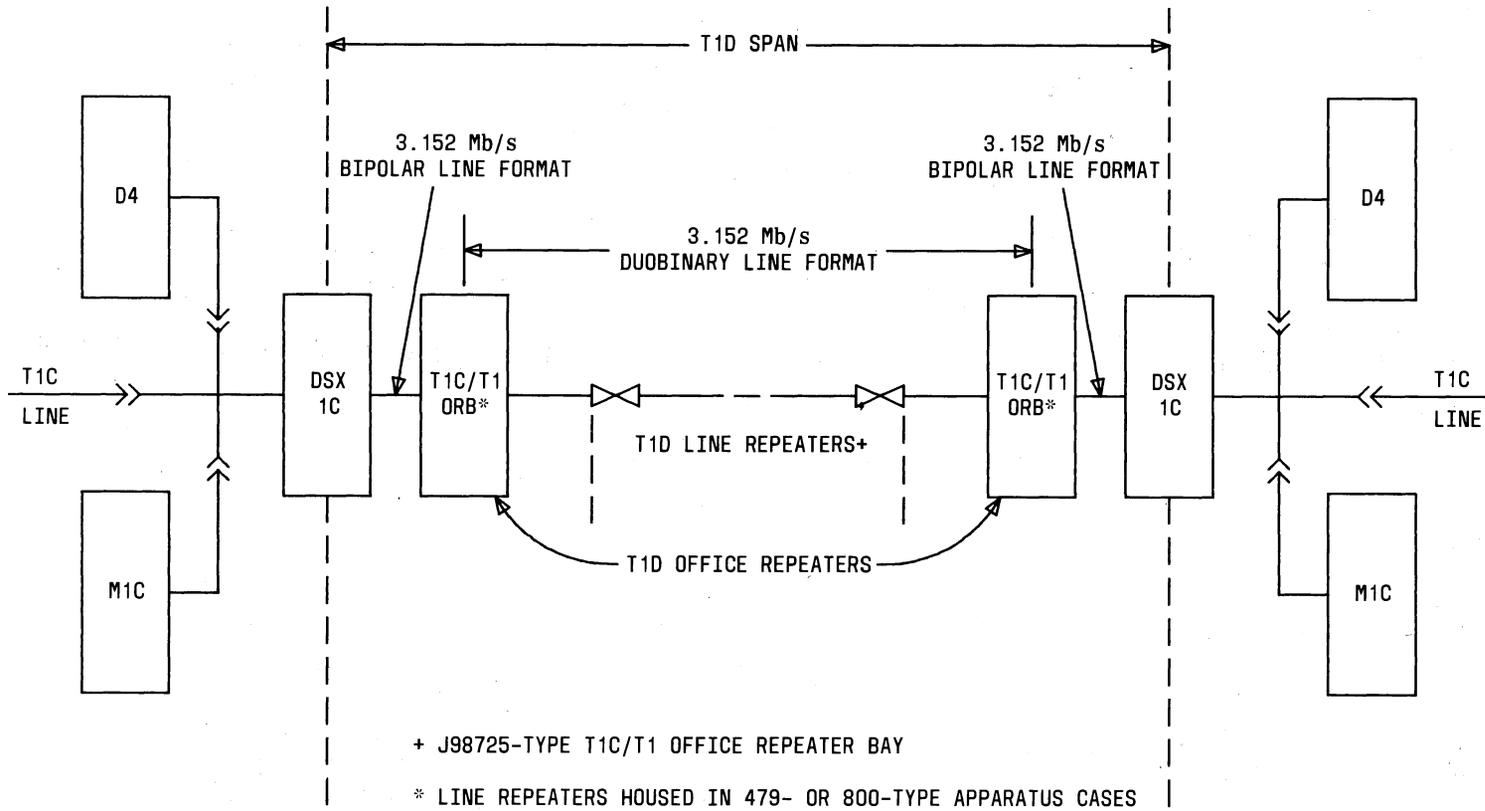
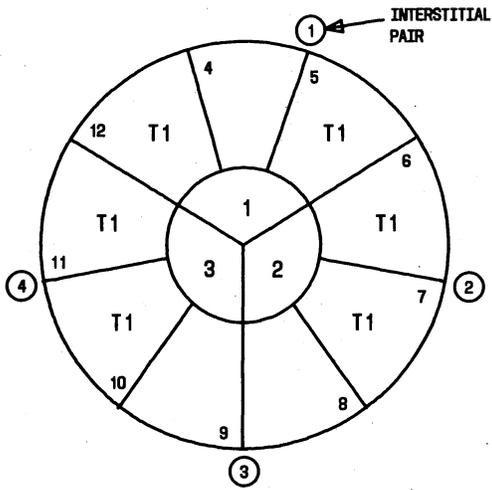
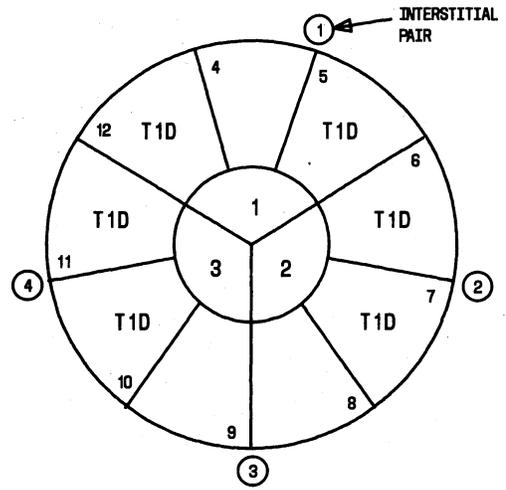


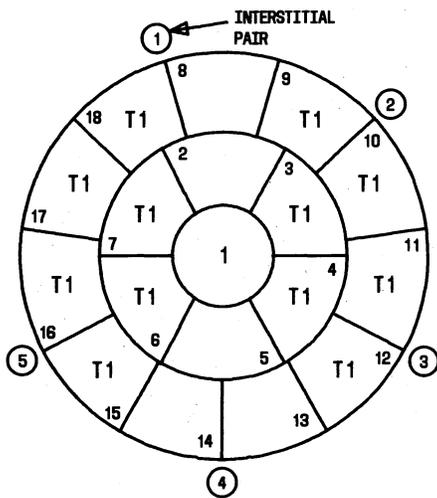
Fig. 1—Basic T1D Span



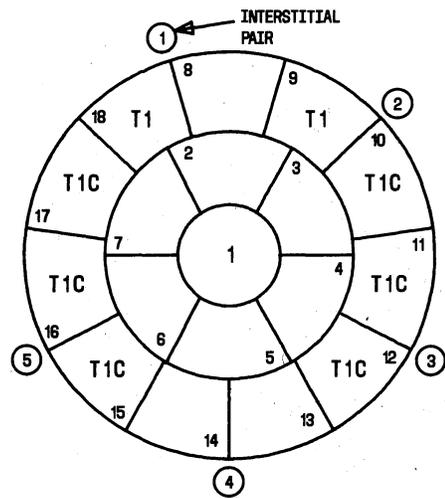
A. 150 T1 SYSTEMS ON A 600-PAIR PULP CABLE



B. 150 T1D SYSTEMS ON A 600-PAIR PULP CABLE

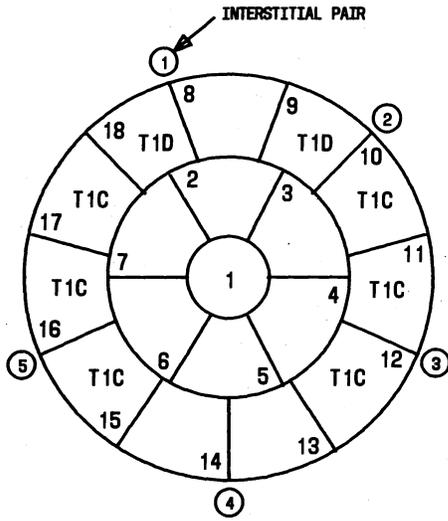


C. 300 T1 SYSTEMS ON A 900-PAIR PULP CABLE

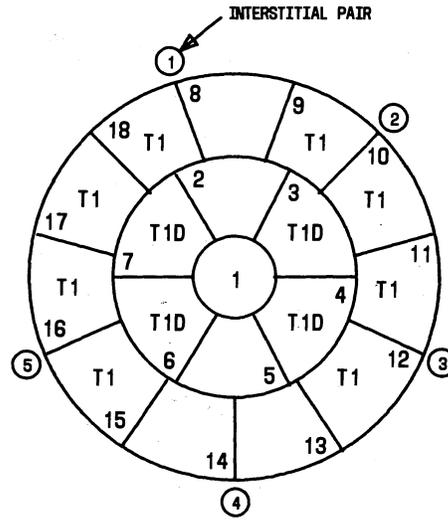


D. 50 T1 SYSTEMS AND 150 T1C SYSTEMS ON A 900-PAIR PULP CABLE

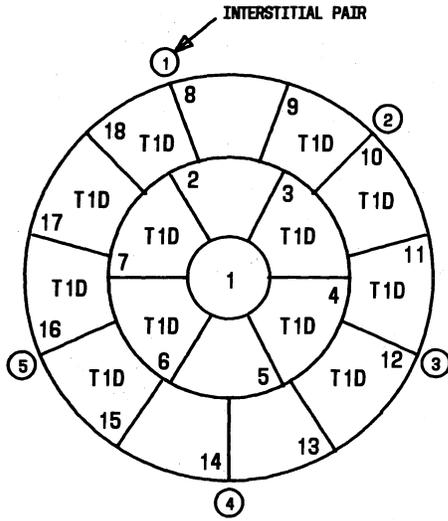
Fig. 2—Unit Selection for 600- and 900-Pair Cable—1-Cable Operation



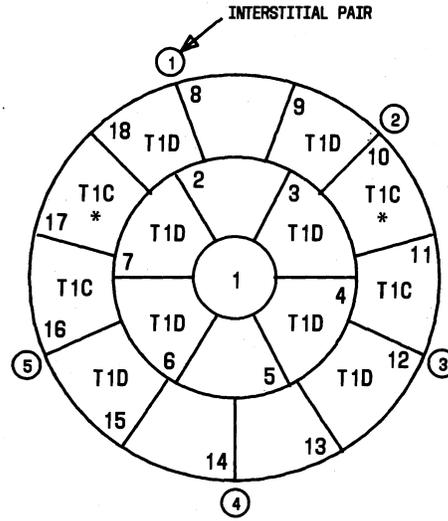
A. 150 T1C SYSTEMS AND 50 T1D SYSTEMS



B. 200 T1 SYSTEMS AND 100 T1D SYSTEMS

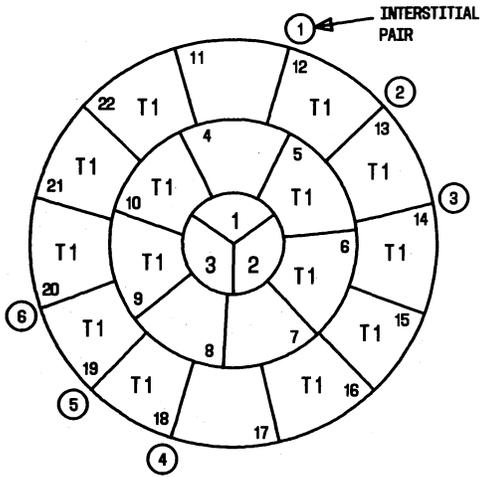


C. 300 T1D SYSTEMS

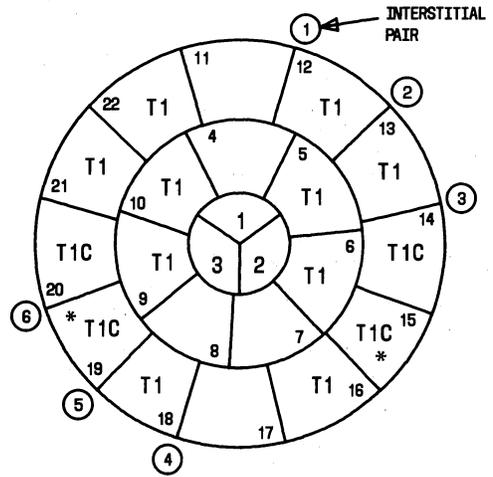


D. 100 T1C SYSTEMS AND 200 T1D SYSTEMS
* LOW POWER REPEATERS

Fig. 3—Unit Selection for 900-Pair Cable—1-Cable Operation

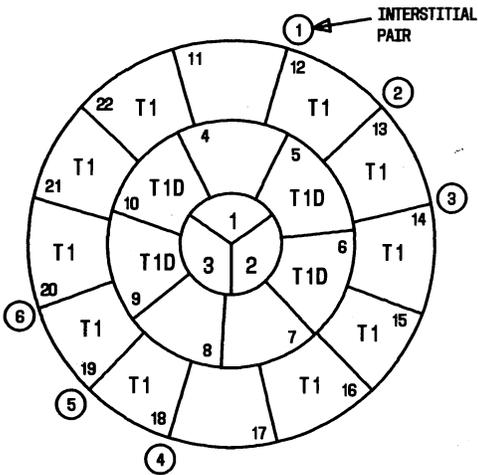


A. 350 T1 SYSTEMS

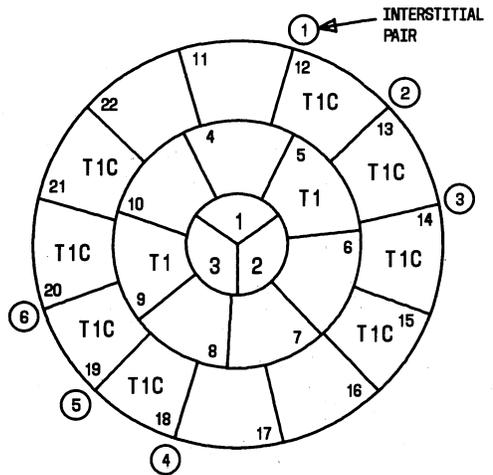


B. 250 T1 SYSTEMS AND 100 T1C SYSTEMS

* LOW POWER REPEATERS

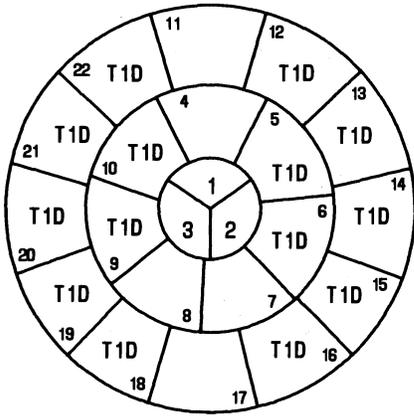


C. 250 T1 SYSTEMS AND 100 T1D SYSTEMS

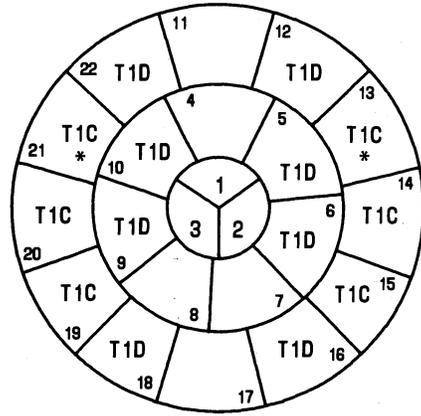


D. 50 T1 SYSTEMS AND 200 T1C SYSTEMS

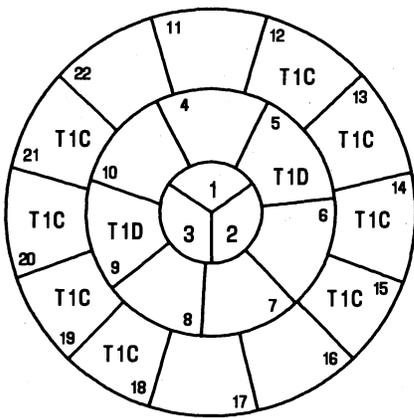
Fig. 4—Unit Selection for 1100-Pair Cable—1-Cable Operation



