

TRANSMISSION AND OUTSIDE PLANT DESIGN PROCEDURES
T1 DIGITAL LINE
CARRIER ENGINEERING

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1. GENERAL

1.01 This section gives a brief description of the T1 digital line providing design guidelines for a facility containing up to 50 repeater sections, and includes information on retrofitting T1 with T1D. The T1 digital line (Fig. 33, Page 97) is a digital transmission facility designed to operate at 1.544 Mb/s over two exchange grade cable pairs. The T1 digital line is used for transmitting data on 24 pulse code modulation (PCM) channels.

1.02 This section is being reissued for the following reasons:

- (a) Add the Digital Carrier Operation, Planning, and Engineering (DCOPE) computer program to Part 9 Span Line Powering Considerations.
- (b) Change T Carrier Restoration and Control Center (TRCC) to Facility Maintenance and Administration Center—Metropolitan (FMAC-M).
- (c) Simplify the formulas for L_d (design loss) and the formula for max loss in Part 7 by substituting L_T for $1+T$.
- (d) Add construction details on the 800-type apparatus case stub cables to Parts 7 and 8.
- (e) Add limits for electromechanical equipment to office cabling considerations in Parts 7 and 10.
- (f) Add double-letter code standard power repeaters to Parts 7 and 9 and Table AB, Page 96.

Revision arrows are used to emphasize the more significant changes.

1.03 It is possible to retrofit a T1 digital line with a T1D digital line. Since T1D retrofit has ad-

ministrative and engineering restrictions, the possibility of eventually retrofitting T1 to T1D should be considered. If necessary, Section 855-351-115 should be used to design the T1 digital line initially.

1.04 It is also possible to replace a T1 digital line with a T1C line. Since T1C has more stringent engineering rules, the possibility of eventual conversion to T1C should be considered. If necessary, Section 855-351-110 should be used to design the T1 line initially.

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

1.06 Table T, Page 88 provides a listing of all past standard screened cable codes together with the modified cable code (if Mfr Disc), and the recommended substitute (if Mfr Disc or NSLA). The present standard cable codes are listed in Table A.

1.07 The maintenance pair color coding scheme in all the standard cables follows that developed for MAT and ICOT cables. That is, the maintenance pairs have normal PIC color coding that is included in a white-red binder group if the number of maintenance pairs is less than 25. If the number of maintenance pairs is more than 25, half of the pairs will be included on each side of the screen in a white-red and orange black binder, respectively. In each binder the standard PIC color code beginning with white-blue is used. Typical core diagrams for some of the cable sizes are shown in Fig. 1.

1.08 It is strongly recommended that MAT or ICOT cables be used for all digital carrier transmis-

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

1.09 The first T1 repeaters were designed with all discrete components. Later repeaters used integrated circuit technology. A discrete component repeater is designed for use over a loss range of 31 ± 4 dB at 772 kHz, equivalent to about 6000 feet of 22-gauge, 0.083- μ F capacitance cable. The integrated circuit repeater will operate over a loss range of 7.5 dB to 35 dB. Cable design losses should be within these limits (see part 7B) to take into account pair loss variations and temperature variations.

1.10 A T1 line layout on either MAT, ICOT, or 22-gauge, 0.083- μ F/mile capacitance cable can be expected to have repeater locations fall at the normal loading points. The use of a single-gauge, single-size express cable, office-to-office, simplifies the engineering design and facilitates expansion in accordance with a long-range plan. With a mixture of gauges, the repeater spacing will depend on the sum of the transmission losses at 772 kHz for the various gauges of cable, plus junction losses. Repeater spacings will therefore be irregular and may not fall at loading points. With a mixture of sizes, it is difficult to ensure nonadjacent binder group separation for a normally spaced 1-cable span. If at all possible, mixed gauge repeater sections should be avoided. ***In no case should MAT or ICOT cable be mixed with paper, pulp, or standard capacitance PIC cable.***

2. DIGITAL LINE OPERATION

2.01 The T1 digital lines provide a means of sending digitally encoded signals at a rate of 1,544,000 bipolar pulse positions per second (Fig. 2). When used with D-type channel banks as terminals, the T1 signal carries the signaling and voiceband information for 24 time-division multiplexed pulse code modulation (PCM) message channels, including pulses interleaved for facility framing. The identity of individual channels is restored only at a terminal. T1 data terminals for data and facsimile transmission also utilize the T1 digital line.

2.02 Each digital line, when used to interconnect two terminals, consists of two cable pairs (one

pair for each direction of transmission) with the necessary repeaters. Repeaters are installed at a nominal spacing of 6000 feet for most types of cables and are powered over simplex paths on the same pairs used for pulse transmission. The details of repeater types, repeater spacing, application to outside cable plant, pair assignments, and other outside plant considerations are covered in subsequent parts of this section. Tables U, V, and W, Pages 89, 90, and 91 include specific information on repeaters for use in T1 line design. Refer to Section 365-200-101 for repeater description.

2.03 The line repeaters are plug-in units that consist of two regenerators and a common power supply. Thus, each repeater regenerates pulse signals for two cable pairs, which can be in the same cable or in separate cables. The repeaters are housed in apparatus cases which contain up to 25 repeaters. Bidirectional or unidirectional repeaters can be used in either 1-cable or 2-cable operation (see Fig. 34, Page 98). This results in four possible modes of operation. Two cable/bidirectional repeater operation (Fig. 34C, Page 98) is not recommended because of the complexity in apparatus case splicing. If bidirectional repeaters are used, each of the 25 repeaters in an apparatus case serves both directions of transmission; thereby accommodating 25 T1 lines per apparatus case. If unidirectional repeaters are used, two apparatus cases are required for both directions of transmission. Each repeater in an apparatus case is used for one direction of two T1 lines. The companion repeater for the other direction exists in a separate apparatus case. (See Part 6 for recommendations.)

2.04 All integrated circuit T1 line repeaters are designed to operate over a range from -40°F to $+185^{\circ}\text{F}$. For aerial cable operation in extremely hot temperatures, the number of discrete component repeaters that can be operated in a 468-type apparatus case is limited. The following conditions govern its use:

- (a) When the average annual maximum temperature for five consecutive years is ***100°F or less***, the 468A case with a full complement of repeaters is completely satisfactory for aerial installation.
- (b) At average annual maximum temperatures ***above 100°F***, the 468A case is satisfactory if repeater positions 6 to 10 and 16 to 20 are left open for cooling. As many as 15 repeaters may be

used in the remaining positions. This restriction is not applicable when using integrated circuit repeaters.

(c) The 468A case is satisfactory for operation at any ambient temperature up to 120°F when equipped with a full complement of low-power (238- or 239-type) repeaters.

Note: The average annual maximum temperature for a locality can be obtained from the nearest weather bureau station.

The 475-type apparatus case will operate with a full complement of standard- or low-power repeaters in aerial applications. The 809- and 819-type apparatus cases must be equipped with low-power repeaters.

3. TRANSMISSION OBJECTIVES

3.01 Pulses sent along the digital lines are regenerated at each repeater. That is, the repeater looks at each pulse position and decides whether a pulse is present. If the repeater decides that there is a pulse, it puts out a new pulse free of noise, distortion, or interference. Because of noisy incoming pulses, a small fraction of the pulses are incorrectly regenerated; ie, a pulse is sent out where none was present or vice versa. Notice that in the bipolar pulse train (Fig. 2), information is carried only in the presence or absence of a pulse in a given position and not in the pulse polarity. The fraction of transmitted pulse positions received in error is called the **error rate** for transmission between the specified end points.

3.02 For a T1 line between terminals, an error rate of 10^{-6} results in completely satisfactory voice transmission. Errors cause transients in the individual voice channels which, at this error rate, are not objectionable to the average listener. A rate of 10^{-5} results in acceptable voice transmission; however, audible clicks may become noticeable. To design for an error rate better than 10^{-6} is not economical because of the reduced repeater spacings or cable fill that would be required. However, if it is known that certain lines may require a better error rate, this can usually be met by line selection. Section 855-351-102 gives the special engineering and development considerations for these lines.

3.03 The T1 engineering rules are derived from a terminal-to-terminal line design objective

that at least 95 percent of properly engineered and installed lines will have an error rate less than 10^{-6} . Studies have shown that an appropriate method for guaranteeing this objective is to engineer each section such that the probability of a line achieving a 10^{-6} error rate due to one section alone is less than $.05/N$ where N is the total number of repeater sections in the overall system, terminal-to-terminal. In the engineering rules that follow, N is a maximum of 50 repeaters.

3.04 The T1 repeaters operate by detecting the presence or absence of pulses after they have been transmitted along the line. The rectangular pulses generated by the repeaters are at a fixed level of 3 or 6 volts (see Fig. 2) peak-to-base and have a width of 0.324 microsecond. After these pulses are transmitted over approximately 6000 feet of 22 gauge standard capacitance cable, their shape is highly distorted. Equalization in the repeater restores the pulse shape sufficiently to permit detection and regeneration. The degree to which equalization matches the attenuation-versus-frequency and phase-versus-frequency characteristics of the cable pairs, from a few kilohertz to about one megahertz, determines the quality of transmission.

3.05 Due to differences in cable characteristics, MAT and ICOT cables require equalization different from standard capacitance cable. Refer to Tables U and W, Pages 89 and 91 for the appropriate MAT and ICOT cable repeater codes.

4. REPEATERS AND REPEATER BAYS

A. Line Repeaters

4.01 The line repeater codes used in original T1 installations have been replaced by new designs. All line repeaters have two regenerators and a common power supply. (See Tables U and V, Pages 89 and 90.)

4.02 For pulp cable, the maximum line repeater spacing is 6200 feet on 0.083 μF capacitance, 22-gauge copper cable; for MAT cable, the spacing is 6100 feet on 0.064- μF capacitance, 25-gauge copper cable. For ICOT cable, the spacing is 8700 feet on 0.052 μF capacitance, 24-gauge copper cable. The nominal spacing between an office repeater and the first line repeater is 3000 feet \pm 1500 feet. Between central offices, the repeaters are in apparatus cases located in manholes or on poles. The apparatus cases

are designed to mount 25 repeaters (475-, 818-, and 819-type cases) or 12 repeaters (809- type cases), each repeater containing 2 regenerators.

4.03 Bidirectional repeaters are used in a line which provides transmission in both directions in the same apparatus case. Unidirectional repeaters are used in a line which provides one direction of transmission in each apparatus case. One- or two-cable operation is possible in either situation. However, two-cable operation with bidirectional line repeaters is not recommended because of the complex apparatus case splicing.

201- and 205-Type Repeaters (MD)

4.04 The 201-type repeaters are designed for use in 466-type apparatus cases. The 205-type repeaters are used in 468-type cases and are equipped with secondary surge protection networks.

208- and 209-Type Repeaters

4.05 The 208- and 209-type line repeaters are significantly smaller than the 201 and 205 types and are designed for use in the 475-type apparatus case. The features of each code of the 208- and 209-types are given in Table U, Page 89. The 208 and 209 type repeaters are identical except that the 209 types have built-in secondary surge protection networks. The various codes of both types indicate whether the repeater is applicable to unidirectional or bidirectional repeater operation and whether power is fed through or looped at the repeater. Some repeater codes have fault-locate outputs for the two regenerators that are brought out separately for some active fault-locate systems.

4.06 The 208- and 209-type repeaters are electrically compatible with the 201- and 205-type repeaters. The 208-type repeaters can be used in the 466-type apparatus case by mounting the repeaters in 215A adapters, which are the same size as 201-type repeaters. The 209-type repeaters can be used in the 468-type apparatus case by mounting the repeaters in 273A adapters. The 208- and 209-double-letter-code-type repeaters are built with the latest low-power technology, but they have the same voltage and current requirements as standard power repeaters. They offer the advantage of field adjustable options and improved immunity to 60-Hz induced current.

238- and 239-Type Repeaters

4.07 Low-power 238- and 239-type repeaters use less line current and have lower voltage drops

than standard power codes. These repeaters are designed for 475-, 809-, 818-, and 819-type apparatus cases. Low-power repeaters have field adjustable options and improved immunity to 60-Hz induced current. All features now available using the 208- and 209-type repeaters are also available from the low-power repeaters. See Table U, Page 89.



4.08 *Mixing of low-power (238 and 239) and standard-power (201 and 205 and 208 and 209) repeaters in the same apparatus case or on the same digital line is prohibited. Such mixing would lead to administration, maintenance, and operation problems.*

B. Office Repeater Bays and Office Repeaters

4.09 Central offices (COs) employing T1 digital lines are equipped with office repeater bays (ORBs). The available bays, including capacities and typical arrangements, are shown in Sections 801-523-150 (J98710 201 and 206 ORB) and 801-523-153 (J98725 T1C/T1 ORB). These bays provide space for office repeaters and other CO equipment. Provision is made for order-wire panels, fuse and alarm panel, telephone set panel, fault-locate filter panels, equalizers, and plug-in resistors. Office repeaters used are identified as either office- or bridging-type repeaters. These repeaters provide power to the line, loop power at the office, or act as a bridge in the office.

J98710A Span-Terminating Assembly (STA)

4.10 Certain codes of 201- and 208-type line repeaters can be used in STAs as office repeaters. These line repeaters must be unidirectional with loop power. See Tables U and V, Pages 89 and 90 for specific codes that meet these requirements.

4.11 The J98710A1, List 5 and List 6 STAs include the artificial lines as standard equipment. Older STAs include a 3-dB pad instead of an artificial line. This feature can be added by replacing the 3-dB pads (ED-97079-30, G4) in the J98710A1, List 1 and List 4 STAs with the 100-ohm artificial lines (ED-97079-30, G5). If a 3-dB pad is replaced by a 100-ohm artificial line in a working facility using discrete component repeaters, the 836-type build-out network at the first line repeater location from the office should be reduced by two lettered steps (eg, from D to B) to compensate for the change in the insertion

loss of the network in the office. A more precise adjustment can be ensured by making a pair loss measurement from the first line repeater location to the ORB. ***If an integrated circuit type repeater (see Table U, Page 89) is used in the first line repeater location out of the office, no change is necessary*** since the repeater automatically compensates for the difference in insertion loss.

J98710J, K, and L Office Repeater Bays (206 ORBs)

4.12 The 206- and 236-type office repeaters used in the 206 ORBs offer several advantages over the repeaters used in the STAs: complete span line termination, single regenerator, access jacks for incoming and outgoing lines, and in some codes, a constant current regulator for powering the line. Some 236-type repeaters operate at either 60 mA or 140 mA and replace the 206 repeaters. (See Table W, Page 91.)

4.13 The constant current regulator in certain office repeaters (see Table W, Page 91) provides approximately 60 mA or 140 mA to develop the operating voltage of the line repeaters. The line current remains constant over the range of load resistance specified in Part 9. Line-powering voltage capabilities are shown in Table W, Page 91. Choice of regulator and line voltage depends upon cable length and the number of repeaters in the power loop (see Part 9). The 206- and 236-type repeaters have a regenerator on the receiving side and a passive network on the transmitting side.

4.14 All 206- and 236-type repeaters have either artificial lines or flat loss pads at the input to the regenerating side and output of the passive side. See Tables V and W, Pages 90 and 91 for repeater codes and descriptions of artificial lines and pads. The artificial line network provides a frequency characteristic similar to the shaped loss of the cable. This characteristic requires the use of short end sections in the digital line. In addition, the artificial line provides current limiting for lightning surges and proper termination for the output of repeaters connected to short end sections.

4.15 The 100-ohm artificial line provides sufficient control of reflections from the first repeater out of the office so that no restriction need be imposed on the minimum length of the end section. Thus, very short end sections are feasible, and interfloor or interbuilding digital circuits can be en-

gineered where 180-foot maximum cross-connection distances are exceeded. If impulse noise is a problem, additional restrictions on the line design may apply. These restrictions are discussed in Part 7.

4.16 Near-end interference may dictate the use of 3-dB pads rather than the 100-ohm artificial lines. The 206- or 236-type repeaters are available with the 3-dB pad as listed in Tables V and W, Pages 90 and 91. ***To avoid level difference problems, the connecting cable pairs associated with the 3-dB pad and the 7.5-dB artificial line must be loaded in different splice groups.***

J98725A, B, and C DSX-Optional and J98725D, E, and F DSX-Dedicated Office Repeater Bays (T1C/T1 ORBs)

4.17 The 221- and 231-type office repeaters are used in the J98725 T1C/T1 ORB. This bay can be used for either T1, T1C or T1D operation. When used for T1 facilities, the bay requires 221- or 231-type repeaters. The 221-type repeaters are functionally equivalent to the 206-type repeaters and have the same features. However, the 221-type configuration does not include jacks as the repeaters are accessed at the DSX or at a separate jack field. The 231 repeaters replace the 221, and additional codes are provided for use with MAT and ICOT cable. All 221 and 231 codes are extended cross-connect package (EXCP) repeaters with 7.5/4.5-dB artificial lines. Equalizers for the 221- and 231-type repeaters are furnished in the shelf assembly of the ORB and are determined from Table B.

4.18 The T1C/T1 ORB has increased capacity over the 206 ORB and can accommodate eight or more shelves of repeaters. When used with a DSX, the dedicated bay can be equipped with up to 12 shelves of repeaters.

J98710U Express Office Repeater Panel (EORP)

4.19 When through lines are encountered in intermediate offices, the express office repeater panel (EORP) may be used. Though located in an office, its function is to regenerate through lines with a line repeater arrangement, and it is the equivalent of one apparatus case. Details of the EORP are found in Section 365-200-105. The repeater sections containing the EORP must be engineered as end sections. In addition, no mixing of lines from different apparatus cases is allowed at the EORP. Of equal importance is the need for uniform pair numbering on both sides of

the EORP; eg, if the pairs approaching the EORP are numbered 1 through 25 and 301 through 325, this numbering must be retained until the termination of the pairs in the T1 office repeater bay.

Extended Cross-Connect Package (EXCP) Repeaters

4.20 Extended cross-connect package (EXCP) repeaters are listed in Table W, Page 91. These repeaters have a 6-volt output and were developed to allow increased office cabling distances between the ORB and DSX-1, between ORBs, or between ORBs and channel banks. The EXCP repeaters are intended chiefly for retrofit use in applications where cross-connect restrictions have previously prohibited the use of DSX-1. (Refer to Section 855-350-105 for information on cross-connect restrictions.) ***If the EXCP repeaters are used, integrated circuit repeaters must be installed in the first apparatus case on the outgoing side of the facility.*** Each 206- and 236-type EXCP repeater must be equipped with a 983-type equalizer which mounts on the die-cast frame and connects to the printed wiring board using slip-on connectors. Equalizers for the 206- and 236-type EXCP repeaters are furnished in the repeater. The equalizer codes are determined from Table C.

5. SPANS

A. Span Concept

5.01 A span line is a string of regenerators from the DSX-1 or the ORB in one office to the DSX-1 or ORB in another office with no intervening ORBs. The sum of all span lines between two CO buildings is called the **span** between these buildings. The DSX-1 patch and cross-connect panels or ORBs may be used to monitor and route the span outputs and inputs at any location. Refer to Section 855-350-105 or Section 855-350-106 for DSX-1 capabilities. The jacks at the repeater output or DSX-1 are at a standard level point. The output of a span line may be connected to DS1 level equipment in the office or to any span line going out of the office. Span lines may be in different cable sheaths and lie along different geographical routes. For administration, the span line is a convenient unit since all span lines from one office to another are, for all practical purposes, indistinguishable. For example, any span line from one office to another office may act as a maintenance or backbone line for any other span line between those offices in the same direction. The selection of routes and spans is part of the formulation of the

general trunk plan. ***A long-range estimate of the expected cross section of each span should be made before applying any of the given line engineering procedures.***

5.02 The basic engineering of the T1 facility for the T1 digital line can be reduced to designing an individual span. The span concept is shown in Fig. 3. This provides an administrative unit for assignment, maintenance, powering, and provision of maintenance lines. The span concept makes it possible to provide maintenance lines, order wire, and fault location on a span basis without regard to the terminal location. The design of the span line is independent of the facility of which it is to be a part, so that the design is reduced to individual spans. Spans are engineered in minimum blocks of 25 two-way lines for bidirectional repeater operation and 50 one-way lines for unidirectional repeater operation to match the capacity of the apparatus case.

5.03 Span lines may be connected in tandem to the current limit of 50 repeater sections. Facility lengths in excess of 50 repeater sections become increasingly difficult to maintain and should not be designed without some form of controlled maintenance plan, such as a Facility Maintenance and Administration Center—Metropolitan (FMAC-M). Lines in excess of 50 repeater sections should be engineered per Section 855-351-200 in order to insure meeting the error rate objective. Span lines may be rerouted and interchanged between terminals at the DSX-1, or at the ORB if there is no DSX-1, to respond to failures or changes in traffic requirements. Because of the zero-loss characteristic of the span line, it is much less important for a trunk route to be the shortest distance between two terminals than it is for voice-frequency (VF) cable. This feature may produce a considerable reduction in the total spans required to make up a metropolitan trunk network. Also, in connection with substitution and rearrangement of span lines between terminals, no changes in lineup or adjustments are necessary. However, when more than one facility exists between two terminal points, diverse routing is recommended.

5.04 In the initial span layout, the long-range plan for the route should be considered. In order to derive the greatest economy for T1 facilities, the planning should be on the basis of an entire metropolitan area. An economic study should be made by comparing cable plans for the entire metropolitan area versus carrier plans for the same area. If an in-

intermediate office has several through-connected lines, the use of an EORP should be considered (see Section 365-200-105). If an intermediate office is to have terminals or is to be a junction point with other span lines in the future, initially providing the ORB will simplify rearrangements. **Also, if four or more ORBs are contemplated or installed, a DSX-1 bay will be required and must be installed when the first ORB is installed in a new office. An office with four or more ORBs without a DSX-1 will be considered nonstandard.** Initial installation of DSX-1 may avoid a costly retrofit later and may result in improved cross-connection flexibility and maintenance.

B. Span Engineering

5.05 It is important to consider long-range plans for the use of T1 digital lines in the area before starting to lay out a span. The selection of bidirectional or unidirectional repeater operation, one cable or two cable, locations for the repeaters, and repeater section length will depend on future requirements in the route. All facilities that will use the span must be considered, regardless of the terminal locations. Also, the facilities available for T1 development must be carefully studied. These considerations include the number, type, age, and condition of cables; frame-to-frame termination and uniformity (size and gauge); freedom from branch and Y arrangements; adequate information on splicing integrity for 1-cable applications; suitability of locations for installing apparatus cases; and minimum exposure to electrical and mechanical hazards. These considerations are covered in detail in Part 8.

5.06 The factors that control the design of the digital line are as follows:

- (a) Interference from other T1 facilities
- (b) 772-kHz attenuation of the repeater section
- (c) Central office switching noise
- (d) Interference from induced alternating current (ac).

Interference from other T1 facilities occurs through the near-end crosstalk (NEXT) coupling path at a repeater location and controls the number of lines that may be operated in a single cable sheath. The 772-kHz attenuation determines the maximum re-

peater section length. While it is expected that repeater locations will generally follow the VF loading pattern, the type and gauge of cable available, the splicing arrangements, and the suitability of manholes will nevertheless have an effect. Central office switching noise is in the form of impulse noise and controls the length of repeater sections adjacent to the central office. Interference caused by induced ac current affects performance and may control the length of repeater sections. These factors are covered in detail in Part 7.

C. Communications Requirements

5.07 Adequate communications are essential to the proper maintenance and operation of a T1 facility. A working order wire must be provided for communication between repeater locations in a span and between any repeater location within a span and the DSX-1 or ORB at either end of the span. Order-wire engineering requires the use of Section 855-350-107. The order wire uses a loaded pair and has an appearance at each line repeater location in the span as well as the DSX-1 and ORB at each end of the span. The order wire is treated as a subscriber line in one of the span-terminating offices. In this way, the personnel can dial any number from the line repeater location and, in particular, call the testboard at either span-terminating office.

5.08 In addition to the order wire, all ORB or DSX-1 locations should have access to the switching network to establish contact with other offices when required. The ED-3C660 communications panel meets these needs and has several additional options that can be made available at the desired office bay. Up to seven lines are accessible through the ED-3C660 panel 10-button key with options such as a TOUCH-TONE® or rotary dial, remote headset jack, and a ringer. This panel occupies 2 inches on a 23-inch bay and may be connected to either line or trunk circuits or to 1A1 or 1A2 key telephone systems. Refer to Section 028-349-101 for installation and connection information.

D. Fault-Locate System

5.09 A properly engineered and working fault-locate system is essential to the maintenance of a T1 facility. To identify the location of a fault, a test signal from a fault-locate test set is applied to the line suspected of having trouble.

The signal is received by filters at a given repeater location and a tone is returned to the testing office on a fault-locate pair. The characteristics of the tone, as monitored in the office, determine the condition of the repeater section being interrogated. There are two types of fault-locate systems, active and passive. An active system employs active filters to amplify the return signals. Refer to Section 855-350-104 for an additional description of passive and active systems and fault-locate line engineering.

6. UNIDIRECTIONAL OR BIDIRECTIONAL REPEATER OPERATION

6.01 Digital lines may use a unidirectional or bidirectional mode of transmission. The four possible configurations are shown in Fig. 34, Page 98. The most prevalent operation is a single cable with bidirectional repeaters (Fig. 34A, Page 98) followed by two cables with unidirectional repeaters (Fig. 34D, Page 98). A digital line is not properly identified unless both the type of repeater and the cable arrangement are identified. Full-fill maximum length sections can be achieved with either two-cable or screened-cable operation. Two-cable bidirectional operation requires greater outside plant splicing complexity than the other three modes of operation. Therefore, 2-cable bidirectional operation is not recommended. Section 365-200-100 covers the various modes of line operation in detail.

6.02 The comparative advantages and costs of starting out with a one- or two-cable operation depend on the particular route. One-cable installation requires a knowledge of the cable (physical unit makeup and splicing integrity) to ensure physical separation of the two directions of transmission for control of near-end crosstalk (NEXT) coupling. NEXT coupling is discussed further in Part 7.

6.03 Unidirectional repeater installation requires the immediate installation of a pair of apparatus cases, one for each direction of transmission, but does not require a knowledge of sheath count integrity when operating in the 2-cable mode. This does not mean, however, that cable conditioning can be overlooked. Each repeater used in a unidirectional repeater installation serves one direction of two facilities. Thus, when a repeater is removed, it will affect two facilities. This is of small consequence for large installations, but it may be a factor for small initial installations. Note that when one side of a repeater fails, both sides must be patched to main-

tenance lines before the repeater is removed for repair. An office repeater in a span-terminating assembly (STA) is always shared by two facilities in which case two maintenance repeaters are required in each direction.

6.04 The decision to provide bidirectional or unidirectional repeater operation should be based on circuit requirements and the availability of suitable cables. First costs should not be the sole determining factor. Maintenance, reliability, and performance considerations as discussed in Part 3 should be of equal concern. Screened cable will permit the maximum number of T1 lines per sheath. Bidirectional operation should be considered first, using screened cable if fill is a deciding factor. Operation in this mode will permit full utilization of the cables for T1 Carrier use. On the other hand, a single 900-pair 22-gauge cable will provide separation of the two directions of transmission and will accommodate up to 200 facilities (4800 circuits) using only the outer binder groups and 300 facilities (7200 circuits) if the middle ring binder groups are used. This is usually adequate to care for circuit requirements for several years, except in the fast-growing route sections. No additional advantage in service continuity is obtained with 2-cable operation since disruption of one cable of a 2-cable arrangement will cause the loss of all circuits. Normally, it is expected that 2-cable operation will be employed in the large cross-section spans near large COs in the heart of metropolitan areas. A changeover to 1-cable operation can be implemented at a repeater bay location in outlying offices where cross-section requirements are reduced.

6.05 The advantages of using a bidirectional repeater operational mode are economy, less complex design for light T1 Carrier needs, and the ability to share the cable with VF. However, the rules for pair separation to prevent cross talk allow only partial fill for 1-cable nonscreened operation. Maximum fill approaching 100 percent is possible in a screened or 2-cable operation. Two-cable using unidirectional repeater operation mode has the advantage of providing economical maximum pair fill for areas that have large T1 Carrier requirements.

7. DIGITAL LINE DESIGN

A. Maximum and Minimum Cable Loss of a Repeater Section

7.01 There are two basic types of repeaters for use in the T1 digital line: the discrete component

and integrated circuit repeaters. The integrated circuit repeaters are further broken down into two types: standard and low power. Both type repeaters are available in either the protected or unprotected design. Integrated circuit repeaters have automatic line build-out (ALBO) and are designed to meet the same electrical performance requirements as the discrete component repeaters. All repeaters manufactured during the past several years are of the integrated circuit type.

7.02 Discrete component repeaters (Table V, Page 90) are designed to operate over a range of losses centered at 31 dB at 772 kHz. This is the optimum loss of the cable pair between the sending repeater and the input terminals of the receiving repeater. In practice, the loss is not always exactly 31 dB. To allow the use of cable sections of losses as low as 7.5 dB, an 836-type line build-out (LBO) network is installed in the input of each repeater. This makes the sum of the cable loss plus the LBO loss approach 31 dB. The LBO simulates the attenuation-versus-frequency characteristic of cable pairs in the T1 frequency band. As the repeater section loss (the sum of cable loss and LBO loss) departs from 31 dB, the signal-to-noise ratio required at the repeater input increases as shown in Fig. 4. To achieve the error rate objectives in Part 3 without requiring an unduly high signal-to-noise ratio, only 1-dB increase is allowed relative to the signal-to-noise ratio at 31-dB loss. Figure 4 shows that repeaters must operate over a range of 27 to 35 dB, or 31 ± 4 dB. Operation over a wider range is possible, but the fixed repeater equalization cannot accommodate the varying pulse shapes that result from too high or too low loss. At losses much higher or lower than 31 ± 4 dB, the repeater is unable to derive timing information from the incoming signal and ceases to operate properly.

7.03 Integrated circuit line repeaters (see Table U, Page 89) are designed to provide optimum performance at a cable loss of approximately 31 dB at 772 kHz. To allow use of cable sections of lower loss, an ALBO network is provided in each repeater. The ALBO network is analogous to the 836-type line build-out (LBO) network used in the discrete component repeaters. The ALBO simulates the attenuation-versus-frequency characteristic of the cable pairs in the T1 frequency band. As the cable loss changes, a regulator circuit in the repeater senses the change and automatically inserts the correct amount of shaped loss to make the sum of the cable loss and ALBO loss approach 31 dB. At cable losses greater

than 31 dB, the ALBO network is essentially ineffective; however, the repeater gain and equalization are adequate to permit operation to 35 dB of loss. Thus, the repeater is designed to provide satisfactory performance over a range of cable losses from 7.5 dB to 35 dB. Protected repeaters, when used at both ends of a repeater section, will provide satisfactory performance over a range of cable losses from 7.5 dB to 33.5 dB.

B. Cable Loss Values

7.04 It is imperative that the total insertion loss between repeaters in a T1 line be within the 35 dB maximum to 7.5 dB minimum equalization range. In order to guarantee this with varying temperature and pair loss, section lengths must be engineered for design losses greater than 7.5 dB and less than 35 dB by calculated amounts. The design loss can be converted to design length by dividing by the engineering loss.

$$\text{design length (kft)} = \frac{\text{design loss}}{\text{engineering loss}} \quad (1)$$

Table X, Page 92 lists engineering losses in dB/kft for the various cable types.

7.05 The minimum cable design loss is 9.0 dB for all sections except those terminating in an office repeater or EORP. If the terminating repeater is equipped with flat loss pads, then the minimum design loss is 6.0 dB. If the terminating repeater has an artificial line, then there is no restriction on the minimum design loss.

7.06 A summary of the maximum design loss, L_{d1} , for various Western Electric cables at standard maximum temperatures of 100°F and 140°F is given in Table X, Page 92. These cable losses apply to all repeater sections except those listed below:

- (a) For sections terminating in an office repeater or an EORP, L_{d1} must be reduced by 3 dB if the terminating repeater is equipped with a pad or 7.5 dB if it is equipped with an artificial line.
- (b) Also on end sections, losses of office wiring must be subtracted from L_{d1} . Losses of office cables are listed in Table D.
- (c) If protected repeaters are used at both ends of a section, the maximum design loss should be

reduced by 1.5 dB; when they are used only at one end, the loss should be reduced by 1.0 dB.

(d) When a repeater section contains a mixture of cable types, junction losses per Table E must be subtracted from L_{it} .

(e) If a section is limited by interference (cross-talk, office noise, or induced 60 Hz) to a loss less than that calculated from insertion loss considerations, this lower value of loss must be used for L_{it} . Most end sections will be limited by CO noise.

7.07 The maximum design *loss* after all factors have been considered can be converted to the maximum design *length* by dividing by the *engineering loss*.

$$L_{max} = L_{it} / \text{engineering loss} \quad (2)$$

The engineering loss of a cable type (see Table X, Page 92) is the specific value of the 772-kHz loss in dB per 1000 feet which represents the highest average loss likely to be encountered with that cable type. L_{it} is the maximum allowable loss for the *average* of all the pairs in a given cable, measured at 55°F. When a maximum length section is engineered, it is suggested that pair loss measurements be made before establishing the repeater locations. This will enable a change of repeater location to be made in case pair loss measurements show that the line is too long.

7.08 Maximum temperature of 100°F for underground and 140°F for aerial cable are not likely to be exceeded except in very special situations. Therefore, depending on local conditions, it may be desirable to compute new values of L_{it} for Table X, Page 92 using a lower value of maximum temperature. Paragraphs 7.09 and 7.10 describe this procedure. When considering temperature extremes, these extremes may not exist for the entire route. For instance, in some cities, steam is distributed through underground pipes and may cause temperature extremes in telephone cables that are in proximity. Since this condition is not likely to prevail throughout the repeater section (eg. 6000 feet) it would not be appropriate to apply the temperature correction for the entire distance.

7.09 The formulas to be used in finding L_{it} are different for PIC-type cables, which are color

coded, than for randomly spliced pulp or paper type cables. ♦For PIC cables use the following:

$$L_d = \frac{G_{max}}{2.33 \sigma_p + f_T} \quad (3)$$

Where

G_{max} = Repeater maximum range. Use 35 dB except for WP ICOT cable use 34.4 dB and for AIR ICOT cable use 34.15 dB. This takes into account the impedance mismatch loss when using 238- and 239-type repeaters on ICOT cable.

σ_p = Pair-to-pair loss standard deviation. See Table X, Page 92 for a summary of these. Note that, for example, 1.5 percent from Table X, Page 92 should be used as 0.015 in equation 3.

$$f_T = 1 + \left[\frac{T_C \Delta T}{10 \times \text{engineering loss}} \right]$$

T_C = temperature coefficient (from Table H)

ΔT = maximum or measured temperature (°F) - 55

Engineering losses are also given in Table X.

For pulp and paper type cables use the following:

$$L_d = \frac{G_{max}}{\frac{.25}{\text{engineering loss}} + f_T} \quad (4)$$

where G_{max} is 35 dB and values of f_T are listed in Table X, Page 92 for temperatures of 100° and 140°F. ♦To find values of f_T for other temperatures use linear interpolation between the given values of f_T and an f_T 55 value of 1.00.

♦Two other formulas are used to calculate L_{it} for part of a route exposed to relatively higher temperatures (paragraph 7.08). For PIC cables use the following:

$$L_d = \text{engineering loss} \times l_h \left[\frac{G_{\max} - \dots}{\dots} - \frac{\text{engineering loss} \times l_h (2.33 \sigma_p + f_{Th})}{(2.33 \sigma_p + f_T)} \right]$$

and for pulp and paper type cables use the following:

$$L_d = \text{engineering loss} \times l_h \left[\frac{G_{\max} - \dots}{\dots} - \frac{\text{engineering loss} \times l_h \left(\frac{.25}{\text{engineering loss}} + f_{Th} \right)}{\frac{.25}{\text{engineering loss}} + f_T} \right]$$

where l_h is the length of cable (in kft) exposed to the higher temperature and f_{Th} is the value for f_T at the higher temperature. ♦

7.10 Using equation 3 or 4 of paragraph 7.09 guarantees that the probability of any pair exceeding the maximum insertion loss is less than 1 or 2 percent under the worst case conditions of a maximum average capacitance cable and at the maximum temperature. An example of the use of these equations is given below.

Suppose you are engineering an underground WP ICOT cable installation in a northern state. Based on climatic data and/or observations of conductor temperatures, you have determined that the maximum cable temperature at the cable depth will be 70°F. Since this is a PIC-type cable, use equation 3 in paragraph 7.09. For WP ICOT cable, use $G_{\max} = 34.4$ dB. ♦ From Table X, Page 92 we get:

$$T_c = .04; \text{engineering loss} = 3.9; \sigma_p = 0.02$$

Calculate f_T

$$f_T = 1 + \left[\frac{.04 \times (70 - 55)}{10 \times 3.9} \right] = 1.0154$$

Calculate L_d

$$L_d = \frac{34.4}{2.33 \times .02 + 1.0154} = 32.39 \text{ dB}$$

Now, referring to paragraph 7.06, suppose no further restrictions apply. ♦ In other words, you are not dealing with end sections; you are not using protected repeaters; you do not have a mixture of cable types; and you do not have interference limitations. ♦ Under these conditions the maximum section length can be calculated as follows:

$$L_{\max} = \frac{32.39}{3.9} = 8.3 \text{ kft}$$

It is left to the outside plant engineer to determine how much to reduce L_{\max} to take into account any route map errors. ♦

C. Cable Acceptance

7.11 The following paragraphs apply to the methods of accepting cables and determining values of LBO networks when required. **Direct current (dc) testing for shorts, opens, crosses, and grounds should be done during cable acceptance.** When using integrated circuit repeaters, the same cable tests must be performed and the requirements are the same; however, there are no LBO networks to select since an ALBO network is provided in each repeater. The cable test readings also should be interpreted to ascertain the integrity of the cable pairs and whether they are within the prescribed loss limits. Pairs that can be used for discrete component repeaters can be used for integrated circuit repeaters.

7.12 Cable sections are laid out on the basis of engineering loss and then the losses are verified by measurements between repeater locations. Refer to Sections 103-493-100, 103-493-101, 103-494-104, 365-211-516, 365-211-517, 365-211-518, 640-525-220, 640-527-220, and 365-800-002 (TOP) for the specific test sets and pair loss tests. These measurements do not give the pair losses in dB directly. Rather, for each of the 25 pairs in one transmission direction, the LBO switch position (A1, A, B, . . . , M) and meter reading (- or +) are recorded by making a tally in one of the columns (A1-, A1+, A-, A+, . . . , M+) of Form E-6779, "113-type or J98725AA Pair Loss Test Set Data Sheet" (see Fig. 5). Each column corresponds to a range of losses in dB which is approximately ± 1.2 dB from the mean (Table F). Pair loss data obtained from using either a 113-type or J98725AA test set should appear in a pattern similar to the data on Fig.

5. When the J98725AA set is used at a 206 ORB with a 175 adapter, be sure that the reading taken plus the office repeater pad or artificial line loss does not exceed the LO column reading on Table F. **The required LBO network (836A, 836B, etc) is determined solely from the test set data and not from the calculated losses.** The loss calculated in Part 7B should, in most cases, be higher than the measured loss. **However, calculated loss must be compared to measured loss to ensure the validity of the readings, and any discrepancy must be investigated.**

7.13 The pair loss data, besides showing the LBOs required, are also used to ascertain those pairs which have loss deviations too far from the mean loss of the group of 25 pairs and thus must be corrected. For simplicity, the mean is identified as the lettered column of Form E-6779 (Fig. 5) containing the greatest number of tallies; as explained previously, each column actually represents a range of losses, as given in Table F. The mean consists of the two columns which make up one lettered (A, B, C, or D) LBO switch position. Pairs in the mean letter column as well as pairs in the half-column (- or +) on either side are acceptable, but pairs outside of this range are not acceptable for T1. For example, if the greatest number of tallies is in the C- half-column, pairs in the B+, C-, C+, and D- half-columns are acceptable, but others are not. **Pairs that are not acceptable should be investigated and corrected or replaced.** It is important to realize that, initially, for a small number of circuits, pairs out of the mean may work; however, as more facilities are added, marginal operation may be encountered. Defects may be the result of a load coil not having been removed, the presence of a stub cable, etc. If the defect cannot be corrected, then another pair should be substituted. This subject is covered in more detail in Part 8. The uniform 25-pair group count must be maintained since the apparatus case stubs are color coded accordingly. Also, in the case of a one-cable operation, it is important that all 100 pairs in the appropriate 100-pair sheath count group be made usable so that future additions of apparatus cases can progress in an orderly and efficient manner.

7.14 In the case of maximum loss sections (readings in column A1 of Form E-6779), temperature at the time of measurement should be considered when interpreting the measured pair loss. ♦ The measured pair loss should not exceed the following:

$$\text{max loss} = \frac{G_{\text{max}} \times f_{T\text{meas}}}{f_T}$$

Referring to paragraph 7.09, G_{max} is either 35, 34.4, or 34.15 dB. The $f_{T\text{meas}}$ is calculated using the equation for f_T and substituting the temperature at the time of measurement in computing ΔT . The f_T term is calculated using the maximum temperature. ♦

7.15 Two methods of assigning LBO networks from pair loss data are used. For underground and buried sections, the LBO code for **all 25 pairs** is chosen as the letter of the mean column of Form E-6779. In the example discussed in paragraph 7.13 where the greatest number of tallies is C-, pairs in the B+, C-, C+, and D- half-columns would all be built out with the 836C network, which has a nominal loss of 4.8 dB at 772 kHz. Since the pairs have a loss range of 23.8 dB to 28.6 dB, the range of pair plus build-out losses, taking account only of pair-to-pair deviations, is 28.6 dB to 33.4 dB, or 31 ± 2.4 dB for all built-out sections with LBO codes B, C, D, . . . , M. When the temperature variations are added, an overall range of 27.0 dB to 34.7 dB results. **For aerial sections, LBOs are chosen on an individual pair basis.** Thus, in the example above, pairs in the B+ half-column would use 836B networks, pairs in the C- and C+ half-columns would use 836C networks, and pairs in the D- half-column would use 836D networks. In this case the range of pair plus build-out losses is 31 ± 1.2 dB. When temporary variations are added, the resulting overall range is 27.1 dB to 34.6 dB. If LBOs were assigned in underground sections on a pair-by-pair basis, the spread of losses for built-out sections would be reduced to a 28.2 to 33.5 dB range. Experience has not shown this to be necessary, and it is not recommended because of the likelihood of errors and administrative problems.

