

**T1 OUTSTATE DIGITAL LINE
 TRANSMISSION AND OUTSIDE PLANT DESIGN PROCEDURES
 CARRIER ENGINEERING**

CONTENTS	PAGE	CONTENTS	PAGE
1. GENERAL	2	E. Fault Locate and Order Wire	12
A. Description of Overall Line	2	4. DIGITAL LINE DESIGN	12
B. Application	4	A. Repeater Section Design Objective; Design Numbers	12
C. Design Objectives	4	B. Choice of Repeaters	13
2. CENTRAL OFFICE ENGINEERING	4	C. 772-kHz Loss Limitation	13
A. Terminal Equipment	4	D. Intersystem Interference—Near-End Crosstalk (NEXT) Limitations	13
B. Test Equipment	6	E. Intersystem Interference—Far-End Crosstalk (FEXT) Limitations	14
3. OUTSIDE PLANT ENGINEERING	6	F. Presence of Other Services and Systems Within the Cable	16
A. Choice of Cable Type and Mode of Operation	6	G. End-Section Design—Central Office Noise	16
B. Span Powering	6	H. Splicing Apparatus Cases to Main Cables	16
General	6	I. Apparatus Case Stub Cables	16
Power Loop Structure	7	J. Entrance and Tip Cables	17
Office Repeater Options	8	K. Measurement of NEXT Losses	17
Battery Voltage Selection	8	L. Route Junctions	17
Example Calculation	9	M. Junctions in Office Cables	17
Calculation of Voltage Limits	10	5. MAINTENANCE CONSIDERATIONS—IMPACT ON LINE DESIGN	18
Use of Calculated Limits	10		
C. 60-Hz Induction	10		
D. Power Line Fault Conditions	11		

NOTICE

Not for use or disclosure outside the
 Bell System except under written agreement

CONTENTS	PAGE
6. CONNECTING T1/OS SPANS WITH METROPOLITAN-T1, T1C, T2, OR D4	18
7. REFERENCES	19
8. GLOSSARY	20

1. GENERAL

1.01 This section gives a brief description of the T1 Outstate (T1/OS) digital line and provides design guidelines for a facility containing up to 200 repeater sections. The engineering required to maintain quality of the longer lines is included, along with new techniques of line protection and maintenance. The repeaters used for T1/OS are described in Section 365-200-101. A versatile span terminating bay (STB) is available with various interface and maintenance components. Improved order-wire and fault-locate facilities are also described. Cables, cable operation, and other outside plant considerations are discussed. A glossary of terms used in this section is provided in Part 8.

1.02 This section is being reissued for the following reasons:

- (1) Provide additional information on D4 channel banks used with T1/OS.
- (2) Include low power line repeaters impact on 60-Hz induction interference.
- (3) Add the J98725H order wire which is required for long maintenance spans.
- (4) Include 818/819 apparatus cases.
- (5) Include the J98725AJ fault line powering module which is used for active fault-locating if an ED-2C374 is not provided.
- (6) Include the ED-2C375 fault locate and jack panel which can be used if a J98725AJ fault line powering module is available.
- (7) Make reference to four Sections, 365-800-002(TOP), 855-350-105, 855-351-110, and 855-351-115.
- (8) Include 24 gauge ICOT screened cable.

(9) Provide additional information on powering.

Revision arrows are used to emphasize the more significant changes.

A. Description of Overall Line

1.03 The T1/OS facility comprises of T1 digital lines with automatic protection switching (APS). The APS is provided at span terminating offices of maintenance spans to establish protection groups for lines within a span. Powering sections may be interconnected with each other or with terminal equipment to provide the desired network configuration. In some cases, where only two or three D3 or D4 channel banks are required, the channel banks may be contained in the bay with the T1/OS span terminating units. Such bay space may also be used for an initial complement of larger numbers of D-type channel banks or spillover of D-type channel banks beyond their own bay (see Section 801-523-156).

1.04 Powering of T1/OS lines is done in essentially the same manner and with the same choices of battery supply as the metropolitan-T1 (see Section 855-351-101). **However, power dissipation arrangements in the T1/OS equipment do not encourage the choice of powering office repeaters from -48 volt battery; this should not be done, because of potential heat dissipation problems, unless it is essential to achieving the maximum length of a power span.** Another difference is the assignment of odd- and even-numbered lines within an office repeater shelf to separate battery feeds to minimize the effect of blown main or feeder fuses. Also, the assignment of D3 or D4 channel banks to feeders in combined bays is correlated with line powering to minimize loss of service upon failure of a feeder fuse.

1.05 A desired feature of T1/OS is the active fault-locate system designed to improve signal-to-noise performance of the fault-locate line and to permit separate fault identification for opposite directions of bidirectional line repeaters. The latter is made possible by the use of a dual-amplifier filter and line repeaters having separate fault-locate output leads for the two sides of the repeater. With apparatus cases wired to maintain separation of fault-locate outputs, the choice of powering polarity for the common fault-locate line and the dual-amplifier filters enables the return

of fault-locate signals from one repeater direction or the other. Complemented by digital line loop-back capability in the APS equipment, this arrangement permits single-end testing of both directions of the 12 repeater locations allowable with 12 filter frequencies. For configurations where separation of the fault-locate return signals of the two directions is not required, the use of a single-amplifier filter and control of powering polarity, in conjunction with selected tip-ring reversals in the fault-locate line, permit extension of fault identification to a maximum of 24 repeaters.

Note: Fault-locate pair splicing must ensure continuous tip-ring integrity. Tip-ring reversals (other than the selected reversal for use with more than 12 repeaters) may result in an incorrect identification of the direction of transmission in which the fault has occurred.

1.06 Active filters in the 1114 (single) and 1115 (dual) series have been made mechanically interchangeable with the 1068-type for insertion in 475, 818- and 819- type apparatus cases. Some codes of these apparatus cases and of the 208-, 209-, 238-, and 239-type repeaters (see Section 855-351-101) implement splitting the fault-locate outputs. The 205M and 205N repeaters, which are identical to 205G and 205H except for the split fault-locate feature are also available for the 468C6 apparatus cases. At STBs, line powering and access is provided by an ED-2C374 fault-locate panel or an ED-2C375 fault-locate and jack panel and J98725AJ fault line powering module. In those applications where only passive fault-locate lines are required, or where the J98725AJ fault line powering module is available, it is usually preferable to install the ED-2C375 panel. This panel has provision for terminating eight fault-locate lines or through-connecting four fault-locate lines. It also has two -48V TST jacks for powering test sets, and provision for six fault-locate filters for connection to the office repeaters. Up to six fault-locate lines may be terminated on ED-2C374 panel and up to three fault-locate filters may be inserted to serve office repeaters within the bay. One filter position is arranged to be accessed automatically by filter test jacks on the panel, thus providing capability for field testing active filters. Successive pairs of fault-locate line ports may be arranged for through-connection as desired to permit extension of line(s) through an office.

1.07 The APS (paragraph 1.03) terminates each end of a group of T1 lines (N "service" lines together with one "protection" line) to comprise a maintenance span. The APS is used with the active fault-locate system (paragraph 1.05) and provides capability for remote monitoring of the T1/OS lines and control of the APS by use of a status reporting and control (SRC) system as described in paragraph 1.08. Because the APS removes bipolar violations to provide span-by-span protection, fault location cannot be performed **through** an APS and is thus limited to the portion of a maintenance span **between** protection switches.

1.08 Another feature of T1/OS is a built-in SRC system, operating over T1 protection lines and incorporated physically in the APS shelf. This optional feature is provided by equipping the requisite plug-ins. The SRC presupposes designation of a master control station to which a number of remotes have been linked via protection line spans cross-connected in tandem. Thus, if the protection line is called to switch over in place of a failed service line, status reporting or control is available only to the nearest end of the section in which a failure has occurred. In T1/OS facilities containing branches or side legs, junction and end offices are cross-connected in a way that provides a continuous protection line loop. As a result, status of a branch can always be reported back to the control office. From one master control station the system provides the capability of six status indications from, and two orders to, up to eight distant points. SRC action is confined to monitoring and control functions arising out of APS operation; the first places remote units at the control office end only of a distant maintenance span; the second places remote units at both ends of the distant span. The latter mode yields added control of the distant span and far-end maintenance span monitoring. The two modes can be mixed in a T1/OS facility.

1.09 A passive fault-locate system may be used in special cases where the single-end testing (APS and SRC systems) is not required for the T1/OS operation (Section 855-350-104).

1.10 Consistent with the longer maintenance spans expected for T1/OS, the J98725H order wire is provided. The system remains a dial-loop line like the older T1 order wire, but with improved sensitivity and extended range up to 40 miles with 22 gauge copper cable. This distance will vary using other gauge cable. To improve balance of

SECTION 855-351-200

battery current drains when two or more linemen sets are bridged on the order-wire pairs, a simple R-C network is required at each bridge tap and must be incorporated in each apparatus case involving a tap. Office equipment consists of a panel with space for two plug-ins, which are varied to implement the feature available (see Section 855-350-107).

1.11 An overall block diagram of the T1/OS facility showing the general features and layout appears in Fig. 1. Not a substitute for detailed engineering rules and other BSPs, the diagram is intended to show the several physical equipment blocks in functional relationship and to clarify the choice of options within the equipment (SD/CD-1C597-01 provides detailed engineering guidelines). It is assumed that T1/OS will generally conform to the one-cable bidirectional repeater mode of operation as a standard; however, screened cable (see Fig. 2) or equivalent layouts may be commonly employed to establish the 2-way lines. Thus, the apparatus cases will usually contain bidirectional repeaters; however, a large cross-section might use the unidirectional repeater.

B. Application

1.12 T1/OS fills the need for extending metropolitan-T1 into the rural area. In general, this may entail interface with any DS1 facility meeting the DSX-1 format and include all 1.544 megabit per second (Mb/s) D-type channel banks, T1 wideband data banks, digital multiplexers and regular T1 lines. More typically, it is expected that T1/OS will stand on its own, with the usual terminal connection being with either a D3 or D4 channel bank.

1.13 In addition to connecting distant central offices, it is anticipated that T1/OS will also be used to connect to independent telephone company digital facilities. Care must be taken to ensure end-to-end compatibility with the line powering, APS, and fault-locate equipment used by the independent company.

C. Design Objectives

1.14 T1/OS engineering rules are derived from the end-to-end facility design objective that at least 95 percent of properly engineered and installed lines will have a bit error rate less than 10^{-6} . Studies have shown that an appropriate method for engineering long T1 lines is to assign

the same error rate objective, 10^{-6} , to each repeater section. The probability of exceeding this error rate is then allocated on a section-by-section basis. For T1/OS, allocate (100 - 95) percent = 5 percent to the facility length. As discussed later, 200 properly designed repeater sections are possible; hence, each repeater section shall have a maximum probability of 5 percent/200 = 0.025 percent of exceeding a 10^{-6} bit error rate.

2. CENTRAL OFFICE ENGINEERING

A. Terminal Equipment

2.01 All central office equipment for terminating a T1/OS line is found in one STB. This bay can be obtained in three heights: 11 feet 6 inches, 9 feet, or 7 feet. The bay is engineered using the "building block" concept, which allows the greatest latitude in determination of needs. It also provides for field additions within the limitations of the local cable design. The building blocks are as follows:

- (1) Protector panel (303-type connector)
- (2) T1 only fuse panel
- (3) D3 channel bank fuse panel
- (4) D4 channel bank fuse panel
- (5) D3 channel bank shelf
- (6) D4 channel bank shelf
- (7) D3 channel bank hot spare and maintenance shelf
- (8) D4 channel bank test and maintenance panel
- (9) DS1 jack and cross-connect panel
- (10) Order-wire panel
- (11) Filter panel
- (12) Fault-locate panel
- (13) Writing shelf (optional on STB)

- (14) Line terminating module (LTM), which is anyone of the following:
- (a) Terminating repeater shelf (TRS)
 - (b) Intermediate powering repeater shelf (IPRS)
 - (c) Span terminating module (STM), 1 × 11
 - (d) ♦Span terminating module (STM) dual, 1 × 5
 - (e) Expansion span terminating module (ESTM), 0 × 13.♦

♦Applications of those equipments are shown in Fig. 3 through 8. For example, Fig. 4 illustrates the building block flexibility for T1/OS combined bay in that LTM No. 2 position may be used for D3 channel bank No. 3. Similar choices arise in other combined bay configurations as shown in Fig. 3, 5, 6, 7, and 8, which illustrate the J98728A, C, G, H, and J bays. Other bays, coded J98728D, E, F, K, L, and M♦ provide a bay-mounted protector panel in addition to the other building block features.

2.02 The provision for cross-connection of DS1 interfaces is of particular interest in the bay arrangements. These interfaces will occur between span line sections or between span lines and channel banks or other DS1 facilities. Cross-connect jumpers are run in the vertical ducts appearing at the face of the left upright as shown in Fig. 3. If the cross-connection is to be made to an adjacent STB, the horizontal duct at the base of the bay permits such an extension. In general, DS1 facilities external to the T1/OS STB, in addition to the channel banks, will be made to appear on the DS1 jack and cross-connect panel for easy interface, provided that the cable length meets the restrictions given in SD/CD-1C597-01.

2.03 For detailed descriptions of the previously discussed building blocks and their functions, refer to Section 801-523-156 and SD/CD-1C597-01.

2.04 As previously noted, office cabling from T1/OS STBs will generally terminate on terminal strips of the appropriate building block or, as in the case of channel bank shelves, via connector interfaces at the position on the bay. Attention is drawn specifically to line pair connections for T1/OS transmission pairs between line terminating

modules (LTMs) and the main distributing frame (MDF). Since it is expected that line assignments for a given protection group are to be dedicated to that group, no provision is made, nor considered desirable, for cross-connecting flexibility within this interface. Thus, cabling arrangements provide that ABAM cables of appropriate size run directly from an LTM to the vertical side of the MDF. Repeaters are assigned to an STM in groups of 6 or 12, Section 801-523-156. Pairs for order-wire and fault-locate lines are run separately and may be arranged for cross-connecting at the MDF if desired. Where the protector panel is provided in the LTM, tip cables from the cable vault terminate directly on the bay-mounted protector.

2.05 Essentially, all T1/OS building blocks involve supplementary notation of plant assignment information. This information is intended to be entered on designation strips affixed to the face of the righthand bay upright. Thus, plug-in slots or switch positions which are numbered or designated in somewhat arbitrary sequence can be correlated with actual service assignments and/or office line and bay locations.

2.06 Location of the STBs is important because of the 85-foot cable length limitation between interfacing bays ♦when non-extended cross-connect package (EXCP) repeaters are used.♦ It is recommended that all STBs be installed as near to each other as possible, and within specified cabling distance of DSX-1 bays when connection to DSX-1 is expected, with sufficient aisle space to accommodate the test equipment (3 feet or 3 feet 6 inches). ♦If EXCP repeaters are installed TRS only, the cable length between bays can be 655 feet.♦ When the STBs are located in different lineups, interconnection between STBs may be provided by one or two 6-pair ABAM cables terminated at the DS1 jack and cross-connect panels. ♦Refer to Section 855-350-105 for specific cross-connect requirements needed for large DSX installations.♦

2.07 ♦Equalizers are available for equalizing the office cabling between the channel bank and the STBs. The equalizer codes and their ranges are shown in Table A.♦

2.08 When ABAM-type cables are used between the STB and the MDF, the cables must be separated by at least 3 inches from other carrier cables on common runs. It is permissible in small installations using three or fewer fault-locate lines

SECTION 855-351-200

to use shielded pairs to terminate these lines on the MDF.

B. Test Equipment

2.09 T1/OS does not require routine tests except performance tests required by the Equipment Test List. Test sets are used for clearing faults on troubled lines and for turning up additional lines. The test equipment used for T1 and T1C (J98725) is applicable to T1/OS. One additional test set KS-20775, L2 Error Rate Test Set Section 103-493-109 or ♦DS1/DS1C/DS2 Error Rate Test Set (KS-22331, L1 and KS-22332, L1) Section 103-493-120♦ is required for overall tests of span lines in the presence of an APS. Each control office will probably require one or more of these sets, with others placed in outlying span terminating offices as required.

2.10 Repeater testing is the same as for the metropolitan-T1. However, when testing with the J98710H repeater test set per Section 365-221-500, interference tests are not required.

3. OUTSIDE PLANT ENGINEERING

A. Choice of Cable and Mode of Operation

3.01 A wide range of cables will be used, the choice depending on economical and geographical considerations. Waterproof cable will receive wide usage, although screened waterproof and air-core PIC cables will provide better performance. ICOT cable is the preferred choice for relief and extension of digital trunk routes because of the system economics. Screened 22 or 19-gauge cables should be considered for use only for additions to or maintenance of existing systems, or where detailed individual economic studies indicate savings resulting from the longer power spans. Unscreened one-cable operation is possible, but limited by a near-end crosstalk (NEXT) constraint (see Part 4D). Table B lists currently available PIC, DEPIC and ICOT cables including pair sizes and maximum intermediate section lengths they allow. Also shown in Table B are the engineering loss and temperature coefficient factors.

3.02 In Table B some of the values shown are estimates. Note that waterproof cable may have solid (PIC) or dual-expanded (DEPIC) types of insulation. All screened cables provide sufficient isolation for pairs on opposite sides of the screen

thus NEXT is never limiting for T1/OS repeater spacing. In the absence of explicit data for aluminum, the NEXT and FEXT data for copper cable may be applied to aluminum cable of equivalent gauge. (For example, 20-gauge aluminum is equivalent to 22-gauge copper cable.)

3.03 Representative cable lay-ups for screened cables are shown in Fig. 2. ***The screen in the cable is not electrically continuous and must be left floating, not grounded.*** Splicing is accomplished with any approved connector, but the screen requires special handling as explained in Section 632-410-205. Maintenance pairs for screened cable are shown in Fig. 2. ♦When other type cables are used, maintenance pair assignment should be per Section 855-351-101.♦

B. Span Powering

General

3.04 ♦Powering of T1/OS line repeaters is accomplished by simplexing a regulated dc current over the cable pairs in a simplex manner when powering from a STB. 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 standard power repeaters is approximately 10.9 volts at a line current of about 140 mA; for low power repeaters, the voltage drop is approximately 6.8 volts at about 60 mA. The office repeaters provide for use of office battery voltages of -48 volts dc, +130 volts dc, and -130 volts dc. 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 STBs, it is desirable to use the lowest possible supply voltage which will properly power the span and office repeater in series with the span.