A. 350 T1D SYSTEMS

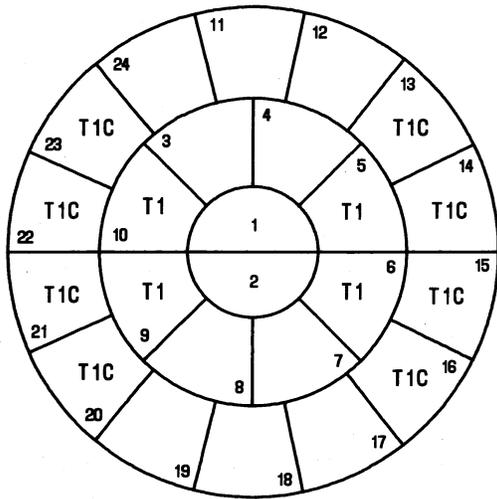


B. 150 T1C SYSTEMS AND 200 T1D SYSTEMS
* LOW POWER REPEATERS

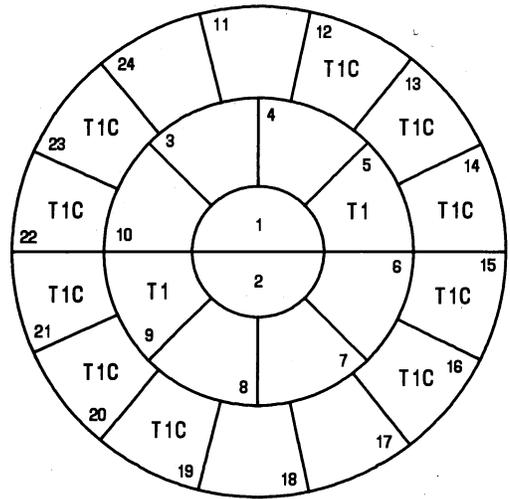


C. 50 T1D SYSTEMS AND 200 T1C SYSTEMS

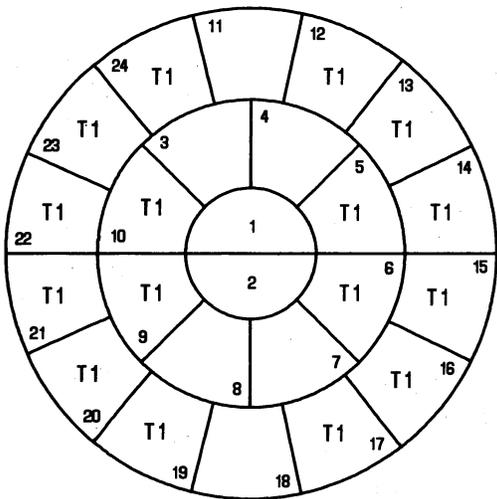
Fig. 5—Unit Selection for 1100-Pair Cable—1-Cable Operation



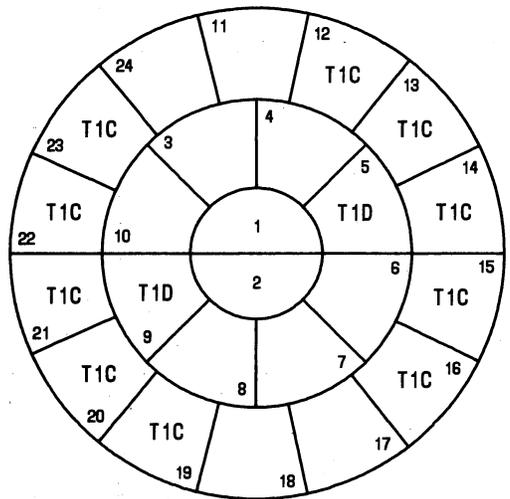
A. 100 T1 SYSTEMS AND 200 T1C SYSTEMS



B. 50 T1 SYSTEMS AND 250 T1C SYSTEMS

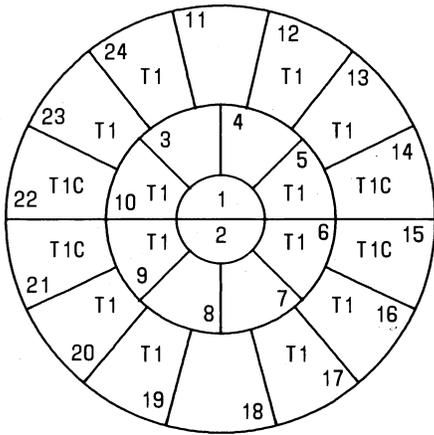


C. 400 T1 SYSTEMS

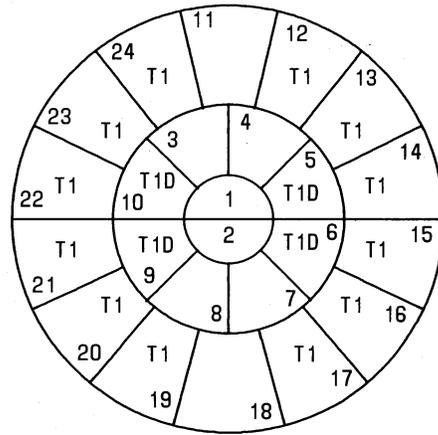


D. 50 T1D SYSTEMS AND 250 T1C SYSTEMS

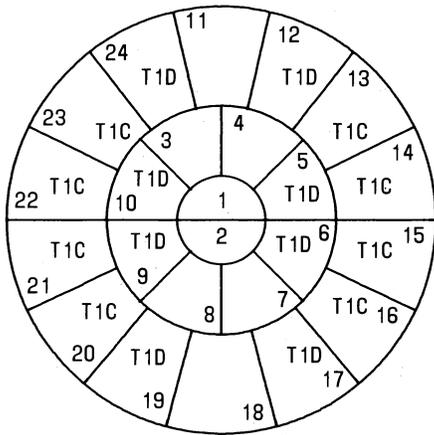
Fig. 6—Unit Selection for 1200-Pair Cable—1-Cable Operation



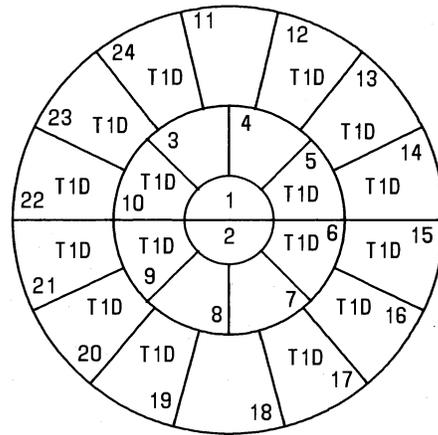
A. UNIT SELECTION FOR 1-CABLE OPERATION WITH 300 T1 SYSTEMS AND 100 T1C SYSTEMS



B. UNIT SELECTION FOR 1-CABLE OPERATION WITH 300 T1 SYSTEMS AND 100 T1D SYSTEMS

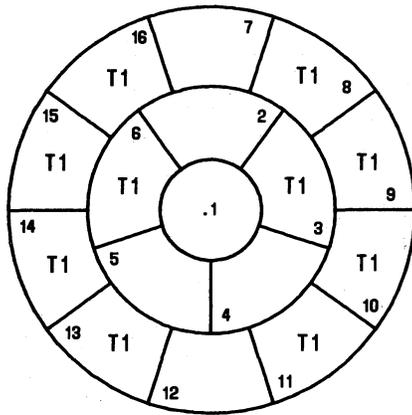


C. UNIT SELECTION FOR 1-CABLE OPERATION WITH 200 T1C SYSTEMS AND 200 T1D SYSTEMS

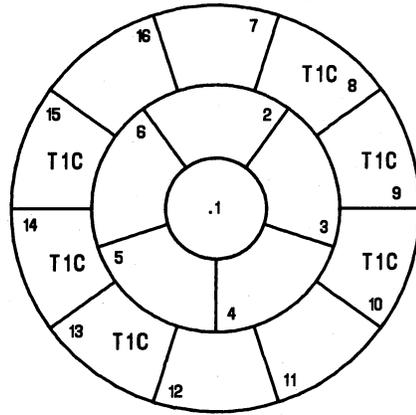


D. UNIT SELECTION FOR 1-CABLE OPERATION WITH 400 T1D SYSTEMS

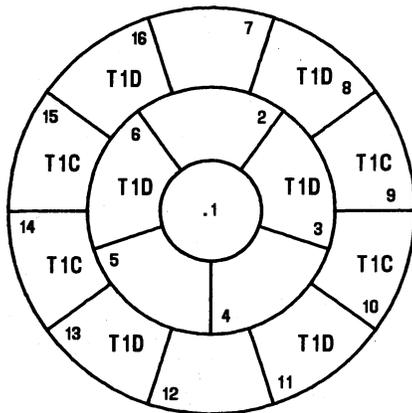
Fig. 7—Unit Selection for 1200-Pair Cable—1-Cable Operation



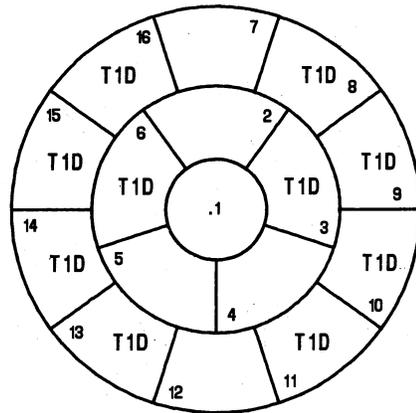
A. 500 T1 SYSTEMS



B. 300 T1C SYSTEMS

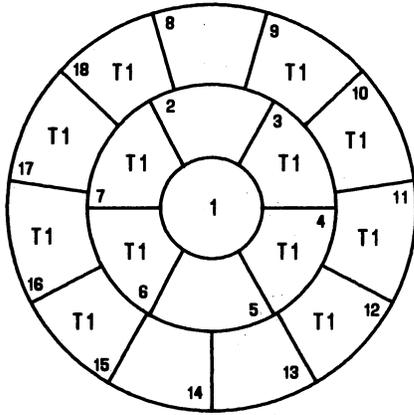


C. 300 T1D SYSTEMS AND 200 T1C SYSTEMS

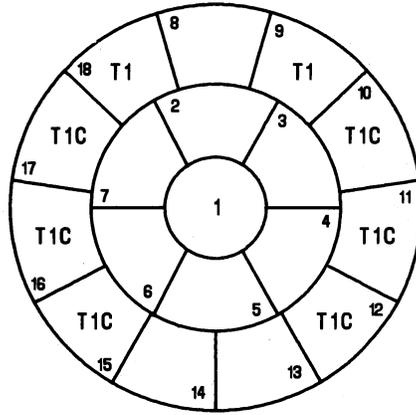


D. 500 T1D SYSTEMS

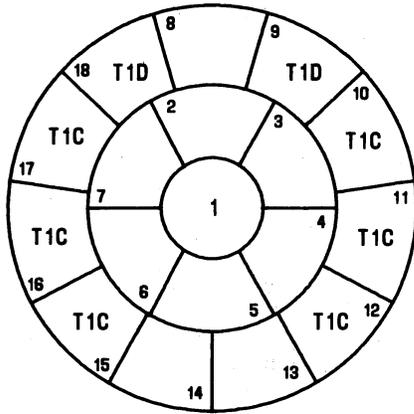
Fig. 8—Unit Selection for 1500-Pair Cable—1-Cable Operation