D. Intersystem Interference—NEXT, Bidirectional Repeater Sections

7.16 For nonscreened one-cable lines, near-end crosstalk (NEXT) interference may limit the maximum section design loss to a value less than that calculated using equation (2) or Table X, Page 92. The following paragraphs give the procedure for calculating NEXT impact. In one-cable operation (Fig. 34A, Page 98) with pairs for both directions of transmission in the same sheath, the degree of NEXT interference depends on the number of lines, the repeater section loss, and the crosstalk properties of

the groups of cable pairs used for the two directions. Refer to the maximum design loss tables listed in paragraph 7.33. The following equation is used to find the **maximum section design loss, L_d , which is the maximum loss** for which a section can be designed based on NEXT interference only:

$$L_d = (m - \sigma - 32 - 10 \log n)/f_T \quad (5)$$

In equation (5), the crosstalk properties of the cable determine m and σ , which are the mean and standard deviation, respectively, of the pair-to-pair NEXT coupling loss distribution in dB at 772 kHz. Also, n is the ultimate number of lines expected, and f_T is a conversion factor for temperature. Values of f_T for the maximum temperatures in underground (or buried) cable and in aerial cable, 100°F and 140°F, respectively, are given in Table X, Page 92. Only the maximum temperature is significant here, because operation at reduced temperatures (relative to f_T) and the consequent lower losses reduce susceptibilities to crosstalk. Equation (5) is most often used to find L_d when the other quantities are known, but it is equally suited to finding the greatest number of lines, n , for a given design loss when m and σ are given, or the minimum required value of $m - \sigma$ when L_d and n are given, etc. **The constant term (-32) in equation (5) includes a 6-dB reduction in the value of L_d . This reduction, which makes the value of L_d conservatively low, accounts for**

- Variations in cable manufacturing and splicing arrangements
- The presence of additional interference from far-end crosstalk (FEXT) couplings among the pairs
- Crosstalk within the apparatus cases.

7.17 The values of m and σ to be used in equation (5) depend on the assignment of groups of pairs for the two transmission directions and are shown in Table Y, Page 93. Referring to the unit-type cable of Fig. 6, pairs for both directions may be in the same 100-pair splicing layer group, eg, count 401 through 500. This type of assignment is mentioned only as an illustration, since the repeater spacings required would, in general, be limited to distances too short for practical T1 layouts. Because NEXT coupling is related to physical separation, there is obviously a lower degree of NEXT coupling if the pairs for the two directions are in **adjacent**

100-pair layer groups; eg, one direction in count 401 through 500 and the other in count 501 through 600. An even lower degree of NEXT coupling would exist if groups 401 through 500 and 701 through 800 were used, because of the further physical separation of the groups in the cable. This is called **nonadjacent group assignment**. For T1 lines the presence of a screen reduces the level of NEXT coupling to an insignificant level. The angular position of the middle ring (count 51 through 350) with respect to the outer ring (count 351 through 900) is not constant. In the manufacturing process they may be displaced. Pair groups in the middle and outer rings will therefore be treated as potentially adjacent.

7.18 For various large count pulp-type cables (Fig. 35, Page 99), it has been verified that the rotation is limited making it possible to use selected binder groups in the middle ring with the following restrictions:

- (1) New facilities in the middle ring must use either 479-type apparatus cases, 800-type dual stub apparatus cases (limited to unidirectional operation), or 800-type quad screened stub apparatus cases (bidirectional or unidirectional operation).
- (2) New within-unit incidental junctions (segments of level difference between splices, see Fig. 7) must not be created in splicing the apparatus cases to the cable.
- (3) Any interstitial pairs used to replace defective pairs must conform to the rule of not being adjacent to binder groups bearing the opposite direction of transmission.
- (4) If the center binder group is used for any T Carrier, the middle ring binder groups cannot be used for T1 Carrier.

7.19 In addition to the restrictions in paragraph 7.18, the middle ring binder groups must be free of splicing defects, stubs, bridge taps and wandering pairs. It is also recommended that:

- All pairs to be ultimately used in the middle ring be spliced in initially or stubbed out to eliminate any need to reenter the main cables at some future date. The base unit (81A1-1H) of the 800-type apparatus case may be used for this purpose.
- The age of the cable must be considered when planning to utilize the middle binder groups.

The pulp insulation on older cables could be damaged during a splice reentry, resulting in failed facilities or defective pairs.

- Past history and maintenance of the cable must be investigated and those cables with poor maintenance history must be eliminated from consideration for middle ring T1 facilities.
- With the potential of using the middle binder groups of a cable, it becomes doubly important that binder group integrity be maintained through the full length of the sheath. If any doubt exists about the binder group integrity for a particular sheath, spot checks should be made (possibly at the repeater location or quarter points of the span to verify that binder groups used for T1 Carrier do in fact fall consistently in the sheath when they should.

7.20 Defective pairs in the large count pulp type cables should be replaced only by interstitial pairs adjacent to the count group with the T1-Carrier assignment. For example, assume T1-Carrier assignments in the shaded groups as shown in Fig. 6. Defective pairs in the 101 through 200 and 401 through 600 count should be replaced only by interstitial pairs 4 and 5. Defective pairs in the 251 through 350 and 701 through 900 count should be replaced only by interstitial pairs 1 and 2.

7.21 In a 900-pair layer cable (Fig. 8), an adjacent group assignment is, for example, counts 1 through 100 and 101 through 200 and a nonadjacent group assignment is counts 1 through 100 and 201 through 300. Notice that to be nonadjacent, groups must have no pairs in adjacent layers; for example, counts 1 through 400 and 501 through 900 do not qualify as nonadjacent and must be considered adjacent. Because of the concentric geometry of the layer cable, the near-end interference when more than 200 lines are installed is judged to be no worse than for 200. Therefore, if 400 lines are installed in counts 1 through 400 and 401 through 800, the maximum design loss is found from equation (5) in paragraph 7.16 using $n = 200$ and m and σ for adjacent groups (see Table G). If 300 facilities are installed in counts 1 through 300 and 501 through 800, the maximum design loss is found from equation (5) using $n = 200$ and m and σ for nonadjacent groups. Table H shows design loss versus number of facilities. This principle

also applies to layer cables of smaller size; eg, 600 pairs, in which more than 200 facilities are operated.

7.22 The cross-section configuration of 22-gauge, 900-pair, ADA pulp unit-type cables is shown in Fig. 6; Fig. 8 shows 900-pair, 22-gauge layer-type cables, but there are some variations. The MAT cable configuration of a 25-gauge, 1200-pair, 12-unit-type is shown in Fig. 9. The construction of various sizes, types, and gauges of cables is contained in the outside plant series of Bell System Practices in the 626-YYY-ZZZ division. This data should be referred to in all cases where pair separations are being considered.

7.23 The MAT and ICOT cables are screened for full-fill, single cable, T-Carrier operations and are available in sizes from 400 to 1800 pairs (MAT cable) and 50 to 900 pairs (ICOT cable). Extra pairs are included in these cables for use as substitutes for faulty or missing pairs on the same side of the screen. Also, additional units are included in MAT and ICOT cables to provide for regular T-Carrier maintenance pairs. The design of the MAT and ICOT cable multi-units reduces the far-end crosstalk (FEXT) at T1 frequencies which improves the noise margin allocation to NEXT for a single-cable operation of T Carrier.

7.24 In Table Y, Page 93, values of m and σ are given for various cables. The figures for smaller cables are based on measurements within units and between adjacent units of large cables. For example, if 1-cable operation in an ADA cable with 51 pairs is contemplated, the value of m cannot be assumed to be greater than 75 dB, as the given cable has all 51 pairs in a single core. Cables with nonstaggered pair twists are excluded from Table G because they have much poorer NEXT properties and **are not** suitable for T1 Carrier.

7.25 If data on a particular cable is not available in Table Y, Page 93, the value of $m - \sigma$ can be approximated by equation (6):

$$(m - \sigma)' = (m - \sigma) + 10 \log (k/L) \quad (6)$$

Where $(m - \sigma)'$ is the new value required for equation (5), k is the engineering loss in dB per 1000 feet for the cable in question as shown in Table X, Page 92, and L is the engineering loss of the nearest cable for which data is available. For example, for 24 BKM (24 PIC) $k = 5.8$, and the nearest cable type is 22 PIC for which $L = 4.6$ and $(m - \sigma) = 98$ (from Table Y, Page 93 for large 22 PIC nonadjacent unit separation). Therefore $(m - \sigma)' = 98 + 1 = 99$.

7.26 If a single cable section is made up of two segments of different cable types spliced together, it is advisable to secure equally good separation of pair groups in each segment. Otherwise, a penalty of a reduction in the maximum design loss is determined by the lesser value of $m - \sigma$ in equation (5) in paragraph 7.16. For example, in a segment of layer cable with adjacent group separation, the value of $m - \sigma$ from Table Y, Page 93 is $83 - 8 = 75$ dB. If this is spliced to a segment of unit cable with adjacent group separation ($m - \sigma = 90 - 9 = 81$ dB), then, in applying equation (5), the lesser number, 75 dB, is used for $m - \sigma$. In order that the maximum design loss not be limited by the properties of the layer cable segment, it is necessary to have nonadjacent group separation in it ($m - \sigma = 93 - 9 = 84$ dB). ***If segments of different cable types (excluding nonstaggered twist) occur more than 3 dB away from both repeater locations, their contribution to NEXT interference may be neglected.***

7.27 As an example of the use of equation (5) in paragraph 7.16, assume $n = 25$ lines and adjacent group separation of pairs in a large 22-gauge CSA cable. Thus:

$$L_{d1} = (m - \sigma - 32 - 10 \log n)/f_T$$

From Table Y, Page 93, $m = 90$ and $\sigma = 9$. From Table X, Page 92, $f_T 100 = 1.042$ and $f_T 140 = 1.078$. For underground or buried cable,

$$L_{d1} = (90 - 9 - 32 - 13.98)/1.042 = 33.6 \text{ dB}$$

and for aerial cable,

$$L_{d1} = (90 - 9 - 32 - 13.98)/1.078 = 32.5 \text{ dB}$$

Both of these values of L_{d1} exceed the maximum values of Table X, Page 92, so the latter are controlling in this instance. That is, 25 lines may be installed at the full spacing of 32.2 dB (6300 feet of CSA cable) for underground or buried lines, or 31.1 dB (6100 feet) for aerial lines. (In designing a maximum section, pair loss measurements should be made before installing apparatus cases.) For $n = 50$ lines, the corresponding maximum design losses are $L_{d1} = 30.7$ dB (5970 feet), underground and buried, and $L_{d1} = 29.7$ dB (5820 feet), aerial. If it were possible to obtain nonadjacent group separation ($m = 103$ dB and $\sigma = 7$ dB), the maximum design loss L_{d1} calculated from equation (5) exceeds the maximum values of Table X, Page 92 for each

case discussed here, so that the limits of 32.2 dB and 31.1 dB prevail.

7.28 In some cases, the use of smaller size cables will be required. Some small even-count PIC cables are made up as shown in Fig. 10. In practice, one binder group is used for one direction of transmission and another binder group for the other direction (bidirectional repeater operation). In this case, NEXT is the prime limiting factor. From NEXT measurements on PIC cables, the mean and standard deviations (m and σ) were estimated for a 22-gauge, 50-pair PIC cable at 772 kHz. As shown in Table Y, Page 93 the estimated m and σ values are 77 and 9 dB for adjacent unit separation, 84 and 9 dB for nonadjacent unit separation, and 82 and 13 dB when three smaller units are used together to form a 25-pair group.

7.29 For nine (or fewer) lines, alternate splicing units can be chosen (eg, pairs 17 through 25 and pairs 42 through 50) and the crosstalk limit on maximum engineering loss would be 41 dB for one line and 32.1 dB for nine lines [equation (5) in paragraph 7.16]. Accordingly, there is no restriction in section length above that of the normal maximum of 32.2 dB (31.1 aerial) which applies for any kind of line section.

7.30 If more than nine lines (in a 50-pair cable) are required, it is necessary to use enough pairs so that some of the pairs will be in adjacent splicing units. Therefore, an m and σ of 82 and 13 dB should be used.

7.31 From equation (5) in paragraph 7.16, the range of 10 to 25 lines yields a range for L_{d1} of 26 to 22 dB, respectively. This limits the maximum length of digital line sections from 4800 feet to 5600 feet, respectively, of 22-gauge, BHA PIC cable. However, if 19-gauge, BHB PIC cable is used, then maximum section lengths of 6100 to 7300 feet are possible for 10 to 25 facilities.

7.32 The situation of 25 T1 facilities with one direction in each 25-pair binder group of a 50-pair cable is quite similar to that of 25 T1 facilities in a single 50-pair splicing group of a much larger cable. In the latter case, the m and σ are 75 and 10 dB, respectively.

7.33 Maximum design loss for adjacent and nonadjacent group separation is given in the following:

Adjacent Groups, Layer-Type Cables—Table G

Nonadjacent Groups, Layer-Type Cables—Table H

Nonadjacent Splicing Groups, Unit-Type Cables—Table I

Adjacent Splicing Groups, Unit-Type Cables—Table J.

These tables apply only to nonscreened cables larger than 200 pairs. When small cables are used, the maximum design loss must be calculated from equation (5) in paragraph 7.16, using Table Y, Page 93.

7.34 Certain underground bidirectional repeater sections will, for protection reasons, have a protected-type apparatus case at one end and an unprotected-type case at the other end. There will then be protection networks (protected repeaters), which add a flat loss of 0.5 dB at the input and 1.0 dB at the output of each regenerator, **at the protected end only**. The ratio of received signal to NEXT interference is reduced 1.0 dB at the unprotected end, relative to the ratio for a section with the same type of case (protected or unprotected) at both ends. Thus, the maximum design loss is 1.0 dB less than L_{d1} as given by equation (5) for values not exceeding 32.2 dB. In applying Tables G through J, values less than 32.2 dB should be reduced by 1.0 dB for this kind of section. For example, for 50 facilities and adjacent group splicing in a unit cable as discussed previously in paragraph 7.27, the maximum design loss is $30.7 - 1.0 = 29.7$ dB.

7.35 For the same reason as discussed in the preceding paragraph, the maximum design loss L_{d1} **includes** the loss of the 3-dB office repeater pad or 7.5-dB artificial line (206- and 236-type repeaters) or the 7.5/4.5 dB artificial line (221- and 231-type repeaters) in dealing with a bidirectional repeater section that terminates in an office repeater (an end section). For example, if the value of L_{d1} calculated from equation (5) in paragraph 7.16 is 28 dB, then the end section is limited to 25 dB of cable loss with 3-dB repeater pads or to 20.5 dB of cable loss with 7.5-dB artificial lines. **The cable loss is the sum of the outside cable and office wiring losses.** In all cases where equation (5) in paragraph 7.16 limits the average section loss, the average pair insertion loss measurements must reflect this limitation. Table F should be used to convert L_{d1} to a corresponding LBO reading. For example, if equation (5) results in $L_{d1} =$

25.5 dB, pairs with higher losses (C—...A—) cannot be used. The special case of a section that has office repeaters at both ends is discussed in paragraph 7.76. It should be noted that the maximum design loss L_{d1} is not the only criterion; CO noise (paragraph 7.70) may impose an additional restriction.

E. Measurement of NEXT Losses

7.36 If it becomes necessary to measure the NEXT losses in a cable section to ensure that the values stated in Table Y, Page 93 are realized, the measurements should be made on the section before any lines are placed in operation. An oscillator of very good frequency stability, such as the 56A oscillator, and a detector of good accuracy, such as the 37B transmission measuring set, are required. To ensure that reliable values of m and σ are found, **at least** 200 coupling losses must be measured. If, because of equipment limitations, measurements must be made at a frequency lower than 772 kHz, they may be corrected by adding $15 \log (772/f)$ from the measured mean crosstalk loss, where f is the frequency in kHz. A frequency of at least 500 kHz is desirable. **When measured values of m and σ are inserted in equation (5) in paragraph 7.16, the constant term in equation (5) is changed from -32 to -29 .**

F. Intersystem Interference—FEXT, Unidirectional Repeater Sections

7.37 Far-end interference among the lines in each cable repeater section potentially places an upper limit on the workable section loss when FEXT is considered. Just as in the case of NEXT, Part 7D, the critical factors are the number of facilities, the section loss, and the crosstalk properties of the cable. The equation that determines the maximum design loss is somewhat more complicated than equation (5) in paragraph 7.16 and does not lend itself to engineering calculations. When the detailed analysis is carried out, the section error rates are satisfactory with losses up to the maximum losses of Table X, Page 92. This analysis shows that the far-end couplings among the pairs in a unit (50 pairs for 22-gauge cable) are predominant. A value of mean equal-level far-end coupling loss, m_p , of 72 dB/mile at 772 kHz is used, which is typical of within-unit couplings in staggered-twist cables. Table K provides mean pair-to-pair loss using a standard deviation of 11 dB for all cable types.

7.38 Repeater sections for each direction in a unidirectional repeater span are separately engi-

neered. They may be of different gauge, size, and length and may use different repeater locations. It is technically possible to use pair complements in sheaths that follow different routes between offices, but this is usually undesirable from the standpoint of maintenance and administration because activation of a new facility for instance, will require visits to two separate line repeater locations for each repeater installation.

G. Splicing of Apparatus Cases to Main Cables

7.39 Frequently, it is necessary to splice a number of apparatus cases to a main cable at nearby points because of the mechanical limitations of splice closures in accommodating a large number of case stubs at one point. There is then a FEXT problem complicated by level difference in the short segments of the main cable between splices. For example, assume unidirectional repeater operation in a unit cable (Fig. 6) and two apparatus cases spliced into count 401 through 500. The common splicing practice in older cables was to treat this 100-pair count as a group, so it must be assumed that in each unit (401 through 450 and 451 through 500) there are pairs from both apparatus cases. A distance up to 10 feet would not introduce enough far-end interference to adversely affect line performance, even for maximum loss cables. Refer to Fig. 11. If separate 50-pair units were available for the two apparatus cases, the distance could be 40 feet. The older cables were seldom spliced in 50-pair units, but splicing practices revised in 1964 specified maintenance of unit integrity. When it is established that unit splicing integrity has been maintained, the 40-foot figure may be used.

7.40 Suppose that two apparatus cases have been spliced into count 401 through 500 (Fig. 6), as in the example in paragraph 7.39, and that two more cases are to be added. These will be spliced into a different group, eg, 501 through 600. The third and fourth cases must be as close to one another as the first and second; ie, there must be a multiple closure for two splices very close together. A splice closure for the third and fourth cases must be 60 feet or less from that for the first and second cases. It is apparent from this that the arrangement of the apparatus cases at splices requires careful planning to avoid FEXT problems as apparatus cases are added to provide additional circuits.

7.41 Although these examples have dealt with unidirectional repeater operation, the same re-

strictions apply in bidirectional repeater operation. For example, if 100 facilities are installed, using separate 100-pair groups for the two transmission directions, each group will contain pairs spliced to each of the four apparatus cases. Ideally, the stubs from all four cases should be at a single closure. In some situations this may not be possible; so if two splice closures must be used, they should not be more than 10 feet apart. If separate splicing groups in the main cable are used (eg, connecting two apparatus cases to one 50-pair group for each direction and connecting the other two apparatus cases to another 50-pair group for each direction), the spliced closures are in nonadjacent groups and may be separated by as much as 60 feet.

H. Apparatus Case Stub Cables

7.42 In all repeater sections, whether the main cable is operated in the one-cable or two-cable mode, the apparatus case stub cables are equivalent to short one-cable sections. To ensure that the section loss is not limited by NEXT interference in the stub cables, the stub length should be no longer than 40 feet. The standard stub cable, CA-2110, is of unit construction with 104 pairs of 22-gauge copper wire, insulated with polyvinyl chloride (PVC) over polyethylene (PE). This provides for four 25-pair units for repeater connections and four maintenance pairs. For details of stub cable CA-6032, 106-pair cable, refer to Section 640-525-212.

7.43 If it is necessary to extend a stub which is shorter than 40 feet, the extra length should be CA-2110 cable or equivalent. The extension must be spliced to the existing stub in a manner that preserves the unit separation that is standard in the stub, and the extra four pairs may be extended in any convenient way. An alternate method of extending the stub, although not recommended because it complicates splicing arrangements, is by separate cables for the two directions of transmission. In this case, there is no additional near-end interference because of the extension. The extra loss of the extension must be included in the calculations of loss for the related repeater sections. If the combined length of the apparatus case stub and the extensions exceeds 40 feet, another alternative (not recommended because of splicing arrangement complications) is to use a unit-type, pulp-insulated 22-gauge cable of large enough size so that nonadjacent units can be selected for the two directions of transmission. A third method of extending the stub is to use 104-pair or larger screened cable.

7.44 ♦The 818- and 819-type repeater cases are equipped with a 30-foot screened stub; the 809-type case has a 25-foot stub cable. If the standard stub length is not sufficient, the repeater cases may be special ordered from Western Electric with a longer stub cable. However, a special order is costly and should be avoided if possible. The screened construction of the stub will prevent cross talk in the additional length.♦

7.45 These considerations obviously restrict the use of longer stubs to reach an auxiliary manhole in large underground installations where space is unavailable in the main manhole for all the necessary apparatus cases. When an auxiliary manhole is employed to accommodate apparatus cases, the main cable should be looped through the auxiliary manhole so that the apparatus cases can be attached to it with short stubs and with minimum distances between splice closures (see Fig. 12). While there are alternatives as previously stated, the security of the circuits involved and facilitation of future expansion justify the extra expense of initially setting up the cable and apparatus cases in accordance with the ideal long-range plan. Other restrictions, arising from FEXT, on the spacing of apparatus case splices along a main cable were previously discussed.

I. Entrance and Tip Cables—Office Wiring

7.46 While the combining of T1 pairs from both directions of transmission in an entrance cable is inconsistent with recommendations that T1 cables be fully terminated frame-to-frame, there may be some situations where it is not practical to avoid such entrance cables. Suppose, for example, that there are two main cables, one with 100 facilities and the other with 200 facilities both operated in the one-cable bidirectional repeater mode, and that all 300-facilities are brought into a CO in a 600-pair entrance cable. Assume that the latter consists of 500 feet of 22-gauge DSA cable, underground. Adjacent group separation is the best that can be maintained in this size entrance cable, and it is assumed that the splice is arranged for this degree of separation. For this example, the NEXT in the entrance cable will limit the maximum end section loss as shown in the following paragraph.

7.47 If the mean NEXT loss for a particular cable is m dB for long sections (those with 10 dB loss or more), then the mean NEXT loss for short lengths is

$$m' = m + I \quad (7)$$

where

$$I = 10 \log [1/(1 - r^2)] \quad (8)$$

where

$$r = 10^{L/10} \quad (9)$$

m is the mean NEXT loss and L is the engineered cable insertion loss in dB. Therefore, if $m = 90$ dB and $L = 1.0$ dB:

$$m' = 90 + 10 \log [1/(1 - 10^{-2})]$$

$$m' = 90 + 4.3 = 94.3$$

If L (engineered loss) is known, the quantity I can be determined from Fig. 13 which shows I vs L . It is assumed that σ is the same for short sections as for long cable sections, but for **short sections, when using equation (5) in paragraph 7.16, substitute for m the value m'** , using the entrance cable loss example in paragraph 7.46. From Table X, Page 92, $L = 2.6$ (500 feet of DSA cable) and from Table Y, Page 93, $m = 90$ and $\sigma = 9$.

From Fig. 13 (I vs L) $I = 1.6$.

From equation (5), the maximum design loss, as limited by the entrance cable, is:

$$L_{ei} = m' - \sigma - 32 - 10 \log n / f_T$$

$$L_{ei} = (91.6 - 9 - 32 - 10 \log 300) / 1.042 = 24.8 \text{ dB}$$

Thus, the design loss of the end section for either the 100-facility cable or the 200-facility cable may not exceed 24.8 dB. This is a further restriction compared to the L_e shown in Table J for 100 or 200 facilities. As previously stated, the end section loss consists of the sum of the main cable loss, entrance cable loss (here, 2.6 dB), office wiring loss, and the 3-dB, 7.5-dB, or 4.5-dB loss of the office repeater pad or artificial line. Note particularly that the end section losses may be subject to further restrictions because of FEXT interference (Part 7F) and CO noise (Part 7L).

7.48 Some existing **tip cables**, between cable vault and main distributing frame, may be spliced to outside cables to contain both transmission directions. It is impractical, in general, to reterminate the outside cables to avoid this. In most cases, the tip cable lengths are short enough so that the resulting NEXT interference is insignificant. When new tip

cables are installed, it is advisable to arrange the vault splices so that the tip cables contain only one direction of transmission.

7.49 Office wiring, as shown in Fig. 14, should be installed specifically for T1 on the vertical side of a distributing frame (DF). If congestion is a problem, or if four or more ORBs are anticipated, the DF should be separate from the main distributing frame (MDF). Tip cable is run from the cable vault to the DF. Each direction of transmission is run in a separate ABAM or 600-type cable from the DF to the ORB. Heat coils are necessary on the DF when the cable requires protection; otherwise, they should be strapped out because their inadvertent removal would cause a loss of any pair involved. There should be no termination on the horizontal side of the frame. The separate DF for T1 lines may be on a different floor from the MDF.

7.50 Office wiring between the ORB and the DF should not be run above bays or a lineup for electromechanical or crossbar switching equipment. It should not be run in parallel (in the same rack) with power, ground, or interbay cabling for electromechanical equipment. If necessary, office wiring may be run once across (perpendicular to) an electromechanical bay lineup or cable run. If these limits are not observed, a high level of induced impulse noise may develop which will cause errors on the T-Carrier line.⚡

J. Route Junctions

7.51 A junction is formed where lines from two or more facilities enter a sheath at different levels. Figure 15, view A and view B, shows junctions of two-cable and one-cable facilities respectively. For simplicity, no through facilities from office A to office B are included. FEXT between the A to C lines and the B to C lines is the source of interference. Specifically, engineering limits arise because of FEXT in cable section 3 (Fig. 15A) and in the lines toward office C in cable section 9 (Fig. 15B).

7.52 Designing a junction into a span layout may not be in the best interests of the long-range plan. Suppose (see Fig. 15A as an example) that the cable route from office A to office B is along a main highway and that office C is a short distance from this route. There is a temptation to consolidate A to C and B to C facilities in cable sections 3 and 4, but this involves certain drawbacks. If more lines are

needed in the future from A to C or from B to C, they can be obtained only by reentering and rearranging splices at the junction. This presents hazards to the service and should therefore be avoided. Through facilities from A to B (in cable sections 1-2 and 5-6) further complicate the requirements of the junction layout and may seriously limit the selection of repeater locations on either side of the junction. In the situation described, it is preferable to have fully terminated cables suitable for T1 between offices A and C and between C and B, and thus obtain full flexibility in pair assignment. This is true even if a number of pairs in these cables are not immediately turned over for carrier use but are connected through or loaded for VF use. If, however, office C is some distance from the A to B route and relatively few pairs are available between the junction point and office C, a junction may be necessary. In this case it may still prove better in the long run to use separate sheaths for A to B facilities. The use of expedient arrangements will seriously impair the orderly expansion of T1 facilities and cause service interruptions.

7.53 The presence of a junction places limits on the difference in loss, $L_B - L_A$ (Fig. 15C) (assuming L_B is greater than L_A), in terms of the exposure section loss, L_c . To determine the maximum value of $L_B - L_A$ equation (10) is used:

$$L_B - L_{A(\text{MAX})} = m_F - H \quad (10)$$

7.54 In this equation, m_F is the mean equal-level FEXT loss in dB at 772 kHz between the A and B facilities in the exposure or L_c section, and H is a quantity that varies with the number of A facilities (n_A) and with the exposure section loss, L_c . (Refer to Table K for values of m_F .) The value of H is read from Fig. 16; note that n_A is a parameter in these figures. Figures 16A and 16B are based on the properties of 22-gauge cable but are applicable for all gauge cables. For example, suppose that in Fig. 15A, 200 A facilities and 400 B join in a 600-pair ADA pulp cable (cable section 3), and that $L_c = 18$ dB. Consider $m_F = 82$ dB, assuming that A and B pairs are in separate splicing groups in cable section 3. From Fig. 16B, for $L_c = 18$ dB and $n_A = 200$, $H = 66.0$ dB. Substituting in equation (10), $L_B - L_A = 16.0$ dB. That is, L_B may be 16.0 dB more than L_A . Of course, the total section losses $L_A + L_c$ and $L_B + L_c$ may not exceed the maximum losses of Table X, Page 92 and may be subject to further restrictions if the L_c is an end section.

7.55 Pursuing the same example, suppose that the A and B pairs are in the same splicing group

in the exposure section. Then the predominant FEXT is among the 50 pairs in a unit. If it is assumed that the **A** and **B** lines are completely mixed, so that each unit of the 600-pair ADA pulp cable contains 25 pairs of each kind, $n_A = 25$ and $m_F = 72$ dB. For $L_C = 18$ dB, Fig. 16B shows that $H = 60.3$ dB; equation (10) in paragraph 7.53 gives $L_B - L_A = 11.7$ dB. The allowable loss difference measured from the junction point of the nearest **A** and **B** repeaters is appreciably reduced compared to the above case because of the poorer FEXT situations.

7.56 In the single cable junction (Fig. 15B), the section losses $L_A + L_C$ and $L_B + L_C$ may not exceed the appropriate values of L_d from equation (5) in paragraph 7.16. Also the difference $L_B - L_A$ (assuming L_B is greater than L_A) is bounded by the maximum. To illustrate, suppose that cable section 7 (Fig. 15B) contains 100 facilities with adjacent splicing group separation and that cable section 8 contains 50 facilities, all in the same 100-pair splicing group. Assume further that the splicing at the junction point places the two directions of transmission in separate groups in cable section 9 but that it is impossible to achieve group separation of the A to C and B to C pairs; ie, they are mixed in the units of cable section 9. To complete the picture, assume that all of the cable is type DSA in underground ducts and that $L_C = 10$ dB.

7.57 In cable section 7, $n = 100$, $m = 90$ dB, and $\sigma = 9$ dB. Since $n = 150$ and the values of m and σ are the same in cable section 9, the maximum design loss L_d which limits $L_A + L_C$ is $(90 - 9 - 32 - 10 \log 150)/1.042 = 26.1$ dB. Since in the example $L_C = 10$ dB, L_A may not exceed 16.1 dB.

7.58 In cable section 8, $n = 50$, $m = 82$ dB, and $\sigma = 11$ dB. From equation (5), $L_d = (82 - 11 - 32 - 10 \log 50)/1.042 = 21.1$ dB. Since this value is less than that calculated for cable section 9, it is controlling, and $L_B + L_C$ must be less than 21.1 dB; thus, L_B may not exceed 11.1 dB.

7.59 Considering the restriction imposed by the junction, for cable section 9, $n = 25$ and $m_F = 63$ dB, because of the mixture of A to C and B to C pairs within units there. From Fig. 16B, $H = 58.2$ dB (for $L_C = 10$ dB). Inserting these values in equation (10) in paragraph 7.53, $m_F - H$ or $(L_B - L_A)$ maximum = $63 - 58.2$ dB. That is, $L_B - L_A$ may not be greater than 4.8 dB.

7.60 Putting the three limits together results in the lines shown in Fig. 17. The usable area of L_A

and L_B values consists of the points for which all three limits are satisfied simultaneously. If L_C were not fixed at 10 dB but were variable, it would be necessary to find the areas corresponding to that in Fig. 17 for various values of L_C and to select the desired layout from among them.

7.61 In either the one-cable or two-cable junction, if through facilities from A to B use pairs in the same sheaths as the A to C and B to C facilities, the number of restrictions on the junction layout is increased. In general, the allowable loss difference $L_B - L_A$ depends on L_C , $L_B - L_C$ on L_A , and $L_A - L_C$ on L_B . While the necessary limits can be found by a straightforward application of the same procedures used in the simpler examples, the calculations are involved and may require graphic aids such as Fig. 17. A detailed knowledge of the splicing group arrangements in all cable sections is necessary, and the placement of the splices in a manhole may present a space problem. Complications can be avoided by making the junction point a repeater location, thereby reducing level differences to zero; but this is usually impractical because of the limited space available at junction locations for the splices and apparatus cases that would be needed. Also, FEXT problems, introduced by complicated splicing arrangements, may limit the addition of more facilities.

7.62 In calculating losses L_A , L_B , and L_C around junctions such as those in Fig. 15, the 3-dB loss of an office repeater pad, 7.5-dB or 4.5-dB loss of the artificial line, as well as the office wiring loss, must be included if these losses contribute to the level difference of the sections that enter the junction. For example, if cable sections 5 and 6 (Fig. 15A) terminate in office repeaters that contain 7.5 dB artificial line in office B, then $L_B = L_C + L_o + 7.5$ where L_o = loss of cable section 6, and L_o = office wiring loss. If cable section 3, which is the exposure section, terminates in office repeaters in office C, the office repeater pads or artificial lines there have no effect on the junction calculations, and L_C = loss of cable section.

K. Junctions in Office Cables

7.63 Two general plans for interconnecting outside cables and office repeater bays (ORBs) are acceptable. In the first plan, cables intended for T1 Carrier use are terminated on the DF with trunks or subscriber loop cables. In the second plan, cables are terminated in a separate DF to reduce cable congestion.

7.64 The ABAM or 600-type cables are used to extend the outside plant facilities from the DF to the ORBs. Series 606B through 611B cables are color coded which should eliminate split pair problems in the office. Restrictions for office cable, given in this section, must be satisfied. The desired flexibility from digital line to digital line or from digital line to channel banks is obtained by placing cross-connections on the DSX-1 or on the ORB when DSX-1 is not provided. The provision of flexibility at the DSX-1 minimizes FEXT problems, since all facilities are at an equal level at this point. The DSX-1 **is required for carrier installations of four or more ORBs, or when ORBs appear in more than one lineup.** Otherwise, a cross-connect field is available for use between the ORB and the channel banks. The DSX-1 should be part of the T Carrier Maintenance Center (TCMC), if available. **Determination of DSX-1 requirements must be done at a very early stage in the engineering of a T1 facility.**

7.65 *Since the outside plant is arranged in 25-pair complements, these complements should be dedicated to a shelf pair of 25 repeaters on the ORB.* The office cables are arranged in fanning strips on the jumper side of the main or protector frame verticals and are tied down permanently as the base facilities are placed in use for T1 Carrier. The pairs in the base facility complement which have not been used for T1 Carrier can be used with 904A or 939A connectors on a nonloaded VF basis or on a loaded VF basis by the use of 180-type or 184-type plug-in coils in the repeater apparatus cases (see Part 8E).

7.66 If office wiring is installed so that **incoming** span lines at different levels (ie, lines from incoming repeaters with different end section losses) are in the same office cable, a restriction arises similar to that discussed in Part 7J. The permissible length of office cable is limited by the level difference of the facilities, according to equation (11):

$$D = m_{FK} - H \quad (11)$$

Here, D is the level difference in dB; m_{FK} is the mean equal-level far-end loss in dB at 772 kHz; and H takes into account the number of interfering facilities. Figure 18 shows values of H versus l_c , the length of office cable in feet. Figure 18 is similar to Fig. 16A. The only difference is that Fig. 16A is based on typical properties of outside cables; Fig. 18 is based on the properties

of office cable. In particular, a standard deviation of far-end losses of 11.2 dB is assumed for outside cables and 10 dB for office cable. The standard deviation enters into the calculation for H in a manner that is somewhat complicated, and the two sets of curves are not interchangeable. In office cables, the following values of m_{FK} are:

- (a) 70 dB for pairs within a 25-pair unit
- (b) 77 dB for pairs in separate 25-pair units.

Note: This mixing of levels within a cable is not recommended. The information in paragraphs 7.64, 7.65, and 7.66 is provided in case no other alternative exists.

7.67 For example, suppose that incoming pairs from two apparatus cases are mixed within an office cable so that a single unit contains a half-and-half mixture, ie, $n = 13$. From Fig. 18, $H = 60.7$ for 1000 feet of cable; thus, a level difference of $70 - 60.7 = 9.3$ dB may exist for this length.

7.68 As another example, suppose a 50-pair office cable has 25 facilities from each of two apparatus cases with unit integrity maintained. If the required level difference is 17 dB, from equation (11), H must be $77 - 17 = 60$ dB. As shown in Fig. 18, the maximum allowable cable length is 540 feet.

7.69 If office cables are connected to the span lines from the outside plant in such a way that each office cable contains lines from only one span, or from spans at equal levels, the above restriction does not apply. If it is necessary to mix levels, the length allowable may be increased by the use of separate cables containing fewer lines.

L. Interference From Central Office (CO) Noise

7.70 Sections near COs are subject to office noise. ♦The principal source of this noise is switching impulses from pairs in the same cable as the T1 pairs provided the limits of paragraph 7.50 have been observed. ♦Through NEXT or FEXT couplings in the cable, these pairs contribute noise to the T1 repeaters, the most serious effects of which occur in repeaters in the offices and in adjacent sections. The underlying guide in engineering these sections is that **the difference between the loss in the path by which the noise arrives at the repeater input,**

or noise path loss (NPL), and the cable loss incoming to the repeater must be at least 52 dB. The calculation of these losses is clarified by the examples below. Figure 19A shows the incoming T1 pair in a simple entrance section. Noise reaches the office repeater via path **A**. This secondary induction is expected to be much greater than any direct induction noise within the office, because carrier pairs and switched VF pairs do not appear in the same sheath inside the office as they do in the outside plant. Thus, the effect of office noise on an incoming office repeater is estimated by:

- imaging the noise source to be at the main frame termination of the switched pairs and by
- calculating the NPL and the cable loss at this point.

A conservative value for the NPL, the NEXT loss of path **A**, is the mean within-unit loss (Table Y, Page 93), 75 dB, for a 22-gauge pulp insulated cable of 200 or more pairs and 50 pairs per unit. The cable loss in the first section out of the office is L_1 , so $75 - L_1 \geq 52$, or $L_1 \leq 23$ dB. For the first regenerator outside the office, $NPL = L_1 + 75$, and the requirement is that $L_1 + 75 - L_2 \geq 52$, or $L_2 \leq L_1 + 23$, where L_2 is the loss of the second section out of the office. Note that L_2 is not limited by this inequality unless L_1 is less than 9.2 dB or 8.1 dB for underground or aerial sections, respectively, because L_2 is subject to the maximum loss restriction of Part 7A.

7.71 Incoming repeater sections farther from the office are not restricted by office noise considerations, nor are any outgoing sections in unidirectional repeater operation. (In bidirectional repeater operation, repeaters for both transmission directions are always at the same point.) For incoming sections beyond the L_2 section of Fig. 19A, this is evident when considering, for example, the inequality for the next section with $NPL = L_1 + L_2 + 75$: namely, $L_1 + L_2 + 75 - L' \geq 52$, where L' is the section loss. Thus, $L' \leq 23 + L_1 + L_2$, and no limitation on L' results because $L_1 + L_2$ must be at least 15 dB. For the first outgoing section, suppose the equal-level, far-end crosstalk loss in dB at 772 kHz is L_F , and the section loss is L' . Then $NPL = L_F + L'$, and the requirement is simply that $L_F + L' - L' \geq 52$ or $L_F \geq 52$, a value which is exceeded even for a 6000-foot section of 22-gauge cable.

7.72 In Fig. 19B, one direction of T1 transmission is shown in an arrangement where the T1 lines

do not enter the office but are exposed to distributing pairs which do enter the office. For the repeater subject to noise via path **C**, $NPL = L_F + L_n$, where L_F is the mean equal-level FEXT coupling loss at 772 kHz in the cable between points **X** and **Y**. As an estimate, use equation (12):

$$L_F = 101 - 10 \log d \quad (12)$$

where d is the distance between **X** and **Y** in feet; for example, if $d = 2000$ feet, L_F is about 68 dB. Then $L_n + 68 - L_1 \geq 52$, or $L_1 \leq L_n + 16$. For the repeater subject to noise via near-end path **D**, $NPL = L_r + 75$, and the requirement is $L_r + 75 - L_3 \geq 52$, or $L_3 \geq L_r + 23$. For bidirectional repeater operation with oppositely directed repeaters at the same points, as in Fig. 19B, a similar set of inequalities applies, relating to noise paths not shown in the figure.

7.73 A third arrangement is that of Fig. 19C, in which the T1 lines are cross-connected at the DF or MDF. For noise path **E**, $NPL = L_n + L_F$, where L_F is the far-end loss in the L_n section. The requirement is that $L_n + L_F - (L_n + L_{10}) \geq 52$, or $L_F - L_{10} \geq 52$; if the disturbed repeater is 2000 feet from the office (measured along the cable), $L_{10} \leq 16$ dB. The inequalities for the other direction of transmission in bidirectional repeater operation are found similarly.

7.74 All previous examples are worked out with the assumption that the noisy pairs are closely coupled to the T1 pairs. If this is not the case, the value of NPL is increased, with a corresponding relaxation of the design limits for L_1 , L_2 , etc. Specifically, if the switched pairs in Fig. 19A are in a splicing group that does not enter the office but is cross-connected at the DF or MDF, then NPL for path **A** is increased by 10 dB, and the limit would be $L_1 \leq 33$ dB. As L_1 may not exceed the maximum values of Part 3, it may be concluded that CO noise is not limiting. A similar increase in NPL applies to Fig. 19A, if an entire 50-pair unit or other splicing group is initially equipped for T1 and group integrity is maintained, at least in the end section. In Fig. 19B an increase of 10 dB in NPL for paths **C** and **D** is realized if the VF pairs in the T1 splicing group do not enter the office.

7.75 As stated, the amount of noise directly induced into T1 lines within the office is judged to be small relative to that from secondary induction, provided the limits of paragraph 7.50 are observed. Nevertheless, metallicly shielded wiring is required

in the office since it is difficult to measure or predict the exact amount of direct induction. Cabling between the DF or MDF and ORBs should be separated from N carrier cables by at least six inches to avoid interference in T1 office wiring. Special cable racks or hangers are not necessary.

7.76 Two special layouts involving end sections are shown in Fig. 20. Figure 20A shows a direct connection from one office repeater bay to another, with no intermediate repeater. In Fig. 20B, the span has only one intermediate repeater. The design limits, based on the procedures above and taking into account the other restrictions that apply, are given in the figure for the direction of transmission shown.

M. 60-Hz Induction Interference

7.77 The presence of induced 60-Hz (ac) can degrade the performance of T1 digital lines. The principal cause of the induced (ac) is unbalanced 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. Increasing the voltage across the line current regulator in the powering office repeater may, in some cases, offset the effects of the induced current. Standard power 201-, 205-, and some 208-, and 209-type line repeaters will tolerate up to 30 mA rms induced current only when the regulator voltage is increased to offset the induced current. Methods for increasing the regulator voltage are given in Part 9, Span Line Powering. Standard power 208 and 209 double-letter code and low-power 238 and 239 code line repeaters will tolerate up to 30 mA rms induced current with no regulator voltage adjustment. Levels of from 30- to 100-mA induced current can be tolerated but with some degradation in error rate performance which must be accounted for by the following line engineering rules.

7.78 In general, it is good practice to engineer T1 lines so that the induced current level does not exceed 30 mA rms. In the following paragraphs, a procedure is given for determining the minimum required radial separation between T1 cables and ac power lines so that the induced ac is limited to 30 mA. When it is not possible to design a T1 line in accordance with this minimum separation, paragraph 7.86 can be used to determine the actual induced current. ♦If the induced current is between 30- and 100-mA rms, standard-power double-letter code and low-power repeaters can be used, but the line engineering rules must be changed per paragraph 7.87. ♦ To use

the following procedure, an estimate of the rms unbalance current in the ac power line is required (consult the local power company).

