

**CARRIER ENGINEERING
SYSTEM APPLICATION**

T2 DIGITAL LINE

TRANSMISSION AND OUTSIDE PLANT DESIGN PROCEDURES

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1. GENERAL

1.01 This section gives a brief description of the T2 digital line and provides guides for application of T2 to low-capacitance (LOCAP) cable. Section 365-500-100 gives a general description of the T2 digital line.

1.02 This section is reissued to cover waterproof LOCAP cable, and the joint use of T2 and T1/Outstate (T1/OS). Changes are indicated by arrows.

1.03 The T2 system (a complement of T2 lines operating over the same route) is primarily a high-capacity, intercity-type system used to transmit digital signals at the second level (DS-2) of the digital network over distances of approximately 500 miles maximum. The DS2 signal is a 6.312-Mb/s bitstream; its sources are the M12, M12A, M12B multiplexer-demultiplexers (muldems), and the D4 (Mode 4 or 4A) channel bank. The muldems combine four DS1 signals into one DS2 signal, giving the T2 line a capacity of 96 message channels. Two paired D4 (Mode 4 or 4A) channel banks combine 4 groups of 24 message channels into one DS2 signal, compatible end-to-end with the M12, M12A, or M12B muldems. The interface between the M12 or M12B muldem or the D4 (Mode 4) channel banks and the T2 line is provided at the DSX-2 patch and cross-connect bay. Interfaces with the M12A and the D4 (Mode 4A) channel banks are discussed in paragraphs 1.12 and 1.13.

1.04 The transmission medium for the T2 system is a 22-gauge, paired, LOCAP cable currently available in 27-, 52-, and 104-pair sizes. (Table A summarizes LOCAP cable characteristics.) LOCAP cable is available in both air core and waterproof designs. The two designs employ the same insulated

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conductors; however, the capacitance and loss of the waterproof design are larger than those of the air core design because of the effect of the filling compound. The T2 line is a 2-way transmission facility, using one pair of cable conductors for each direction of transmission. Separate cables are used for each direction of transmission to reduce the effects of near-end (NEXT) and interaction crosstalk. Two 27-pair cables provide a maximum of 24 T2 lines; two 52-pair cables, a maximum of 48 lines; and two 104-pair cables, a maximum of 96 lines. The remaining pairs are used for fault locating, order wire, gas pressure monitoring, and other auxiliary dc or voice-frequency functions.

1.05 The basic system building block for the T2 digital line in terms of line length is the maintenance span. Maintenance spans contain repeater stations and intermediate powering stations

(IPs) as necessary; and each end terminates at a span terminating bay (STB) in a maintenance office (MO) as shown in Fig. 1. (See paragraph 1.12 for an exception.) The maximum number of repeater locations permitted in a maintenance span is 44, including those in the STBs and in the IPs. T2 lines can be extended by connecting maintenance spans in tandem using the DSX-2 bays. The maximum number of repeater locations permitted in an overall T2 line is 250. This limit is imposed by the system objectives given in paragraph 2.02.

1.06 In terms of route capacity, the basic system building block is the protection group. A protection group is composed of 24 T2 lines: 23 are service lines and one is a standby line which is available for automatically switched protection of the service lines. The STB provides mounting space for regenerators, power units, violation monitors and removers (VMRs), and protection

→ TABLE A ←

SUMMARY OF LOCAP CABLE CHARACTERISTICS

PHYSICAL CHARACTERISTICS:			
Size:	27, 52, or 104 Pairs		
Conductor:	22 AWG Copper		
Insulation:	Expanded polypropylene with a 2 mil, polyolefin coating		
	Size	Air Core (ARPAP) Dia. Over Sheath	Waterproof (ASP) Dia. Over Sheath
	104 pairs	2.24 inches	2.00 inches
	52 pairs	1.64 inches	1.43 inches
	27 pairs	1.24 inches	1.04 inches
ELECTRICAL CHARACTERISTICS:			
		Air Core	Waterproof
Capacitance:		0.037 to 0.41 μ f/mile	0.044 to 0.048 μ f/mile
Insertion loss at 3.15 MHz, 75° F:		19.4 to 23.5 dB/mile	21.3 to 25.4 dB/mile
Far-end crosstalk, 3.15 MHz:		Power sum less than -38 dB per 1000 feet for any pair in cable	
Nominal impedance, 3.15 MHz:		178 Ω	165 Ω
DC conductor resistance:		\leq 90 Ω per mile at 68° F	

switching apparatus for one protection group. In addition, provision is made for alarm indicators. Access to the T2 lines for fault locating is provided at the STB.

1.07 The digital signal transmitted over a T2 line is subject to distortion and attenuation. The signal is restored to its original shape and transmission level by regenerators located in the STBs and IPSs, and at repeater stations along the cable. The regenerator is a one-way device. The pair of regenerators required for 2-way transmission is called a repeater. At a repeater station, a maximum of 24 of these regenerators, transmitting in one direction, are housed in one 473-type apparatus case. The regenerators for the opposite direction of transmission are housed in a separate 473-type case. A repeater section is defined as the cable length (one-way) between repeater locations.

1.08 The regenerators in the T2 line are powered by feeding constant current over the simplex loop formed by the pairs for the two directions of transmission on the T2 line. This current is supplied by a power unit which is fed from a central office battery. A building or a conveniently located central office serves as an IPS.

1.09 The 2-wire order-wire and fault locating circuits in the T2 transmission system are similar to those in the T1 system. For the T2 system, however, a separate 477-type apparatus case is provided at repeater stations to house the fault locating and order-wire equipment. Access to the order wire is provided on the outside of this apparatus case. A 4-wire order-wire circuit and an alarm remoting circuit can also be implemented by making use of auxiliary pairs in the LOCAP cable.

1.10 Two protection groups with 52-pair cables or four protection groups with 104-pair cables can share cables over a common route and then be branched in increments of one protection group to serve separate end offices. Branching can be accomplished at either a repeater station or an IPS. Special attention must be given to the engineering of fault locating circuits and other auxiliary circuits when branch routes are formed.

1.11 It is possible to terminate one or more protection groups by means of STBs at an intermediate office and to carry the remaining protection groups through the office by means of

IPS bays. This arrangement is called a combination office (COMBO). Where a protection group is carried through the office, a special arrangement for the fault locating circuit is available which permits the sharing of one fault locating circuit between a terminated group and a group that is carried through the intermediate office.

1.12 An M12A/T2A terminal bay (MTB) that provides an economical means of terminating a maximum of six 2-way T2 lines and of mounting a maximum of three M12A multiplexer units (shelves) providing two M12A muldems each is available for use in maintenance offices. It is intended for use only on short and slow-growing routes not needing the protection and monitoring features of a full T2 system and as an interim arrangement for routes with low initial circuit requirements. With the exception of two circuit packs per muldem, all plug-in apparatus and equipment used for T2A and M12A can also be used in standard T2 and M12 arrangements. Also, it is recommended that cables from the protectors to the M12A/T2A bays be cut to lengths that will allow reuse when an STB is installed later. Protection switching is not available on this bay and, since performance monitoring VMRs are not furnished, all service alarms appear at the M12A unit and associated D-type channel banks. Where more than six T2 lines are implemented, it is recommended that the lines be terminated by STBs.

1.13 At IPSs, a maximum of six T2 lines per protection group can be dropped by a field modification of the repeater bay to provide connection to six M12A muldems, or six pairs of D4 (Mode 4A) channel banks, or six combinations thereof. No monitoring or protection switching for the dropped T2 lines is provided when this arrangement is selected, and the muldem or D4 channel bank must be within 25 feet (cable length) of the T2 line jacks. However, one of the six T2 lines can be used as a standby line for manual restoration. Special provisions, discussed in paragraph 2.25, must be made for the fault locating circuit at IPSs where lines are to be dropped. When more than six lines are to be dropped, it is recommended that an MO or a COMBO be established with one or more protection groups terminated by means of STBs.

1.14 Provision is made for implementing T1/OS lines and T2 lines on the same LOCAP cable. It is expected that this option will be used primarily to provide T1/OS lines between an IPS

and the nearest T2 maintenance office, where the T1/OS lines will be multiplexed for connection to T2.

1.15 For combined T2 and T1/OS operation, the outside plant arrangement is essentially that for T2 and the facility is engineered according to the T2 engineering guides.

1.16 A T1 regenerator (7A) is provided which is accepted by the slots in the T2 regenerator apparatus case. However, the newer codes of apparatus cases (473A3 and 473B3) are required to implement T1/OS lines because only they provide a fault locating signal bus for the T1 regenerators.

1.17 At MOs and IPSs, the T1/OS J98728 span terminating module (STM) is required to terminate the T1/OS lines. The interface with the T2 lines is made at the T2 protector. The T1/OS maintenance arrangements are described in Section 801-523-156.

1.18 When T1/OS lines are to be implemented, the length of repeater sections not adjacent to an MO or IPS must not be less than 5000 feet.

1.19 For engineering purposes, the ends of a maintenance span are designated A and B. The cable transmitting from A toward B is called the A-B cable and the cable transmitting from B toward A is called the B-A cable. This convention is followed in designating apparatus cases at repeater stations and regenerator mountings at IPSs. Similarly, each IPS, COMBO, and repeater station has an A side, the side facing end A, and a B side. (See Fig. 1.)

2. ENGINEERING GUIDES

2.01 The following guides do not necessarily provide the optimum configuration for all situations because local conditions can have a significant influence on the layout. The guides are intended to assist the designer in obtaining an initial layout that can be further refined to meet local conditions.

System Objectives

2.02 The guides for engineering T2 transmission systems provided in this section allow the following objectives to be met:

(a) For an overall T2 line consisting of a maximum of 250 repeater sections, an accumulated error rate of less than 1×10^{-7} on 95 out of every 100 lines.

(b) For a T2 line consisting of a maximum of 250 repeater sections, an outage due to equipment failures of less than 2×10^{-2} percent, ie, 1.7 hours/year, when protection switching is equipped. (Outage is that percentage of the time that service over a given line is interrupted due to unprotected failures.)

A. Maintenance Spans and Offices

2.03 The T2 system consists of one or more maintenance spans (MSs). The spans are laid out after the locations of the MOs have been determined. To permit unattended operation, provision is made in the STB for alarm remoting via the E2 Status Reporting and Control System or via an equivalent alarm remoting system. MOs are required at the ends of the system, at intermediate offices where cross-connection of T2 lines is required, and where the number of repeater locations including MOs and IPSs exceeds 44. The maximum maintenance span length with underground or buried air core LOCAP cable is 114 miles, and with waterproof LOCAP cable it is 104 miles. The limitation of 44 repeater locations applies where the regenerator apparatus cases are located in manholes. For this situation, it is expected that the ambient temperature in a manhole will not exceed 110°F when the case is fully equipped. It also is possible to house the apparatus cases in above-ground structures, and the limitation of 44 repeater locations in a maintenance span applies if the ambient temperature is controlled so that it does not exceed 110°F. If this temperature requirement is not met and temperatures in the range of 110 to 120°F are expected, then the maximum number of repeater locations in a maintenance span must be reduced to 33 to meet reliability objectives. For locations where ambient temperatures in the repeater station are expected to exceed 120°F, a means of cooling must be provided. For routes with a mixture of manhole and above-ground repeater stations and where

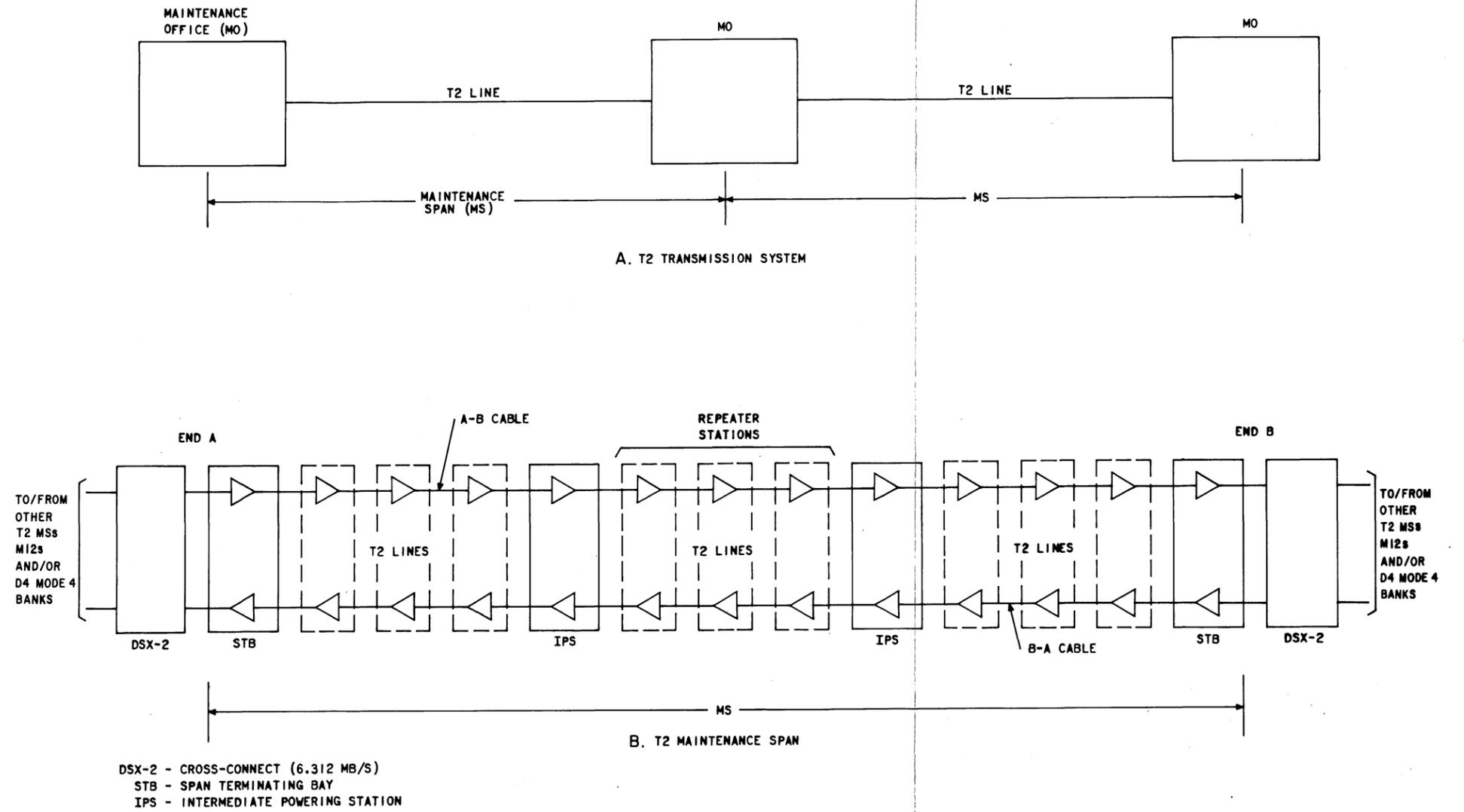


Fig. 1—Typical Maintenance Span

temperatures in the range of 110 to 120°F are expected, the above-ground stations are considered to be equivalent to 1-1/3 manhole stations.

B. Repeater Section

2.04 The maximum repeater section lengths using underground or buried LOCAP cable are shown in Table B. Section lengths adjacent to offices are shortened to compensate for the presence of the impedance build-out network discussed in paragraph 2.09 and to reduce the effect of office noise. The section lengths in Table B are based upon expected temperature extremes of +20°F and +90°F for underground or buried cable. Temperatures can usually be limited to this range by placing the cable at a depth of from 2 to 4 feet, depending upon geographic location.

2.05 The expected extremes of cable temperature at a given location can be estimated through use of Fig. 2 and 3. Figure 2 shows contours of annual mean earth temperature and Fig. 3 shows the annual maximum-to-minimum range of earth temperature for a 4-foot depth. The temperature range at depths of from 1 to 6 feet can be estimated by multiplying the range at a 4-foot depth by

$$e^{0.13(4 - d)}$$

where d is the depth of interest in feet. For example, in Southern Indiana the annual mean temperature is about +55°F and the annual range of temperatures is about 26°F at a depth of 4 feet. The range at a 2-foot depth would be approximately

$$26e^{0.26} = 34^\circ\text{F}.$$

Thus, the expected temperature extremes for cable at a 2-foot depth in this location are estimated to be +38°F and +72°F. Temperature extremes estimated in this way should be confirmed by other methods employed by the operating company.

2.06 LOCAP cable can also be installed aerially in limited circumstances (see paragraph 3.01). However, maximum repeater section lengths must be reduced as shown in Table B to compensate for the more extreme temperatures to be expected. The section lengths in Table B are based upon expected extremes of cable temperature of -40°F and +140°F for aerial cable.

2.07 The type of regenerator assigned to an STB, MTB, apparatus case, or IPS repeater bay depends upon the type of cable at the input and output of the regenerators. Two types of cable are involved: ABAM, which is used on the office side of STBs, and LOCAP. No distinction is made between air core and waterproof LOCAP in the selection of regenerator types. Table C indicates the available regenerator codes for different applications in LOCAP installations. The 1E, F, G, and H are of an improved design and have replaced the original 1A, B, C, and D.