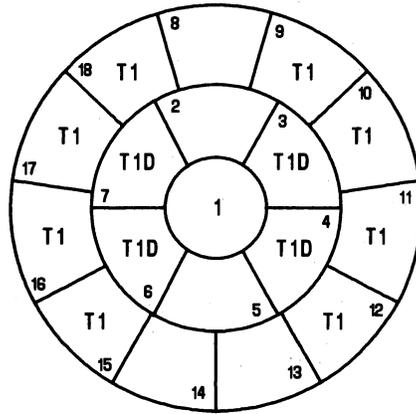
A. 600 T1 SYSTEMS



B. 100 T1 SYSTEMS AND 300 T1C SYSTEMS

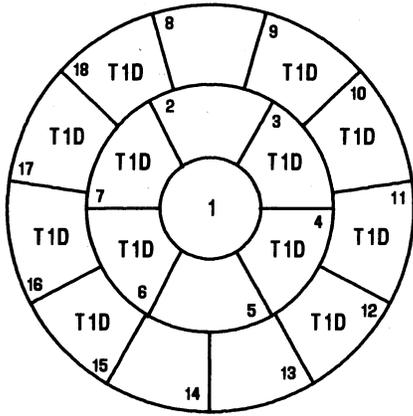


C. 300 T1C SYSTEMS AND 100 T1D SYSTEMS

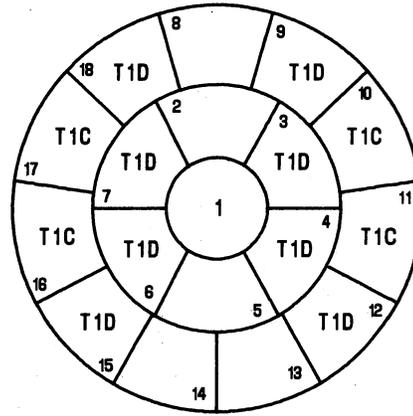


D. 400 T1 SYSTEMS AND 200 T1D SYSTEMS

Fig. 9—Unit Selection for 1800-Pair Cable—1-Cable Operation



A. 600 T1D SYSTEMS



B. 200 T1C SYSTEMS AND 400 T1D SYSTEMS

Fig. 10—Unit Selection for 1800-Pair Cable—1-Cable Operation

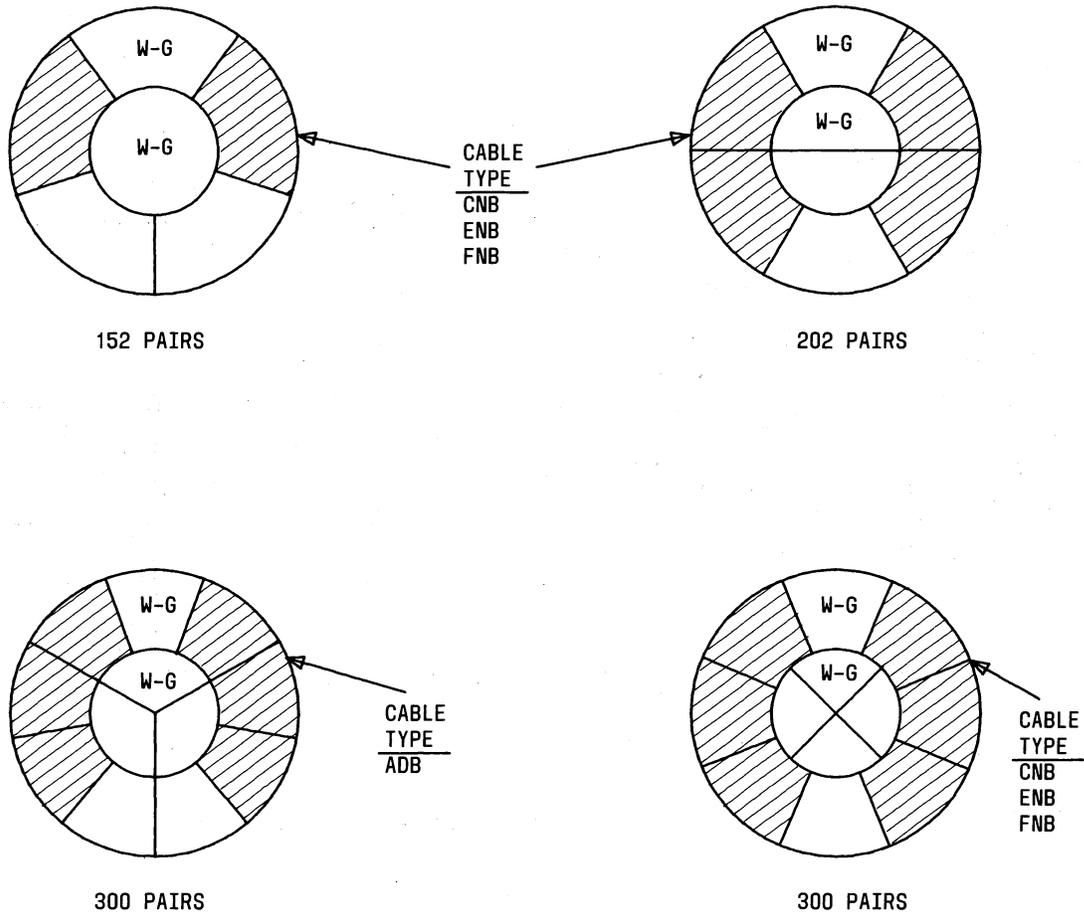


Fig. 11—Unit Selection For 1-Cable T1/T1D Operation on Various 19 Gauge Cable Types

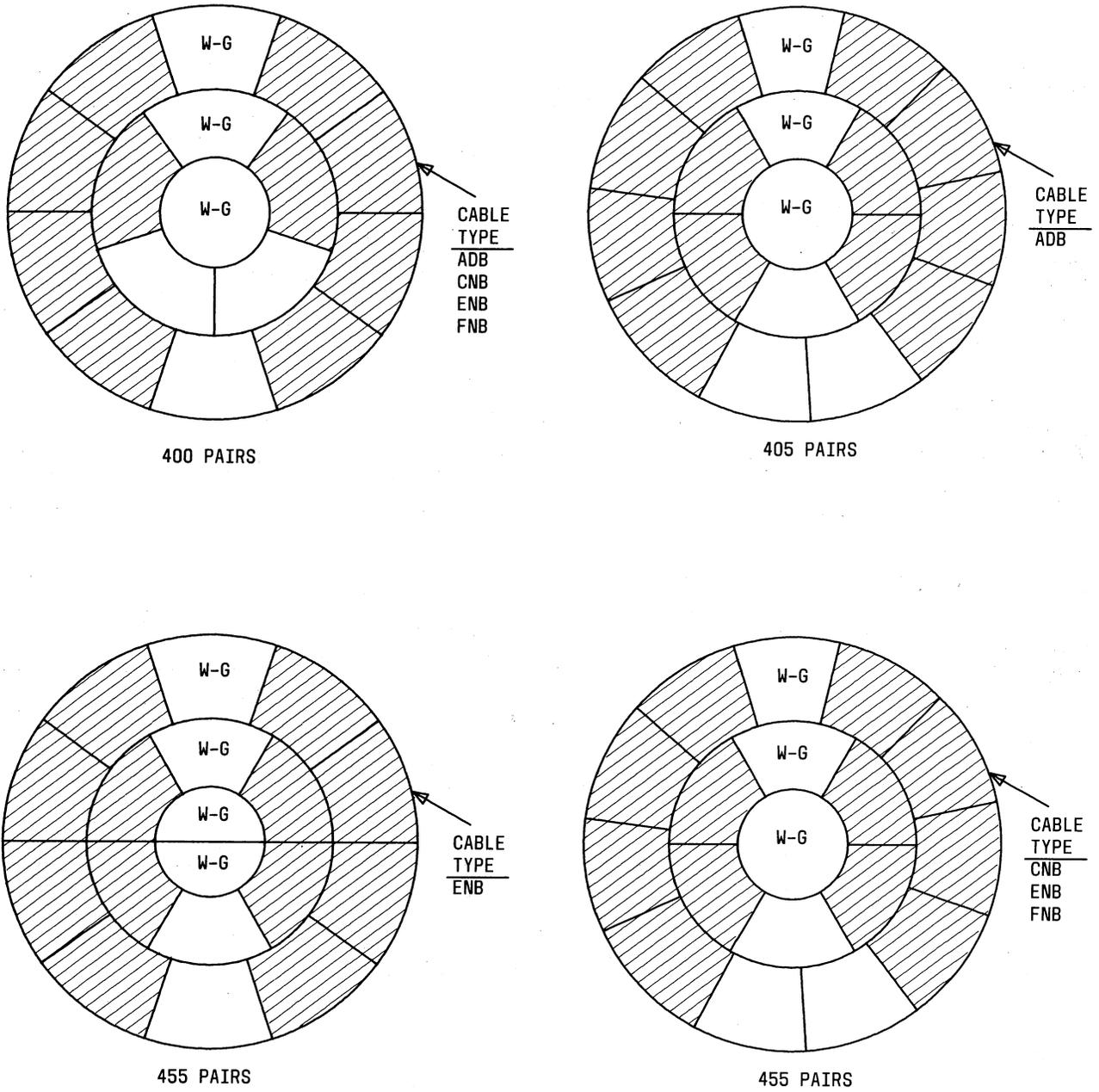


Fig. 12—Unit Selection For 1-Cable T1/T1D Operation on Various 19-Gauge Cable Types

