

**TRANSMISSION DESIGN CONSIDERATIONS  
 AND OBJECTIVES  
 SPECIAL SERVICES CIRCUITS  
 AND PBX SERVICES**

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1.04 While the design considerations outlined in this section will be adequate for most cases, a high degree of engineering judgment will be required for the exceptional situations.

1.05 The increasing numbers and complexity of special services, as well as the emphasis on providing good service, require that adequate provision be made for transmission measurement of the facilities. To assure that the measured values will agree with the design values, the objectives are stated in terms of *Expected Measured Loss* (EML). The EML is determined by adding to the loss of the facility and associated equipment any additional losses involved in the connection to test lines or portable test equipment. A more detailed discussion of EML objectives is given in Part 5 of this section. As in the message network, design losses are specified at 1000 cps.

1.06 The objectives outlined in this section are based on providing universal service between the special facilities and the message network. (See Part 3D for definition of universal service.) In many cases, a universal service connection will encounter more links than are contemplated for the message network. For this reason, the grade of service on universal service calls may not be as good as on the message network alone. This is particularly true when tandem tie trunk networks are connected through PBX central office trunks or FX trunks to the message network.

## 2. DESCRIPTION OF SPECIAL SERVICES CIRCUITS AND PBX SERVICES

### A. Special Services

2.01 *A Foreign Exchange (FX) Line* provides service between a station at a customer's premises and a remote central office other than the central office which normally would serve that customer's location.

2.02 *A Wide Area Telephone Service (WATS) Line* is a customer's line that is used exclusively for outgoing calls to the toll network. WATS lines may terminate either in the same central office that normally serves the customer's location or in a distant central office.

2.03 *An Off-Premise Extension (OPX) Line* connects an extension telephone station to a main station line. The extension telephone set is located at a customer's location which is remote from the main station location. The extension line may be bridged at the main station location but more often the main station line and the extension line will be bridged at the central office.

2.04 *L.D. Lines* provide a direct connection from a telephone station or PBX at a customer's location to a toll switchboard.

2.05 *Secretarial Service* provides telephone answering service when a customer is not available to answer his calls. Lines similar to Off-Premise Extension Lines connect the customer's line to the Secretarial Service location and usually terminate in a Secretarial Service switchboard.

### B. PBX Services

2.06 *A Main PBX* is one which has a directory number and can connect PBX stations to the message network for both incoming and outgoing calls. Tie trunks, FX trunks and WATS trunks may also be terminated at the PBX.

2.07 *A Satellite PBX* does *not* have a directory number and all incoming calls are routed from the main PBX via tie trunks. The satellite PBX may have outgoing C.O. trunks so that outgoing calls may be routed either to the central office which normally serves the satellite PBX location or via the tie trunk and the main PBX to its serving central office. The satellite PBX is usually located in the same exchange area as its main PBX.

2.08 *A Tandem PBX* is one which is used as an intermediate switching point to connect tie trunks to two or more main PBXs.

2.09 *A Tributary PBX* refers to a PBX which has tie trunks to a main or tandem PBX but also has inward and outward central office trunks and its own directory number. Designs associated with Switched Services Tributary PBXs are covered in Section AB23.053.4.

### C. PBX Trunks and Lines

**2.10 PBX — Central Office (C.O.) Trunks** connect the PBX to the central office which normally serves the PBX location. These trunks appear as station lines at the central office equipment.

**2.11 PBX Foreign Exchange (FX) Trunks** are the same as PBX C.O. trunks except that they terminate in a remote central office rather than the one which normally serves the PBX location.

**2.12 PBX WATS Trunks** are similar to WATS lines except that they connect a PBX instead of a telephone set to a WATS central office. These trunks are used exclusively for outgoing calls from the PBX to the toll network.

**2.13 PBX Station Lines** (usually called PBX extensions) connect the telephone stations that are on the same premises as the PBX to the PBX. The station lines can be connected through the PBX to other station lines, PBX tie trunks, central office trunks, and FX or WATS trunks.

**2.14 PBX Off-Premises Station (OPS) Lines** provide the same services as on-premises station lines except that the telephone station equipment is located off the premises of the PBX location.

### D. PBX Tie Trunks

**2.15** A tie trunk is used to interconnect two PBXs. Later in this section the design objectives will be discussed fully. In order to simplify the discussion, tie trunks will be classified into categories as discussed later. Switched Services Network trunks, access lines and tie trunks are covered in Section AB23.053.0 to AB23.053.4 series and will not be discussed in this section.

**2.16 Satellite Tie Trunks** are used to connect a satellite PBX to its main PBX.

**2.17 Non-Tandem Tie Trunks** are used between two main PBXs which do not have tie trunks to other PBXs. These trunks are primarily intended for connection to PBX stations

at both ends but may also be connected to central office trunks, FX trunks and WATS trunks. ***Simultaneous connections to central office trunks, FX trunks or WATS trunks at both ends of any tie trunk connection cannot be expected to provide good transmission.***

**2.18 Tandem Tie Trunks** are used between main PBXs and tandem PBXs which may be connected together in a customer's PBX tie trunk network (not a Switched Services Network).

**2.19** In larger PBX tie trunk networks some tandem tie trunks may be connected to other tie trunks at both ends simultaneously. Tie trunks which may be connected in this manner are referred to as ***Intertandem Tie Trunks.***

## 3. GENERAL DESIGN CONSIDERATIONS

### A. Echo and Stability

**3.01** The provision of good transmission requires a compromise between: (1) the need for sufficiently low loss to provide satisfactorily high received volumes, (2) minimum contrast in received volumes on different calls, and (3) the need for sufficiently high losses to insure adequate performance from the standpoint of talker echo, noise, and near singing.

**3.02** The disturbing effect of echo is dependent on the magnitude of the echo and the time delay between the speech input and arrival of the echo at the talker's receiver. The magnitude is controlled by the round trip losses of the facilities in the overall connection and by the degree of balance or impedance match at each of the principal reflection points. The time delay between input and echo is determined by the round trip absolute delay from the talker to the reflection point and return. The round trip delay is dependent on the type and length of all facilities involved in the connection and the presence of gain and delay equalizers.

**3.03** Studies of the effect of echo indicate that certain minimum losses are required to give satisfactory echo performance. In the lower ranges of round trip delay, the losses of facilities without gain and the losses required to provide

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stability (singing margin) when the gain is used will result in satisfactory echo performance. As the round-trip delay increases, the talker's sensitivity to echo also increases and a higher circuit loss is necessary. The designs to be discussed in this section have been classified into two categories which take into account the requirements for loss, echo protection and stability. Practical use of facilities and economic factors are also considerations. The two categories are:

| CIRCUIT DESIGNATION<br>FOR DESIGN | ROUND TRIP DELAY       |
|-----------------------------------|------------------------|
| Short Haul                        | 6 milliseconds or less |
| Long Haul                         | Over 6 milliseconds    |

**3.04** As mentioned above, a round-trip delay of 6 milliseconds can be permitted before echo becomes a controlling design limitation. Charts A, B, and C have been prepared to simplify round-trip delay computations for a single facility or a combination of facilities. The delays of all facilities used to make up a circuit are added together to determine the overall delay.

**3.05** The charts are based on the velocity of propagation for various facilities except for carrier derived circuits. For carrier, the round-trip delay of the carrier terminal must be taken into account. The delay of the carrier line is added to the carrier terminal delay. Chart B includes the round-trip delay of the carrier terminal and will be used for all carrier systems. This chart is a compromise of the characteristics of various types of carriers and will provide adequate margin against echo. Chart C is included to cover two carrier channels used in tandem. The chart may be used for any combination of carriers. The round-trip delay of some delay equalization arrangements can add as much as 4 milliseconds to the circuit delay. Therefore, this delay must be added to that of the facility to determine the total round-trip delay. Detailed delay information is covered in Sections AB27.401.1 and AB27.401.20.

**3.06** Examples of the use of charts are given below:

- A. Single Facility:** 20 miles 19H88 Toll, 10 miles 24H88

|                         |          |
|-------------------------|----------|
| <u>RTD from Chart A</u> |          |
| 20 miles H88 Toll       | = 3.0 MS |
| 10 miles 24H88          | = 2.0 MS |
| TOTAL RTD               | = 5.0 MS |

- B. Carrier:** 60 miles N carrier;

|                         |          |
|-------------------------|----------|
| <u>RTD from Chart B</u> |          |
| 60 miles CXR            | = 3.4 MS |

- C. Carrier and Cable:** 50 miles N carrier; 15 miles 22H88

|                         |           |
|-------------------------|-----------|
| <u>RTD from Chart A</u> |           |
| 15 miles 22H88          | = 3.0 MS  |
| <u>RTD from Chart B</u> |           |
| 50 miles CXR            | = 3.25 MS |
| TOTAL RTD               | = 6.25 MS |

**B. Design Loss Considerations — Long Haul**

**3.07 Long-Haul Circuits** are those which have round-trip delays exceeding 6 milliseconds.

**3.08** In order to control echo to acceptable levels it is necessary to design long-haul facilities with certain *MINIMUM* losses. The Via Net Loss (VNL) concept, as discussed in detail in Section AB23.025.2 and other Bell System literature, is used to determine the minimum losses for these circuits. This minimum loss will generally be the objective loss for the circuit. Maximum losses are also specified in this section. Designs which result in VNLs which exceed the maximum objective should be reassigned to higher velocity (lower VNLF) facilities. Where this is not possible, echo suppressors must be considered. The design loss objectives for long-haul circuits of all types are discussed later in this section.

**3.09** The VNL of any facility is calculated by using the following formula:

$$VNL = VNLF \times \text{Length} + 0.4 \text{ db} + D$$

**VNLF** — Via Net Loss Factor for particular type of facility in db per mile. (See Table I.)

**Length** — Length of the facility in miles.

**0.4 db** — This factor is added to account for variations in circuit loss due to changes in temperature, the effects of maintenance, and other environmental factors.