7.79 Alternating current (ac) induction should be considered separately for each powering loop. The powering loop extends from the powering point to the first power-looping point. Where power lines are located at a roughly constant distance from the T1 route, Fig. 21 can be used in estimating the minimum required distance between the T1 cables and the power line to limit the induced ac to 30 milliamperes. It is assumed that the power line parallels the T1 line over the entire powering loop which is assumed to be 50 kilofeet in length. The earth resistivity is needed to use Fig. 21, 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.

7.80 Each of the correction factors discussed in paragraphs 7.82 and 7.84 is used successively, changing the effective unbalance current. After applying all factors, Fig. 21 is used.

7.81 To determine the minimum required separation to limit induced ac to 20 mA, multiply the rms unbalance current by 1.5. To limit the induced current to 10 mA, multiply by 3.0.

7.82 In Fig. 21, 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 of calculating shield factors. If the shield factor is known, the power line unbalance current should be multiplied by that factor. Shield factors rapidly approach 1.0 if poor grounds or bonds are present; a single faulty bond can cancel all shielding effects.

7.83 For powering loops of length other than 50 kilofeet, multiply the power line unbalance current by

$$(\ell/50 \text{ kft})^2$$

where ℓ is the actual length in kilofeet.

7.84 Where power line exposure exists over only a part of the powering loop, multiply the unbalanced current by the fraction of the loop exposed. In addition, if the exposure is not centered about the

midpoint of the powering loop, multiply the unbalanced current by the correction factor

$$2(\ell-c)/\ell$$

In this expression, ℓ is the powering-loop length and c is the distance from the powering point to the center of the exposure.

7.85 If the minimum permissible separation determined from Fig. 21 is impractical, induction can be reduced by installing additional shield conductors. Section 873-800-178 should be used to compute the shield factor. Alternatively, induction can be reduced by reducing the powering-loop length.

7.86 When the minimum separation determined in the previous paragraphs cannot be met, the following procedure can be used to determine the expected induced current level. By using Fig. 21 in reverse, determine the effective unbalance current that can be tolerated with the minimum separation attainable. Divide the actual effective unbalance current by this current to give the multiplication factor. The expected induced current will be 30 mA times this factor.

7.87 When low-power and standard power double-letter code repeaters are used in lines with more than 30 mA rms of induced current, the engineering rules must be modified. For lines with 30 mA to 60 mA, the degradation factor is 2 dB. For lines with 60 mA to 100 mA, the degradation factor is 3 dB. More than 100 mA cannot be tolerated as power dissipation in the repeater becomes excessive. The degradation factor must be applied to the design loss calculations made previously. The 60-Hz degradation factor must be subtracted from the L_{d1} calculated in equation (5). For the range of induced current levels where the performance degradation applies, increasing the regulator voltage is not an effective means of improving facility performance; therefore, power loop design for low-power facilities is not changed by the presence of induced currents.

8. OUTSIDE PLANT CONSIDERATIONS

A. Selection of Cables

8.01 The application of T1 Carrier to a cable is a relatively permanent undertaking, so considerable care must be taken in the selection of suitable base facilities. In making the selection, be aware that

this cable must be maintained in place for the next 20 to 40 years. ***Newer cable in good condition should be used since experience has indicated that old cable (due to rearrangements and/or age) is largely responsible for line troubles affecting performance and reliability.*** Select cables that:

- are known to be in good condition (consult cable maintenance record and discuss condition of cable with a representative of the construction and maintenance forces),
- have not experienced rearrangements and are free of split pairs,
- are not more than 25 years old (cables devoid of paraffin splices),
- extend from DF to DF,
- have no N Carrier in the sheath.

Keep in mind that bridge taps, build-out capacitors, load coils, and cable stubs are to be eliminated. Experience has indicated that older cables generally require splice rebuilding to maintain splice integrity in a single-cable T1 layout or to provide good conductors for future use. If splice rebuilding is necessary, ***all*** splices must be rebuilt ***before*** the first T1 installation. When planning T1 Carrier, this additional cost for establishing and maintaining T1 facilities in older cables must be considered as increased costs for the facilities. Depending upon whether one cable or two-cable operation is contemplated, it may be of considerable importance to know the splicing arrangement and the physical arrangement of the conductors within the cable. Desiccants have been used as a means for drying cables since about 1940. Cables placed prior to this time are likely to have paraffin-filled splices and lower insulation resistance which, with splices filled with plugging compound, may result in somewhat higher attenuation and impedance irregularities. This can cause marginal repeater operation if located near the repeater output. If an older cable is considered, its selection should be made jointly by transmission engineering, outside plant construction, and maintenance.

8.02 Where more than one cable route is available, the most permanent and accessible one should be chosen. Also, a very important consideration is

minimum exposure to hazards that might interrupt service continuity. Where two-cable operation is contemplated, it is desirable, but not essential, that the two cables follow the same route. When repeaters are at different locations, additional maintenance costs will be incurred. There is nothing to be gained through dispersion of routes for the two directions of transmission.

8.03 Since *many* facilities may be carried in the basic cable, it is worthwhile to examine all available cables closely, including their past maintenance history. Before establishment of T1 facilities, consideration should also be given to rearranging cables to obtain cables of uniform size and gauge fully terminated on a frame-to-frame basis. In addition, where one-cable operation is contemplated, this may include opening of splices at strategic locations to establish definitely the physical arrangement of conductors, splicing arrangement, and consistency of splicing.

8.04 With this in mind, *it should be recognized that rearrangements and work on cables which include carrier facilities are difficult and undesirable from the standpoint of service reliability.* Work prints should indicate where cable encompasses carrier lines and where carrier facilities are vulnerable to craft hazards.

8.05 Cables best suited to T1 Carrier are fully terminated at end CO and at intermediate COs in separate cable sheaths.

8.06 The practice of bringing the "in" and "out" counts of a cable into an intermediate CO in a single sheath of reduced gauge tends to complicate application of T1 Carrier. With such arrangements (for instance, bringing two 900-pair, 22-gauge cables into a CO with a single 1800-pair, 26-gauge cable), the carrier signals of the same direction of transmission (as well as those of opposite directions of transmission) will be at different levels within the same sheath; therefore, crosstalk problems will result. Also, reduced gauges will affect orderly and uniform repeater spacings. The subject of crosstalk in entrance cables is covered in Part 7.

8.07 Cables may be selected on an even-count or odd-count basis. Spans are engineered in minimum blocks of 25 two-way lines using bidirectional line repeaters and 50 one-way lines using unidirectional line repeaters. For one-cable bidirectional

repeater operation, even-count and selection of uniform 25-pair group counts are essential to provide the standard relationship between the pair count and the color-coded conductors of the apparatus case stub. On the other hand, two-cable or screened-cable operation makes possible full-fill on the cable, making odd-count cable desirable to furnish the necessary pairs for order wire and fault locating.

8.08 While application of T1 Carrier to underground cables in conduit predominates, T1 may also be applied to aerial and buried cables. With such cables, the problems of selection and suitability become more critical, because these cables are usually of smaller size and are more inconsistent than underground cables. With the smaller size cables, selection of pair counts that provide nonadjacent group separation for the two directions becomes more difficult, but it can be achieved in many situations. The PIC cables are especially suitable for bidirectional T1 Carrier facilities because the position of the conductors and the splicing arrangement are known. Also, the attenuation and change of attenuation characteristics with temperature variations are more favorable than with pulp-insulated cables. The PIC cables with PASP sheath should be pressurized if used for T1 facilities. *There must be complete assurance that such cables do not contain moisture because moisture changes the attenuation characteristics.* The PIC cables with alpeth or PAP sheath are not entirely impervious to moisture. Depending on the vapor pressure between the inside and the outside, moisture may diffuse through the sheath. The PASP sheath cables have a soldered steel barrier included in the multiple sheath which is impervious to moisture as long as continuity is maintained. Interbuilding and intercity trunk cables sometimes contain facilities for customer loops and therefore have distribution terminals and distribution cable branches. Such cables are not well suited to the application of T1 because they are subject to sheath openings for service connections and rearrangements. Their use for T1 is not completely ruled out, however. Even-count PIC cables are especially well suited for T1 because they are composed of units, and crosstalk between units is less than between pairs in the same unit. Even-count cables as small as 25 pairs may support up to eight T1 facilities with both directions of transmission in the same cable and with appropriately designed repeater spacing, as explained in Part 7.

8.09 Screened waterproof and air-core PIC cable for T1 digital lines will provide better results.

Requirements for NEXT isolation and maximum fill of all cables are both obtained by using screened PIC cable. Refer to Table L for available cables.

Note: It is recommended that MAT and ICOT cables be considered for all future T-Carrier cable routes.

8.10 Cables containing coaxial tubes for cable television distribution systems are not recommended for T1 because they are subject to many sheath openings for installing amplifiers, dividers, and couplers. Also, T1 digital line and N-Carrier Systems are not compatible in the same cable sheath.

8.11 Cables containing paired complements and coaxial tubes for educational television or other closed-circuit television operations and cables containing paired complements together with video pairs may, under some conditions, be suitable for T1 use. In general, cables containing paired complements large enough to ensure that splicing units selected for T1 **are not adjacent** to coaxial tubes or video pairs may be used successfully for T1. Compatibility cannot be ensured unless there is a layer of units or four layers of pairs between the T1 facilities and coaxial tubes or video pairs.

8.12 Since new trunk cables are continually being placed and existing ones are being rearranged, it is worthwhile to examine such additions and rearrangements for compatibility where future T1 digital line transmission is anticipated. Some considerations toward this end are as follows:

- Uniform size and gauge in each route section;
- Elimination of bridge taps and cable stubs (unterminated cable ends);
- Preferably, full termination at end and intermediate central offices;
- Advance planning for repeater locations and provision of adequate sheath and manhole space for apparatus cases where possible;
- Adding one or two apparatus cases at a time increases the maintenance costs for splicing. If apparatus cases are to be added in the future, it would be helpful to consider using 818- or 819-type apparatus case base units, then carrier housing can be added as needed.

Any assistance provided by the engineer on the work prints concerning the estimated future requirements

at the repeater locations will greatly reduce future splicing rearrangements and splice rebuilding. This will, in turn, reduce the possibility of future troubles.

B. Selection of Conductors

8.13 The T1 equipment is designed on the assumption that base facilities will be made available in groups of 25 pairs.



It is inadvisable to open exchange-type main cable splices repeatedly to unload and connect additional pairs. Pairs should be made available to provide growth for 2 to 5 years with a minimum of 50 pairs per cable per entry.

Thus, in a bidirectional repeater facility, a minimum of 25 pairs for each direction of transmission (total of 50 pairs) would be connected to apparatus cases during the initial installation. For a unidirectional repeater facility, a minimum of 50 pairs in each direction (total of 100 pairs) should be connected to the apparatus cases in the interest of minimum entrances into main cable splices. Repeated reentry into splices is a costly practice and degrades performance and reliability of existing lines.

8.14 It is recommended that pairs be selected in uniform 25-pair even-count groups; ie, with consecutive pair counts starting with 01, 26, 51, or 76. It is not impractical to select pairs at random or in small groups throughout a cable count. The problems of unloading, splicing, maintaining, and record keeping make such an arrangement unworkable.

8.15 Selection of pair counts is necessary for bidirectional repeater operation to provide separation of the directions of transmission. This is discussed further under the paragraphs on intersystem interference, Parts 7D and 7F.

8.16 Selection of pair counts for the long-range plan for T1 should be made with the initial installation for either the bidirectional or the unidirectional repeater plan. For unidirectional repeater operation with 22-gauge, 6000-foot repeater spacing, complete physical separation of the two directions of transmission must be maintained. This is necessary for both bidirectional and unidirectional repeater operation so that the long-range complement of conductors can be made available at splice points where

work is being done, and interference with working facilities will be minimized while new facilities are being added. Preparation of the splice in connection with the initial entry includes tagging and splicing out pairs, where appropriate, so the succeeding apparatus cases can be connected without additional pair identification and disturbance within the splice.

8.17 Actual cable counts should be the same as the sheath count. For instance, the count assigned to a 900-pair cable should be 1 through 900. Pairs assigned to T1 Carrier use should not be assigned to separate complement counts. The use of identical pair and sheath counts will help identify the physical position of the pairs within the cable. Section 901-350-510 contains a discussion of sheath counts and pair counts.

8.18 Any defective pairs (ie, pairs with shorts, opens, grounds, crosses, or substandard transmission) must be corrected so that the uniform 25-pair group count will be maintained. Any defective pair that is a matter of record and falls within the uniform 25-pair count will probably be in trouble in only one repeater section in the span complement. In this repeater section, the defect should be located and corrected. If the defective pair is in a section between splices, it should be interchanged with a good pair in the same splicing group or a good pair in another splicing group. The same procedure should be followed with pairs which fail the attenuation test. Instances of failure of the attenuation test because of irregularities in the cable itself will be rare. If such failures occur, it is probably because a load coil, a bridged pair, a stub cable, etc, was left connected. The condition should be located and corrected. Where one-cable bidirectional repeater operation is involved, it is advisable to select pairs for interchanging from different splicing groups for each direction of transmission. For instance, in a 900-unit type cable, and the middle binder units are not being used for T1 facilities, defective pairs in the 401 to 600 count may be interchanged with pairs in the 101 to 200 count and defective pairs in the 701 to 900 count may be interchanged with pairs in the 250 to 350 count. This procedure will reduce the possibility of adjacent pair crosstalk coupling. If the middle binder units (count 101 to 200 and 251 to 351) are being used for T1 facilities, defective pairs in the outer units must be corrected. Correction of defective pairs within their own splicing group is the best solution.

8.19 With two-cable operation, the problem of defective pairs is diminished since group separa-

tion is not required. An interchange of defective pairs must be worked out, however, so that the uniform 25-pair group count is maintained; otherwise, there will be no correlation between the pair count and color code in the apparatus case stub cables. In working to ensure uniform color count, potted splices should not be opened. If an interchange is required, a switch may be made at the cable side of the DF.

8.20 In the pulp-type coded cables, splicing instructions specify integrity of each binder group rather than a color group. Also, in these cables the interstitial extra pairs are in well-defined positions, thus making it relatively simple to work out a plan to care for defects in such a manner that complete separation of the two directions of transmission will be maintained.

Note: *Special consideration is required when assigning T1 Carrier on a large count cable, since it is possible to have T1C and T1 in the same cable. Refer to Fig. 22 for an example. See Section 855-351-110 for other cable sizes with combined T1 and T1C operation.*

C. Construction Details and Splicing Considerations

8.21 Bell System Practices (BSPs) specify that cables be spliced color group to like color group and layer to layer. These practices have been in existence for many years and it appears that, regardless of age, there should be splicing integrity in cables. Beginning in 1963, splicing practices have specified that pulp-insulated cables be spliced binder group to binder group, regardless of the size of the binder group. The PIC cables are color coded and are spliced pair to pair as well as binder group to binder group. Having selected a pair count, the conductors should then be found in a certain physical position within the cable. In some instances, the standard splicing arrangement may have been altered in cables that have been subjected to considerable rearrangement and direction of feed change. Since the physical arrangement of the conductors will be of special importance in one-cable operation, the integrity of the splicing arrangement must be established if there is any reason to believe that it does not conform to specifications. This can be accomplished best by consulting construction forces and having them inspect various splices.

8.22 *The digital line should be engineered so that no splices or pressure plugs are*

located within a range of more than 100 feet and less than 300 feet from the output of a repeater. Any serious impedance discontinuity within this critical range may cause marginal operation or failure. This is because a portion of the pulse transmitted through a discontinuity in the critical range is reflected back to the repeater during the beginning of the next time slot, which may cause the repeater output to misfire. The integrated circuit type repeaters are not as sensitive to impedance discontinuities as the older repeater types and therefore may be used if trouble exists or is expected. The details of repeater types, repeater spacing, application to outside cable plant, pair assignments, and other outside plant considerations are covered in subsequent parts of this section. Tables U and V, Pages 89 and 90 includes specific information on line repeaters available for use in T1 line design.

8.23 Defective cable pairs in existing cables are sometimes made good by cross-splicing between units in unit cable or between color groups in layer cables. Such pairs are sometimes referred to as "wandering" pairs. If these pairs wander into a group which is used for the opposite direction of transmission for T1 Carrier, a "within unit" crosstalk coupling would exist and excessive interference might occur in any T1 facility using the wandering pair. This is of importance in one-cable operation near repeaters where level differences between the two directions of transmission are high. No trouble is anticipated where sections containing wandering pairs are more than 7 dB (about 1400 feet of 22-gauge, 0.083- μ F capacitance cable) at 772 kHz from the repeater because the pulses will be attenuated and level differences diminished.

8.24 If a wandering pair exists in the groups of pairs to be used for T1 in the section on either side of the repeater, it should be noted by the splicer when connecting the apparatus case. If such a condition is found, this pair must be interchanged with a pair "in group" in this repeater section. If a wandering pair exists within 7 dB of a repeater, and yet is not "out of group" in splices which are entered while connecting the apparatus cases, faulty operation of the carrier facility may occur. It will then be necessary to locate and correct the wandering pair. Interchanging the wandering pair for a good "within group" pair may require opening one or more splices between repeaters to make the correction. If it is not possible to make this correction because of a section defect, the change should then be made with a pair

which is in a group that will not be used for T1 Carrier. Experience has shown that, even if there are only a few wandering pairs in a repeater section, the cable as a whole becomes very expensive to establish and maintain as a T1 facility.

8.25 A simple attenuation measurement may be made between adjacent apparatus cases when they are installed to verify the suitability of the installation in each repeater section as well as to determine the required build-out. These tests can be made between apparatus cases and before splices are closed so that reopening of splices to correct unsuitable pairs can be avoided.

D. Apparatus Case Installations

8.26 The question of physical and splicing arrangement of the cables, together with that of man-hole space and arrangement, should be given very careful consideration before installing the first T1 facility. The probable ultimate arrangement should be planned and made a matter of record. ***Line man-holes used initially should have the capacity to accommodate the ultimate number of cases for a given span.*** The initial installation should be in accordance with this ultimate plan.

8.27 Apparatus cases for T1 Carrier are available as listed in Tables U and V, Pages 89 and 90 and further identified by Fig. 23, 24, 25, and 26. The case selected for a line will be dictated by the specific requirements of an installation. Considerations for apparatus case selection should include growth possibilities to reduce the future need for replacement.

8.28 The application of all T1 repeaters in underground cable not subject to lightning surges is one of the first uses of electronic equipment in the outside plant environment without special surge protection. The repeater has been designed to withstand the following:

- ***Metallic: Pulse with 10 microseconds of rise time, 30-volt peak, and exponential decay to one-half peak in 1000 microseconds.***
- ***Longitudinal: Pulse with 10 microseconds of rise time, 600-volt peak, and exponential decay to one-half peak in 1000 microseconds.***

Where higher surges are expected, special protective devices must be provided. The 468-type, 475B, 475G,

479B, 809-type, and 819-type apparatus cases have been designed to provide this primary protection.

8.29 Underground cable is generally considered as not being subject to lightning surges when it is located in multiple duct runs with other sheaths in built-up areas (ie, areas with metallic pipe lines for water or gas in the vicinity and overhead wire construction to provide shielding). Local experience should be considered in determining whether a cable is exposed to lightning surges. A duct run may be considered not exposed if it contains at least three sheaths. If the trunk cable is partly underground (and considered not exposed) and partly aerial, the first apparatus case and repeaters in the underground portion should be protected. ***Buried cable is generally considered to be exposed and is therefore used with protected cases.***

8.30 All apparatus cases (except the 468C6, five-repeater case and the 809 twelve-repeater case) are equipped with a color-coded stub cable containing four standard color-coded 25-pair binder groups and maintenance pairs. The maintenance pairs are used for the fault-locating, and pressure alarm functions. The 468C6 and 809-type apparatus cases are equipped with smaller color-coded stub cables. Apparatus cases to be used with filled cable should be either 475G2F, 809-type, 819B1, or 819B2C.

8.31 Apparatus cases associated with aerial cable may be mounted vertically on a pole. It is not usually practical to mount more than one apparatus case on a pole; where more than one apparatus case is involved, an alternate arrangement must be devised. A stub pole with a very short buried section to the line pole, an underground box at the base of the pole, or an H fixture may be a solution. A box such as that described in Section 919-240-310 may be the best solution because this will also help solve the problem of temperature rise when the case is exposed to the sun. This also conforms to current "out-of-sight within-reasonable-cost" policy.

8.32 Mounting the second apparatus case on an adjacent pole will seldom be an appropriate solution because of FEXT considerations. With buried installations, mounting apparatus cases on a stub pole, stub H fixtures, or an underground box will usually provide a suitable arrangement.

8.33 Apparatus case spacing is determined by computation of cable attenuation (as discussed in

Part 7), by geographical and physical conditions, by manhole space conditions, and by splicing conditions. There is no need to reduce repeater section lengths arbitrarily to provide safety margins unless there are adverse conditions present. For instance, if there is a condition of suspected adjacency to steam pipes that would cause excessive temperatures, further investigation might be in order if a limiting-section length were involved. If there is any question about cable lengths and characteristics and a limiting-section length is involved, it would appear desirable to arrange for preliminary pair-loss measurements to establish definitely that the proposed section length would fall within the pair-loss requirements.

8.34 The assignment of binder groups in the apparatus case stub depends on the particular mode of operation (bidirectional or unidirectional). This splicing is covered in Section 640-525-307. Figures 27 and 28 show examples of this splicing. If a case is ultimately to be used for bidirectional T1C or T1D and is used initially for T1, it ***must*** be spliced per bidirectional T1C rules which are different from bidirectional T1.



All 479-type apparatus cases are provided with two stubs and must be spliced per T1C requirements in Section 855-351-110.

8.35 Direction of transmission information and the pair count associated with apparatus cases must be uniform throughout a span and will therefore need to be indicated only once on the detail plans for that span. No detail of individual pair splicing arrangement or stub cable counts is necessary since this is a standard arrangement, as long as uniform 25-pair group counts are used.

8.36 A fault-locate pair is associated with each apparatus case. This pair should be chosen as specified in Section 855-350-104, which will also indicate procedures for acceptance of fault-locate pairs. Improper selection of this pair will interfere with full utilization of splicing groups for T1 Carrier base facilities and with use of uniform 25-pair, even-count groups. ♦Standard Western Electric screened cables have designated "odd count" pairs for fault locating, order wire, and alarm functions. ♦The pair should be loaded for VF transmission, and the pair number should be indicated on the construction detail drawings.

8.37 A 598-type filter is required at each 466- or 468-type apparatus case and its code should be

indicated on the detail drawings. A 1068-, 1114-, or 1115-type filter is required with 475-, 479, 809-, 818-, or 819-type cases. There are 12 codes that apply to either the 598-, 1068-, 1114-, and 1115-type filter. The 1115-type filters can only be used in the apparatus cases which have split fault-locate outputs. The fault-locate plan is defined in Section 855-350-104. Design of the fault-locate plan involves equipment and outside plant engineering with plant operations.

8.38 One order wire is required for each route. Definition of the order-wire plan for T1-Carrier lines is given in Section 855-350-107. The same considerations apply to the selection of a suitable pair as with the fault-locating pair. As discussed in Part 5, this order wire is merely a talking pair which can be associated with central office line equipment so that it may be used by splicers and maintenance people for communication with operating centers. This order wire will normally be connected with each of the apparatus cases installed first in a span. The pair number to be connected with each of these apparatus cases should be indicated on the construction details. This pair should be loaded; and if its length is such that its continuity should be broken (as discussed in Part 5), this point should be specified on the construction details.

8.39 Each of the positions in the 466- or 468-type apparatus case may contain a repeater, a 904A connector, or a 180-type coil case. Slots in the 475-, 809-, 818-, and 819-type case may contain a repeater, a 939A connector, or a 184 type coil case. Slots in 479-type apparatus cases may use the plug-ins for 475-type cases with appropriate adapter. Section 640-525-315 covers all associated plug-in units used in the T1 apparatus cases. The construction details should indicate which device is to be installed in each of the positions.

8.40 The 904A and 939A connectors (Fig. 29) are devices for establishing continuity of conductors through an apparatus case for the conductors that are not being used for T1 or are not being loaded for interim use as VF facilities.

8.41 The 180- and 184-type coil cases (Fig. 30) contain loading coils and facilities for installing building-out capacitors. Their use is to load cable pairs that are not being used for T1. These loaded pairs are for interim use as VF facilities as discussed in Part 8E.

8.42 In designing the physical arrangement of the cables and apparatus cases, it is best to avoid

stub cables other than the apparatus case stub itself. The additional stub would contain "in" and "out" counts in which signal strength is at different levels, creating potential crosstalk problems. This condition exists in the apparatus case stub; but its length is short and it is unitized. It is, therefore, advisable to connect the apparatus case directly to the main cable. This can often be done at the same splice at which unloading is done. ♦The 800-type cases use screened stub cables, and any additional stub connected to the apparatus case stub which does not maintain pair separation and screen continuity cancels the crosstalk advantage of the 800-type cases. ♦

8.43 There should be no reluctance to make 3-way splice closures (three cables from one end of splice closure) where the existing splice is a lead sleeve. The plastic 2-type splice closure, described in Section 633-506-201, can be used for 3-way splicing. Grommets are available for terminating up to eight stub cables in one 2-type splice closure.

8.44 Where large T1 Carrier installations are contemplated, the construction of a new center rack or side rack manhole over the existing cables may be advisable. It may be desirable to build new manholes to the side of the main route to improve accessibility and provide space for a large number of apparatus cases. In such a situation, the entire main cable count that may ultimately be used for T1 should be looped through the auxiliary manhole (Fig. 12). Nonadjacent unit separation **must be** maintained in these loops. In other words, "in" and "out" counts in the same sheath should be avoided. Arrangement of apparatus cases in auxiliary manholes is contained in the 640-525-ZZZ series of practices.

E. Interim Reloading of Base Facilities

8.45 When apparatus cases are installed for T1 digital lines, 50 pairs for bidirectional repeater installations and 100 pairs for unidirectional repeater installations will be unloaded and terminated. Plug-in coil cases are available for insertion in the apparatus case in lieu of repeaters so that the facilities not required immediately for the T1 line can be loaded on an interim basis and used as voice-frequency facilities. The 466- and 468-type apparatus cases use 180-type coil cases; the 475-, 809-, 818-, 819-, and 479-type apparatus cases use 184-type coil cases.

8.46 Where repeaters coincide with load points, the use of the carrier base facilities on an interim

basis, using plug-in load coils, is relatively simple and inexpensive. When apparatus case locations are not at desired load-point locations, a satisfactory arrangement can usually be worked out through the use of building-out capacitors. The 180- and 184-type coil cases are arranged for the installation of building-out capacitors. In some situations, special cases for these load coils may be placed together with bridging through at the repeaters points, but such an arrangement may be somewhat complex and costly. The economy of interim reloading will be dependent upon the length of time the circuits may be used on a VF basis. For instance, in a one-cable plan where 50 cable pairs are arranged for base facilities with a growth rate of 200 circuits per year, one-third of these facilities would be placed in use each year; roughly, 34 pairs would be available for voice frequency for the first year and 18 for the next year. As an alternative, a comparable number of facilities could be provided by advancing one T1 facility two years and another T1 facility one year. The economy is based on present worth annual charges (PWAC) of advancing the T1 facilities versus all of the costs involved in placing interim loading.

9. SPAN LINE POWERING CONSIDERATIONS

A. General

9.01 Powering of T1 line repeaters is accomplished by applying a fixed dc current to the cable pairs through the use of simplex transformers. When powering from a T1C/T1 ORB or 206 ORB, office battery is applied to constant current regulators in the office repeaters. When powering from a 201 ORB (STA), the line current is set manually by selecting the appropriate resistance at the control unit; this current should be checked periodically and adjustments made to compensate for battery voltage variations and cable temperature variations. 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. The normal voltage range and emergency limits are shown below. In order to minimize power dissipation in the ORBs, it is desirable to use

the lowest possible supply voltage which will properly power the span and power the office repeater in series with the line.

| NOMINAL VOLTAGE | NORMAL RANGE | EMERGENCY LIMITS | MAX. LIMITS FOR ESS OFFICE |
|-----------------|--------------|------------------|----------------------------|
| -48 | 45 to 50 | 42.5 to 53 | 45 to 52 |
| +130 | 125 to 135 | 115 to 140 | 125 to 135 |
| -130 | 125 to 135 | 110 to 140 | 125 to 135 |

9.02 If the office includes a span-terminating assembly (201 ORB), continue with paragraph 9.27. Otherwise continue with paragraph 9.03.

9.03 Typical simplex power loops using T1C/T1 ORBs, and 206 ORBs, are shown in Fig. 36, 37, and 38, Pages 100, 101, and 102. In Fig. 36, Page 100 the loop is completed (looped back) at a line repeater location. This is accomplished by installing a looping line repeater 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 or 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 location. For T1, a unidirectional power loop can be looped at one of the offices as shown in Fig. 37 and 38, Pages 101 and 102.

9.04 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 regenerator circuits in a 221-type office repeater requires 140 mA, they cannot be series powered in a low power line. **Local powering puts an extra load on the -48 volt supply. This significantly increases the power dissipated in the ORB and should be avoided if possible.**

9.05 Following is a general procedure for engineering the powering of T1 spans. 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.

9.06 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. 31).

B. Power Loop Structure

9.07 The simplest power loop structure is bidirectional operation (Fig. 36, Page 100). 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 ORB represents one complete, independent power loop.

9.08 For unidirectional operation, the power loops are more complex as shown in Fig. 37 and 38, Pages 101 and 102. 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 regulator output of one office repeater minus (221- and 231-type repeaters) or plus (206- and 236-type repeaters), goes through one side of each line repeater, through both looping office repeaters, or a looping line repeater. The return is through the other side of the line repeaters, and reaches battery return plus (221- and 231-type repeaters) or 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 for T1, the ORBs are arranged with groups of 4 shelves (50 repeaters) which comprise 25 power mate pairs of 50 two-way lines (see Fig. 32). Power mates appear in shelf positions of the same number separated by one shelf. Shelf numbering starts at the bottom of the ORB and proceeds upwards; thus shelf 1, position 1, and shelf 3, position 1 are power mates as are shelf 5, position 1, and shelf 7, position 1, etc. In the examples of Fig. 37 and 38, Pages 101 and 102, the lower shelf repeaters power the receive line repeaters and the upper shelf repeaters power the transmit line repeaters. Lower shelf lines transmit and receive through side 1 of the line repeaters while upper shelf lines use side 2.

9.09 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.***

C. DCOPE/T-PWR Applications

9.10 As an aid in designing T1 power loops, a computer program has been developed to compute the required power design parameters from known circuit data input. This subprogram called T-Carrier Power Loop Calculations (T-PWR) is part of the application package Digital Carrier Operation, Planning, and Engineering (DCOPE) which is a program in the **Engineering Planning Analysis System (EPLANS)**. Using the T-PWR program, an engineer can determine the powering arrangement and select the looping point for powering T-Carrier line repeaters between two central offices. The T-PWR program benefits include:

- (a) Listing the optional looping point for a span

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

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

9.12 Ordering information for DCOPE (T-PWR) package can be obtained from the EPLANS coordinator. General information and references for using DCOPE for specific designs are given in the DCOPE program application handbook, PA-1N160-01. This document describes how DCOPE provides the data necessary for a given span. The power calculations include maximum and minimum total loop resistance ($R_{L,MAX}$ and $R_{L,MIN}$), required voltage (48 or 130 volts), and specific repeater power options (CEK, AGM, etc). Figure 39 is a typical example of T-PWR program output, including optional data. The output is based on the bidirectional power loop shown in Fig. 40.♦

D. Office Repeater Options

9.13 Office repeaters (221-, 231-, and 236-type) contain two sets of option selectors, one for regulator option (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 M). The 206-

type office repeaters contain only the powering option selectors. Regulator options for the 206-type are selected by repeater code (see Table W, Page 91). Repeater powering options are chosen to power the office repeater regenerator either from the local -48 volt supply or in series with the line. Table Z, Page 94 summarizes the repeater powering option choices which are accomplished by turning down the indicated screws with all others up two turns.

9.14 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 lower shelf and A, F, H, and N for the upper shelf. However, if the office repeaters are to be powered in series with the simplex loop, as recommended, there are two options to choose from for the lower shelf B, D, and G or C, E, and K. The upper shelf is always A, G, and M when series powered. ***The two repeaters of a power mate pair at the same end of the loop must be powered the same, either both locally or both in series.***

9.15 The significance of choice between B, D, G and C, E, K can be understood by careful examination of Fig. 37 and 38, Pages 101 and 102. The A, G, and M option in the upper shelf repeater always puts that repeater power supply in series with the power loop which power the receive line repeaters (received power loop, powered by the regulator in the lower shelf). In the lower shelf repeater, the C, E, and K option puts that repeater power supply in series with the receive power loop, while the B, D, and G option puts it in the transmit power loop. 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. Therefore, selecting the B, D, and G option 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 N 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.

E. Battery Voltage Selection

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

$$R_{l,max} = R_{c,max} + R_R$$

$$R_{l,min} = R_{c,min} + R_R$$

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

$$R_{c,max} = \text{Cable length (kft)} \times R_{max} \times [1 + 0.0022 (T_{max} - 68^\circ\text{F})]$$

$$R_{c,min} = \text{Cable length (kft)} \times R_{min} \times [1 + 0.0022 (T_{min} - 68^\circ\text{F})]$$

Where R_{max} and R_{min} depend on cable gauge and material and are given in Table O, 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 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. 36, 37, or 38, Pages 100, 101, and 102. Starting at the powering office repeater regulator "walk along" each loop stopping at the looping point. The resistance of each repeater walked through (Table P and Table AA, Page 95) 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.

9.17 Minimum and maximum cable resistance ($R_{c,min}$ and $R_{c,max}$) are added to R_R to determine minimum and maximum loop resistance ($R_{l,min}$ and $R_{l,max}$), using the formula given in paragraph 9.16. Both $R_{l,max}$ and $R_{l,min}$ must fall within the range of the allowable R_l for the battery voltage used to power the loop (see Table AB, Page 96). 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 office repeater may be selected from Table W, Page 91; or the proper regulator options can be determined for a 221, 231, or 236-type repeater by referring to Table M. A power loop is most efficient and the power dissipated in the ORB is minimized when $R_{l,max}$ 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.**

9.18 When using an express office repeater panel (EORP) it is considered the same as a line repeater location for the purpose of calculating loop resistance except for the following consideration. The EORP contains pads or artificial lines on the repeater inputs and outputs, and the resistance of these networks must be added to the resistance of the line repeater used. When using a J98710U or J98725J EORP add a total of 36 ohms to the through resistance value or 18 ohms to each of the side 1 in and side 1 out loop resistance.

9.19 ♦ Consideration of 60-Hz induced currents must be given when designing power loops

using standard power single-letter code repeaters. However, standard power double-letter code repeaters and 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 AB, Page 96 and must be applied when choosing the battery voltage to be used to power the span.

F. ORB Options

9.20 Each ORB must be optioned correctly, depending on which powering options are chosen for the repeaters in that bay. Power dissipation units must be inserted into the shelf at the top of the bay if standard power regulating repeaters are used with battery voltages greater than 48 volts. Low power regulating repeaters do not require power dissipation units. However, 291A plug in adapters, or M wiring option (206-ORB), or 292A plug-in adapters, or P wiring option (T1C/T1 ORB) must be provided when using low power repeaters. When looping repeaters are used for unidirectional operation, option YY (206-ORB) or option W (T1C/T1 ORB) must be provided in the ORB.

G. Sample Calculation

9.21 An example of a power loop calculation for low-power unidirectional operation is shown in Fig. 41. Cable resistance will be the same for both loops:

$$R_{C_{max}} = \text{Cable Length (kft)} \times R_{max} [1 + 0.0022 (T_{max} - 68^{\circ}F)]$$

$$R_{C_{min}} = \text{Cable Length (kft)} \times R_{min} [1 + 0.0022 (T_{min} - 68^{\circ}F)]$$

$$R_{C_{max}} = (3.600 + 5.900 + 6.000 + 5.800) 16.7 [1 + 0.0022 (100 - 68)]$$

$$= (21.3) 16.70 (1.07) = 381 \text{ ohms}$$

$$R_{C_{min}} = (3.600 + 5.900 + 6.000 + 5.800) 16.1 [1 + 0.0022 (30 - 68)]$$

$$= (21.3) 16.10 (0.916) = 314 \text{ ohms}$$

Repeater resistance will be different:

| | | TMRT LOOP | RCV LOOP |
|-------------------|---------------------------------------|-----------|----------|
| 236AA | (CEK and AGM) | 30 | 256 |
| 238B | (Thru X 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 chosen (Table AB, Page 96) the only possibility is 130 volts. Thus, regulator options R and Z would be chosen, see Table M.

H. Calculation of Voltage Limits

9.22 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:

$$V_{L_{max}} = R_{L_{max}} \times I_L$$

$$V_{L_{min}} = R_{L_{min}} \times I_L$$

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:

$$V_{R_{max}} = V_{B_{max}} - [(V_{L_{min}} + 6.2) + (I_L \times R_X)]$$

$$V_{R_{min}} = V_{B_{min}} - [(V_{L_{max}} + 8.5) + (I_L \times R_X)]$$

Values for V_{Bmax} and V_{Bmin} (office battery voltage limits) and for R_X (miscellaneous bay resistance) are given in Table Q. Once these voltage values are calculated, a record should be made of them on Form E-10604 (Fig. 31) for use in initial installation testing, periodic routine maintenance, and trouble isolation procedures.

I. Use of Calculated Limits

9.23 Initial installation and periodic maintenance procedures require that the power loop measurements be within the calculated voltage limits of paragraph 9.22. 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.

9.24 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 a shelf-pair. The values measured on the suspected line should not deviate more than ± 4 percent from the average of all good lines in the shelf-pair. If there is a significant difference, such problems as a shorted 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.

9.25 It should be noted, however, that records of actual measurements made at some time in the past can be misleading. The operating voltages of lines in a shelf-pair can change significantly with time or temperature, and yet all may still be working properly. Unless trouble is suspected, the only valid requirement is operation within the calculated maximum and minimum values which are valid for all times and temperatures.

9.26 Powering rules for T1 span lines and sketches of bidirectional and unidirectional repeater operation are included in SD-3C252-02, SD-3C371-01 (T1C/T1 ORB), and SD-97080-02 (206 ORB).

J. Span Line Powered by Span Terminating Assembly (201 ORB)

9.27 Span lines that use span terminating assemblies may be powered by one or two powering loops. For a span line powered by a single loop, use the calculated values of $R_{l,max}$ and $R_{l,min}$ to determine voltage requirements from the power loop resistance ranges shown in Table R.

When two power loops are involved, $R_{l,max}$ and $R_{l,min}$ must be calculated for each power loop and then the voltage for each loop must be selected. The looping point should be chosen so that the total voltage required by both offices is minimized and the differences between the maximum resistance ranges from the voltage chosen and $R_{l,max}$ are approximately equal for both loops. As an example of a single power loop use the values. $R_{l,max} = 737$ and $R_{l,min} = 682$; therefore, the minimum battery voltage would be 130 volts.

9.28 The data in paragraph 9.27, which is used to select battery voltage, is based on a midrange value of CO resistance provided in the control unit for

each repeater. This resistance is adjustable, and the exact value is established when the span line is powered in accordance with Section 365-223-500. A preliminary calculation should be made, however, to determine whether the control unit resistance range is adequate for the computed power loop resistance and selected battery voltage. This is determined by equation (13):

$$\begin{aligned} R_{O,min} &= 7.15 E - R_{l,max} \\ R_{O,max} &= 7.15 E - R_{l,min} \end{aligned} \quad (13)$$

where R_O is the control unit resistance, E is the battery voltage, and R_l is the power loop resistance. Both $R_{O,max}$ and $R_{O,min}$ should fall in the appropriate range shown in Table S.

9.29 In the example in paragraph 9.27 ($R_{l,max} = 737$, $R_{l,min} = 682$, and $E = +130$ volts), $R_{O,min} = 192.5$ and $R_{O,max} = 247.5$. Both of these values lie between the minimum and maximum R_O values for 130-volt powering.

9.30 If the control unit resistance is near the limit of the range, final adjustment may not be possible when the span is powered. In this case, the power loop design must be changed to more nearly center R_O within the appropriate range.

9.31 Powering rules for span lines using 201 offices repeater bays and sketches of bidirectional and unidirectional repeater operation are included in SD-97080-01.

10. CENTRAL OFFICE (CO) CONSIDERATIONS

10.01 The T1-Carrier office equipment requirements depend on carrier facility contents. They may vary from a J98713F line terminating unit (LTU) to a combination of 7-, 9-, and 11-foot office repeater bays (ORBs) in a large office. The more complex offices should provide for a mixture of equipments such as: office repeaters, bridging repeaters, express office repeater panels, DSX patch and cross-connect bays, TCAS, possible T1/OS (Section 855-351-200) and T1C (Section 855-351-110) and T1D (Section 855-351-115). Refer to Section 365-200-100 for specific T1 equipment. It is important for the maintainability of the office that the location of this equipment relative to existing carrier equipment be considered, see Section 760-100-084.

10.02 ♦The T1 ORBs should be physically located as far away as possible from any electrome-

chanical (eg. switches, crossbar, etc.) equipment. The ORBs should not be in the same lineup nor in back-to-back lineup with electromechanical equipment. To avoid interference, minimum separation should be cross-aisle between ORBs and switches.♦

10.03 When planning the addition of T1 Carrier in a CO, the engineer should be aware of DSX-1 considerations (see Sections 855-350-105 and 855-350-106). T1 ORBs can be no farther than 85 feet from the DSX-1 when using 3-volt output office repeaters and no farther than 655 feet when using 6-volt EXCP repeaters. As explained in Sections 855-350-105 and 855-350-106, it is important to decide early on the use of DSX-1 in order to provide a central point for patching, cross-connection, and testing. This early decision is also important if growth is anticipated to be more than 600 facilities or the ORBs appear in different lineups. (See paragraph 5.04.)

10.04 When a CO contains T-Carrier equipment, consideration should be given to the establishment of a T-Carrier Maintenance Center (TCMC). The TCMC provides a central location for most T-Carrier records, spare parts, test equipment, and administrative functions. When a DSX-1 bay is part of the TCMC, maintenance functions such as trouble isolation, service restoral, circuit rearrangements, and fault locating can also be centralized. The components and layout of a TCMC and other maintenance systems are described in Section 855-350-108.

11. MAINTENANCE AND TEST CONSIDERATIONS

11.01 The T1-Carrier digital lines require standardized procedures for maintaining the facility. Maintenance lines are required for signal restoration of failed span lines. Within each operating area either slot 1 (201 ORB) or slot 25 (206 and T1C/T1 ORB) from each span should be designated as the maintenance line in all ORBs. A bridging repeater should be provided for each maintenance line. When a ♦Facility Maintenance and Administration Center—Metropolitan (FMAC-M)♦ is part of a network, backbone lines should be provided for restoration. Refer to Section 190-200-001. Patching arrangements must be provided to allow access to the backbone line from each facility in the office terminal. All backbone lines also require bridging repeaters.

11.02 Specific pairs are required to support the gas alarm, fault-locate, and order-wire needs.

Engineering rules for the T1 fault locate and order wire are in Sections 855-350-104 and 855-350-107, respectively. In addition to order wires, each repeater location should have access to the switching networks for adequate communications.