3.05 Typical simplex power loops using STBs are shown in Fig. 9 through 11. In Fig. 9 the loop is completed (looped back) at a line repeater location. This is accomplished by installing a looping instead of a through-line repeater at that location or by selecting the loop power option on repeaters with an option selector. All other line repeater locations would have through-code repeaters on the through option selected. When a looping line repeater is used, it actually completes two

power loops at once, one looking toward each office. Each of these power loops must be treated separately when doing 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 at that office as shown in Fig. 10 and 11.

3.06 Powering of the regenerator circuits in office repeaters can be accomplished in either of two ways: The repeater can be locally powered from the -48 volt office battery and be independent of the simplex loop, or it can be powered in series with the simplex loop in the same manner as the line repeaters. Since the standard-type office repeater requires 140 mA it can not be series powered in a low powered line. ***Local powering puts an extra load on the -48 volt supply. This significantly increases the power dissipated in the STB and should be avoided if possible. Local powering does allow a slightly longer power loop, therefore, it will be necessary in a limited number of applications.***

3.07 Following is a general procedure for engineering the powering of a T1/OS span. Transmission design will usually determine the office and line repeater locations and cable type and lengths used in the powering span. With these parameters fixed, one office in the span is chosen as the powering (regulating) office. A looping point is chosen either at the other office or at a line repeater location. Office repeater powering options are chosen based on efficiency and service restoral 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 powering options chosen and recalculate the required supply voltage to optimize efficiency or to consider special limitations such as available battery supplies, unmanned offices, or diversity of looping points. It is possible to go through several iterations of the above procedure before arriving at an optimum configuration.

3.08 Powering options, regulator voltage requirements, line voltage requirements and powering information must be shown on the Initial Span Line Powering Record, Form E-10604 (Fig. 12).

Power Loop Structure

3.09 The simplest power loop structure is bidirectional operation (Fig. 9). It is composed of a current regulator, powering repeater, 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 an STB represents one complete, independent power loop.

3.10 For unidirectional operation, the power loops are more complex as shown in Fig. 10 and 11. Each loop is composed of the same elements as for bidirectional operation, but pairs of loops share the office repeaters at each end. Examination of these figures will show that each loop starts at the plus regulator output of one office repeater (206- and 236-type repeaters). The return is through the other side of the line repeaters, and reaches battery return minus (206- and 236-type repeaters) through the other regulating office repeater. Thus, each power loop passes through all of the repeaters. The two office repeaters in each office appearing in a power loop are called power mates. Both must be installed to have either power loop complete. In unidirectional operation the power mates are arranged between the two protection groups. In the 1×5 protection arrangement (Fig. 13) the first protection group is repeater position 1 through 6, and the second protection group is repeater position 7 through 12. In the 1×11 and 1×24 protection arrangement (Fig. 14) protection group numbering starts at the bottom of the STB and proceeds upward. With the 1×5 arrangement the power mates are positions 1 through 6 of the first protection group and positions 7 through 12 of the second protection group. Whereas in the 1×11 and 1×24 arrangement power mates appear in the same position number between the first protection group and the second protection group. The first protection group repeater powers the transmit line repeaters and the second protection group repeater powers the receive line repeaters. First protection group lines transmit and receive through side 1 of the line repeaters and the second protection group lines use side 2.

3.11 This somewhat complex arrangement is necessary with unidirectional line repeater

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

Office Repeater Options

3.12 Office repeaters (236-type) contain two sets of option selectors, one for regulator options (on regulating codes) and one for repeater powering options. The regulator option selectors are configured for the particular voltage supplies chosen to power the span (see Table C). The 206-type office repeaters contain only the powering option selectors. Regulator options for the 206-type are selected by repeater code (see Table B). Repeater powering options are chosen to power the office repeater regenerator either from the local -48 volt supply or in series with the simplex line current. Table D summarizes the repeater powering option choices which are accomplished by turning down the indicated screws with all others up two turns.

3.13 For bidirectional operation the choice of repeater powering options depends only on whether it is a regulating or looping repeater and whether it is locally or series powered. For unidirectional operation, the choice is more complex. The two office repeater power mates on one end of a unidirectional loop require different option selections to configure them correctly. When the office repeaters are to be locally powered, the options are B, E, H, and N for the first protection group power mate and A, F, H, and N for the second protection group. However, if the office repeaters are to be powered in series with the simplex loop, as recommended, there are two options to choose from for the first protection group power mate, B, D, and G or C, E, and K. The second protection group is always A, G, and M when series powered. ***The two repeaters of***

a power mate pair at the same end of the loop must be powered the same, either both locally or both in series.

3.14 The significance of choice between B, D, G and C, E, K can be understood by careful examination of Fig. 10 and 11. The A, G, and M option in the second protection group repeater always puts that repeater power supply in series with the power loop which powers the receive line repeaters (receive power loop, powered by the regulator in the first protection group). In the first protection group repeater, the C, E, and K option puts that repeater power supply in series with the receive power loop, while the B, D, and G option puts it in the transmit power loop (powered by the regulator in the second protection group). From a transmission standpoint, it is desirable to have both office repeaters powered by the receive power loop so that removal of a transmit line repeater, which breaks that power loop, will not rob power from the office repeaters and interrupt receive transmission. This would indicate the use of the C, E, and K option. However, the B, D, and G option is offered because it minimizes the difference between the transmit and receive loop resistance when series powering is used at one end of a loop and not at the other or when a line repeater looping point is used. This can be important when choosing the office supply voltage since both loops must use the same voltage. The choice between B, D, G and C, E, K, therefore, breaks down to whether it is more desirable to minimize the patching required when a line repeater is replaced (C, E, and K) or to minimize the difference between transmit and receive loop resistance (B, D, and G). Table E will clarify this choice. It should be noted that unequal loop resistances will result in different loop voltages between power mates. The combination of B, D, and G at one end of a loop and C, E, and K at the other results in neither of the above benefits and is therefore not recommended.

Battery Voltage Selection

3.15 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,

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

$$R_{L\text{MIN}} = R_{C\text{MIN}} + R_R$$

R_R is the total resistance of all repeaters in the loop while $R_{C\text{MIN}}$ and $R_{C\text{MAX}}$ are the cable resistances at low and high temperature extremes. Cable resistances are determined from the following formulas:

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

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

Where R_{MAX} and R_{MIN} depend on cable gauge and material are given in Table F, T_{MAX} and T_{MIN} are the maximum and minimum temperatures which the cable will experience. The total repeater resistance for a loop, R_R is calculated by adding up the resistance of each repeater in that loop. The suggested way to do this is to sketch out the particular loop as is done in Fig. 9, 10, or 11. Starting at the powering office repeater regulator "walk along" each loop stopping at the looping point. The resistance of each repeater walked through (Tables G and H) is added to get the total repeater resistance for the loop, R_R . The resistance of an office repeater will depend on the options used in that repeater (and sometimes the options in its power mate) and whether it is a regulating or looping repeater. The resistance of a line repeater depends on whether it is protected or unprotected, whether it is at a through or looping location, and if looping, whether the loop includes the side 1 input or side 1 output. Each repeater in a loop is counted only once; but when a looping line repeater is used, part of its resistance is counted in each of the two power loops involved. When a unidirectional line has the same option at both ends or with B, D, G and A, G, M at one end and B, E, H, N and A, F, H, N at the other, the two power loops are symmetrical and the loop resistance will be the same for both loops (if cable resistances are the same). Use of a looping line repeater results in different resistance for the two loops and each must be calculated separately. In bidirectional lines each loop is the same as all of the others in that span.

3.16 Minimum and maximum cable resistance ($R_{C\text{MIN}}$ and $R_{C\text{MAX}}$) are added to R_R to determine minimum and maximum loop resistance ($R_{L\text{MIN}}$ and $R_{L\text{MAX}}$), using the formula given in paragraph 3.15.

Both $R_{L\text{MAX}}$ and $R_{L\text{MIN}}$ must fall within the range of the allowable R_L for the battery voltage used to power the loop (see Table I). When the two loops of a unidirectional power mate pair result in different R_L values, the values for both loops must fall within the range of allowed R_L for a single battery voltage, since the same voltage must be used on both loops. Once a voltage is chosen the proper code of 206-type office repeater may be selected from Table C; or the proper regulator options can be determined for a 236-type repeater by referring to Table C. A power loop is most efficient and the power dissipated in the STB is minimized when $R_{L\text{MAX}}$ is as close as possible to the maximum R_L allowed for the battery voltage used. The lowest battery voltage which will power a loop should always be used.

3.17 Consideration of 60-Hz induced currents must be given when designing power loops using standard power repeaters. Low power loop designs are not affected by induced currents up to 100-mA RMS. Standard power loops require a reduced range of allowable loop resistance for more than 10-mA RMS and cannot operate with more than 30-mA RMS. The reduction of allowable loop resistance for standard power designs with induced currents of 0- to 30-mA RMS is shown in Table I and must be applied when choosing the battery voltage to be used to power the span.

Example Calculation

3.18 An example of a power loop calculation for low-power unidirectional operation is shown in Fig. 15. Cable resistance will be the same for both loops:

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

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

$$R_{C\text{MAX}} = (3.600 + 5.900 + 6.000 + 5.800) 16.7 [1 + .0022 (100 - 68)] = (21.3) 16.70 (1.07) = 381 \text{ ohms}$$

$$R_{C\text{MIN}} = (3.600 + 5.900 + 6.000 + 5.800) 16.1 [1 + .0022 (30 - 48)] = (21.3) 16.10 (9.16) = 314 \text{ ohms}$$

Repeater resistance will be different:

	TRMT LOOP	RCV LOOP
236AA (CEK and AGM)	30	256
238B (Thur × 3)	348	348
238B (Loop)	114	2
R _R (Total)	492	606
R _{LMAX} (R _R + R _{CMAX})	873	987
R _{LMIN} (R _R + R _{CMIN})	806	920

Since both 806 and 987 must fit within the range for the battery voltage shown in (Table I), the only possibility is 130 volts. Thus, regulator options R and Z would be chosen, see Table B.

Calculation of Voltage Limits

3.19 In order to provide information for the evaluation of the power loop performance, minimum and maximum values for both line voltage and regulator voltage must be calculated for each power loop. Line voltage can be calculated from the following equations:

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

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

R_{LMAX} and R_{LMIN} are the values for line resistance calculated previously and I_L is the value of line current (0.06 or 0.14). 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 resistance) are given in Table J. Once these voltage values are calculated, a record should be made of them on Form E-10604 (Fig. 12) for use in initial installation testing, periodic routine maintenance, and trouble isolation procedures.

Use of Calculated Limits

3.20 Initial installation and periodic maintenance procedures require that the power loop measurements be within the calculated voltage limits. If at any time the limits are not met, trouble isolation procedures should be implemented. In new installations, engineering reevaluation may be required if the limits are not met.

3.21 Although 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 to be the cause of a transmission failure, one further procedure is useful. Both line voltage and regulator voltage can be measured on all repeaters within the two protection groups. The values measured on the suspected line should not deviate more than ±4 percent from the average of all good lines in the two protection groups. If there is a significant difference, such problems as a shorted repeater power supply diode or a pair-to-ground short may be present often. These trouble conditions do not cause enough shift in voltage measurements to make them fall outside the minimum and maximum limits.

3.22 It should be noted, however, that records of actual measurements made at some time in the past can be misleading. The operating voltages of lines in two protection groups 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 maximum and minimum values which are valid for all times and temperatures.♦

C. 60-Hz Induction

3.23 The presence of induced 60-Hz alternating current (ac) limits the length of powering spans. The principal cause of the induced ac is unbalanced currents or the presence of ground-return currents in a nearby ac power system. Induced currents flow in phase along both pairs of the simplex power loop rather than around the loop. Design procedures are covered in Section 855-351-101 for induced ac in the ranges from 0 to 20 milliamperes and from 20 to 30 milliamperes. ♦Levels from 30 to 100 milliamperes can be tolerated by using low power type repeaters and changing the degradation factor from 2 to 3 db.♦ Procedures

are given here for estimating the minimum required radial separation between T1/OS cables and ac power lines so that induced ac will be limited to one of the two ranges above. (The procedure is essentially the same as that for the T2 facility Section 855-352-101, with appropriate scaling for the higher capacitance cables used for T1/OS.) To use the procedure, an estimate of the RMS unbalanced current in the ac power line is required. (The local power company should be consulted for assistance, if necessary.)

3.24 Alternating current (ac) induction should be considered separately for each powering loop. The powering loop extends from the powering point to the first-looping point. Where power lines are located at a roughly constant distance from the route, Fig. 16 can be used to estimate the minimum required distance between the cables and the power line to limit the induced ac to 20 milliamperes. It is assumed that the power line parallels the line over the entire powering loop which is assumed to be 50 kilofeet in length. The earth resistivity is needed to use Fig. 16; although a value of 100 meter-ohms is a rough average, earth resistivity can vary greatly and should be measured locally. Section 873-800-580 covers such measurements.

3.25 To determine the minimum required separation to limit induced ac to 30 milliamperes, multiply the RMS unbalance current by two-thirds before using Fig. 16.

3.26 In Fig. 16 the shielding effects of the cable sheath have been neglected. If the cable sheath is well-bonded and grounded, considerable reduction in interference is possible. Section 873-800-178 contains methods for calculating shield factors. If the shield factor is known, the power line unbalanced current should be multiplied by that factor before Fig. 16 is used. Note that shield factors rapidly approach 1.0 if poor grounds or bonds are present; a single faulty bond can eliminate all shielding effects.

3.27 For powering loops of length other than 50 kilofeet, multiply the power line unbalanced current by $(\ell/50 \text{ kft})^2$ where ℓ is the actual length in kilofeet, and then use Fig. 16.

3.28 Where power line exposure exists over only a part of the entire powering loop, multiply the unbalanced current by the fraction of the loop

exposed before using Fig. 16. In addition, if the exposure is not centered about the midpoint of the powering loop, multiply the unbalanced current by the correction factor $2(\ell-C)/\ell$ before using Fig. 16. In this expression, ℓ is the powering loop length and C is the distance from the powering point to the center of the exposure.

3.29 The above correction factors are used successively, each changing the effective unbalanced current. After applying all factors, Fig. 16 is used.

3.30 If the minimum permissible separation determined from Fig. 16 is impractical, induction can be reduced by installing additional shield conductors. Section 873-800-178 should be consulted to compute the shield factor. As an alternative, induction can be controlled by reducing the powering loop length.

D. Power Line Fault Conditions

3.31 Part 3C is used to ensure T1/OS line performance under continuous-duty power line induction. Many times, power line unbalanced current under fault conditions exceeds the prescribed levels. Transmission may be interrupted during faults, which generally last from 100 to 500 milliseconds, depending on the utility equipment. Where high fault currents occur, it may be necessary to consider the possibility of damage to T1/OS regenerators from the surges.

3.32 Tests show that permanent damage to regenerators does not occur if induced longitudinal currents on the T1/OS pairs are less than the following:

- (1) 11 amperes RMS for fault durations of 0.25 seconds or less,
- (2) 7 amperes RMS for fault durations of 0.5 seconds,
- (3) 5.5 amperes RMS for fault durations of 1 second.

3.33 High induced fault current can occur only when the gas tube or carbon protectors at each end of a regenerator section conduct during a fault. Consequently, fault induction may be considered for each regenerator section independently. Protectors are provided at repeater stations for

both the input and the output of each regenerator. During surge conditions, either of the protectors associated with a regenerator may operate. Since the protector that operates may be on the opposite side of the regenerator from the disturbed cable section, the entire induced current may flow through the regenerator. A worst-case assumption is that the voltage drop across an operated protector is small. Therefore, the maximum current induced in a regenerator can be determined by dividing the total voltage induced in a regenerator section by the total resistance of the cable pair (tip and ring in parallel) in the section.

3.34 Where the separation between the T1/OS cable and power line is constant through a regenerator section or constant throughout the exposed portion of a regenerator section, Fig. 17 may be used to determine the minimum safe separation.

3.35 If the inductive exposure is only present in part of the regenerator section, multiply the unbalanced current by the fraction of the regenerator section exposed.

3.36 The effective power line unbalanced current should be reduced by multiplying by the shield factor as in paragraph 3.08.

3.37 The current included in a regenerator section by a fault cannot be appreciably reduced by shortening the regenerator section; no correction for regenerator section length is needed.

3.38 When using Fig. 17, multiply the effective unbalanced power line current by the following factors:

- (1) 2.0 if the surge is present for 1 second
- (2) 1.6 if the surge is present for 0.5 seconds
- (3) 1.0 if the surge is present for 0.25 seconds or less.

Apply the resulting current in Fig. 17 to determine the minimum safe separation, using the curve for the appropriate earth resistivity.

3.39 If the minimum spacing cannot be met, it may be necessary to install additional shielding conductors and to compute the shield factor with the methods of Section 873-800-178.

E. Fault Locate and Order Wire

3.40 The T1/OS fault-locate system is described in paragraph 1.05. Engineering should be done in accordance with Section 855-350-104.

3.41 The T1/OS order wire is described in paragraph 1.10. Engineering should be done in accordance with Section 855-350-107.

4. DIGITAL LINE DESIGN

A. Repeater Section Design Objective; Design Numbers

4.01 As indicated previously, T1/OS engineering rules are derived from the terminal-to-terminal design objective that at least 95 percent of properly engineered and installed lines will have a bit error rate less than 10^{-6} . This objective is the same as that for metropolitan-T1; but in T1/OS it applies to as many as 200 tandem repeater sections, a number much greater than originally envisioned for metropolitan-T1. Studies have shown that an appropriate method for engineering long T1 lines is to assign the same bit error rate objective, 10^{-6} , to each repeater section. The **probability** of exceeding this bit error rate is then allocated on a section-by-section basis. For T1/OS, (100 - 95) percent = 5 percent is allocated across the maximum allowable length of 200 repeaters. Hence, each repeater section is designed to have a maximum probability of 5 percent/200 = 0.025 percent of exceeding a 10^{-6} bit error rate.