**D** — Additional loss (db) which must be designed into the circuit to compensate for the absolute envelope delay contributed by delay equalization devices. The value for "D" may be determined from the following:

$$D(\text{db}) = 0.1X \text{ (Sum of the 1000-cycle absolute envelope round-trip delays in milliseconds of all delay devices in the circuit.)}$$

Note that when a circuit is made up of more than one type of facility the individual (VNL  $\times$  L)s for each type are added together but the 0.4 db is added only once as shown below:

$$\text{VNL} = \text{VNLF}_1 \times L_1 + \text{VNLF}_2 \times L_2 + \text{VNLF}_3 \times L_3 + 0.4 \text{ db} + D$$

**TABLE I**  
**Via Net Loss Factors**  
**for Representative Telephone Facilities**  
**Used in the Bell System**

| FACILITY                          | VNL (db per mile) |        |
|-----------------------------------|-------------------|--------|
|                                   | 2-WIRE            | 4-WIRE |
| 19H88-50 side and phantom         | .03               | .014   |
| 19H44-25 side and phantom         | —                 | .010   |
| 19B88-50 side and phantom         | .04               | —      |
| All Carrier Systems               | —                 | .0015  |
| H88 on Paired Exchange Cable      | .04               | .017   |
| D88 on Paired Exchange Cable      | .04               | .017   |
| NON-LOADED PAIRED EXCHANGE CABLE* | .04               | .017   |

\* VNL for N.L. cable represents a compromise based on facilities with lowest velocity of propagation.

**3.10** "B" factor losses are sometimes specified to be added to all **VNL** circuits terminating in tandem PBXs which do not meet **THROUGH** balance requirements. In cases where the **THROUGH** balance requirements cannot be met, "B" factors as given in Table II may

be applied *temporarily*. It is not intended that "B" factors compensate for poor design, but rather that they serve as a temporary expedient until the deficient balance condition can be corrected.

**TABLE II**

| AVERAGE THROUGH BALANCE (db) | B FACTOR (db) |
|------------------------------|---------------|
| 27 or more                   | 0.            |
| 25                           | 0.1           |
| 23                           | 0.2           |
| 21                           | 0.3           |
| 19                           | 0.5           |
| 17                           | 0.8           |
| 15                           | 1.2           |
| 13                           | 1.7           |

Note that these factors should be applied only after tests have been made and deficient **through balance** conditions cannot be corrected immediately. In any case, "B" factors are intended to be applied only at tandem PBXs where VNL circuits are switched to other VNL circuits.

**3.11** Tie trunks which will be switched alternately to other tie trunks, C.O. trunks, station lines, etc, are equipped with 2 db switchable pads to protect against echo for terminating connections. The pads should be switched **out** on through connections to other VNL facilities, and should be left **in** on terminating connections to station lines or other lines and trunks which do not provide adequate terminal balance.

**3.12** Circuits designed to operate at VNL will **require** 4-wire facilities all the way to the PBX. VNL+2 or higher loss circuits may be designed as 2-wire or 2-wire extensions from the 4-wire portion of the long-haul facility if the loss and return loss objectives can be met. If severe economic penalties are not incurred it is preferable to design these circuits on 4-wire facilities with the 4-wire terminating set and/or repeater at the PBX. This will more readily permit redesign to VNL if future changes require tandem switching. Also, frequency response, noise and other transmission considerations can usually be improved through the use of 4-wire facilities.

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### C. Design Loss Considerations — Short Haul

**3.13** Short-haul circuits are those which have round-trip delays of 6 milliseconds or less.

**3.14** The losses required for stability on repeated short-haul circuits which are connected to telephone stations at both ends will provide adequate echo protection. However, in some cases these circuits may be connected so as to become a link in a long built-up connection involving VNL facilities. Under this condition it will be necessary to design these circuits so that the loss will not be less than  $VNL+2$ ; however, to reduce design effort and to insure echo and stability margins, minimum losses of 3.0 db have been adopted for short-haul circuits except as discussed below.

**3.15** Some circuits which would ordinarily fall under the short-haul category by definition will require VNL design because these will function as tandem or intertandem tie trunks with switchable pads at one or both ends. This type of circuit requires 4-wire facilities all the way to the PBX where the switchable pads are located.

### D. Universal Service

**3.16** The design objectives discussed in this section are intended to provide adequate transmission quality on most universal service connections. Universal Service is defined as the interconnection between switched private line facilities and the message network at one point only on any one call. ***This arrangement does not contemplate message network connections at both ends of the private line facility. Also, while calls originating over one private line network may route via the message network to a second private line network, it should be recognized that this type of operation will not provide adequate transmission in most cases.*** In general, transmission over either the exchange or toll network via a single PBX trunk should be at least as good as that obtained over a long station loop on the same type of connection. Certain limitations exist with present design techniques; namely, that transmission on a call from a PBX station to the message network via the normal serving central office will generally be better than on a call involving PBX tie lines. This is a

condition that will continue to exist until improved switching and/or circuit design techniques are developed to economically provide lower loss circuits.

**3.17** Satisfactory transmission performance on Universal Service calls presents major transmission problems. However, it is felt that satisfactory results can be achieved on most calls if the following limitations are accepted:

- (1) Simultaneous interconnection at both ends of a switched network cannot be expected to provide satisfactory transmission.
- (2) Data transmission is not contemplated for Universal Service interconnections between tandem networks and the message network.
- (3) The interconnection should not be made at a satellite PBX.

**3.18** To improve the probability of giving satisfactory transmission on universal service calls, the loss between PBX where interconnections occur and the central office where the message network starts should be held to a minimum. A more detailed discussion of this design consideration is covered in Part 5D of this section. In all cases, the circuits interconnecting the tandem network with the regular message network, i.e., PBX C.O. trunks, PBX FX trunks, and WATS lines, should meet the objectives specified in this section.

### E. Data Service

**3.19** The design objectives for intertandem and tandem tie trunks should provide a quality of data service on the tie trunk networks at least as good as DATA-PHONE service on the DDD network. This assumes that tandem PBXs will be treated as the transmission equivalent of Class 3 DDD offices and the terminating PBX will be the equivalent of a Class 5 central office. Intertandem tie trunks, tandem tie trunks, and station loops are equivalent, respectively, to intertoll trunks, toll connecting trunks and subscriber loops in the DDD network. As such, they should meet the DATA-PHONE transmission requirements given in Section AB27.425.00, with the possible exception of slope distribution. While

the previous similarities generally apply, the preponderance of PBX station loops are extremely short and some economic trading between loops and trunks may be possible. Under no circumstances, however, should the station-to-station slope given in Section AB27.425.00 be exceeded.

**3.20 DATA-PHONE** service to PBX stations has presented considerable difficulty because special treatment of a large number of central office trunks is required to handle a few data sets, and satisfactory devices to improve the nonloaded trunks for both voice and data have not been available. The advent of the nonloaded LBO for the E6 repeater provides a satisfactory device to reduce the loss and improve the return loss and frequency response of these trunks for data operation. In many cases it will be necessary to apply repeaters to a large number of

PBX central office trunks to serve relatively few data stations; however, the application of such repeaters to meet the data objective will also provide considerable improvement in voice transmission.

#### F. Balance Considerations and Pad Switching

**3.21** The transmission objectives outlined later in this section require certain tie trunks to be operated at VNL when switched to other tie trunks. This type of operation requires adequate balance in order to provide satisfactory echo performance. When these same VNL tie trunks are switched to other lines or trunks not meeting terminal balance requirements, 2 db pads are switched into the transmission path to provide protection against echo.

**TABLE III**  
**BALANCE MEASUREMENT OBJECTIVES**

| TYPE CONNECTION                            | 2 db SWITCH PAD | TYPE TEST              | AVERAGE OF ALL TRUNK MEASUREMENTS NOT LESS THAN | NO TRUNK MEASUREMENT LESS THAN         | CONNECTED CIRCUIT TERMINATION                        |
|--------------------------------------------|-----------------|------------------------|-------------------------------------------------|----------------------------------------|------------------------------------------------------|
| <b>THROUGH BALANCE</b>                     |                 |                        |                                                 |                                        |                                                      |
| 4-W VNL TIE TRUNK TO<br>4-W VNL TIE TRUNK  | OUT             | ERL<br>SP              | 27.0 db<br>20.0 db                              | 23 db<br>16.0 db                       | 4-WIRE LEGS OF<br>HYBRID TERMINATED<br>IN 600 OHMS   |
| <b>TERMINAL BALANCE</b>                    |                 |                        |                                                 |                                        |                                                      |
| 4-W VNL TIE TRUNK TO<br>4-W NON-VNL TIE TK | OUT             | ERL<br>SP              | 22.0 db<br>15.0 db                              | 16.0 db<br>11.0 db                     | 900 OHMS + 2 MF<br>AT DISTANT PBX                    |
| TO<br>2-W NON-VNL TIE TK                   | OUT<br>(NOTE 1) | ERL<br>SP              | 18.0 db<br>10.0 db                              | 13.0 db<br>6.0 db                      | 900 OHMS + 2 MF<br>AT DISTANT PBX                    |
| TO<br>CENTRAL OFFICE<br>OR FX TRUNK        | OUT<br>(NOTE 1) | ERL<br>SP              | SAME AS<br>NON-VNL TIE<br>TRUNKS                |                                        | 900 OHMS + 2 MF<br>AT CENTRAL OFFICE                 |
| TO<br>PBX STATION<br>LINES                 | IN              | ERL<br>SP<br>ERL<br>SP | 24.0 db<br>18.0 db<br>12.0 db<br>8.0 db         | 20.0 db<br>14.0 db<br>9.0 db<br>6.0 db | 900 OHMS + 2 MF<br>AT PBX<br>PBX STATION<br>OFF HOOK |

**NOTE 1:** If the facility loss is less than 2 db *or* adequate impedance correction is not provided, the 2 db pad cannot be switched out.