C. Line and Impedance Buildout

2.08 Each T2 line requires a line build-out (LBO) network in each STB, following the receiving regenerators. The LBO is selected to build out the 3.15-MHz line loss between the LINE OUT jacks of the STB and the DSX-2 bay jacks to 9 dB ±0.75 dB (see T2 application schematic). The LBO network code, 888(), depends on the length of ABAM cable between the STB and the DSX-2

TABLE B

MAXIMUM REPEATER SECTION LENGTHS IN KILOFEET

REPEATER SECTION TYPE	UNDERGROUND OR BURIED LOCAP CABLE		AERIAL LOCAP CABLE	
	AIR CORE	WATERPROOF	AIR CORE	WATERPROOF
Sections adjacent to an office or IPS	11.8	10.7	10	9
Sections not adjacent to an office or IPS	15	13.7	13	12

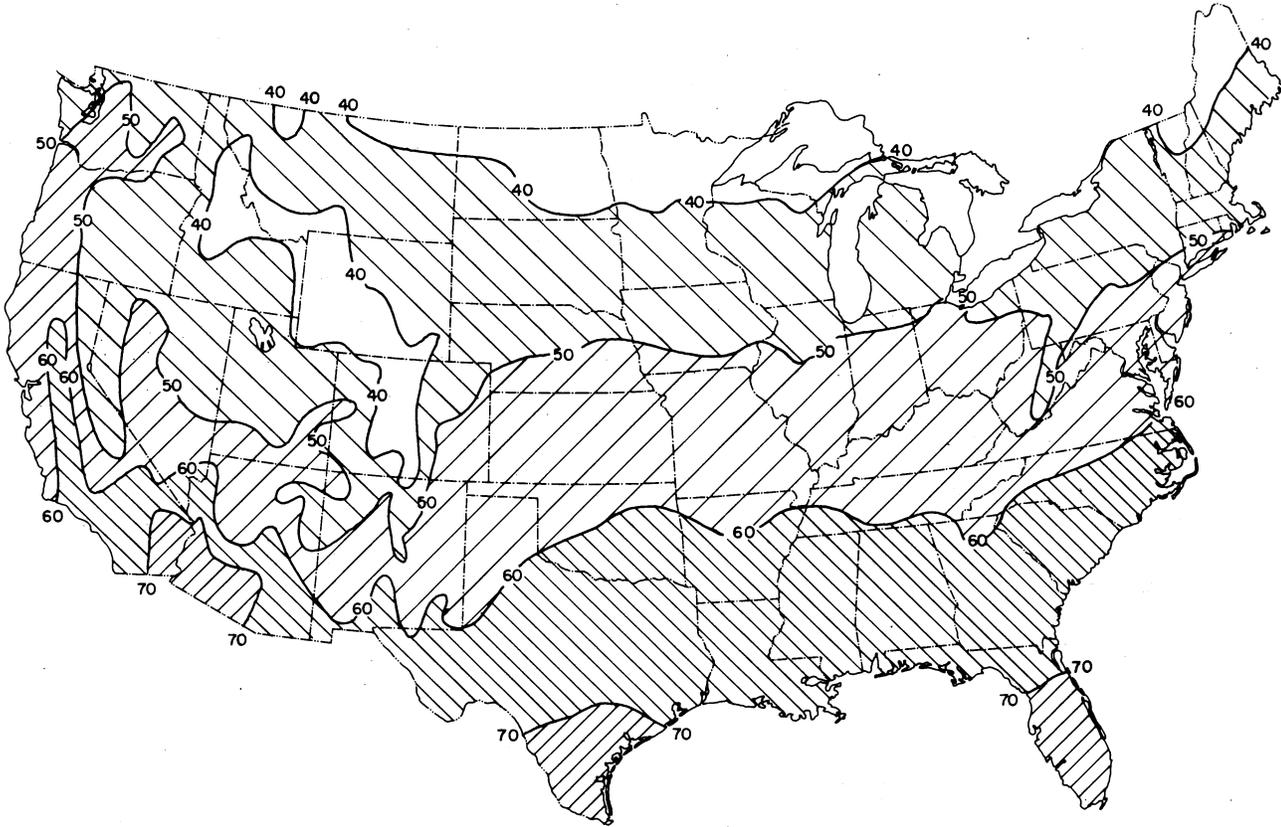


Fig. 2—Annual Mean Earth Temperature, Degrees Fahrenheit

bay and is available in increments of 1.5 dB to a maximum of 9.0 dB. The STB comes equipped with LBOs, and the code is selected indirectly when ordering an STB in accordance with SD-99505-01-C1, Table A. Another LBO network, 882(), is required for the FM3 circuit pack for protection switching. The specific code depends upon the length of the ABAM cable between the STB and the DSX-2, and must be ordered separately in accordance with SD-99512-01, Note 104.

2.09 An impedance build-out (IBO) network for each T2 line is incorporated into every STB, MTB, and IPS repeater bay. The IBO is placed following the transmitting regenerators to increase the return loss in the transmitting side of the line between the regenerator output and the cable vault splice. Since the repeater section lengths adjacent to an office or an IPS are reduced, the loss of the IBO can be compensated for when the equalizers for the regenerators that receive signals via the IBOs are selected, as described in paragraph 2.10. For LOCAP installations, the IBO is equivalent

electrically to about 2000 feet of LOCAP cable. ♦Where gas plugs are required in repeater sections not adjacent to an office, the plug must be located more than 2000 feet from the transmitting side of a regenerator and within the maximum lengths given in Table B.♦

D. Line Equalization

Underground or Buried Repeater Sections

2.10 ♦Each regenerator must be equipped with a plug-in equalizer which is selected in accordance with cable length or pair loss on the input side of the regenerator. Table D1 lists the equalizer codes and their loss ranges. Cable length ranges are listed for each code for both air core and waterproof LOCAP. The length ranges include allowances for pair loss variations, temperature variation over the range of +20 to +90°F, and cable length uncertainty of ±2 percent. For waterproof LOCAP, an additional allowance is included for a 2 percent increase in loss with age. For underground or

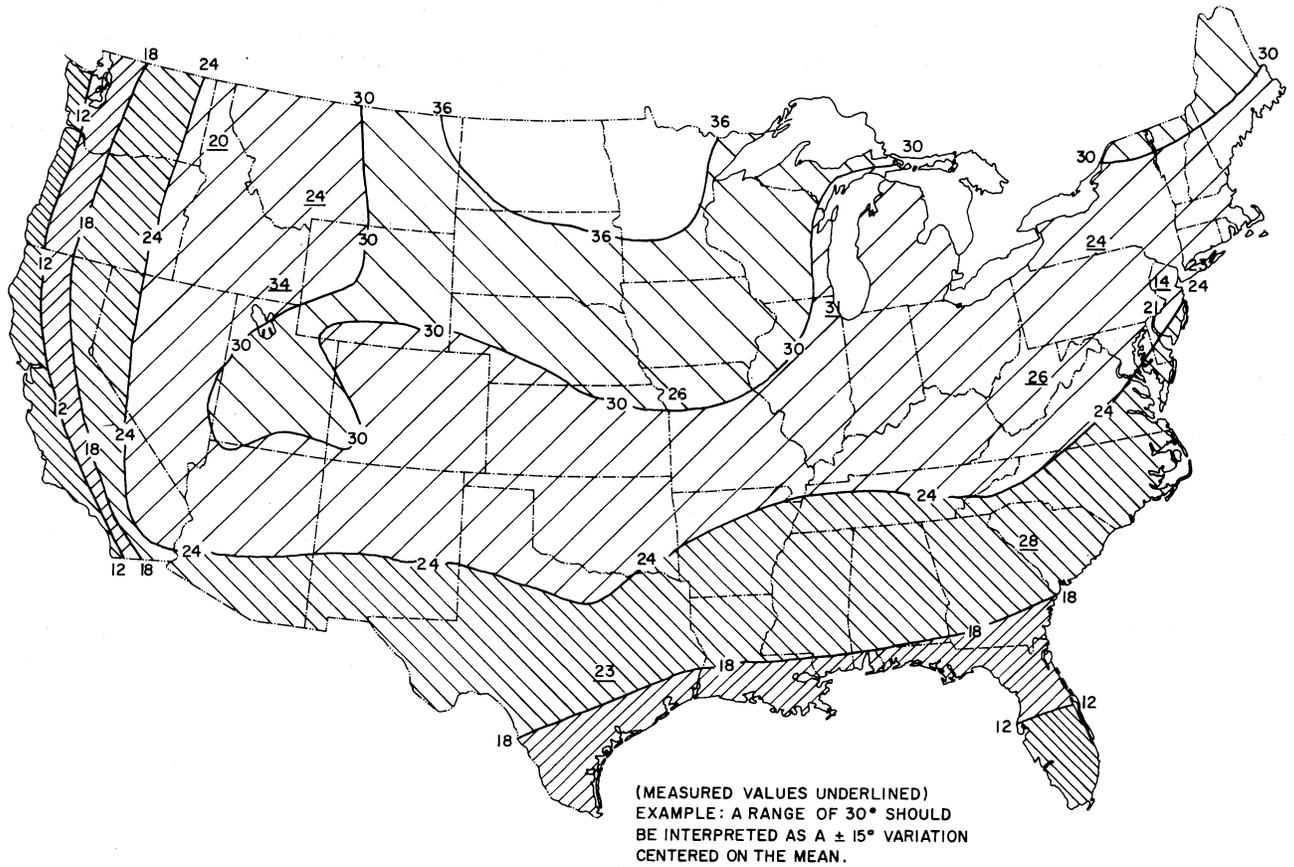


Fig. 3—Annual Range of Earth Temperature (Maximum-to-Minimum) for a 4-Foot Depth, Degrees Fahrenheit

→ TABLE C ←

REGENERATOR CODES AND LOCATIONS

REGENERATOR LOCATION	CABLE TYPE		REGENERATOR CODE
	INPUT	OUTPUT	
Bridging Regenerator for M12A/T2A bay or DSX-2 bay	ABAM	ABAM	1A or 1E
Apparatus cases at repeater stations	LOCAP	LOCAP	1B or 1F
STBs at MOs:			
Receiving Regenerator	LOCAP	ABAM	1D or 1H
Transmitting Regenerator	ABAM	LOCAP	1C or 1G
Lines connecting to M12As at IPSs or MOs:			
Receiving Regenerator	LOCAP	ABAM	1D or 1H
Transmitting Regenerator	ABAM	LOCAP	None required

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buried applications, the equalizer codes should be selected on the basis of cable length between regenerators. There is an overlap in cable length of approximately 10 percent between the upper limit of one code and the lower limit of the next higher-loss code. For section lengths falling in an overlap region, either of the indicated codes can be used. However, best use can be made of the equalizer loss range by using the indicated lower-loss code for section lengths which fall below the center of the overlap region and the higher-loss code for section lengths which fall above the center of the overlap region. When an equalizer is being chosen for the first regenerator out from an office or IPS transmitting away from the office or IPS, the code selected must correspond to a cable length that is 2000 feet longer than the actual cable length to account for the loss in the IBO network.

Aerial Repeater Sections

2.11 Table D2 gives the cable length ranges for each applicable equalizer code for aerial air

core and waterproof LOCAP. In this case, the length ranges include the same allowances as those for underground or buried applications except that the temperature range is increased to -40°F to +140°F. Because of the larger allowances, gaps exist in the cable length ranges of adjacent codes. For section lengths which fall in or near a gap between codes, cable loss measurements must be made with the J98717K pair loss measuring set (Section 103-498-100) to verify the choice of equalizers. The measurements must be adjusted to the maximum and minimum temperatures expected using the following equations:

$$L_{MAX} = L_T [1 + \alpha_T (T_{MAX} - T)]$$

$$L_{MIN} = L_T [1 + \alpha_T (T_{MIN} - T)]$$

where L_T is the measured loss; L_{MAX} is the loss at the highest temperature, T_{MAX} ; L_{MIN} is the loss at the lowest temperature, T_{MIN} ; T is the estimated cable temperature in °F; and α_T is the temperature coefficient of loss.

→ TABLE D ←

EQUALIZER CODES

EQUALIZER CODE	FOR USE WITH CABLE TYPE	EQUALIZER LOSS RANGE (dB)	CABLE LENGTH BETWEEN REGENERATORS (Kft)	
			AIR CORE LOCAP	WATERPROOF LOCAP
1 — For Underground or Buried Repeater Sections				
933AATR	ABAM	0 - 22	Office Cable	Office Cable
933AALC	LOCAP	0 - 28	0 - 6.05	0 - 5.51
933ABLC	LOCAP	18.3 - 46.3	5.46 - 10.01	4.92 - 9.11
933ACLC or 933BCLC	LOCAP	30.2 - 58.2	9.01 - 12.58	8.11 - 11.45
933ADLC or 933BDLC	LOCAP	38 - 66	11.34 - 14.27	10.21 - 12.98
933AELC or 933BELC	LOCAP	43 - 70	12.83 - 15.00	11.55 - 13.70
2 — For Aerial Repeater Sections				
933AATR	ABAM	0 - 22	Office Cable	Office Cable
933AALC	LOCAP	0 - 28	0 - 5.70	0 - 5.23
933ABLC	LOCAP	18.3 - 46.3	5.94 - 9.43	5.35 - 8.65
933ACLC or 933BCLC	LOCAP	30.2 - 58.2	9.81 - 11.85	8.84 - 10.88
933ADLC or 933BDLC	LOCAP	38 - 66	12.34 - 13.0	11.12 - 12.0

$\alpha_T = 0.00126$ per °F air core LOCAP

$\alpha_T = 0.00106$ per °F waterproof LOCAP

The value of T can be estimated on the basis of measured air temperature. The equalizer selected for a given cable pair should be the one that best centers the adjusted measured loss range for the pair into the equalizers loss range. For use with loss measurements, the loss of the IBO for LOCAP installations is 8.2 dB \pm 0.1 dB at 3.15 MHz.

E. Powering Span

2.12 The powering span of a T2 line consists of one or two loops, each powered by its own power unit. Two possible powering arrangements are shown in Fig. 4 and 5. Table E lists the various codes of power units and their characteristics. The 37-type units require +130 volt battery and codes are provided for return to ground, -48 volts, and -130 volts. The 38-type units require a -48 volt input. The units designated Mfr Disc in Table E have been replaced by improved designs. The 37E, F, G, and H replace the 37A1, B1, C1, and D1, respectively. The 38E and F replace the 38A1 and B1, respectively, and the 45B replaces the 45A1. The improved units can be used in place of their counterparts in existing T2 bays.

2.13 The STB (J98717A, B, or C) and the IPS bays [J98717D, E, F, G, or R (Mfr Disc) or J98717S, T, U, W, or Y] must be ordered with list numbers that correspond to the type of power unit selected for the MO or the IPS. STBs ordered with lists providing wiring for the new codes of power units cannot make use of the original codes. The J98717P MTB is available only for operation from -48 volt battery and requires use of a 38A or 38E power unit.

2.14 The original power unit codes provided for use in the STB (37B1, 37D1, and 38B1) powered the STB regenerators in series with the regenerators located outside the office. Thus, the STB regenerators consumed a maximum of 26 volts of the assured output voltage. The improved codes for use in the STB (37F, 37H, and 38F) provide a separate 160-mA output for powering the office regenerators. Thus, the full amount of the assured output voltage is available for powering the regenerators outside the office with the new units for STBs. The units for use in IPS power bays (37E, 37G, and 38E) and in the MTBs (38E)

power one bay-mounted regenerator in series with the outside regenerators.

2.15 The power unit supplies a constant loop current of 160 mA. The length of the loop and the number of regenerators in the loop determine the minimum required voltage the power unit must develop. The power unit chosen from Table E should have assured output voltage, V_{PU} , greater than or at least equal to the required voltage.