4.02 For convenience, the probability that a T1/OS "component" (be it line section, span, or terminal-to-terminal) 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 simply the sum of the design numbers for the constituent components. For example, a span with 14 T1/OS repeater sections has a design number of 14×0.025 percent = 0.350 percent. If this span is connected to another with a design number of 1.000 percent, then the design number for the combination is 1.000 percent + 0.350 percent = 1.350 percent. The fundamental rule is that the terminal-to-terminal design number must not exceed 5.000 percent. This approach to engineering rules is very convenient for defining rules for tandem connections of T1/OS, metropolitan-T1, T1C, T1D, and T2 (see Part 6).

4.03 In the remainder of Part 4, the digital line engineering design is considered. Maintenance considerations are covered separately in Part 5. It is important to note that the design number to be assigned to a T1/OS repeater section depends on **both** engineering design considerations **and** maintenance considerations. While a low design number may be justified, based on engineering considerations, that number may be overruled by a larger design number resulting from maintenance considerations (See Parts 5 and 6).

B. Choice of Repeaters

4.04 The recommended line repeaters are the 238/239 (low power) type. However, 208/209 (standard power) type line repeaters can also be used. Use of these ALBO-type units simplifies installation, automatically compensates for thermal changes in the cable, and avoids the "free-run" problem of the 201/205 nonintegrated circuit type repeaters. When bidirectional repeater operation is used and single-end testing is desired, 208E, F, AA, 209E, F, AA, 238A, C, 239A, C repeaters are required. MAT repeaters are preferred for MCM and MLM cables. At an interface with an independent telephone company where the independent is using PIC or waterproof cable, "MAT" repeaters should be used. The new ICOT cable uses the 238C, D and 239C, D MAT repeaters. It is preferable that the ICOT cable interface only with ICOT or MAT cables. However, on ICOT-PIC cable, repeater point interface is also permitted.

Note: The low power repeaters have been designed to operate on low power (60 mA line current) and are not compatible with the powering requirements of standard power (140 mA line current) lines. In general, the intermixing of low power repeaters with standard power repeaters either within a line, within an apparatus case, or STB is not recommended. Low power repeaters should be installed only in new apparatus cases or STBs specifically designed to take advantage of the low powering requirements.

C. 772-kHz Loss Limitation

4.05 As in metropolitan-T1, the maximum 772-kHz design loss for underground facilities is 32.2 dB. For aerial designs, the maximum is 31.0 dB (see Section 855-351-101, Part 7A).

D. Intersystem Interference—Near-End Crosstalk (NEXT) Limitations

4.06 One-cable unscreened operation is permitted for T1/OS, but such operation is limited by NEXT. The constraint on line loss is

$$L \leq (m-s - 37 - 10 \log n)/f_r$$

where L = section loss (dB)

m = mean NEXT coupling loss (dB)

s = standard deviation of coupling loss (dB)

n = planned number of two-way lines

f_r = temperature correction factor

A T1/OS repeater section must meet this constraint to obtain a design number of 0.025 percent. (A section which does not meet the constraint may still be usable. See paragraph 4.07. Application of the formula is essentially the same as that for metropolitan-T1 in Section 855-351-101. Note that the T1/OS NEXT constraint is 5 dB more conservative than the metropolitan-T1 constraint. Figure 18 shows the maximum permissible value of f_rL in nomogram form.

Note: The information in paragraphs 4.07 through 4.10 is required only in special engineering situations. (See Part 4L for example.)

4.07 A T1/OS or metropolitan-T1 section design which does not meet the constraint of equation in paragraph 4.06 may still be usable, but the design number will be larger than 0.025 percent. To compute the design number, first compute

$$M_e = -37 + (m-s) - 10 \log n - f_r L \text{ dB}$$

where M_e is the engineering margin against NEXT. (As with metropolitan-T1, the T1/OS next constraint includes a built-in 6-dB allowance against unknowns. The engineering margin represents margin over and above the 6-dB allowance.) The design number, d, is then given by Table K.

4.08 Note from Table K that if M_e ≥ 0, then d = 0.025 percent, the smallest value for d. If M_e lies between 0.0 and -5.0 dB then the T1/OS

SECTION 855-351-200

NEXT constraint is not met, but the metropolitan-T1 constraint (Intersystem Interference, Section 855-351-101) is satisfied. Accordingly, Table K assigns a design number of 0.100 percent to such sections. To avoid limiting the ultimate facility length it is recommended that the T1/OS constraint be used whenever possible. The provisions given here are primarily intended to provide some flexibility to the engineer who is trying to interconnect or extend existing metropolitan-T1 spans into outstate areas (see Part 6).

4.09 If more than one *type* of NEXT exposure (ie, adjacent-unit, nonadjacent-unit, etc.) is present in a section design, equation in paragraph 4.07 should be used once for each exposure type. The net engineering margin, M_e , will be smaller than any of the constituent margins. It is computed from

$$M_e = -10 \log [10^{-M_1/10} + 10^{-M_2/10} + 10^{-M_3/10} + \dots]$$

where M_1 , M_2 , and M_3 are the margins from each exposure type. The ... indicates that as many terms as required (one for each exposure type) should be included in the brackets. Figure 19 shows this in nomogram form. Once M_e is found, the design number is determined with Table K.

4.10 To illustrate, consider a 100-pair 22-gauge air-core PIC cable with $L = 24$ dB. This cable has a central 25-pair unit surrounded by six alternating 12- and 13-pair units. Suppose 36 two-way lines are present in the 12- and 13-pair units such that the worst-case NEXT exposure is one adjacent-unit exposure (12 lines) and two nonadjacent-unit exposures (12 lines in each unit). The 25-pair unit carries no T1. Using equation in paragraph 4.07 and Table C, the margin for adjacent-unit exposure is

$$M_1 = -37 + (79-9 - 10 \log 12 - 1.044) (24.0) = -2.8 \text{ dB.}$$

The margin for nonadjacent-unit exposure is

$$M_2 = -37 + (90-9) - 10 \log (12+12) - 1.044 (24.0) = 5.1 \text{ dB.}$$

Then from equation in paragraph 4.09 the engineering margin against NEXT is

$$M_e = -10 \log [10^{0.28} + 10^{-0.51}] = -3.5 \text{ dB.}$$

From Table K, the design number $d = 0.100$ percent.

E. Intersystem Interference—Far-End Crosstalk (FEXT) Limitations

4.11 As in metropolitan-T1, FEXT seldom limits the allowable loss of “normal” sections (that is, no route junctions) in a nonscreened two-cable or screened-cable (especially ICOT) design. A design number of 0.025 percent per repeater section applies to properly engineered and installed two-cable designs of up to 200 lines for most of the cable types in Table B. This covers most anticipated T1/OS applications.

4.12 For nonscreened one-cable, still larger facility counts are possible, subject to a possible FEXT constraint. Since the FEXT equations are rather complicated for everyday engineering use, the constraint is summarized in Table L. For a given mean $m_{F\ell}$ and standard deviation s_F of FEXT coupling loss, Table M gives the maximum permissible number of lines, n . A repeater section meeting the constraint indicated in the table may be assigned a design number of 0.025 percent. Note that $m_{F\ell}$ is the mean FEXT coupling loss for a cable section of length ℓ where ℓ is the repeater spacing in kilofeet. FEXT coupling is usually specified at some reference length ℓ_0 . A value for $m_{F\ell}$ may be computed by using

$$m_{F\ell} = m_{F\ell_0} - 10 \log (\ell/\ell_0)$$

4.13 For example, suppose a large-count 22-gauge air-core PIC cable were known to have within-unit mean FEXT coupling loss of 76 dB (for 1 kft section) with a standard deviation of 10 dB. Assuming 7 kft spacing,

$$m_{F\ell} = 76 - 10 \log \frac{7}{1} = 67.5 \text{ dB.}$$

Table L shows (with interpolation) that n may be as large as 303. This estimate is approximate, since within-unit coupling statistics only have been used. When a more accurate estimate is required, a detailed margin computation must be made as indicated in paragraph 4.17, method (b). If the margin (M_e) so obtained is not negative, a design number of 0.025 percent applies to the repeater section.

4.14 *Unlike the NEXT constraint, there is no provision for assigning design*

numbers larger than 0.025 percent to FEXT-limited T1/OS repeater section designs.

Designs which have a negative value for FEXT margin should not be used for T1/OS. Existing metropolitan-T1 sections which meet the constraints of Section 855-351-101 but which have negative M_e when evaluated by T1/OS rules may be connected in tandem with T1/OS (see Part 6), but such sections must be assigned a design number no less than 0.100 percent.

Note: The information in the remainder of this Part (4E) is required only in special engineering situations. (See Part 4L for example).

4.15 While FEXT is rarely a constraining factor in T1/OS repeater section design, there are some cases in which the engineering margin, M_e , against FEXT must be known. In these cases Table K may be used for the computation. The margin is a function of four variables, $m_{F\ell_0}$, s_F , n , ℓ , where

$m_{F\ell_0}$ = mean FEXT coupling loss (dB) in a section of length ℓ_0 kft

s_F = standard deviation of FEXT coupling loss (dB)

n = number of FEXT interferers + 1

ℓ = repeater section length in kft

The steps to compute the margin are as follows:

- (1) compute $m_{F\ell} = m_{F\ell_0} - 10 \log (\ell/\ell_0)$ where $m_{F\ell}$ is the mean FEXT coupling loss for a section of length ℓ kft.
- (2) Refer to column in Table L headed by standard deviation s_F dB, locate the value n in that column, and find the corresponding value of m_F for that value of n (interpolate when necessary). Call this value $m_{F\ell}'$.
- (3) Compute the margin $M = (m_{F\ell} - m_{F\ell}')$ dB.

4.16 To illustrate, suppose a 25-pair 22-gauge filled PIC cable is to be fully loaded with T1/OS, and the repeater spacing is to be 8.0 kft. From Table C, $m_{F\ell} = 74$, $s_F = 10$ dB. Following the steps above,

- (1) $m_{F\ell} = 74 - 10 \log 8 = 65$ dB;
- (2) The value $n = 24+1 = 25$ appears in the $s_F = 10$ dB column between $m_{F\ell} = 64$ and $m_{F\ell} = 65$ dB; interpolating, $m_{F\ell}' = 64.0$ dB;
- (3) The margin $M_e = (m_{F\ell} - m_{F\ell}') = 65 - 64 = 1$ dB. Since $M_e > 0$, a design number of 0.025 percent may be assigned to this section.

4.17 In large cables where more than one *type* of FEXT exposure (eg, within-unit, adjacent-unit, remote-unit) may occur, the margin may be:

- (1) Approximated by assuming within-unit FEXT statistics for *all* the pairs in the cable or
- (2) More accurately estimated by computing the margin for each type of exposure separately and then combining these margins to form a net margin as indicated by equation in paragraph 4.09.

To illustrate, M_e will be computed by both methods (a) and (b) above for 100-pair 22-gauge filled DEPIC, fully loaded, with 7.1-kft spacing. The core configuration of this cable consists of a central 25-pair unit surrounded by six units with alternating 12- and 13-pair counts. Table C shows a within-unit $m_{F\ell_0} = 69$, $s_F = 8$ dB. By method (1) described above, $M_e = 1.3$ dB. By method (2) there will be three exposure types for which margins must be computed. Considering M_e for a 13-pair unit, there exists:

- (1) a within-unit exposure with $n = 12+1 = 13$, $m_{F\ell} = 69 - 10 \log 7.1 = 60.5$, $s_F = 8$ dB. Hence $M_1 = 4.3$ dB,
- (2) an adjacent-unit exposure from three units with $n = 12 + 12 + 25 + 1 = 50$, $m_{F\ell} = 78 - 10 \log 7.1 = 69.5$; $s_F = 9$ dB. Hence $M_2 = 8.3$ dB,
- (3) a nonadjacent-unit exposure from three units with $n = 12 + 13 + 12 + 1 = 38$, $m_{F\ell} = 90 - 10 \log 7.1 = 81.5$; $s_F = 9$ dB. Hence $M_3 = 20.6$ dB.

Substituting into equation in paragraph 4.07, there results $M_e = 2.8$ dB for the 13-pair unit. This is 1.5 dB higher than the estimate of 1.3 dB obtained with method (1). Similarly, the margin for the

SECTION 855-351-200

central 25-pair unit may be computed by method (1) to yield $M_e = 1.0$ dB or method (2) to yield 1.3 dB. The less accurate method (1) is included because it is easier to use, especially if cable data is incomplete.

F. Presence of Other Systems and Services Within the Cable

4.18 No N-carrier is permitted. Except for end sections, VF trunking will be permitted as on metropolitan-T1. Rules for compatibility with T1C and T2 facilities are under study. For the purposes of T1/OS line engineering, pairs carrying SLM* or SLC* subscriber loop carrier are equivalent to pairs carrying T1/OS. The effect of SLM or SLC pairs must be included in all computations for NEXT, FEXT, route junctions, etc.

*Trademark of Western Electric Company

4.19 Joint sheath operation of subscriber service and T1/OS presents hazards to the T1/OS. These include station set interference into T1/OS, increased 60-Hz induction brought in on subscriber pairs, and increased craft activity involved with loop plant modifications. ***It is recommended that, whenever possible, subscriber loops not share the same sheath with T1/OS.*** Where joint sheath usage is the only way to provide subscriber service, the two services should not be placed in the same binder group. Even with binder group separation, an interference situation may arise. In that event, local measures may be necessary to maintain acceptable performance of the T1/OS lines.

G. End Section Design—Central Office Noise

4.20 T1/OS end sections (that is, repeater sections nearest the central office) are subject to the same design rules as metropolitan-T1 (see Interference from Central Office Noise in Section 855-351-101). In addition:

- (1) There must be no VF trunking or subscriber pairs in end-section binder units carrying T1/OS.
- (2) In no case should end section design loss exceed 24.5 dB.

These restrictions provide additional margin against central office noise and permit the use of bidirectional tip cables (see Part 7I).

4.21 Metropolitan-T1 end sections which do not meet T1/OS constraints should be assigned a design number not less than 0.100 percent.

H. Splicing Apparatus Cases to Main Cables

4.22 When more than one apparatus case must be spliced to a cable, it is recommended that the stubs be spliced in a single splice enclosure. If the splices must be separated, a FEXT exposure occurs over the intervening distances (see Fig. 20). Although the distance may be short, the problem may be serious because a level difference of up to 32 dB may exist between disturbing and disturbed lines. For this reason the maximum recommended distance between splices for T1/OS is 10 feet. Longer distances are permitted subject to the rules in Splicing of Apparatus Cases to Main Cables in Section 855-351-101, but the repeater section design number must be increased according to the following rules:

- (1) For distances of 0 to 10 feet, add 0 percent
- (2) For 10 to 20 feet, add 0.025 percent
- (3) For 20 to 60 feet, add 0.075 percent.

I. Apparatus Case Stub Cables

4.23 Signals in apparatus case stubs for the 466, 468, and 475-type cases are subject to NEXT interference. For this reason the maximum recommended stub length for T1/OS is 15 feet. Longer lengths are permitted, but the section design number must be increased according to the following rules:

- (1) For stubs of length 0 to 15 feet, add 0 percent
- (2) For 15 to 25 feet, add 0.025 percent
- (3) For 25 to 40 feet, add 0.075 percent.

All other rules regarding metropolitan-T1 stubs apply as well to T1/OS.

4.24 The 809, 818 and 819-type apparatus cases are equipped with screened stub cables.

Signals in these cables are not subject to NEXT interference, and the stubs may be used to their full supplied length without section design number impairment.

J. Entrance and Tip Cables

4.25 For entrance cables, the recommendations in Entrance and Tip Cables-Office Wiring in Section 855-351-101 apply to T1/OS as well as to metropolitan-T1. However, the design equation used in Section 855-351-101 must be replaced with the NEXT equation of paragraph 4.06. Also, there must be no VF trunking or subscriber pairs in entrance or tip cable binder units carrying T1/OS. Those metropolitan-T1 lines which do not meet these T1/OS constraints should be assigned an end section design number not less than 0.100 percent.

4.26 In some T1/OS designs it is economically advantageous (as in the case of bay-mounted protectors) to combine both directions of transmission in a single tip cable. This is permissible in T1/OS if as follows:

- (1) Tip cable length does not exceed 100 feet,
- (2) Cable size does not exceed 100 pairs,
- (3) High- and low-level signals have at least adjacent-unit separation, and
- (4) Office repeaters use 7.5-dB artificial lines (maximum end section loss therefore being 24.5 dB).

K. Measurement of NEXT Losses

4.27 The method of NEXT loss measurement is the same as the measurement of NEXT losses in Section 855-351-101 except that measurement of NEXT losses on a cable permits a change of the constant in the NEXT equation to -34 rather than -29.

L. Route Junctions

4.28 As in metropolitan-T1, designing a junction into a span layout may not be in the best interests of a long-range plan. See Route Junctions in Section 855-351-101. When a junction is necessary, FEXT or NEXT exposures may be more severe because of level differences between signals in the same cable.

4.29 Consider first the general route junction exposure for one direction of a two-cable facility shown in Fig. 21. The problem is to find the engineering margin M_e at point B. The region of common exposure is the length of cable marked ℓ_2 . As shown, the mean FEXT coupling loss for this cable is $m_F \ell_0'$ with standard deviation s_F' . The margin M_e at point B is computed in three steps:

- (1) Compute M_1 , the margin in the AB section, ignoring the CD section; that is, apply Part 4E using $n = n_1$, $\ell = \ell_1$, $m_F \ell_0' = m_F \ell_0'$, $s_F = s_F'$.
- (2) Compute the margin M_2 at B due to FEXT from CD. This is done by using Part 4E with $n = n_2$, $\ell = \ell_2$, $m_F \ell_0 = (m_F \ell_0' - L_d)$, $s_F = s_F'$, where L_d is the level difference (dB) between the pairs in the CD section and those in the AB section where they are coincident. (Note that L_d is positive if the CD pairs are at a higher level than the AB pairs.)
- (3) Combine M_1 and M_2 according to equation in paragraph 4.09 to obtain M_e .

4.30 For a one-cable system the NEXT margin, M_e , at point B is found by the following procedure (see Fig. 22).

- (1) Compute M_1 , the margin in the AB section, ignoring the CD section; that is, apply Part 4D using $n = n_1$, $L = L_1$, $m = m'$, $s = s'$.
- (2) Compute the quantity M_2 , the NEXT margin at B due to section CD. This is done by using Part 4D with $n = n_2$, $L = L_1$, $m = m' + L_3 + L_4$, $s = s'$. (If L_2 is less than 10 dB, use $m = m' + L_3 + L_4 + 10 \log [1/(1 - r)]$ where $r = 10^{-2L_2/10}$. (This is the same correction factor found in Section 855-351-101.)
- (3) Combine M_1 and M_2 according to equation in paragraph 4.09 to obtain M_e .