**NOTE 2:** Refer to Sections 310-350-100 and 310-350-500 for details on PBX balance requirements and methods.

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**3.22** The switched pads are associated with the tie trunk equipment. The SD-65718-01 tie trunk is a typical example of a pad switching arrangement. While it is desirable to switch the pads out wherever the balance requirements can be met, control arrangements are not available for all types of circuits. The latest information on providing pad control should be obtained for a particular situation.

**3.23** Table III gives the balance objectives for various switching conditions at PBXs. It must be emphasized that *VNL* operation of tie trunks requires that these balance objectives be met in order to provide satisfactory echo performance.

**3.24** The theoretical aspects of balance objectives and testing for PBXs are covered in Section 310-350-100 and the testing methods are covered in Section 310-350-500.

**G. Noise**

**3.25** Long-Haul tie trunks, FX lines and trunks, and WATS lines and trunks should be designed to be compatible with the maintenance requirements given in Table IV.

**TABLE IV**

| CIRCUIT LENGTH (Miles) | NOISE REFERRED TO OTLP<br>SHALL BE LESS THAN |
|------------------------|----------------------------------------------|
| 0 — 50                 | 31 dbrnc                                     |
| 51 — 100               | 34 "                                         |
| 101 — 400              | 37 "                                         |
| 401 — 1000             | 41 "                                         |
| 1001 — 1500            | 43 "                                         |
| 1501 — 2500            | 45 "                                         |
| 2501 — 4000            | 47 "                                         |

**3.26** When a circuit is made up of compandored facilities, a combination of compandored and voice-frequency facilities, or two or more compandored facilities in tandem, decrease the above limits by 5 db; i.e., 31 dbrn becomes 26 dbrn. The limits given in Table IV apply to circuits made up of compandored facilities plus noncompandored carrier facilities.

**3.27** Maintenance noise limits for short-haul facilities are given in Table V.

**TABLE V**

| TYPE OF CIRCUIT             | SHALL BE LESS THAN |
|-----------------------------|--------------------|
| Off-Premise Station         | 28 dbrnc #         |
| Secretarial lines or trunks | 28 "               |
| Short-Haul FX line or trunk | 28 "               |
| Short-Haul WATS line        | 20 "               |
| PBX Central Office Trunks   | 20 "               |

# Levels referred to point of measurement as shown in Section 331-855-501, 331-855-502.

**3.28** Impulse noise requirements for various circuits that may be involved in providing data service are shown in Table VI.

**TABLE VI**

| TYPE CIRCUIT          | REQUIREMENT FROM AB27.425.00  |
|-----------------------|-------------------------------|
| Off-Premise Station   | Same as station loop          |
| PBX C.O. trunk        | Same as station loop          |
| PBX tie trunk         | Same as toll connecting trunk |
| Tandem tie trunk      | Same as toll connecting trunk |
| Intertandem tie trunk | Same as intertoll trunk       |

**H. Echo Suppressors**

**3.29** Split echo suppressors are required under the following conditions:

- (1) If the VNL of the facility exceeds 3.5 db and it is not possible to use a higher velocity facility.
- (2) If any combination of tie trunks in a customer's network has a combined VNL of 4.5 db or more, an echo suppressor should be used on the link with the largest VNL contribution.

**Note:** When echo suppressors are applied, the VNL should be reduced to zero. Thus, a facility with an EML objective of (VNL + .5 + 2S + 2S) db equipped with an echo suppressor should be designed to operate at (.5 + 2S + 2S) db.

**3.30** The following Figs. 1A, 1B, and 1C, illustrate the hangover time requirements for the 1AS echo suppressor (split) when used at different locations in a circuit.

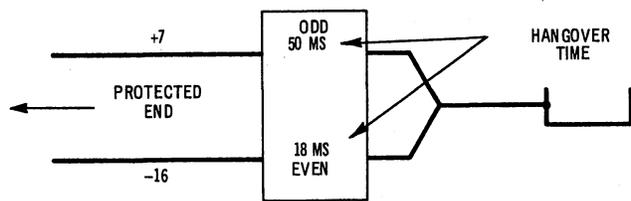


Fig. 1A - Far End - Terminal

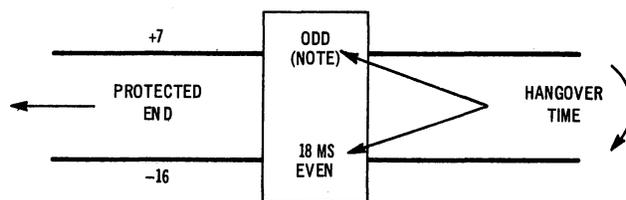


Fig. 1B - Intermediate (Split)

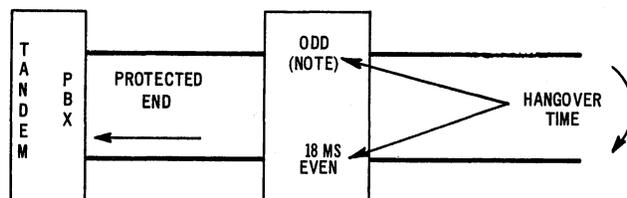


Fig. 1C - Near End - Terminal

**Note:** In split operation, the odd side is disabled.

**3.31** Ideally, every echo suppressor hangover setting should cover the farthest customer location that may be connected in addition to penetration into the message network. While it is possible to have a delay of 45 ms in the message network without encountering an echo suppressor, it is more reasonable to expect a round-trip delay of 22.5 ms.

**3.32** Detailed discussion of the operation and application of echo suppressors is covered in Section AB23.026.

## 4. FACILITIES

### A. Carrier

**4.01** Any of the carrier systems that are used for the message network may also be used for most special services circuits. In general, the same considerations as to assignment of channels, use of companders, etc, will apply.

**4.02** Some carrier systems such as the N and T systems provide special channel units which are specifically designed for certain types of special services.

**4.03** Since very few carrier system terminals are installed on customer premises, a physical 4-wire or 2-wire facility will be extended from the carrier terminal in a central office to the customer location. Many special services circuits will be made up of a carrier section in the center with physical facilities at both ends. It is obvious that the design objectives covered in this section are to be applied to the entire circuit including the carrier channel, the physical end links and the terminal and intermediate equipment.

**4.04** Since the VNL factors are lower for carrier than for physical facilities, the maximum use of carrier will result in the lowest overall losses for such circuits as tie trunks, FX trunks and off-premise station lines. In some cases the maximum loss objective will be exceeded if long physical facilities are used. Increased use of carrier may permit meeting the objective in such cases.

### B. Physical Facilities

**4.05** A question that arises when designing special services facilities to meet low loss objectives is whether the facilities should be 2-wire or 4-wire. Because of the strict balance requirements for echo protection, tie trunks to be operated at VNL will require 4-wire facilities throughout. Facilities that are always operated at higher losses such as VNL+2 or 3 db or higher, can generally meet loss and balance requirements with 2-wire facilities or 2-wire extensions from 4-wire carrier systems. Circuits that are to be switched at VNL and are equipped with switchable pads must use 4-wire facilities to the PBX where the pads are located.

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**4.06** Some of the principal transmission factors, pro and con, that enter into the considerations of 4-wire versus 2-wire facilities are:

### *Pro*

- (a) 4-wire circuits can generally be operated at lower net losses than 2-wire circuits.
- (b) 4-wire circuits provide better balance than 2-wire.
- (c) Finer gauge cable can be used for 4-wire facilities.

### *Con*

(a) 4-wire facilities may be more expensive than 2-wire. This consideration requires the comparison of two fine gauge pairs plus 24V4 repeaters against all costs involved for one coarse gauge pair plus E-type repeaters and impedance compensators.

(b) Fine gauge cable will have poorer temperature regulation than coarse gauge, particularly in aerial cable.

**4.07** Other considerations such as the use of standardized layouts or prescription design or future requirements for better balance or pad switching favor the use of 4-wire facilities.

**4.08** Special services circuits almost always employ facilities provided for regular message telephone service. Universal service and interconnection of special services circuits require high grade facilities to provide satisfactory service.

**4.09** A thorough investigation should always be made of the relative merits of loading, gain devices, and coarse gauge cable when determining the most economical and practical means of providing facilities that will meet the objectives.

**4.10** Heretofore it has been necessary to apply loading on a special basis to meet the objectives for special services circuits using physical facilities. The introduction of the networks for the application of E6 repeaters to nonloaded cable pairs will reduce the requirement for load-

ing on a special basis. However, there will still be some situations where loading will provide the most logical and/or economical means to meet the objectives. Initially the nonloaded cable repeater will only be available for PBX central office trunks; however, it is expected that further development will make the repeater suitable for other applications.

**4.11** The nonloaded cable repeater will provide attenuation equalization and good return loss as well as gain. These characteristics will provide a means to meet objectives on exchange loop plant which would not normally be loaded.

**4.12** Where loading is used, it is important to maintain good coil spacing and to eliminate bridged taps. Many special services circuits require a high degree of balance which cannot be obtained with poor loading layouts. Load coil spacing is covered in other sections of the practices.

## **C. Repeaters**

**4.13** A large proportion of the special services circuits on physical facilities will require voice-frequency repeaters to meet the transmission objectives outlined in this section. The use of repeaters introduces considerations of stability and echo and the designs should provide adequate margins. Other sections of the practices give the details on the design of circuits involving voice-frequency repeaters.

**4.14** The type of repeaters which will be used for special services circuits in most cases are:

- (a) 44V4 — 4-wire to 4-wire  
used on loaded or nonloaded cable pairs
- (b) 24V4 — 4-wire to 2-wire  
used on loaded or nonloaded cable pairs
- (c) E6 or E23 — 2-wire  
used on loaded cable pairs
- (d) E6 with nonloaded line build-out network and impedance compensator used on nonloaded cable pairs

**D. Battery Supply**

**4.15** Many special services circuits will terminate in telephone sets and the transmitter talking battery supply may be located at various points in the circuit depending on the type and location of the equipment used. The 500-type telephone sets are equipped with networks which control the efficiency of the set depending on the amount of the current flowing through the transmitter.