11.03 The six test units briefly described below are only initial requirements. Duplicates may be required as growth of the office dictates.

(1) ***J98725AA Pair Loss Test Set:*** This battery-powered set measures the loss of a conductor pair at 650 or 1300 kHz between adjacent manholes and ORBs and manholes. This information is taken before repeater installation and is used to select fixed line build-out (LBO) networks in older T1 repeaters and to select adequate range in the automatic line build-out (ALBO) network in newer T1 and T1C repeaters. Comparisons from pair to pair allow out-of-limit pairs to be identified for troubleshooting. Connecting adapters allow the set to be used in the ORB as well as in all T1 and T1C apparatus cases. (See Section 103-494-104.)

(2) ***J98725AB Manhole Bipolar Violation Detector:*** This portable battery-powered set is used to troubleshoot failed line sections, either confirming a remote fault-locate diagnosis or determining the location of a marginal repeater or section. It also indicates the presence or absence of a valid signal. Its plug-together construction allows its use in either the 466-, 468-, 475-, 809-, 818-, and 819-type T1 apparatus cases or the 479 T1C apparatus case. The set is supplied with adapters in a reinforced case. (See Section 103-494-101.)

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

(4) ***J98725AD Fault-Locating Test Set:*** This set, powered by the -48 volt office supply, is used to isolate defective repeaters to a specific section and manhole. Bipolar violations are introduced in a variable density bit stream at an audio

rate. The audio tone is returned to the office from a manhole via a fault-locate filter in the manhole and a loaded pair in the cable. The transmitter and selective receiver are contained in one package with all tuning fixed by switch positioning. (See Section 103-494-106.)

(5) **J98710H Repeater Test Set:** This set, powered by 110-volt alternating current, is used to identify defective office and line repeaters before installation. This set is used in conjunction with the J98710F fault-locating set and the J98710G error-detecting set to perform the tests. This set is capable of testing both standard and low-power type repeaters. (See Section 103-492-100.)

(6) **KS-14510 Volt-Ohm-Milliameter:** This meter is internally battery powered and usually is furnished for dc measurements for shorts, opens, crosses, and grounds. (See Section 100-520-101.)

11.04 Whenever new equipment is ordered, first considerations should be given to the latest test sets available. However, existing installations may be using older test equipment such as the J98710F fault-locate set which can detect a faulty repeater when used in conjunction with a noise measuring set. The J98710P error-detecting set is used to isolate or evaluate a repeater. Also, the J98710G error-detecting set can be used on an in-service basis to detect a deviation from the transmitted signal.

11.05 The T1 digital lines using discrete component repeaters have a tendency to oscillate when no signal is present. This tendency, known as **free running**, introduces noise at the repeater fault-locate input and may cause trouble even in properly engineered, installed, and maintained T1 lines or in VF circuits in the same cable. To prevent free running, a continuous signal of 1.544 Mb/s should be placed on the maintenance line and all unassigned lines.

11.06 To provide a continuous signal, at least one quasi-random signal source (QRSS) should be provided in each T1-Carrier office. Refer to Section 103-494-105.) The signal source provides a quasi-random signal that consists of any combination of 20 bits. When the QRSS provides a test signal, it must be connected through a bridging repeater and should always be used for the maintenance lines. When

DSX-1 is furnished, the QRSS is located in the DSX-1 bay as detailed in Sections 855-350-105 and 855-350-106.

11.07 When there are two ORBs in an office with no DSX-1 and they are neither adjacent nor in the same lineup, some method of patching between them, other than DSX-1, is required. A suggested minimum of six patch trunks (three for each directional in ABAM or 600-type cable is recommended, together with six jacks in each ORB. Interbay patch trunks should be laid out so that only one trunk is necessary when patching between only two lines.

11.08 A number of systems such as the Digital Data System (DDS) and various private line applications utilize T1 digital lines as their primary transmission media. However, some of these systems require higher transmission availability, reliability, and performance than can generally be expected from every randomly selected T1 line. The higher performance objectives are expected to be met by carefully selecting T1 lines that can qualify for the required improved performance. To meet the higher transmission availability objectives, a new equipment arrangement known as the T1 automatic standby unit (T1ASU) has been developed. The T1ASU provides improved T1 line transmission availability. Although T1ASU is required for DDS, it may also be used for other critical applications which justify the dedication of a second T1 digital line as a standby. A description of T1ASU is given in Section 365-200-104.

11.09 A J98710T line monitor can be rack-mounted in a CO to monitor certain T1 lines. It can be hard-wired to one T1 line and set to activate the office alarms; or it can be mounted with office repeater equipment so that it can be patched to MON jacks within 12 feet. Separate logic circuits in this unit simultaneously detect bipolar violations and absence violations.

11.10 Additional maintenance aids such as the maintenance lines status indicators (MLSI), the directed line monitor (DLM), the local maintenance center display (LMCD), and T Carrier Maintenance Center (TCMC) are discussed in Section 855-350-108.

12. SUMMARY

12.01 In engineering for performance and reliability, the following points are pertinent:

SECTION 855-351-101

- Use new cable or cable in good condition. The MAT and ICOT cable are recommended.
- Avoid mixed gauge or mixed-type cable sections.
- Use low-power or standard power double-code repeaters on lines where 60-Hz induced currents are a problem.
- Buried cable requires the use of protected apparatus cases and protected line repeaters.
- Any **planned** installation of 600 pairs or more requires a DSX-1.
- Carefully assess future requirements since the early installation of DSX-1 equipment may save a costly retrofit later.
- New facilities should be designed using low-power repeaters for better economics.
- Cable loss computations are essential to proper design of repeater sections.
- Tip cables should be ABAM or 606B, carry only one direction of transmission, and be terminated on a DF.
- Screened cable should be used to allow full fill single-cable operation.
- Cable pairs should be provided initially to allow 2 to 5 years growth with a minimum of 50 pairs per cable per splice entry.

13. REFERENCES

13.01 The following Bell System Practices are referenced in this section.

| SECTION | TITLE |
|----------------|---|
| 103-494-100 | J98725AC Office Bipolar Violation Detector Description and Maintenance |
| 103-494-101 | J98725AB T1C/T1 Manhole Bipolar Violation Detector—Description and Maintenance |
| 103-494-104 | J98725AA Pair Loss Test Set—Description, Operation, and Maintenance |
| 103-494-105 | J98725AF T1C/T1 Quasi-Random Signal Source (QRSS)—Description, Operation, and Maintenance |
| 103-494-106 | J98725AD T1C/T1 Fault-Locating Test Set—Description and Maintenance |
| 190-200-001 | Organization and Responsibilities |
| 190-202-041 | Controlled Maintenance Plan—Facility Maintenance and Administration Center (FMAC) |
| 190-202-101 | Organization, Responsibilities, and Objectives—Facility Maintenance and Administration Center - Metropolitan (FMAC-M) |
| 365-000-000 | Numerical Index Division 365—Digital Transmission Systems |
| 365-010-006 | DS1, DS1C, DS2, DS3, and DS4—Equipment Document Indexes |
| 365-200-100 | T1 Digital Line—General Description |
| 365-200-101 | Repeater Description |
| 365-200-104 | T1 Automatic Standby Unit—Description |
| 365-200-105 | J98710U Express Office Repeater Panel—General Description |
| 365-211-516 | Pair Loss Measurements—(Using 113-type Test Set) |
| 365-211-517 | J98710U Express Office Repeater Panel-Pair Loss Measurements |

| SECTION | TITLE | SECTION | TITLE |
|-------------|---|----------------|--|
| 365-211-518 | Pair-Loss Measurements (Using J98725AA Test Set) | 855-350-108 | D/T1 System—T1 Central Office Maintenance Center and Other Maintenance Aids |
| 365-223-500 | Initial Span Line Powering—T1 Digital Line | 855-351-102 | T1 Digital Line Special Engineering and Design Considerations |
| 365-800-002 | T1 Line—Routine, Acceptance, and Company Order Tasks (TOP) | 855-351-110 | T1C Digital Line—Transmission and Outside Plant Design Procedures |
| 633-506-201 | 2-Type Plastic Closure—Description and Installation | 855-351-115 | T1D Digital Line—System Application—Transmission and Outside Plant Design Procedures |
| 640-525-211 | 475-Type Apparatus Cases—Splicing and Maintenance | 855-351-200 | T1 Outside Digital Line—Transmission and Outside Plant Design Procedures |
| 640-525-220 | Pair Loss Measurements in T1 Repeater Sections | 873-800-178 | Fundamental Frequency Electromagnetic Shielding of Communication Circuits |
| 640-525-307 | 800-Type Repeater Cases—Description, Installation, Splicing and Maintenance | 873-800-580 | Determination of Earth Resistivity by the DC Method |
| 640-525-315 | Apparatus Cases and Associated Plug-In Equipment | 901-350-510 | Sheath and Pair Counts |
| 640-527-220 | Pair Loss Measurements in T1C/T1 Repeater Sections | 919-240-310 | Manholes and Service Boxes for T1 Carrier Apparatus Cases |
| 760-100-084 | T1, T1/OS, T1C and T2 Digital Carrier Terminal Office Planning | 13.02 | The following drawings are referenced in this Section. |
| 801-523-150 | (J98710) T1 Carrier—System Requirements and Repeater Bay Equipment | DRAWING | TITLE |
| 801-523-153 | (J98725) T1 Carrier—System Requirements and Repeater Bay Equipment | SD-3C252-02 | T1 Application Drawing For the T1C/T1 Office Repeater Bay |
| 855-350-104 | T1, T1 Outstate, and T1C—Engineering Design Fault-Locating System | SD-3C371-01 | T1C/T1 Office Repeater Bay DSX Dedicated Application |
| 855-350-105 | DSX-1, DSX-1C, and DSX-2—New Installation | SD-97080-01 | T1 Carrier Application Schematic (Span-Terminating Assembly) |
| 855-350-106 | DSX-1 and DSX-1C—Retrofit | SD-97080-02 | T1 Carrier Application Schematic (206-Type Office Repeater) |
| 855-350-107 | T1, T1 Outstate and T1C—Engineering Design Order-Wire System Application | | |

TABLE A

PRESENT STANDARD SCREENED CABLE

| CABLE TYPE | CABLE CODE (NOTE) | TYPE CAPACITANCE | CABLE TYPE | CABLE CODE (NOTE) | TYPE CAPACITANCE |
|--------------------|-------------------|------------------|-------------------|-------------------|------------------|
| ICOT (Air Core) | MCMC-54 | Low | PIC (Air Core) | KHAH-28 | Standard |
| | MCMC-106 | Low | | KHAH-54 | Standard |
| | MCMC-158 | Low | | KHAH-106 | Standard |
| | MCMC-210 | Low | | KHAH-158 | Standard |
| | MCMC-314 | Low | | KHAH-210 | Standard |
| | MCMC-418 | Low | | KHAH-314 | Standard |
| | MCMC-616 | Low | | KHAH-418 | Standard |
| | MCMC-922 | Low | | KHAH-616 | Standard |
| | MCMH-54 | Low | ICOT (Filled) | MLMW-54 | Low |
| | MCMH-106 | Low | | MLMW-106 | Low |
| | MCMH-158 | Low | | MLMW-158 | Low |
| | MCMH-210 | Low | | MLMW-210 | Low |
| | MCMH-314 | Low | | MLMW-314 | Low |
| | MCMH-418 | Low | | MLMW-418 | Low |
| MCMH-616 | Low | MLMW-616 | Low | | |
| MCMH-922 | Low | MLMW-922 | Low | | |
| MAT (Air Core) | MCRC-412 | Low | PIC (Filled) | KJAW-28 | Standard |
| | MCRC-616 | Low | | KJAW-54 | Standard |
| | MCRC-1024 | Low | | KJAW-106 | Standard |
| | MCRC-1228 | Low | | KJAW-158 | Standard |
| | MCRC-1432 | Low | | KJAW-210 | Standard |
| | MCRC-1840 | Low | | KJAW-314 | Standard |
| | MCRH-412 | Low | KJAW-418 | Standard | |
| | MCRH-616 | Low | KJAW-616 | Standard | |
| | MCRH-1024 | Low | DEPIC (Filled) | KLAW-54 | Standard |
| | MCRH-1228 | Low | | KLAW-106 | Standard |
| MCRH-1432 | Low | KLAW-158 | | Standard | |
| MCRC-1840 | Low | KLAW-210 | | Standard | |
| PIC (Air Core) | KHAG-28 | Standard | KLAW-314 | Standard | |
| | KHAG-54 | Standard | KLAW-418 | Standard | |
| | KHAG-106 | Standard | KLAW-616 | Standard | |
| | KHAG-158 | Standard | | | |
| | KHAG-210 | Standard | | | |
| | KHAG-314 | Standard | | | |
| | KHAG-418 | Standard | | | |
| | KHAG-616 | Standard | | | |

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

TABLE B

EQUALIZERS USED IN T1C/T1 ORB

| ORB | CABLE LENGTH (FT) (NOTE) | EQUALIZER (NOTE) |
|--|--------------------------|------------------|
| T1C/T1 ORB (DSX optional) J98725A, B, C | 0 to 220 | ED-3C585-30, G1 |
| | 220 to 440 | ED-3C585-30, G2 |
| | 440 to 655 | ED-3C585-30, G3 |
| T1C/T1 ORB (DSX dedicated) J98725D, E, F | 0 to 220 | ED-3C744-30, G6 |
| | 220 to 440 | ED-3C744-30, G7 |
| | 440 to 655 | ED-3C744-30, G8 |

Note: At cable length transition point, use equalizer for the shorter length. **Do Not Overequalize.**

TABLE C

EQUALIZERS USED IN 206- AND 236-
TYPE EXCP REPEATERS

| REPEATER TYPE | CABLE LENGTH (FEET) (NOTE) | EQUALIZER CODE | LOSS RANGE |
|-------------------|-------------------------------|-------------------|---------------|
| 206 and 236 | 0 to 220 | 983A | 0 to 1 dB |
| | 220 to 440 | 983B | 1 to 2 dB |
| | 440 to 665 | 983C | 2 to 3 dB |

Note: At cable length transition point, use equalizer for the shorter length. **Do Not Overequalize.**

TABLE D
OFFICE CABLE LOSSES AT 772 KHZ

| CABLE TYPE | AVERAGE LOSS AT 70°F. dB/1000 ft |
|--|--|
| ABAM or 606B thru 611B | 4.6 |
| 750-type, shielded | 7.3 |
| ABMM (24 gauge) | 5.2 |
| BUA and other 22-gauge textile-insulated | 5.2 |
| Tip cable, 22-gauge, 300-type connector | 6.1 |

TABLE E
JUNCTION LOSSES (DB) AT 772 KHZ

| GAUGE | CAP. μ F/MILE | 19 | 22 | | 24 | | 26 |
|-------|-------------------|-------|-------|-------|-------|-------|-------|
| | | 0.084 | 0.073 | 0.083 | 0.072 | 0.084 | 0.079 |
| 19 | 0.066 | 0.3 | 0.1 | 0.3 | 0.2 | 0.2 | 0.2 |
| 19 | 0.083 | | 0.2 | 0.1 | 0.3 | 0.1 | 0.2 |
| 22 | 0.073 | | | 0.2 | 0.1 | 0.1 | 0.1 |
| 22 | 0.083 | | | | 0.2 | 0.1 | 0.1 |
| 24 | 0.073 | | | | | 0.2 | 0.1 |
| 24 | 0.083 | | | | | | 0.1 |
| 24* | 0.052 | | | | | | |
| 24* | 0.060 | | | | | | |
| 25* | 0.064 | | | | | | |

Note: Where a short section of a different type cable is inserted, use the following function loss at each end:

| | |
|----------------|--------------------|
| 0 to 50 feet | No junction loss |
| 50 to 150 feet | 1/2 junction loss |
| over 150 feet | Full junction loss |

* Junctions are not allowed on MAT and ICOT cable.

TABLE F

**APPROXIMATE PAIR LOSSES CORRESPONDING TO
READING ON PAIR LOSS TEST SET — DB AT
772 KHZ, 55°F**

| LBO SWITCH POSITION | METER READING (NOTE) | | |
|------------------------|----------------------|------|------|
| | (-) | (+) | |
| | LO | MEAN | HI |
| A1 | 34.6 | 33.4 | 32.2 |
| A | 32.2 | 31.0 | 29.8 |
| B | 29.8 | 28.6 | 27.4 |
| C | 27.4 | 26.2 | 25.0 |
| D | 25.0 | 23.8 | 22.6 |
| E | 22.6 | 21.4 | 20.2 |
| F | 20.2 | 19.0 | 17.8 |
| G | 17.8 | 16.6 | 15.4 |
| H | 15.4 | 14.2 | 13.0 |
| J | 13.0 | 11.8 | 10.6 |
| K | 10.6 | 9.4 | 8.2 |
| L | 8.2 | 7.0 | 5.8 |
| M | 5.8 | 4.6 | 3.4 |

Note: For example, a pair for which the C column is checked on Form E-6779, "113A or J98725AA Test Set Data Sheet," has loss between 26.2 dB and 27.4 dB. When using the 175C adapter with the J98725AA test set at a 206 ORB or LTU, add the loss associated with the office repeater pad or artificial line to the pair loss values shown. (The 175C adapter does not contain these losses.)

TABLE G

**MAXIMUM DESIGN LOSSES (DB) FOR LAYER-TYPE CABLE WITH
ADJACENT SPLICING GROUPS (NOTES 1 AND 2)**

| TYPE | | | NUMBER OF FACILITIES | | | | |
|-------|--|-----|----------------------|------|------|------|------|
| GAUGE | CAPACITANCE $\mu\text{F}/\text{MILE}$ | USE | 25 | 50 | 100 | 200 | 400 |
| 19 | 0.066 | UG | 25.7 | 22.8 | 20.0 | 17.1 | |
| | | AER | 24.9 | 22.1 | 19.3 | 16.5 | |
| 19 | 0.083 | UG | 26.8 | 23.9 | 21.0 | 18.1 | |
| | | AER | 26.1 | 23.2 | 20.4 | 17.6 | |
| 22 | 0.073 | UG | 27.4 | 24.5 | 21.7 | 18.8 | 18.8 |
| | | AER | 26.5 | 23.7 | 20.9 | 18.2 | 18.2 |
| 22 | 0.083 | UG | 27.8 | 25.0 | 22.1 | 19.2 | 19.2 |
| | | AER | 26.9 | 24.1 | 21.3 | 18.5 | 18.5 |
| 24 | 0.073 | UG | 28.4 | 25.5 | 22.6 | 19.7 | 19.7 |
| | | AER | 27.3 | 24.6 | 21.8 | 19.0 | 19.0 |

Note 1: For buried cable, use underground losses.

Note 2: Applies to cables larger than 200 pairs.

TABLE H

**MAXIMUM DESIGN LOSSES (DB) FOR LAYER-TYPE CABLE WITH NONADJACENT
SPLICING GROUPS (NOTES 1 AND 2)**

| TYPE | | | NUMBER OF FACILITIES | | | |
|-------|--|-----|----------------------|------|------|------|
| GAUGE | CAPACITANCE $\mu\text{F}/\text{MILE}$ | USE | 25 | 50 | 100 | 200 |
| 19 | 0.066 | UG | * | 31.8 | 29.0 | 26.1 |
| | | AER | * | * | 28.3 | 25.5 |
| 19 | 0.083 | UG | * | * | 30.0 | 27.1 |
| | | AER | * | * | 29.4 | 26.6 |
| 22 | 0.073 | UG | * | * | 30.7 | 27.8 |
| | | AER | * | * | 29.9 | 27.2 |
| 22 | 0.083 | UG | * | * | * | 28.2 |
| | | AER | * | * | 30.3 | 27.5 |
| 24 | 0.073 | UG | * | * | 31.6 | 28.7 |
| | | AER | * | * | 30.8 | 28.0 |

Note 1: For buried cable, use underground losses.

Note 2: Applies to cables larger than 200 pairs.

* Use maximum design losses in Table X.

TABLE I

**MAXIMUM DESIGN LOSSES FOR UNIT-TYPE
CABLES WITH NONADJACENT SPLICING GROUPS
(NOTES 1 AND 2)**

| TYPE | LOSS |
|-------------|------|
| Underground | * |
| Aerial | * |

Note 1: For buried cable, use underground losses.

Note 2: Applies to cables larger than 200 pairs.

* Use maximum design losses in Table X.

TABLE J

**MAXIMUM DESIGN LOSSES FOR UNIT-TYPE CABLES WITH
ADJACENT SPLICING GROUPS (NOTES 1 AND 2)**

| TYPE | | | NUMBER OF FACILITIES | | | | |
|-------|-----------------------------|-----|----------------------|------|------|------|------|
| GAUGE | CAPACITANCE μ F/MILE | USE | 25 | 50 | 100 | 200 | 400 |
| 19 | 0.066 | UG | 31.5 | 28.6 | 25.7 | 22.8 | |
| | | AER | 30.4 | 27.7 | 24.9 | 22.1 | |
| 19 | 0.083 | UG | * | 29.7 | 26.8 | 23.9 | |
| | | AER | * | 28.9 | 26.0 | 23.2 | |
| 22 | 0.083 | UG | * | 30.7 | 27.8 | 25.0 | 22.1 |
| | | AER | * | 29.7 | 26.9 | 24.1 | 21.3 |
| 24 | 0.073 | UG | * | 31.2 | 28.4 | 25.5 | 22.6 |
| | | AER | * | 30.1 | 27.3 | 24.6 | 21.8 |
| 24 | 0.083 | UG | * | 31.8 | 28.9 | 26.1 | 23.2 |
| | | AER | * | 30.7 | 27.9 | 25.1 | 22.4 |
| 26 | 0.079 | UG | * | 32.1 | 29.2 | 26.4 | 23.5 |
| | | AER | * | 30.7 | 27.9 | 25.2 | 22.5 |
| 26 | 0.083 | UG | * | * | 29.4 | 26.6 | 23.7 |
| | | AER | * | 30.9 | 28.2 | 25.5 | 22.7 |

Note 1: For buried cable, use underground losses.

Note 2: Applies to cables larger than 200 pairs.

* Use maximum design losses in Table X.

TABLE K

MEAN PAIR-TO-PAIR FEXT LOSS AT 772 KHZ (DB/MI)

| CABLE TYPE | | WITHIN UNIT ^m F/MI | ADJACENT UNIT ^m F/MI | UNIT SIZE |
|-----------------|---------------------------------|-------------------------------|---------------------------------|-----------|
| AJB BJB | 19-gauge waterproof PIC | 66 | 74 | 12, 13 |
| AJA BJA, KJA | 22-gauge waterproof PIC | 69 | 74 | 25 |
| AJT | 26-gauge waterproof PIC | 64 | 74 | 12, 13 |
| | | 65 | 72 | 25 |
| DSA CSA, KDA | 22-gauge pulp | 63 | 77 | 51 |
| ADA BDA, CDA | 22-gauge pulp | 72 | 82 | 50 |
| BHB CHA, KHA | 19-gauge PIC | 69 | 74 | 12, 13 |
| BHA CHA, KHA | 22-gauge PIC | 69 | 74 | 50 |
| MCR | 25-gauge DEPIC | 73 | 90 | 100 |
| MCM | 24-gauge DEPIC | 78 | 87 | 50, 100 |
| MLM | 24-gauge waterproof DEPIC | 76 | 85 | 50, 100 |
| CDM | 24-gauge PULP | 71 | 82 | 25 |

TABLE L
T1 CABLE INFORMATION

| GAUGE | CODE | INSULATION | NUMBER OF PAIRS | REMARKS |
|-------|---|---|---|---|
| 17 | ALC, BLC | DEPIC | 25, 50, 75, 100, 150, 200, 300 | WP — Aluminum |
| 19 | ADB | Pulp | 300, 400, 450 | WP Air core, even count Superseded Superseded Superseded |
| | AJB | PIC | 6, 11, 16, 25, 50, 75, 100, 150, 200, 300 | |
| | ALB, BLB | DEPIC | SAME AS AJB | |
| | BHB, CHB | PIC | 6-300 | |
| | DNB, GNB | Paper | 6-303 | |
| | ENB | Pulp | 6-455 | |
| | FNB, KLB | Paper | 6-455 | |
| 20 | ALD, BLD KLD | DEPIC | 25, 50, 75, 100, 150, 200, 300, 400, 600 | WP — Aluminum |
| 22 | ABM, 600- Type | PE-PVC | 6, 11, 16, 25, 50, 75, 100, 150, 200, 400, 600 | Intra-office use |
| | ADA, BDA AJA, CDA BJA, KJA KLA, ALA, BLA | Pulp PIC DEPIC | 300, 400, 600, 900, 1100, 1200 11, 16, 25, 50, 75, 100, 150 200, 300, 400, 600 SAME AS AJA | WP WP |
| | ANA BHA, CHA BJAW CSA, DSA ESA NA, KHA | Paper PIC PIC Pulp Paper Paper | 11-606 11-600 50, 100, 200 11-909 11-909 11-606 | Superseded Air core, even count SP — Screened Superseded Superseded Superseded |
| 24 | ADM, CDM | Pulp | 300, 400, 600, 900, 1200, 1500, 1800, 2100, 2400, 2700 | WP WP Air core, even count Superseded Superseded ICOT Cable |
| | AJM | MUP PIC | 25, 50, 100, 200, 300, 400, 600, 700 | |
| | ALM BLM | DEPIC | 25, 50, 100, 200, 300, 400, 600, 900 | |
| | BKM | PIC | 11-900 | |
| | CSM, DSM, FSM ESM MCM, MLM | Pulp Paper DEPIC | 11-909 11-1212 54, 106, 158, 210, 314, 418 616, 922 | |
| 25 | MCR | DEPIC | 412, 616, 1024, 1228, 1432, 1840 | MAT Cable |
| 26 | AJT | PIC | 25, 50, 100, 200, 300, 400, 600, 900 | WP WP Air core, even count Superseded Superseded Superseded |
| | ALT, BLT | DEPIC | SAME as AJT | |
| | BKT | PIC | 11-900 | |
| | BST | Pulp | 11-2121 | |
| | CST | Paper | 11-1818 | |
| | DST | Pulp | 11-2424 | |

TABLE M

**LOOP POWERING USING 221-, 231-, AND 236-
TYPE REPEATERS**

| POWERING VOLTAGE | BATTERY SUPPLIES REQUIRED | REGULATOR OPTIONS REPEATER TYPE | | |
|---------------------|---------------------------------|------------------------------------|--------------|--------------|
| | | 221 (NOTE 1) | 231 (NOTE 1) | 236 (NOTE 2) |
| 48 | -48* | W, Z & Y † | W, Z & V † | Y |
| 130 | +130* | X & Z | X & Z | R & Z † |
| 178 | +130 & -48 | W & Z | W & Z | Z |
| 260 | +130 & -130 | W & Y | W & Y | Z |

Note 1: For 140 mA line current operations using 221- and 231-type repeaters, select option T. For 60 mA line current operation, **DO NOT** select option T.

Note 2: For 140 mA line current operations using 236-type repeaters, select option X. For 60 mA line current operation, select option W.

* 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 options V and R are selected, turn screw fully down, otherwise two turns up.

TABLE N

**TRANSMISSION LOSS FOR POWER LOOP FAILURES
IN UNIDIRECTIONAL OPERATION (NOTE 1)**

| POWERING OFFICE OPTIONS | LOOPING POINT OPTIONS | RCV LOOP FAILURE (NOTE 2) | | | | TRMT LOOP FAILURE (NOTE 2) | | | |
|----------------------------|--------------------------|------------------------------|-----|-------------|-----|-------------------------------|-----|-------------|-----|
| | | LOWER SHELF | | UPPER SHELF | | LOWER SHELF | | UPPER SHELF | |
| (LOWER/UPPER) | (LOWER/UPPER) | TRMT | RCV | TRMT | RCV | TRMT | RCV | TRMT | RCV |
| BEHN/AFHN | Line Repeater | | X | | X | X | | X | |
| BEHW/AFHN | BEHN/AFHN | | X | | X | X | | X | |
| BDG/AGM | Line Repeater | | X | | X | X | X | X | |
| CEK/AGM | Line Repeater | | X | | X | X | | X | |
| BDG/AGM | BEHN/AFHN | | X | | X | X | X | X | |
| CEK/AGM | BEHN/AFHN | | X | | X | X | | X | |
| BEHN/AFHN | BDG/AGM | X | X | | X | X | | X | |
| BEHN/AFHN | CEK/AGM | | X | | X | X | | X | |
| BDG/AGM | BDG/AGM | X | X | | X | X | X | X | |
| CEK/AGM | CEK/AGM | | X | | X | X | | X | |

Note 1: The X indicates end-to-end transmission loss for the indicated power loop failure.

Note 2: Failure of regulator or removal of a line repeater in RCV and TRMT directions relative to powering office.

TABLE O

MAXIMUM AND MINIMUM CABLE RESISTANCE COEFFICIENTS

| WIRE GAUGE | | OHMS PER 1000 FT OF SPAN LINE | |
|------------|----------|-------------------------------|------------------|
| COPPER | ALUMINUM | R _{max} | R _{min} |
| | 17 | 8.33 | 8.04 |
| 19 | | 8.33 | 8.04 |
| 21 | | 13.24 | 12.79 |
| | 20 | 16.70 | 16.13 |
| 22 | | 16.70 | 16.13 |
| 24 | | 26.55 | 25.65 |
| 25 | | 33.48 | 32.34 |
| 26 | | 42.22 | 40.78 |

TABLE P

EFFECTIVE RESISTANCE IN OHMS OF LINE REPEATERS

| REPEATER OPERATION | LOW POWER 60 mA | | STD. POWER 140 mA | |
|----------------------|-----------------|-------|-------------------|-------|
| | UNPROT. | PROT. | UNPROT. | PROT. |
| Through | 116 | 128 | 80 | 92 |
| Loop - Side 1 Input | 114 | 120 | 78 | 84 |
| Loop - Side 1 Output | 2 | 8 | 2 | 8 |

TABLE Q

OFFICE BATTERY LIMITS AND MISCELLANEOUS BAY RESISTANCES

| POWERING VOLTAGE | V _B max (VOLTS) | V _B min (VOLTS) | R _x (OHMS) ORB | |
|------------------|----------------------------|----------------------------|---------------------------|---------------|
| | | | J98710 206 BAY | J98725 T1C/T1 |
| 48 | 50 | 45 | 10 | 10 |
| 130 | 135 | 125 | 10 | 120 |
| 178 | 185 | 170 | 20 | 130 |
| 260 | 270 | 250 | 110 | 130 |

TABLE R

**SPAN-TERMINATING ASSEMBLY
POWER LOOP RESISTANCE RANGES**

| BATTERY VOLTAGE | R _L min | R _L max |
|-----------------|--------------------|--------------------|
| -48 | 0 | 332 |
| +130 | 272 | 807 |
| -130 | 272 | 807 |
| -48 and +130 | 662 | 1149 |
| +130 and -130 | 942 | 1614 |

TABLE S

**SPAN-TERMINATING ASSEMBLY
CONTROL UNIT RESISTANCE RANGE (NOTE)**

| | POWER CONNECTION | | REMOVE STRAPS FROM RESISTORS | | R _O min | R _O max |
|----|------------------|------|------------------------------|----|--------------------|--------------------|
| | A | B | R1 | R2 | | |
| or | C | D | R3 | R4 | | |
| | -48 | GND | | | 11 | 361 |
| | GND | +130 | | X | 121 | 617 |
| | -130 | GND | X | | 111 | 607 |
| | -48 | +130 | | X | 121 | 617 |
| | -130 | +130 | X | X | 221 | 717 |

Note: Control unit resistors R1, R2, R3, and R4 are strapped by the shop. Resistors R2 and R4 are tapped and both sections are strapped. The strap across the 147-ohm section of R2 and R4 should not be removed unless it is necessary to supplement the office resistance.

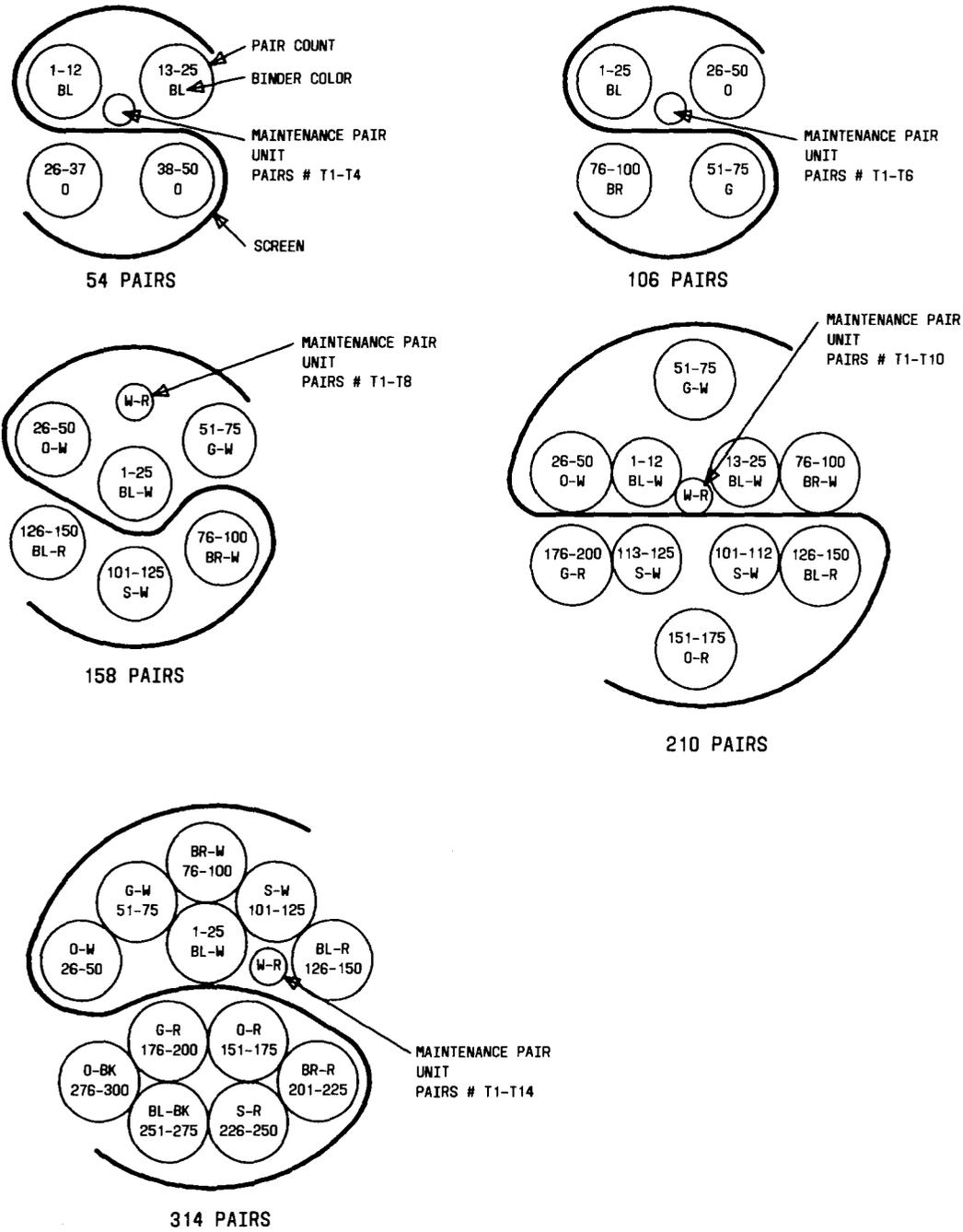


Fig. 1 — Typical Core Diagrams for Screened Cable (Sheet 1 of 2)

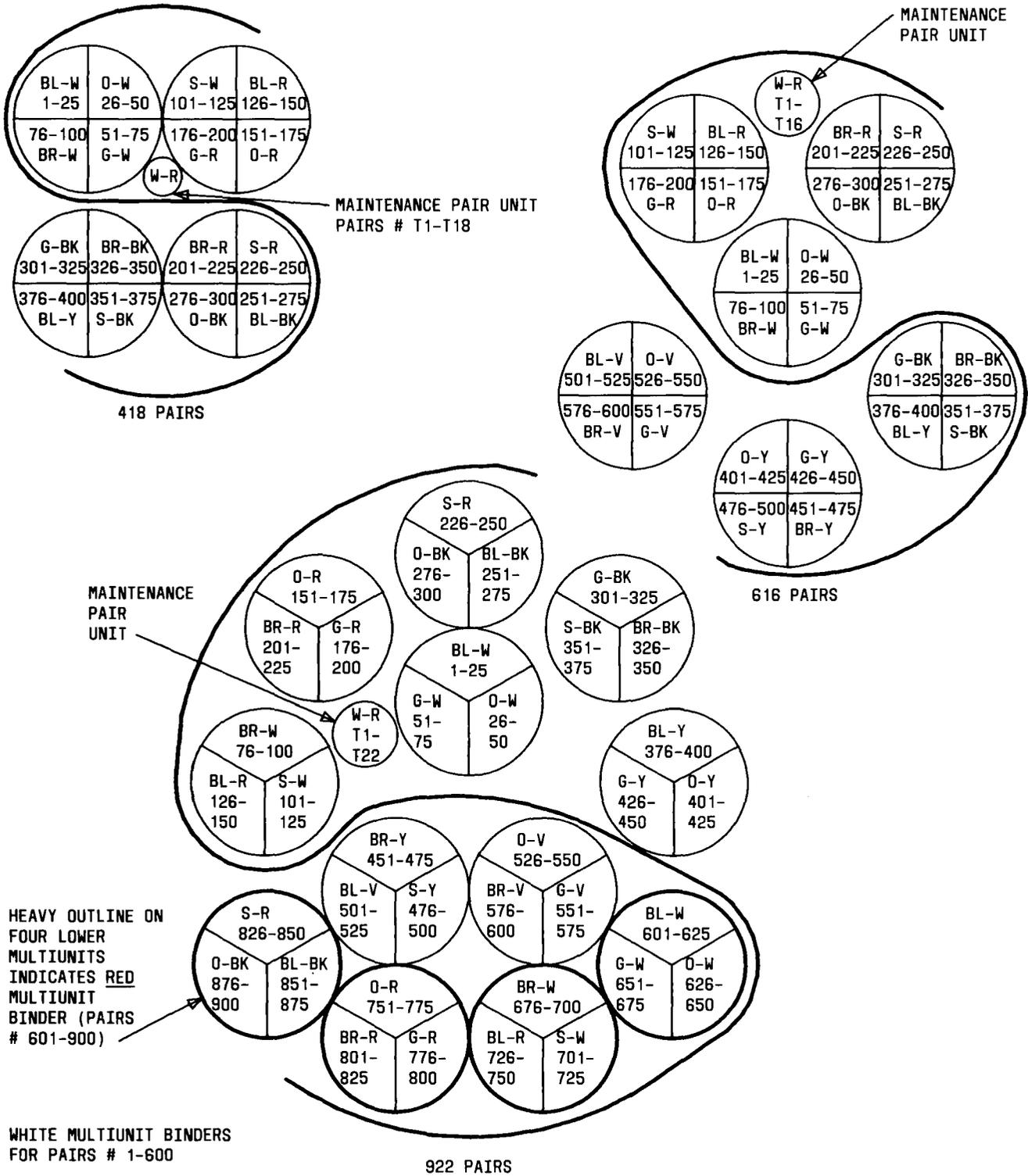


Fig. 1—Typical Core Diagrams for Screened Cable (Sheet 2 of 2)

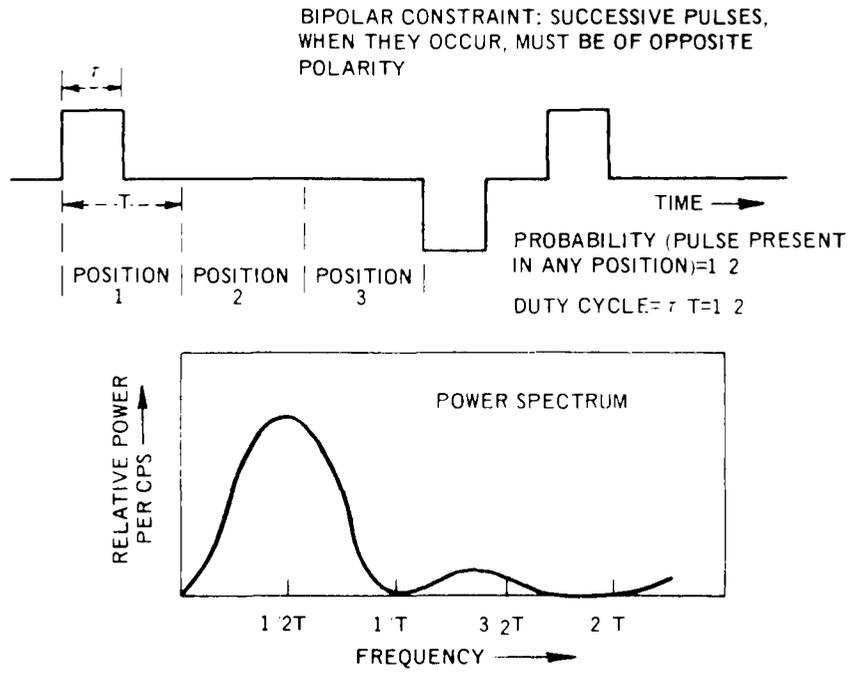


Fig. 2—Random Bipolar Pulse Train

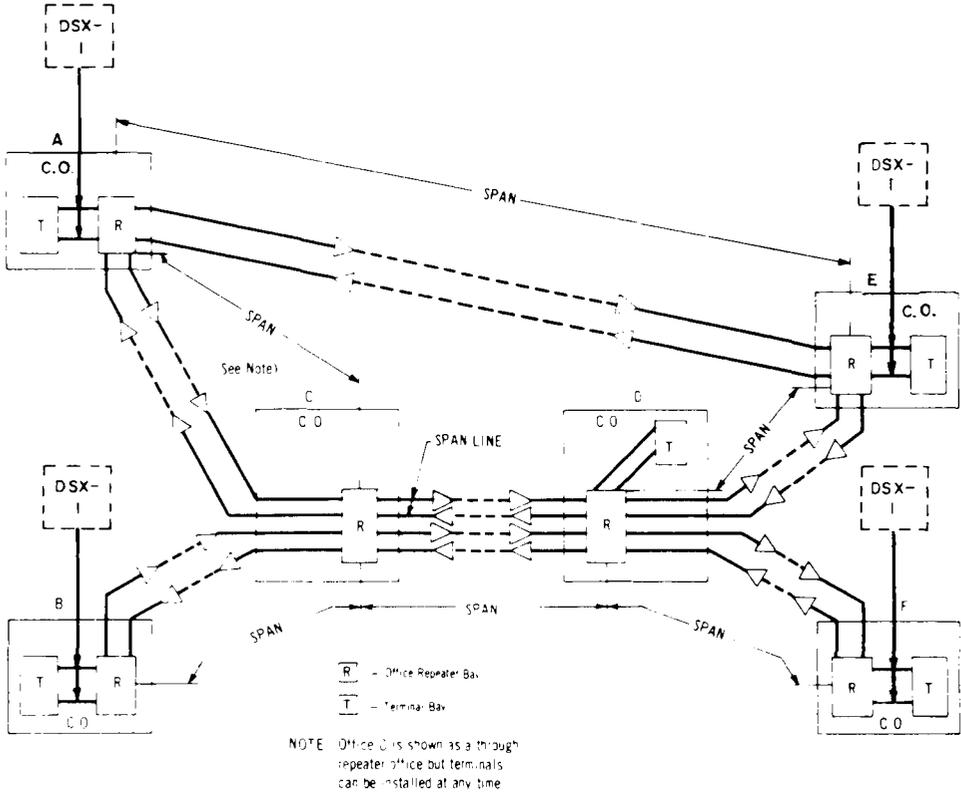


Fig. 3—Span Concept

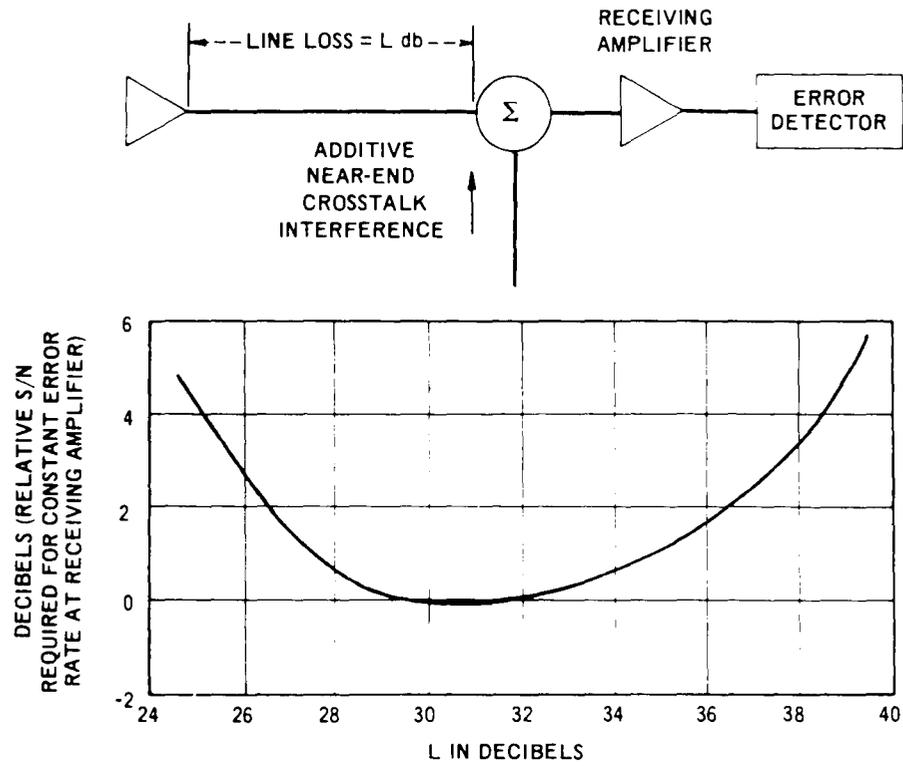


Fig. 4—Effect of Line Loss on Amplifier Performance

PAIR LOSS TEST SET DATA SHEET

TEST SET USED J98725AA

| SHELF | REPEATER SLOT | AC TEST | | | | | | | | | | | | | | | | DC TEST | | | | | | | | | | | | |
|----------------|---------------|---|----|---|---|---|---|----|---|---|---|---|---|---|---|---|---|---------|---|----|----|---|---|---|---|---|---|---|---|------|
| | | LBO OR LOSS SWITCH POSITION INCLUDING POLARITY OF DEVIATION | | | | | | | | | | | | | | | | T-R | | TG | RG | | | | | | | | | |
| | | A1 | A1 | A | A | B | B | C | C | D | D | E | E | F | F | G | G | H | H | | | J | J | K | K | L | L | M | M | OPEN |
| SHELF NUMBER 1 | 1 | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | | |
| | 2 | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | |
| | 4 | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | |
| | 5 | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | |
| | 6 | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | |
| | 7 | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | |
| | 8 | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | |
| | 9 | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | |
| | 10 | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | |
| | 11 | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | |
| | 12 | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | |
| | 13 | | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | |
| SHELF NUMBER 2 | 14 | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | |
| | 15 | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | |
| | 16 | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 17 | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | |
| | 18 | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | |
| | 19 | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | |
| | 20 | | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | |
| | 21 | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | |
| | 22 | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | |
| | 23 | | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | |
| | 24 | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | |
| | 25 | | | | | | | ✓ | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL | | | | | 1 | | 3 | 17 | 2 | 1 | 1 | | | | | | | | | | | | | | | | | | | |
| | | A1 | A1 | A | A | B | B | C | C | D | D | E | E | F | F | G | G | H | H | J | J | K | K | L | L | M | M | | | |
| | | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | - | + | | | |

LARGEST TOTAL IS IN COLUMN C-
CABLE SECTION

FROM MH357
TO MIDDLE-C.O.