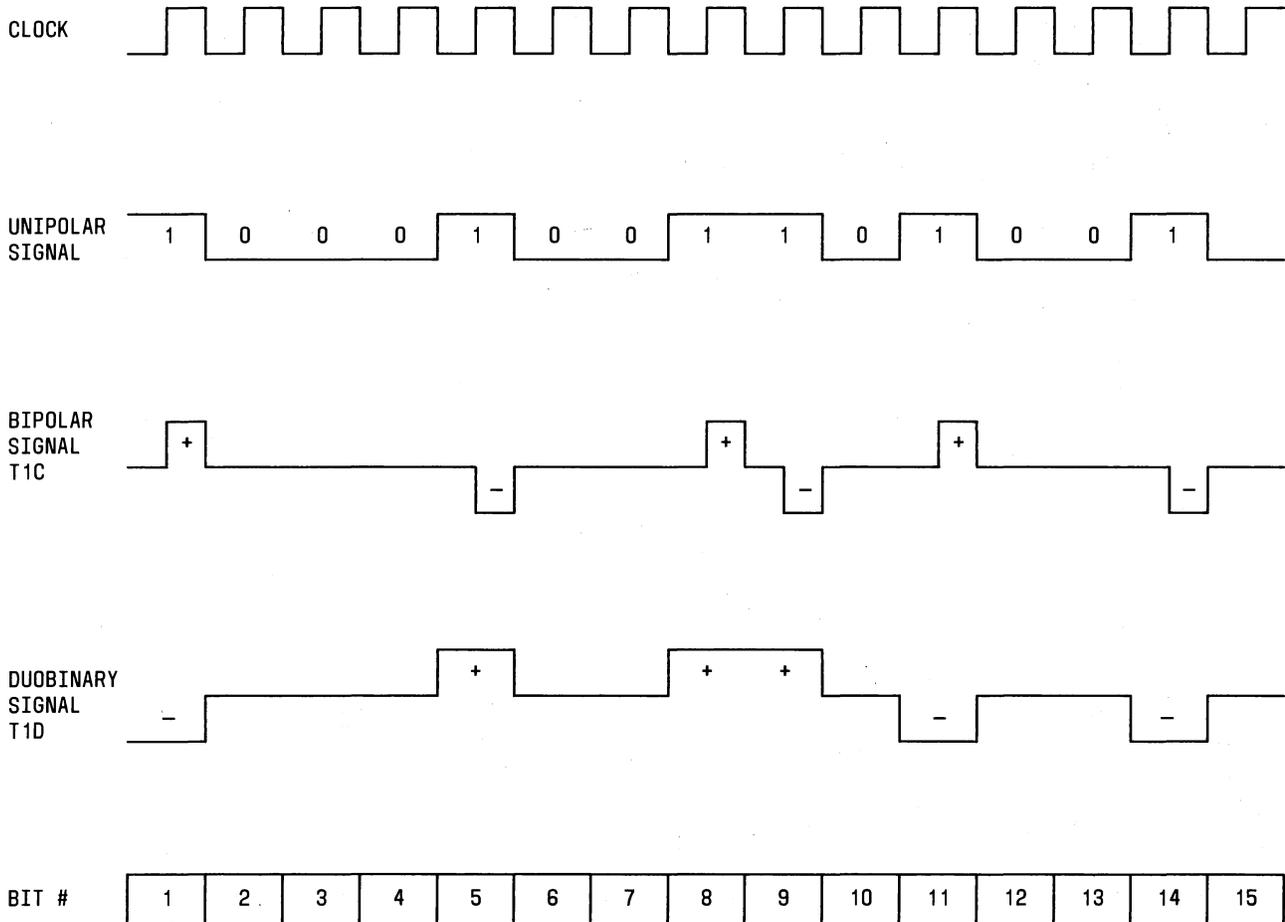


Fig. 13—T1C and T1D Timing Diagram

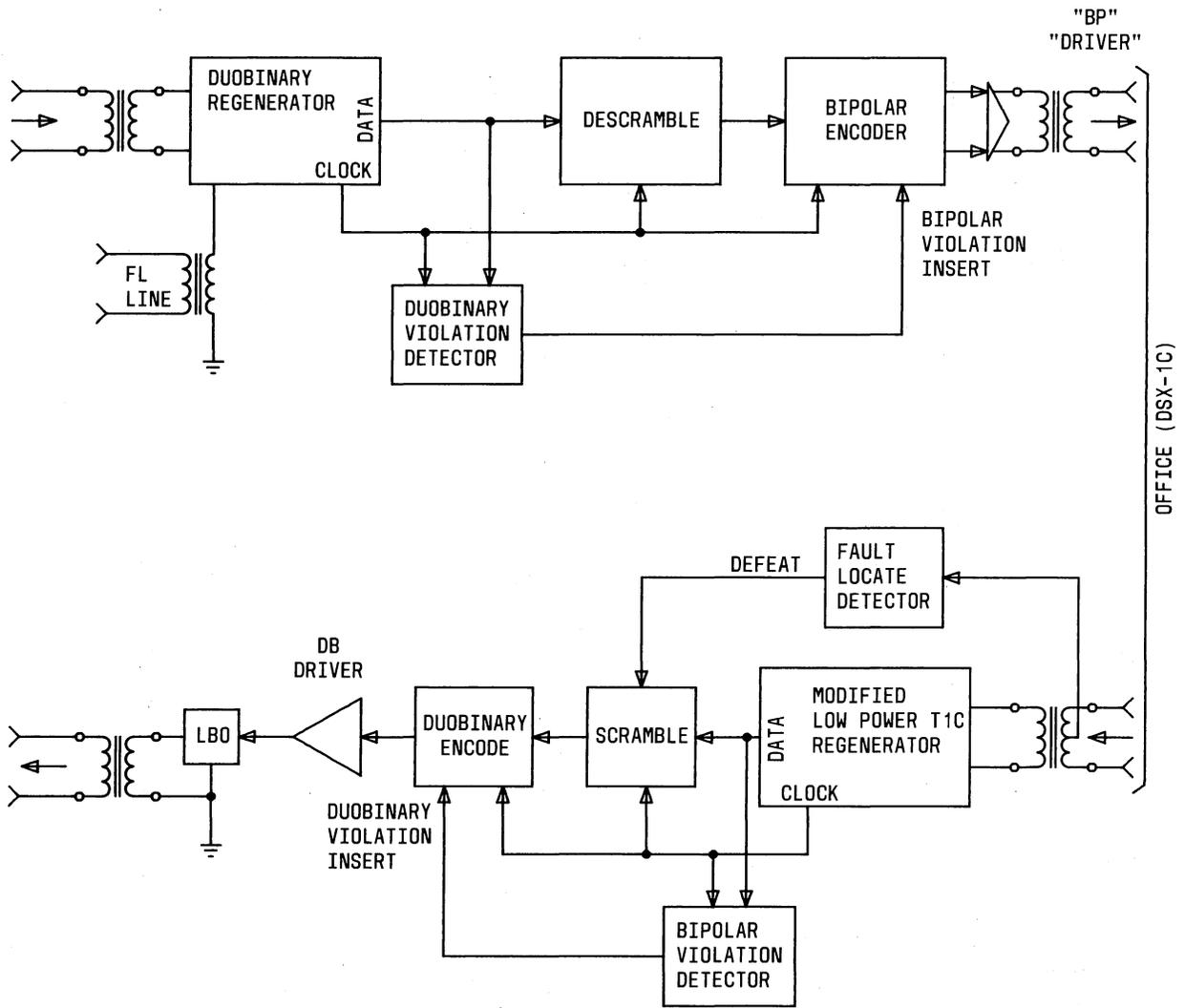
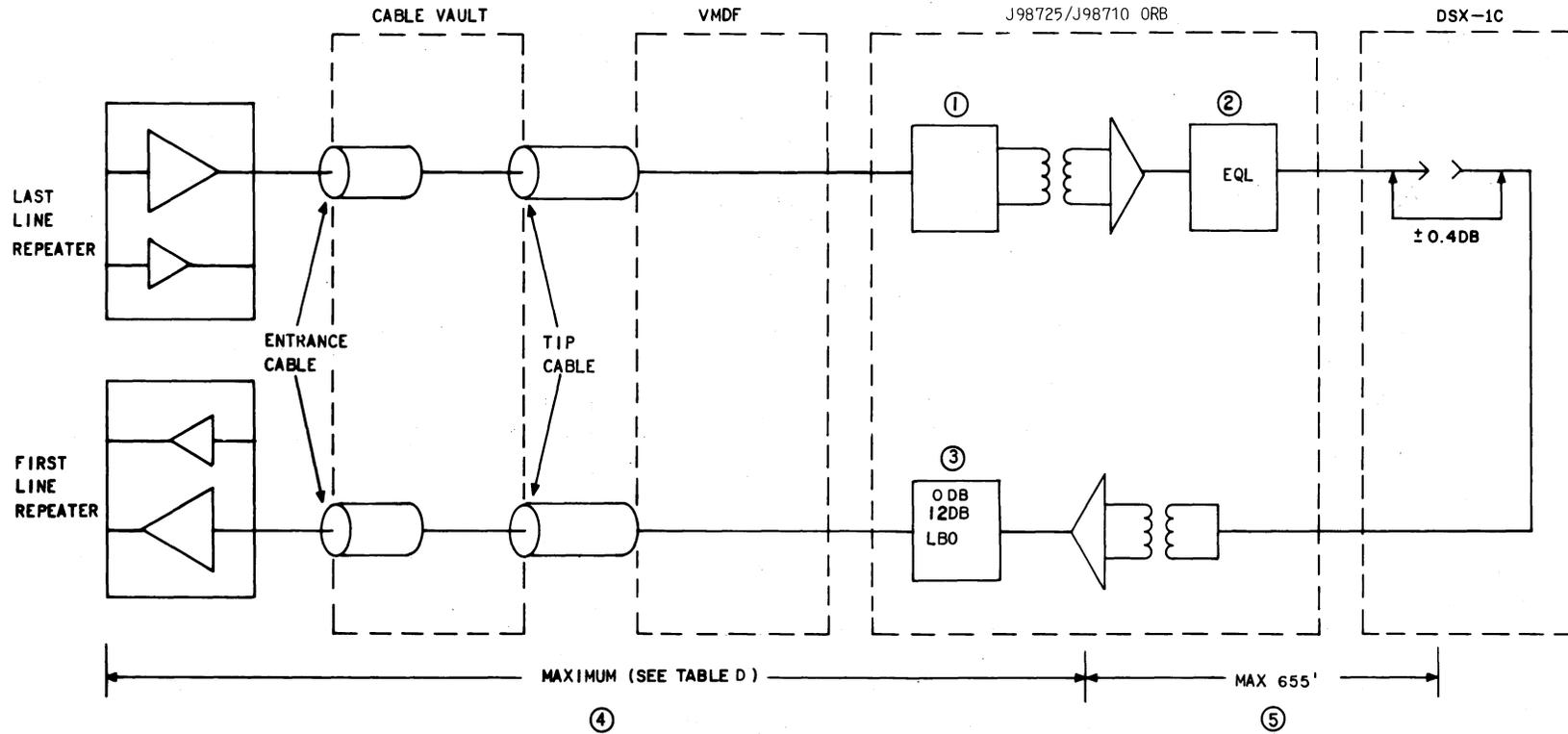


Fig. 14—Duobinary Office Repeater



- ① PROVIDE SECONDARY LIGHTNING PROTECTION
- ② EQUALIZER SELECTED TO GIVE $\pm 0.4\text{DB}$ AT CROSS CONNECT
- ③ LINE BUILD OUT EQUIVALENT TO 0 OR 1500 FEET OF 22-GAUGE PULP INSULATED CABLE
- ④ INCLUDES ALL CABLING BETWEEN THE LINE REPEATER AND THE OFFICE REPEATER
- ⑤ 22-GAUGE ABAM OF 600 TYPE CABLE

Fig. 15—Central Office Layout

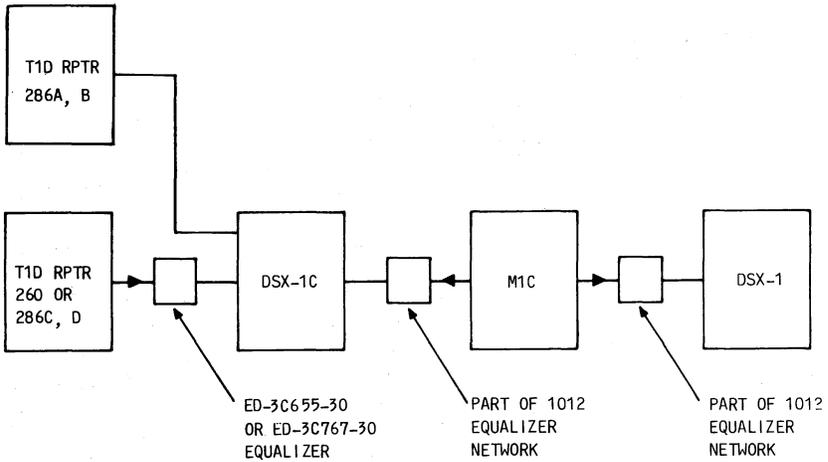
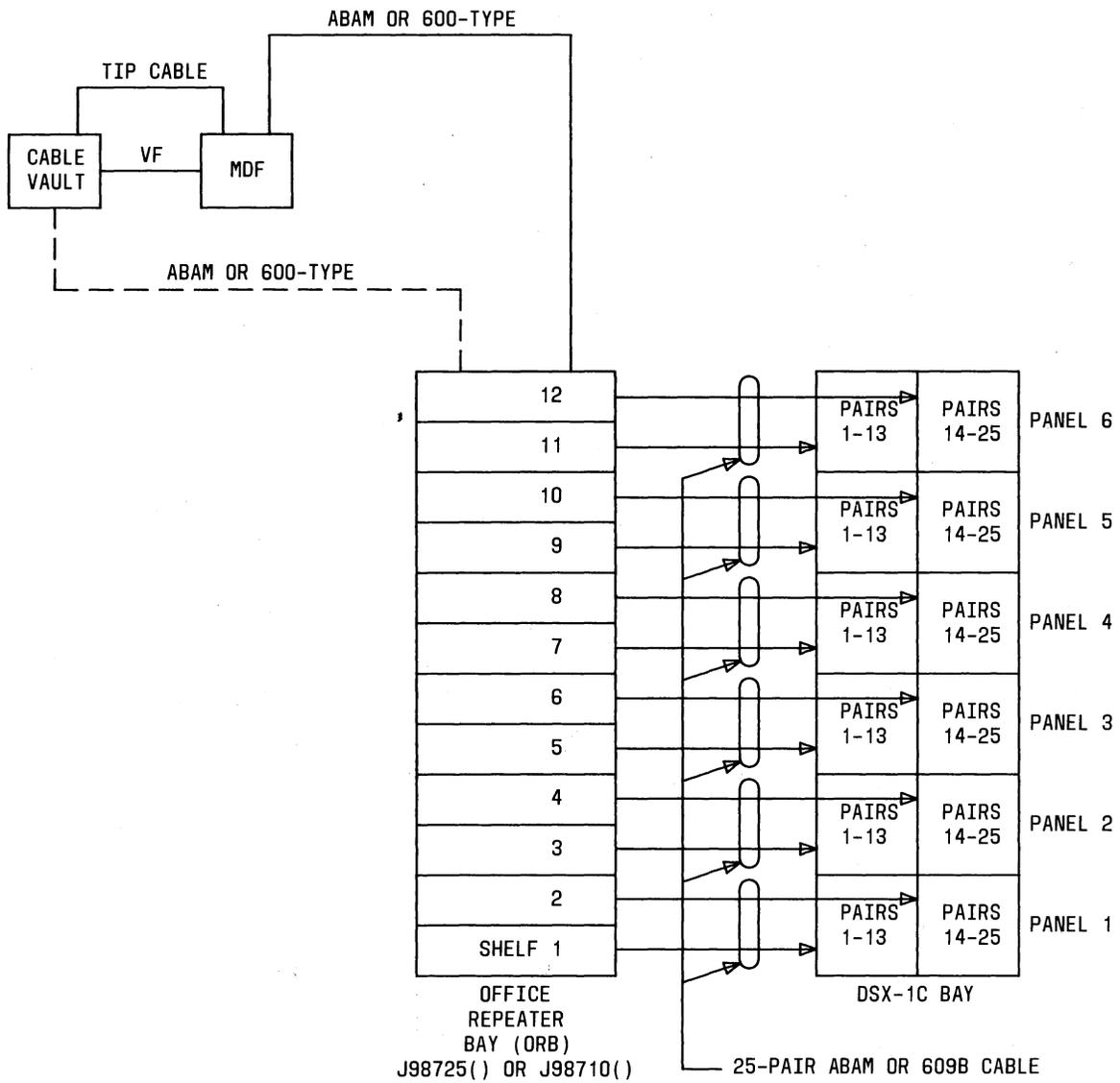