**4.16** The transmission objectives covered in this section are given in terms of 1000-cycle losses and are based on optimum transmitter current of approximately 50 milliamperes. Currents smaller than this will provide less output from the transmitter, while currents greater than this will reduce the efficiency of the receiver.

**4.17** The output of the tone generator in TOUCH-TONE telephone sets is also a function of the loop current. This level varies inversely as the loop current, and as a result the minimum output level occurs with maximum loop current.

**4.18** When transmitter battery is supplied from the normal serving central office, there will generally be no problem in maintaining satisfactory loop current. However, when dial long line (DLL) equipment is required, the location of such equipment must be considered from a loop current standpoint as well as from supervision aspects. Although the DLL circuit will introduce a loss of only about 0.4 db at 1000 cycles, its location may affect the transmission performance more than this since the DLL furnishes talking and TOUCH-TONE signaling battery to the telephone set.

**4.19** The maximum limits given in this section should be adjusted where indicated (Figs. 3, 4, 5, 6, and 7) to account for the battery supply current. Table VII provides corrections to partially compensate for the effects discussed in the preceding paragraphs. NOTE: These corrections apply to maximum limits only and no correction is required if the loop current is in the range of .036 to .065 ampere.

**TABLE VII**

| LOOP CURRENT         | SUBTRACT FROM<br>MAXIMUM OBJECTIVE | TYPE SET                       |
|----------------------|------------------------------------|--------------------------------|
| .081 amp or higher   | 2 db                               | 500                            |
| .066 amp to .080 amp | 1 db                               | 500                            |
| .036 amp to .065 amp | 0                                  | 500                            |
| .027 amp to .035 amp | 1 db                               | 500                            |
| .023 amp to .026 amp | 2 db                               | 500                            |
| under .023 amp       | 0                                  | Long Loop set<br>or equivalent |

**4.20** As an example of a situation requiring a correction, assume the following conditions:

- (a) A Foreign Exchange Line involving cable only and requiring a DLL in the office adjacent to the station.
- (b) The conductor loop resistance from the DLL to the station is 1325 ohms.
- (c) The DLL available is SD-96234-01.

From Table IX (this section) the nominal resistance of this DLL is 231 ohms and the resistance of the 500 set is 150 ohms. These, when added to the conductor loop resistance of 1325 ohms give a total resistance of 1706 ohms. With a 48-volt supply the current is approximately .028 ampere. From Table VII the correction required is 1 db. Since the maximum limit for a Foreign Exchange Line is 8.5 db with optimum current, the maximum loss in this case should not exceed 7.5 db to the milliwatt supply in the foreign central office. NOTE: The actual *objective* is 5.5 db and not 7.5 db. See Part 5 for definitions of objectives and limits.

**E. Frequency Response**

**4.21** In order to preserve the quality on voice transmission the frequency response of circuits which may become a part of built-up connections should be controlled. When the circuits are used for data transmission it is essential that the frequency response meet the objectives for the particular data service to be used.

**4.22** Voice grade tie trunks should be designed so that the frequency response will be within -1 db and +3 db of the 1000-cycle loss at 700 cycles and 2300 cycles and within -3 db

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and +8 db at 300 cycles and the upper test frequency. For circuits not equipped with voice-frequency transmission filters, the upper test frequency will be 3000 cycles.

### 5. OBJECTIVES

#### A. General

5.01 The objectives given in this section will provide good transmission and are based on the following concepts:

(a) To provide good volume, the circuits should be designed and operated at the lowest loss which noise objectives, other design parameters, and economic considerations will permit.

(b) Echo protection on long-haul circuits and built-up connections requires that the minimum losses be based on VNL design.

These factors must receive careful consideration in the design, line-up and maintenance of all circuits which can be involved in switched connections. The cumulative effect of relatively small errors in the design, line-up and maintenance of individual circuits can result in a high incidence of trouble when these circuits become a part of an overall switched connection.

5.02 As mentioned in Par. 1.05 the design objectives discussed in this section are given in terms of 1000-cycle loss so that transmission measurements can be compared with design values.

5.03 Ideally, the design loss of a circuit should be from the center-of-the-switching arrangement at one end to the center-of-the-switching arrangement (or telephone set) at the other end. These "center-of-the-switch" points are not readily accessible for testing. From a practical standpoint, therefore, common points at each end of the circuit are specified for both design and testing. Figures 2A thru 2D illustrate the "center-of-switch" concept and the practical design and measuring points. In these cases, the common design and measuring points are the jack appearances on the outgoing trunk circuits. These principles may be applied to the design and testing of a wide variety of special service circuits.

5.04 Many central offices and PBXs are now being equipped with dial test lines to facilitate measurement of the circuits terminating in these switching arrangements. The milliwatt supply in such installations is reached by dialing through the switches in a normal manner. This arrangement introduces a loss in the test condition that is present in the terminating condition, but is not present in the switched-through condition. It is important to include this loss in the design EML (Expected Measured Loss) specified on the Circuit Layout Record card so that the circuit will be operating at the proper loss when switched to other trunks or lines.

5.05 The objectives covered in this section are stated in terms of EML. EML is defined as the expected measured loss between specified test points. This definition means that all wiring and equipment loss from the MDF (or equivalent) to the test point must be included in the calculated EML. This loss will vary as it depends on the type of switching equipment and the location of the test points. To properly assign an EML would require that this loss be known to a reasonable degree of accuracy. However, it is not practical to account for this variability in establishing System loss objectives. Hence, an average loss of 0.5 db has been assumed in converting center-of-switch objectives to EML objectives.

5.06 The 0.5 db allowance will cover most testing arrangements involving losses due to step-by-step connectors, attendant cord circuits, and auxiliary tie trunks at crossbar PBXs.

5.07 Certain testing arrangements involving circuits such as WATS Lines to a Toll C.O. may contain a test pad in the testing condition. The EML objectives should be adjusted to account for the presence of these pads where applicable.

5.08 Two values of losses associated with each type of service are given in this section: An *objective* loss and a *maximum* limit. In general, circuits should not have losses which exceed the *objective*, and only in the case of severe economic penalty or technical difficulty should the circuit losses approach the *maximum* limits. Even in these difficult cases, every effort should