FUNCTION RCV B
SWITCH POSITION RCV B
RELAY RACK NUMBER _____
OR

APPARATUS CASE NUMBER CA-1(S-1)
DATE 1-20-76

TIME 3 PM
TESTER J.J. JONES
CABLE NUMBER IDENTIFICATION TK-7761
COUNT 201-225

(THESE PAIRS GOOD
PAIRS 16 & 20 SHOULD
BE CHECKED FOR TROUBLE)

CONTINUITY CHECK
FAULT LOCATE PAIR
ORDER WIRE PAIR

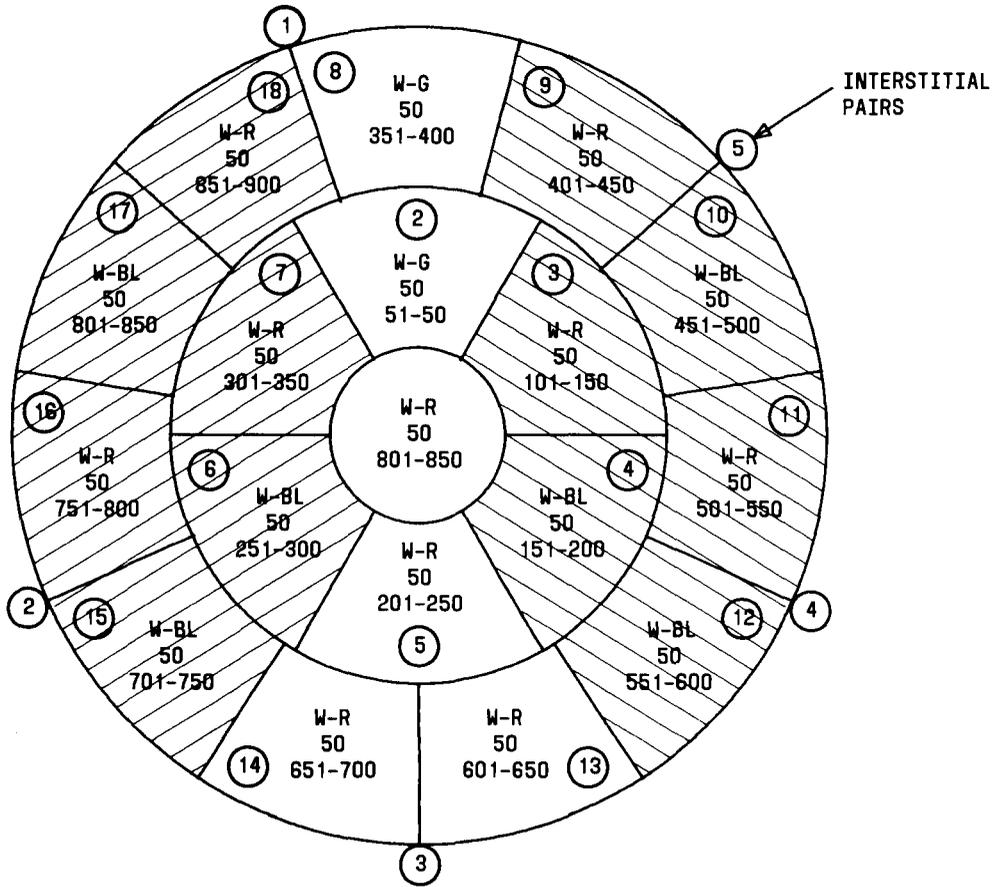
E-6779 OCTOBER, 1977

CABLE

| | UNDERGROUND | AERIAL |
|---------------------|-------------------|--------|
| TYPE (CHECK ONE) | (22GacuPULP) ✓ | |
| LENGTH | 5 KFT | |

| J98725AA SYSTEM SWITCH POSITION | | |
|------------------------------------|--------|--------|
| T1 | T1C LO | T1C HI |
| ✓ | | |

Fig. 5—Sample of Form E-6779



W-E BINDER UNITS 6, 7, 15, 16, 17 & 18
 E-W BINDER UNITS 3, 4, 9, 10, 11 & 12

Fig. 6—Unit Assignment 900-Pair Unit Type Cable

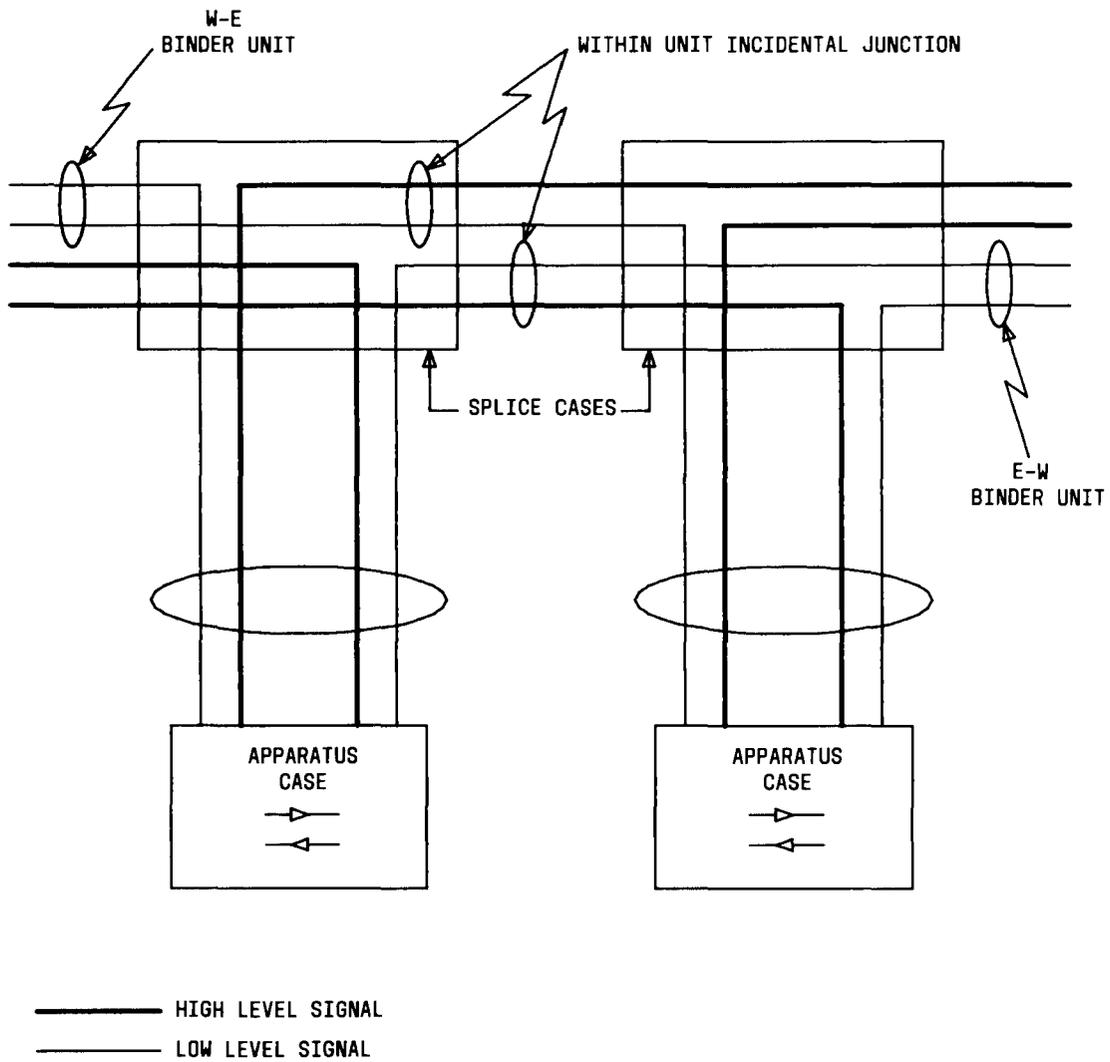


Fig. 7—Within Unit Incidental Junction

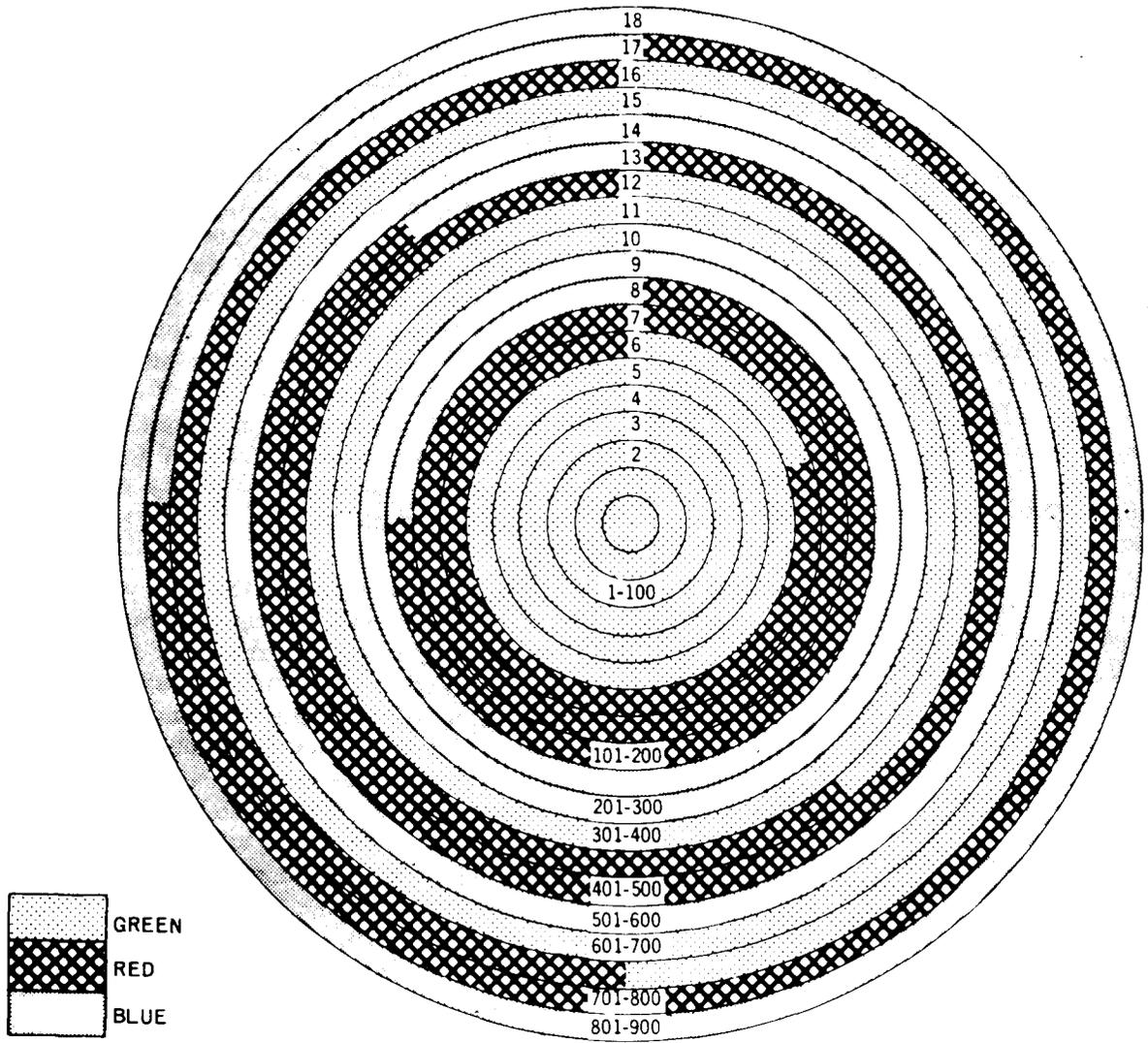


Fig. 8—Layer Assignment, 900-Pair Layer Type Cable

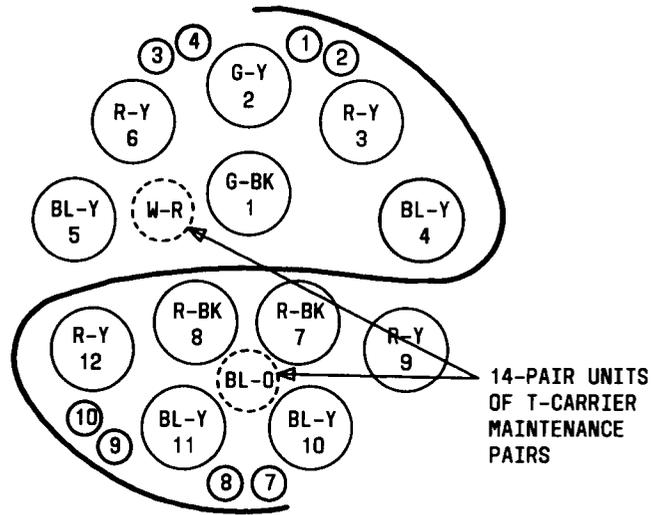
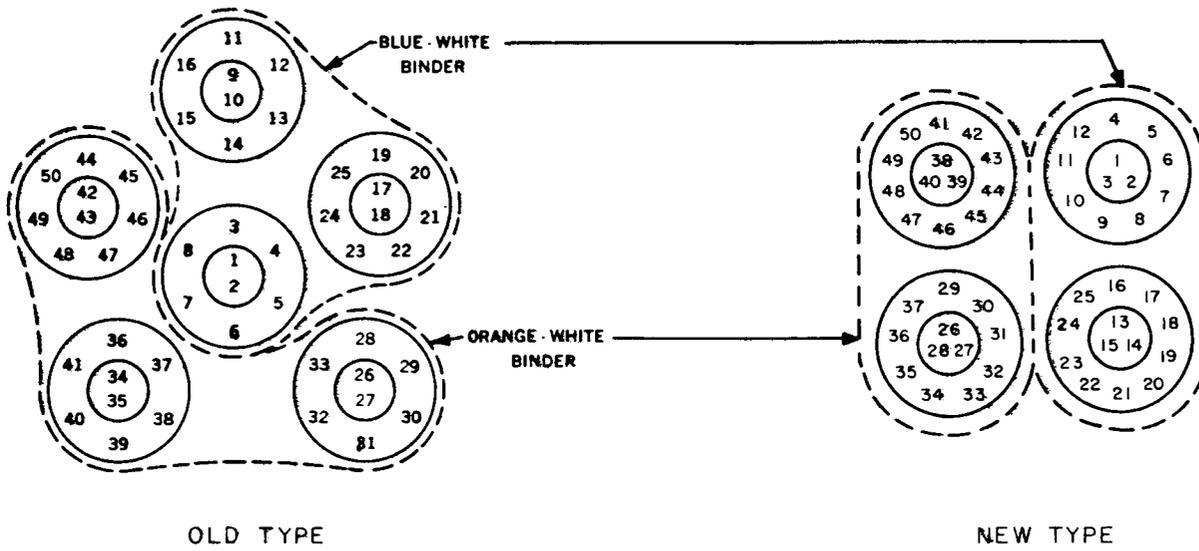


Fig. 9—1200-Pair MAT Cable (MCR) Screened Cable



50 PAIR EVEN COUNT
PIC CABLE

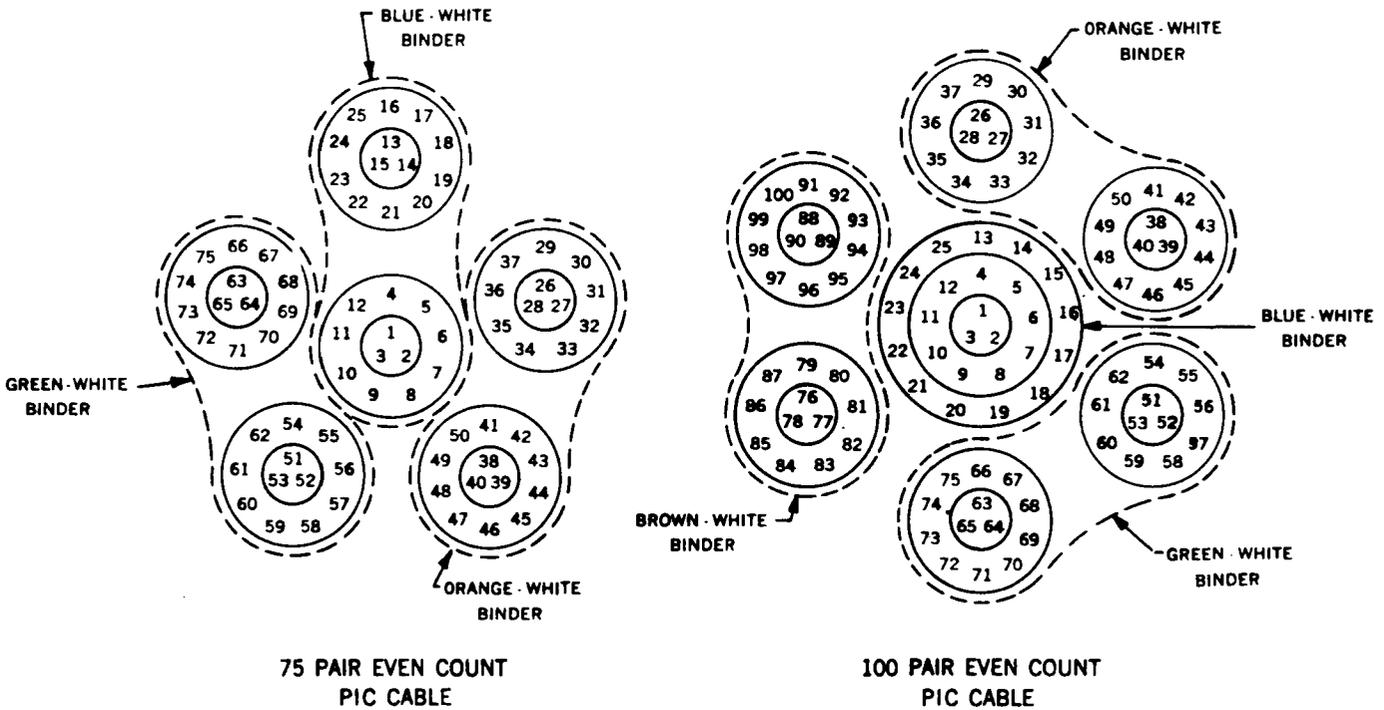


Fig. 10—Typical Core Diagrams For Even Count PIC Cables

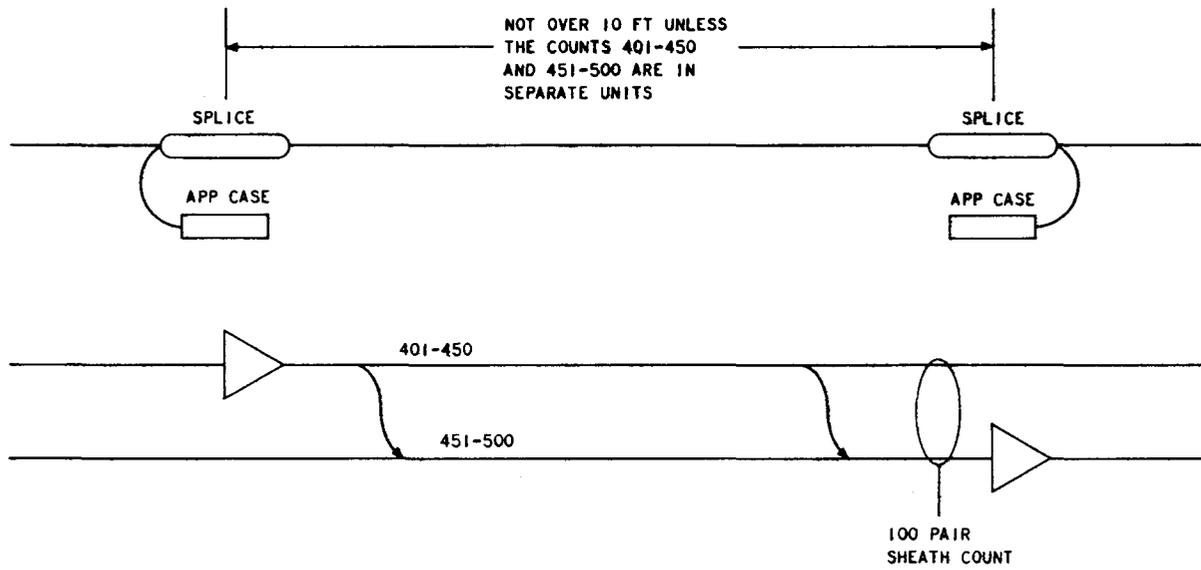


Fig. 11—Separation of Apparatus Cases

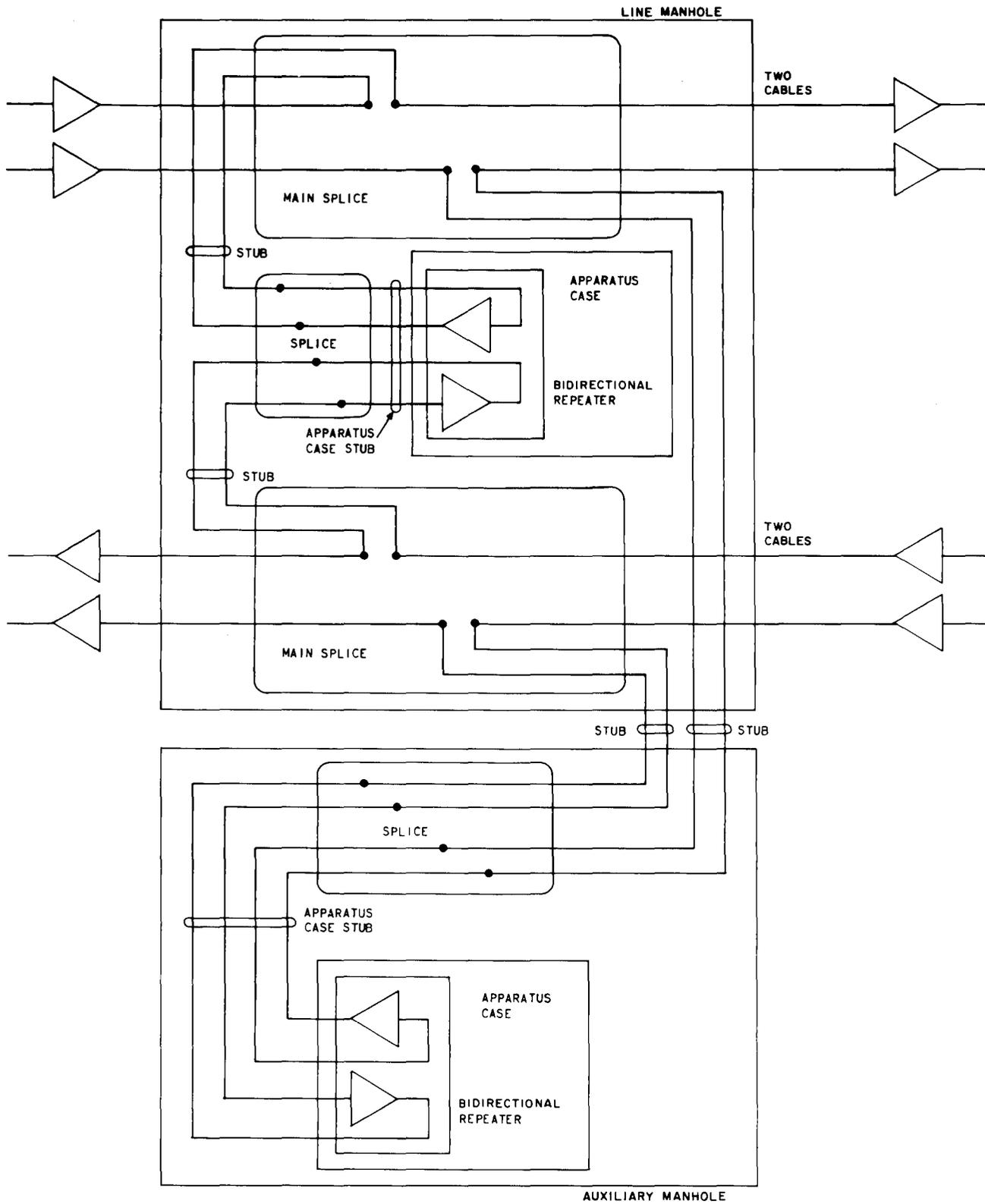


Fig. 12—Cable Looped Through Auxiliary Manhole

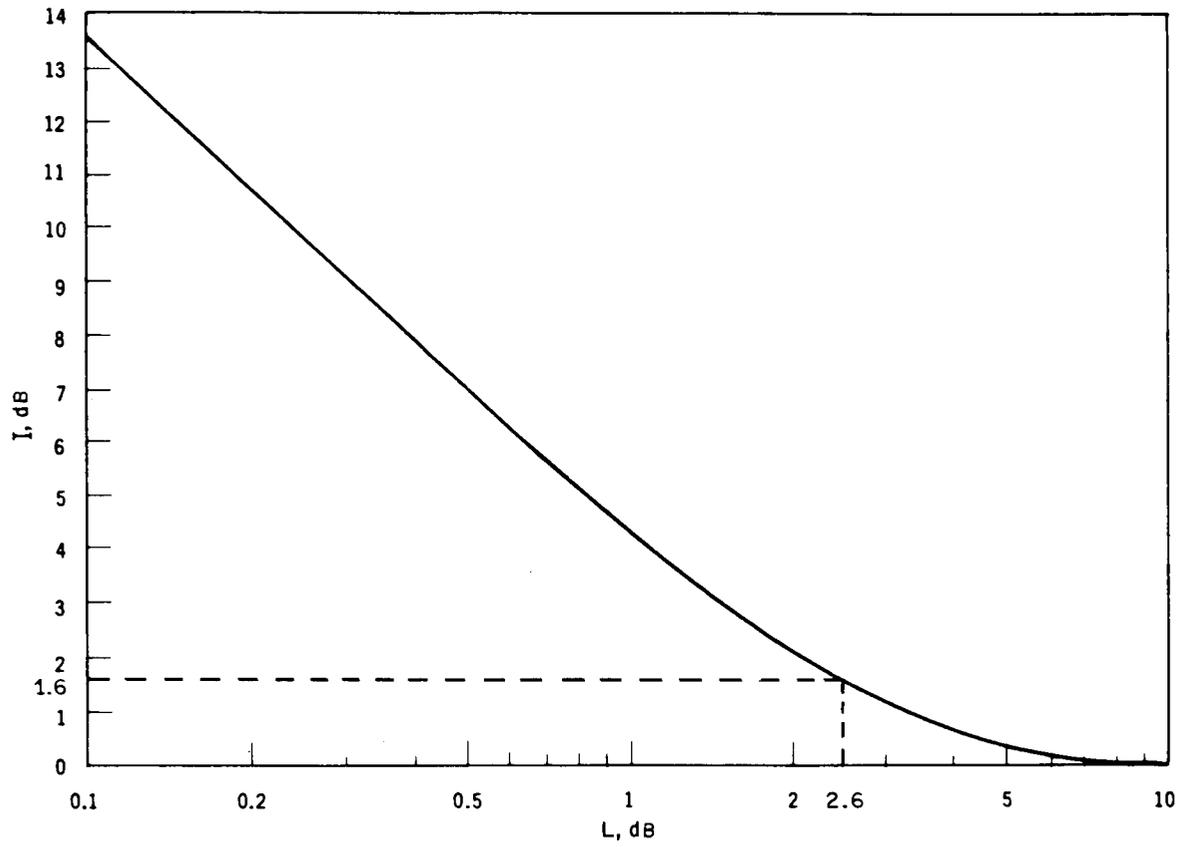
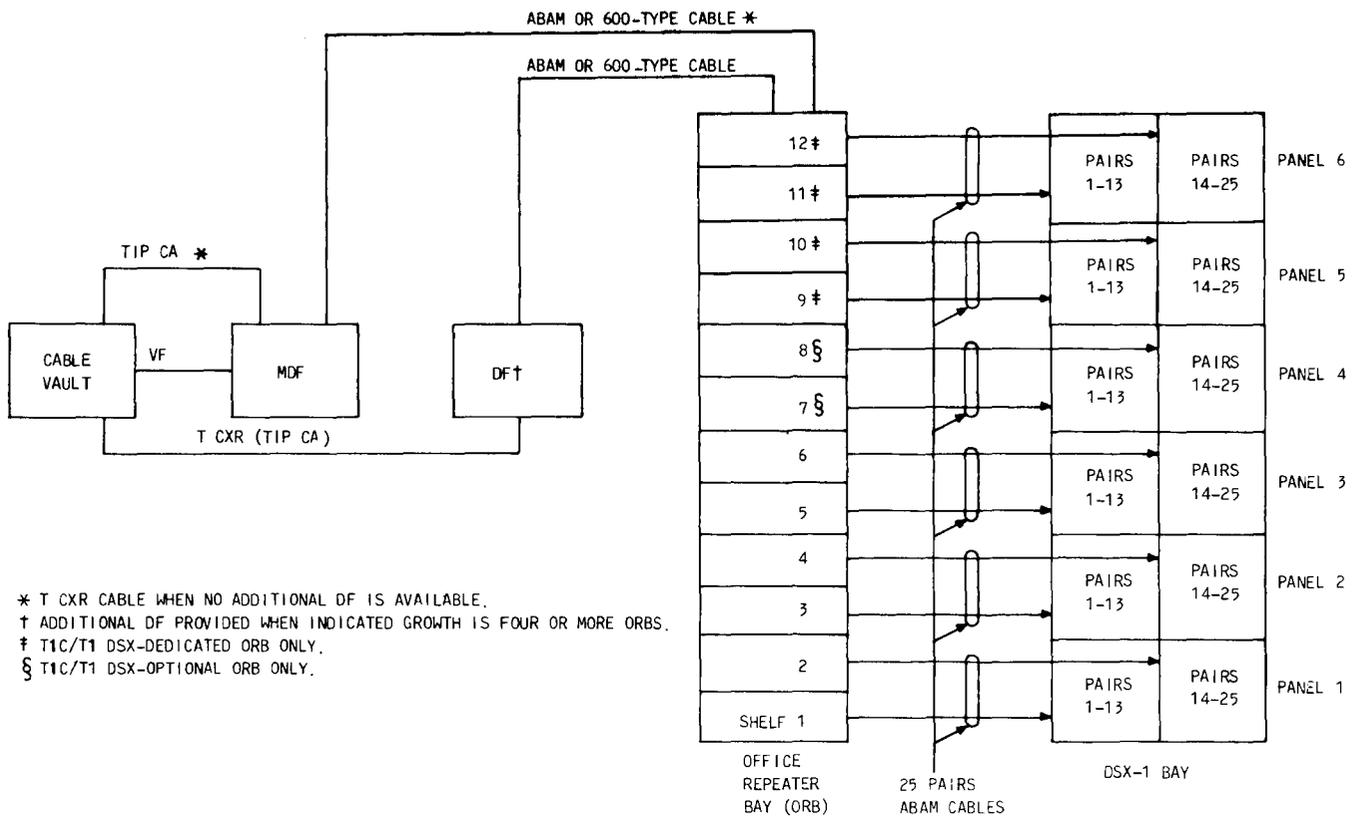
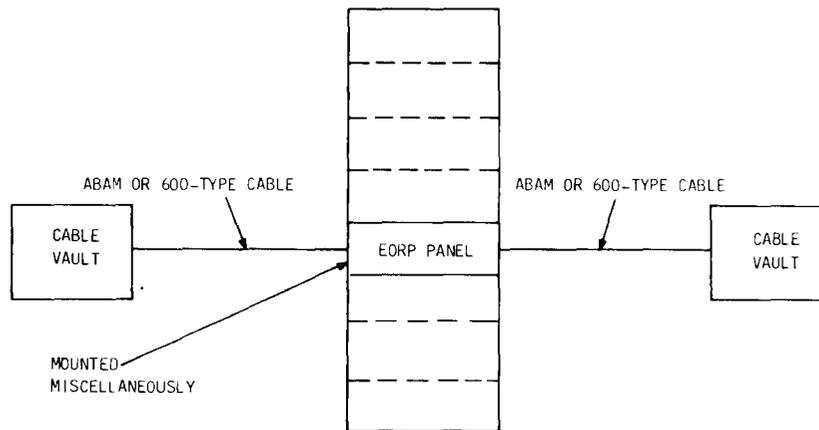


Fig. 13—I vs. L



* T CXR CABLE WHEN NO ADDITIONAL DF IS AVAILABLE.
 † ADDITIONAL DF PROVIDED WHEN INDICATED GROWTH IS FOUR OR MORE ORBS.
 ‡ T1C/T1 DSX-DEDICATED ORB ONLY.
 § T1C/T1 DSX-OPTIONAL ORB ONLY.