2.16 The output voltage that is required can be found by using the equation:

$$V_{PU} \geq (13.0 \times N_R) + (V_1 \times L)$$

where

V_{PU} = maximum output voltage required for loop being considered

13.0 = voltage drop across a regenerator

N_R = total number of regenerators in power loop

$$N_R = N_{PP} + 2(N - 1) + N_{LP}$$

where

N_{PP} = number of regenerators in loop at powering point

= 1 at IPS and MTB

= 0 at STB

(= 2 at STB with Mfr Disc codes of power units)

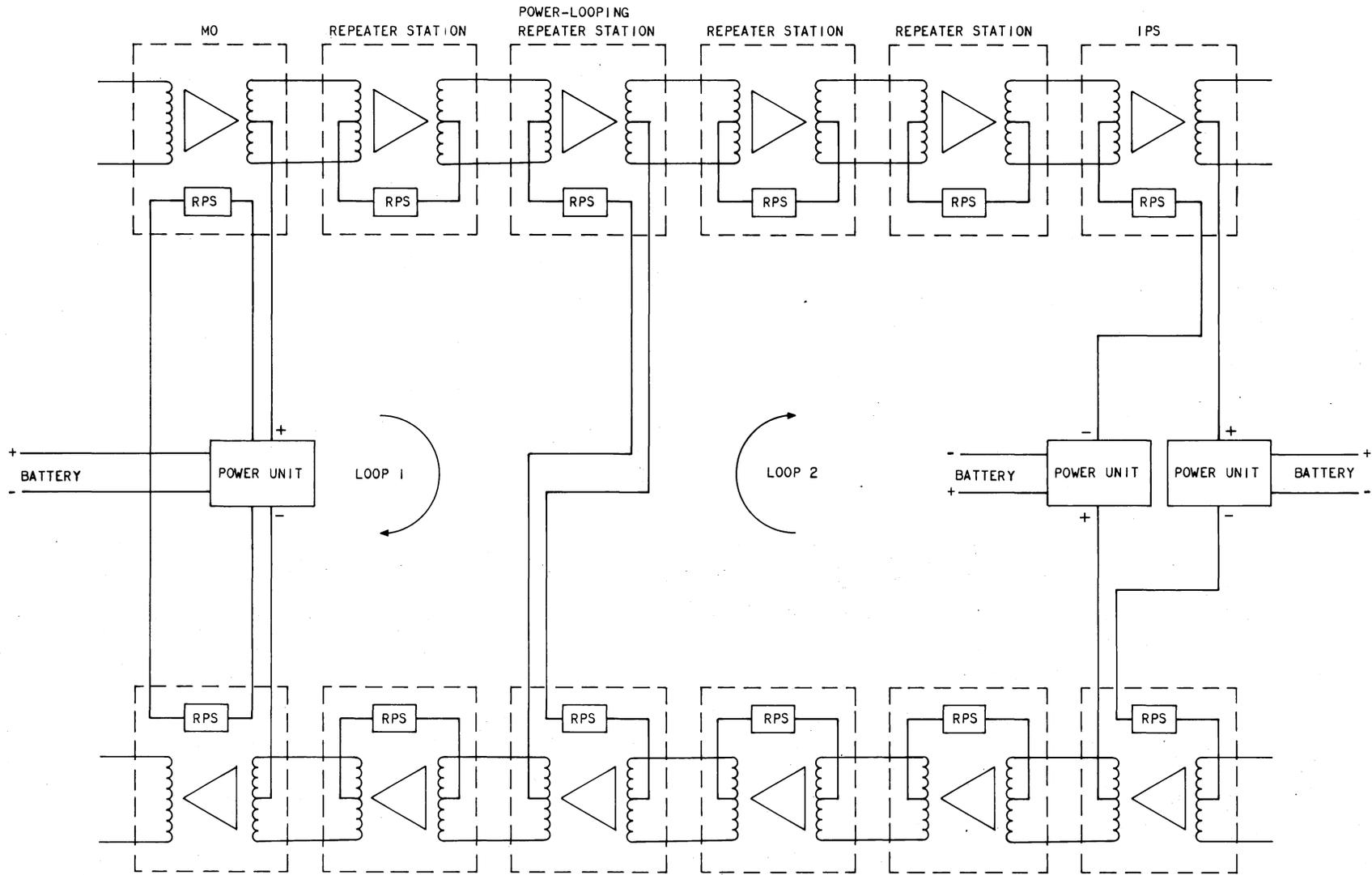
N = number of repeater sections in loop

N_{LP} = number of regenerators in loop at power-looping point

= 1 when looping point is at a repeater station or IPS

= 0 when looping point is at an STB

(= 2 at STB with Mfr Disc codes of power units)



RPS - REGENERATOR POWER SUPPLY
 MO - MAINTENANCE OFFICE
 IPS - INTERMEDIATE POWERING STATION

Fig. 4—Example of a 2-Loop Powering Span for a T2 Line

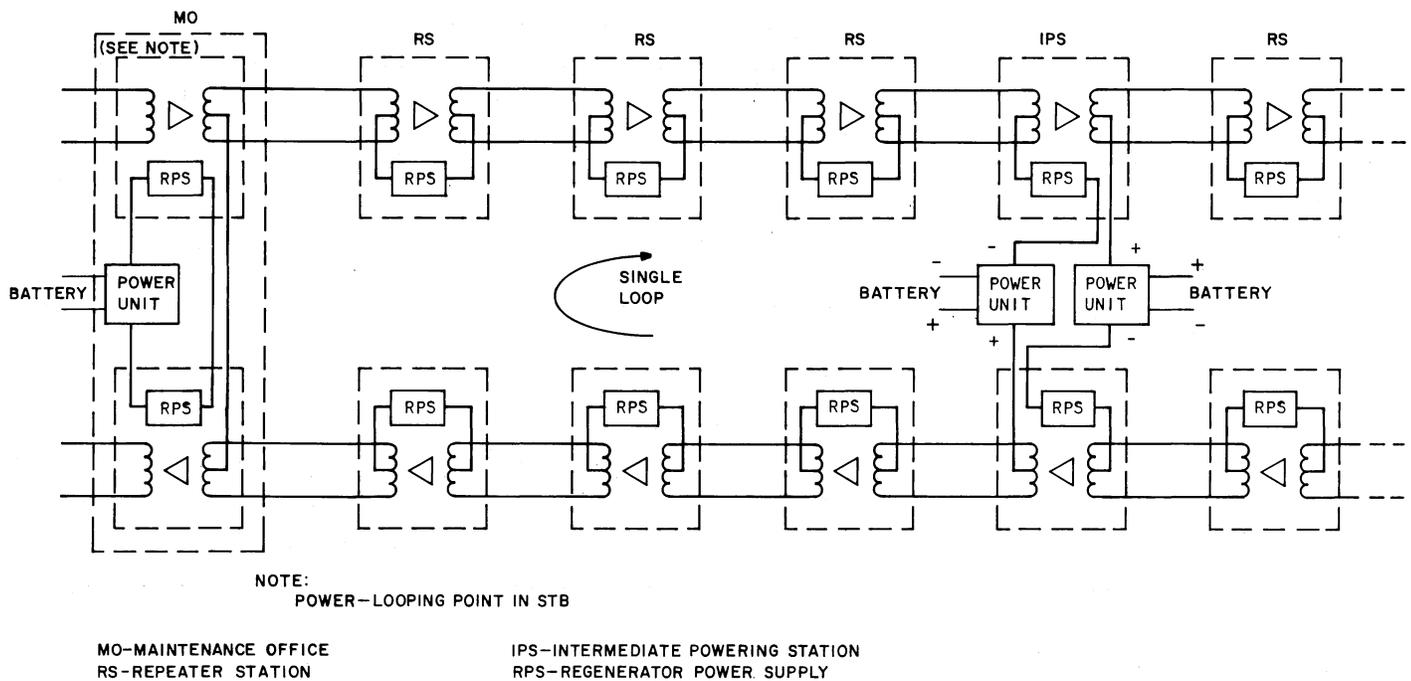


Fig. 5—Example of a One-Loop Powering Span for a T2 Line

V_i = voltage drop/kft for worst-case temperature conditions

= 2.85 volts/kft for underground or buried installations, $+90^\circ\text{F}$

= 3.21 volts/kft for aerial cable installations, $+140^\circ\text{F}$

L = cable length one-way to looping point in kft

= sum of individual repeater section lengths.

This equation is plotted in Fig. 6 and 7 with N_R as a parameter. Figure 6 applies for underground or buried installations; Fig. 7, for aerial cable installations.

2.17 Using the equation in paragraph 2.16 or Fig. 6, it can be determined that with buried or underground air core LOCAP cable, the maximum length to a looping point is 56.8 kilofeet or 10.76 miles. This loop consists of one end repeater section 11.8 kilofeet and three maximum length

repeater sections of 15.0 kilofeet each. The power unit voltage required for this loop is 252.9 volts if seven regenerators are included in the loop (powering from an STB) and 265.9 volts if eight regenerators are in the loop (powering from an IPS or an M12A/T2A bay). A 38F power unit is required in the loop powered from an STB; a 38E, in the IPS-powered loop. For underground or buried waterproof LOCAP, the maximum loop length is 51.8 kilofeet. For other loop lengths, the power unit requirements can be determined from Fig. 6. Examples for using Fig. 6 are given below and in Part 3. The maximum powering span lengths, consisting of two loops for underground or buried installations are 113.6 kilofeet (21.52 miles) for air core LOCAP and 103.6 kilofeet (19.62 miles) for waterproof LOCAP.♦

Example: The loop to be powered includes one buried 11.0-kilofeet section out of an MO and two buried 14.8-kilofeet sections to the power-looping point, with a total of five regenerators ($N_R = 5$) in the loop. To use Fig. 6, enter at the bottom by locating the appropriate length to the looping point (40.6 kilofeet), and then move vertically until the line indicating $N_R = 5$ is intercepted. The

TABLE E
CHARACTERISTICS OF THE VARIOUS CODES OF POWER UNITS

CODE	USED IN	TYPE	ASSURED OUTPUT VOLTAGE*	NOMINAL BATTERY DRAIN (AMPS)		
				+130V	-130V	-48V
37A1 (MFR DISC)	IPS	Regulator with return to: -48V Ground	143 107	0.175 0.175	— —	0.160 —
37B1 (MFR DISC)	STB	Same as 37A1 with 5-volt VMR supply: -48V return Ground return	143 107	0.175 0.175	— —	0.330 0.170
37C1 (MFR DISC)	IPS	Regulator with return to -130V	209	0.175	0.170	—
37D1 (MFR DISC)	STB	Same as 37C1 with 5-volt VMR supply	209	0.175	0.170	0.170
37E	IPS	Regulator with return to: -48V Ground	148 113	0.160 0.160	— —	0.160 —
37F	STB	Same as 37E with 5-volt VMR supply and a supply to power two STB regenerators: -48V return Ground return	148 113	0.160 0.160	— —	0.460 0.300
37G	IPS	Regulator with return to -130V	218	0.160	0.162	—
37H	STB	Same as 37G with 5-volt VMR supply and a supply to power two STB regenerators	218	0.160	0.162	0.300
38A1 (MFR DISC)	IPS	Converter	268	—	—	1.200†

TABLE E (Contd)
CHARACTERISTICS OF THE VARIOUS CODES OF POWER UNITS

CODE	USED IN	TYPE	ASSURED OUTPUT VOLTAGE*	NOMINAL BATTERY DRAIN (AMPS)		
				+130V	-130V	-48V
38B1 (MFR DISC)	STB	Converter with 5-volt VMR supply	268	—	—	1.400†
38E	IPS, M1-2A/T2A	Converter	270	—	—	1.330†
38F	STB	Converter with 5-volt VMR supply and a supply to power two STB regenerators	270	—	—	1.630†
45A1 (MFR DISC)	STB	VMR supply only	—	—	—	0.170
45B	STB	VMR and a supply to power two STB regenerators	—	—	—	0.300

* Based upon the following input voltages of standard central office battery power plant under commercial ac power failure conditions:

Nominal Power Plant Voltage	Minimum Voltage (Emergency Limits)
+130	+125
-130	-110
-48	42.75

If the emergency limits of the specific installations are different, then the assured output voltage for regulators should be changed by the difference. For converters, the maximum assured output voltage applies for a -42.75 to -52.50 volt range of the -48 volt plant.

† Current drains for converters are values for maximum output voltage and are lower for loops requiring less than the maximum output voltage. All current drains are given for nominal battery plant voltages.

total voltage drop in the loop may be determined from the scale at the left. From Table E or by noting the horizontal lines indicating the maximum assured output voltage for a particular power unit, it can be determined that either a 37H or a 38F power unit is required. **The specific power unit depends on the type of battery plant available; eg, the 37H requires +130 and -130 volts and the 38F requires -48 volts.**

2.18 Voltage requirements for aerial installations are given in Fig. 7. Maximum aerial loop lengths are 49.0 kilofeet air core LOCAP and 45.0 kilofeet for waterproof LOCAP.◀

F. Fault Locating Circuit

2.19 The fault locating circuit for the T2 system uses a fault locating output from each

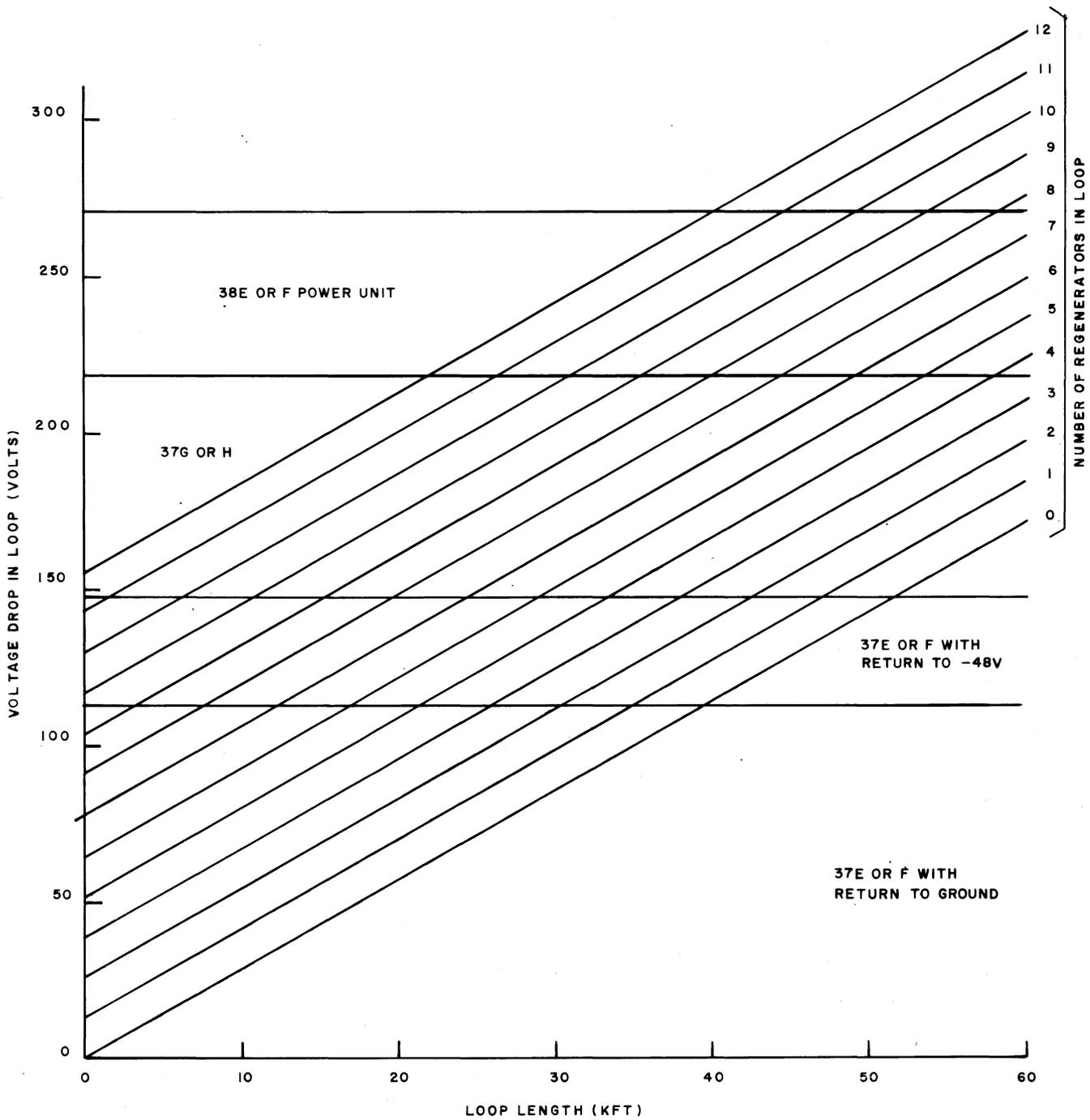


Fig. 6—Graphic Representation of Equation in Paragraph 2.16 for Underground or Buried Installations With Either Air Core or Waterproof LOCAP

regenerator, a maintenance unit, and a 1008-type (Mfr Disc) or a 1108-type fault locating filter associated with a maximum of 96 regenerators (48 in each direction) at each repeater location, and a J98717J fault locating set. The maintenance unit

filters are located in STBs, M12A/T2A bays, intermediate power station repeater bays, and 477-type apparatus cases at repeater stations. The fault locating pair is normally assigned in the B-A cable. In installations where two protection groups

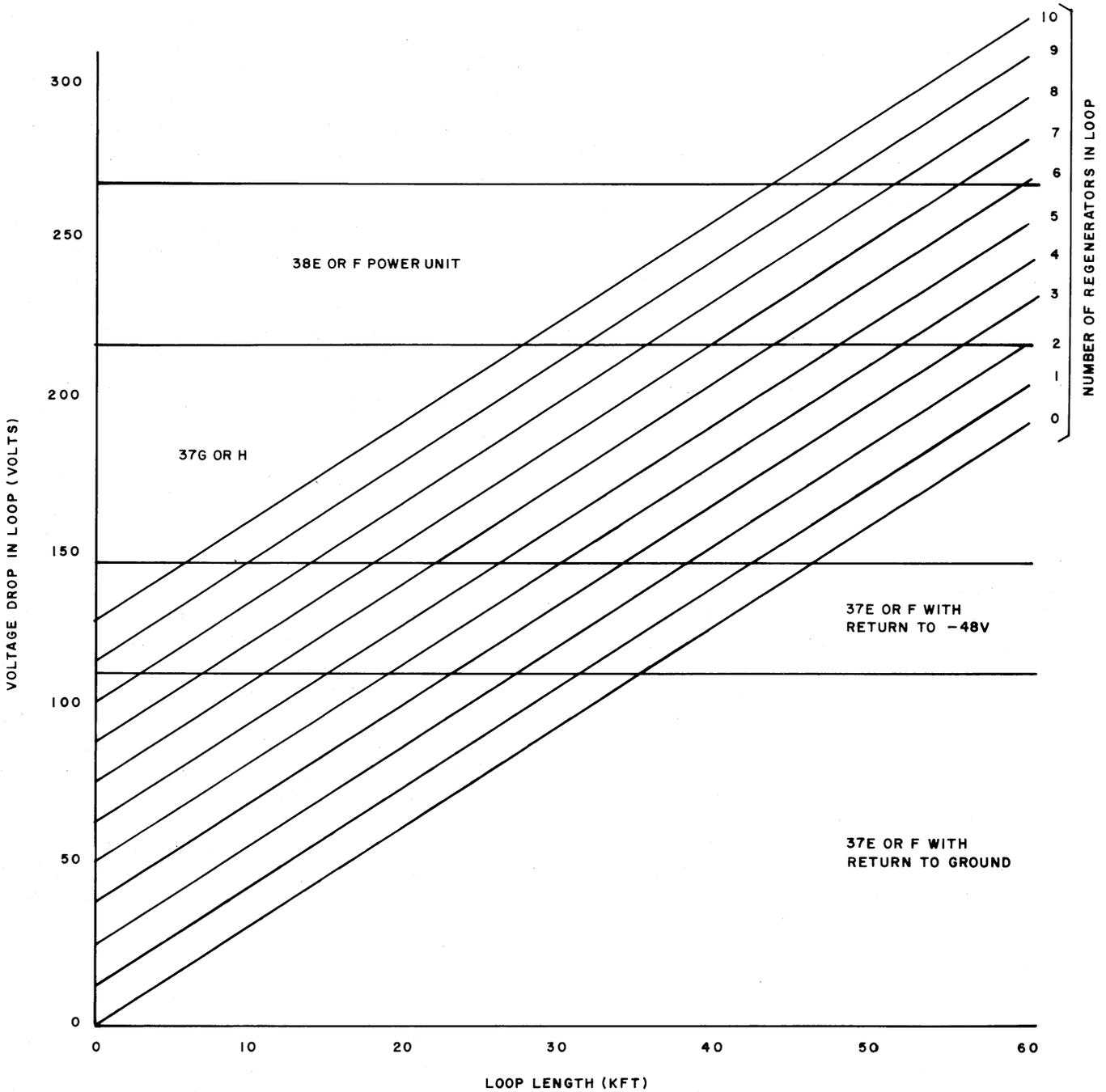


Fig. 7—Graphic Representation of Equation in Paragraph 2.16 for Aerial Installations With Either Air Core or Waterproof LOCAP

split from a common route into separate routes, a second fault locating circuit is required for the common portion of the routes. The second fault locating circuit is normally assigned to a pair in the A-B cable. The 477C1 apparatus case will accommodate two line maintenance plug-in units (LMUs) for the fault locating circuits.