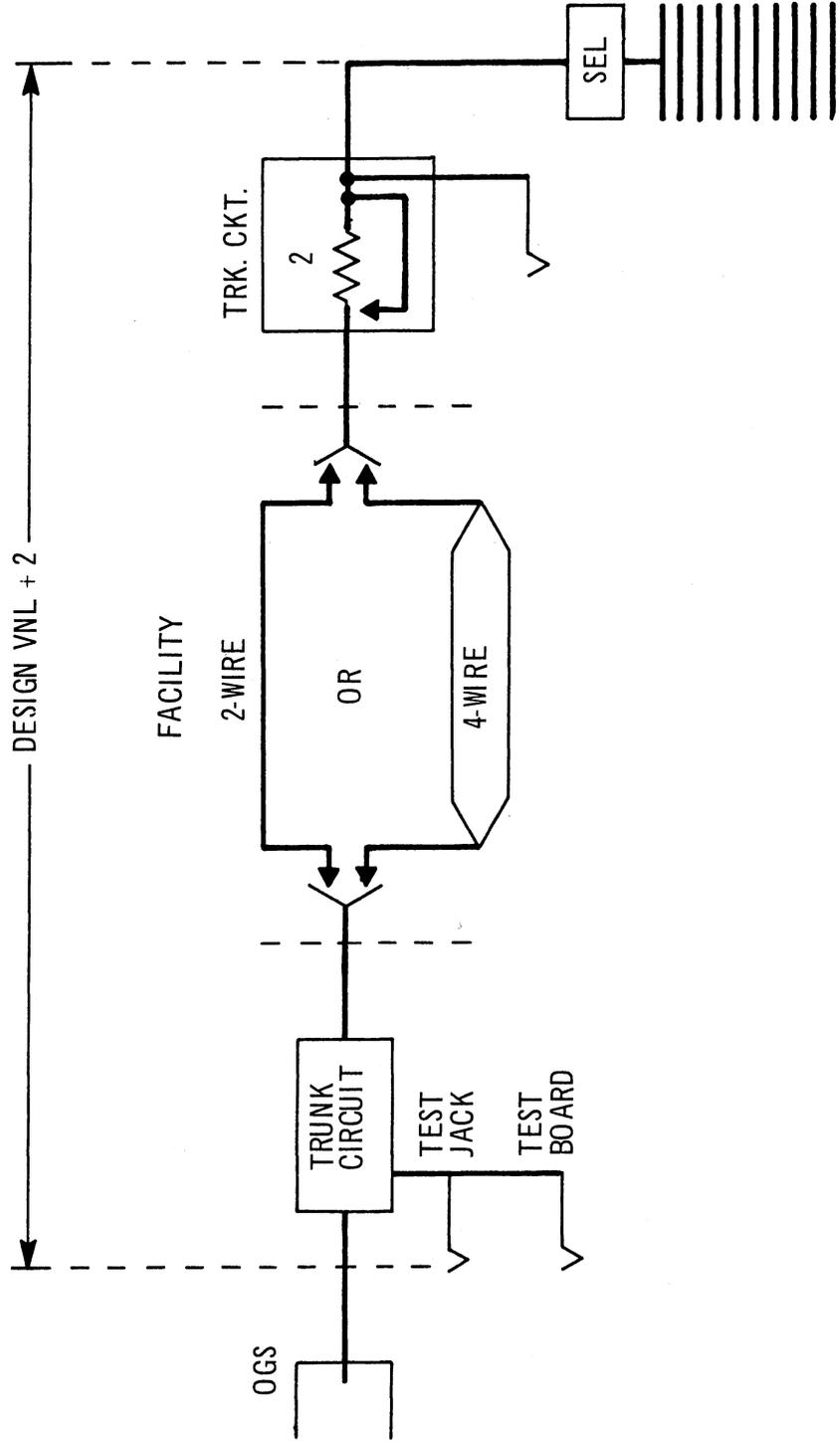


Fig. 2A - Center-of-Switch to Center-of-Switch

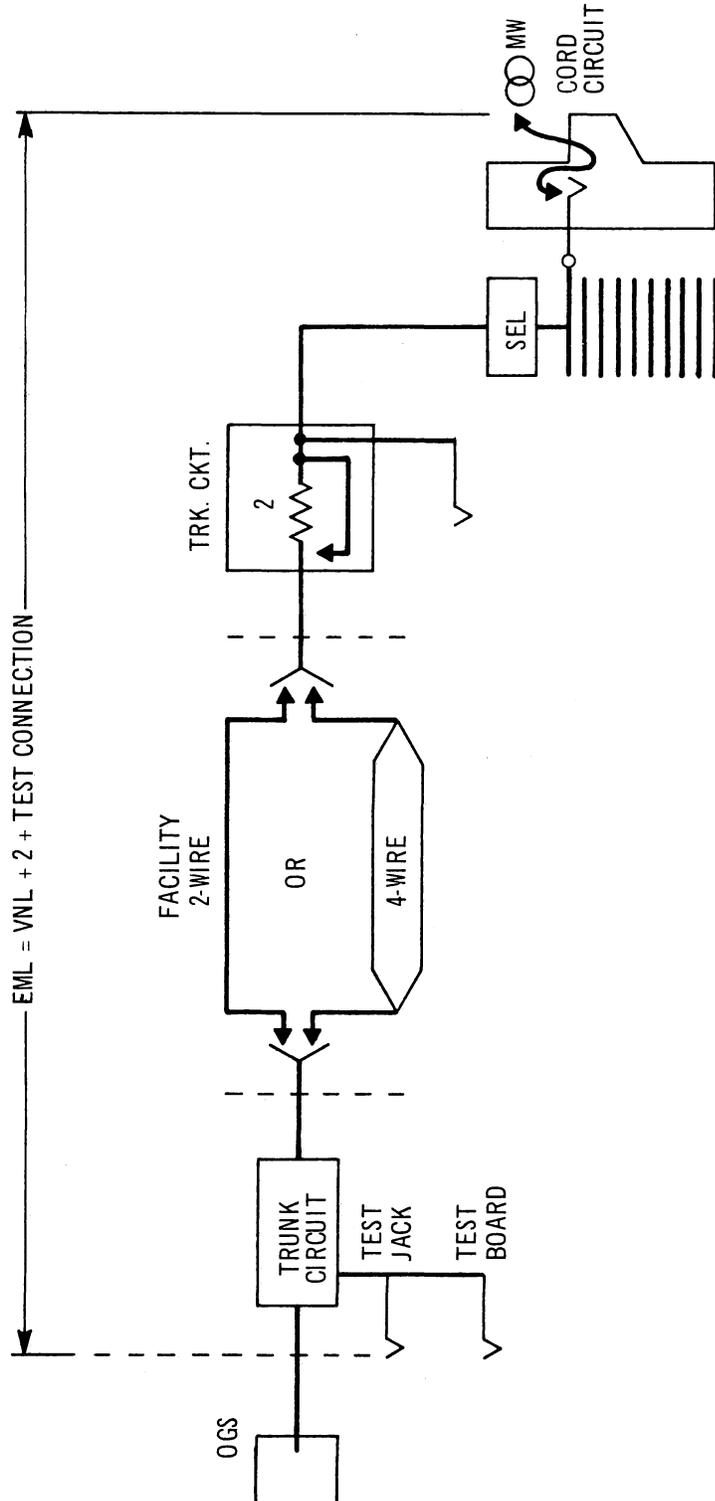


Fig. 2B - Outgoing Switch to Switchboard

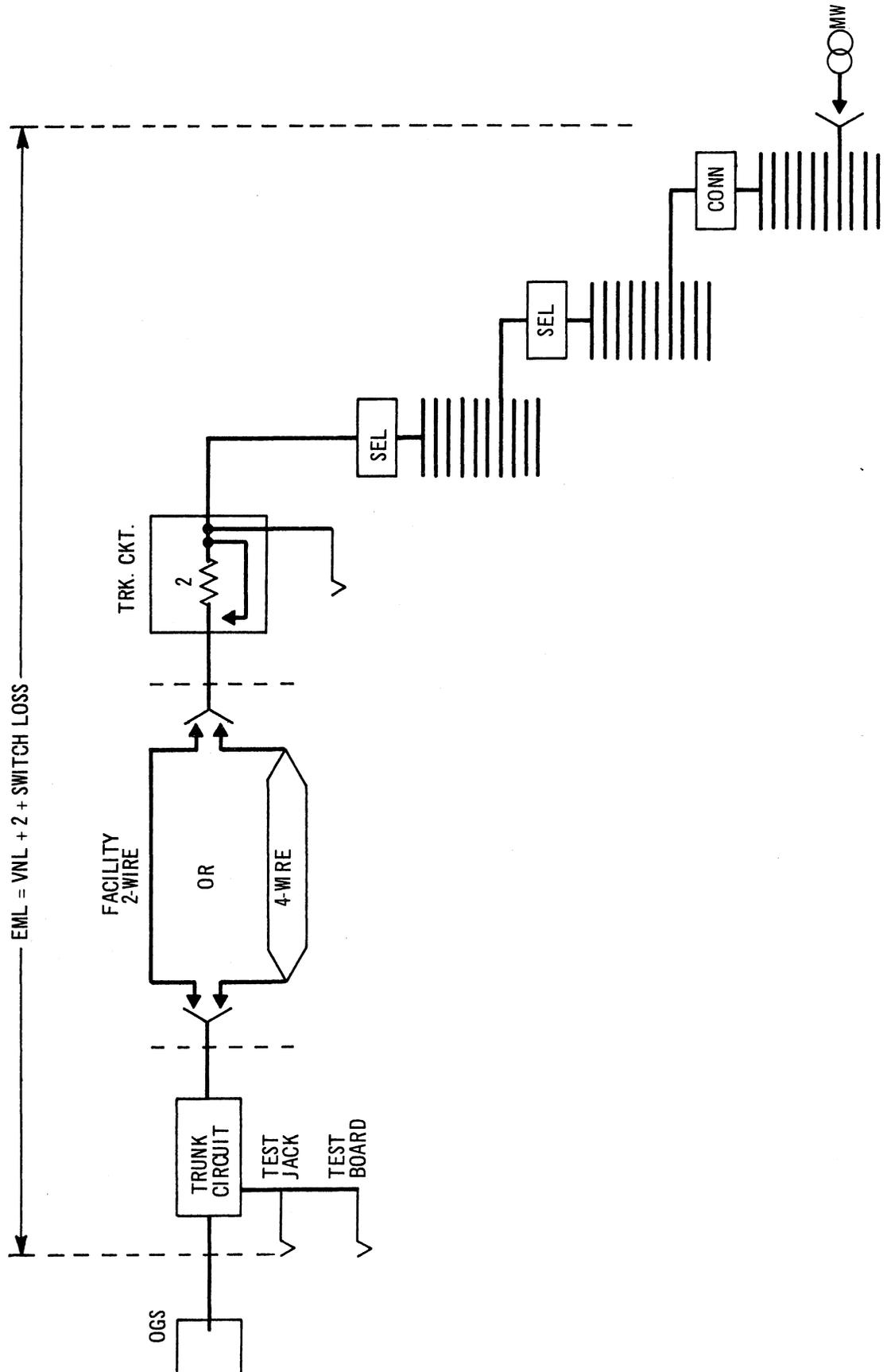


Fig. 2C - Outgoing Switch to Dialed Milliwatt Supply

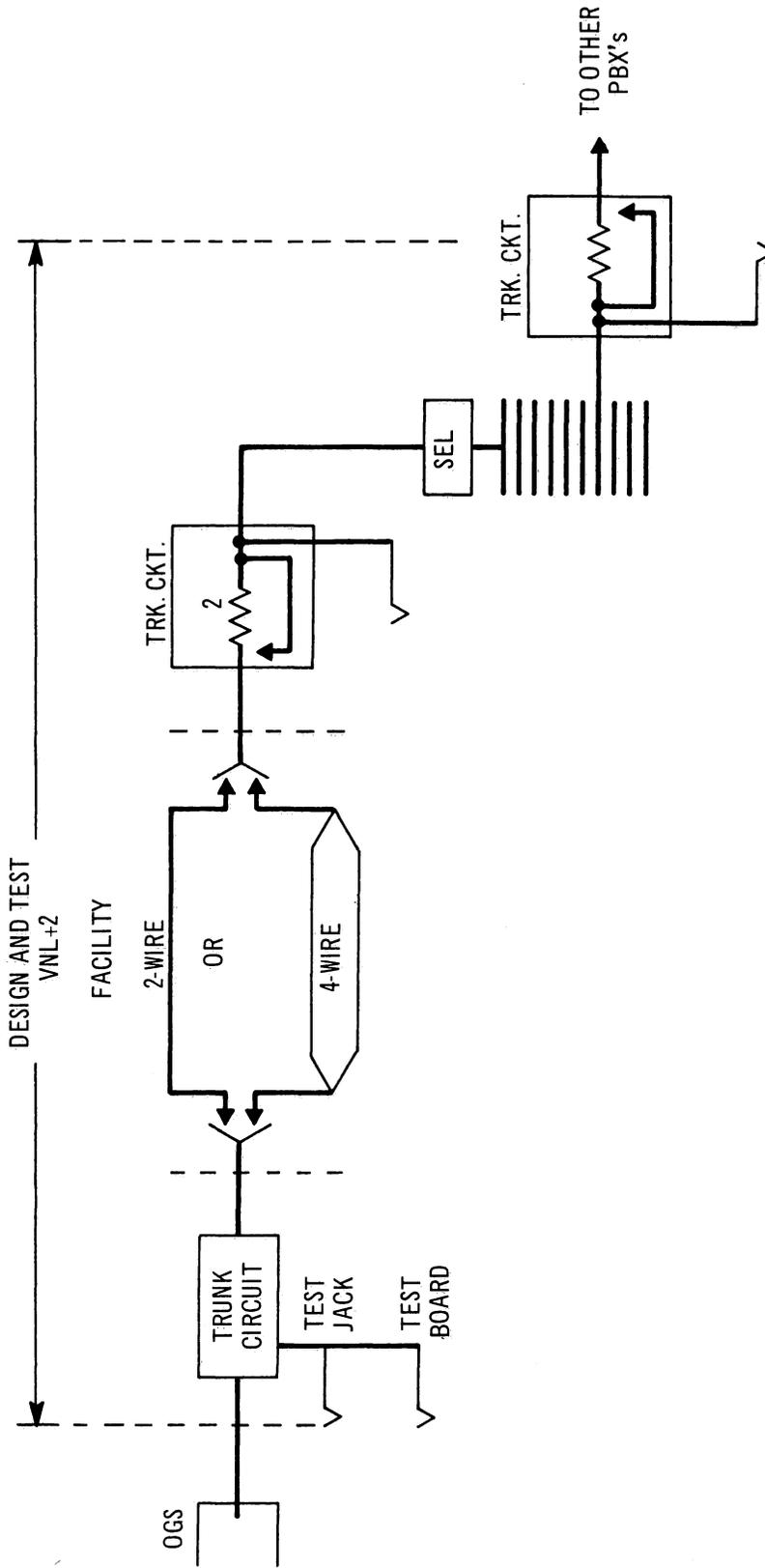


Fig. 2D - Outgoing Switch to Outgoing Switch

be made to keep the losses as close to the objectives as possible.

**5.09** As discussed in Part 3 of this section, certain types of facilities also require a minimum amount of loss to provide adequate echo protection. For such cases the *objectives* are given in terms of VNL plus a fixed loss, and the *objectives* also represent the minimum allowable design losses with the following exception: When the facility is derived from short, nonloaded cable sections with a 1000-cycle loss of 2 db or less, the minimum allowable design loss is (VNL+2.5) db including a 2 db pad.

### B. Line-Up and Maintenance

**5.10** The lower loss design objectives and the use of VNL design require good line-up and maintenance procedures. Stable circuit operation cannot be achieved and maintained unless procedures at least as good as those used for the message network are developed and implemented for special service circuits.

**5.11** Modern transmission testing instrumentalities and techniques must be used for testing PBX and other special service circuits.

**5.12** A line-up procedure including circuit layout information is necessary to insure accurate line-up and maintenance of special service circuits.

**5.13** Information on testing methods and objectives is covered in other sections of the practices in the Plant Series.

### C. Special Services

#### **5.14 Foreign Exchange (FX) lines**

FX lines will require interoffice facilities and terminating equipment which will supply talking battery to the telephone set. High grade facilities with loading and/or repeaters may be required to meet the objectives. The battery supply should be located to provide optimum current to the telephone set. Fig. 3 illustrates FX lines and the objectives.

**5.15 WATS Lines** are provided for toll business exclusively. In some cases they may be used alternately for DATA-PHONE service. If the central office which normally serves the customer's location is not equipped to provide WATS service, a line similar to an FX line is provided to a WATS office. Fig. 4 illustrates WATS lines and the transmission objectives.

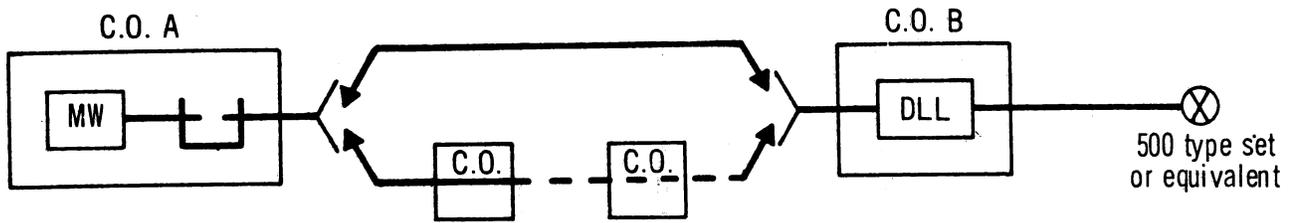
**5.16** In some cases WATS lines may be served from a toll office rather than a Class 5 central office. This type of operation requires that terminal balance tests be made on the WATS line since it will be connected directly to VNL intertoll trunks. Fig. 5 illustrates this type of arrangement and the transmission objectives.

**5.17** When WATS service is provided for a tandem network from a central location such as one specific PBX, it is highly desirable that the WATS line terminate directly in a toll office. Such an arrangement will reduce the contrast considerably between WATS calls originated over tie trunks and regular DDD calls originated from the same location. A method of reducing this contrast is:

- (1) Equip the tie trunks at the PBX where connection to the WATS line is contemplated with switch pads or thru and terminating jacks at the switchboard.
- (2) Either thru-jacks or pad-out operation requires that the WATS line be impedance compensated to meet terminal balance requirements at the PBX.