Fig. 16—T1D Equalizer Arrangement for Outputs to DSX



--- INDICATES POSSIBLE DIRECT CONNECTION WHEN NO PROTECTION REQUIRED

Fig. 17—Typical T1D Carrier Office Wiring

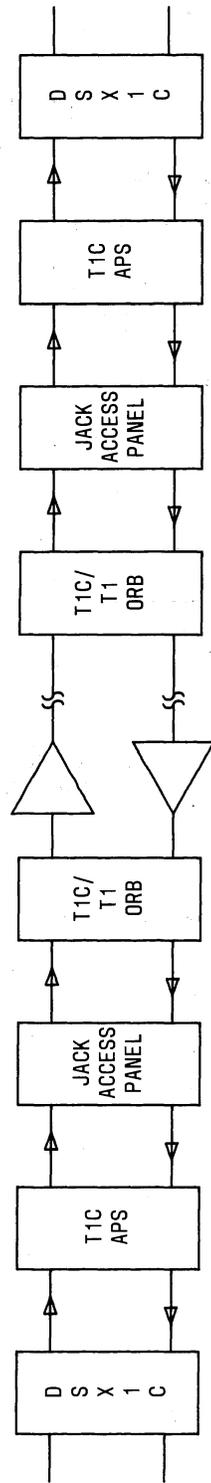


Fig. 18—Block Diagram of APS in T1D Span

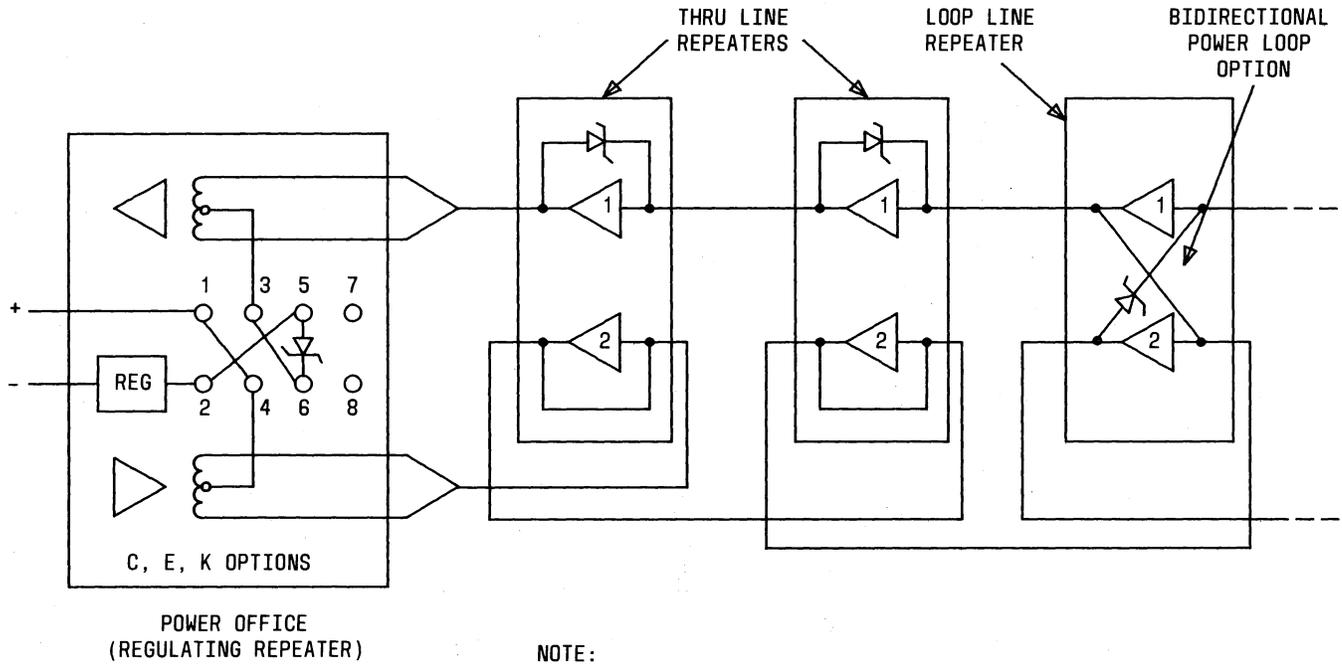
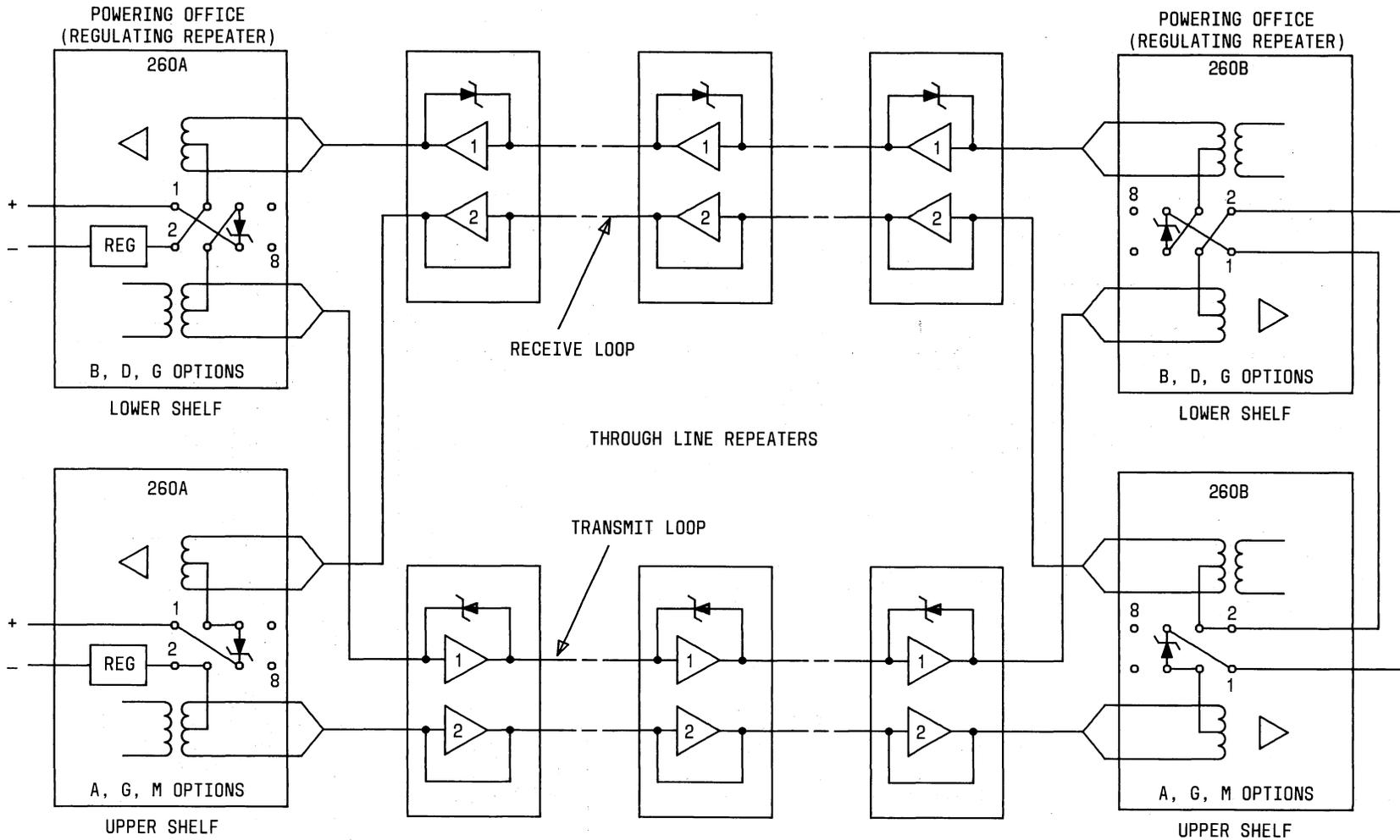


Fig. 19—Bidirectional Power Loop (Note:)



NOTE:
280 TYPE REPEATERS HAVE REGULATOR ON + SIDE OF LINE

Fig. 20—Unidirectional Power Loop B, D,G and A, G, M Options

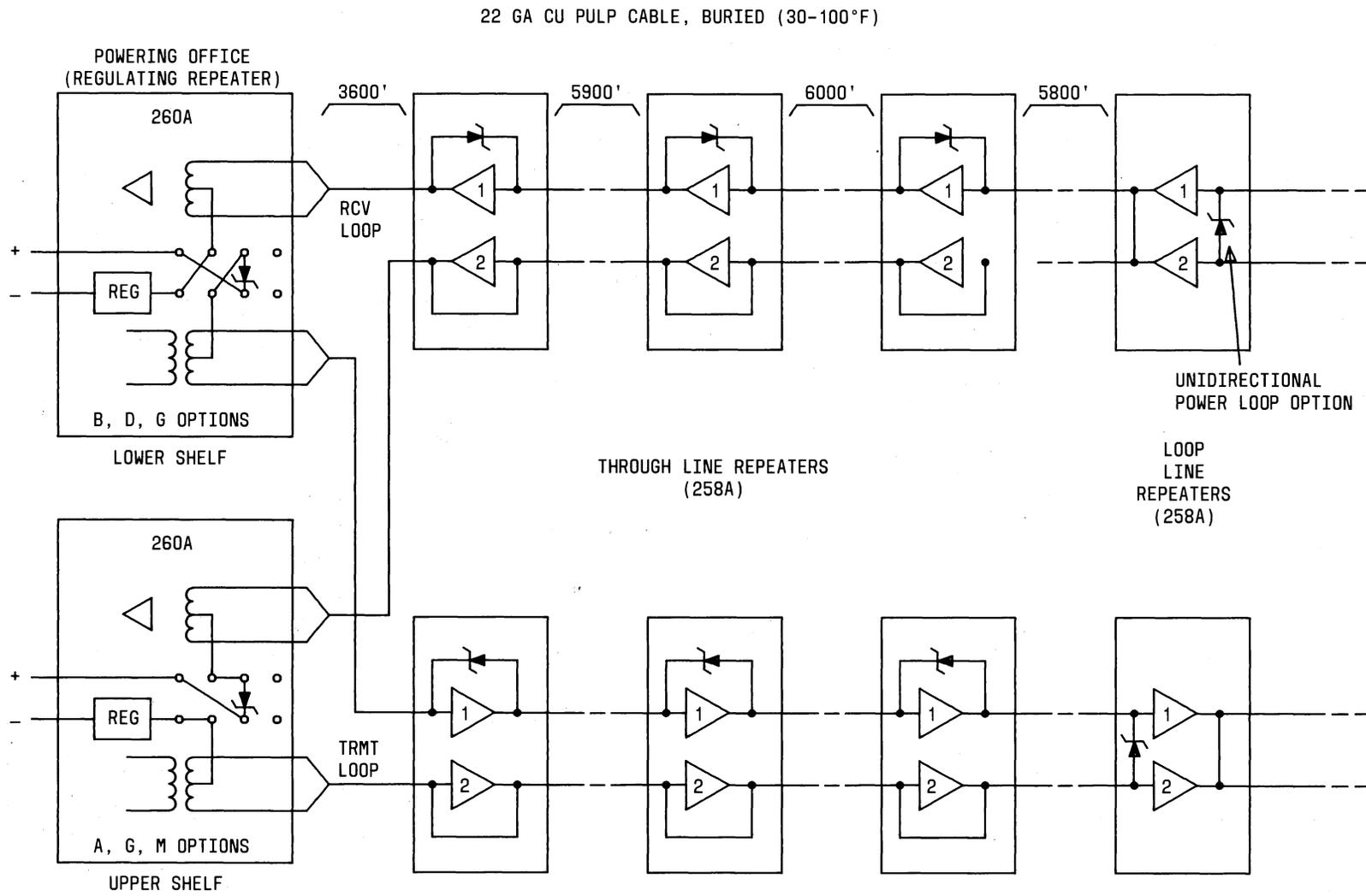


Fig. 21—Example Power Loop

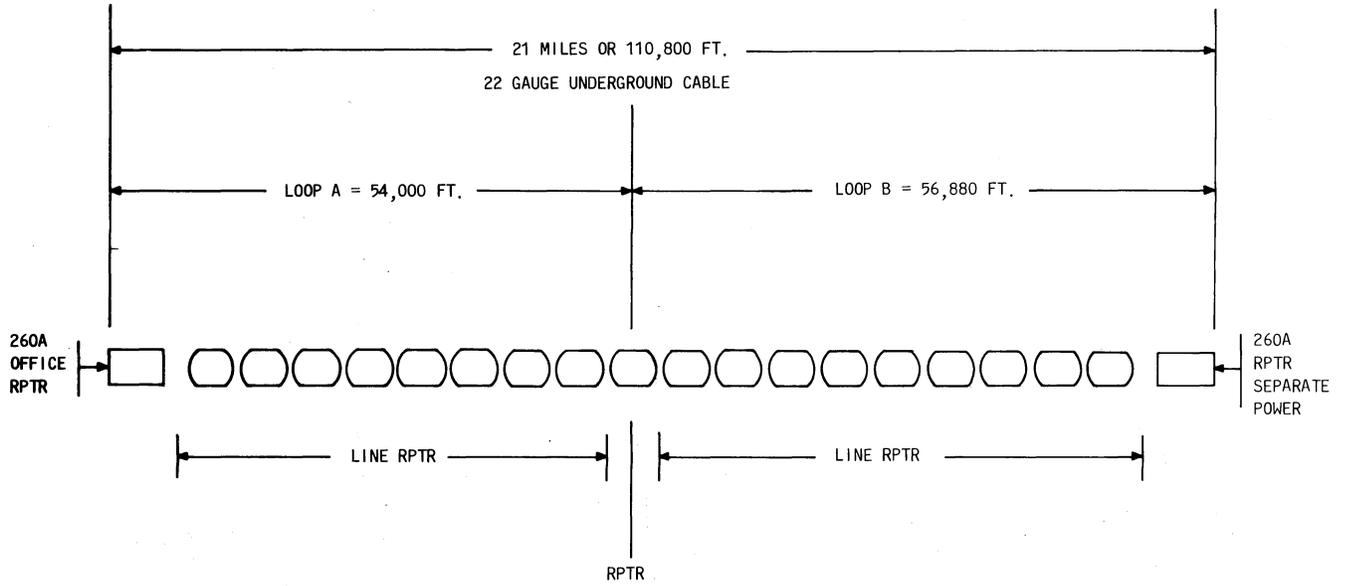


Fig. 22—T1D Line Span Engineering

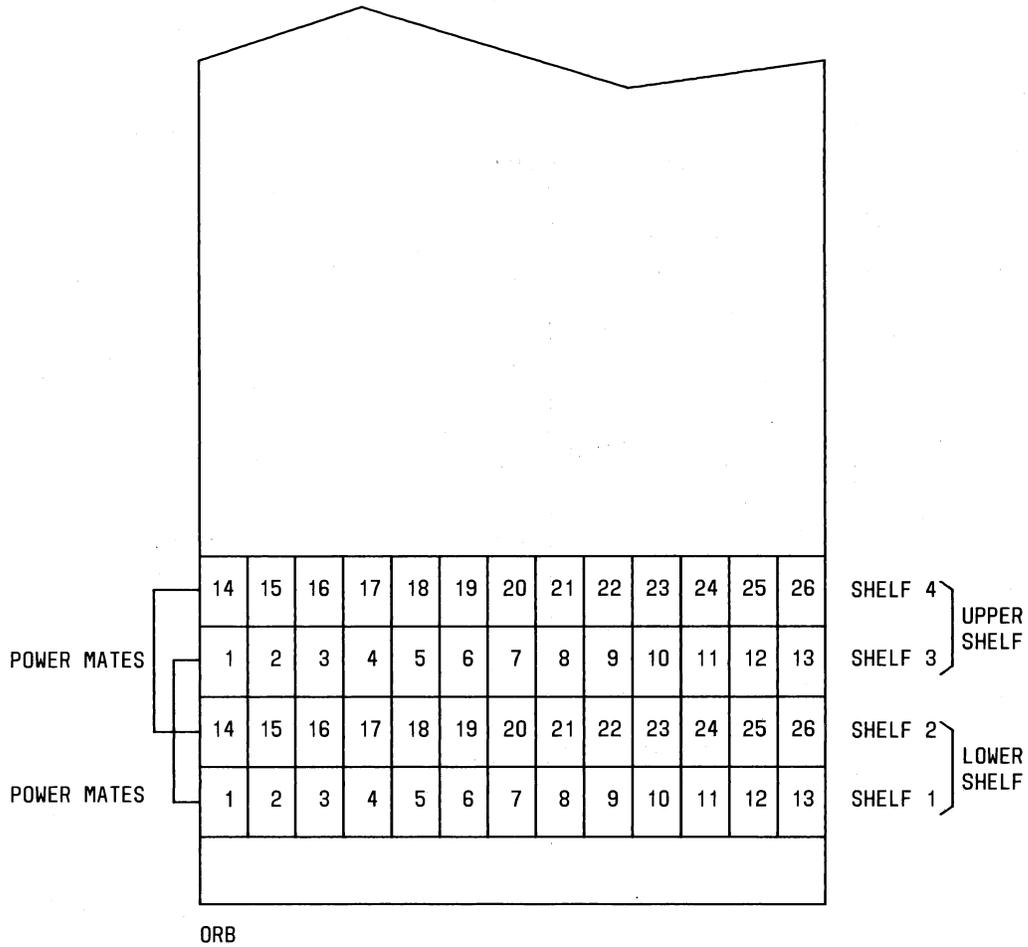


Fig. 23—Unidirectional Line ORB Layout



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 Operation <input type="checkbox"/> Bidirectional <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. 24—Form E-10604—Initial Power Loop Information