2.20 There are 22 filter codes [1008A (Mfr Disc) or 1108A through N, omitting I; and P through AB, omitting Q, V, X, and Z], each with a different center frequency. The filter codes are assigned in reverse order with the same code (AB) appearing in the STBs at each end of a maintenance span and with duplicate codes assigned from each

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end progressively toward the center of the span. An example of the code assignments in a maintenance span is shown in Fig. 8.

2.21 To permit operation of the fault locating circuit with duplicate filter codes, a tip-ring reversal must be made in the fault locating pair at a point near the center of the maintenance span such that two filters of the same code do not appear in the same half of the span. Maintenance units in the two halves of the span are powered selectively by the near-far (polarity reversing) switch in the fault locating set. A tip-ring reversal also is required at end B and is provided by the B wiring option for the STB at the time the STB is installed. Additional options apply for a COMBO (see SD-99510-03, Note 118). Tip and ring integrity must be maintained for the fault locating pair throughout the maintenance span.

2.22 Fault locating amplifiers are located at IPSs to provide gain on the fault locating pair. These amplifiers are part of the maintenance circuit panel in the repeater bay at the IPS. The fault locating circuit also is repowered at IPSs by an ED-1C906-() regulator and relay unit which is mounted in the maintenance panel of the repeater bay.

2.23 Inductive loading of the fault locating pair is required to obtain uniformity of transmission over the band of fault locating frequencies. Loading is accomplished with 44-mH coils, 88-mH coils, and build-out capacitors. Line maintenance units, ED-1C799-(), G1 (Mfr Disc) or G3 for use at

repeater stations and IPSs, provide two 44-mH coils and terminals for mounting two build-out capacitors for the fault locating pair. In addition, 88-mH coils normally are required between maintenance unit locations. The following requirements apply to the location and use of loading coils and build-out capacitors:

- (a) At repeater stations, both 44-mH coils in the line maintenance unit are to be used.
- (b) Where the distance between two repeater stations is greater than 8100 feet with air core LOCAP or 7450 feet with waterproof LOCAP, an 88-mH coil must be spliced into the fault locating pair midway (± 600 feet) between the repeater stations.
- (c) At maintenance offices (using the ED-1C749-(), G1 OMUs) and IPSs, the 44-mH coils in the office and line maintenance units are to be strapped out.
- (d) Where the distance from a maintenance office or an IPS to the first repeater station out is greater than 4050 feet with air core LOCAP or 3725 feet with waterproof LOCAP, an 88-mH coil must be spliced into the fault locating pair at a point which is one-third of the repeater section length (± 300 feet) out from the maintenance office or IPS.
- (e) If the distance between a repeater station and an adjacent 88-mH coil is less than 6900 feet with air core LOCAP or 6250 feet with

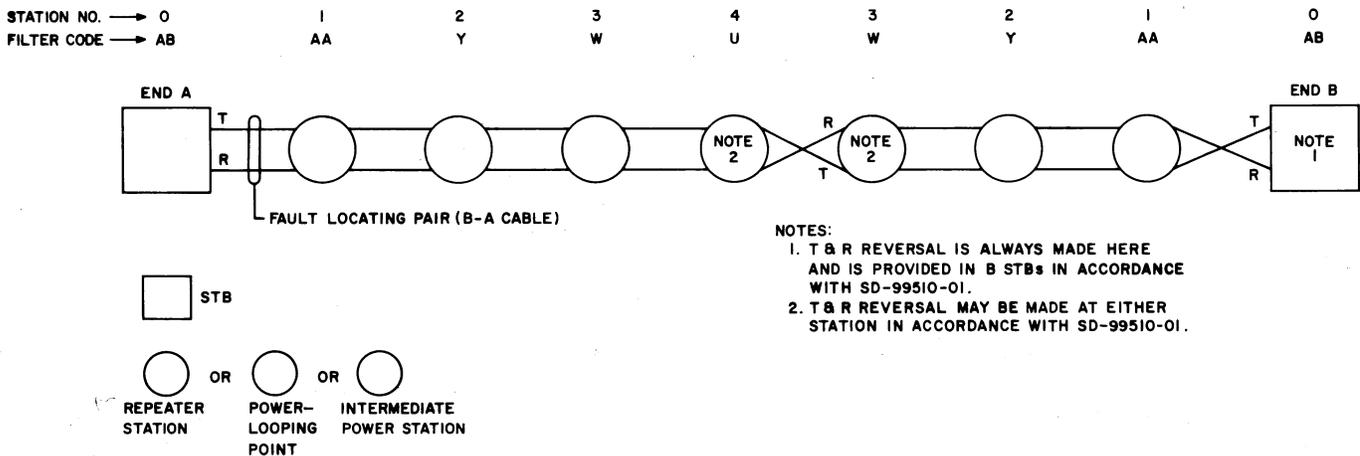


Fig. 8—Typical Assignment of Fault Locating Filters in Maintenance Span

waterproof LOCAP, a build-out capacitor is required at the repeater station to build out this distance to 7500 ±600 feet with air core LOCAP or 6850 ±600 feet with waterproof LOCAP.♦

(f) If the distance from a maintenance office or an IPS to an adjacent 88-mH coil is less than ♦3450 feet with air core LOCAP or 3125 feet with waterproof LOCAP, a build-out capacitor is required in the maintenance unit at the maintenance office [equipped with an ED-1C749-(), G1], or IPS to build out the distance to 3750 ±300 feet with air core LOCAP or 3425 ±300 feet with waterproof LOCAP. ED-1C749-(), G3 OMUs have no provision for mounting build-out capacitors. In that situation, the capacitors can be mounted in the splice case or on the 136A1A-52 protector.♦

(g) The build-out capacitors should be type AT-8080C. ♦The value, C in microfarads, of the capacitor is determined by the equations:

$$C = 0.0074 \times L \text{ for air core LOCAP}$$

$$C = 0.0087 \times L \text{ for waterproof LOCAP}♦$$

where L is the length in kilofeet required to build out the pair to the required length.

2.24 One fault locating circuit can be assigned to serve either one protection group (24 T2 lines) or two protection groups (48 T2 lines). The first arrangement is required for 27-pair cable routes and for 52- and 104-pair cable routes that branch into multiple 27-pair cable routes. The second arrangement can be used for economy when two protection groups extend between the same offices. For each fault locating line implemented, ♦one ED-1C799-(), G3♦ line maintenance unit is required at each repeater station, one equipped J98717H maintenance circuit pack is required at each IPS, and one ED-1C749-(), G3 office maintenance unit is required at each MO. When one fault locating line is assigned to two protection groups, the two STBs serving the two groups must be located side by side to permit sharing of the office maintenance unit provided in the first bay equipped. Alternatively, three adjacent 7-foot bays provide the same capability.

2.25 An ♦ED-1C997-()♦ fault locating drop control unit is available for use at COMBOs and at

IPSs where T2 lines are to be dropped for connection to M12As. This control unit enables access to the fault locating line at the intermediate offices for local use and provides continuity through the office for fault locating from the remote ends of the maintenance span.

G. Order Wire

2.26 A 2-wire order circuit, which is essentially the same as that used for T1, is provided as shown in the T2 digital line application schematic. ♦An auxiliary pair in the LOCAP cable must be assigned for the order circuit.♦ Loading of this pair is required and is the same as that described in paragraph 2.23, with loading coils being provided by voice frequency auxiliary filter units [AFU-VF, ED-1C914-(), G3]. The voice frequency auxiliary filter unit provides continuity for the circuit through a repeater station, filtering for the T2 frequencies, and loading coils for use as needed in the loading plan. It is available for installation in the 477-type apparatus case. The order wire is normally powered at each powering point. Provision must be made at each IPS and MO to connect to the DDD network (see Fig. 9).

2.27 Signaling range for the order wire is limited to 12 miles. To accommodate powering spans of a maximum of ♦21.52♦ miles, a capacitor is inserted at the half-way points and the order-wire circuit is powered from both ends of the span. Auxiliary filter units (VF) that plug into the 477-type apparatus cases have provision for mounting blocking capacitors for this purpose (see Fig. 9). The 477-type apparatus case also provides for installation of an order-wire tap (separately ordered) which allows access for a handset without opening the apparatus case.

2.28 Alternatively, a 4-wire order circuit can be implemented by using two auxiliary pairs in the LOCAP cables. The pairs assigned for this purpose (one in each cable) should be loaded with 88-mH coils as described in paragraph 2.23. At repeater stations, the 4-wire order wire is served by both sides of an AFU-VF. The MO and IPS equipment for the circuit should be engineered in accordance with Section 801-026-155 (J99340) using 44V4 repeaters. A 100C communications set is required for use at repeater stations, and access to the 447B1 apparatus case is provided by the 100B1-4 cable terminal. The 4-wire order circuit

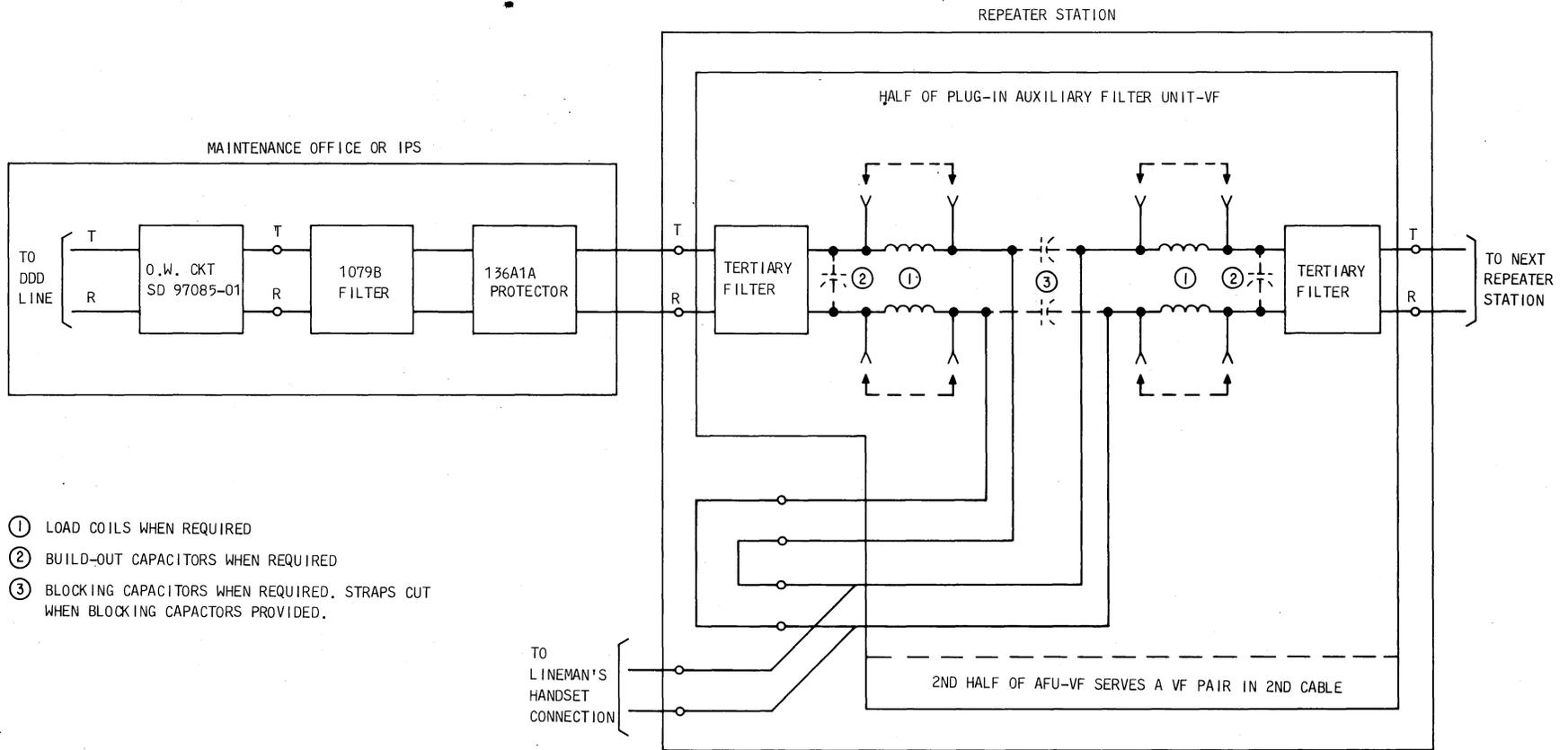


Fig. 9—Typical Order-Wire Arrangement (2-Wire)

is a complete circuit and does not require connection to the DDD network.

2.29 On routes that branch to separate offices at one end, separate 2-wire order circuits can be provided for the branch routes. Where the general purpose 4-wire order circuit is implemented, the capability of branching at an intermediate office is included.

H. Protection Switching System

2.30 The facility for protection switching is provided as an integral part of the T2 system. The protection switching equipment for one protection group is provided by optional plug-in units which are mounted in the STBs at the ends of maintenance spans. This equipment provides protection by switching in a protection line for any of the remaining 23 lines terminating in the bay. Protection is provided for each direction of transmission independently. The protection switching plug-in units can be installed when the STBs are installed or at any time thereafter.

I. Miscellaneous

2.31 The interface between the STB, repeater bay, or M12A/T2A bay and the outside cable is provided by wall- or bay-mounted 136A1A-52 protectors. The protectors provide primary protection for a 52-pair LOCAP cable. Separate protectors are required for each direction of transmission and for each route entering an office or an IPS on different cables. An aluminum cover provides shielding and eliminates the need for fuse cable when transitions are made between underground and aerial sections.

2.32 The protectors are equipped with 52-pair, bonded, ALVYN-sheathed, LOCAP cable stubs for splicing directly to the outside cable. ALVYN-sheathed, 27-pair, LOCAP cable connects the protectors to STBs or intermediate repeater bays (IRBs).

2.33 One auxiliary pair in each LOCAP cable may be assigned for gas pressure monitoring. Monitoring can be accomplished by either pressure contactors or transducers, depending upon the system selected by the operating company. The contactors or transducers can be mounted within the 477-type apparatus case and connected by tubing to the cable splice cases. An ED-1C914-(),

G1 auxiliary filter unit is required for installation in the 477-type case. This unit provides filtering of T2 frequencies to minimize crosstalk and provides dc continuity through a repeater station. When transducers are used, tip-ring identification must be maintained in the pairs because operation of the transducer is dependent upon the direction of current flow. Information covering pressure transducer systems and contactor-type systems is contained in Sections 637-080-100 and 637-210-100, respectively.

2.34 At MOs and IPSs, access to or through connection of the auxiliary pairs is provided by 1079B filter units which mount on the 136A1A-52 protectors as indicated in the T2 digital line application schematic.

2.35 Alarm provisions in STBs include major and minor bay lamp indications of individual alarm sources, with arrangements to provide major or minor indications to central office alarm systems. Optional arrangements are provided to remote alarm and status indications via an E2 or similar system. Remote operation via the E2 system of certain switching, lock-in, and lockout features, provided with the protection switching circuit, may be provided for STBs.