**5.18 Off-Premise Extension (OPX) lines** are generally bridged on the main station line at the central office. In order to prevent transmission impairment on either the *off-premise* loop or the main station loop, bridge lifters should be installed at the central office whenever:

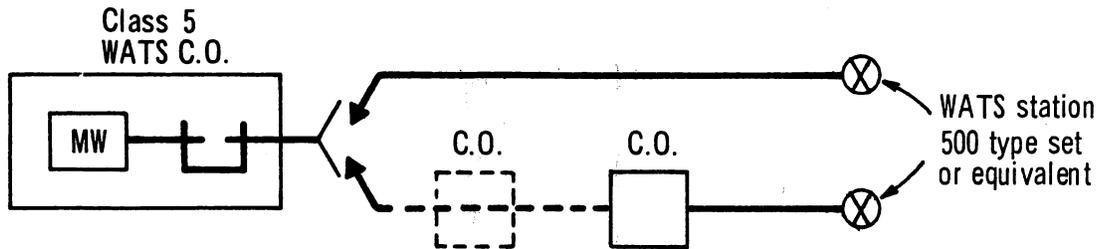
- (1) Either the main station loop plus its bridged tap or the *off-premise extension* loop plus its bridged tap exceeds 6000 feet of nonloaded cable.
- (2) Either the main station loop or the extension loop is loaded. Dial long line equipment or other battery supply source should be located so as to provide optimum loop current. Fig. 6 illustrates OPX lines and



| <u>From</u>    | <u>To</u> | <u>EML (1000~)</u> |                  |
|----------------|-----------|--------------------|------------------|
|                |           | <u>Short Haul</u>  | <u>Long Haul</u> |
| Milliwatt      | Station   | Obj. 0-5.5 db      | (VNL + 4.5) db   |
| Supply - C.O.A |           | Max. 8.5 db*       | 8.5 db*          |

\*Adjust maximum objective for battery supply current - Sect. 4D

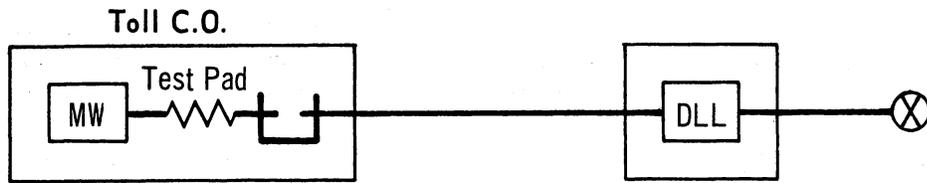
Fig. 3 - FX Lines



| <u>From</u>   | <u>To</u> | <u>EML (1000~)</u> |                  | <u>Data Objective</u> |
|---------------|-----------|--------------------|------------------|-----------------------|
|               |           | <u>Short Haul</u>  | <u>Long Haul</u> |                       |
| Milliwatt     | Station   | Obj. 0-3.5 db      | (VNL+4.5)db      | Same as DATA-PHONE    |
| Supply - C.O. |           | Max. 5.5 db*       | 6.5 db*          | loop per AB27.425.00  |

\*Adjust maximum objective for battery supply current per Sect. 4D

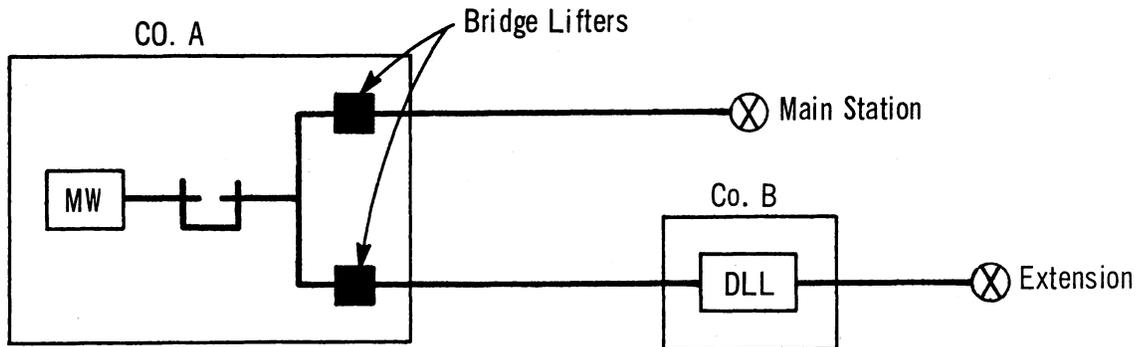
Fig. 4 - WATS Lines



| <u>From</u> | <u>To</u> | <u>EML (1000~)</u>             |                                      | <u>Data Objective</u> |
|-------------|-----------|--------------------------------|--------------------------------------|-----------------------|
|             |           | <u>Short Haul or Long Haul</u> |                                      |                       |
| Milliwatt   |           |                                |                                      |                       |
| Supply at   | Station   | Obj.                           | (VNL + 4.5) db + Test Pad            | Same as DATA-PHONE    |
| Toll office |           | Max.                           | 8.5 db*                              | loop per AB27.425.00  |
|             |           |                                | Min. Echo Return Loss at toll office |                       |
|             |           |                                | to off-hook telephone set = 15 db    |                       |

\*Adjust maximum objective for battery supply current, Sect. 4D

Fig. 5 - WATS Line to Toll Central Office



| <u>From</u>    | <u>To</u> | <u>EML (1000~)</u> |                         |
|----------------|-----------|--------------------|-------------------------|
|                |           | <u>Short Haul</u>  | <u>Long Haul</u>        |
| Milliwatt      | OPX       | Obj.               | 0-5.5 db (VNL + 4.5) db |
| Supply - C.O.A | Station   | Max.               | 8.5 db* 8.5 db*         |

\*Adjust maximum objective for battery supply current - Sect. 4D

Fig. 6 - Off-Premise Extension Lines

objectives when interoffice facilities are required. Normal resistance design criteria should be used when both the OPX line and the main station are within the same serving central office.