4.31 In a two-cable T1/OS lines, negative values of M_e are not permissible (see Part 4E). In a one-cable lines, negative values of M_e are permitted, but the design number for such a section design will exceed 0.025 percent (See Part 4D).

M. Junctions in Office Cables

4.32 In T1/OS installations, wiring from the distributing frame to the STB is span-dedicated

SECTION 855-351-200

with separate directions in separate ABAM cables. Each cable is dedicated to, and terminated at, a specific LTM. These restrictions effectively eliminate the possibility of junctions in T1/OS office cables. This is different from metropolitan-T1 which permits office cable junctions according to Junctions in Office Cables of Section 855-351-101.

4.33 In metropolitan-T1 if the office ABAM cables contain signals at different levels, then

- (1) The wiring must meet the restrictions of Junctions in Office Cables in Section 855-351-101,
- (2) The end section associated with the lower level pairs in the ABAM cable must be assigned a design number not less than 0.100 percent.

If the ABAM cables are connected to span lines from the outside plant in such a way that each ABAM cable contains lines from only one span or from spans at equal levels, then no design number penalties need be applied due to office wiring.

5. MAINTENANCE CONSIDERATIONS—IMPACT ON LINE DESIGN

5.01 Experience with metropolitan-T1 has shown that the design objective for T1 (95 percent of lines with a bit error rate less than 10^{-6}) is usually met or exceeded when proper installation, check-out, and routine maintenance procedures are followed. The importance of maintenance, in particular, will increase with the longer distances permitted by T1/OS. Therefore, to allow for the effects of maintenance in facility planning, a design number less than 0.100 percent may be assigned to a repeater section only where that section is covered by appropriate overall maintenance procedures for:

- (1) rapid detection of degraded transmission,
- (2) rapid sectionalization of transmission problems,
- (3) rapid restoration of service in the event of transmission failure.

The existence of controlled, well-defined maintenance procedures is therefore a necessary condition for the assignment of repeater section design numbers as low as 0.025 percent.

5.02 The T1/OS maintenance hardware/documentation package is directed specifically toward satisfying the above requirements and permits assignments of design numbers as low as 0.025 percent. For T1 repeater sections not covered by the T1/OS maintenance package or other effective means and routines, the minimum assignable design number is 0.100 percent.

6. CONNECTING T1/OS SPANS WITH METROPOLITAN-T1, T1C, T2, OR ♦T1D♦

6.01 When spans of metropolitan-T1, T1C, T2, or ♦T1D♦ are included in tandem with T1/OS spans, the basic approach is to assign design numbers to each span and verify that the sum of the design numbers on the terminal-to-terminal system does not exceed 5.000 percent.

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

- (1) The original engineering design of the repeater sections which make up the span,
- (2) The performance history of the span,
- (3) The maintenance procedures which will be applied to the candidate span when it is connected in tandem with T1/OS.

6.03 For the first consideration, original engineering design, the detailed design of each repeater section should be evaluated by the T1/OS standards in Part 4. In many cases, metropolitan-T1 repeater sections meet these standards and may be assigned a design number of 0.025 percent. Special situations in metropolitan-T1, such as heavily loaded one-cable operation, long apparatus case stubs, route junctions, noisy office environments, or widely spaced apparatus case points, will require special consideration. Design numbers larger than 0.025 percent may have to be assigned. If any of the design information required in Part 4 is unobtainable, the section must be assigned a design number not less than 0.100 percent.

6.04 For the second consideration, past performance history, 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 system must have consistently passed the monthly maintenance test

specified in Section 365-225-500 or Section 365-800-002 (TOP). Provided that the engineering considerations are also met, a span meeting this performance history requirement may be assigned a design number as low as 0.025 percent 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 0.100 percent. 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.

6.05 For the third consideration, maintenance procedures, a clearly defined set of maintenance procedures (see Part 5) must exist or be established for a candidate metropolitan span if the span is to be assigned the minimum design number of 0.025 percent per repeater section. In the absence of such maintenance procedures, the minimum design number assignable to each repeater section in the candidate span is 0.100 percent.

6.06 Since all three of the above considerations are equally important, the most conservative of the three must always overrule the other two. For example, suppose a 20-foot apparatus case stub in a particular metropolitan repeater section indicates a design number of 0.050 percent. Even if past performance history and maintenance procedures warrant a design number of 0.025 percent, the larger number, 0.050 percent, must be applied to the repeater section.

6.07 The present guideline for T1C is for regenerative sections engineered according to the rules of Section 855-351-110 may be assigned the design number values depending on type of cable and configuration used, as shown in Table N. Although the tabulated design numbers suggest that as many as 1000 such sections may be cascaded for maintainability, T1C lines are limited to 250 regenerative sections. For T1D regenerative sections engineered according to the rules of Section 855-351-115 are assigned the design number values depending on type as cable and configuration used, as shown in Table O.

6.08 T2 is a medium-haul (up to 500 miles) facility using dedicated LOCAP cable that has been pretested for crosstalk properties. This makes

the probability very low that a T2 facility has a bit error rate greater than 10^{-6} . The present guideline for connecting T2 spans in tandem with T1/OS is to assign a design number of 0.200 percent per 100 miles of T2 up to a maximum of 1.000 percent for 500 miles. Present indications are that the design risk on T2 is less than these figures indicate; however, for a medium-haul transmission facility such as T2, these are appropriate values to use in planning.

7. REFERENCES

7.01 The following drawings pertain to the T1/OS digital line:

DRAWING	TITLE
SD-1C597-01	T1/OS Span Terminating Circuit
SD-1C603-01	Fault-Locating Circuit

7.02 The following Bell System Practices are referred to in this section:

SECTION	TITLE
103-493-109	KS-20775, L1 and L2 Error Rate Test Set—Description and Operation
103-493-120	DS1/DS1C/DS2 Error Rate Test Set (KS-22331, L1 and KS-22332, L1) Description, Operation, and Maintenance
365-200-100	T1 Digital Line—General Description
365-221-500	Line Repeaters and Regenerators—Tests Using The J98710H Test Set
365-225-500	T1 Digital Line—Routine Maintenance Tests
365-800-002	T1 Line Routine, Acceptance, and Company Order Tasks (TOP)
632-410-205	Splicing Screened Air-Core Cable
801-523-156	T1 Outstate Digital Transmission System—Line and Terminal Equipment

SECTION 855-351-200

855-350-104	T1, T1 Outstate, and T1C—Engineering Design Fault-Locating Lines
855-350-105	◆DSX-1, DSX-1C, and DSX-2—New Installations◆
855-350-107	T1, T1 Outstate, and T1C—Order-Wire Lines
855-351-101	T1 Digital Line—Transmission and Outside Plant Design Procedures
855-351-110	◆T1C Digital Line—Transmission and Outside Plant Design Procedures
855-351-115	T1D Digital Line—Transmission and Outside Plant Design Procedures◆
855-352-101	T2 Digital Line—Transmission and Outside Plant Design Procedures
873-800-178	Fundamental Frequency Electromagnetic Shielding of Communications Circuits
873-800-580	Determination of Earth Resistivity by the DC Method

8. GLOSSARY

8.01 The items in this glossary are defined relative to their T1/OS usage.

Apparatus Case—The housing for a maximum of 25 line repeaters and an associated fault-locating filter.

Automatic Protection Switch (APS)—This switch located in the span terminating bay, protects service by automatically transferring the DS1 signal from the failed service line to a good protection line. When the trouble clears, the transmission is switched back to that line. The switch can be commanded to set up a remote loop after a line has failed.

Bidirectional—Repeater operation in which side one of the line repeaters in an apparatus case transmits in one direction and side two transmits in the opposite direction.

Cable—All gauges of cable from 17-gauge aluminum to 24-gauge copper are possible for use with T1/OS.

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

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

Entrance Cable—This is the cable which comes into the cable vault from the outside. For T1/OS the cable should be the same gauge, insulation, and layout from vault-to-vault.

Tip Cable—This is 100-pair cable which runs from cable vault to the main distributing frame.

Interstitial Pairs—These are extra pairs included in the cable at manufacture. They lie between the units and are used at voice frequency to make-good pairs that are damaged. They are not used for T1/OS transmission but can be used for fault-locate and order-wire pairs.

Tertiary Pairs—These are cable pairs that are spliced through at T1/OS regeneration points. They provide a crosstalk path and hence are not permitted in the same unit with T1/OS.

Stub Cable—A 104-pair stub cable connects the T1/OS apparatus case to the main cable.

Design Number—The probability that a T1 component has a bit 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. An outstate repeater section has a design number of 0.025 percent if properly engineered. Design numbers are useful in defining rules for connecting T1/OS in tandem with T1C, ◆T1D,◆ T2, and metropolitan-T1.

◆ **Expansion Span Terminating Module (ESTM)**—Provides repeater, powering, switching and jack access for an additional 13 service lines.

FEXT (Far-End Crosstalk)—Crosstalk caused by signals transmitted in the same direction as the DS1 signal.

◆ **Filter Panel**—A panel that provides for mounting up to six fault-locating filters plus -48 volt battery in the STB. A combination of 1114- or 1115-type active and 1068-type passive filters may be installed for terminating and through-connecting lines.

ICOT Cable—Intercity and Outside Trunk Cable

Intermediate Powering Repeater Shelf (IPRS)—A 206 office repeater shelf wired to power six lines passing through an office with both sides of the powering point independent.

Line Terminating Module (LTM)—Anyone of STM, ESTM, TRS, and IPRS assemblies◆

Maintenance Span—A division of the T1/OS system set up for maintenance, typically 20 to 50 miles.

Master Control Station—The control office for reporting the eight remote points used in the SRC:

NEXT—Near-End Crosstalk—Crosstalk caused by signals transmitted in the opposite direction of the DS1 signal.

Nomograph—A graphic representation that consists of several lines marked off to scale and arranged in such a way that by using a straight edge to connect known values on two lines, an unknown value can be read at the point of intersection with a third line.

Outstate—T1 facilities of route cross-section but with route length considerably longer than the present limit of 50 miles; up to 200 repeater sections.

Power Loop—Extends from the powering point to the first power-looping point. If the span is powered from both ends, the looping repeater will be powered by the office transmitting in the direction of side 1 of the repeater.

Protection Group—A number of protection lines protecting a number of service lines. At present there are three choices available: 1 for 5, 1 for 11 or 1 for 24.

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—Houses two regenerators that can be transmitting in the same or opposite directions. Fault-locate outputs are either combined or separated, depending on repeater codes.

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

Span-Terminating Bay (STB)—A bay providing all the interfaces necessary to terminate a T1/OS span, including LTM, jacks, cross-connections, order wire, fault locate, D3 ◆ or D4◆ channel banks, and a maintenance shelf. The bay makeup is flexible, and it is available in 7-foot, 9-foot, or 11-foot 6-inch heights.

Span-Terminating Module (STM)—Consists of two major shelf assemblies—the office repeater shelf and the automatic protection switching (APS) shelf. Also contained on the unit are the power dissipating resistors associated with repeater powering.

Status Reporting and Control System (SRC)—Built-in telemetry and command for operation with the designated maintenance control office. It is optional and is provided by equipping the proper plug-ins located on the APS shelf.

◆ **Terminating Repeater Shelf (TRS)**—A 206 office repeater shelf used to terminate up to 13 T1 lines when protection switching is not required.◆

T1/OS Facility—The tandem connection of a number of maintenance spans, normally interfacing with D-type channel banks.

Unidirectional—Repeater operation in which all regenerators in an apparatus case transmit in the same direction.

TABLE A
EQUALIZERS

D1 CHANNEL BANK (Note 1)	CABLE LENGTH
ED-97079-30, G1	0—150
358A	150—450
358B	450—750
D3 CHANNEL BANK (Note 1)	
ED-97079-30, G6	0—150
358D	150—450
358E	450—750
D4 CHANNEL BANK (Note 1 and 2)	
ED-3C585-30, G1	0—220
ED-3C585-30, G2	220—440
ED-3C585,30, G3	440—655

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

Note 2: The high frequency line equalization between the D4 channel bank and either an office repeater bay or cross-connect bay is obtained by plug in equalizers located in the trunk processing unit.

TABLE B
TYPICAL CABLES USED IN T1/OS

COPPER GAUGE	DESCRIPTION	CODE	RATING	PAIR SIZES		T1 MAX SECTION LENGTH KFT		ENGINEERING LOSS AT 55°F db/kft	TEMP COEFFICIENT dB/kft/10°F	f _{T100}	f _{T140}	NOTES
				UP TO 106	OVER 106	100°F	140°F					
AIR CORE UNSCREENED												
19	PIC	BHB	STANDARD	25, 50, 100	Up to 300	9.5	9.1	3.3	.034	1.046	1.088	1
22	PIC	BHA	STANDARD	25, 50, 100	Up to 600	6.9	6.7	4.6	.045	1.044	1.083	2
WATERPROOF UNSCREENED												
19	SOLID INSULATION	AJB	NSLA	6, 11, 16, 25, 50, 75, 100	Up to 300	10.8	10.5	2.9	.020	1.031	1.059	3 & 4
19	DEPIC INSULATION	ALB	STANDARD	6, 11, 16, 25, 50, 75, 100	Up to 300	9.8	9.5	3.2	.027	1.038	1.072	3
22	SOLID INSULATION	CJA	STANDARD	11, 16, 25, 50, 75, 100	Up to 600	7.9	7.7	4.0	.035	1.039	1.074	3 & 5
22	DEPIC INSULATION	ALA	STANDARD	11, 16, 25, 50, 75, 100	Up to 1200	7.2	7.0	4.4	.040	1.041	1.077	3
AIR CORE SCREENED												
22	PIC	KHA	NSLA	106	Up to 616	6.9	6.7	4.6	.045	1.044	1.083	4 & 6
24	ICOT (DEPIC)	MCM	STANDARD	54, 106,	Up to 922	8.7	8.3	3.6	.044	1.055	1.104	
WATERPROOF SCREENED												
19	DEPIC INSULATION	KLB	NSLA	50, 100	Up to 300	9.8	9.5	3.2	.027	1.038	1.072	3, 4, & 7
22	SOLID INSULATION	KJA	STANDARD	28, 54, 106	Up to 616	7.9	7.7	4.0	.035	1.039	1.074	3 & 8
22	DEPIC INSULATION	KLA	STANDARD	54, 106	Up to 616	7.2	7.0	4.4	.040	1.041	1.077	3 & 9
24	ICOT (DEPIC)	MLM	STANDARD	54, 106	Up to 922	8.0	7.7	3.9	.040	1.046	1.087	3

Note 1: Self supporting 6 thru 50 pairs.

Note 2: Self supporting 16 thru 100 pairs.

Note 3: Although data are given at the "maximum aerial temperature" of 140° waterproof cables are intended for predominantly buried installation with maximum temperature of 100° F.

Note 4: Nonstandard limited availability.

Note 5: CJA cable replaces AJA cable, it has a higher core to sheath dielectric strength.

Note 6: Previous codes: CA 6033, CA 6077.

Note 7: Previously BLB.

Note 8: Previously CA 6076.

Note 9: Previously BLA.

TABLE C

LOOP POWERING USING 206, 236-TYPE REPEATERS

POWERING VOLTAGE	BATTERY SUPPLIES REQUIRED	236 REGULATOR OPTIONS	206-CODE
48	-48 *	Y	H, L, T, or Y
130	+130 *	R & Z +	J, M, U, or AA
178	+130 & -48	Z	J, M, U, or AA
260	+130 & -130	Z	J, M, U, or AA

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

+ When option R is selected, turn screw fully down, otherwise turn two turns up.

TABLE D

REPEATER POWER OPTIONS FOR 206 OR 236-TYPE REPEATERS

METHOD OF POWERING OFFICE REPEATER (NOTE 1)		POWER OPTION (NOTE 2)	POWERING ARRANGEMENT (NOTE 3)	REPEATER POWER OPTION BLOCK SCREWS (NOTE 4)
Office Repeater Powered In Series With Line Repeaters	At Powering Office	1	Bidirectional Operation	C, E, K*
		1	Unidirectional Operation — 1st shelf of power loop, office repeater powered in series with receive line repeaters	
		7	Unidirectional Operation — 1st shelf of power loop, office repeater powered in series with transmit line repeaters	
		2	Unidirectional Operation — 2nd shelf of power loop, office repeater powered in series with receive line repeaters	
	At Power Looping Office	3	Bidirectional Operation	D, K
		1	Unidirectional Operation — 1st shelf of power loop, office repeater powered in series with receive line repeaters	C, E, K*
		7	Unidirectional Operation — 1st shelf of power loop, office repeater powered in series with transmit line repeaters	B, D, G*
		2	Unidirectional Operation — 2nd shelf of power loop, office repeater powered in series with receive line repeaters	A, G, M
Office Repeater Powered Separately From Line	At Powering Office	4	Bidirectional Operation	B, E, H, N
		4	Unidirectional Operation — 1st shelf of power loop	
		5	Unidirectional Operation — 2nd shelf of power loop	
	At Power Looping Office	6	Bidirectional Operation	H, J, N
		4	Unidirectional Operation — 1st shelf of power loop	B, E, H, N
		5	Unidirectional Operation — 2nd shelf of power loop	A, F, H, N

Note 1: When using 206T, U, Y and AA repeaters for powering low power (60 mA) lines, they cannot be powered in series with the line because the regenerators in these repeaters require a minimum of 70 mA.

Note 2: Power options are covered by seven different combinations of screwdown straps. Options 1, 2, 3, and 7 provide for powering the office repeater in series with the line for both unidirectional and bidirectional operation. Options 4, 5, and 6 provide for powering the office repeater and line separately.

Note 3: For unidirectional operations, two office repeaters are required to complete the power loop.

Note 4: Power conditions are furnished by turning option screws to the maximum clockwise position. Option screws not specified in the table should be turned back two complete turns counterclockwise.