2.36 Alarm provisions for IPS bays are limited to fuse alarms, and there are no special provisions for remoting other alarm and status indications from IPSs. However, within the capabilities of the plug-ins accepted by the 477-type apparatus case, pairs in the LOCAP cables can be assigned for alarm remoting.

2.37 Test equipment designed especially for use on T2 lines is comprised of four portable units: two intended for central office use and two for general line application. The two central offices sets are the J98717J fault locating set (FLS) and the J98717M regenerator test set (RTS). The line sets are the J98717K T2 pair measuring set (PMS) and the J98717L bipolar violation detector (BVD). Information on these sets can be found in Sections 103-496-100, 103-497-100, 103-498-100, and 103-495-100, respectively; and in Section 801-523-151.

2.38 Atmospheric environmental requirements for equipment space as given in Section 760-555-151 are applicable for MOs and IPSs.

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J. Combined T2 and T1/OS Operation

2.39 T1/OS lines can be implemented on T2 outside plant facilities constructed after 1976 and which employ the 473A3, 473B3, and 477C1 (or later) codes of apparatus cases.

2.40 A 7A T1 regenerator is available which fits the slots of the 473A3 and 473B3 apparatus cases. These apparatus cases contain two fault locating collector busses. One is for the T2 fault locating signal and connection to it is made when a T2 regenerator is inserted into a slot. The other is for the T1/OS fault locating signal and the 7A T1 regenerator connects to it.

2.41 The fault locating collectors are carried to the 477C1 maintenance apparatus case using the green-white pair in the 7-pair maintenance stubs. The T2 fault locating signal appears on the green wire and the T1/OS fault locating signal appears on the white wire. The return for both is on the braided shield for this pair.

2.42 The 477C1 apparatus case provides positions for two line maintenance units (LMU). When T1/OS lines are to be equipped, one of the positions (normally LMU2) must be assigned to T1/OS and equipped with an ED-1C799-(), G4 LMU and either 1114() or 1115() T1/OS fault locating filters. The other position is assigned to T2 and equipped as described in paragraph 3.07.

2.43 The interface between the T2 lines and the T1/OS lines occurs at the 136 A1A-52 protectors at MOs and IPSs. The telephone company must designate which protector positions are to be assigned to T1/OS lines and to the T1/OS fault locating circuit. These positions must be connected to the T1/OS J98728 STM using ABAM cables which are separate from the T2 office cables.

2.44 It is recommended that the protector position assignments be such that the T1/OS regenerators will be located in slots starting from the top and proceeding downward in the 473-type apparatus cases.

2.45 The 236N T1 office repeater is required to implement T1/OS lines on LOCAP cable. It is compatible with the T1/OS STM and matches the LOCAP cable impedance. It can be used to supply a regulated 80 ± 4 mA to the T1/OS powering loop or it can be used as a power looping repeater.

2.46 The 7A regenerator provides automatic equalization over a range of cable loss from 7.5 to 35 dB at 772 kHz. The 236N office repeater operates over a range of cable loss from 0 to 27 dB at 772 kHz.

2.47 The maximum permissible losses of the 7A and 236N are compatible with the maximum T2 repeater section lengths given in Table B. However, because of the 7.5-dB minimum loss limit of the 7A, the minimum repeater section length permissible when T1/OS lines are to be equipped on LOCAP cable is 5000 feet for sections not adjacent to an MO or IPS.

2.48 The office battery voltage required to power the T1/OS lines is determined by the equivalent resistance of the powering loop. Table F shows the equivalent resistances of facilities and regenerators as used in the power loop. The power-looping point is established by the T2 powering requirements, and the T2 and T1/OS looping points must coincide.

2.49 The following tabulation specifies the loop resistance ranges from the powering point to the looping point for each battery option:

0 to 400 ohms, 48 volts
0 to 1350 ohms, 130 volts
660 to 1875 ohms, 178 volts (-48, +130)
1640 to 2720 ohms, 260 volts (+130, -130)

2.50 The standard T1/OS maintenance features as described in Section 801-523-156 can be implemented.

2.51 The T1/OS fault locating circuit should be loaded as described in paragraph 2.23 for T2. Fault locating filter code assignments are covered in Section 855-351-200.♦

3. OUTSIDE PLANT CONSIDERATIONS

3.01 As previously stated in paragraph 1.04, the transmission medium for the T2 system is 22-gauge, paired, LOCAP cable, which is available in 27-, 52-, and 104-pair sizes ♦and in air core and waterproof designs. The air core design is provided with an ARPAP sheath and the waterproof design has an ASP sheath. Both designs are available with an additional UM sheath.♦ The UM sheath is recommended for protection against gophers and against abrasion in rocky terrain. The air core

→ TABLE F ←

T1/OS EQUIVALENT RESISTANCES

CABLE TYPE	REGENERATOR TYPE	CONDITION OF USE	OHMS EQUIVALENT RESISTANCE
	7A	ALL	140
	236N	Regulator, fed in series with line	90
	236N	Regulator powered separately	0
	236N	Loop power, repeater in series with loop	100
	236N	Loop power, repeater powered separately	10
Buried Cable		At 90° F	17.8 per Kft.
Aerial Cable		At 140° F	20.1 per Kft.

cables are also available with a LEPETH sheath covered by light wire armor or jacketed light wire armor for water crossings. The waterproof cables are available with either light wire armor over an ASP-UM sheath or jacketed light wire armor over an ASP sheath for applications where extra protection is needed. For dimensions and electrical characteristics of LOCAP cable, consult Table A. Because of the important need for reliability and permanency of this facility, only below-ground installations should be considered when feasible. Though an aerial installation is technically possible, it should only be used where a below-ground installation is not feasible.

3.02 For underground or buried installations, the cables should be placed at a depth that gives adequate protection against exposure due to dig-up or soil erosion. Also, the depth must be sufficient to constrain temperature extremes to within the +20°F and +90°F design limits to use the maximum repeater section and powering span lengths for underground or buried cable given in paragraphs 2.04 and 2.17.

3.03 Only dedicated, two-cable operation is permissible. The two directions of transmission must be in separate cable sheaths. Any LOCAP cable pairs not used for T2 lines, T1/OS lines, or their associated maintenance circuits must not be used for any other purpose. Unused pairs should be bunched together and grounded to the cable shield at each splice case at each manhole. Cable pairs must not be spliced directly through a station so as to bypass the apparatus cases, bays, or filter units. Air core cables should be maintained under gas pressure with monitoring devices at each regenerator location. With waterproof LOCAP, the apparatus cases are maintained under static pressure and should be monitored. A pressure plug is required in each air core cable at the central office vault. Central office grounding of the LOCAP cable should be in accordance with Section 638-300-011.

3.04 It is permissible to place two LOCAP cables (dual operation) in the same underground conduit or trench. Field trials indicate that two 52-pair LOCAP cables can be pulled into a 3-1/2 inch round or square duct that is in good alignment

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and free of silt (such as new conduit). The minimum recommended manhole size to be provided at all regenerator locations is 6 feet wide, 12 feet long, and 7 feet high, giving consideration to ample working space as well as to the ultimate regenerator housing requirements. Existing manholes may be used as splicing manholes in the duct portion. Use of the new auxiliary manholes (38Y), dedicated to T2 repeaters and splicing, is recommended on existing duct runs. Additional information can be found in Section 640-530-230.

3.05 For uniformity of documentation, the functions of the LOCAP cable pairs have been assigned as shown in Table G. ♦Only those pairs designated as T2 quality are suitable for T2 transmission.♦ Where branch routes are to be formed, it may be necessary to use spare T2 pairs for implementation of auxiliary circuits. ♦The assignments given in Table G are also used in SD-99510-03 and in Sections 640-530-230 and 640-010-005.♦

3.06 Two rectangular 473-type apparatus cases approximately 36 inches long, 12 inches wide, and 13 inches deep are required for 24 lines (one case for each direction of transmission). The 473A2 apparatus case is shown in Fig. 10. Also, one ♦477C1♦ apparatus case for maintenance circuitry approximately 12 inches in diameter and 11 inches high (Fig. 11) is required at each regenerator site for ♦up to 48 T2 lines. The 473A3 apparatus case is used at nonpower-looping manholes. It is equipped with two 27-pair LOCAP cable stubs (one input and one output) and with an ARPAP stub containing seven individually shielded pairs for connection to the 477C1 apparatus case. The 473B3 apparatus case is the same as the 473A3 except that it is equipped with a fourth stub, a 25-pair, 22-gauge, PIC cable with a LEPETH sheath, for use at power-looping manholes. Splicing instructions are contained in Section 640-530-230.

3.07 The plug-in units accommodated by the 477C1 apparatus case are:

- (a) Two ED-1C799-() LMUs, which are used to equip T2 or T1/OS fault locating circuits. The G3 LMU is required for a T2 fault locating circuit and accepts the 1108() T2 fault locating filter. The G4 LMU is required to implement a T1/OS fault locating circuit and accepts either the 1114() or the 1115() fault locating filter.

- (b) Three ED-1C914-() auxiliary filter units which are used as required to implement 2- or 4-wire VF circuits for order wire and alarm remoting purposes, and dc circuits for pressure monitoring. The G3 auxiliary filter unit contains loading coils for VF circuits; the G1 unit is for dc circuits and contains no loading coils.

Refer to Section 801-523-151 for detailed ordering information.

3.08 Earlier codes of the regenerator apparatus case (473A2 and B2) did not have the capability for static pressurization or of accepting the T1/OS regenerator and have been rated Mfr Disc.

3.09 Earlier codes of the maintenance apparatus case (477B1), now rated Mfr Disc, accepted only one LMU and two auxiliary filter units.♦

3.10 Where manhole mounting is not feasible, the apparatus cases should be housed in a suitable structure, such as a small masonry or prefabricated concrete building. It is recommended that regenerators not be placed in an exposed environment or in a building of low protective quality. On new routes, both public and private right-of-way should be considered for either buried or underground construction. Evaluation of the accessibility, reliability, and cost of each should be weighed carefully. Where use of public right-of-way is being considered, the likelihood of road widening and improvements requiring subsequent relocation or the subjection of the installation to hazards should be fully evaluated.

3.11 ♦When excessive carrier group alarms due to lightning surges are experienced on channel banks associated with existing T2 facilities, the problem can be mitigated by grounding the idle pairs in the 473-type apparatus cases and in the repeater bays and STBs. To facilitate this operation, an 8A clip and an 823A insertion and removal tool are available (see Section 640-530-230). Justification for implementing such grounds depends upon the experience of the individual operating company. Typically, the need should arise most frequently in areas having much thunderstorm activity and high earth resistivity. As pairs are utilized for added T2 lines, the pairs are mutually protective as shielding, and the removal of clips for adding T2 lines should be balanced by this mutuality. Before resorting to the use of clips, the integrity of the bonding of the cable shield should be assured

→ TABLE G ←

STANDARD ASSIGNMENT OF LOCAP CABLE PAIRS

PROTECTOR		PROTECTOR TERMINAL NUMBER		CABLE PAIR NUMBER						REPEATER STATIONS		FUNCTIONS					
				27-PAIR CABLE		52-PAIR CABLE		104-PAIR CABLE		473 CASE NO.	477 CASE NO.						
AB	BA	AB	BA	AB	BA	AB	BA	AB	BA	AB	BA						
1	1	1 - 24	1 - 24	1 - 24	1 - 24	1 - 24	1 - 24	1 - 24	1 - 24	1	1	1	T2 Pairs				
		25 - 48	25 - 48			25 - 48	25 - 48	25 - 48	25 - 48	2	2		T2 Pairs				
		49	49			49	49	97	97	2	2		Spare T2 Pairs or Aux. CKT 3				
			50				25		50		99			1	T2 FL CKT 1		
		50				25		50		99			1 or 2		T1/OS FL CKT or T2 FL CKT 2		
		51	51			26	26	51	51	100	100		1	1	Auxiliary CKT 1		
		52	52	27	27	52	52	101	101	1	1	Auxiliary CKT 2					
2	2	1 - 24	1 - 24					49 - 72	49 - 72	3	3	2	T2 Pairs				
		25 - 48	25 - 48					73 - 96	73 - 96	4	4		T2 Pairs				
		49	49					98	98	4	4		Spare T2 Pairs or Aux. CKT 6				
			50								102			3	3	T2 FL CKT 3	
		50								102			102		3 or 4		T1/OS FL CKT or T2 FL CKT 4
		51	51							103	103		103	103			Auxiliary CKT 4
		52	52			104	104	104	104			Auxiliary CKT 5					