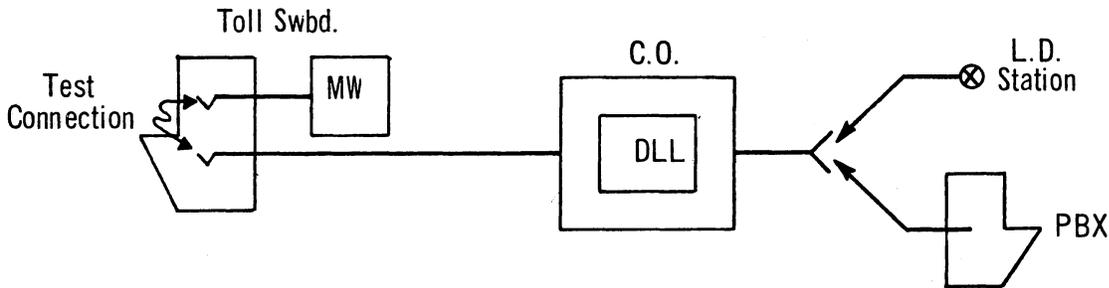
**5.19 L.D. lines** provide direct connections from the terminating station or PBX to a toll switchboard. Since these connections will not be switched through Class 5 central offices, no toll connecting trunk will be involved. These lines must be designed with minimum losses and adequate terminal balance to provide echo protection. Fig. 7 illustrates these lines and the objectives.

**5.20 Secretarial Service** may be provided by either of two methods. One method uses a separate facility for each secretarial line and is bridged to the main station line at the central office and is illustrated in Fig. 8. The second method uses concentrator identifiers to provide secretarial service for a large number of main station lines with relatively few lines between the central office and secretarial switchboard. This method is illustrated in Fig. 9.

**D. PBX Trunks and Lines**

**5.21** Universal service connections from PBXs to the message network are made through the PBX central office or FX trunks. The objectives to be discussed in this part will provide adequate transmission on most connections. It should be recognized that universal service connections which involve more than a single tie trunk in the built-up connection cannot be expected to provide good transmission in all cases. It is obvious that a multilink tie trunk connection connected to the DDD network through PBX central office trunks will, in most cases, involve more links than contemplated for DDD calls.

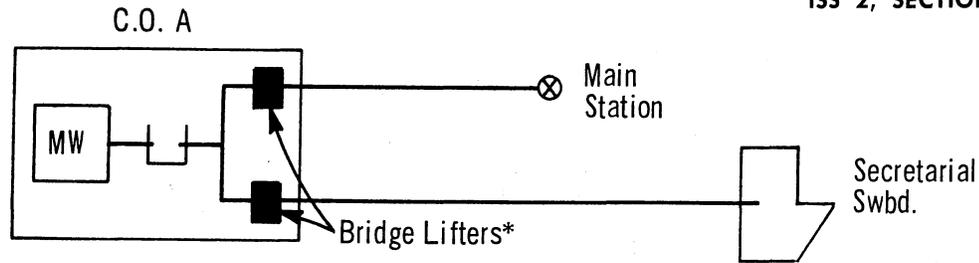
**5.22** The general objective for a tandem PBX network is that the 1000-cycle loss from originating PBX to terminating PBX be designed to VNL+4. Under the universal service concept this same objective applies from PBX to the serving end office. However, instrumentalities to implement this objective are not always available at many locations and can only be provided with severe economic penalty. At



| <u>From</u>  | <u>To</u> | <u>EML (1000~)</u>                | <u>Data Objective</u> |
|--------------|-----------|-----------------------------------|-----------------------|
|              |           | <u>Short Haul or Long Haul</u>    |                       |
| MW supply    | Station   | Obj (VNL + 4.5) db                | Same as DATA-PHONE    |
| at Toll swbd | or PBX    | Max. 8.5* db                      | loop per AB27.425.00  |
|              |           | Min. Echo Return Loss at Toll     |                       |
|              |           | swbd to off-hook tel. set = 15 db |                       |

\*Adjust maximum objective for battery supply current, Sect. 4D

Fig. 7 - L.D. or Toll Terminal Lines



| <u>From</u> | <u>To</u> | <u>EML (1000 ~)</u> |          |
|-------------|-----------|---------------------|----------|
| MW in       | sect.     | Obj                 | 0-5.5 db |
| C.O. A      | swbd      | Max.                | 8.5 db   |

\* Use bridge lifters on main station loop when:

- (1) The secretarial loop plus its bridged tap exceeds 6000 feet of nonloaded cable, or
- (2) The secretarial loop is loaded.

\* Use bridge lifters on secretarial loops when:

- (1) The main station loop plus its bridged tap exceeds 6000 feet of nonloaded cable, or
- (2) The main station loop is loaded.

**Fig. 8 – Secretarial Service — Direct Loop**

newer locations and where customer requirements justify the cost, new development in the following three areas will enable meeting these objectives. These areas are: (1) the provision of devices for loss and impedance correction for nonloaded cable, (2) tie trunks with pad switching options, and (3) PBXs with more flexible pad control.

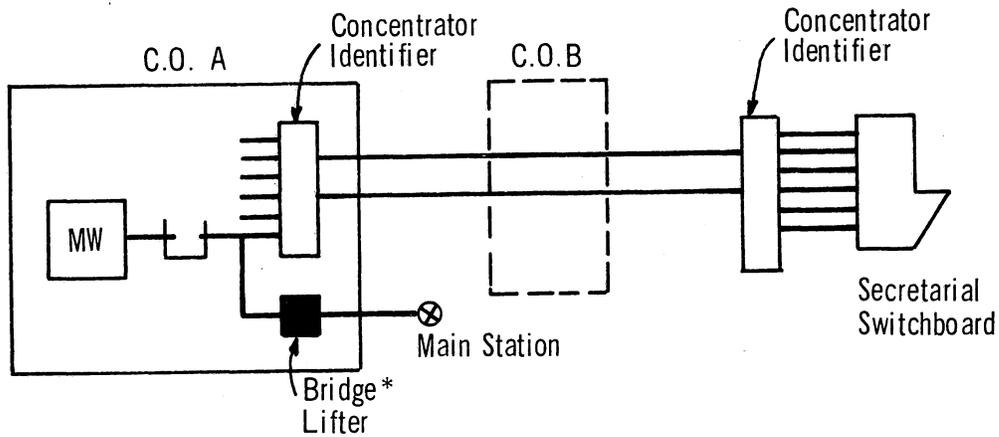
**5.23** The nonloaded LBO used with the E-6 repeater provides the necessary return loss improvement of the nonloaded facility to meet terminal balance requirements. This permits VNL facilities with pad control capabilities to switch the pad out when terminating in impedance corrected nonloaded facilities. Loaded facilities may be treated with presently available impedance compensators and repeaters as required to meet loss and terminal balance requirements necessary for pad out operation.

**5.24** The modernization of tie trunk equipment to provide for pad options and 4-wire operation and termination is continuing. Options

are presently available with SD-65718 to provide the above features. Work is also continuing in the field of operator handled calls to provide thru and terminating arrangements at PBX switchboards. The latest information should be obtained for any specific application.

**5.25** It is not anticipated that short cable sections derived from nonloaded facilities with a 1000-cycle loss of 2 db or less be treated for pad switching. In these cases the pad should be left in the circuit even when control arrangements are available.

**5.26** It will not be economically feasible to meet universal service objectives on many of the systems now in service. (Furthermore, in many instances the customer's operation does not require this grade of service.) However, the overall 1000-cycle loss from any PBX station, whether it is on-premise, off-premise, satellite or tributary PBX station to the milliwatt supply in the serving central office should not exceed



| <u>From</u> | <u>To</u>   | <u>EML (1000~)</u> |          |
|-------------|-------------|--------------------|----------|
| MW in       | secretarial | Obj.               | 0-5.5 db |
| C.O.A       | switchboard | Max.               | 8.5 db   |

\* Use bridge lifter on main station loop at C.O.A when:

1. The main station loop plus its bridged tap exceeds 6000 feet of non-loaded cable.
2. The main station loop is loaded.
3. The concentrator-identifier trunk is loaded.