A. WIRING TO ORB AND DSX-1 BAYS



B. WIRING TO EORP PANELS

Fig. 14—T1 Carrier Office Wiring

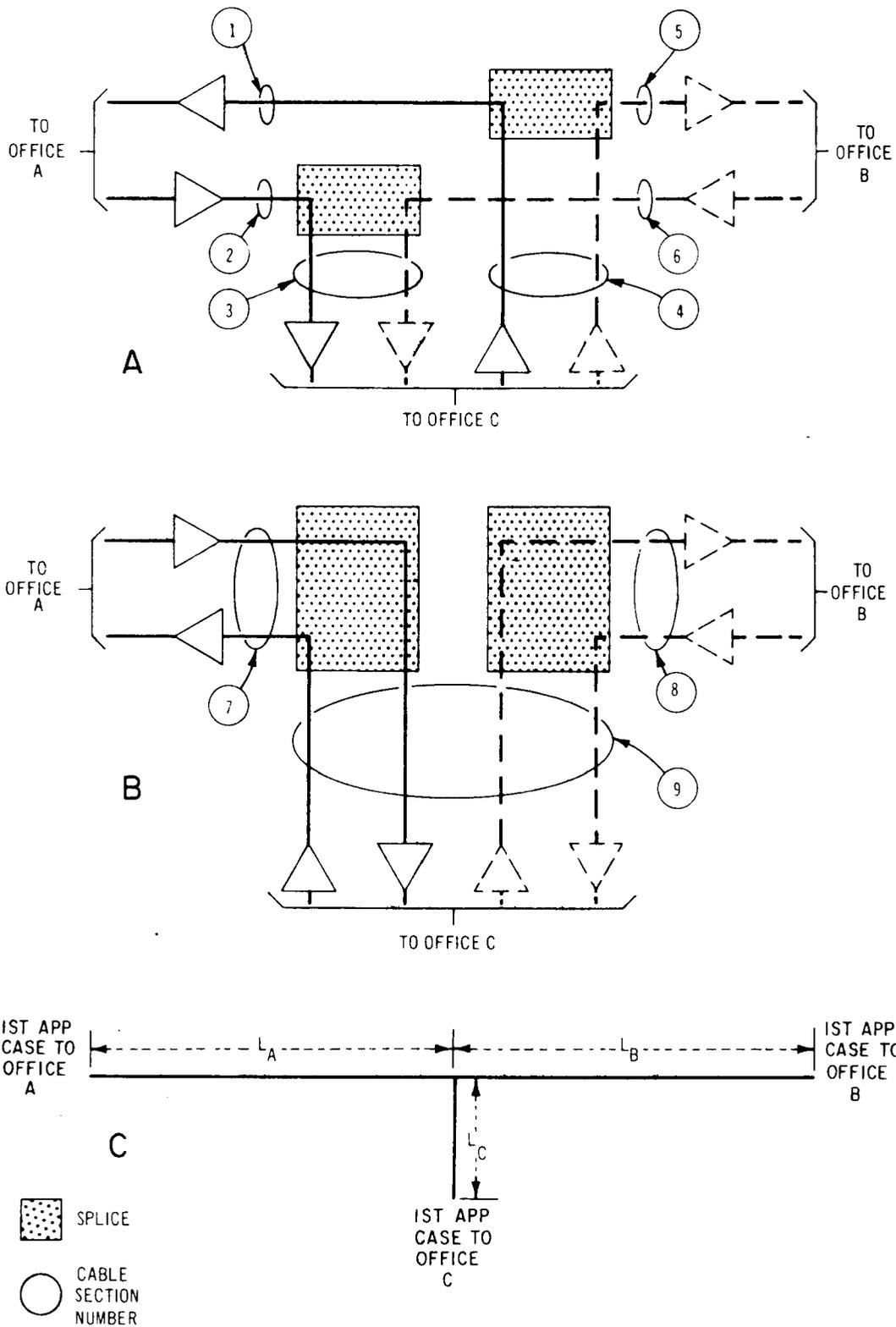
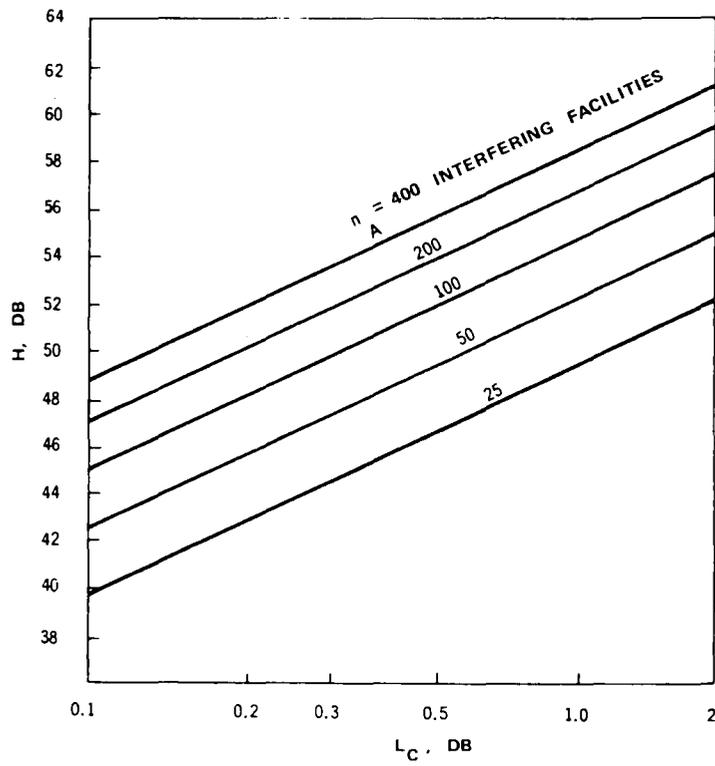
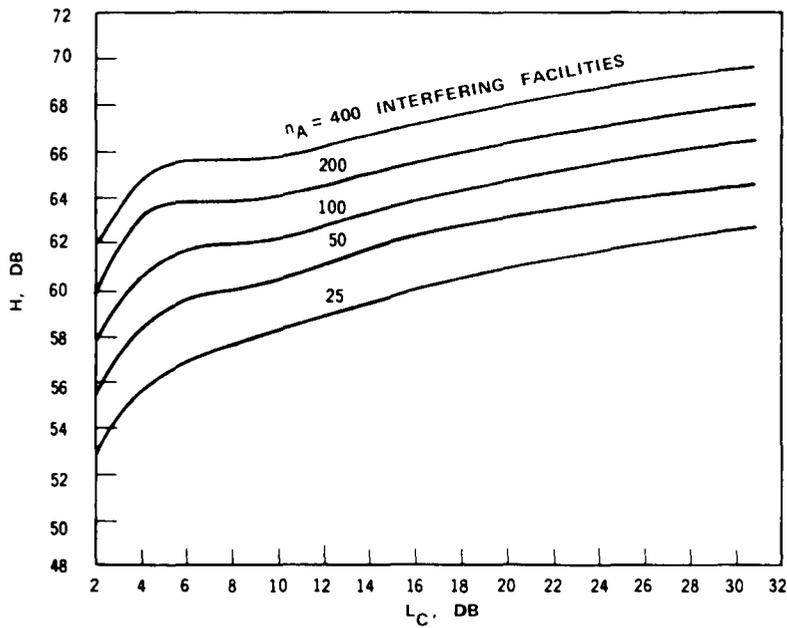


Fig. 15—Line Junctions



A. VALUES OF L_c FROM 0.1 DB TO 2 DB



B. VALUES OF L_c FROM 2 DB TO 30 DB

Fig. 16—Values of L_c

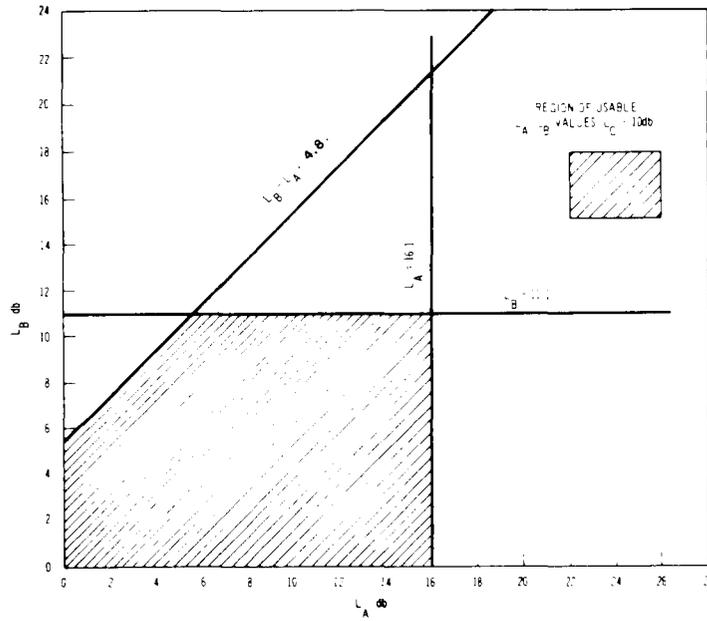


Fig. 17—One Cable Junction Example

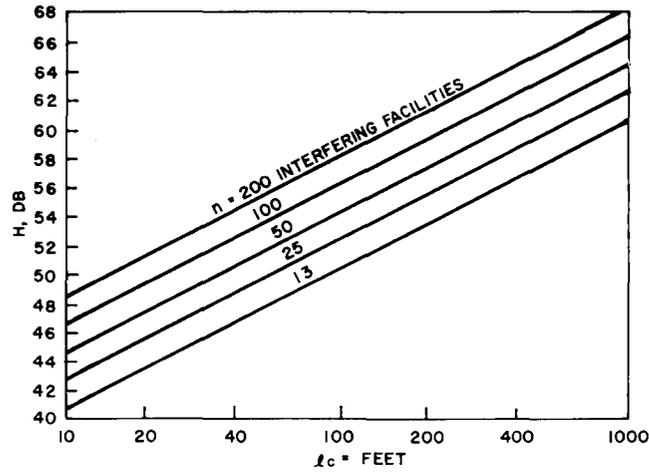


Fig. 18 — H_i vs. L_c For ABAM And 600-Type Cable

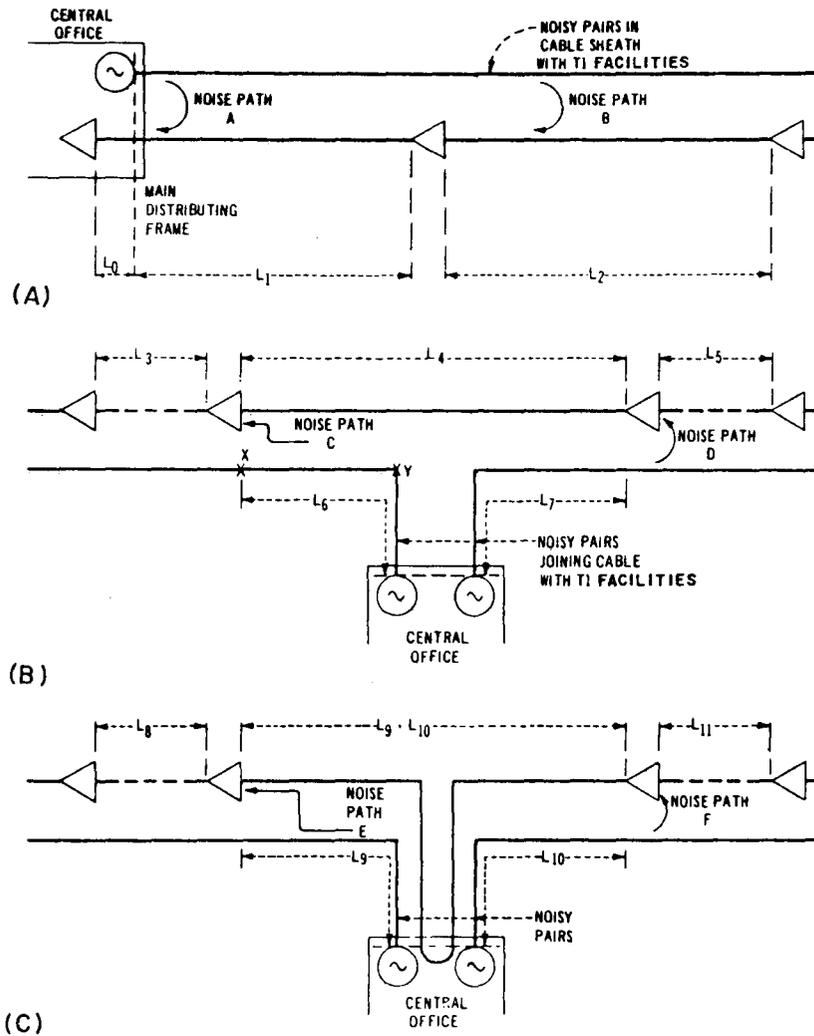
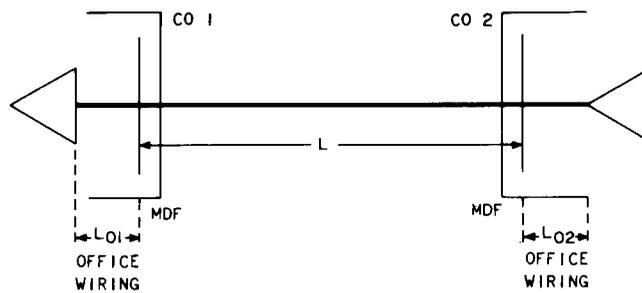


Fig. 19—Repeater Sections Near a Central Office



$$L_{01} + L + L_{02} + 6 \text{ (NOTE 1)} \leq L_{\text{MAX}} \text{ (NOTE 2)}$$

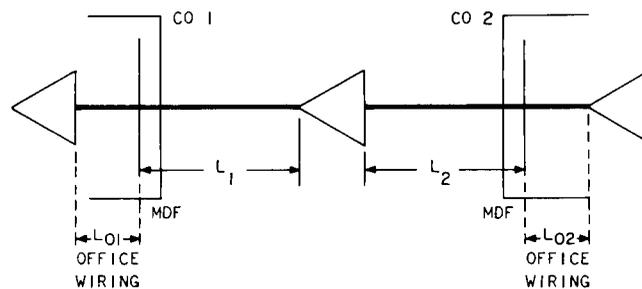
BUT NOT LESS THAN 6 (NOTE 3)

$$L_{02} + L + 3 \text{ (NOTE 1)} \leq 23 \text{ (NOTE 4)}$$

IN ADDITION, FOR ONE-CABLE OPERATION:

$$L_{01} + L + L_{02} \leq L_d \text{ (NOTE 5)}$$

A. SPAN WITH NO INTERMEDIATE REPEATER



$$L_{01} + L_1 + 3 \text{ (NOTE 1)} \leq L_{\text{MAX}} \text{ (NOTE 2)}$$

BUT NOT LESS THAN 6 (NOTE 3)

$$L_{02} + L_2 + 3 \text{ (NOTE 1)} \leq L_{\text{MAX}} \text{ (NOTE 2)}$$

BUT NOT LESS THAN 6 (NOTE 3)

$$L_1 \leq 23 \text{ (NOTE 4)}$$

IN ADDITION, FOR ONE-CABLE OPERATION:

$$L_{01} + L_1 \leq L_d \text{ (NOTE 5)} - 3 \text{ (NOTE 1)}$$

$$L_{02} + L_2 \leq L_d \text{ (NOTE 5)} - 3 \text{ (NOTE 1)}$$

B. SPAN WITH ONE INTERMEDIATE REPEATER

NOTES:

1. ASSUMING OFFICE REPEATERS WITH 3-DB PADS. FOR OFFICE REPEATERS WITH 7.5-DB ARTIFICIAL LINES, SUBSTITUTE 7.5 FOR 3 AND 15 FOR 6 IN THE EQUATIONS.
2. $L_{\text{MAX}} = 31.1$ DB FOR AERIAL CABLE OR 32.2 DB FOR UNDERGROUND OR BURIED CABLE.
3. ASSUMING OFFICE REPEATERS WITH 3-DB PADS. THERE IS NO MINIMUM RESTRICTION (OTHER THAN NOISE CONSIDERATIONS) WHEN OFFICE REPEATERS WITH 7.5-DB ARTIFICIAL LINES ARE USED.
4. THIS RESTRICTION APPLIES ONLY IF SWITCHED PAIRS ARE IN THE SAME SPLICING GROUP WITH T1 PAIRS.
5. L_d = MAXIMUM DESIGN LOSS AS DEFINED IN PART 7.

Fig. 20—End Sections, Special Cases

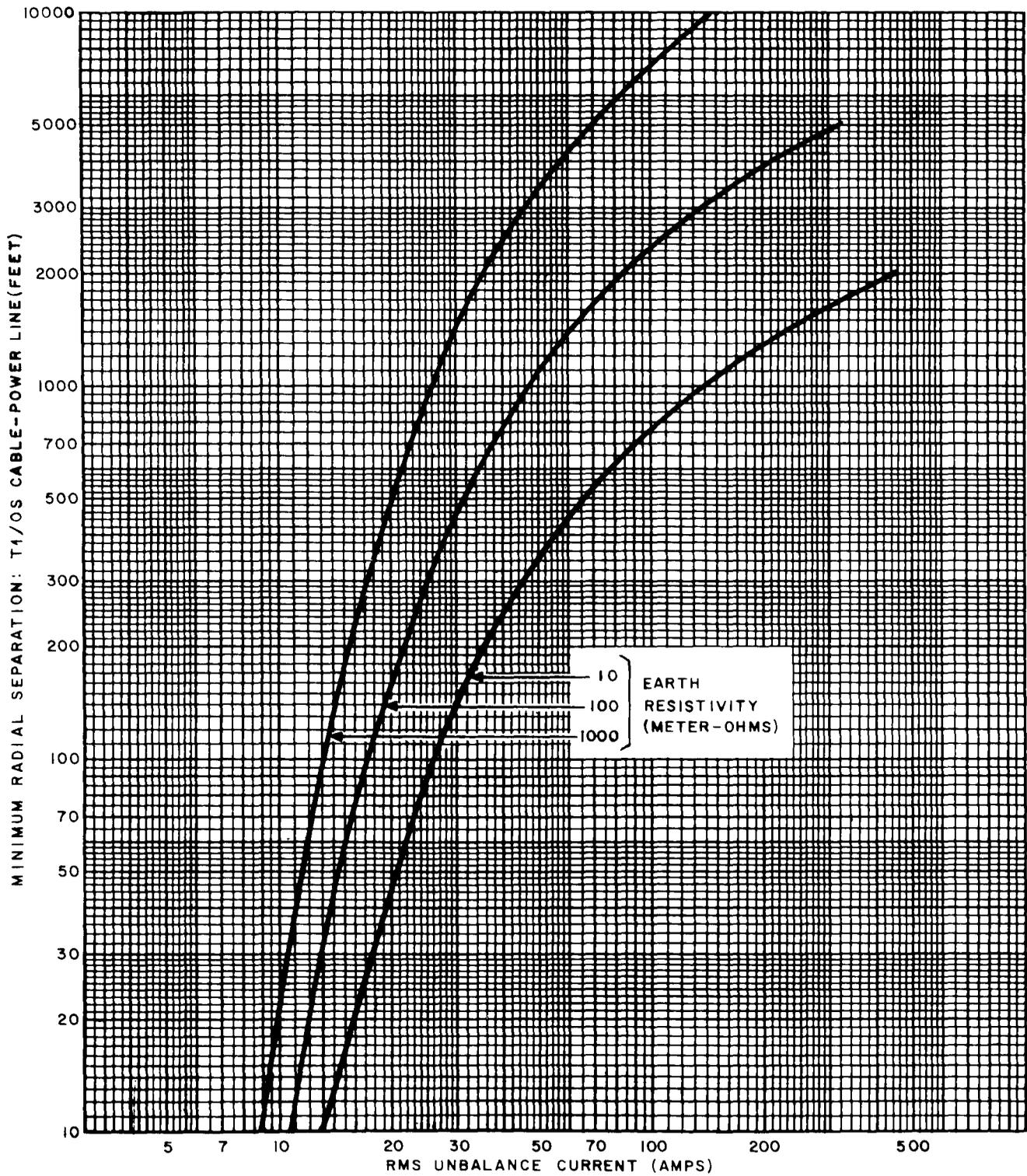


Fig. 21 — Separation of T1 Cables and Parallel Power Lines

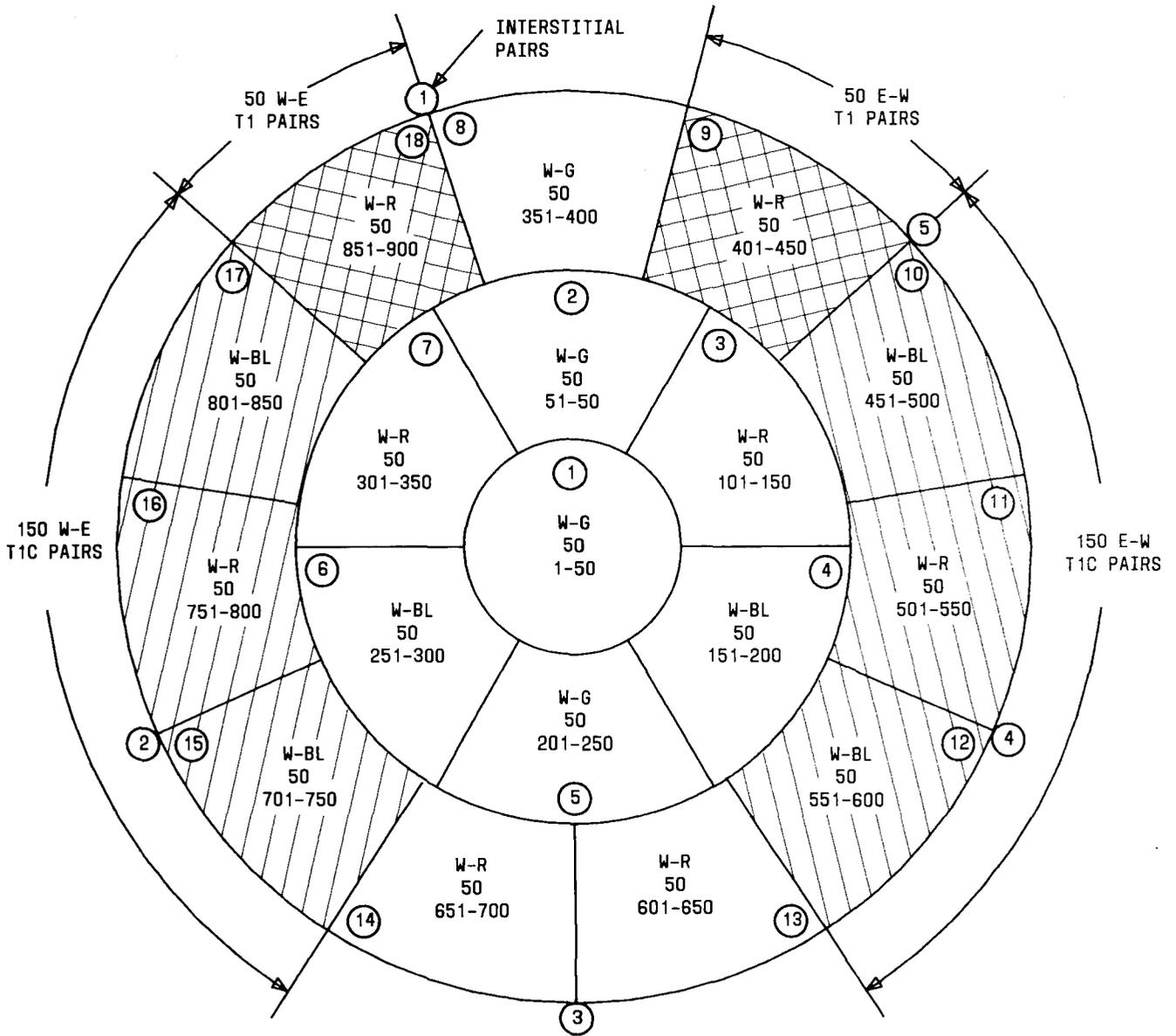
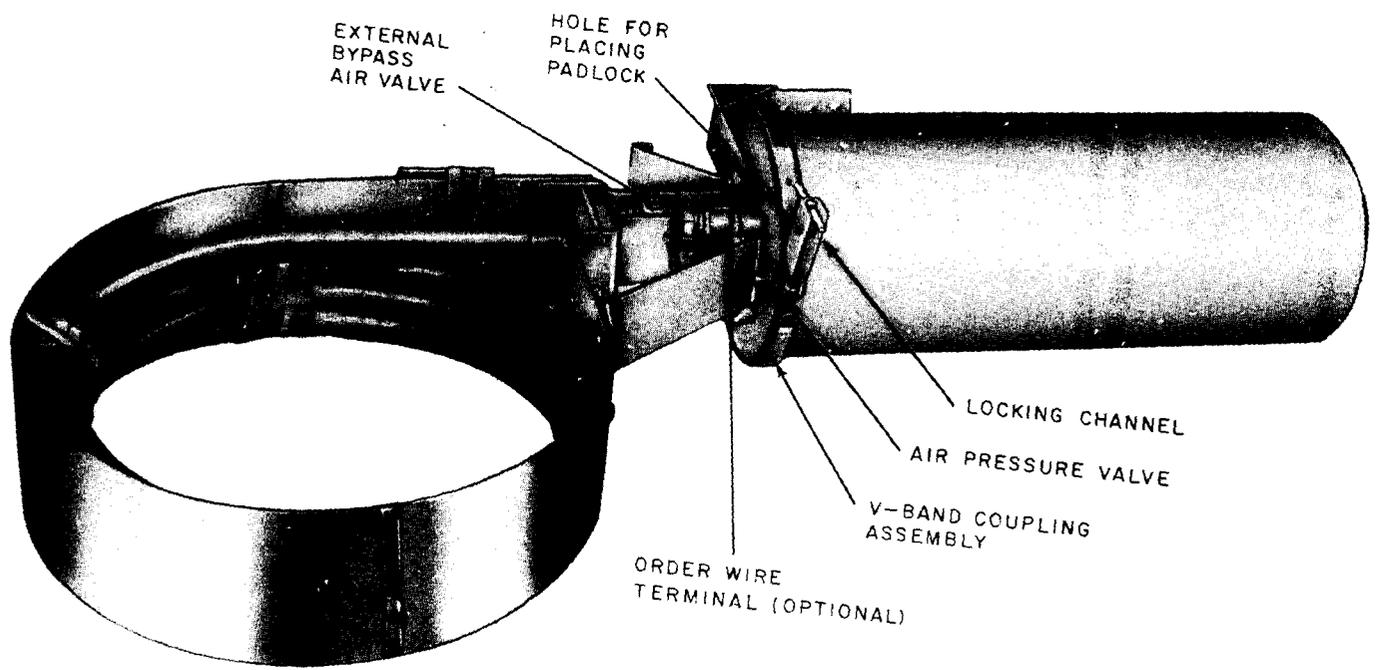
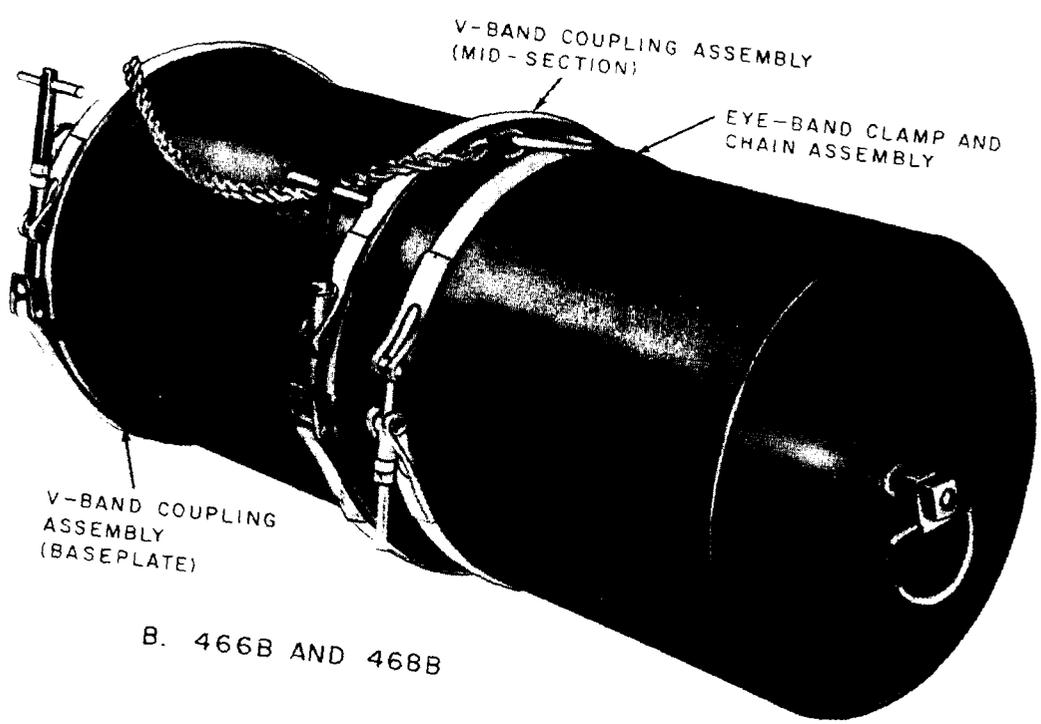


Fig. 22—T1 and T1C in Same 900-Pair Cable



A. 466A AND 468A



B. 466B AND 468B

Fig. 23—466- and 468-Type Apparatus Cases

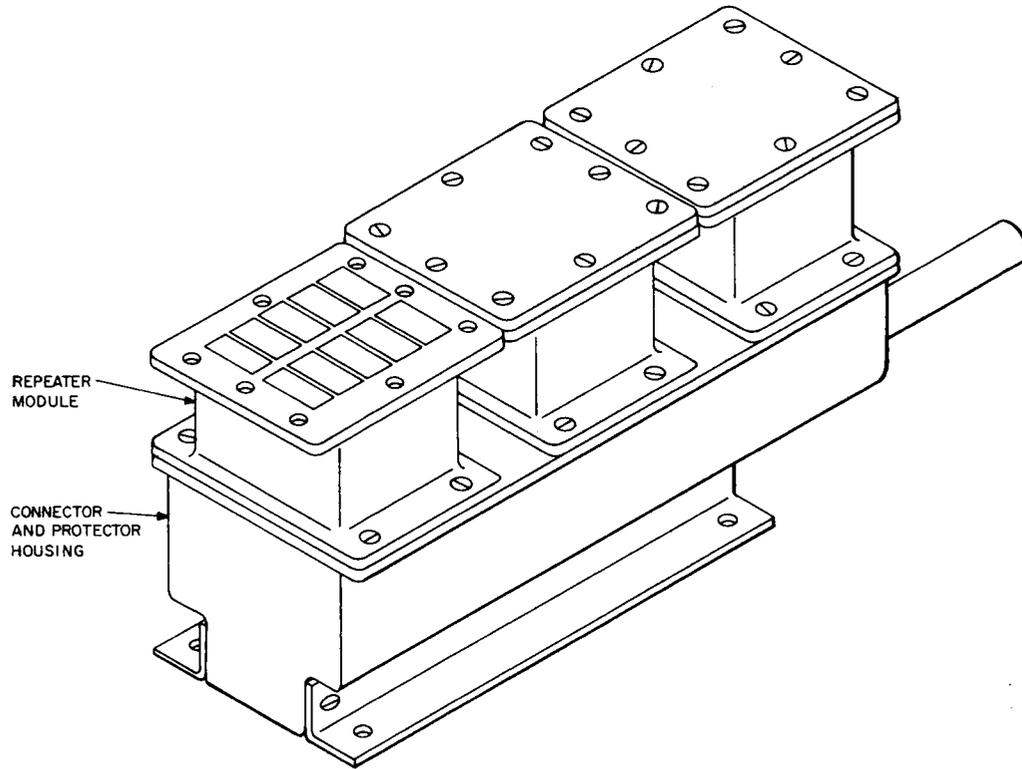


Fig. 24—475-Type Apparatus Case

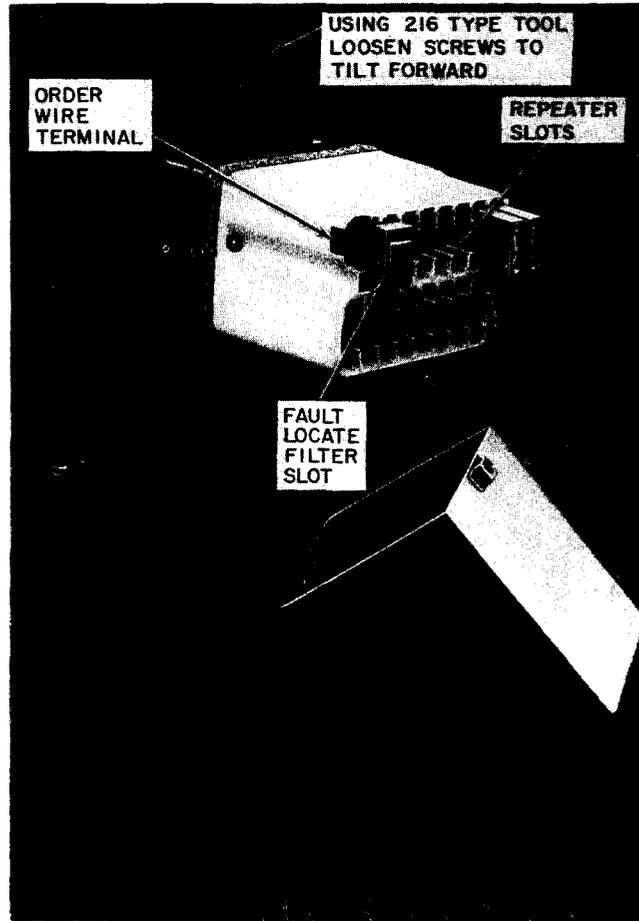


Fig. 25—809-Type Apparatus Case

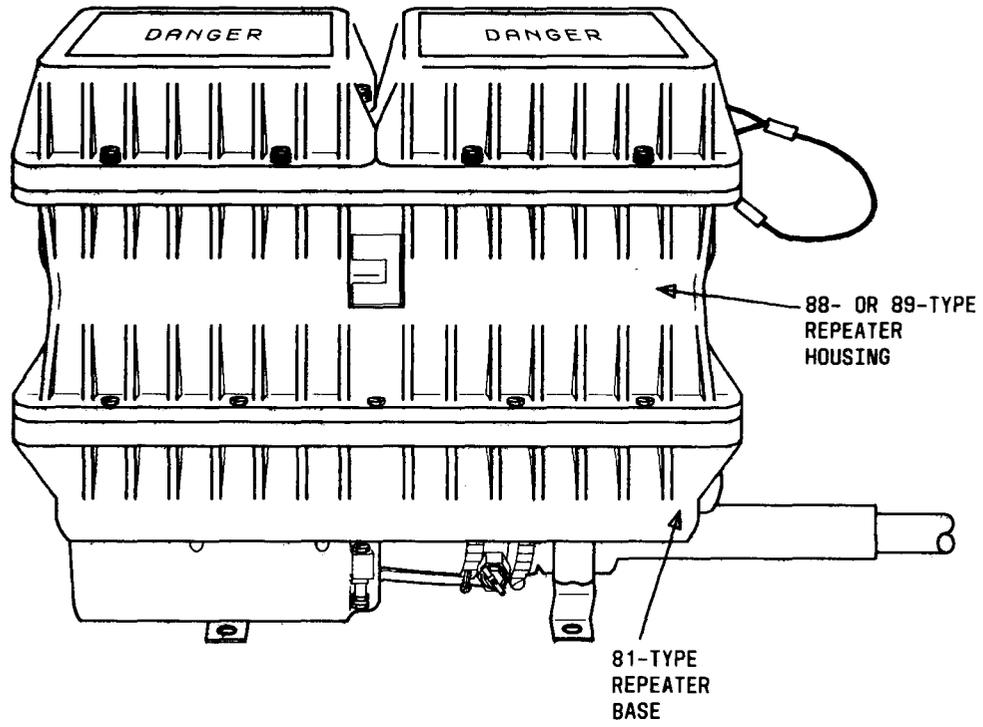
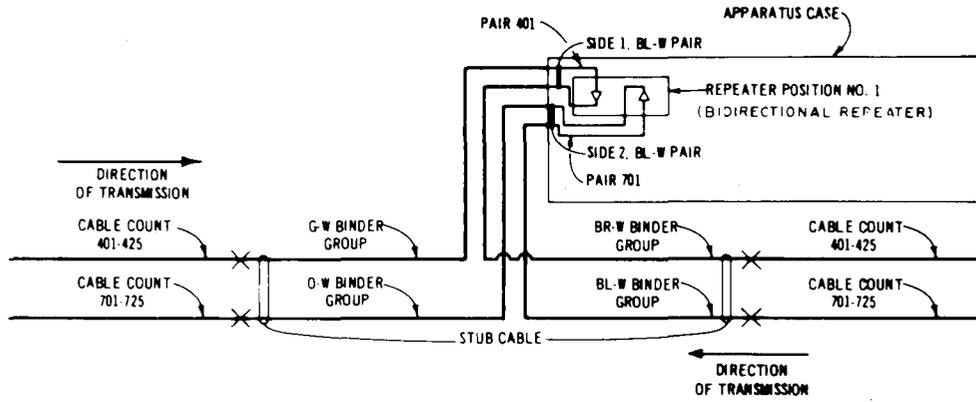
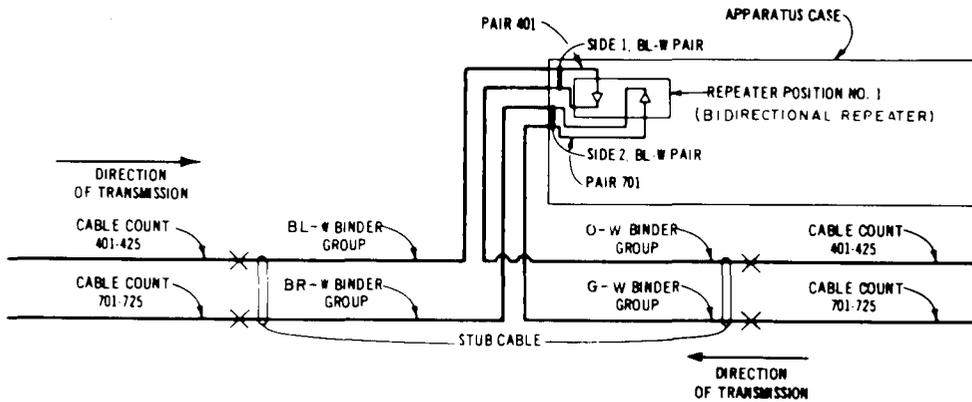


Fig. 26—818- and 819-Type Apparatus Case

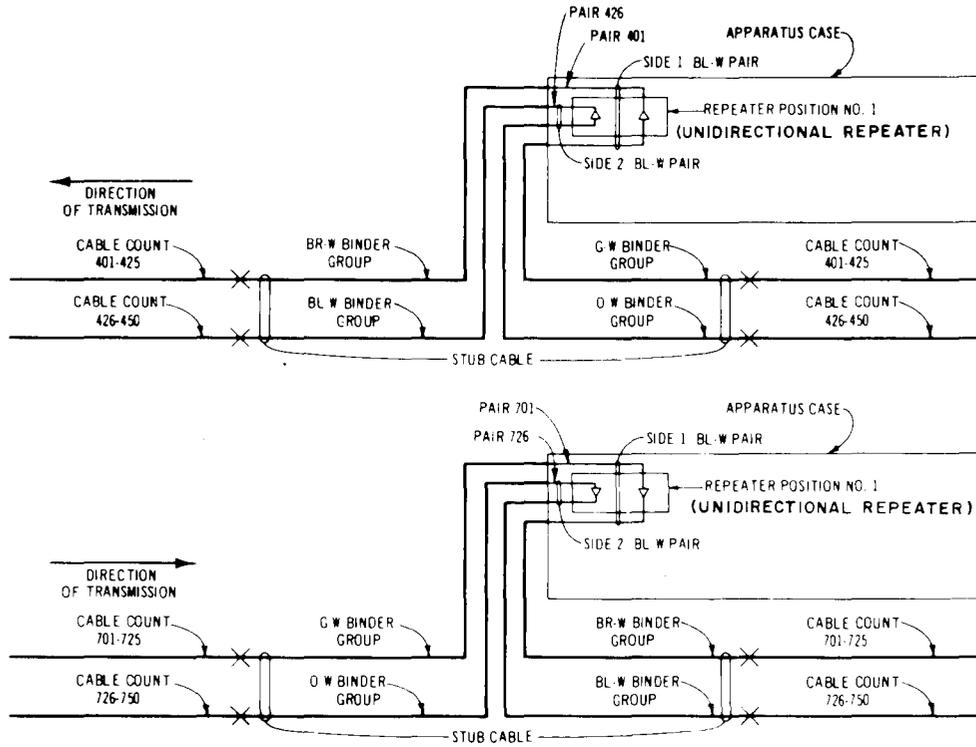


A. 466 - AND 468 - TYPE APPARATUS CASES

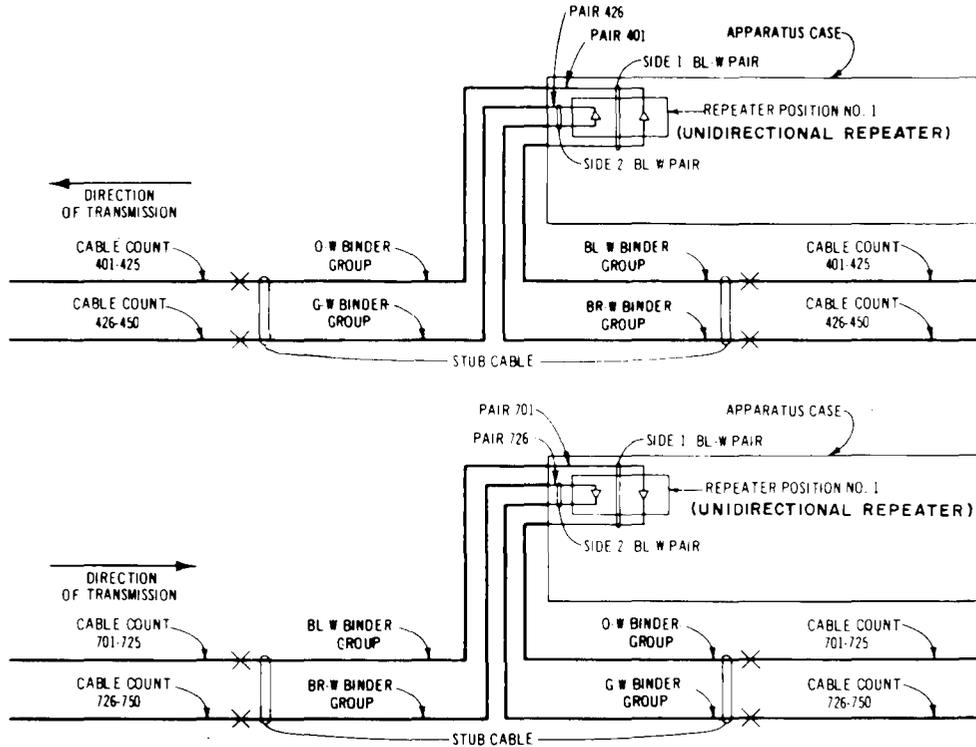


B. 475-, 809-, 818-, AND 819- TYPE APPARATUS CASES

Fig. 27—Apparatus Cases—Wiring and Binder Group Arrangement (One-Cable Bidirectional Line Repeater Operation)

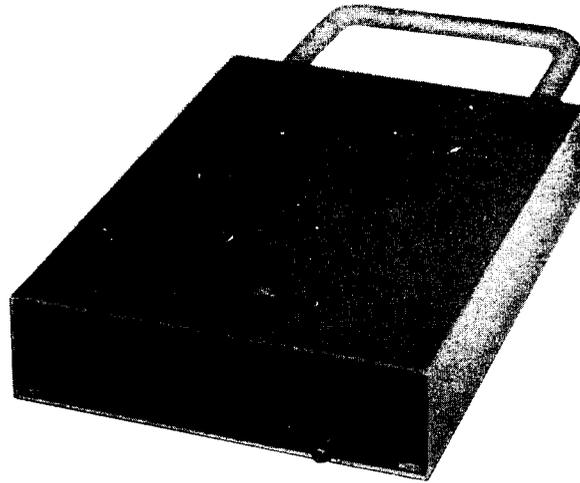


A. 466- AND 468- TYPE APPARATUS CASES

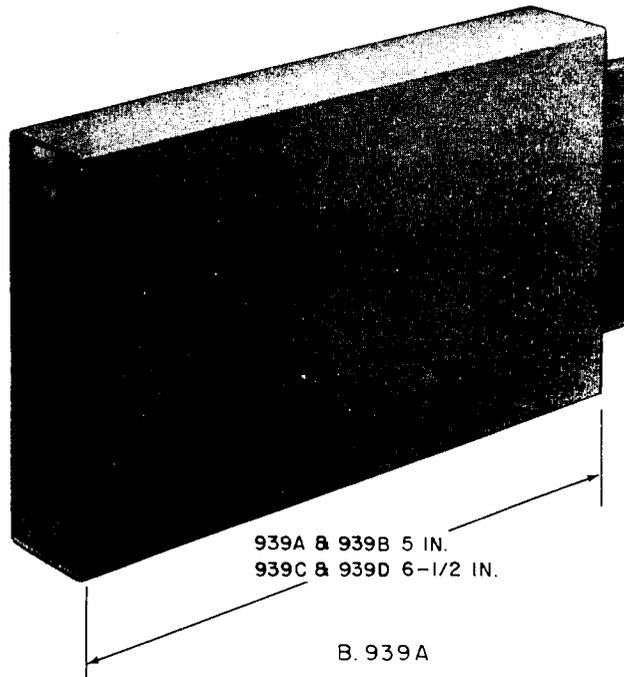


B. 475-, 809-, 818-, AND 819- TYPE APPARATUS CASES

Fig. 28—Apparatus Cases—Wiring and Binder Group Arrangement (Two-Cable Unidirectional Line Repeater Operation)



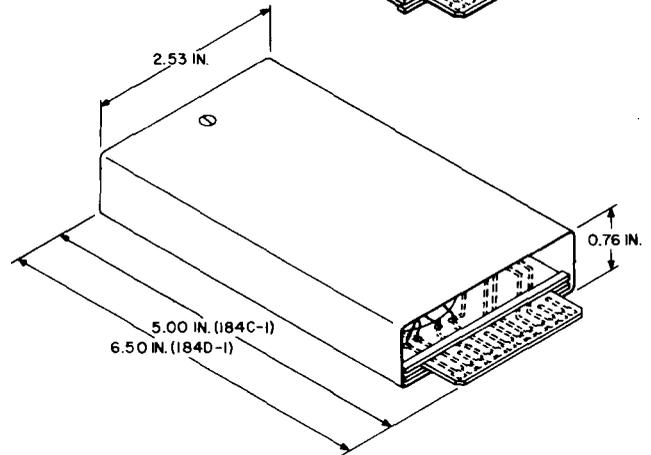
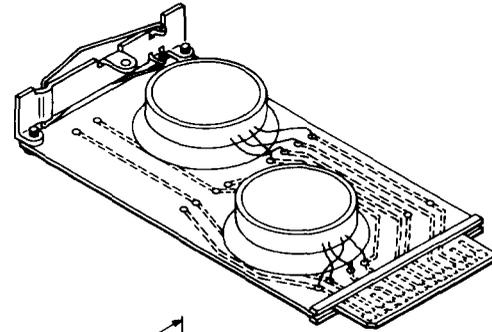
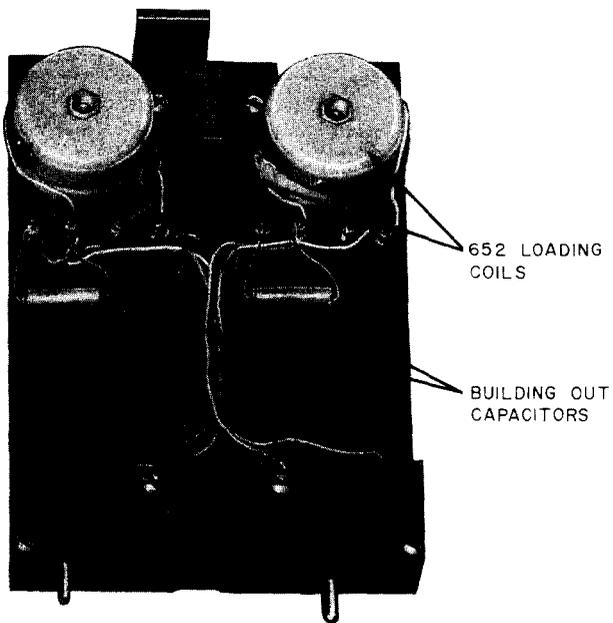
A. 904A



939A & 939B 5 IN.
939C & 939D 6-1/2 IN.