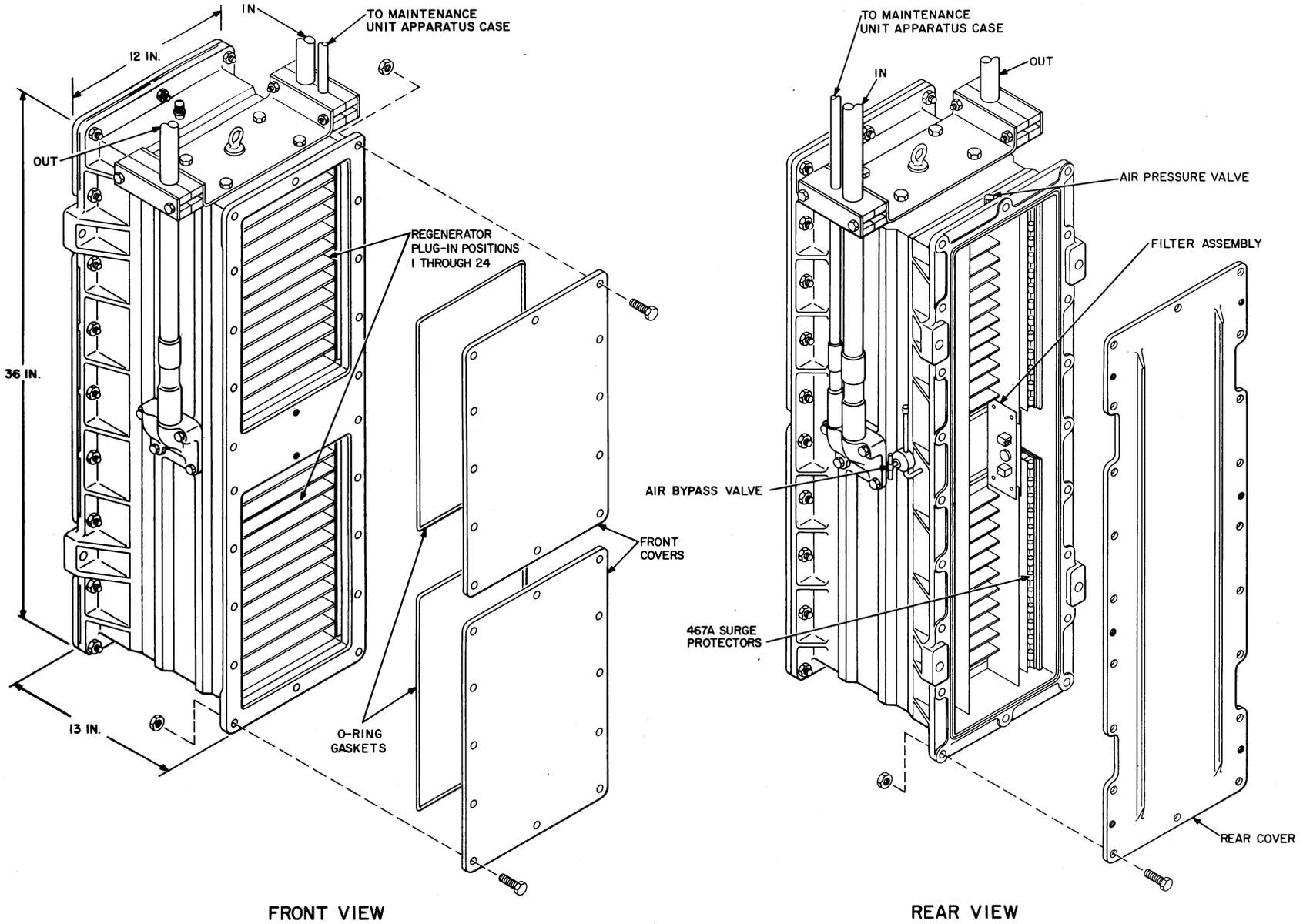


Fig. 10—473-A2 Apparatus Case

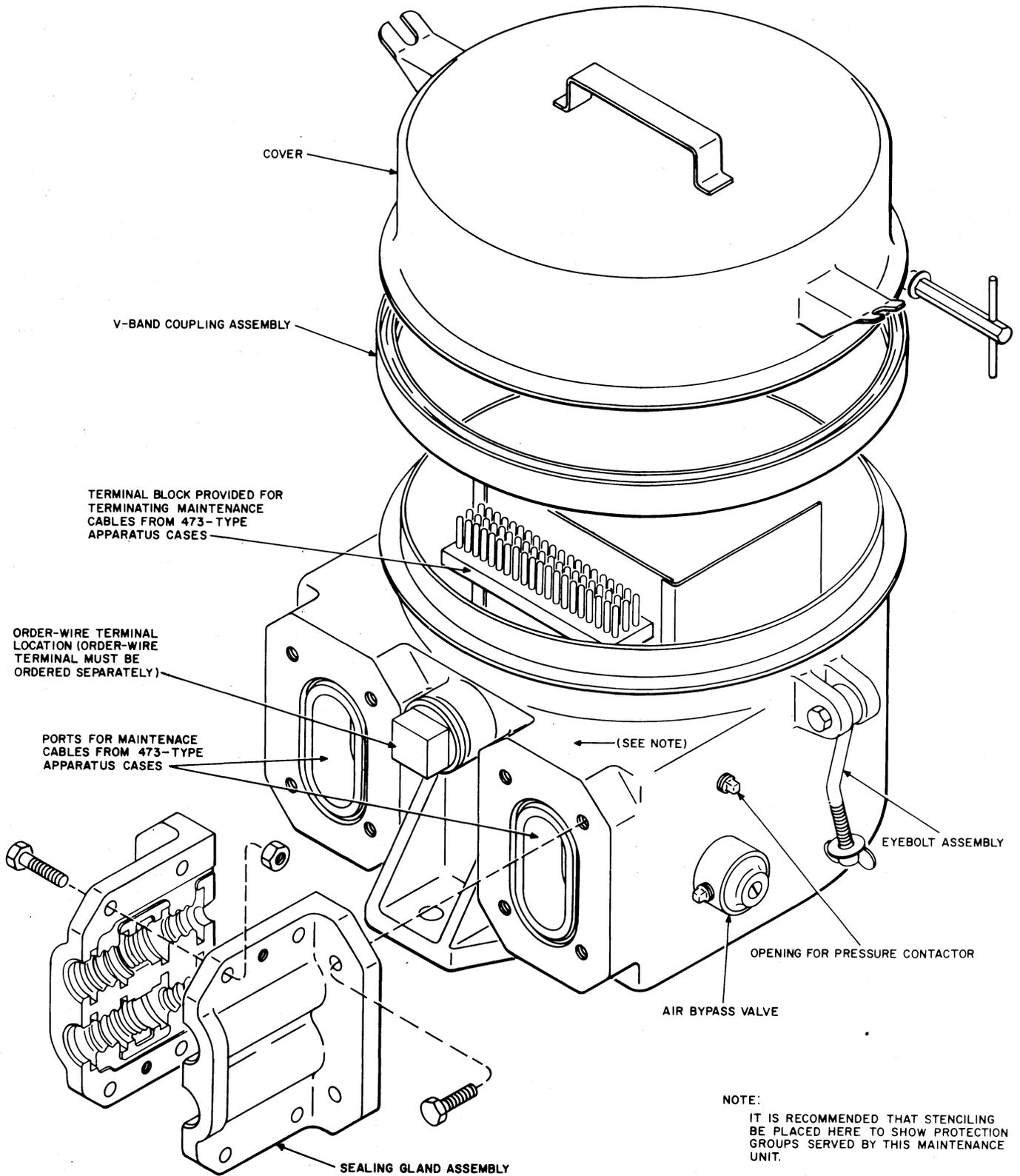


Fig. 11—477-Type Apparatus Case

at all splices. Good shield bonding is of primary importance in minimizing the effects of lightning and power line faults.⚡

4. POWER LINE INDUCTION CONSIDERATIONS

4.01 Installation of the T2 line in proximity to commercial power lines can result in 60-Hz induction disturbance. The principal cause of inductive interference is unbalanced or ground-return currents in the power system, which cause 60-Hz currents to flow in the T2 line powering loops. Induced currents flow in phase along both pairs of the powering simplex rather than around the powering loop. The induced currents return through ground; the paths to ground are through the line power supply and through pair-to-sheath capacitance along the cable. Under power line fault conditions, the induced currents may reach ground through operation of gas tube or carbon protectors. Under normal operating conditions, a 60-Hz longitudinal current of 15 milliamperes RMS can be tolerated on each T2 cable pair. During power line fault conditions, much higher currents may be experienced. These surges usually interrupt digital transmission for the duration of the fault surge. In extreme situations, fault surges can cause permanent damage to regenerators.

A. Normal Operation of Power Line

4.02 Under normal operating conditions, 60-Hz induction should be considered separately for each powering loop. A T2 powering loop extends from the powering point, which is a maintenance office or an IPS, to the first power-looping point, which is usually located at a repeater station but can also be in an office.

4.03 Where power lines are located at roughly constant distance from the T2 route, Fig. 12 can be used in estimating the minimum distance permissible between the LOCAP cables and the power line. It is assumed that the power line parallels the T2 line for the entire powering loop, which has been assumed to be 50 kilofeet in length. The earth resistivity is needed to use the chart; 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.

4.04 In Fig. 12, 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 before Fig. 12 is used. Shield factors have been calculated for twin LOCAP cables, assuming perfect bonding and negligible-resistance grounds at offices. For 100 meter-ohms earth resistivity, the shield factors are: 27-pair cables, 0.68; 52-pair cables, 0.66; and 104-pair cables, 0.56. For 10 meter-ohms earth resistivity, add 0.03 to these values; for 1,000 meter-ohms, subtract 0.04. These factors increase rapidly if poor grounds or bonds are present; a single faulty bond can eliminate all shielding effects.

4.05 Figure 12 applies to powering loops of 50 kilofeet in length. For other lengths, multiply the power line unbalanced current by

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

where L is the actual length in kilofeet before using the figure.

4.06 Figure 12 applies where the power line exposure exists for the entire powering loop. If the exposure is only partial, before using Fig. 12, multiply the unbalanced current by the fraction of the powering loop exposed.

4.07 In addition, if the exposure is not centered about the midpoint of the powering loop, before using Fig. 12, multiply the unbalanced current by the correction factor $2[1 - (C/L)]$. In this expression, L is the powering loop length as in paragraph 4.05, and C is the distance from the powering office to the center of the exposure.

4.08 The correction factors of paragraphs 4.04, 4.05, and 4.06 are used successively, each changing the effective unbalanced current; after applying all factors, Fig. 12 is used.

4.09 If the minimum permissible separation determined from Fig. 12 is impractical, induction can be reduced by installing additional shield conductors. Section 873-800-178 should be used to compute the shield factor. Alternately, induction can be reduced by reducing the powering loop length.

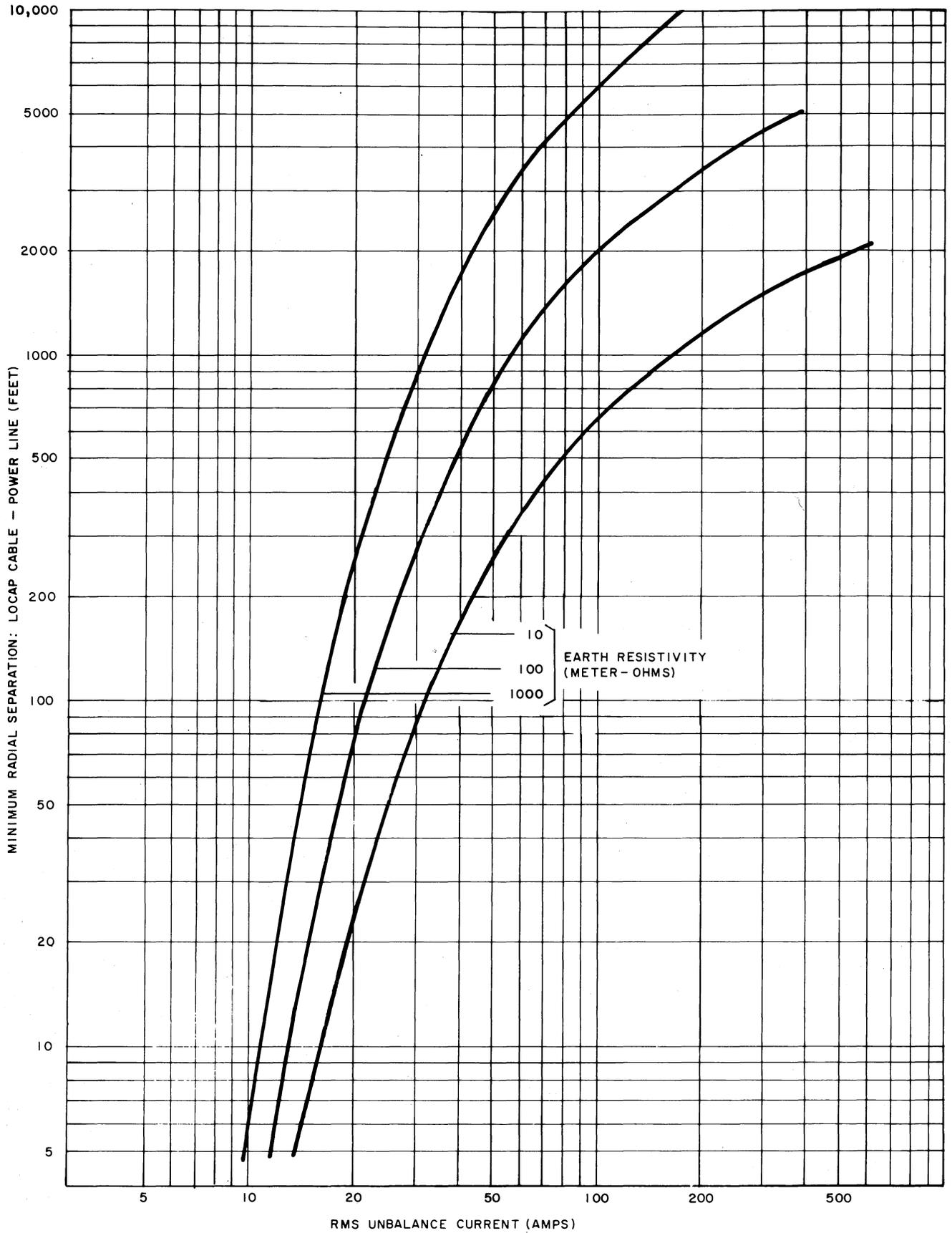


Fig. 12—LOCAP Cable—Power Line Separation—Normal Operation of Utility Power Line

B. Power Line Fault Conditions

4.10 Part 4A is used to ensure T2 line performance under continuous-duty power line induction. Many times, power line unbalanced current under fault conditions exceeds the prescribed levels. Transmission may be interrupted during faults, which generally last from 100 to 500 milliseconds depending upon the utility's equipment. Where high fault currents occur, it may be necessary to consider the possibility of damage to T2 regenerators from the surges.

4.11 Tests show that permanent damage to regenerators does not occur if induced longitudinal currents on the T2 cable pair are less than the following:

- (a) 11 amperes RMS for fault durations of 0.25 second or less
- (b) 7 amperes RMS for fault durations of 0.5 second
- (c) 5.5 amperes RMS for fault durations of 1 second.

4.12 High induced fault current can occur only when the gas tube or carbon protectors at each end of a regenerator section fire during a fault. Consequently, fault induction can be considered for each regenerator section independently. Protectors are provided at repeater stations for both the input and the output of each regenerator. During surge conditions, either of the protectors associated with a regenerator may operate. Since the protector that operates may be on the opposite side of the regenerator from the disturbed cable section, the entire induced current may flow through the regenerator. A worst-case assumption is that the voltage drop across an operated protector is small. Therefore, the maximum current induced in a regenerator can be determined by dividing the total voltage induced in a regenerator section by the total resistance of the cable pair (tip and ring in parallel) in the section.

4.13 Where the separation between the LOCAP cables and the power line is constant through a regenerator section or constant throughout the exposed portion of a regenerator section, Fig. 13 can be used to determine the minimum safe separation, as follows.

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

4.15 The effective power line unbalanced current should be reduced by multiplying by the shield factor, as in paragraph 4.04.

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

4.17 To use Fig. 13, multiply the effective unbalanced power line current by the following factors:

- (a) 2.0 if the surge is present for 1 second
- (b) 1.6 if the surge is present for 0.5 second
- (c) 1.0 if the surge is present for 0.25 second or less.

Apply the resulting current in Fig. 13 to determine the minimum safe separation, using the curve for the appropriate earth resistivity.

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

5. EXAMPLE OF LAYOUT PROCEDURE

5.01 The following is a simple example of a T2 transmission system laid out in accordance with the engineering procedures in Part 2. The route chosen for the example is shown along the upper line in Fig. 14. The system is to operate between offices I and IV, and service between offices II and IV is also required. Service at office III is not required; however, it can serve as an IPS. Part of the route is underground (ducts) and part is buried. All offices are equipped with -48 volt and ± 130 volt power plants. Plant extension forecasts indicate that over the growth interval for the system, 32 T2 lines will be required between offices I and IV and 12 will be required between offices II and IV. Thus, 52-pair cables will be required to implement the two protection groups that will be needed. ♦Air core LOCAP has been selected for the route.♦

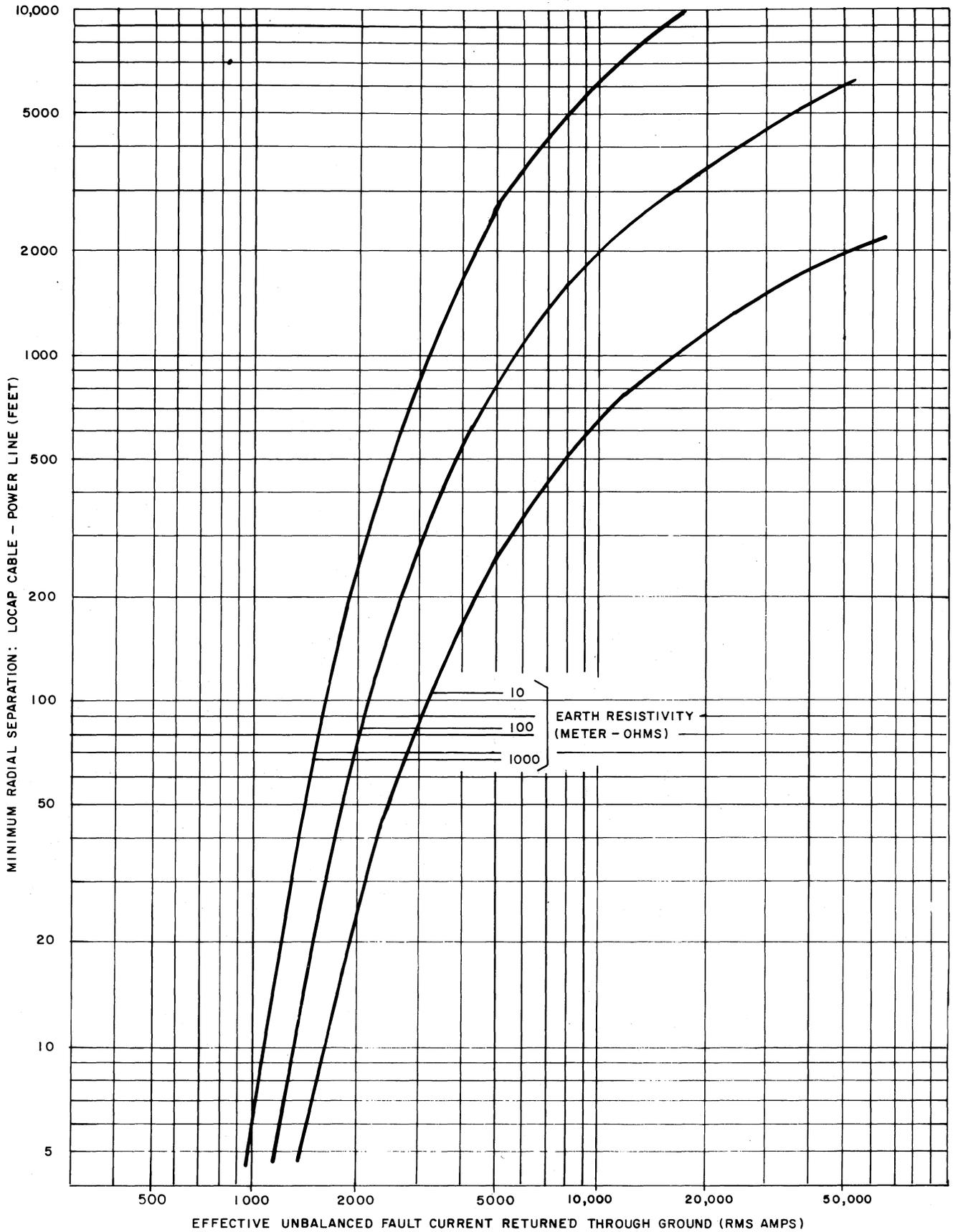


Fig. 13—LOCAP Cable—Power Line Separation—Utility Power Line Fault Condition

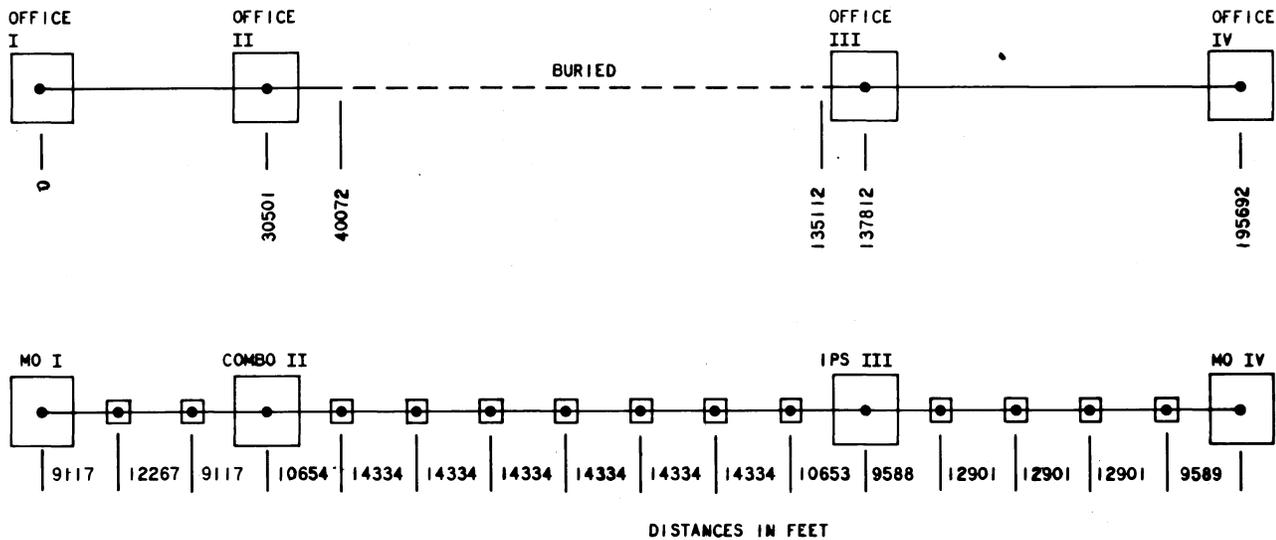


Fig. 14—Example of T2 Route Layout

5.02 The first item to be considered is the manner in which service access is to be provided at office II. Since the forecast indicates that 12 T2 lines will be required ultimately between offices II and IV, the use of STBs with protection switching equipment will be needed for protection of these lines. Neither the use of the M12A/T2A terminal bay nor the establishment of office II as an IPS with an interface with M12A muldems for service is a recommended arrangement for more than six T2 lines. However, only one protection group need be terminated by means of STBs at office II. When the second group is implemented, it can be carried through office II by means of IPS bays. Thus, office II will become a COMBO when the second group is implemented. Offices I and IV are MOs and require STBs for both protection groups when implemented. This arrangement provides flexibility for growth so that the proportioning of I-to-IV lines and of II-to-IV lines can vary substantially from the forecast.