* When the office repeaters are powered in series with the line from both ends, these options must be used in pairs at both ends. When the office repeaters in only one of the two offices are powered in series with the line, options C, E, K on the first shelf and A, G, M on the second shelf will result in one of the two power loops having two more power supply drops than the other. Whereas options B, D, G on the first shelf and A, G, M on the second shelf will result in both power loops having an equal number of power supply drops. However, when using options B, D, G and A, G, M, the loss of either power loop will affect both directions of transmission. When using options C, E, K and A, G, M, only one direction of transmissions will be affected in the case of a power loop failure.

TABLE E

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

POWERING OFFICE OPTIONS	LOOPING POINT OPTIONS	RCV LOOP FAILURE*				TRMT LOOP FAILURE*			
		FIRST PROTECTION GROUP		SECOND PROTECTION GROUP		FIRST PROTECTION GROUP		SECOND PROTECTION GROUP	
FIRST/SECOND PROTECTION GROUP	FIRST/SECOND PROTECTION GROUP	TRMT	RCV	TRMT	RCV	TRMT	RCV	TRMT	RCV
BEHN/AFHN	Line Repeater		X		X	X		X	
BEHW/AFHN	BEHN/AFHN		X		X	X		X	
BDG/AGM	Line Repeater		X		X	X	X	X	
CEK/AGM	Line Repeater		X		X	X		X	
BDG/AGM	BEHN/AFHN		X		X	X	X	X	
CEK/AGM	BEHN/AFHN		X		X	X		X	
BEHN/AFHN	BDG/AGM	X	X		X	X		X	
BEHN/AFHN	CEK/AGM		X		X	X		X	
BDG/AGM	BDG/AGM	X	X		X	X	X	X	
CEK/AGM	CEK/AGM		X		X	X		X	

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

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

TABLE F
MAXIMUM AND MINIMUM CABLE
RESISTANCE COEFFICIENTS

WIRE GAUGE		OHMS PER 1000 FT. OF SPAN LINE	
COPPER	ALUMINUM	R _{MAX}	R _{MIN}
	17	8.30	8.00
19		8.33	8.04
21		13.24	12.79
	20	16.70	16.10
22		16.70	16.13
24		26.55	25.65
26		42.22	40.78

TABLE G

EFFECTIVE RESISTANCE OF OFFICE REPEATERS IN OHMS

REPEATER CODE	POWERING	LOCALLY POWERED				SERIES POWERED					
						BI	BI-L	UNDIRECTIONAL			
		BIDIRECTIONAL		UNIDIRECTIONAL		OPTION		RECEIVE		TRANSMIT	
		SYSTEM	LOOPED	SYSTEM	LOOPED	CEK	DK	BDG	CEK	BDG	CEK
206	STANDARD	30	20	30	30	110	100	110	190	110	30
236	STANDARD	30	20	30	30	110	100	110	190	110	30
236 EXCP*	STANDARD	30	20	30	30	145	135	145	260	145	30
236	LOW	30	20	30	30	143	133	143	256	143	30
236 EXCP*	LOW	30	20	30	30	297	287	297	564	297	30

* To be used only in the Terminating Repeater Shelf (TRS).

TABLE H
EFFECTIVE RESISTANCE OF LINE REPEATERS

REPEATER TYPE	LOW POWER 60 mA		STANDARD POWER 140 mA	
	UNPROTECTION	PROTECTION	UNPROTECTION	PROTECTION
Through	116	128	80	92
Loop - Side 1 Input	114	120	78	84
Loop - Side 1 Output	2	8	2	8

TABLE J
OFFICE BATTERY LIMITS AND MISCELLANEOUS
BAY RESISTANCE

POWERING VOLTAGE	V _R MAX (VOLTS)	V _R MIN (VOLTS)	R _X (OHMS) STB J98728
48	50	45	10
130	135	125	10
178	185	170	20
260	270	250	130

TABLE I
ALLOWABLE R_L

BATTERY VOLTAGE	OFFICE REPEATER TYPE	LOW POWER (60 MA)		STANDARD POWER (140 MA) WITH INDUCED AC CURRENT AS INDICATED					
				0 to 10 MA		10 to 20 MA		20 to 30 MA	
		R _L MIN	R _L MAX	R _L MIN	R _L MAX	R _L MIN	R _L MAX	R _L MIN	R _L MAX
-48 and GRD	206 or 236	0	550	0	230	0	200	0	180
+130 and GRD	206	—	—	185	790	160	590	145	490
	—	—	—	—	—	—	—	—	—
	236	450	1850	185	790	160	590	145	490
+130 and -48	206	—	—	630	1090	470	890	390	790
	—	—	—	—	—	—	—	—	—
	236	1515	2570	630	1090	470	890	390	790
+130 and -130	206 or 236	2190	3760	850	1540	850	1340	850	1240

TABLE K
DESIGN NUMBER d VERSUS MARGIN M_e

M _e (dB)	DESIGN NUMBER d (PERCENT)
0.0 or greater	0.025
0.0 to -5.0	0.100
-5.0 or less	not usable

TABLE L
FEXT LIMITATION*

		STANDARD DEVIATION OF FEXT COUPLING LOSS - s_F (dB)							
		6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0
M	40.0	2	2	1	1	1	1	1	1
E	41.0	3	2	2	1	1	1	1	1
A	42.0	3	2	2	1	1	1	1	1
N	43.0	4	2	2	1	1	1	1	1
	44.0	4	3	2	2	1	1	1	1
F	45.0	5	3	2	2	1	1	1	1
E	46.0	5	3	2	2	2	1	1	1
X	47.0	6	4	3	2	2	1	1	1
T	48.0	8	4	3	2	2	1	1	1
	49.0	10	5	3	2	2	2	1	1
C	50.0	16	6	4	3	2	2	1	1
O	51.0	28	7	4	3	2	2	1	1
U	52.0	44	9	5	3	2	2	2	1
P	53.0	66	15	6	4	3	2	2	1
L	54.0	95	29	7	4	3	2	2	1
I	55.0	132	51	8	5	3	2	2	2
N	56.0	181	81	11	5	4	3	2	2
G	57.0	245	120	24	6	4	3	2	2
	58.0	327	172	51	7	5	3	2	2
L	59.0	433	240	89	10	5	4	3	2
O	60.0	569	329	140	15	6	4	3	2
S	61.0	743	444	208	40	7	4	3	2
S	62.0	965	592	298	85	8	5	4	3
	63.0	1240	783	415	148	12	6	4	3
$m_{F\ell}$	64.0	1610	1020	568	232	23	7	4	3
(dB)	65.0	2070	1310	766	345	64	8	5	4
	66.0	2650	1740	1020	493	136	10	6	4
	67.0	*	2250	1350	687	236	15	6	4
	68.0	*	2900	1770	939	370	35	8	5
	69.0	*	*	2310	1260	548	100	9	5
	70.0	*	*	*	1680	783	211	13	6
	71.0	*	*	*	2230	1090	364	22	7
	72.0	*	*	*	2930	1490	570	55	9
	73.0	*	*	*	*	2010	843	155	11
	74.0	*	*	*	*	2680	1200	320	17
	75.0	*	*	*	*	*	1670	548	33
	76.0	*	*	*	*	*	2280	853	86
	77.0	*	*	*	*	*	*	1250	238
	78.0	*	*	*	*	*	*	1790	478
	79.0	*	*	*	*	*	*	2480	807
	80.0	*	*	*	*	*	*	*	1240
	81.0	*	*	*	*	*	*	*	1830
	82.0	*	*	*	*	*	*	*	2600

* This table gives the maximum permissible number of lines for a given mean FEXT coupling loss, $m_{F\ell}$, and standard deviation, s_F . The mean FEXT coupling loss is for a section of length ℓ kilofeet. If the coupling loss is known for length ℓ_0 kilofeet, then $m_{F\ell} = m_{F\ell_0} - 10 \log \ell/\ell_0$.

TABLE M
PAIR-TO-PAIR CROSSTALK COUPLING LOSS* AT 772 KHZ FOR 1 KFT

CABLE SIZE	UNIT	NEXT dB		FEXT dB	
		m	s	m _F	s _F
	19-Gauge Air Core PIC Cables				
50 pair or less (12- and 13-pair units)	Pairs in same unit	69	11	72**	9**
	Pairs in adjacent units	77	10	79**	10**
	Pairs in nonadjacent units	85	9	86**	11**
300 pairs (12- to 25-pair units)	Pairs in same unit	72	12	72**	9**
	Pairs in adjacent units	76	9	79**	10**
	Pairs in nonadjacent units	96	10	86**	11**
	19-Gauge Filled PIC Cables				
25 pairs	All pairs	69	7	74	8
50 pairs (12- and 13-pair units)	Pairs in same unit	71	9	74	9
	Pairs in adjacent units	80	10	81	10
	Pairs in nonadjacent units	89	11	88	11
	22-Gauge Air Core PIC Cables				
Less than 100 pairs	Pairs in same 12- or 13-pair unit	69	10	72	9
	Pairs in same 25-pair unit	76	13	76**	10**
	Pairs in adjacent 12-or 13-pair units	77	9	80	10
	Pairs in nonadjacent 12-or 13-pair units	84	9	85	11
100 pairs (25-pair unit, six 12- and 13-pair units)	Pairs in same 12- or 13-pair unit	68	9	72**	9**
	Pairs in same 25-pair unit	73	11	76	10
	Pairs in adjacent units	79	9	80**	10**
	Pairs in nonadjacent units	90	9	85**	11**
300 pairs (12- to 25-pair units)	Pairs in same unit	75	12		
	Pairs in adjacent units	81	10		
	Pairs in nonadjacent units	98	11		
500 pairs (12- 50-pair units)	Pairs in same unit	77	11		
	Pairs in adjacent unit	87	9		
	Pairs in nonadjacent units	106	8		
	22-Gauge Filled PIC Cables				
25 pairs	All pairs	72	10	74	10
100 pairs (25-pair unit, six 12- and 13-pair units)	Pairs in same 12- or 13-pair unit	69	9	72	9
	Pairs in same 25-pair unit	77	11	76**	10**
	Pairs in adjacent units	81	10	80	10
	Pairs in nonadjacent units	93	10	92	10

TABLE M (Contd)

PAIR-TO-PAIR CROSSTALK COUPLING LOSS* AT 772 KHZ FOR 1 KFT

CABLE SIZE	UNIT	NEXT dB		FEXT dB	
		m	s	m _F	s _F
	22-Gauge Filled DEPIC Cables				
100 pairs (25-pair unit, six 12- and 13-pair units)	Pairs in same 12- or 13-pair unit	66	7	69	8
	Pairs in same 25-pair unit	74	11	75	10
	Pairs in adjacent units	80	9	78	9
	Pairs in nonadjacent units	91	8	90	9
	22-Gauge Pulp Cable (ADA)				
Small (less than 200 pairs)	Pairs in same 50-pair unit	75	10	79	11**
	Pairs in adjacent 50-pair units	88	8	84	11**
Large (200 pairs or more)	Pairs in same 50-pair unit	75	10	79	11**
	Pairs in adjacent 50-pair units	88	8	84	11**
	Pairs in nonadjacent 50-pair units	100	6	90**	11**

* All values apply to 1 kft sections. NEXT losses apply without corrections to lengths greater than 1 kft. To obtain NEXT losses for shorter lengths see Section 855-351-101, paragraph 7.41. Mean FEXT losses for sections other than 1 kft may be found by adding $\log \ell$ where ℓ is the section length in kilofeet.

* Estimated.

TABLE N

T1C DESIGN NUMBER ASSIGNMENT

CABLE AND CONFIGURATION	DESIGN NUMBER PERCENT
Two-Cable or Screened ICOT Cable all at Maximum Loss	0.005
Screened PIC/DEPIC Cable all at Maximum Loss	0.100
Screened PIC/DEPIC Cable all 1 dB Short Spaced	0.050
Screened PIC/DEPIC Cable all 2 dB Short Spaced	0.025

TABLE O

T1D DESIGN NUMBER ASSIGNMENT

CABLE AND CONFIGURATION	DESIGN NUMBER PERCENT
Single-Cable, Maximum Capacity	0.100
Screened Cable, DEPIC, PIC, and Pulp	0.025