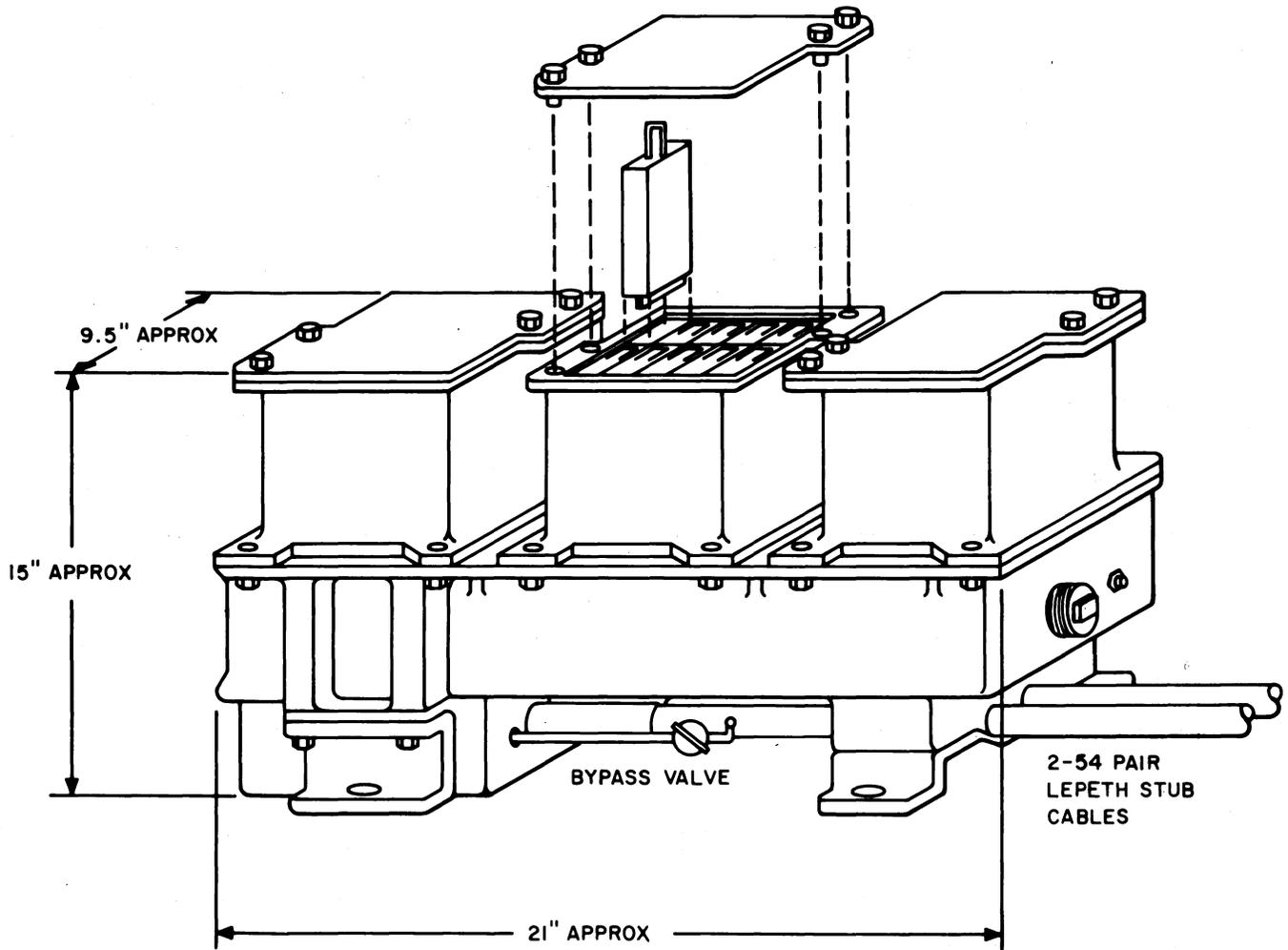


Fig. 25—479-Type Apparatus Case

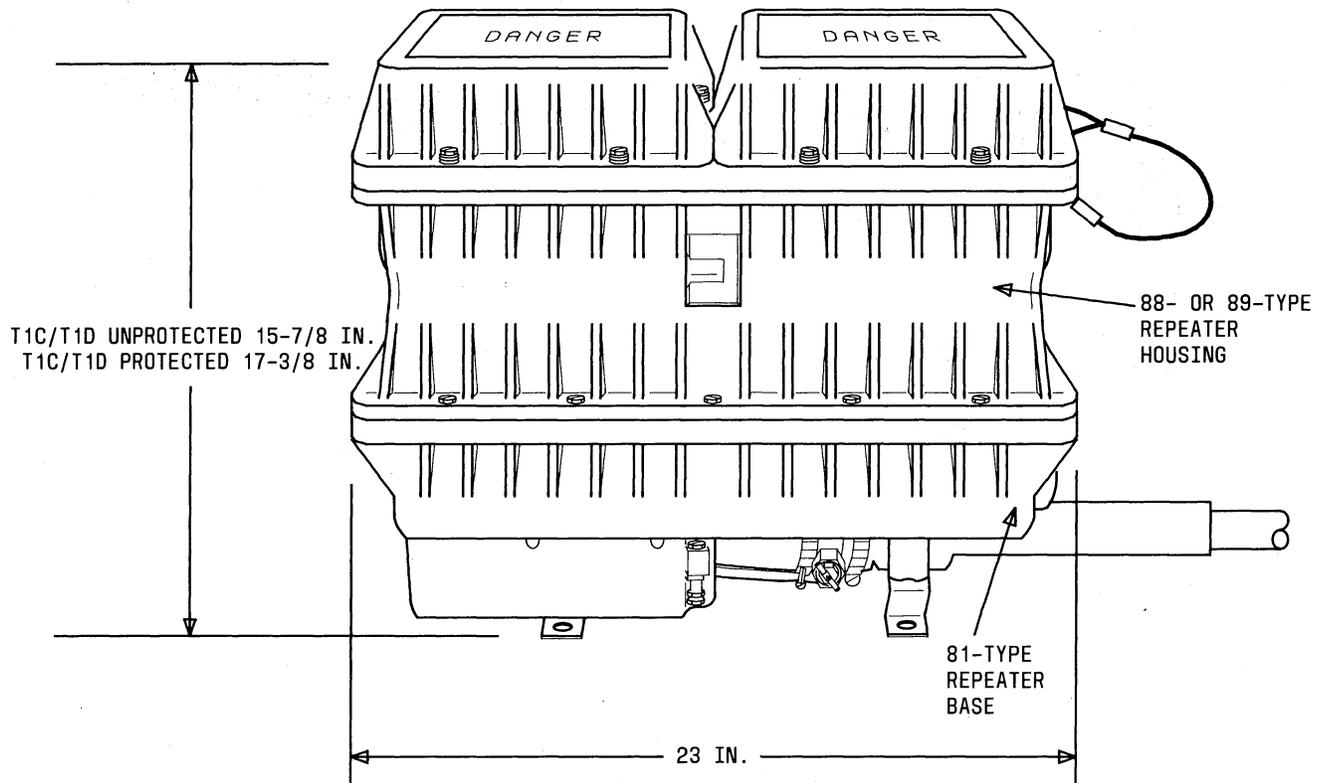


Fig. 26—818/819-Type Apparatus Case

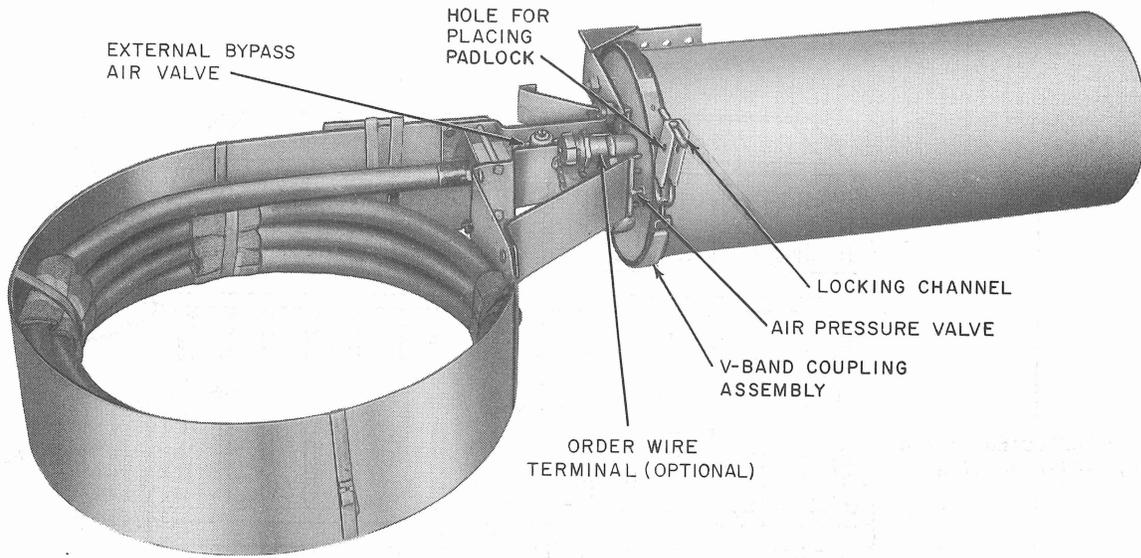


Fig. 27—466A/468A-Type Apparatus Case

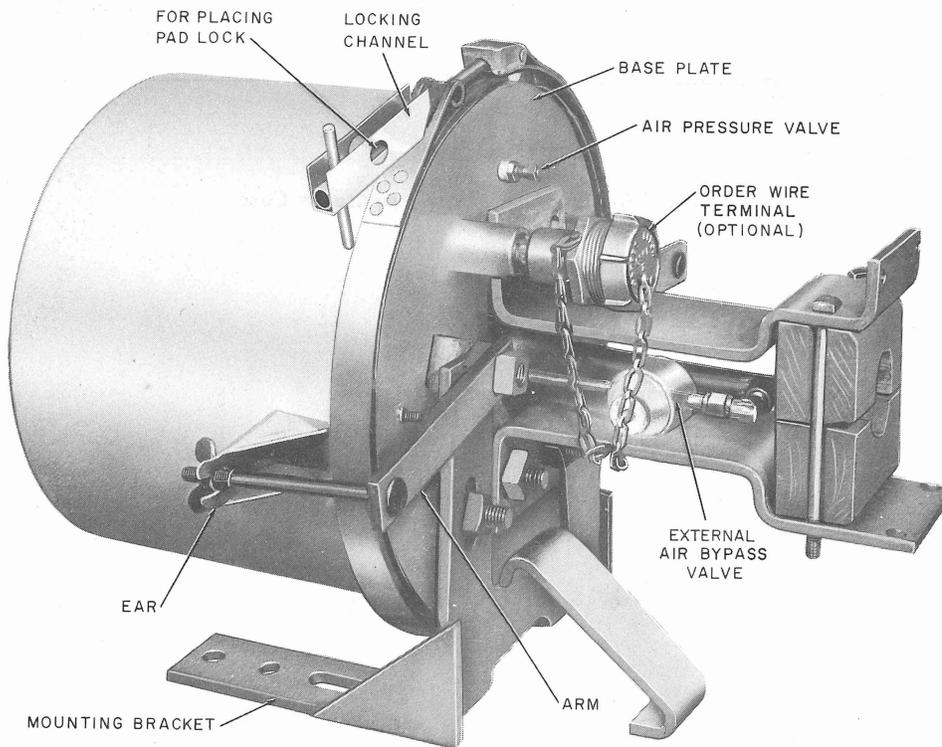


Fig. 28—468C-Type Apparatus Case