5.03 The spans from office I to II and from office II to IV become maintenance spans for the first protection group implemented. The maintenance span for the second protection group will extend from office I to IV.

I-to-II Powering Spans

5.04 Temperature extremes for the cable are estimated to be +38°F and +72°F, so

maximum repeater section lengths and powering span calculations for buried or underground cable are used. As shown in Fig. 14, the I-to-II span is very short (30,501 feet) and requires only three repeater sections (two can cover only 23,600 feet and three can cover a maximum of 38,600 feet). Since in this example no information is given about obstacles to the location of manholes, the repeater spacings shown in Fig. 14 are chosen arbitrarily.

5.05 Since the I-to-II maintenance span for the first protection group is shorter than the maximum powering loop length, only one powering span is needed and it can be powered from either office I or II. To determine the actual powering requirements, find the total voltage drop in such a loop by means of the equation of paragraph 2.16:

$$V_{PU} \geq (13.0 \times N_R) + (V_1 \times L)$$

where, for the first protection group

$$\begin{aligned} N_R &= N_{PP} + 2(N - 1) + N_{LP} \\ &= 0 + 2(3 - 1) + 0 \\ &= 4 \end{aligned}$$

$$V_1 = 2.85 \text{ volts/kft}$$

and

$$L = 30.501 \text{ kft.}$$

Thus,

$$\begin{aligned} V_{PU} &\geq (13.0 \times 4) + (2.85 \times 30.501) \\ &\geq 138.9 \text{ volts.} \end{aligned}$$

The same result can be obtained from Fig. 6. From Table E or from Fig. 6, it can be seen that there is an option of three different power supplies: 38F, 37H, or 37F. The choice depends first on available battery plant (see Table E for battery plant requirements for each unit) in the office and second on economics (37 types are less expensive than 38 types). Since in this example each office has ± 130 volt battery plants in addition to -48 volts, the 37F is the appropriate power unit for this loop. If office I is chosen as the powering point for this loop, 45B power units are needed in the STB in office II. All of the above applies to only the first protection group, ie, the first set of 24 lines, which terminates in an STB in office II.

5.06 For the second protection group, for which office II is an IPS, the following applies. The voltage requirements are:

$$\begin{aligned} V_{PU} &\geq (13.0 \times N_R) + (V_1 \times L) \\ &\geq (13.0 \times 5) + (2.85 \times 30.501) \\ &\geq 151.9 \text{ volts.} \end{aligned}$$

Five instead of four regenerators are powered in a loop for the second set of 24 lines since the regenerator in the IPS regenerator bay at office II is not powered locally as in an STB.

5.07 If office II is the powering point for these loops, 38E or 37G power units must be used in the powering bay at office II and 45B power units must be used in the STB at office I. If office I is used as the powering point, 38F or 37H power units can be used in the STB at office I. One advantage of powering from office I is that a separate powering bay is not required in office II; ie, one of the configuration options [see Section 801-523-151 (J98717)] for an IPS is one 24-line repeater bay housing 48 regenerators for 24 lines and 24 power units to power loops on one side of the office only (B side in this example). Thus, the I-to-II portion of the T2 route is shown in Fig. 15.

II-to-IV Span

5.08 The length of the II-to-IV span is 165,191 feet, or 31.3 miles. The maximum powering loop length is $\blacktriangleleft 10.76 \blacktriangleright$ miles. Thus, a minimum of three powering loops or two powering spans are needed. If three powering loops are used, the amount of leeway (ie, shortened repeater spacings due to physical constraints) is only $\blacktriangleleft (3 \times 10.76) - 31.3 = 0.98 \text{ miles.} \blacktriangleright$ Thus, it is very unlikely that three powering loops are enough and this section will be designed for four powering loops. For either arrangement, only one IPS is required between offices II and IV. A desirable location for this intermediate powering site is office III. The distance from office II to III is 107,311 feet, or 20.3 miles. The repeater sections adjacent to office II and to office III can cover $\blacktriangleleft 23,800 \text{ feet.} \blacktriangleright$ The number of remaining sections is $(107,311 - 23,800)/15000 = 5.57$, ie, six. \blacktriangleleft Again, there is no information given concerning obstacles to the location of repeater stations. There is some leeway as to their location, however, since not all sections are stretched to their maximum length. \blacktriangleleft Arbitrary distribution of the section lengths results in the repeater section lengths as shown in Fig. 14. \blacktriangleleft

II-to-III Powering Span

5.09 The powering unit requirements for the B side loops out of office II are as follows. For the first set of 24 T2 lines:

$$\begin{aligned} V_{PU} &\geq (13 \times N_R) + (2.85 \times L) \\ V_{PU} &\geq (13 \times 7) + (2.85 \times 53.654) \\ V_{PU} &\geq 243.9 \text{ volts.} \end{aligned}$$

38F power units are required in the STB in office II. For the second set of 24 T2 lines:

$$\begin{aligned} V_{PU} &\geq (13 \times 8) + (2.85 \times 53.654) \\ V_{PU} &\geq 256.9 \text{ volts.} \end{aligned}$$

Thus, 38E power units are required in the IPS regenerator/power unit bay. All A side loops out of office III also have a 256.9-volt drop, since in this simplified example these loops are identical to the B side loops out of office II for the second protection group. This powering span is summarized in Fig. 16.

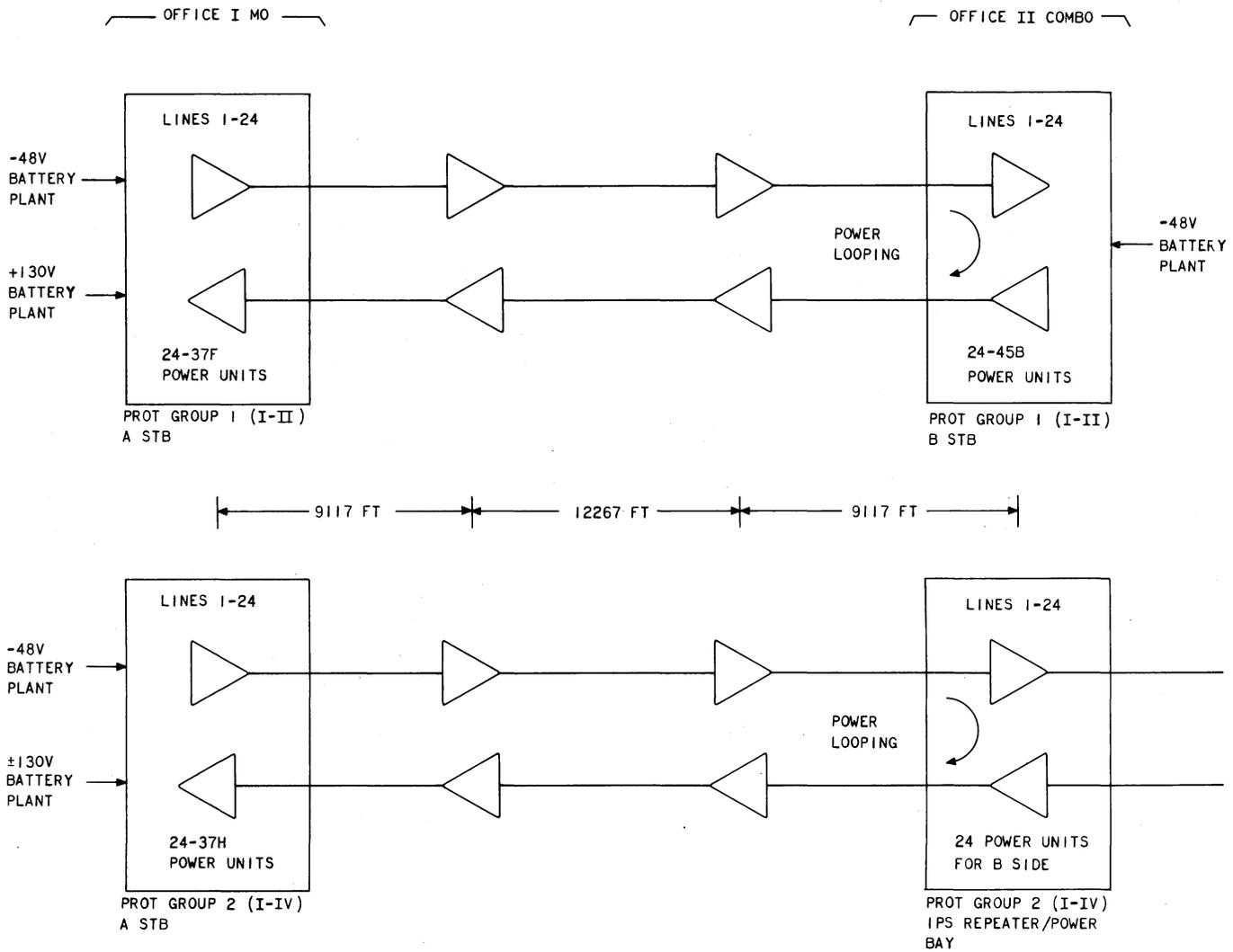


Fig. 15—I-to-II Powering Span

III-to-IV Powering Span

5.10 The distance between offices III and IV is 57,800 feet. The two end sections can cover 23,800 feet. Since $(57.8 - 23.8)/15 = 2.27$, three more sections for a total of five repeater sections are required.

5.11 The powering requirements for the two loops between offices III and IV depend largely on where the power-looping manhole is located. In this particular situation, any one of the four manholes between offices III and IV can be a power-looping manhole. Table H shows the power units that can be used in offices III and IV as a function of the power-looping manhole locations.

Figure 17 summarizes the III-to-IV powering span where the power-looping manhole is the second manhole on the A side of office IV.

5.12 Bays are ordered for specific power units [see Section 801-523-151 (J98717)] and different types of power units are not interchangeable in a bay.

5.13 Figure 18 shows the equalizer codes required. The second repeater section on the B side of office I is an example of a section length which falls in the overlap region between two codes. In this case, the section length is 12,267 feet and either the 933ACLC or 933ADLC could be used. However, the 933ADLC is the better choice since

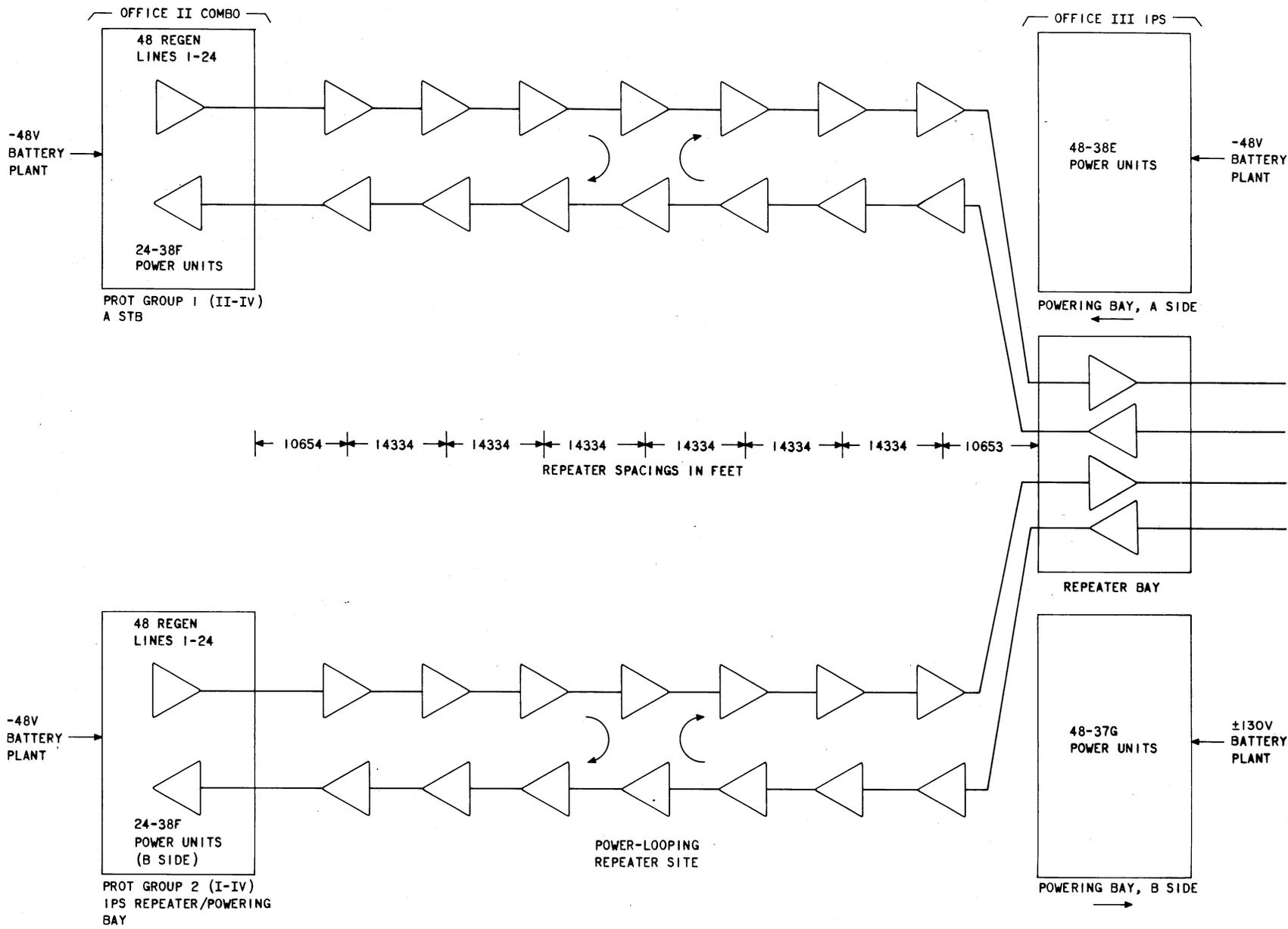


Fig. 16—II-to-III Powering Span

TABLE H

POWER UNITS FOR OFFICES III AND IV

LOCATION OF POWER LOOPING MANHOLE	OFFICE III		OFFICE IV	
	POWER UNIT	BATTERY PLANT	POWER UNIT	BATTERY PLANT
1st manhole on B side of office III	37E	+130	37F	-48
2nd manhole on B side of office III	37E	+130, -48	37H	+130, -130, (-48)*
2nd manhole on A side of office IV	37G	+130, -130	37F	+130, (-48)*
1st manhole on A side of office IV	38E	-48	37F	+130, (-48)*

* -48 volt battery is always required at an STB.

the section length, 12,267 feet, is longer than the center point of the overlap region, which is 11,960 feet.♦

5.14 The fault locating line repeater station filter codes and T-R reversals are shown in Fig. 19. Filter codes are assigned in reverse order, working from offices I and IV (since office II is a COMBO) toward the center of the route. A list of filter codes and fault locating line diagrams for all possible layout options are given in ♦the T2 digital line application schematic.♦ In Fig. 19, the zener diode symbol represents the fault locating amplifier power supply. When current flows in the direction opposite to the direction of the diode, the corresponding fault locating amplifier is powered. The object of the tip-ring reversals is to power only one of the two identical filters at a time. An exception to this rule occurs when a COMBO is included in a route. In this situation, there are four AB filters in the system and thus, two amplifiers with the same filter code can be powered. In Fig. 19, if a positive voltage (NEAR position of fault locating test set near-far switch) is applied to the tip in office I, the AB filters in the A STBs in office I and in office II are powered. However, the regenerators for the first protection group connected to the AB filter in the A STB in office II cannot be accessed from office I and thus, no

conflict exists. For the second protection group, fault locating is accomplished from office I or from office IV; and the filter in the repeater bay in office II that serves lines in this group has code W, which is only repeated once in the I-to-IV span. A fault locating drop control unit [ED-1C997-() G1] must be ordered for the repeater bay at office II when it is installed. Also, wiring options for the STBs in a COMBO must be selected in accordance with the T2 digital line application schematic depending upon the location of the COMBO relative to the T-R reversal in the overall span. For the example shown in Fig. 19, the T-R reversal is on the B side of the COMBO in the overall span; thus, B options are applicable for the STBs in the COMBO office.