B. 939A

Fig. 29—904- and 939-Type Connector



NOTE:
CAPACITORS ARE NOT SHIPPED WITH COIL CASE BUT ARE
INSTALLED BEFORE THE COIL CASE IS PLUGGED INTO THE
APPARATUS CASE.



Fig. 30—180-Type Coil Case (Top) and 184-Type Coil Case (Bottom)



Initial Power Loop Information

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

Office A

Office B

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

Repeater Options

| | |
|-------------|-------------|
| Upper Shelf | Upper Shelf |
| Lower Shelf | Lower Shelf |

Line Voltage

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

Regulator Voltage

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

| | | |
|------------|--------------|------------------|
| Technician | Telephone No | Date Implemented |
| Supervisor | | |

E-10604
Code B
(2-80)

Fig. 31—Form E-10604, Initial Power Loop Information

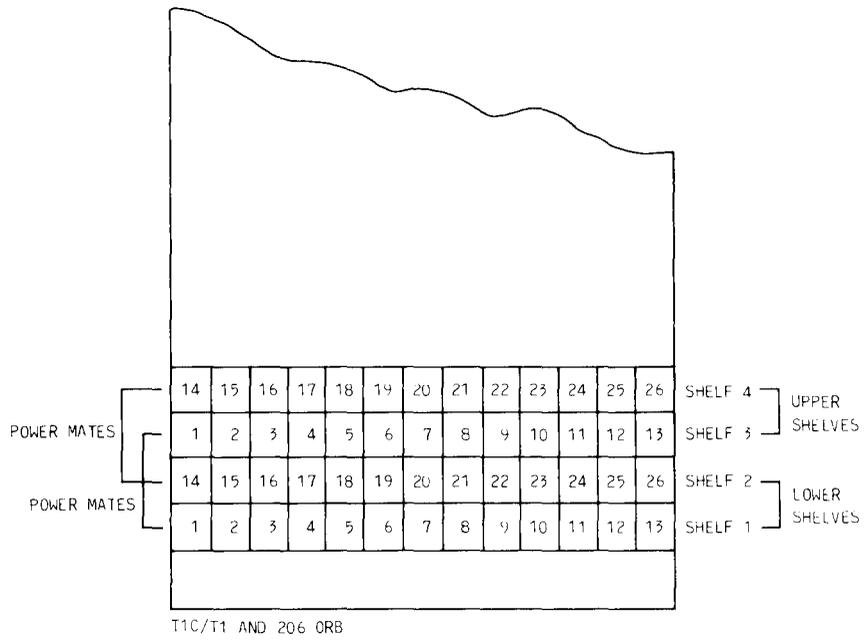


Fig. 32—Location of Power Mates T1C/T1 and 206 ORB

TABLE T
PAST STANDARD SCREENED CABLE

| | EXISTING CABLE CODE | NEW CABLE CODE (EFF. JAN. 1, 1980) | STANDARIZATION RATING (EFF. JAN. 1, 1980) | RECOMMENDED SUBSTITUTE (IF MFR DISC OR NSLA) |
|--------------------------------------|---------------------|------------------------------------|---|--|
| PULP SCREENED CABLE | BDAC-300 | — | Mfr Disc | — |
| | BDAC-400 | — | Mfr Disc | — |
| | BDAC-600 | — | Mfr Disc | — |
| | BDAC-900 | — | Mfr Disc | — |
| | BDAC-1200 | — | Mfr Disc | — |
| | BDAH-300 | — | Mfr Disc | — |
| | BDAH-400 | — | Mfr Disc | — |
| | BDAH-600 | — | Mfr Disc | — |
| | BDAH-900 | — | Mfr Disc | — |
| | BDAH-1200 | — | Mfr Disc | — |
| | KDAC-60 | KDAC-600 | NSLA | MCMC-616 |
| | KDAC-900 | KDAC-900 | NSLA | MCMC-922 |
| KDAC-1200 | KDAC-1200 | NSLA | MCRC-1228 | |
| KDAH-600 | KDAC-600 | NSLA | MCMH-616 | |
| KDAH-900 | KDAH-900 | NSLA | MCMH-922 | |
| KDAH-1200 | KDAH-1200 | NSLA | MCRH-1228 | |
| WATERPROOF COPPER PIC SCREENED CABLE | BJAW-16 | — | Mfr Disc | — |
| | BJAW-25 | KJAW-25 | NSLA | KJAW-28 |
| | BJAW-50 | KJAW-50 | NSLA | KJAW-54 |
| | BJAW-100 | — | Mfr Disc | — |
| | BJAW-150 | — | Mfr Disc | — |
| | BJAW-200 | — | Mfr Disc | — |
| | BJAW-300 | — | Mfr Disc | — |
| | BJAW-600 | — | Mfr Disc | — |
| | CA-6076-W-100 | KJAW-100 | NSLA | KJAW-106 |
| | CA-6076-W-150 | KJAW-150 | NSLA | KJAW-158 |
| | CA-6076-W-200 | KJAW-200 | NSLA | KJAW-210 |
| | CA-6076-W-300 | KJAW-300 | NSLA | KJAW-314 |
| | CA-6076-W-400 | KJAW-400 | NSLA | KJAW-418 |
| | CA-6076-W-600 | KJAW-600 | NSLA | KJAW-616 |
| | BLAW-16 | — | Mfr Disc | — |
| | BLAW-25 | KLAW-25 | Mfr Disc | KJAW-28 |
| | BLAW-50 | KLAW-50 | NSLA | KLAW-54 |
| | BLAW-100 | — | Mfr Disc | — |
| BLAW-150 | — | Mfr Disc | — | |
| BLAW-200 | — | Mfr Disc | — | |
| BLAW-300 | — | Mfr Disc | — | |
| BLAW-600 | — | Mfr Disc | — | |

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

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

* All aluminum cable was "Manufacture Suspended" as of October 1, 1977, due to significant decreases in the price of copper. Should aluminum cable manufacture be resumed in the future, system standard cable will be coded as above and will include service pairs.

TABLE U
INTEGRATED CIRCUIT LINE REPEATERS
(SEE NOTE 1)

| CODE | OPERATION | REPLACE- MENT | OPTIONS | MOUNTING | LINE POWERING | NOMINAL REPEATER CURRENT (NOTE 2) | CABLE | LINE MATCHING | PROTECTED | SEPARATE FL OUTPUTS |
|-------------|-----------|------------------|----------------------------|-----------------------------------|------------------|--|----------|------------------|-----------|---------------------------|
| 201G*, † | BI | 208AA | NONE | 466 APP CASE | THRU | 140 mA | PIC/PULP | ALBO | NO | NO |
| 201H*, † | BI | 208AA | NONE | 466 APP CASE | LOOP | 140 mA | PIC/PULP | ALBO | NO | NO |
| 201J*, † | UNI | 208AB | NONE | 466 APP CASE | THRU | 140 mA | PIC/PULP | ALBO | NO | NO |
| 201K*, †, ‡ | UNI | 208AB | NONE | 466 APP CASE/STA | LOOP | 140 mA | PIC/PULP | ALBO | NO | NO |
| 205G§, † | BI | 209AA | NONE | 468 APP CASE | THRU | 140 mA | PIC/PULP | ALBO | YES | NO |
| 205H§, † | BI | 209AA | NONE | 468 APP CASE | LOOP | 140 mA | PIC/PULP | ALBO | YES | NO |
| 205J§, † | UNI | 209AB | NONE | 468 APP CASE | THRU | 140 mA | PIC/PULP | ALBO | YES | NO |
| 205K§, † | UNI | 209AB | NONE | 468 APP CASE | LOOP | 140 mA | PIC/PULP | ALBO | YES | NO |
| 205M§, † | BI | 209AA | NONE | 468C6 APP CASE | THRU | 140 mA | PIC/PULP | ALBO | YES | YES |
| 205N§, † | BI | 209AB | NONE | 468C6 APP CASE | LOOP | 140 mA | PIC/PULP | ALBO | YES | YES |
| 208A† | BI | 208AA | NONE | 475A or 818 APP CASE EORP | THRU | 140 mA | PIC/PULP | ALBO | NO | NO |
| 208B† | BI | 208AA | NONE | 475A or 818 APP CASE EORP | LOOP | 140 mA | PIC/PULP | ALBO | NO | NO |
| 208C¶, † | UNI | 208AB | NONE | 475A/479A or 818/819 CASE EORP | THRU | 140 mA | PIC/PULP | ALBO | NO | NO |
| 208D¶, † | UNI | 208AB | NONE | 475A/479A or 818/819 CASE EORP | LOOP | 140 mA | PIC/PULP | ALBO | NO | NO |
| 208E | BI | 208AA | NONE | 475F or 818 APP CASE | THRU | 140 mA | PIC/PULP | ALBO | NO | YES |
| 208F | BI | 208AA | NONE | 475F or 818 APP CASE | LOOP | 140 mA | PIC/PULP | ALBO | NO | YES |
| 208AA** | BI | NONE | T/L POWERING/ FL OUTPUT | 475A or 818 APP CASE EORP | THRU/LOOP | 140 mA | PIC/PULP | ALBO | NO | OPT |
| 208AB¶ | UNI | NONE | T/L POWERING | 475A/479A or 818/819 CASE EORP | THRU/LOOP | 140 mA | PIC/PULP | ALBO | NO | NO |

| CODE | OPERATION | REPLACE- MENT | OPTIONS | MOUNTING | LINE POWERING | NOMINAL REPEATER CURRENT (NOTE 2) | CABLE | LINE MATCHING | PROTECTED | SEPARATE FL OUTPUTS |
|-----------|-----------|------------------|----------------------------|--|------------------|--|-----------------------|------------------|-----------|---------------------------|
| 209A† | BI | 209AA | NONE | 475B or 818 APP CASE EORP | THRU | 140 mA | PIC/PULP | ALBO | YES | NO |
| 209B† | BI | 209AA | NONE | 475A or 818 APP CASE EORP | LOOP | 140 mA | PIC/PULP | ALBO | YES | NO |
| 209C††, † | UNI | 209AB | NONE | 475A/479B or 818/819 CASE EORP | THRU | 140 mA | PIC/PULP | ALBO | YES | NO |
| 209D†† | UNI | 209AB | NONE | 475B/479B or 818/819 APP CASE | LOOP | 140 mA | PIC/PULP | ALBO | YES | NO |
| 209E† | BI | 209AA | NONE | 475G or 818 APP CASE | THRU | 140 mA | PIC/PULP | ALBO | YES | YES |
| 209F† | BI | 209AB | NONE | 475G or 818 APP CASE | LOOP | 140 mA | PIC/PULP | ALBO | YES | YES |
| 209AA†† | BI | NONE | T/L POWERING/ FL OUTPUT | 475B or 818 APP CASE | THRU/LOOP | 140 mA | PIC/PULP | ALBO | YES | OPT |
| 209AB | UNI | NONE | T/L POWERING | 475B/479B or 818/819 APP CASE | THRU/LOOP | 140 mA | PIC/PULP | ALBO | YES | NO |
| 238A** | BI | NONE | T/L POWERING/ FL OUTPUT | 475A/475F or 818/819 APP CASE EORP | THRU/LOOP | 60 mA | PIC/PULP | ALBO | NO | OPT |
| 238B¶ | UNI | NONE | T/L POWERING | 475A/479A or 818/819 APP CASE EORP | THRU/LOOP | 60 mA | PIC/PULP | ALBO | NO | NO |
| 238C** | BI | NONE | T/L POWERING/ FL OUTPUT | 475A/475F or 818/819 APP CASE EORP | THRU/LOOP | 60 mA | "MAT"/"ICOT" CABLE | ALBO | NO | OPT |
| 238D¶ | UNI | NONE | T/L POWERING | 475B/479A or 818/819 APP CASE EORP | THRU/LOOP | 60 mA | "MAT"/"ICOT" CABLE | ALBO | NO | NO |

| CODE | OPERATION | REPLACE- MENT | OPTIONS | MOUNTING | LINE POWERING | NOMINAL REPEATER CURRENT (NOTE 2) | CABLE | LINE MATCHING | PROTECTED | SEPARATE FL OUTPUTS |
|------------|-----------|------------------|----------------------------|--|------------------|--|-----------------------|------------------|-----------|---------------------------|
| 239A††, §§ | BI | NONE | T/L POWERING/ FL OUTPUT | 475B/475G or 818/819 APP CASE EORP | THRU/LOOP | 60 mA | PIC/PULP | ALBO | YES | OPT |
| 239B†† | UNI | NONE | T/L POWERING | 475B/479B or 818/819 APP CASE EORP | THRU/LOOP | 60 mA | PIC/PULP | ALBO | YES | NO |
| 239C†† | BI | NONE | T/L POWERING/ FL OUTPUT | 475B/475G or 818/819 APP CASE EORP | THRU/LOOP | 60 mA | "MAT"/"ICOT" CABLE | ALBO | YES | OPT |
| 239D†† | UNI | NONE | T/L POWERING | 475B/479B or 818/819 APP CASE EORP | THRU/LOOP | 60 mA | "MAT"/"ICOT" CABLE | ALBO | YES | NO |
| 7A | UNI | NONE | NONE | 473 TYPE APP CASE | THRU | 80 mA | "LOCAP" CABLE | ALBO | YES | NO |

Note 1: Abbreviations used are as follows:

- BI = Bidirectional Regenerators
- UNI = Unidirectional Regenerators
- ALBO = Automatic Line Buildout
- STA = J98710A Span Terminating Assembly
- EORP = Express Office Repeater Bay

Note 2: Line repeaters can have a maximum line current of 150 mA.

- * The 208-type replacement repeater must be equipped with a 215A adapter.
- † Manufacture discontinued (Mfr Disc).
- ‡ Classified as an office repeater when mounted in an STA.
- § The 209-type replacement repeater must be equipped with a 216A adapter.
- ¶ Can be mounted in 479A apparatus case using a 245A adapter.
- ** Must be mounted in 475F apparatus case to utilize separate FL outputs.
- †† Can be mounted in 479B apparatus case using a 253A adapter.
- ‡‡ Must be mounted in 475G apparatus case to utilize separate FL outputs.
- §§ Can be mounted in 468C apparatus case using a 216A adapter.

TABLE V
NONINTEGRATED CIRCUIT REPEATERS
(MANUFACTURE DISCONTINUED) (SEE NOTE 1)

| CODE | TYPE | REPLACE- MENT | OPERATION | OPTIONS | MOUNTING | LINE POWERING | NOMINAL REPEATER CURRENT (NOTE 2) | CABLE | LINE MATCHING | PROTECTED | CODE | TYPE | REPLACE- MENT | OPERATION | OPTIONS | MOUNTING | LINE POWERING | NOMINAL REPEATER CURRENT (NOTE 2) | CABLE | LINE MATCHING | PROTECTED |
|----------|-----------------|----------------------|-----------|-----------------------|----------------------|------------------|--|----------|---------------------------------|-----------|------|------------------|------------------|-----------|---------------|---------------------|------------------|--|----------|----------------------|-----------|
| 201A* | LINE | 201D 201G 201H | BI | T/L POWERING | 466 APP CASE | THRU/LOOP | 140 mA | PIC/PULP | 836 LBO | NO | 206E | OFFICE | 206L | - | LINE POWERING | 206 ORB/LTU/ STM | 48V | 140 mA | PIC/PULP | 836 LBO/ 3 dB PAD | YES |
| 201B*, † | OFFICE/ LINE | 201E 201J 201K | UNI | T/L POWERING | 466 APP CASE/ STA | THRU/LOOP | 140 mA | PIC/PULP | 836 LBO | NO | 206F | OFFICE | 206M | - | LINE POWERING | 206 ORB/LTU/ STM | 130V | 140 mA | PIC/PULP | 836 LBO/ 3 dB PAD | YES |
| 201C | BRIDGING | 201F 201L | UNI | NONE | STA | - | 140 mA | PIC/PULP | NONE | - | 206G | OFFICE | 206N | - | LINE POWERING | 206 ORB/LTU/ STM | LOOP | 140 mA | PIC/PULP | 836 LBO/ 3 dB PAD | YES |
| 201D* | LINE | 201G 201H | BI | T/L POWERING | 466 APP CASE | THRU/LOOP | 140 mA | PIC/PULP | 836 LBO | NO | 206P | BRIDGING- DSX | 206S | - | NONE | 206 ORB/LTU/ STM | NONE | 140 mA | PIC/PULP | NONE | - |
| 201E*, † | OFFICE/ LINE | 201J 201K | UNI | T/L POWERING | 466 APP CASE/ STA | THRU/LOOP | 140 mA | PIC/PULP | 836 LBO | NO | | | | | | | | | | | |
| 201F | BRIDGING | 201L | UNI | NONE | STA | - | 140 mA | PIC/PULP | NONE | - | | | | | | | | | | | |
| 205A | LINE | 205D 205G 205H | BI | T/L POWERING | 468 APP CASE | THRU/LOOP | 140 mA | PIC/PULP | 836 LBO | YES | | | | | | | | | | | |
| 205B | LINE | 205E 205J 205K | UNI | T/L POWERING | 468 APP CASE | THRU/LOOP | 140 mA | PIC/PULP | 836 LBO | YES | | | | | | | | | | | |
| 205D | LINE | 205G 205H | BI | T/L POWERING | 468 APP CASE | THRU/LOOP | 140 mA | PIC/PULP | NONE | YES | | | | | | | | | | | |
| 205E | LINE | 205J 205K | UNI | T/L POWERING | 468 APP CASE | THRU/LOOP | 140 mA | PIC/PULP | 836 LBO | YES | | | | | | | | | | | |
| 206A | OFFICE | 206H | - | LINE POWERING | 206 ORB/LTU/ STM | 48V | 140 mA | PIC/PULP | 836 LBO/ 7.5 dB ART. LINE | YES | | | | | | | | | | | |
| 206B | OFFICE | 206J | - | LINE POWERING/ GRD | 206 ORB/LTU/ STM | 130V | 140 mA | PIC/PULP | 836 LBO/ 7.5 dB ART. LINE | YES | | | | | | | | | | | |
| 206C | BRIDGING | 206R | - | NONE | 206 ORB/LTU/ STM | NONE | 140 mA | PIC/PULP | NONE | - | | | | | | | | | | | |
| 206D | OFFICE | 206K | - | LINE POWERING | 206 ORB/LTU/ STM | LOOP | 140 mA | PIC/PULP | 836 LBO/ 7.5 dB ART. LINE | YES | | | | | | | | | | | |

Note 1: Abbreviations used are as follows:

BI = Bidirectional Regenerators
UNI = Unidirectional Regenerators
LBO = Line Buildout
STA = J98710A Span Terminating Assembly
206 ORD = J98710J, K, or L Office Repeater Bay
LTU = J98713F Line Terminating Unit
STM = J98728AA, AB, or AC Span Terminating Module

Note 2: Lines equipped with these repeaters can have a maximum line current of 150 mA.

* Protected if equipped with a 4037-type network and is mounted in a 468-type apparatus case.

† The 201J can be used as a replacement for line use only.

TABLE W
INTEGRATED CIRCUIT OFFICE AND BRIDGING REPEATERS
(SEE NOTE 1)

| CODE | TYPE | REPLACE- MENT | OPTIONS | MOUNTING | LINE POWERING | LINE CURRENT REGULATOR | REGENERATOR CURRENT | CABLE | LINE MATCHING | EXCP |
|--------|------------------|------------------|---|-----------------|------------------|------------------------------|------------------------|----------|-----------------------------|------|
| 201K* | OFFICE | 208AB | NONE | STA | LOOP | NONE | 140 mA | PIC/PULP | ALBO | NO |
| 201L | BRIDGING | NONE | NONE | STA | NONE | NONE | 140 mA | ALL | NONE | NO |
| 206H† | OFFICE | 236AA | LINE POWERING | 206 ORB/LTU/STM | 48V | 140 mA | 140 mA | PIC/PULP | ALBO/7.5 dB ART. LINE | NO |
| 206J† | OFFICE | 236AA | LINE POWERING/ GRD | 206 ORB/LTU/STM | 130V | 140 mA | 140 mA | PIC/PULP | ALBO/7.5 dB ART. LINE | NO |
| 206K† | OFFICE | 236AB | LINE POWERING | 206 ORB/LTU/STM | LOOP | NONE | 140 mA | PIC/PULP | ALBO/7.5 dB ART. LINE | NO |
| 206L† | OFFICE | 236AC | LINE POWERING | 206 ORB/LTU/STM | 48V | 140 mA | 140 mA | PIC/PULP | ALBO/3 dB PAD | NO |
| 206M† | OFFICE | 236AC | LINE POWERING/ GRD | 206 ORB/LTU/STM | 130V | 140 mA | 140 mA | PIC/PULP | ALBO/3 dB PAD | NO |
| 206N† | OFFICE | 236AD | LINE POWERING | 206 ORB/LTU/STM | LOOP | NONE | 140 mA | PIC/PULP | ALBO/3 dB PAD | NO |
| 206R†† | BRIDGING | 236P | NONE | 206 ORB/LTU/STM | NONE | NONE | 140 mA | ALL | NONE | NO |
| 206S§ | BRIDGING- DSX | 236P | NONE | 206 ORB/LTU/STM | NONE | NONE | 140 mA | ALL | NONE | NO |
| 206T† | OFFICE | 236E | LINE POWERING/ CURRENT | 206 ORB/LTU/STM | 48V | 60/140 mA | 140 mA | PIC/PULP | ALBO/7.5 & 4.5 dB ART. LINE | YES |
| 206U† | OFFICE | 236E | LINE POWERING/ CURRENT/GRD | 206 ORB/LTU/STM | 130V | 60/140 mA | 140 mA | PIC/PULP | ALBO/7.5 & 4.5 dB ART. LINE | YES |
| 206W† | OFFICE | 236F | LINE POWERING | 206 ORB/LTU/STM | LOOP | NONE | 140 mA | PIC/PULP | ALBO/7.5 & 4.5 dB ART. LINE | YES |
| 206Y† | OFFICE | 236G | LINE POWERING/ CURRENT | 206 ORB/LTU/STM | 48V | 60/140 mA | 140 mA | PIC/PULP | ALBO/3 & 0.5 dB PAD | YES |
| 206AA† | OFFICE | 236G | LINE POWERING/ CURRENT/GRD | 206 ORB/LTU/STM | 130V | 60/140 mA | 140 mA | PIC/PULP | ALBO/3 & 0.5 dB PAD | YES |
| 206AB† | OFFICE | 236H | LINE POWERING | 206 ORB/LTU/STM | LOOP | NONE | 140 mA | PIC/PULP | ALBO/3 & 0.5 dB PAD | YES |
| 221A† | OFFICE | 231A | LINE POWERING/ VOLTAGE/GRD/ CURRENT | T1C/T1 ORB | 48V/130V | 60/140 mA | 140 mA | PIC/PULP | ALBO/7.5 & 4.5 dB ART. LINE | YES |
| 221B† | OFFICE | 231B | LINE POWERING | T1C/T1 ORB | LOOP | NONE | 140 mA | PIC/PULP | ALBO/7.5 & 4.5 dB ART. LINE | YES |
| 221C† | BRIDGING | 231C | NONE | T1C/T1 ORB | NONE | NONE | 140 mA | ALL | NONE | YES |

| CODE | TYPE | REPLACE- MENT | OPTIONS | MOUNTING | LINE POWERING | LINE CURRENT REGULATOR | REGENERATOR CURRENT | CABLE | LINE MATCHING | EXCP |
|---------|----------|------------------|---|-----------------|------------------|------------------------------|------------------------|-----------------------|-----------------------------|------|
| 231A | OFFICE | NONE | LINE POWERING/ CURRENT/GRD/ VOLTAGE | T1C/T1 ORB | 48V/130V | 60/140 mA | 60/140 mA | PIC/PULP | ALBO/7.5 & 4.5 dB ART. LINE | YES |
| 231B | OFFICE | NONE | LINE POWERING | T1C/T1 ORB | LOOP | NONE | 60/140 mA | PIC/PULP | ALBO/7.5 & 4.5 dB ART. LINE | YES |
| 231C¶ | BRIDGING | NONE | NONE | T1C/T1 ORB | NONE | NONE | 60/140 mA | ALL | NONE | YES |
| 231D | OFFICE | NONE | LINE POWERING/ GRD/VOLTAGE | T1C/T1 ORB | 48V/130V | 60 mA | 60 mA | "MAT"/"ICOT" CABLE | ALBO/7.5 & 4.5 dB ART. LINE | YES |
| 231E | OFFICE | NONE | LINE POWERING | T1C/T1 ORB | LOOP | NONE | 60 mA | "MAT"/"ICOT" CABLE | ALBO/7.5 & 4.5 dB ART. LINE | YES |
| 231F | BRIDGING | NONE | NONE | T1C/T1 ORB | NONE | NONE | 60/140 mA | ALL | NONE | NO |
| 236A† | OFFICE | 236AA | LINE POWERING/ GRD/VOLTAGE | 206 ORB/LTU/STM | 48V/130V | 60 mA | 60 mA | PIC/PULP | ALBO/7.5 dB ART. LINE | NO |
| 236B† | OFFICE | 236AB | LINE POWERING | 206 ORB/LTU/STM | LOOP | NONE | 60 mA | PIC/PULP | ALBO/7.5 dB ART. LINE | NO |
| 236C† | OFFICE | 236AC | LINE POWERING/ GRD/VOLTAGE | 206 ORB/LTU/STM | 48V/130V | 60 mA | 60 mA | PIC/PULP | ALBO/3 dB PAD | NO |
| 236D† | OFFICE | 236AD | LINE POWERING | 206 ORB/LTU/STM | LOOP | NONE | 60 mA | PIC/PULP | ALBO/3 dB PAD | NO |
| 236E | OFFICE | NONE | LINE POWERING/ CURRENT/GRD/ VOLTAGE | 206 ORB/LTU/STM | 48V/130V | 60/140 mA | 60/140 mA | PIC/PULP | ALBO/7.5 & 4.5 dB ART. LINE | YES |
| 236F | OFFICE | NONE | LINE POWERING | 206 ORB/LTU/STM | LOOP | NONE | 60/140 mA | PIC/PULP | ALBO/7.5 & 4.5 dB ART. LINE | YES |
| 236G | OFFICE | NONE | LINE POWERING/ CURRENT/GRD/ VOLTAGE | 206 ORB/LTU/STM | 48V/130V | 60/140 mA | 60/140 mA | PIC/PULP | ALBO/3 & 0.5 dB PAD | YES |
| 236H | OFFICE | NONE | LINE POWERING | 206 ORB/LTU/STM | LOOP | NONE | 60/140 mA | PIC/PULP | ALBO/3 & 0.5 dB PAD | YES |
| 236J | OFFICE | NONE | LINE POWERING/ GRD/VOLTAGE | 206 ORB/LTU/STM | 48V/130V | 60 mA | 60 mA | "MAT"/"ICOT" CABLE | ALBO/7.5 dB ART. LINE | NO |
| 236K | OFFICE | NONE | LINE POWERING | 206 ORB/LTU/STM | LOOP | NONE | 60 mA | "MAT"/"ICOT" CABLE | ALBO/7.5 dB ART. LINE | NO |
| 236L | OFFICE | NONE | LINE POWERING/ GRD/VOLTAGE | 206 ORB/LTU/STM | 48V/130V | 60 mA | 60 mA | "MAT"/"ICOT" CABLE | ALBO/7.5 & 4.5 dB ART. LINE | YES |
| 236M | OFFICE | NONE | LINE POWERING | 206 ORB/LTU/STM | LOOP | NONE | 60 mA | "MAT"/"ICOT" CABLE | ALBO/7.5 & 4.5 dB ART. LINE | YES |
| 236N | OFFICE | NONE | LINE POWERING/ GRD/VOLTAGE | 206 ORB/LTU/STM | 48V/130V | 80 mA | 80 mA | "LOCAP" CABLE | ALBO/7.5 dB ART. LINE | YES |
| 236P**¶ | BRIDGING | NONE | DSX/LOCAL | 206 ORB/LTU/STM | NONE | NONE | 60/140 mA | ALL | NONE | NO |

| CODE | TYPE | REPLACE- MENT | OPTIONS | MOUNTING | LINE POWERING | LINE CURRENT REGULATOR | REGENERATOR CURRENT | CABLE | LINE MATCHING | EXCP |
|-------|--------|------------------|---|-----------------|------------------|------------------------------|------------------------|----------|-----------------------|------|
| 236AA | OFFICE | NONE | LINE POWERING/ GRD/VOLTAGE/ CURRENT | 206 ORB/LTU/STM | 48V/130V | 60/140 mA | 60/140 mA | PIC/PULP | ALBO/7.5 dB ART. LINE | NO |
| 236AB | OFFICE | NONE | LINE POWERING/ CURRENT | 206 ORB/LTU/STM | LOOP | NONE | 60/140 mA | PIC/PULP | ALBO/7.5 dB ART. LINE | NO |
| 236AC | OFFICE | NONE | LINE POWERING/ GRD/VOLTAGE/ CURRENT | 206 ORB/LTU/STM | 48V/130V | 60/140 mA | 60/140 mA | PIC/PULP | ALBO/7.5 dB ART. LINE | NO |
| 236AD | OFFICE | NONE | LINE POWERING/ CURRENT | 206 ORB/LTU/STM | LOOP | NONE | 60/140 mA | PIC/PULP | ALBO/7.5 dB ART. LINE | NO |

Note 1: Abbreviations used are as follows:

STA = J98710A Span Terminating Assembly
STM = J98728AA, AB, or AC Span Terminating Module
LTU = J98713F Line Terminating Unit
EXCP = Extended Cross-Connect Package (206- and 236-type repeaters require 983-type equalizers)
206 ORB = J98710J, K, or L Office Repeater Bay
T1C/T1 ORB = J98725A, B, or C Office Repeater Bay
ALBO = Automatic Line Buildout

* The 208-type replacement repeater must be equipped with a 215A adapter.

† Manufacture discontinued (Mfr Disc).

‡ 236P must have LOCAL option selected when replacing 206R.

§ 236P must have DSX option selected when replacing 206S.

¶ 231C and 236P DSX bridging repeater can be used in a T1C/T1 bridging panel.

** Can be used with or without a digital cross-connect by use of DSX/LOCAL option.

Table X
ENGINEERING LOSSES AT 772 KHZ

| CABLE | | | NOMINAL CAPACITANCE μF MILE | (NOTE 1) ENGR. LOSS dB/kft | TEMPERATURE COEFFICIENT dB/kft/10°F | LOSS DEVIATION % | (NOTE 2) τ _T 100 | (NOTE 2) τ _T 140 | MAX. DESIGN LOSS dB (NOTE 3) | | MAX. SECTION LENGTH kft | |
|-------|--------------------------------|-------------|--------------------------------|----------------------------------|--|---------------------|--------------------------------|--------------------------------|------------------------------|-------|-------------------------|-------|
| GAUGE | TYPE | DESCRIPTION | | | | | | | 100°F | 140°F | 100°F | 140°F |
| 17 | ALC, BLC | WP DEPIC | .083 | 3.2 | .034 | 1.5 | 1.048 | 1.090‡ | 32.3 | 31.1‡ | 10.1 | 9.7‡ |
| 19 | GNB | PAPER | .066 | 3.0 | .025 | * | 1.038 | 1.071 | 31.2 | 30.3 | 10.4 | 10.1 |
| 19 | ADB | PULP | .083 | 3.9 | † | * | 1.051 | 1.077 | 31.4 | 30.7 | 8.1 | 7.9 |
| 19 | AJB, BJB | WP PIC | .083 | 2.9 | .020 | 1.5 | 1.031 | 1.059‡ | 32.8 | 32.0‡ | 11.3 | 11.0‡ |
| 19 | ALB, BLB, KLB | WP DEPIC | .083 | 3.2 | .027 | 1.5 | 1.038 | 1.072‡ | 32.6 | 31.6‡ | 10.2 | 9.8‡ |
| 19 | BHB, CHB | AIR PIC | .083 | 3.3 | .034 | 2.5 | 1.046 | 1.088 | 31.7 | 30.5 | 9.6 | 9.2 |
| 20 | ALD, BLD, KLD | WP DEPIC | .083 | 4.4 | .043 | 1.5 | 1.044 | 1.083‡ | 32.4 | 31.3‡ | 7.3 | 7.1‡ |
| 22 | ANA | PAPER | .073 | 4.6 | .040 | * | 1.039 | 1.074 | 32.0 | 31.0 | 6.9 | 6.7 |
| 22 | ADA, BDA, CDA CSA, DSA, KDA | PULP | .083 | 5.2 | † | * | 1.035 | 1.055 | 32.3 | 31.7 | 6.2 | 6.1 |
| 22 | AJA, BJA, KJA | WP PIC | .083 | 4.0 | .035 | 1.5 | 1.039 | 1.074‡ | 32.6 | 31.5‡ | 8.1 | 7.8‡ |
| 22 | ALA, BLA, KLA | WP DEPIC | .083 | 4.4 | .040 | 1.5 | 1.041 | 1.077‡ | 32.5 | 31.4‡ | 7.4 | 7.1‡ |
| 22 | BHA, CHA, KHA | AIR PIC | .083 | 4.6 | .045 | 2.5 | 1.044 | 1.083 | 31.7 | 30.6 | 6.9 | 6.6 |
| 24 | ADM, CDM | PULP | .083 | 6.3 | † | * | 1.048 | 1.063 | 32.2 | 31.7 | 5.1 | 5.0 |
| 24 | AJM | WP PIC | .083 | 5.0 | .048 | 1.5 | 1.043 | 1.082‡ | 32.4 | 31.3‡ | 6.5 | 6.2‡ |
| 24 | ALM, BLM | WP DEPIC | .083 | 5.5 | .052 | 1.5 | 1.043 | 1.080‡ | 32.5 | 31.4‡ | 5.9 | 5.7‡ |
| 24 | BKM | AIR PIC | .083 | 5.8 | .055 | 2.5 | 1.043 | 1.081 | 31.8 | 30.7 | 5.5 | 5.3 |
| 24 | MCM | AIR ICOT | .052 | 3.6 | .044 | 1.5 | 1.055 | 1.104 | 31.3 | 30.0 | 8.7 | 8.3 |
| 24 | MLM | WP ICOT | .060 | 3.9 | .040 | 2.0 | 1.046 | 1.087‡ | 31.5 | 30.3‡ | 8.0 | 7.7‡ |

| CABLE | | | NOMINAL CAPACITANCE μF MILE | (NOTE 1) ENGR. LOSS dB/kft | TEMPERATURE COEFFICIENT dB/kft/10°F | LOSS DEVIATION % | (NOTE 2) τ _T 100 | (NOTE 2) τ _T 140 | MAX. DESIGN LOSS dB (NOTE 3) | | MAX. SECTION LENGTH kft | |
|-------|----------|-------------|--------------------------------|----------------------------------|--|---------------------|--------------------------------|--------------------------------|------------------------------|-------|-------------------------|-------|
| GAUGE | TYPE | DESCRIPTION | | | | | | | 100°F | 140°F | 100°F | 140°F |
| 25 | MCR | AIR MAT | .064 | 5.1 | .055 | 3.0 | 1.049 | 1.092 | 31.3 | 30.1 | 6.1 | 5.9 |
| 26 | ADT | PULP | .083 | 7.8 | † | * | 1.038 | 1.064 | 32.7 | 31.9 | 4.2 | 4.1 |
| 26 | AJT | WP PIC | .083 | 6.3 | .065 | 1.5 | 1.046 | 1.088‡ | 32.3 | 31.2‡ | 5.1 | 5.0‡ |
| 26 | ALT, BLT | WP DEPIC | .083 | 6.9 | .067 | 1.5 | 1.044 | 1.083‡ | 32.4 | 31.3‡ | 4.7 | 4.5‡ |
| 26 | BKT | AIR PIC | .083 | 7.3 | .068 | 2.5 | 1.042 | 1.079 | 31.8 | 30.8 | 4.3 | 4.2 |

Note 1: For 900-pair or larger, pulp, unscreened cable, add 3.6 percent loss for use of pairs in center unit.

Note 2: τ_T = $\frac{\text{Loss, dB per unit length at } T^{\circ}\text{F}}{\text{Loss, dB per unit length at } 55^{\circ}\text{F}}$

Note 3: Reduce the maximum design loss by 1.5 dB when protected repeaters are used at both ends of the repeater section. If protected repeaters are used at only one end of the repeater section, reduce the maximum design loss by 1.0 dB.

* See paragraph 7.09 for loss deviation of PULP and PAPER cables.

† The temperature coefficient of these pulp cables is nonlinear. However, for cable temperatures other than 100°F or 140°F, use linear interpolation between the given τ₁₀₀ and τ₁₄₀ values and an τ₅₅ value of 1.000.

‡ Although data are given at the maximum aerial temperature of 140°F for waterproof cables, this type cable is intended for predominantly buried installations.

TABLE Y
NEAR-END CROSSTALK COUPLING LOSSES AT 772 KHZ (NOTES 1 AND 2)

| CABLE SIZE | CONSTRUCTION | m = MEAN dB | σ = STANDARD DEVIATION dB | m - σ dB |
|---|-----------------------------------|-------------|---------------------------|----------|
| FOR 19-GAUGE AIR CORE PIC CABLES | | | | |
| 50 pairs or less (12- and 13-pair units) | Unit | | | |
| | Pairs in same unit | 69 | 11 | 58 |
| | Pairs in adjacent units | 77 | 10 | 67 |
| | Pairs in nonadjacent units | 85 | 9 | 76 |
| 300 pairs (12-25 pair units) | Unit | | | |
| | Pairs in same unit | 72 | 12 | 60 |
| | Pairs in adjacent units | 76 | 9 | 67 |
| | Pairs in nonadjacent units | 96 | 10 | 86 |
| 19-GAUGE FILLED PIC CABLES | | | | |
| 25 pairs | All pairs | 69 | 7 | 62 |
| 50 pairs (12- and 13-pair units) | Pairs in same unit | 71 | 9 | 62 |
| | Pairs in adjacent units | 80 | 10 | 70 |
| | Pairs in nonadjacent units | 89 | 11 | 78 |
| 22-GAUGE FILLED PIC CABLES | | | | |
| 25 pairs | All pairs | 72 | 10 | 62 |
| 100 pairs (25-pair unit, six 12- and 13-pair units) | Pairs in same 12- or 13-pair unit | 69 | 9 | 60 |
| | Pairs in same 25-pair unit | 77 | 11 | 66 |
| | Pairs in adjacent units | 81 | 10 | 71 |
| | Pairs in nonadjacent units | 93 | 10 | 83 |
| 22-GAUGE FILLED DEPIC CABLES | | | | |
| 100 pairs (25-pair unit, six 12- and 13-pair units) | Pairs in same 12- or 13-pair unit | 6 | 7 | 59 |
| | Pairs in same 25-pair unit | 74 | 11 | 63 |
| | Pairs in adjacent units | 80 | 9 | 71 |
| | Pairs in nonadjacent units | 91 | 8 | 83 |

| CABLE SIZE | CONSTRUCTION | m = MEAN dB | σ = STANDARD DEVIATION dB | m - σ dB |
|---|--|-------------|---------------------------|----------|
| 22-GAUGE PULP CABLE (ADA) | | | | |
| Small (less than 200 pairs) | Pairs in same 50-pair unit | 75 | 10 | 65 |
| | Pairs in adjacent 50-pair unit | 88 | 8 | 80 |
| Large (200 pairs or more) | Pairs in same 50-pair unit | 75 | 10 | 65 |
| | Pairs in adjacent 50-pair units | 88 | 8 | 80 |
| | Pairs in non-adjacent 50-pair units | 100 | 6 | 94 |
| FOR 22-GAUGE AIR CORE PIC CABLES | | | | |
| Less than 100 pairs | Unit | | | |
| | Pairs in the same 8- or 9-pair unit | 66 | 9 | 57 |
| | Pairs in the same 12- or 13-pair unit | 69 | 10 | 59 |
| | Pairs in the same 25-pair unit | 76 | 13 | 63 |
| | Pairs in adjacent 8-, 9-, 12-, 13-pair units | 77 | 9 | 68 |
| | Pairs in nonadjacent 8- or 9-, or 12- or 13- pair units | 84 | 9 | 75 |
| | Pairs in adjacent 25-pair groups (made up to 8+8+9 pair units) | 82 | 13 | 69 |
| 100 pairs (25-pair unit, 6-12 pair units, and 13-pair unit) | Unit | | | |
| | Pairs in same 12- or 13-pair unit | 68 | 9 | 59 |
| | Pairs in same 25-pair unit | 73 | 11 | 62 |
| | Pairs in adjacent units | 79 | 9 | 70 |
| | Pairs in nonadjacent units | 90 | 9 | 81 |
| 300 pairs (12-25 pair units) | Unit | | | |
| | Pairs in same unit | 75 | 12 | 63 |
| | Pairs in adjacent units | 81 | 10 | 71 |
| | Pairs in nonadjacent units | 98 | 11 | 87 |
| 600 pairs (12-50 pair units) | Unit | | | |
| | Pairs in same unit unit | 77 | 11 | 66 |
| | Pairs in adjacent units | 87 | 9 | 78 |
| | Pairs in nonadjacent units | 106 | 8 | 98 |

| CABLE SIZE | CONSTRUCTION | m = MEAN dB | σ = STANDARD DEVIATION dB | m - σ dB |
|--|--|-------------|---------------------------|----------|
| FOR 22-GAUGE CABLES WITH STAGGERED PAIR TWISTS (DSA) | | | | |
| Large (200 pairs or more) | Unit | | | |
| | Pairs in same 100-pair splicing group | 82 | 11 | 71 |
| | Pairs in adjacent splicing groups | 90 | 9 | 81 |
| | Pairs in nonadjacent splicing groups | 103 | 7 | 96 |
| | Pairs in same 50-pair unit | 75 | 10 | 65 |
| | Pairs in adjacent 50-pair units | 88 | 8 | 80 |
| | Pairs in nonadjacent 50-pair units | 100 | 6 | 94 |
| Large (200 pairs or more) | Layer | | | |
| | Pairs in the same 100-pair splicing group | 75 | 9 | 66 |
| | Pairs in adjacent groups | 83 | 8 | 75 |
| | Pairs in nonadjacent groups | 93 | 9 | 84 |
| Small (less than 200 pairs) | Unit | | | |
| | Pairs in same unit | 75 | 10 | 65 |
| | Pairs in adjacent 50-pair units | 88 | 8 | 80 |
| FOR 24-GAUGE PULP CABLES (CDM) | | | | |
| Large (900 pairs or more) | Unit | | | |
| | Pairs in same 50-pair unit | 77 | 11 | 66 |
| | Pairs in adjacent 50-pair units | 90 | 9 | 81 |
| | Pairs in nonadjacent units | 102 | 7 | 95 |
| FOR 25-GAUGE "MAT" CABLES | | | | |
| Large (400, 600, 1000, 1200, 1400, and 1800 pairs in 100-pair multi-units) | Unit | | | |
| | Pairs in the same 25-pair unit | 69 | 7 | 62 |
| | Pairs in adjacent 25-pair units | 77 | 10 | 66 |
| | Pairs in diagonally opposite 25-pair units | 96 | 8 | 86 |

Note 1: These data apply, without correction for length, to sections longer than 1000 feet.