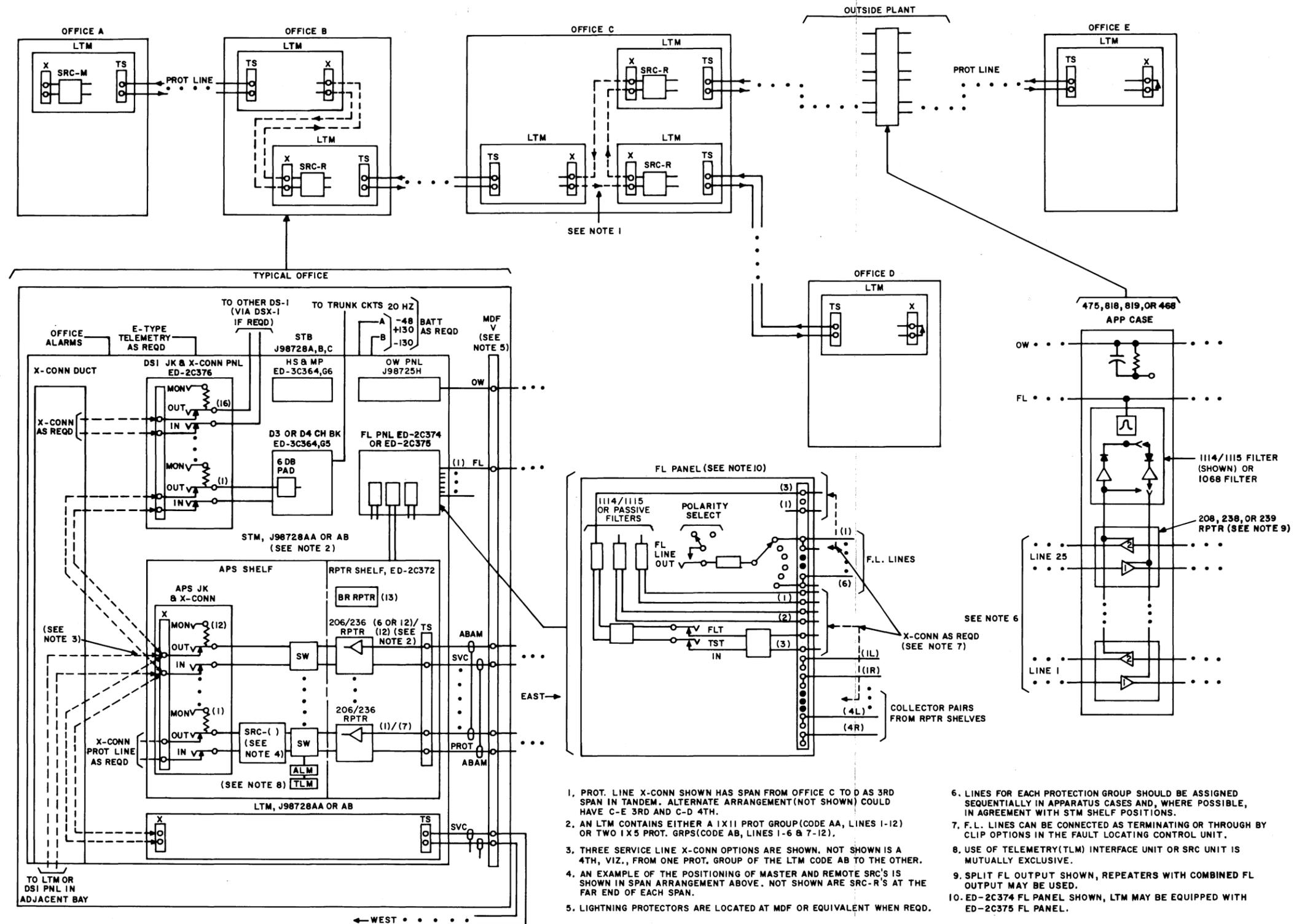


Fig. 1—T1/OS Block Diagram

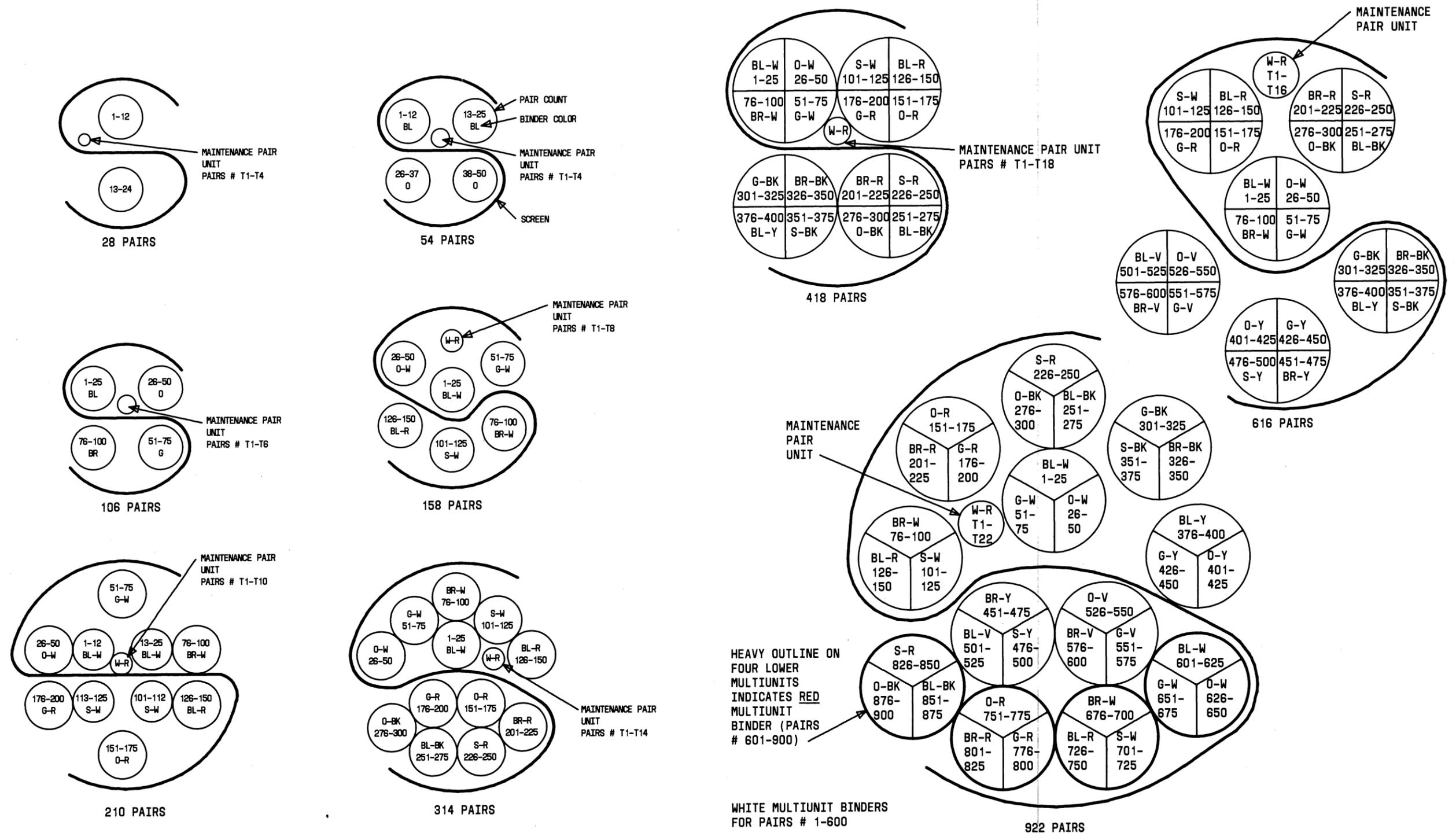
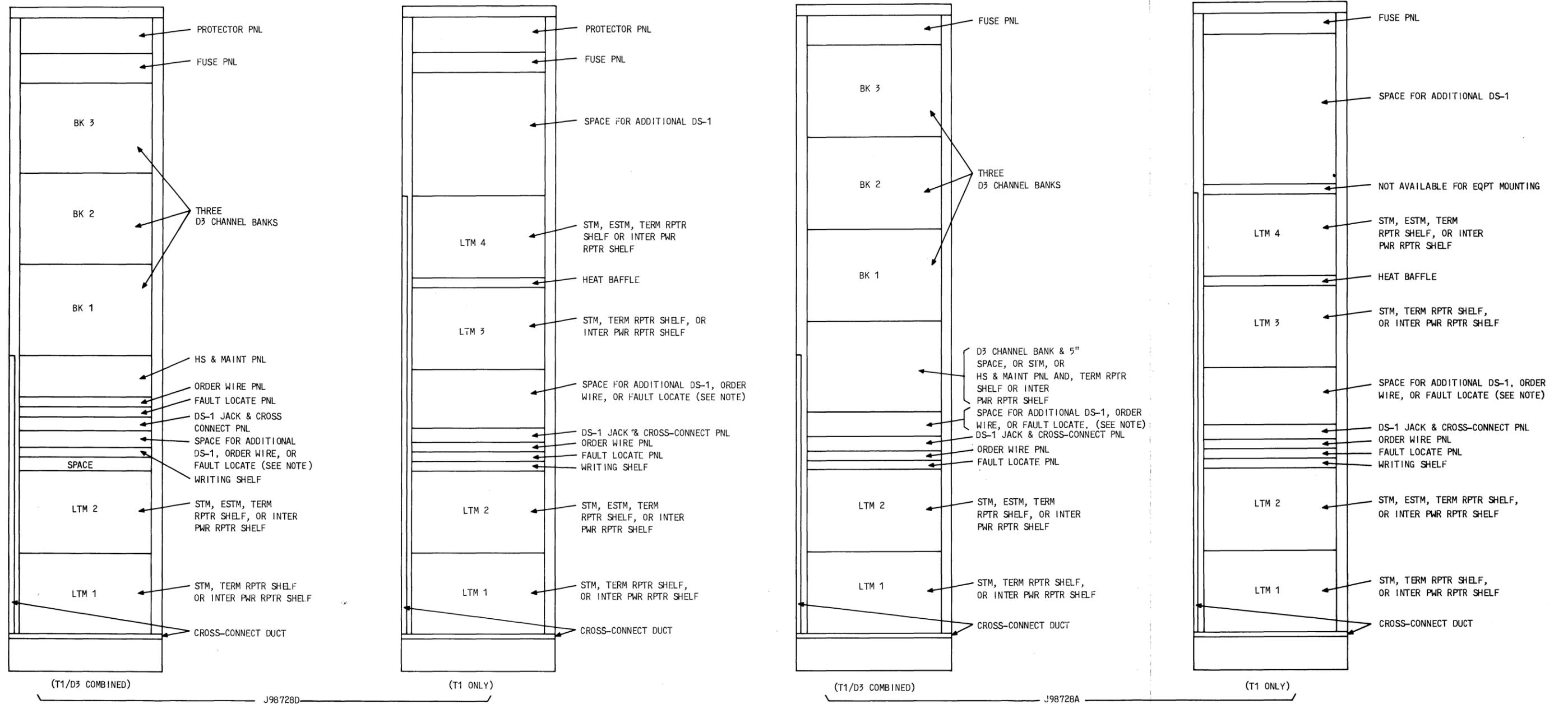
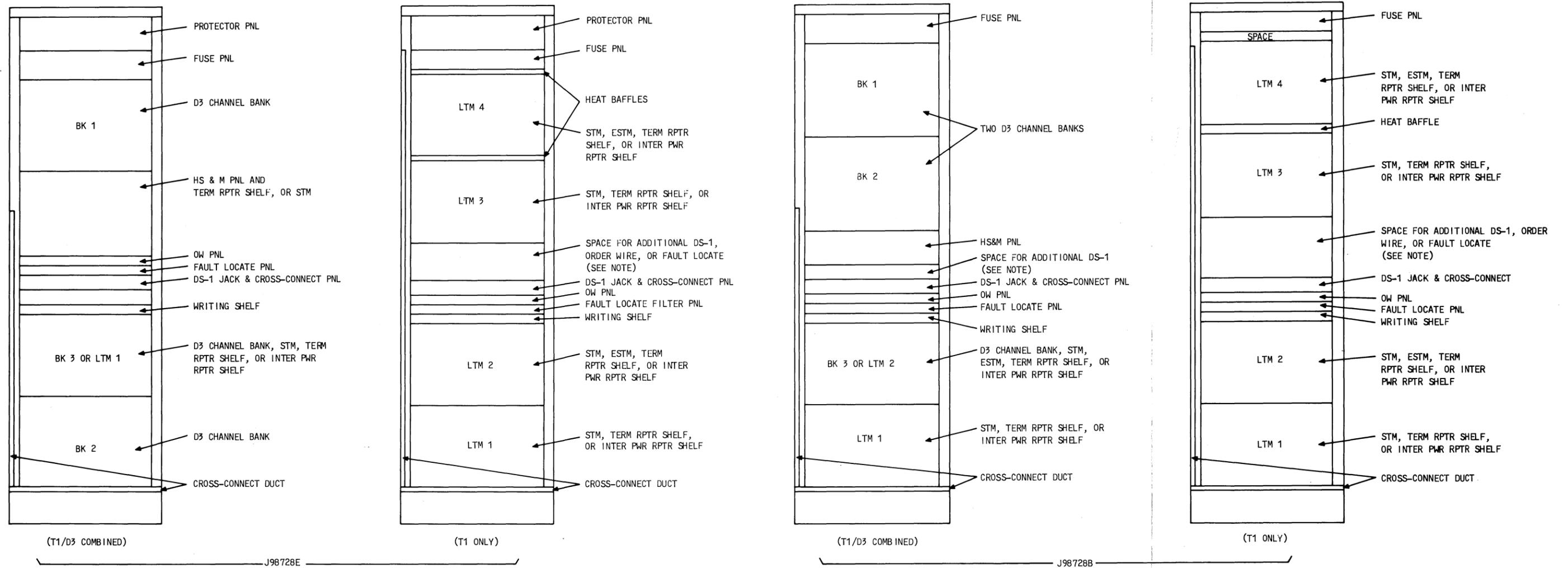


Fig. 2—Typical Core Diagram for Screened Cable



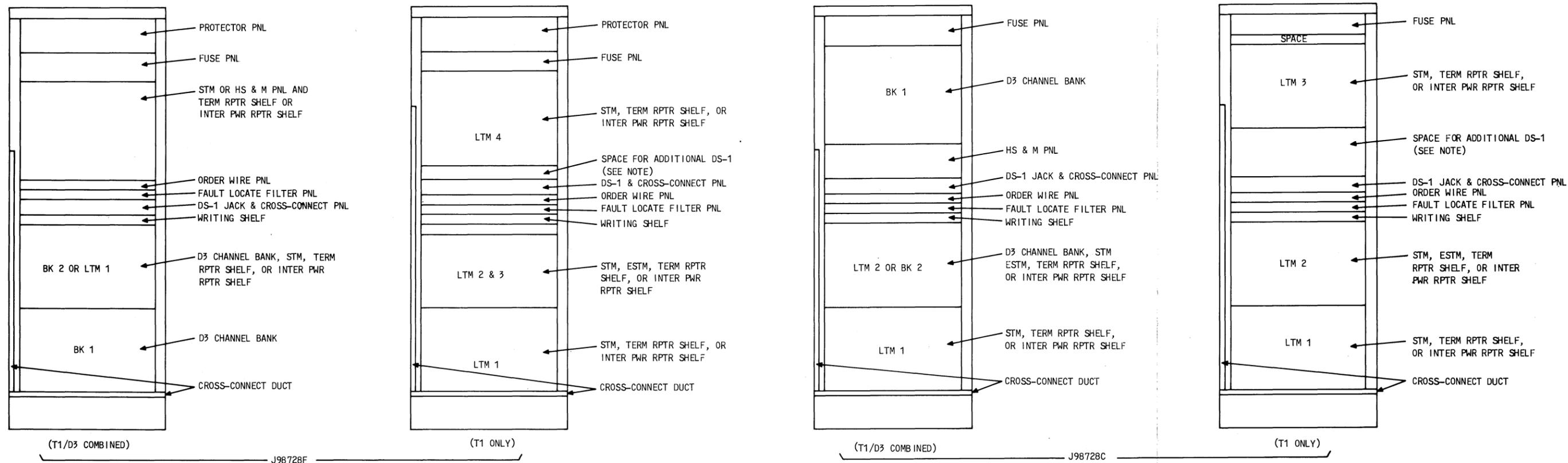
NOTE:
 FOR APPLICATIONS WHERE A SECOND FAULT LOCATE, ORDER WIRE, AND/OR DS-1 PANEL ARE REQUIRED, IDENTICAL PANELS ARE MOUNTED ADJACENT TO EACH OTHER. THE WRITING SHELF MAY BE OMITTED.

Fig. 3—J98728A and J98728D—11 Foot 6 Inch Span Terminating Bays



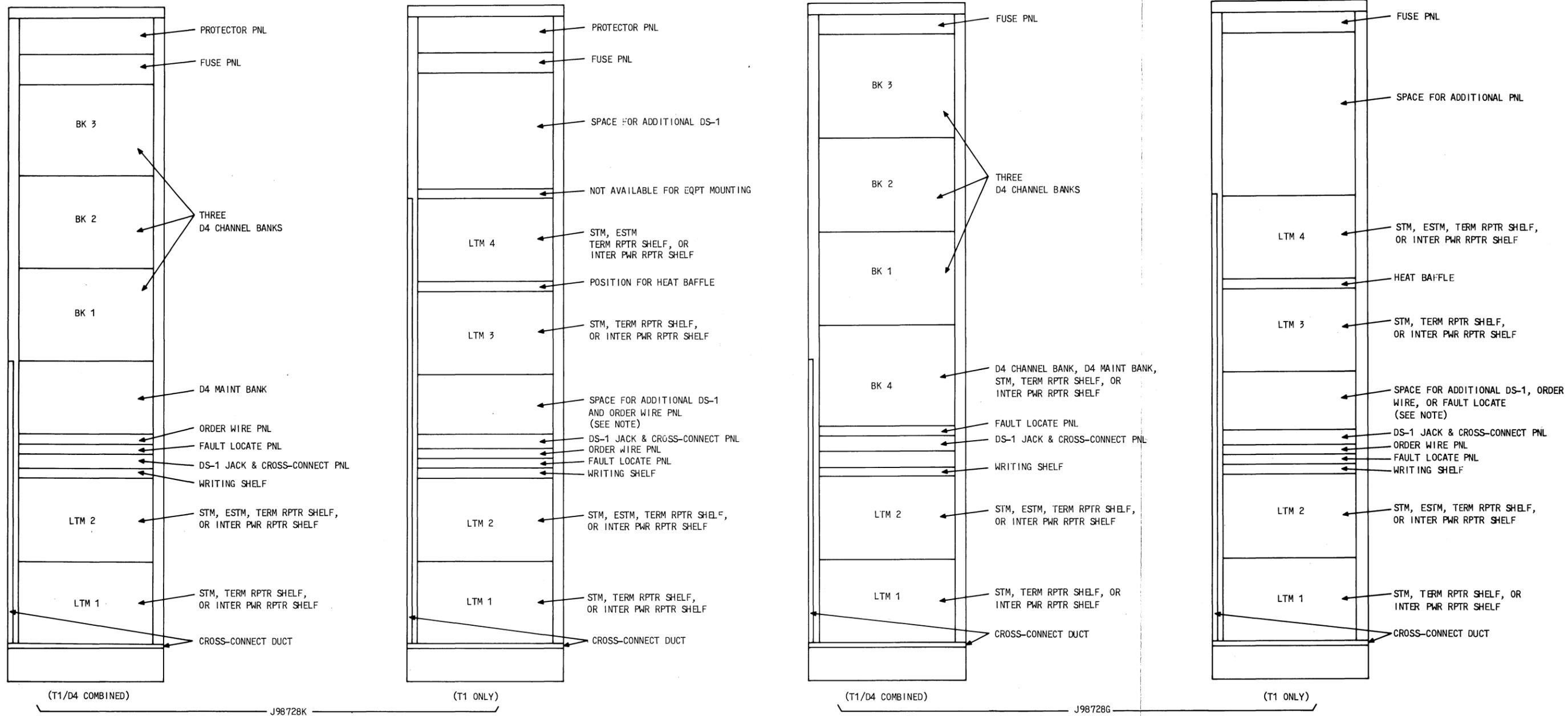
NOTE:
 FOR APPLICATIONS WHERE A SECOND FAULT LOCATE, ORDER WIRE, AND/OR DS-1 PANEL ARE REQUIRED, IDENTICAL PANELS ARE MOUNTED ADJACENT TO EACH OTHER. THE WRITING SHELF MAY BE OMITTED.

Fig. 4—J98728B and J98728E—9 Foot Span Terminating Bays



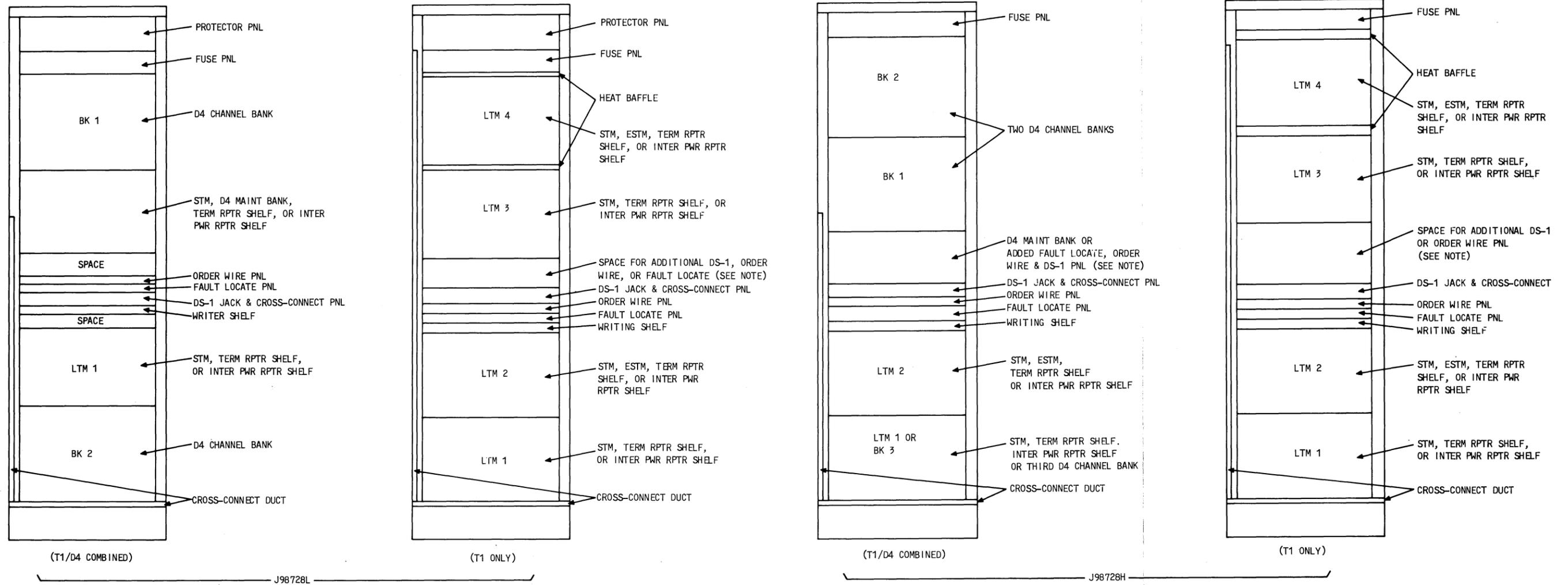
NOTE:
 FOR APPLICATIONS WHERE A SECOND FAULT LOCATE, ORDER WIRE, AND/OR DS-1 PANEL ARE REQUIRED, IDENTICAL PANELS ARE MOUNTED ADJACENT TO EACH OTHER. THE WRITING SHELF MAY BE OMITTED.