5.15 The locations of loading coils for the fault locating circuit, determined in accordance with paragraph 2.23, are given in Fig. 20. In this example the same build-out capacitance value, ♦ $C = 0.0074 \mu\text{F}/\text{kft} \times 1.500 \text{ kft} = 0.011 \mu\text{F}$, can be used throughout the route, since by adding 1500 feet♦ to all coil spacings requiring buildouts, the resultant coil spacings fall within the required length of ♦7500 ±600 feet.♦ For simplicity of installation, the order-wire circuit and any other voice-frequency circuits are loaded in the same way.

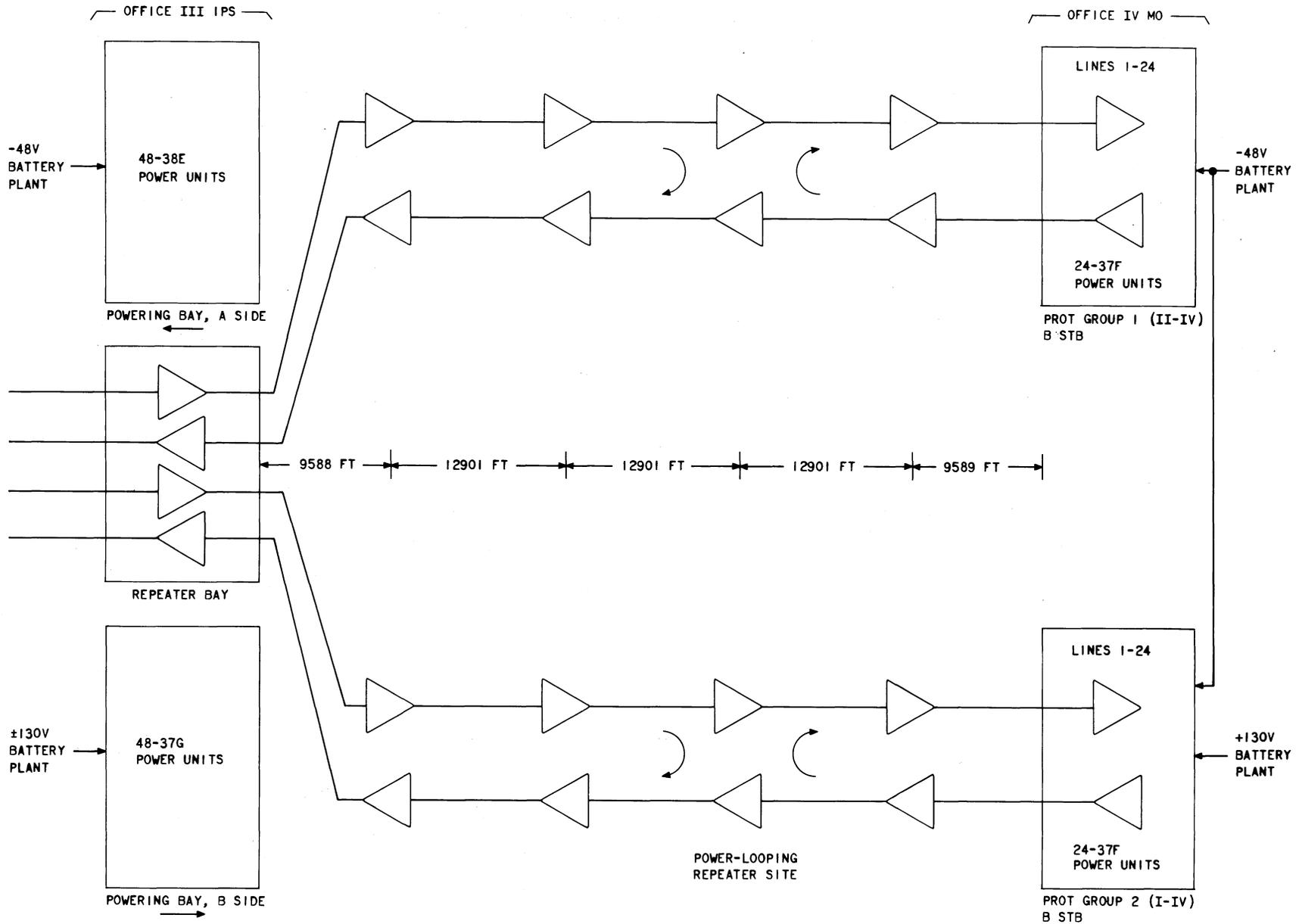


Fig. 17—III-to-IV Powering Span

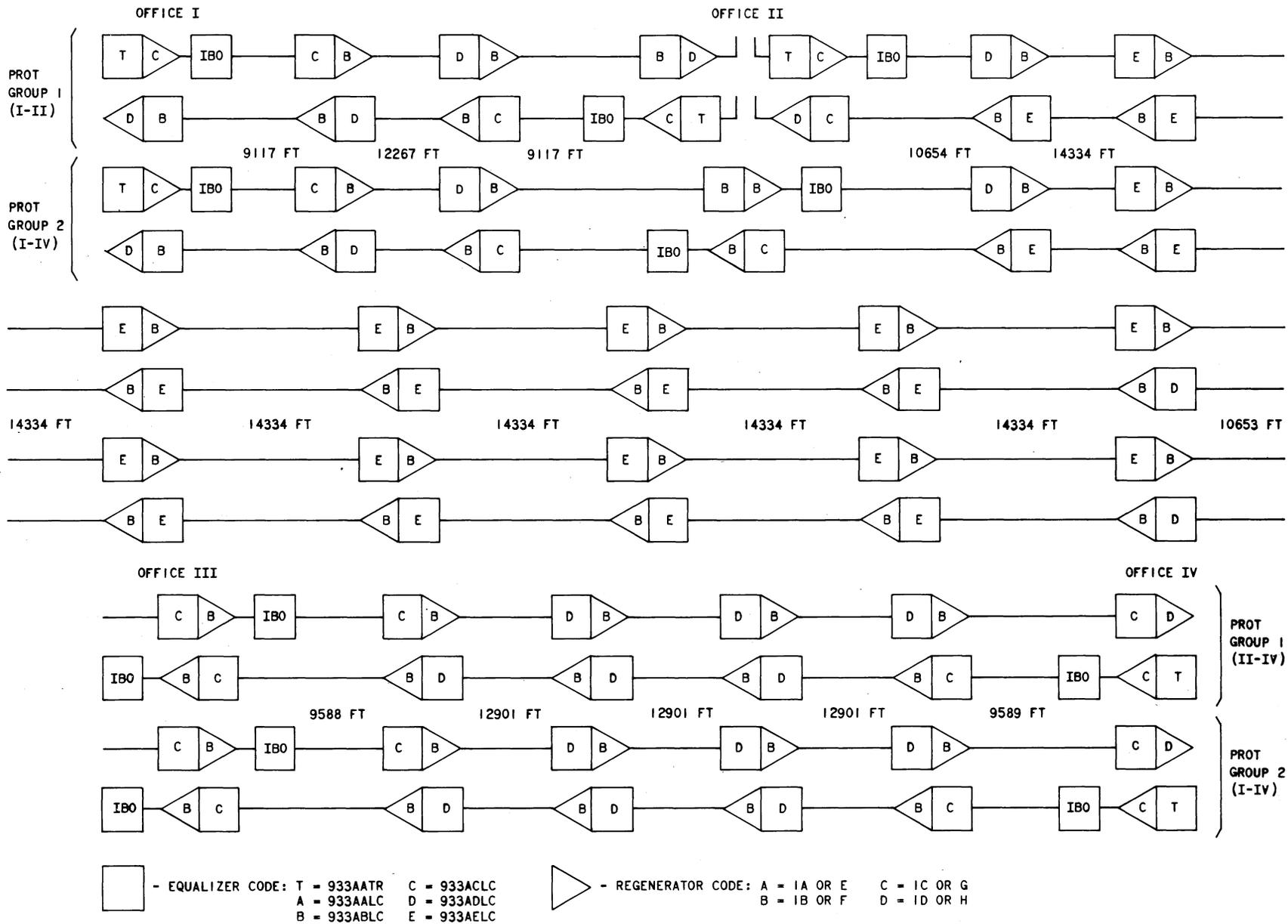


Fig. 18—Equalizer and Regenerator Codes For Example Layout

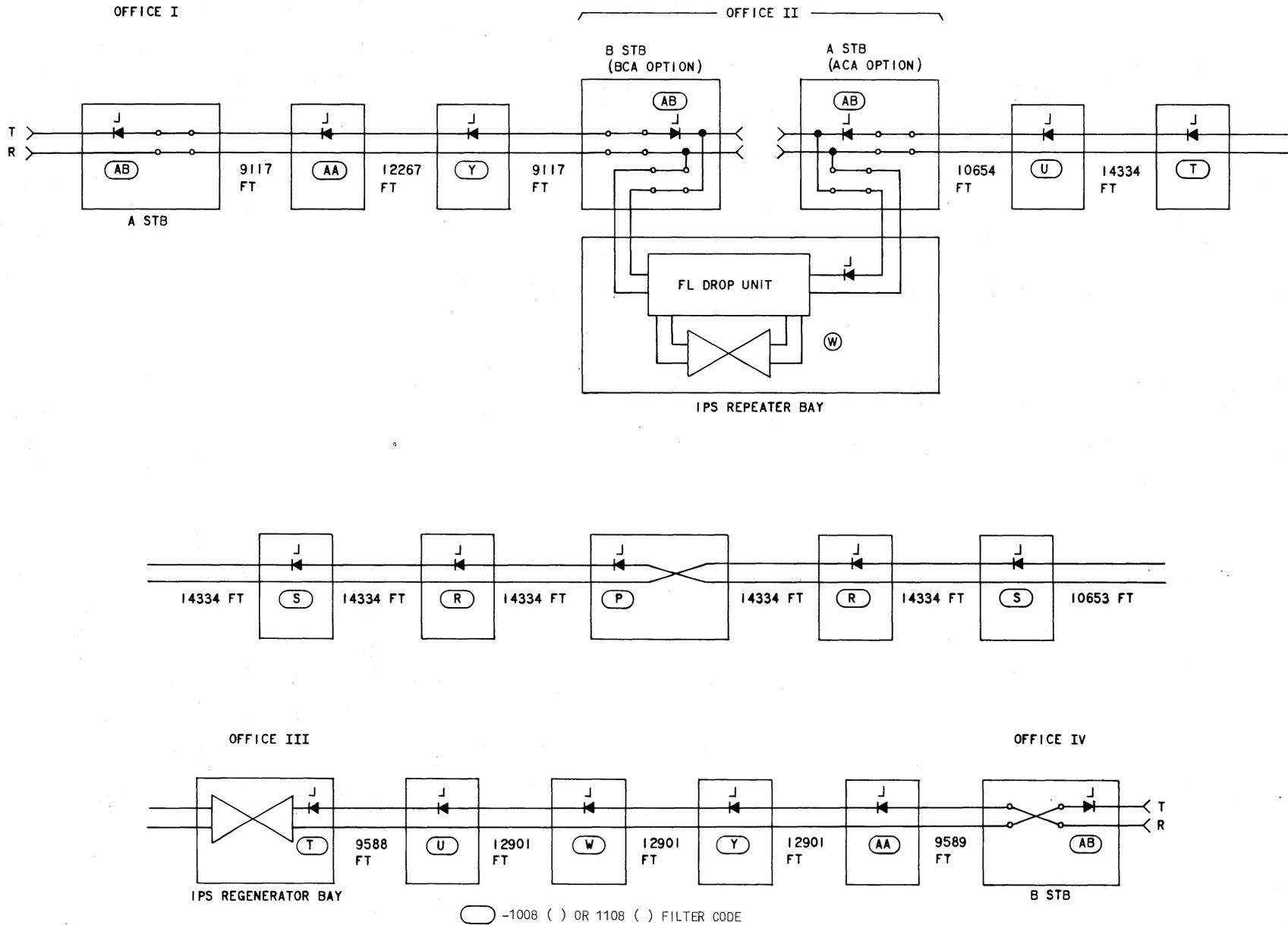


Fig. 19—Fault Locating Line for Example Layout

SECTION 855-352-101

6. REFERENCES

SECTION

SUBJECT

		365-500-104	T2 Line—Power Units—Description
		365-500-107	T2 Digital Line—2-Wire Order Wire Description
103-495-100	17L Bipolar Violation Detector—Description and Operation	365-500-200	T2 Line—Procedure for Equipping Span Terminating Bays, Intermediate Powering Station Bays, and T2A Span Terminating Shelves and Power Shelves
103-496-100	17J Fault Locating Set—Description and Operation		
103-497-100	T2 Line—J98717M Regenerator Test Set—Description, Operation, and Maintenance	365-500-201	T2 Line—Preparation and Installation of Plug-In Units at Repeater Sites
103-498-100	17K Pair Measuring Set—Description and Operation	365-500-300	T2 Line—Protection Switching Circuit—Manual Operations
365-010-110	T1 Outstate (T1/OS) System—General Description	365-500-301	T2 Line—Protection Line Patching (Line Restoration)
365-170-100	D4 Channel Bank—Description	365-500-307	T2 Digital Line—2-Wire Order Wire—Maintenance and Operating Procedures
365-200-160	T1/OS Digital Line Fault Locating System—Description and Operation	365-500-500	T2 Line—Tests and Operations
365-200-170	J98728 Span Terminating Module (STM)—General Description	365-500-501	T2 Line—Line, Line Powering, and Initial Installation—Tests
365-200-410	T1/OS Line and System Maintenance Considerations and Tests	365-500-502	T2 Line—Placing the Line in Service
365-224-600	T1/OS—Turnup Tests	365-500-503	T2 Line—Trouble-Locating Procedures
365-250-110	Lynch B302—Electronic Span Line Switch (T1/OS)◆	365-500-504	T2 Line—Fault Locating Procedures
365-301-101	DSX-2 Patch and Cross-Connect—General Description	365-500-505	T2 Line—Protection Switching Circuit—Operational Tests
365-325-100	T1/OS Order Wire	365-520-501	T2 Digital Line—Pair Measurements at Maintenance Offices and Intermediate Powering Sites
365-500-100	T2 Line—General Description		
365-500-101	T2 Line—Span Terminating Facilities—Description	365-521-501	T2 Line—Regenerator Tests
365-500-102	T2 Line—Intermediate Powering Station—Repeater and Power Supply Bays—Description	365-600-100	Digital Multiplex-Demultiplex Circuit, Type M12, M12A, and M12B—General Description
365-500-103	T2 Line—Regenerator—Description	626-200-122	LOCAP Cable—Cable Sizes and Reel Lengths

626-759-143	T2 System—LOCAP (38 μ F/mile) Cable	801-026-155	J99340 General Purpose 4-Wire—Order Circuit Equipment
636-210-219	136-Type Protectors	801-523-151	T2 Digital Line, Digital Transmission Facilities, System Application Specification and Equipment Design Requirements, Common Systems
637-080-100	Cable Pressure Transducer Systems—Description		
637-210-100	Pressure Monitoring Devices—Superseded Contactors—Description	801-523-156	◆T1/OS Digital Transmission System, Line and Terminating Equipment
638-300-011	Bonding and Grounding, Cable Sheath—General	855-351-200	T1/OS Digital Line, Transmission and Outside Plant Design Procedures
640-010-005	Splicing T Carrier Cables—General	873-800-178	Fundamental Frequency Electromagnetic Shielding of Communication Circuits
640-530-106	473-Type Apparatus Case—Description and Maintenance	873-800-580	Determination of Earth Resistivity by the D-C Method◆
640-530-107	477-Type Apparatus Case—Description		
640-530-215	Installation and Replacement of Repeaters	DRAWING	SUBJECT
640-530-220	T2 Digital Line—Pair Measurements in Repeater Sections	SD-97085-01	T1 Carrier—Order-Wire Circuit
640-530-230	T2 Manhole Layout and Installation	SD-99503-01	Digital Facilities Interconnection Circuit (DSX-2)
760-555-151	Atmospheric Environment for Telephone Equipment Space	SD-99505-01	T2 Digital Line—Span Terminating Circuits
800-020-001	Checking List—Equipment Design Requirements	SD-99510-01	T2 Digital Line Application Schematic
800-600-000	Checking List—General Equipment Requirements	SD-99510-03	◆T2 Digital Line Application Schematic◆
801-000-000	Numerical Index of Equipment Design, Performance Requirements, and Engineering Information	SD-99512-01	T2 Line Protection Switching Circuit
		SD-99513-01	T2 Digital Line—Intermediate Powering Station Circuit