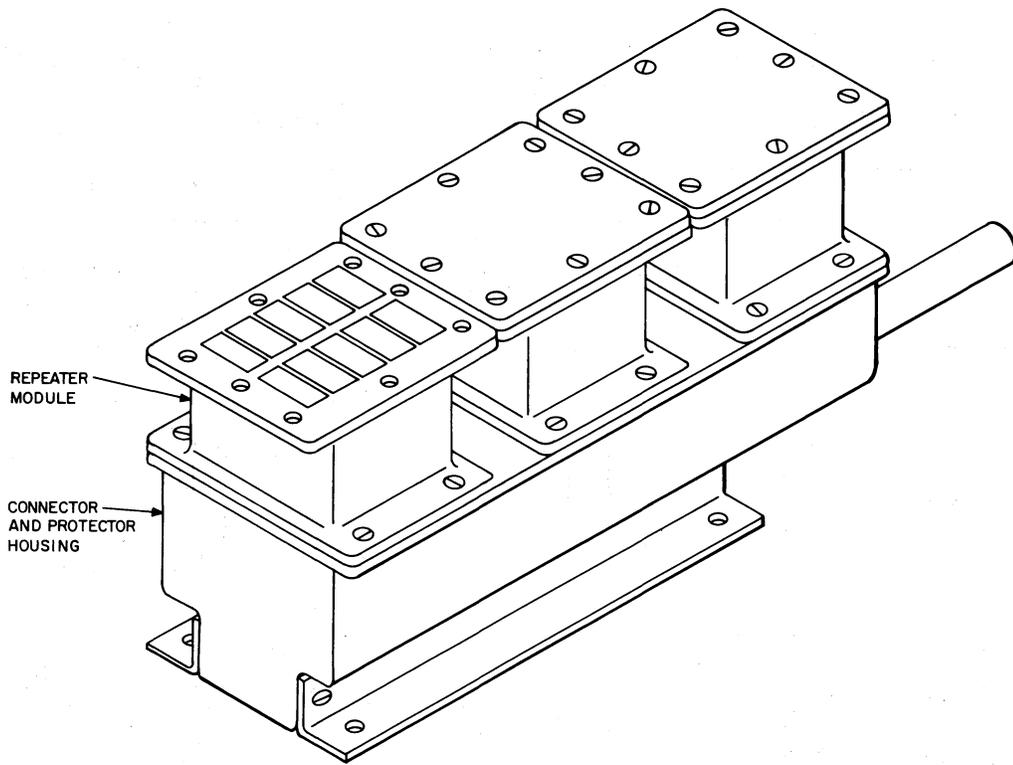


Fig. 29—475-Type Apparatus Case

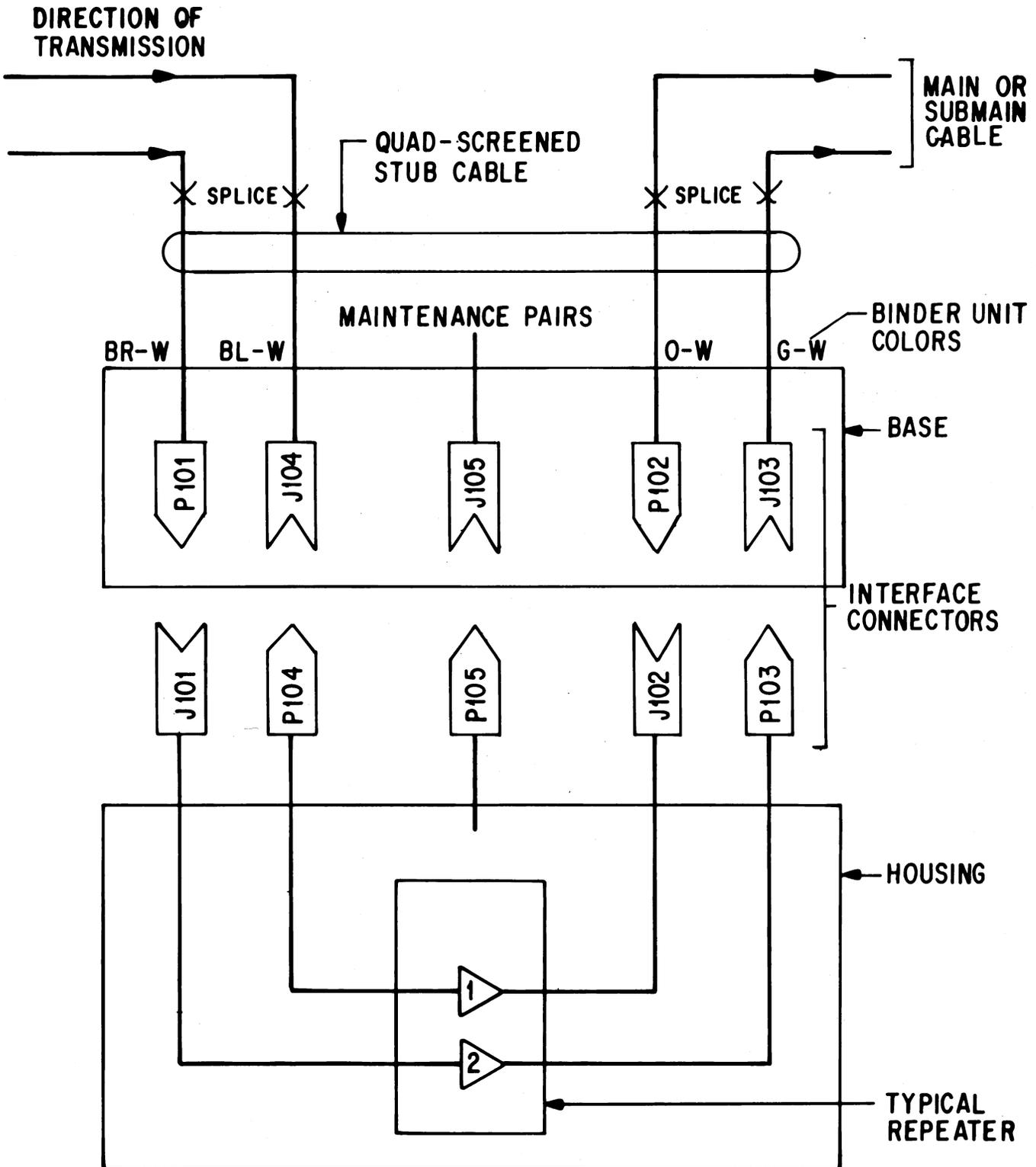


Fig. 30—Splicing for T1 and T1D Unidirectional Operation (Quad Screened Stub Cable)

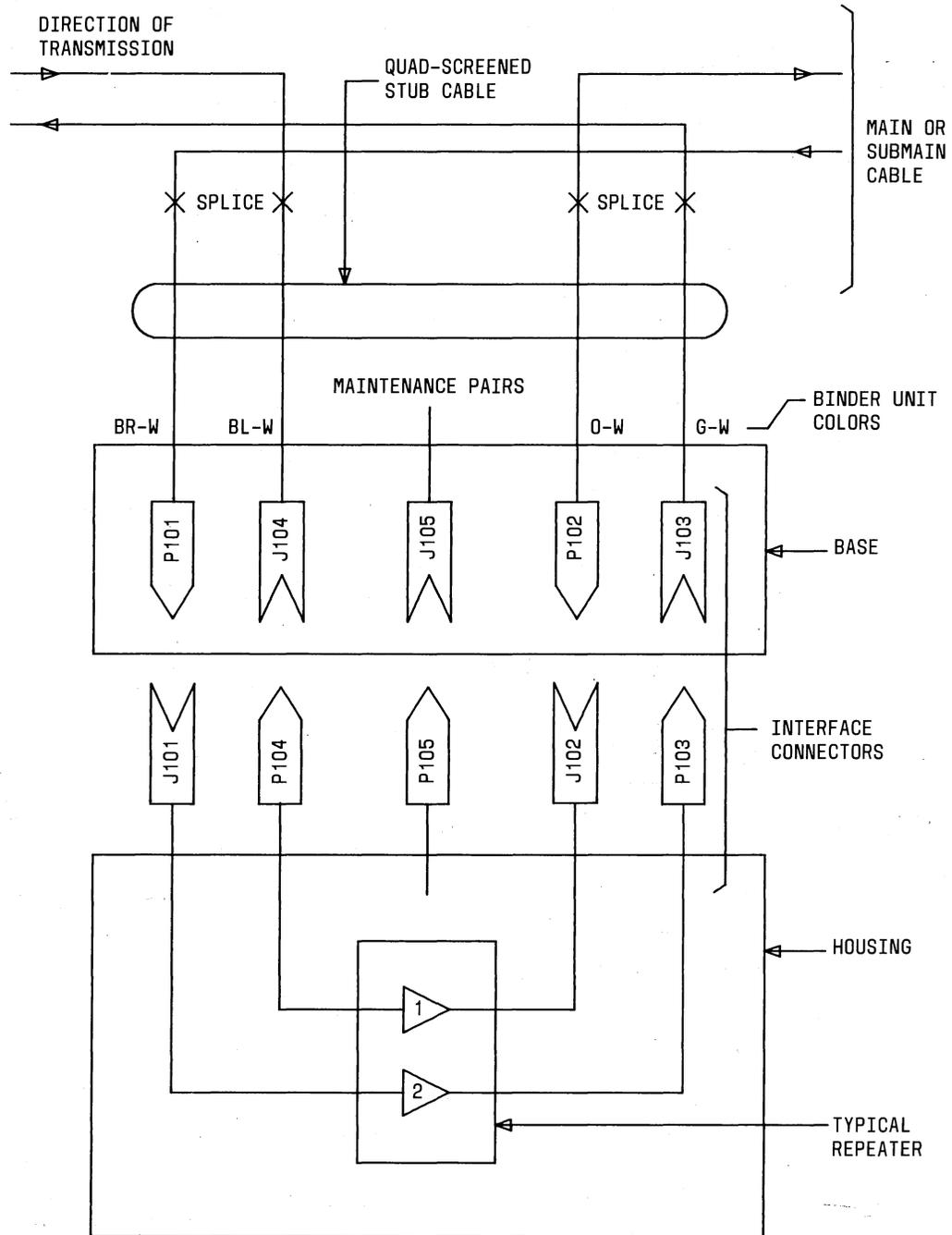
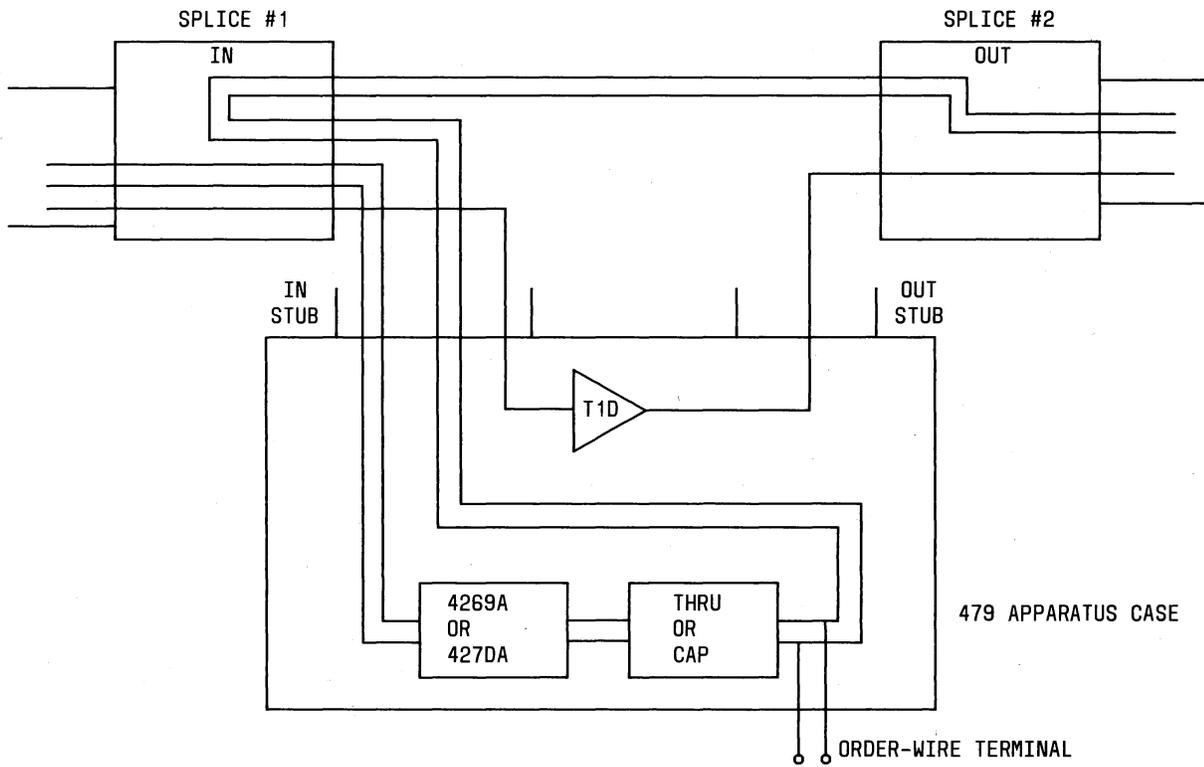
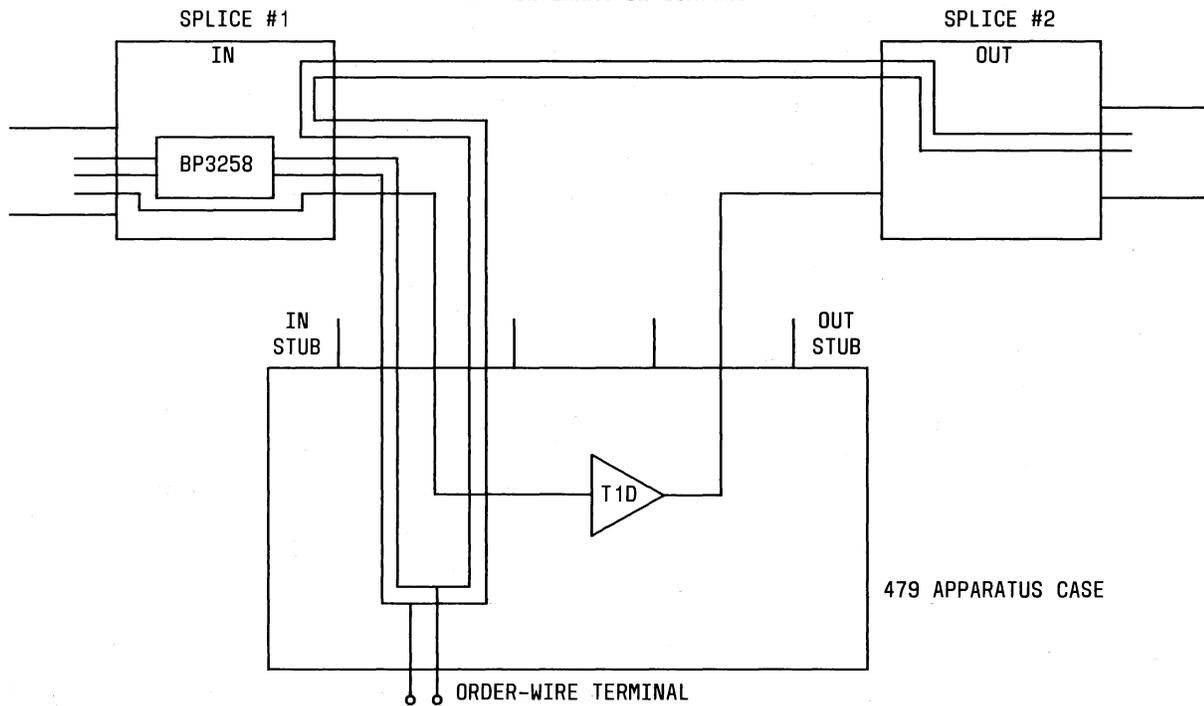