Fig. 5—J98728C and J98728F—7 Foot Span Terminating Bays



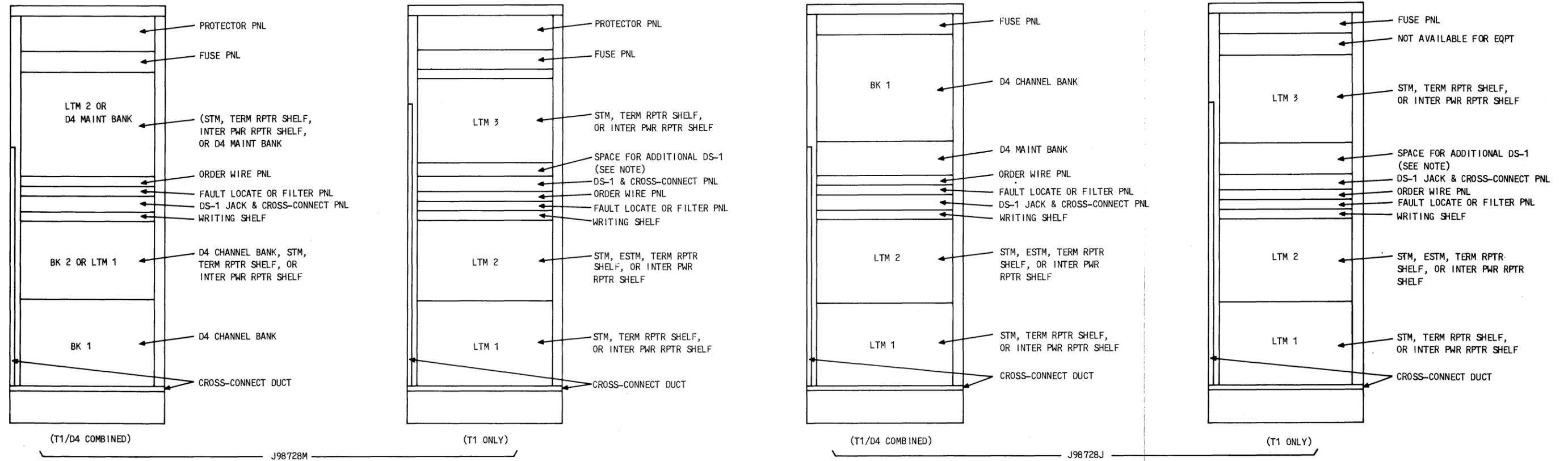
NOTE:
 FOR APPLICATIONS WHERE A SECOND FAULT LOCATE, ORDER WIRE, AND/OR DS-1 PANEL ARE REQUIRED, IDENTICAL PANELS ARE MOUNTED ADJACENT TO EACH OTHER. THE WRITING SHELF MAY BE OMITTED.

Fig. 6—J98728G and J98728K—11 Foot 6 Inch Span Terminating Bays



NOTE:
 FOR APPLICATIONS WHERE A SECOND FAULT LOCATE, ORDER WIRE, AND/OR DS-1 PANEL ARE REQUIRED, IDENTICAL PANELS ARE MOUNTED ADJACENT TO EACH OTHER. THE WRITING SHELF MAY BE OMITTED.

Fig. 7—J98728H and J98728L—9 Foot Span Terminating Bays



NOTE:
 FOR APPLICATIONS WHERE A SECOND FAULT LOCATE, ORDER WIRE, AND/OR DS-1 PANEL ARE REQUIRED, IDENTICAL PANELS ARE MOUNTED ADJACENT TO EACH OTHER. THE WRITING SHELF MAY BE OMITTED.

Fig. 8—J98728J and J98728M—7 Foot Span Terminating Bays

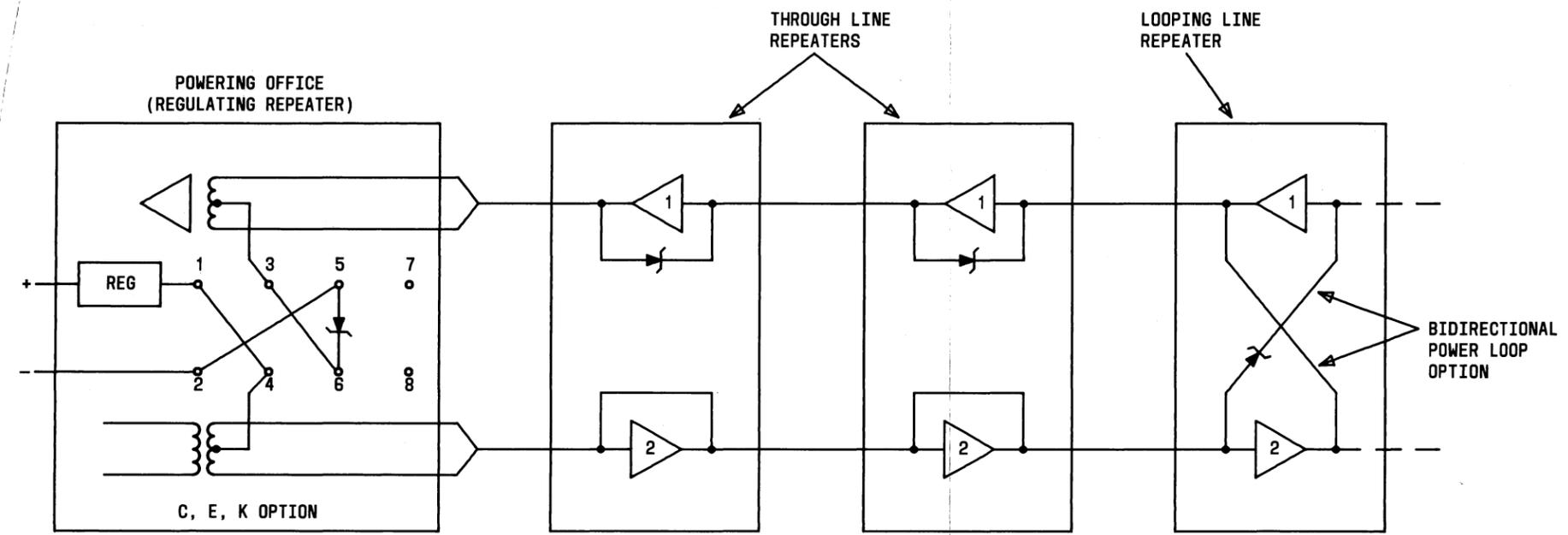


Fig. 9—Typical T1/OS Bidirectional Power Loop With Office Repeater Powered in Series With the Line

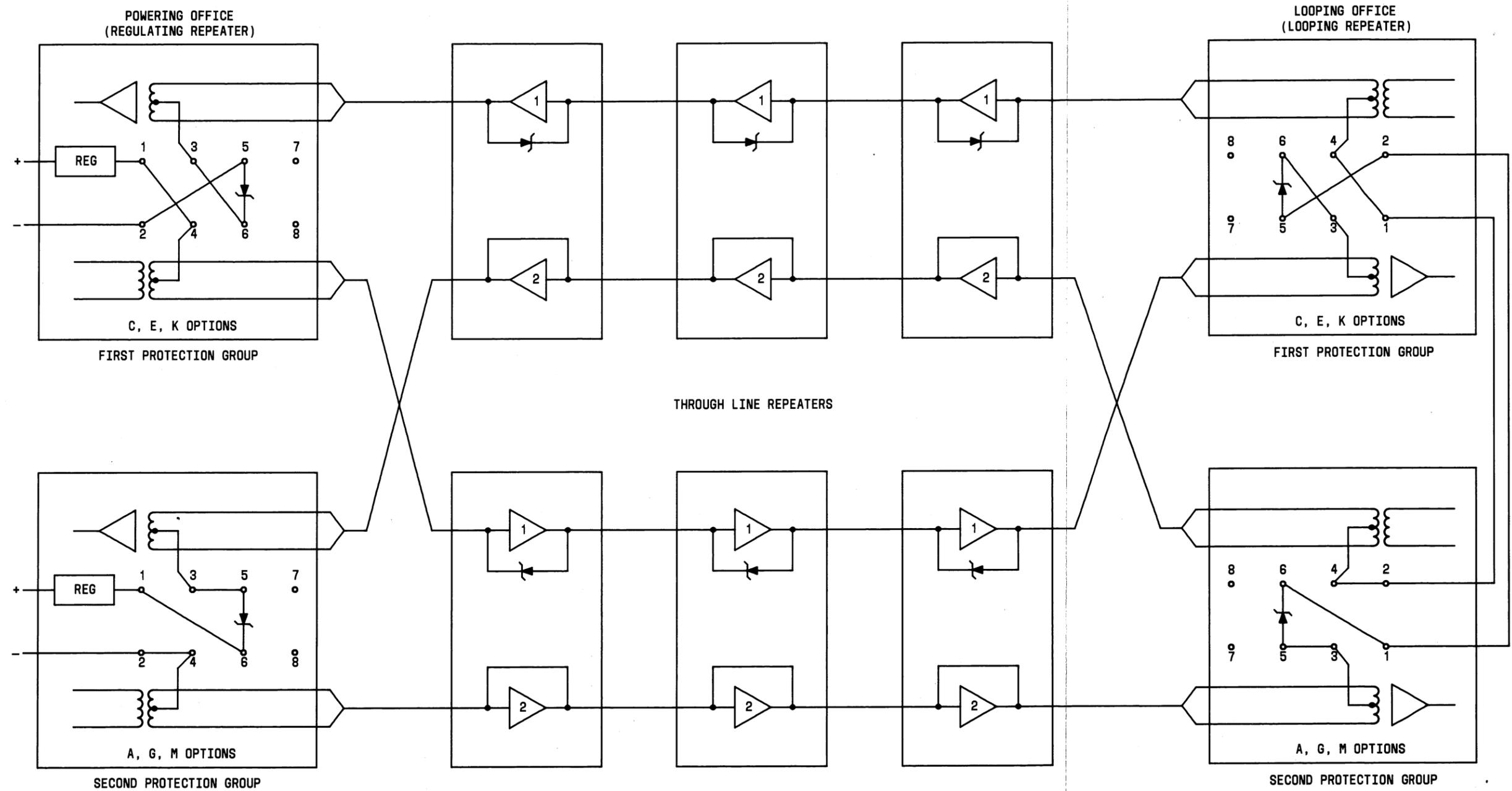


Fig. 10—Typical T1/OS Unidirectional Power Loop (CEK and AGM Options) With Office Repeater Powered in Series With the Line

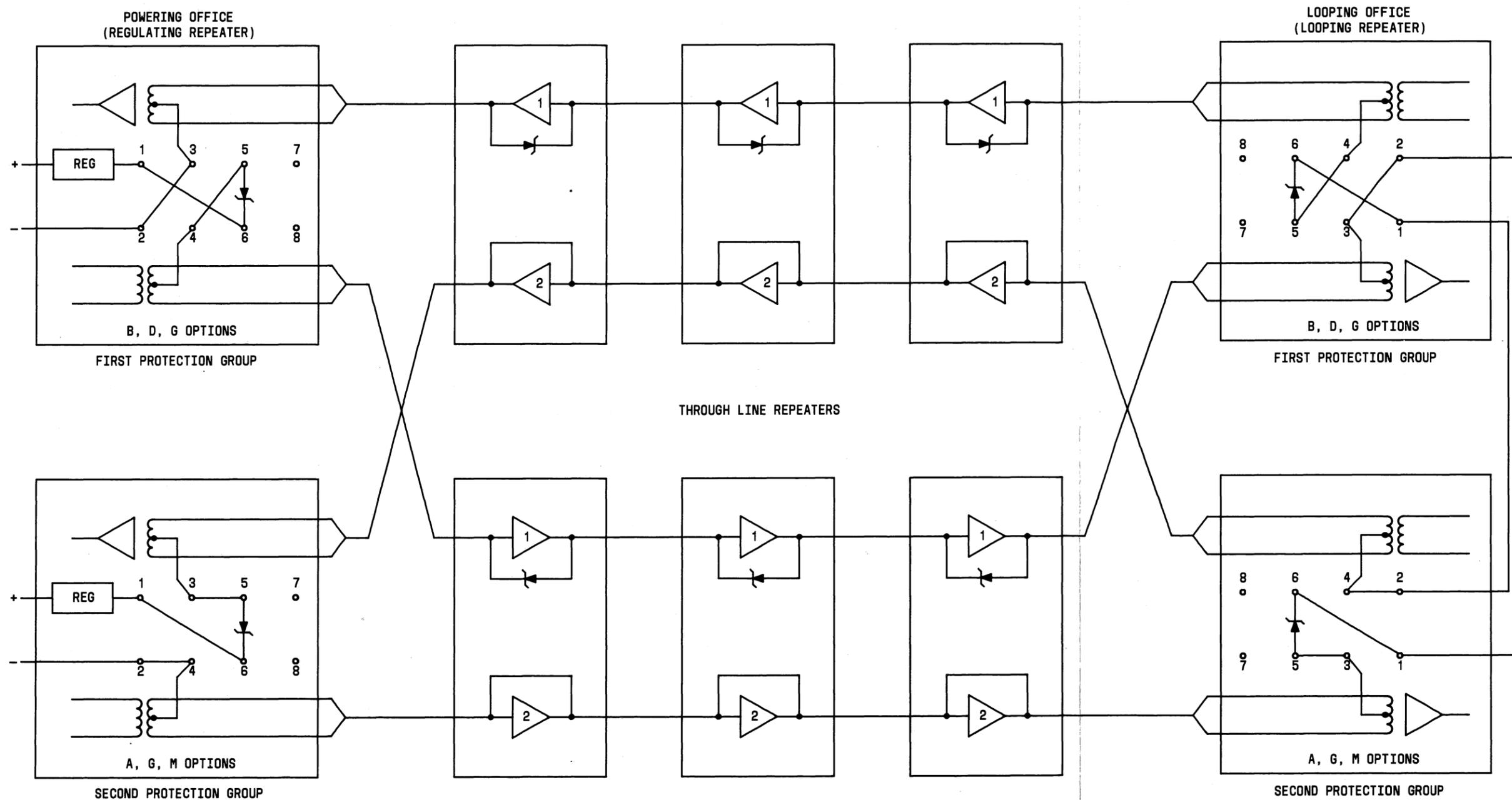


Fig. 11—Typical T1/OS Unidirectional Power Loop (BDG) and AGM Options) With Office Repeater Powered in Series With the Line



Initial Power Loop Information

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

Office A

Office B

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

Repeater Options

Upper Shelf	Upper Shelf
Lower Shelf	Lower Shelf

Line Voltage

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

Regulator Voltage

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

Technician	Telephone No.	Date Implemented
Supervisor		

E-10604
Code B
(2-80)