Note 2: These data apply, for the stated gauge, to copper conductor cable. The data also apply to aluminum conductor cable of the equivalent gauge. That is, 22-gauge copper equals 20-gauge aluminum, etc.

TABLE Z

REPEATER POWER OPTIONS FOR 206-, 221-, 231-, 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 Lines Repeaters | At Power 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 | B, D, G* |
| | | 2 | Unidirectional Operation—2nd shelf of power loop, office repeater power in series with receive line repeaters | A, G, M |
| | 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 | A, F, H, N |
| | 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 221-type or 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 of both unidirectional and bidirectional operation. Options 4, 5, and 6 provide for powering the office repeater and line separately.

Note 3: For unidirectional operation, 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 transmission will be affected in the case of a power loop failure.

TABLE AA

EFFECTIVE RESISTANCE IN OHMS OF OFFICE REPEATERS

| OFFICE REPEATER TYPE (NOTE) | LOCALLY POWERED | | POWERED IN SERIES WITH LINE | | | |
|---|-------------------------|--------------------------|-----------------------------|--------------------------|-------------|-----|
| | BIDIRECTIONAL OPERATION | UNIDIRECTIONAL OPERATION | BIDIRECTIONAL OPERATION | UNIDIRECTIONAL OPERATION | | |
| | BEHN or HJN | BEHN and AFHN | CEK or DK | BDG AND AGM | CEK AND AGM | |
| | | | | TRMT and RCV | TRMT | RCV |
| Standard power, standard output, regulating repeater @ 140 mA | 30 | 30 | 110 | 110 | 30 | 190 |
| Standard power, standard output, power looping repeater @ 140 mA | 20 | 30* | 100 | 110* | 190 | 30 |
| Standard power, EXCP output, regulating repeater @ 140 mA or low power, EXCP output, regulating repeater @ 140 mA | 30 | 30 | 145 | 145 | 30 | 260 |
| Standard power, EXCP output, power looping repeater, @ 140 mA or low power EXCP output, power looping repeater @ 140 mA | 20 | 30 | 135 | 145 | 260 | 30 |
| Low-power, standard output, regulating repeater @ 60 mA | 30 | 30 | 143 | 143 | 30 | 256 |
| Low-power, standard output, power looping repeater @ 60 mA | 20 | 30 | 133 | 143 | 256 | 30 |
| Low-power, EXCP output, regulating repeater @ 60 mA | 30 | 30 | 297 | 297 | 30 | 564 |
| Low-power, EXCP output, power looping repeating @ 60 mA | 20 | 30 | 287 | 297 | 564 | 30 |

Note: Refer to Tables D and E to determine office repeater code.

* Subtract 10 ohms when using 201 ORB.

TABLE AB
ALLOWABLE R_L

| BATTERY VOLTAGE | OFFICE REPEATER TYPE | LOW POWER (60 mA) | | STANDARD POWER DOUBLE-LETTER CODE (140 mA) (NOTE) | | STANDARD POWER SINGLE-LETTER CODE (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 | R_L min | R_L max |
| -48 and GRD | All | 0 | 550 | 0 | 230 | 0 | 230 | 0 | 200 | 0 | 180 |
| +130 and GRD | 206 | 450 | 1850 | 185 | 790 | 185 | 790 | 160 | 590 | 145 | 490 |
| | 221 | 450 | 1740 | 185 | 680 | 185 | 680 | 160 | 480 | 145 | 380 |
| | 231 | 450 | 1740 | 185 | 680 | 185 | 680 | 160 | 480 | 145 | 380 |
| | 236 | 450 | 1850 | 185 | 790 | 185 | 790 | 160 | 590 | 145 | 490 |
| +130 and -48 | 206 | 1515 | 2570 | 630 | 1090 | 630 | 1090 | 470 | 890 | 390 | 790 |
| | 221 | 1425 | 2460 | 545 | 980 | 545 | 980 | 385 | 780 | 300 | 680 |
| | 231 | 1425 | 2460 | 545 | 980 | 545 | 980 | 385 | 780 | 300 | 680 |
| | 236 | 1515 | 2570 | 630 | 1090 | 630 | 1090 | 470 | 890 | 390 | 790 |
| +130 and -130 | All | 2190 | 3760 | 850 | 1540 | 850 | 1540 | 850 | 1340 | 850 | 1240 |

Note: All repeaters in power loop must be double-letter code. If a mixture of double- and single-letter codes are used, engineer for single-letter code.

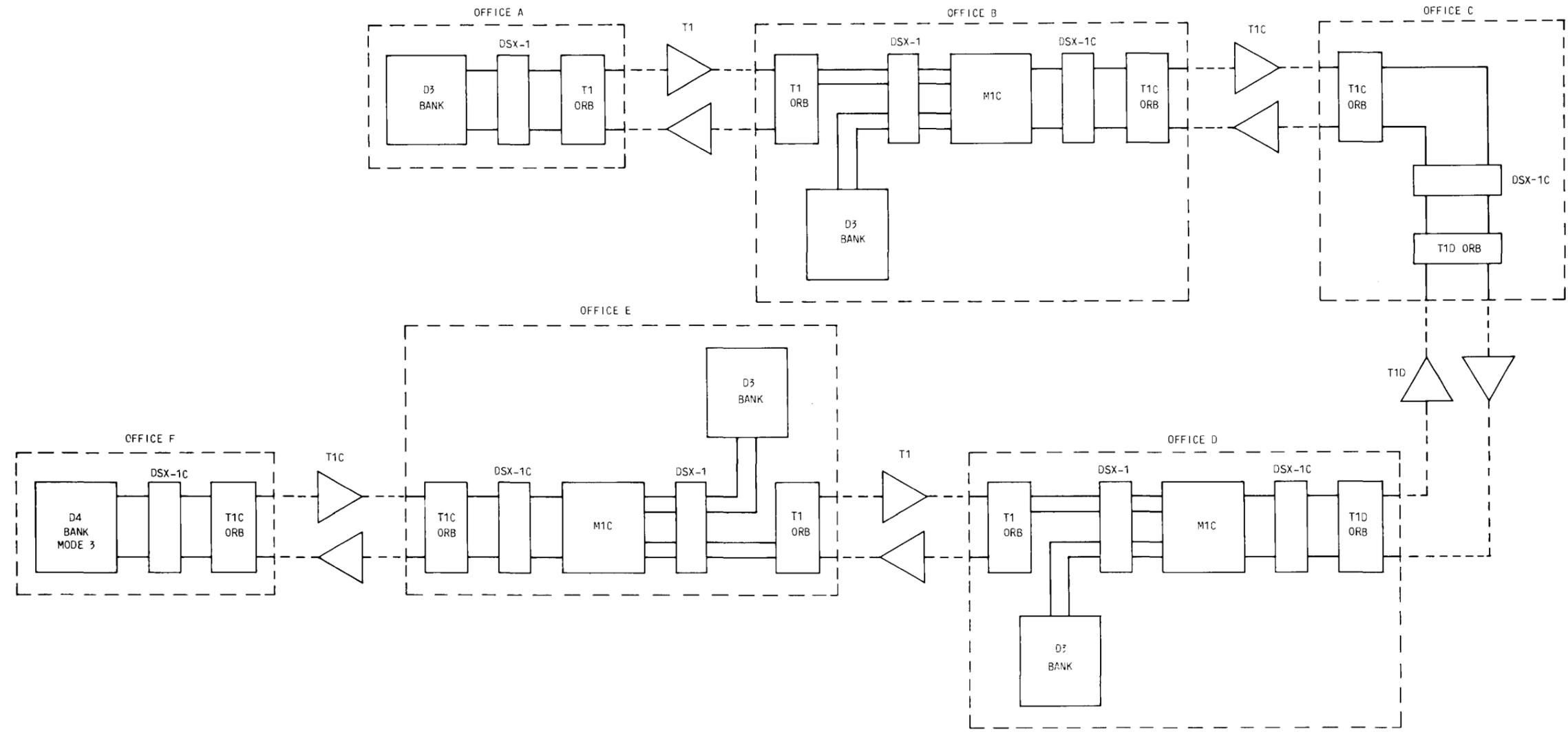
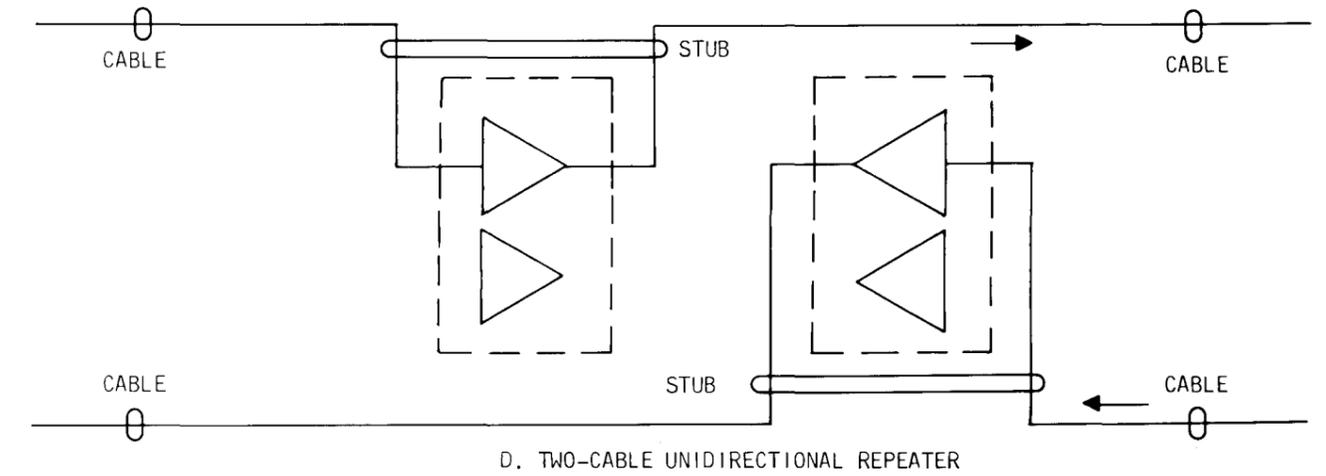
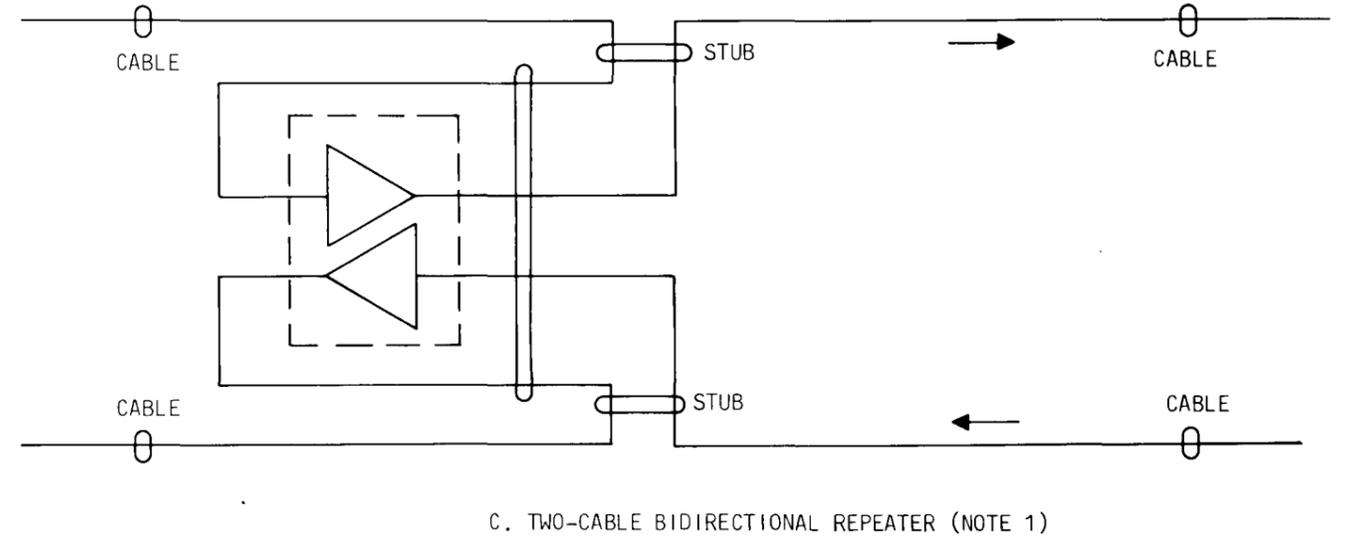
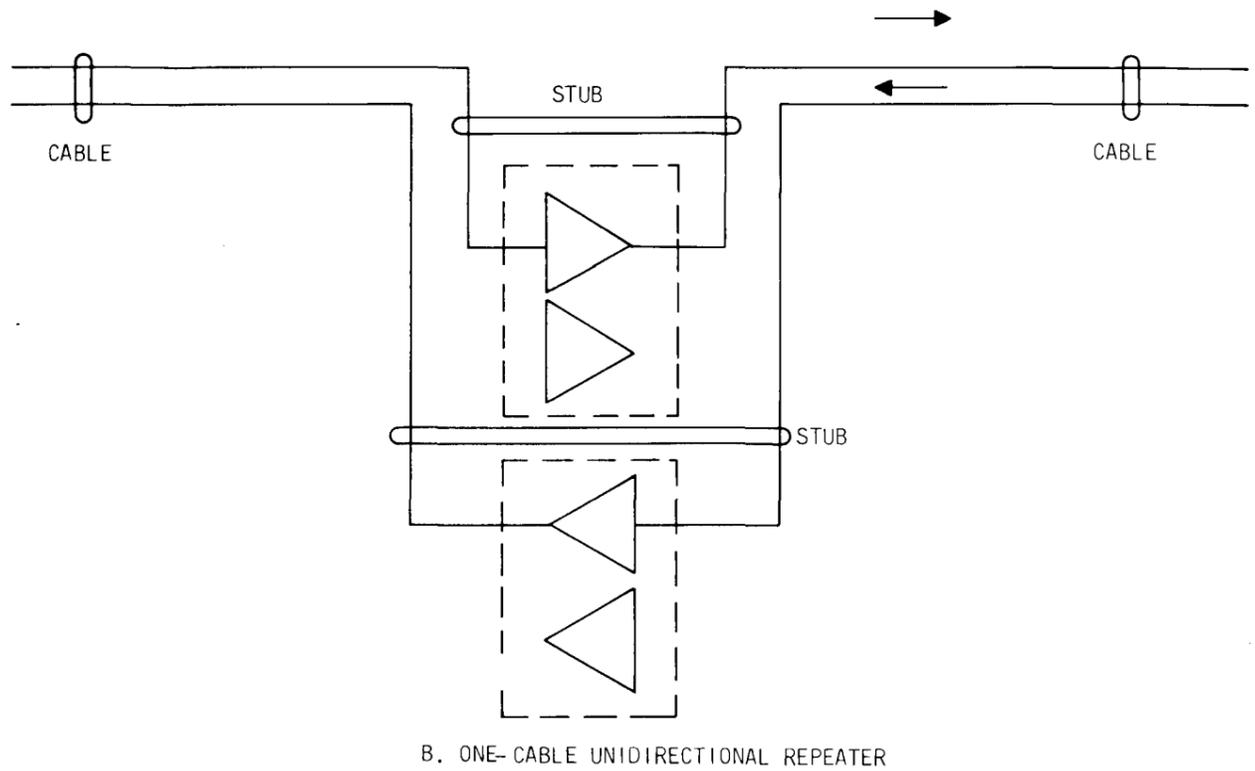
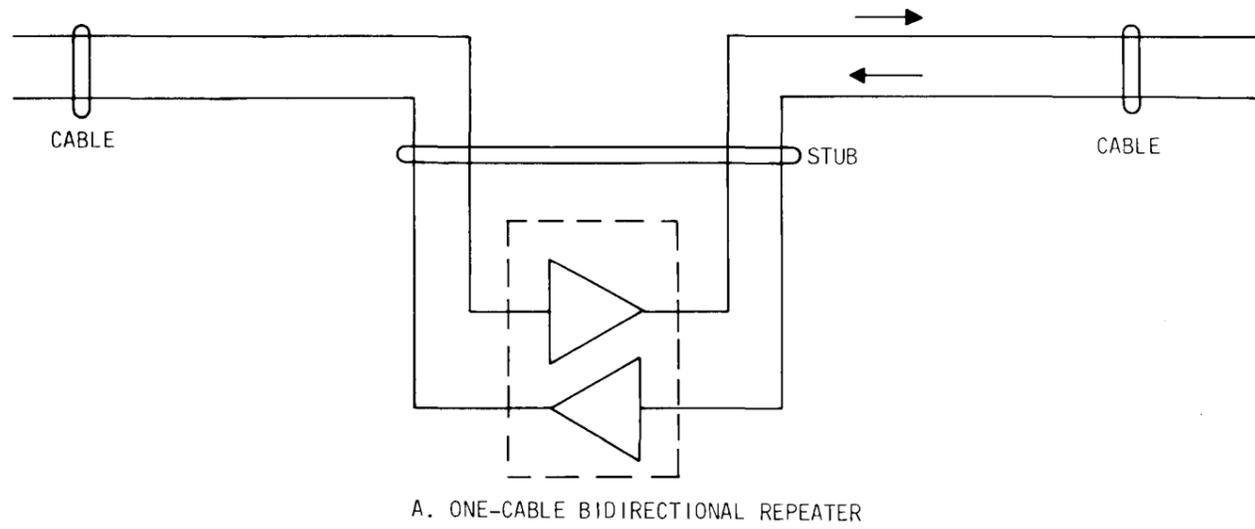
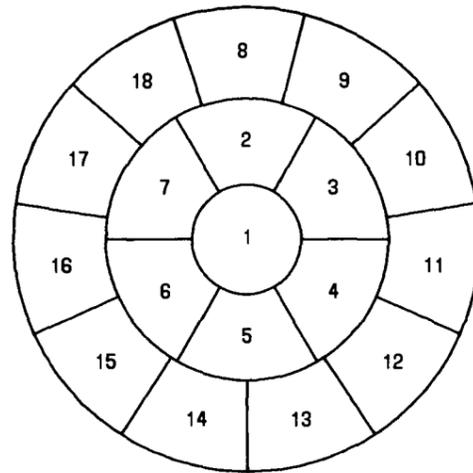


Fig. 33—T1/T1C/T1D Block Diagram



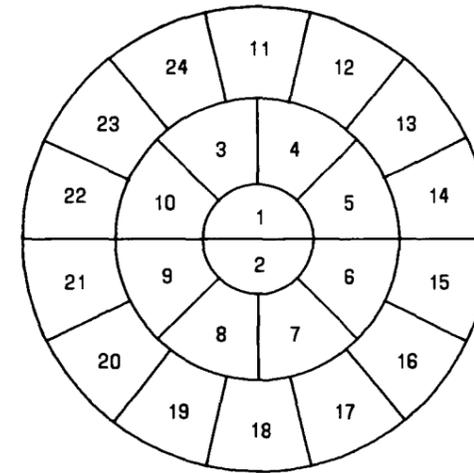
NOTE 1: TWO-CABLE OPERATION WITH BIDIRECTIONAL LINE REPEATERS IS NOT RECOMMENDED BECAUSE OF THE COMPLEX APPARATUS CASE SPLICING.

Fig. 34—Unidirectional and Bidirectional Repeater Operation (Apparatus Cases Shown Dashed)



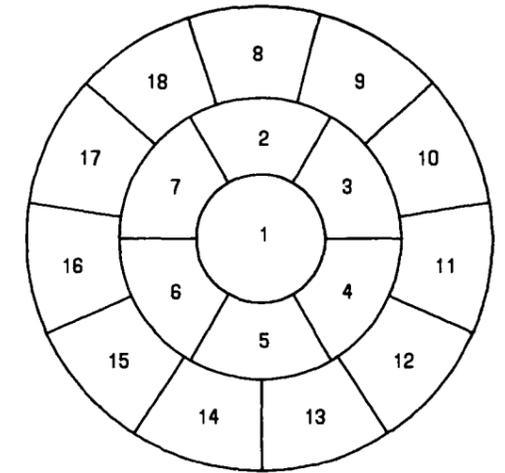
W-E BINDER UNITS 6, 7, 15, 16, 17, & 18
E-W BINDER UNITS 3, 4, 9, 10, 11, & 12

A. 300 T1 LINES IN 900 PAIR PULP CABLE



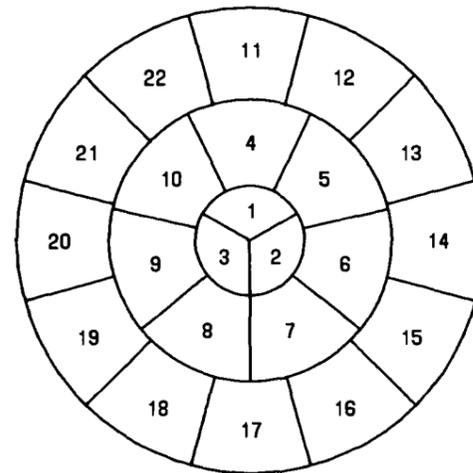
W-E BINDER UNITS 9, 10, 19, 20, 21, 22, 23 & 24
E-W BINDER UNITS 5, 6, 12, 13, 14, 15, 16, & 17

B. 400 T1 LINES IN 1200 PAIR PULP CABLE



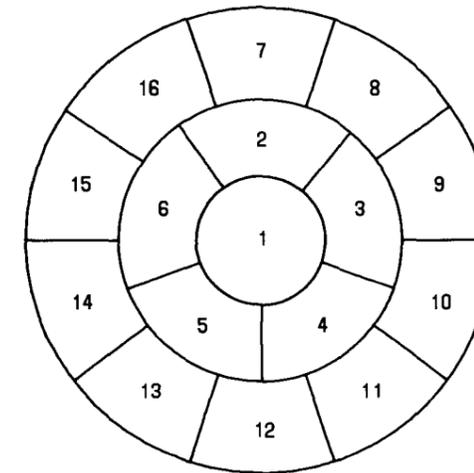
W-E BINDER UNITS 6, 7, 15, 16, 17, 18
E-W BINDER UNITS 3, 4, 9, 10, 11, 12

C. 600 T1 LINES IN 1800 PAIR PULP CABLE



W-E BINDER UNITS 9, 10, 18, 19, 20, 21, 22
E-W BINDER UNITS 5, 6, 12, 13, 14, 15, 16

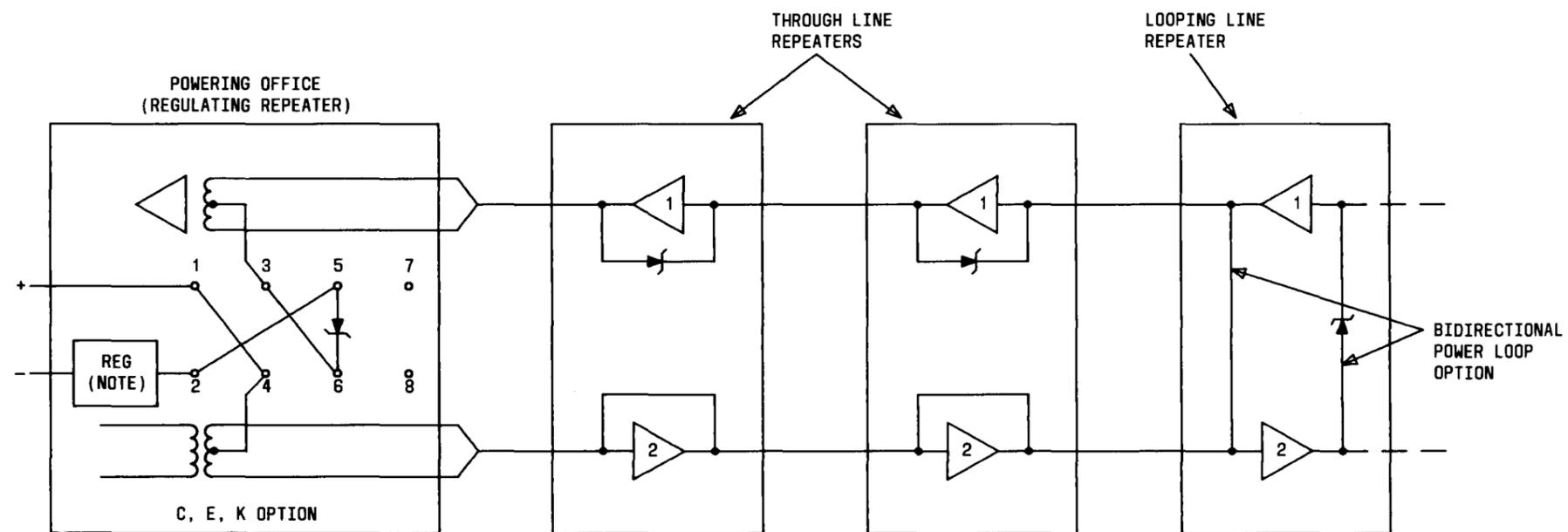
D. 350 T1 LINES IN 1100 PAIR PULP CABLE



W-E BINDER UNITS 6, 13, 14, 15, 16
E-W BINDER UNITS 3, 8, 9, 10, 11

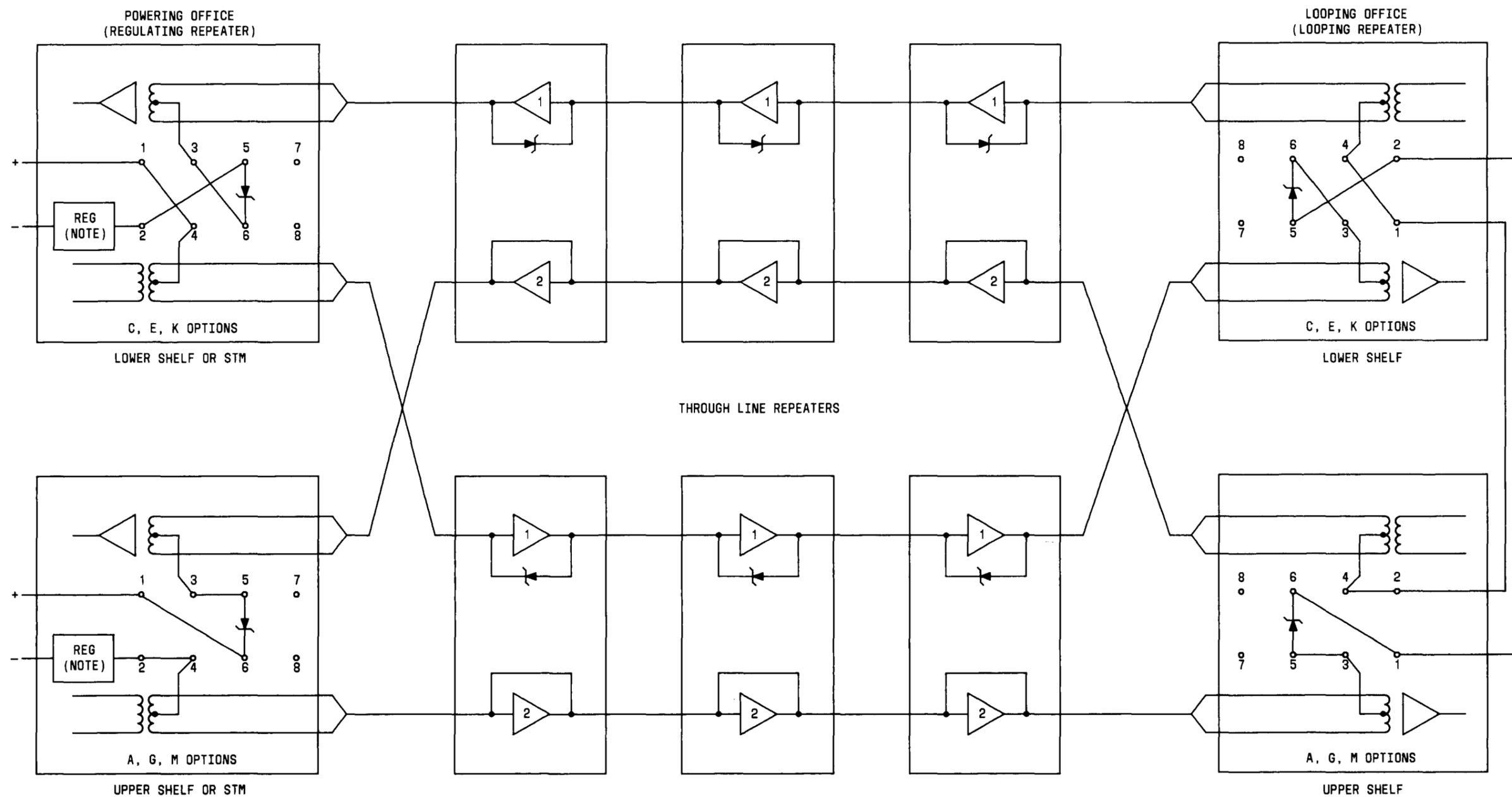
E. 500 T1 LINES IN 1500 PAIR PULP CABLE

Fig. 35—Unit Selection for T1 Lines Using Outer and Middle Binder Units



NOTE: REGULATOR SHOWN FOR 221- AND 231-TYPE REPEATERS;
 REGULATOR IS IN + LEG IN 206- AND 236-TYPE REPEATERS.

Fig. 36—Typical T1 Bidirectional Power Loop With Office Repeater Powered in Series With the Line



NOTE: REGULATOR SHOWN FOR 221- AND 231-TYPE REPEATERS;
REGULATOR IS IN + LEG IN 206- AND 236-TYPE REPEATERS.

Fig. 37—Typical T1 Unidirectional Power Loop With Office Repeaters Powered in Series With the Line (CEK and AGM Options)

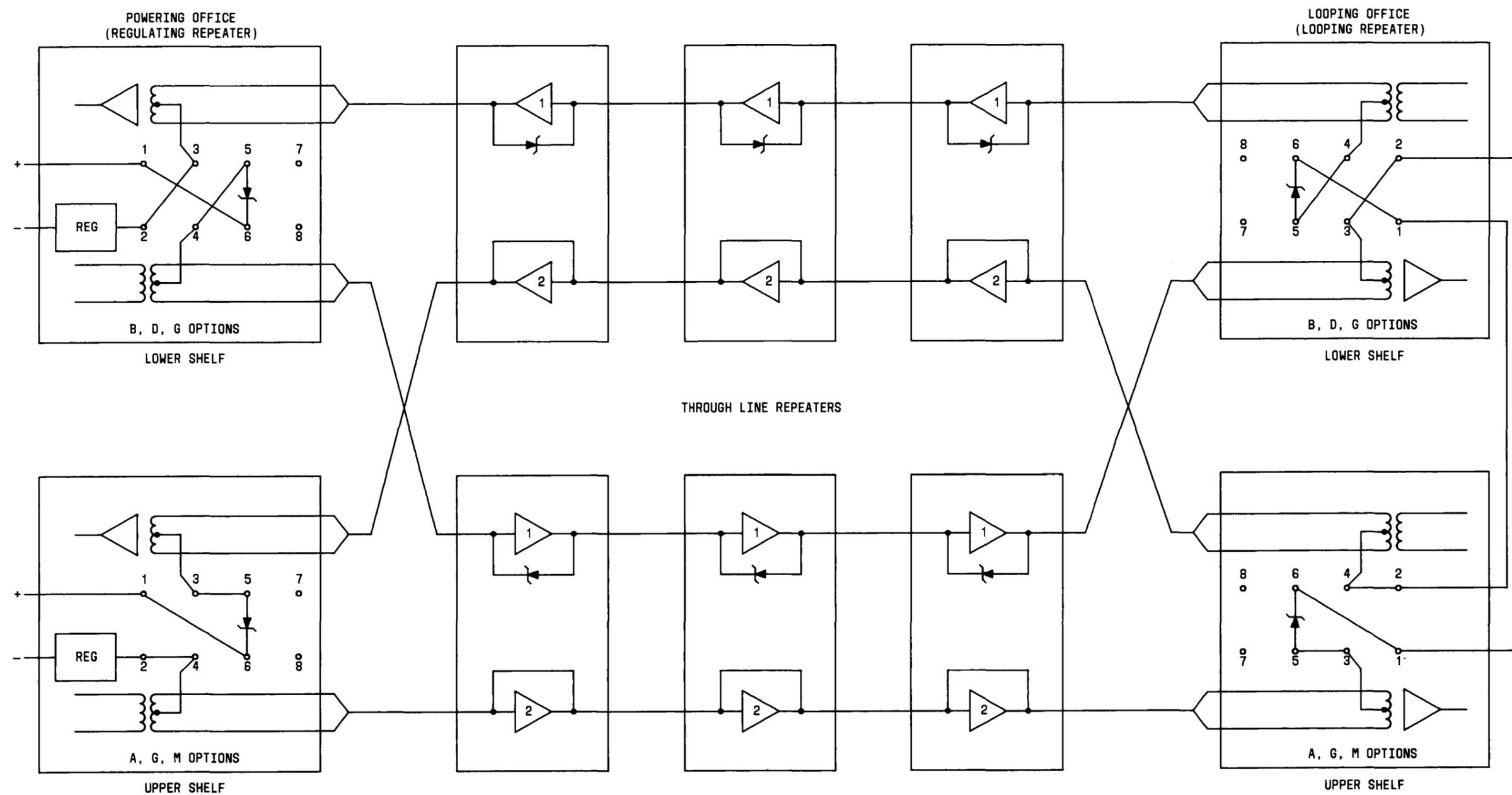
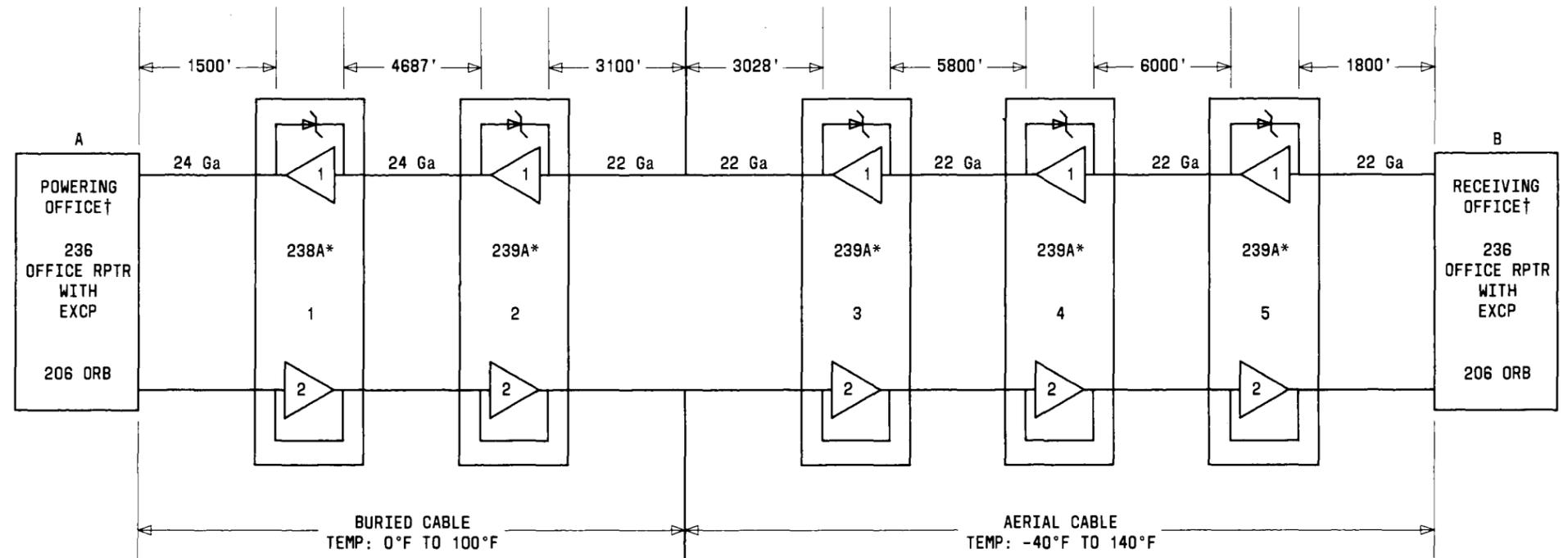


Fig. 38—Typical T1 Unidirectional Power Loop With Office Repeaters Powered in Series With the Line (BDG and AGM Options)

| POWER FROM | LOOP RPTR | # OF RPTRS | RL(MIN) OHMS | RL(MAX) OHMS | REQ'D VOLTS | POWER OFC RPTRS IN SERIES WITH LINE | |
|------------|-----------|------------|--------------|--------------|-------------|-------------------------------------|---------------|
| | | | | | | OPTION CEK | SAFETY MARGIN |
| A | B | 5 | 1060 | 1231 | 130 | A&B | 84 |
| A | 5 | 5 | 1009 | 1168 | 130 | YES | 414 |
| B | | 0 | 60 | 72 | 48 | YES | 210 |
| A | 4 | 4 | 808 | 924 | 130 | YES | 658 |
| B | | 1 | 261 | 316 | 48 | NO | 233 |
| A | 3 | 3 | 608 | 683 | 130 | YES | 899 |
| B | | 2 | 461 | 557 | 130 | YES | 1025 |
| A | 2 | 2 | 400 | 441 | 48 | NO | 108 |
| B | | 3 | 669 | 799 | 130 | YES | 783 |
| A | 1 | 1 | 176 | 186 | 48 | YES | 96 |
| B | | 4 | 893 | 1054 | 130 | YES | 528 |
| B | A | 5 | 1060 | 1231 | 130 | A&B | 84 |

| POWER FROM | LOOP RPTR | # OF RPTRS | RL(MIN) OHMS | RL(MAX) OHMS | REQ'D VOLTS | TEST VOLTAGE LIMITS | | | |
|------------|-----------|------------|--------------|--------------|-------------|---------------------|---------------|----------------|----------------|
| | | | | | | LINE VOLT MIN | LINE VOLT MAX | REG. VOLT. MIN | REG. VOLT. MAX |
| A | B | 5 | 1060 | 1231 | 130 | 95 | 105 | 10 | 32 |
| A | 5 | 5 | 1009 | 1168 | 130 | 76 | 86 | 29 | 51 |
| B | | 0 | 60 | 72 | 48 | 19 | 20 | 15 | 23 |
| A | 4 | 4 | 808 | 924 | 130 | 64 | 71 | 44 | 63 |
| B | | 1 | 261 | 316 | 48 | 15 | 18 | 16 | 27 |
| A | 3 | 3 | 608 | 683 | 130 | 52 | 57 | 58 | 75 |
| B | | 2 | 461 | 557 | 130 | 43 | 49 | 66 | 84 |
| A | 2 | 2 | 400 | 441 | 48 | 24 | 26 | 9 | 19 |
| B | | 3 | 669 | 799 | 130 | 56 | 63 | 51 | 72 |
| A | 1 | 1 | 176 | 186 | 48 | 26 | 27 | 8 | 16 |
| B | | 4 | 893 | 1054 | 130 | 69 | 79 | 36 | 58 |
| B | A | 5 | 1060 | 1231 | 130 | 95 | 105 | 10 | 32 |

Fig. 39—Typical Output of DCOPE—T-PWR Program



*TYPES OF LINE REPEATERS
 †CHOICE OF OPTIONS DETERMINE THE EFFECTIVE RESISTANCE OF POWERING OFFICE

Fig. 40—Example of Bidirectional Power Loop

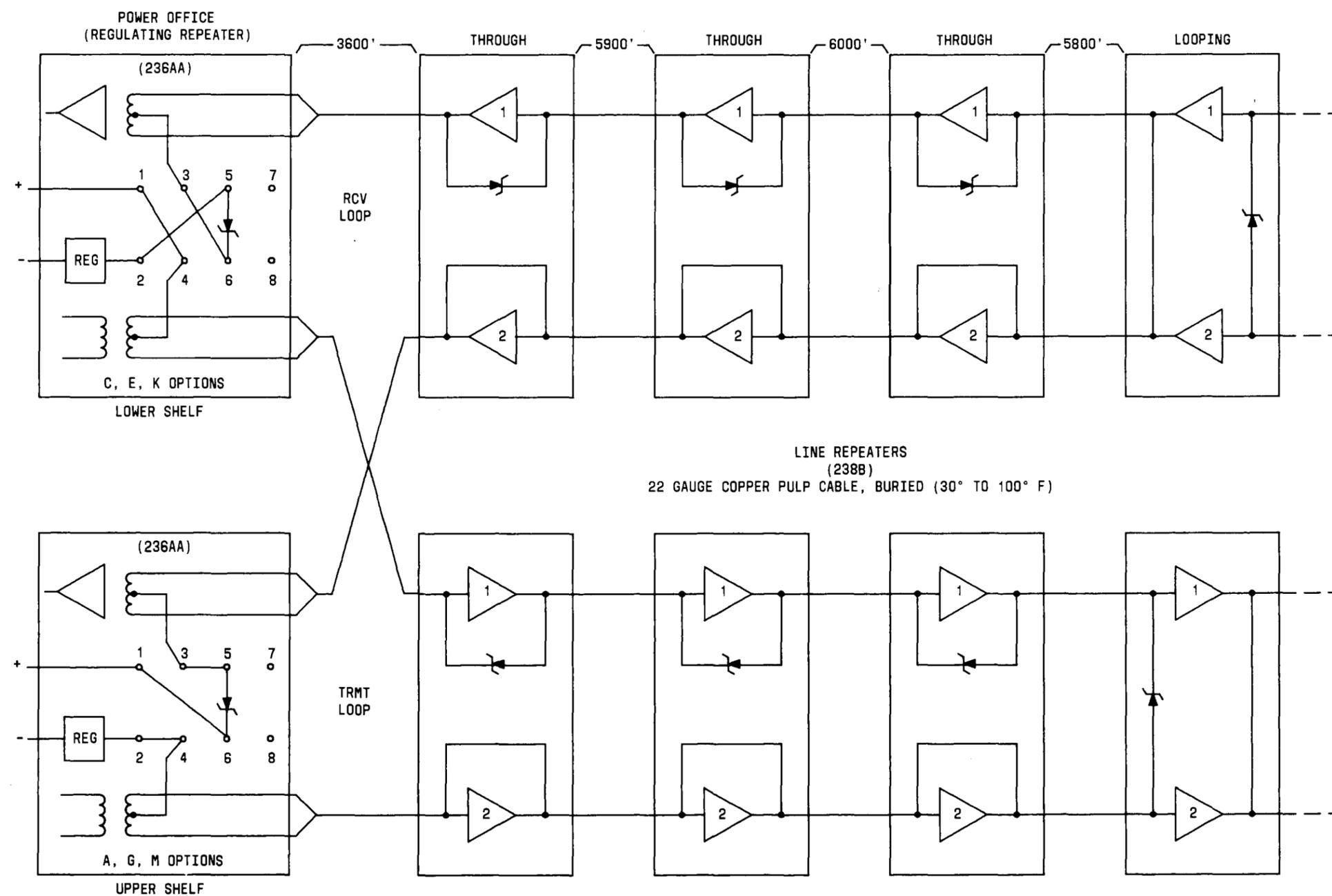


Fig. 41—Example of Power Loop Resistance Determination