Fig. 31—Splicing for TIC and TID Bidirectional Operation (Quad-Screened Stub Cable)

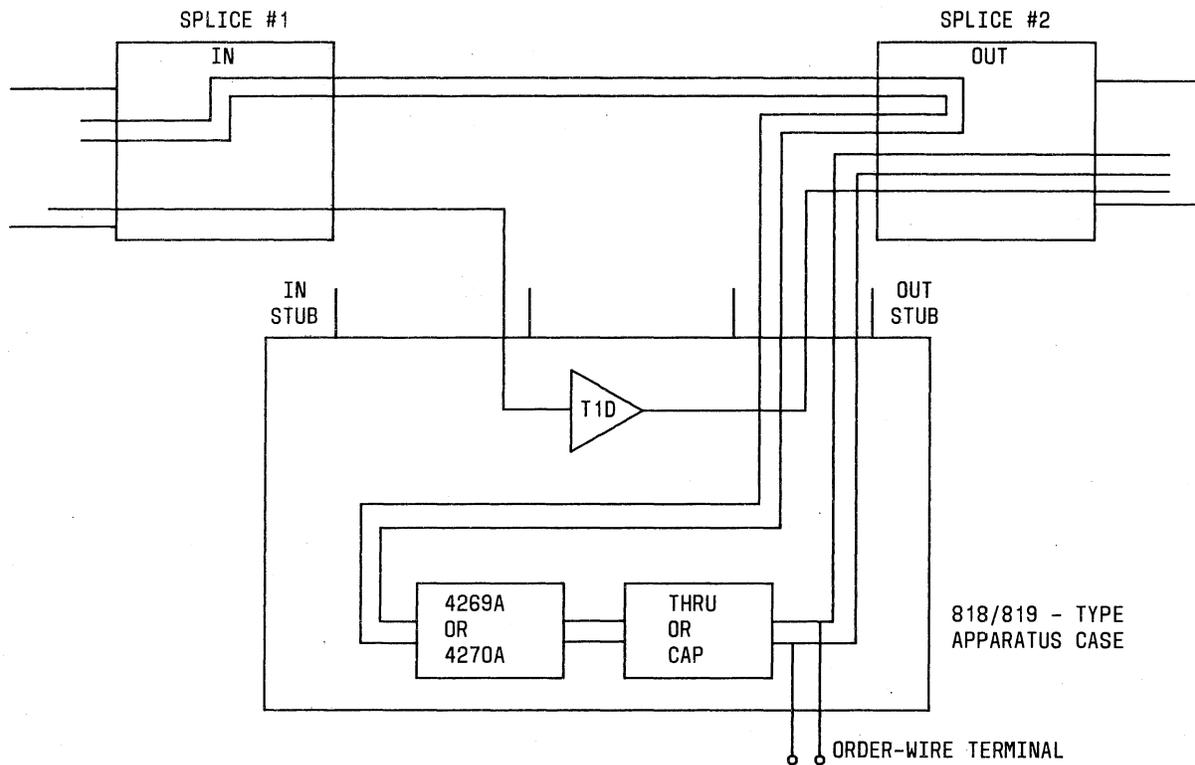


A - INTERNAL OW LOADING

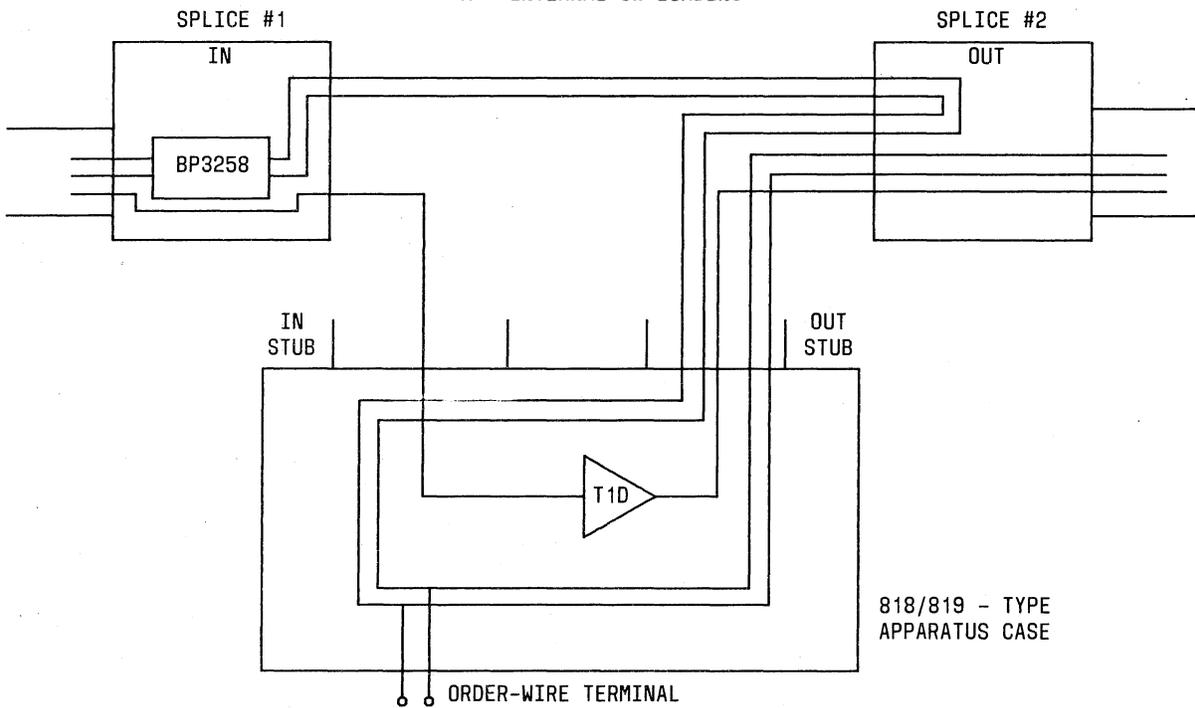


B - EXTERNAL OW LOADING

Fig. 32—Crosstalk Filter Installation on Order Wire Pair in 479-Type Apparatus Case



A - INTERNAL OW LOADING



B - EXTERNAL OW LOADING

Fig. 33—Crosstalk Filter Installation on Order-Wire 818/819 Apparatus Case

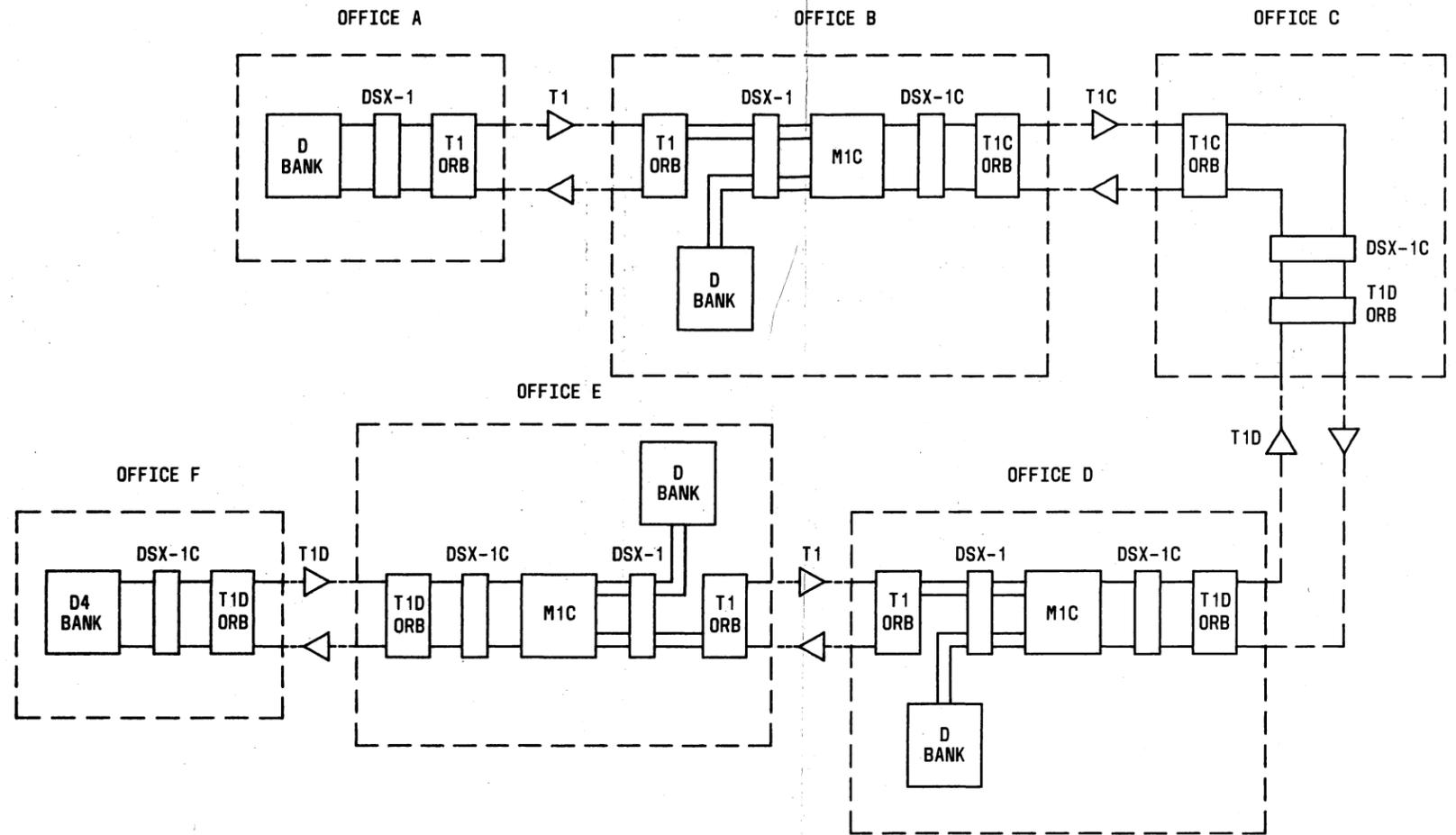


Fig. 34—T1/T1C/T1D System Block Diagram

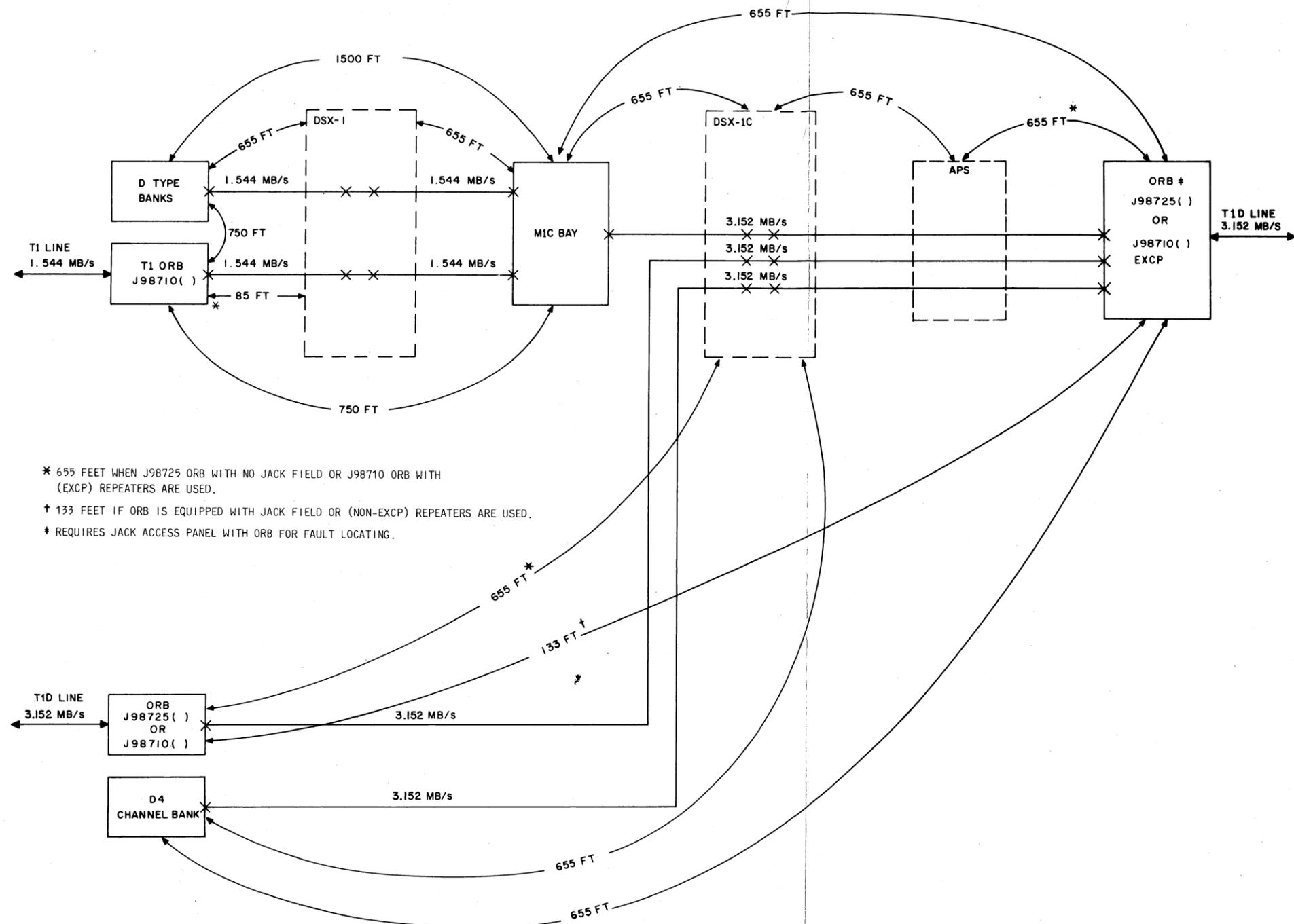


Fig. 35—T1D Line Office Configurations and Interbay Cable Length Limits