Fig. 12—Form E-10604 Initial Power Loop Information

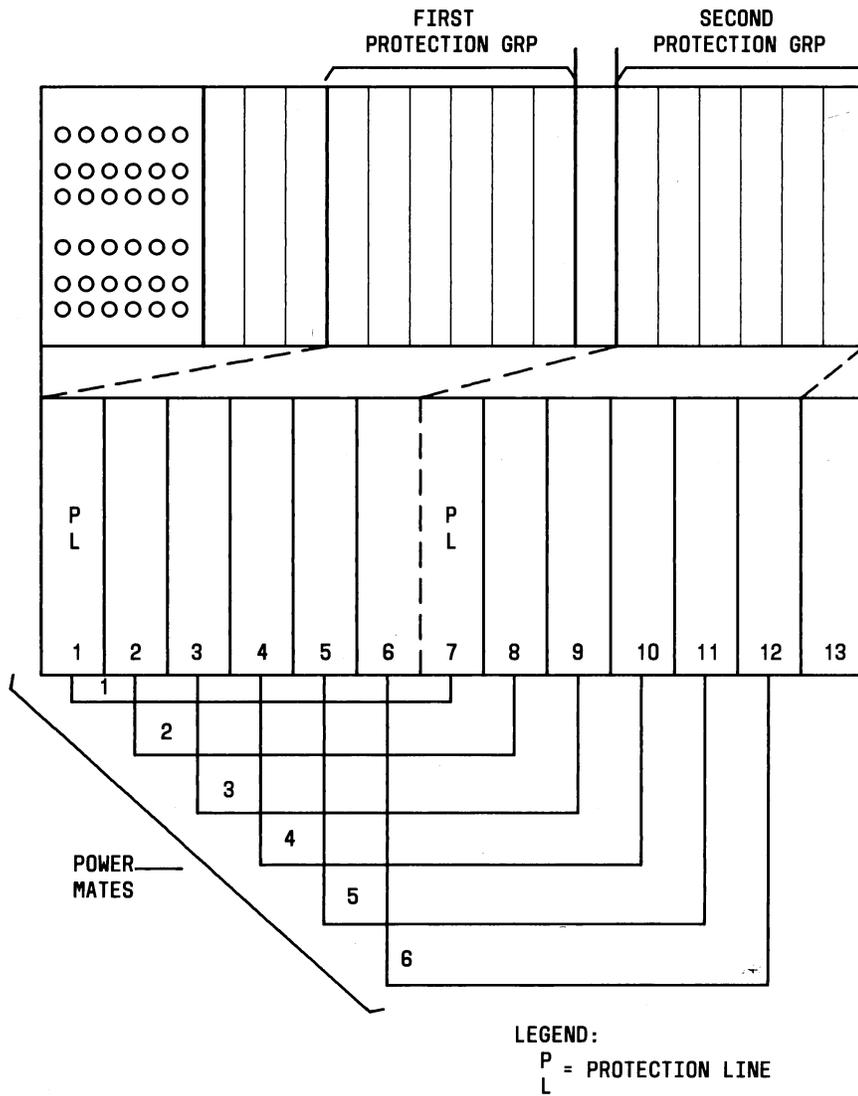


Fig. 13—Location of Power Mates in a 1 X 5 STM

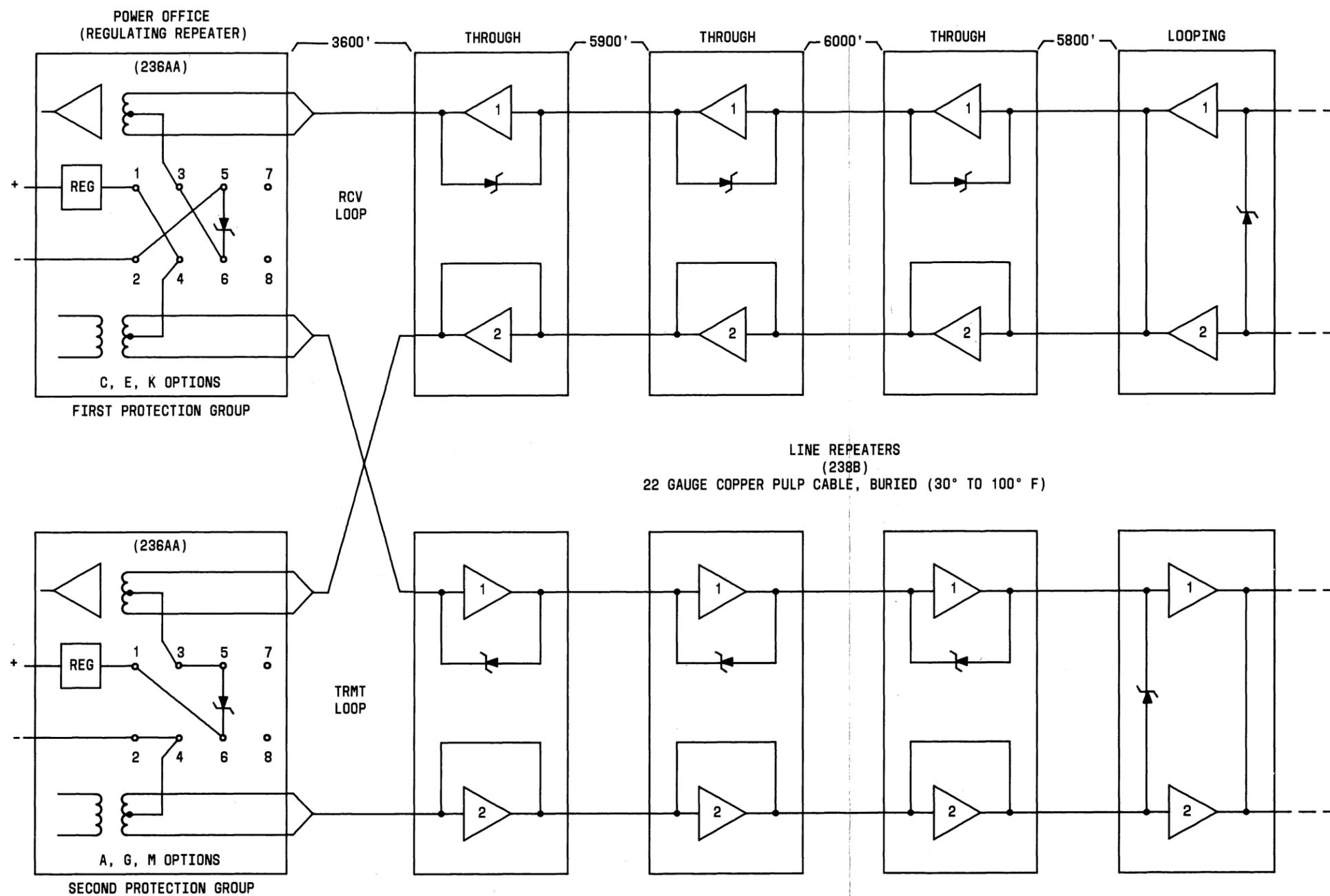


Fig. 15—Typical Example of T1/OS Unidirectional Power Loop

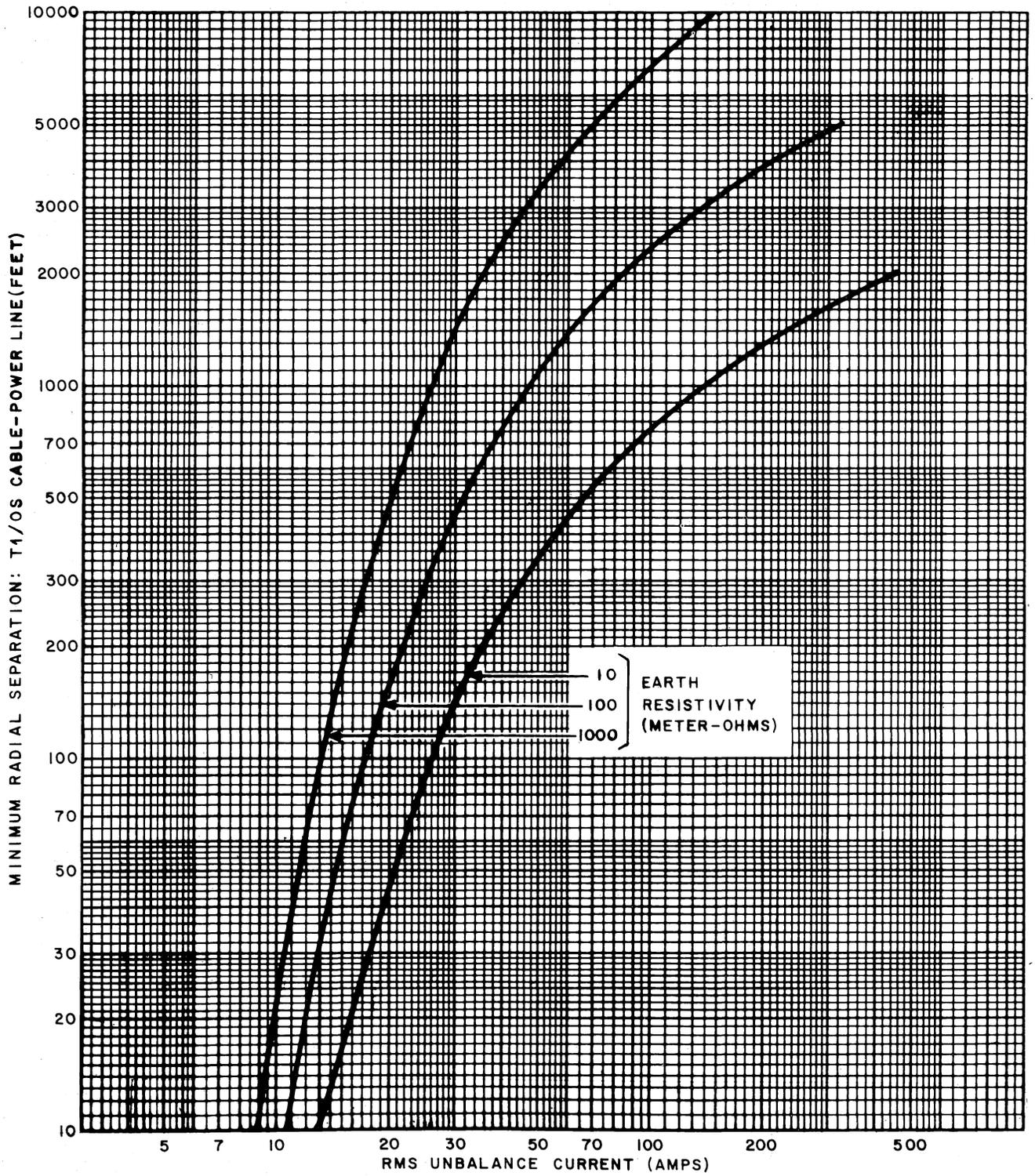


Fig. 16—Minimum Required Separation for 20 MA Induced AC vs RMS Unbalance Current

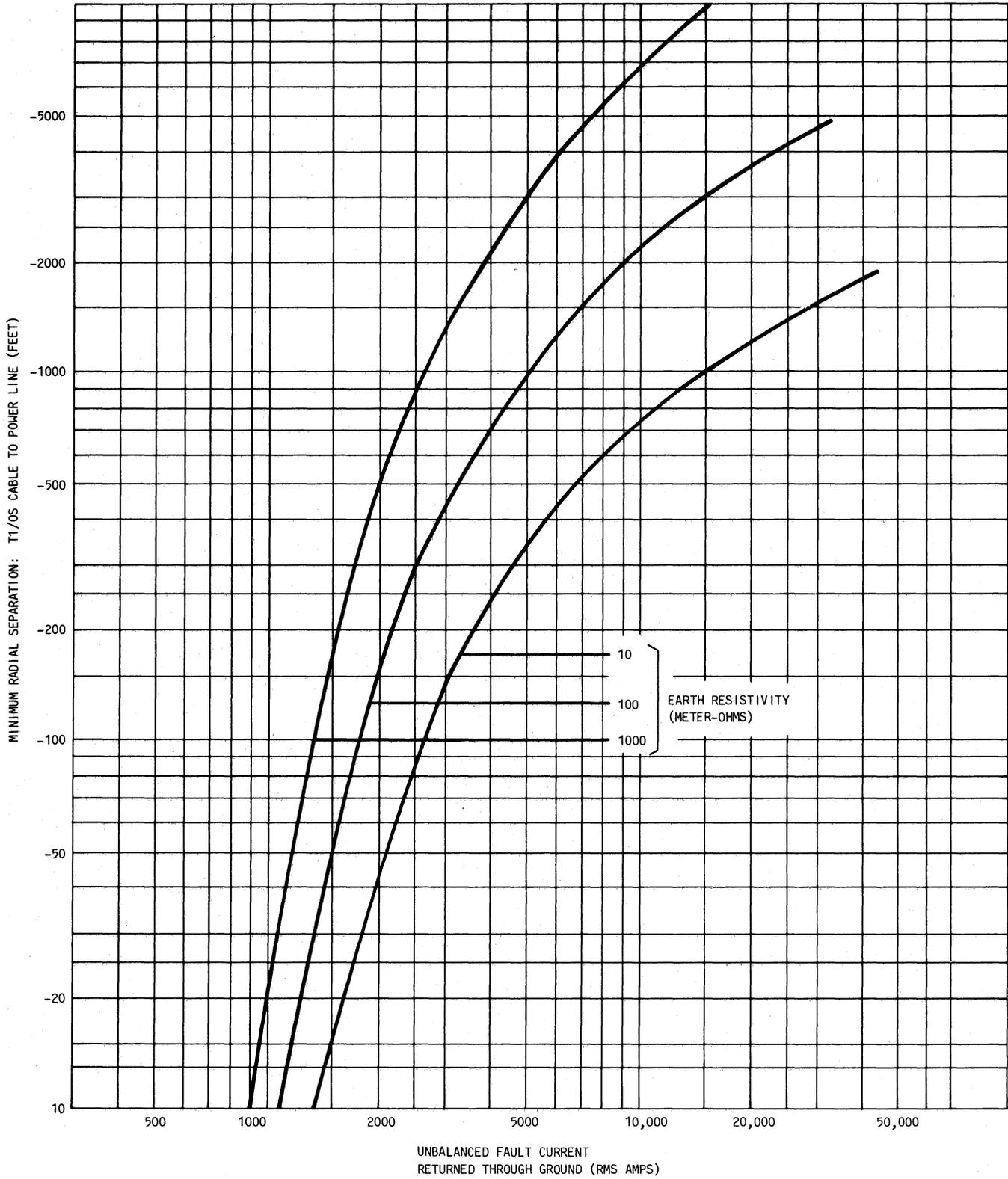


Fig. 17—T1/OS Cable to Power Line Separation Under Utility Fault Condition

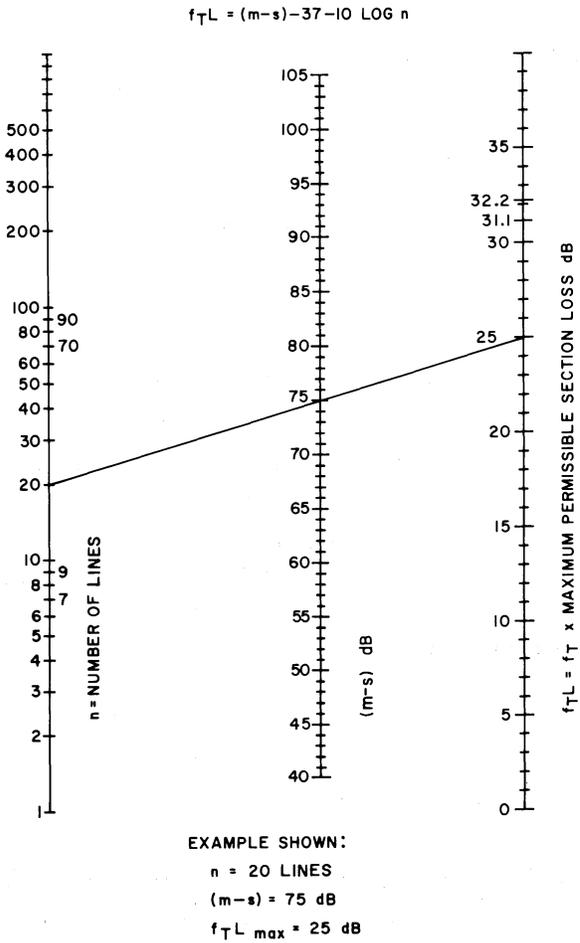


Fig. 18—T1/OS NEXT Limitation

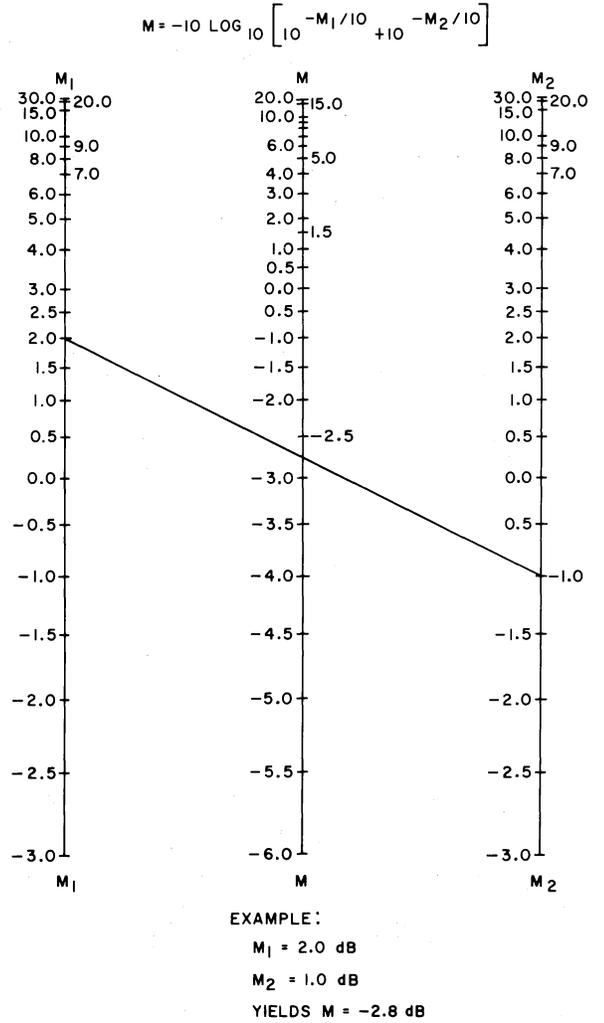


Fig. 19—Margin Addition Nomogram

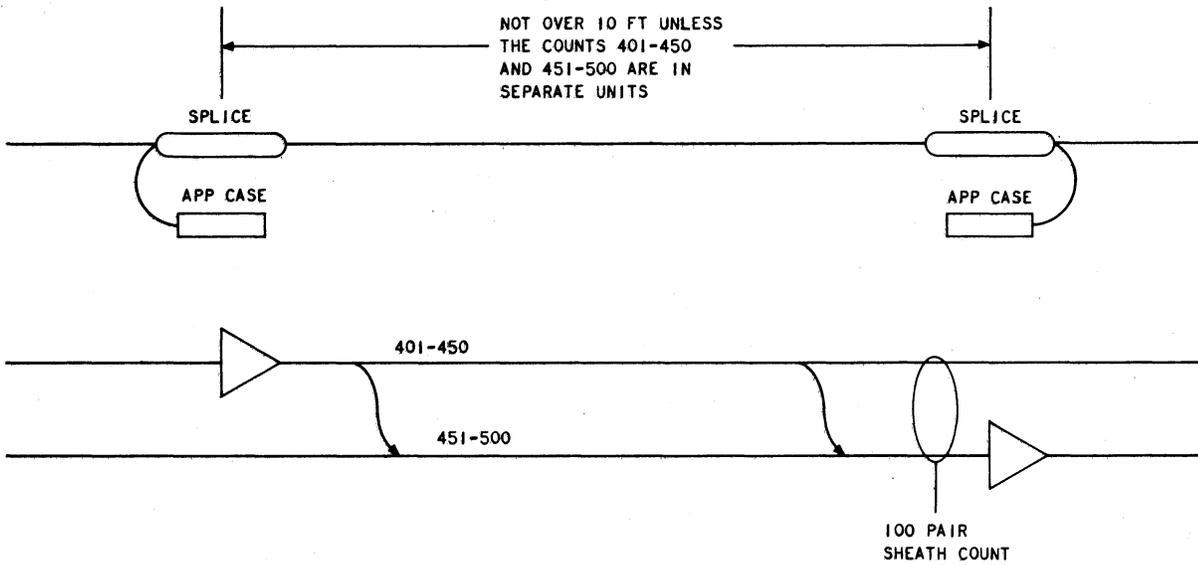
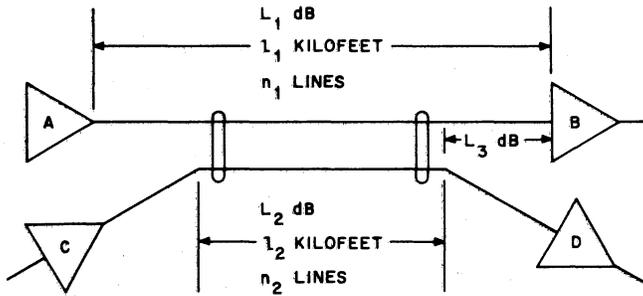
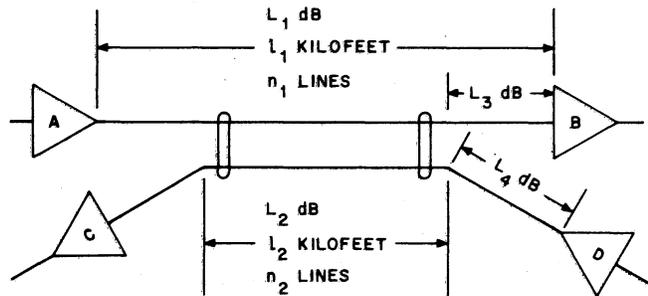


Fig. 20—Separation of Apparatus Cases



CABLE PARAMETERS: MEAN NEXT LOSS = m_{F_0}' dB
 STD DEVIATION = s_F' dB



CABLE PARAMETERS: MEAN NEXT LOSS = m_{F_0}' dB
 STD DEVIATION = s_F' dB

Fig. 21—Route Junction in Two-Cable Facility (One Direction Shown)

Fig. 22—Route Junction in One-Cable Facility