Fig. 9 — Secretarial Service — Concentrator Identifier

8.5 db. The objective for the individual circuits should meet the overall objective when the circuits are switched together. For any particular PBX it may be possible to “trade” between the objectives for the individual circuits to meet the overall objective. It must be realized, however, that changes in the customer’s operation could easily require an expensive redesign of a large number of circuits. ***For this reason, good engineering judgment must be applied when “trading” between objectives is considered.***

5.27 PBX central office trunks and the objectives are illustrated in Fig. 10.

5.28 Foreign Exchange PBX trunks are intended to be used principally for calls between the PBX and the foreign exchange area in which the trunk terminates. In some cases the PBX station battery supply may be in the FX trunk. Under these conditions the battery supply source should be located so as to provide optimum current to the PBX stations. The

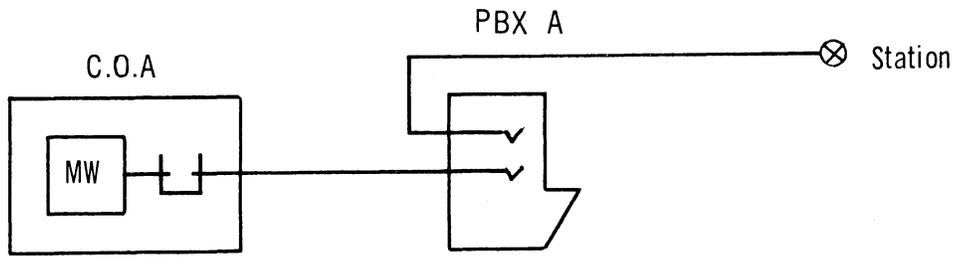
PBX FX trunks and objectives are illustrated in Fig. 11.

5.29 PBX WATS Trunks may be served from the central office which normally serves the PBX location or from a remote central office. Fig. 12 illustrates PBX WATS trunks to a local or remote Class 5 central office.

5.30 In some cases PBX WATS trunks may be terminated at toll central offices. Since this type of operation eliminates the toll connecting trunk which normally provides echo protection, PBX WATS trunks must meet terminal balance requirements. Fig. 13 illustrates PBX WATS trunks terminated at a toll central office. (See Par. 5.17.)

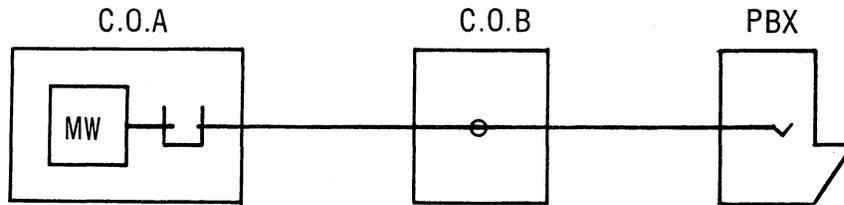
**E. PBX Stations**

5.31 On-premises PBX stations are usually located near the PBX equipment and have short loops with low loss. Transmission at such



| <u>From</u> | <u>To</u>                                                            |      | <u>EML (1000~)</u> |                          |
|-------------|----------------------------------------------------------------------|------|--------------------|--------------------------|
| MW in C.O.A | PBX                                                                  | Obj  | 0-3.5 db           | For PBX's <u>without</u> |
|             |                                                                      | Max. | 5.5 db             | Tie trunks               |
| "           | "                                                                    | Obj  | 0-3.5 db           | For PBX's <u>with</u>    |
|             |                                                                      | Max. | 3.5 db             | Tie trunks               |
| "           | Any PBX station, off-premise station, satellite or Trib. PBX station | Max. | 8.5 db             |                          |

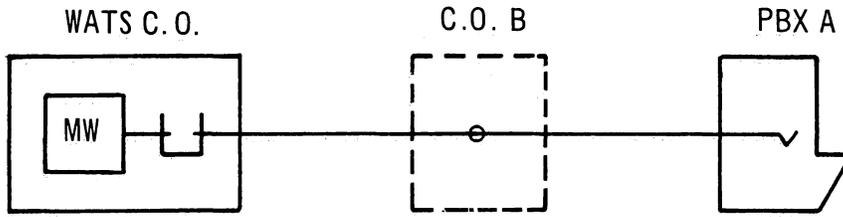
Fig. 10 – PBX Trunks



| <u>From</u>        | <u>To</u> |      | <u>EML (1000~)</u> |                  |
|--------------------|-----------|------|--------------------|------------------|
|                    |           |      | <u>Short Haul</u>  | <u>Long Haul</u> |
| MW supply in C.O.A | PBX       | Obj  | 0-3.5 db           | (VNL + 4.5) db   |
|                    |           | Max. | 5.5 db             | 6.5 db           |

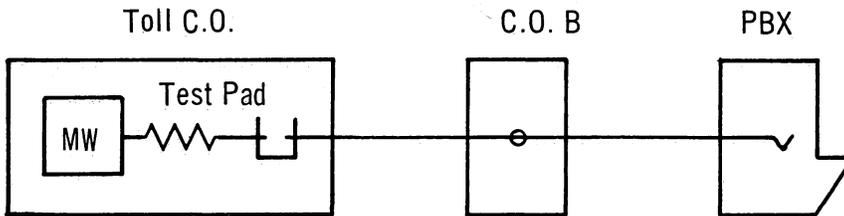
Note: Over-all loss from any PBX station to milliwatt supply at C.O.A should not exceed 8.5 db.

Fig. 11 – PBX — FX Trunks



| <u>From</u>               | <u>To</u> | <u>EML (1000~)</u> |                  | <u>Data Objective</u> |                                                 |
|---------------------------|-----------|--------------------|------------------|-----------------------|-------------------------------------------------|
|                           |           | <u>Short Haul</u>  | <u>Long Haul</u> |                       |                                                 |
| MW supply<br>in WATS C.O. | PBX       | Obj                | 0-3.5 db         | (VNL + 4.5) db        | Same as toll<br>connecting trunk<br>AB27.425.00 |
|                           |           | Max.               | 5.5 db           | 6.5 db                |                                                 |

Fig. 12 – PBX WATS Trunk to Class 5 C.O.



| <u>From</u>               | <u>To</u> | <u>EML (1000~)</u> |                 | <u>Data Objective</u> |                                                 |
|---------------------------|-----------|--------------------|-----------------|-----------------------|-------------------------------------------------|
|                           |           | <u>Short Haul</u>  | <u>or</u>       |                       | <u>Long Haul</u>                                |
| MW supply<br>in Toll C.O. | PBX       | Obj.               | (VNL + 4.5) db* | (VNL + 4.5)*          | Same as toll<br>connecting trunk<br>AB27.425.00 |
|                           |           | Max.               | 5.5 db          | 6.5 db                |                                                 |

\* Plus Test Pad Loss, if any.

Note: Terminal balance at Toll C.O. with trunk terminated in off-hook station at PBX must be at least 15 db.

Fig. 13 – PBX WATS Trunk to Toll C.O.

stations should be adequate if the objectives including the battery supply considerations as outlined in this section are met. The impedance of short station loops terminated in telephone sets does not match the compromise network impedance and low balance may result when the loops are connected to VNL tie trunks. At tandem PBXs it is essential that the 2 db switched pads are *in* when the VNL tie trunks are switched to station loops. These pads will provide protection against echo. Methods to improve the balance when stations are connected to trunks are under study. Fig. 14 illustrates PBX station loops.

**5.32** PBX off-premise stations (*OPS*) usually will make universal service calls to the exchange and toll networks. At PBXs which are a part of a tandem tie trunk network or a Switched Services network the OPSs will also be connected to tie trunks, access lines, FX trunks and WATS trunks. The stringent transmission requirements imposed by these connections may require one or more of the following treatments:

- (1) High grade facilities, generally loaded with good coil spacing.
- (2) Use of repeaters.
- (3) Location of battery supply to give optimum loop current.
- (4) 500-type sets.
- (5) 4-wire facilities.

PBX off-premise stations are shown in Fig. 15.

**5.33** In many cases it will be very difficult to meet the overall maximum objective of 8.5 db to the serving central office milliwatt supply from off-premise stations off satellite PBXs. This type of station should be used only if the 8.5 db objective can be met when the normal objectives are used for the main PBX central office trunks and the satellite tie trunks. If the objective cannot be met in this way the off-premise station should be re-homed on the main PBX or restricted to calls between the satellite and main PBXs only.

#### F. Tie Trunks

**5.34** Tie trunk operation can range from a simple one-link connection which is used only for voice transmission between PBX sta-

tions at both ends to a complex tandem network which is used for both voice and data transmission. The objectives given in this part for tie trunks will provide good transmission on the tandem networks and on many universal service connections. As mentioned before, some universal service connections will involve a multilink tandem network connected to the DDD network through PBX central office trunks. All such connections cannot be expected to produce transmission equivalent to the DDD network alone because the number of links may exceed the number contemplated for the toll network.

**5.35** *Satellite tie trunks* are used between satellite PBX and the main PBX. In some cases these tie trunks may become a part of a tandem tie trunk network. Fig. 16 illustrates satellite tie trunks.

**5.36** *Nontandem tie trunks* are used primarily for connections between stations at two main PBXs. Universal service connections may also be made at either main PBX, but not simultaneously at both ends of the same tie trunk. Nontandem tie trunks are shown in Fig. 17.

**5.37** Tandem PBX networks may be quite complex and provide a flexible private line switching system. The tandem switching for these networks will be performed at PBXs. This differs from the Switched Services networks where the tandem switching is performed at switching units in Telephone Company buildings. Sections AB23.053.0 thru AB23.053.4 discuss Switched Services networks.

**5.38** A tandem tie trunk network may have a single tandem PBX with two or more main PBXs homing on it through tandem tie trunks. This arrangement and the objectives for tandem tie trunks are shown in Fig. 18.

**5.39** A more complex tandem tie trunk network may have more than one tandem PBX. *Intertandem tie trunks* are used between the Tandem PBXs. The Intertandem tie trunks will be equipped with 2 db switchable pads at both ends. Balance tests are required at tandem PBXs where intertandem tie trunks terminate. Intertandem tie trunks are shown in Fig. 19.

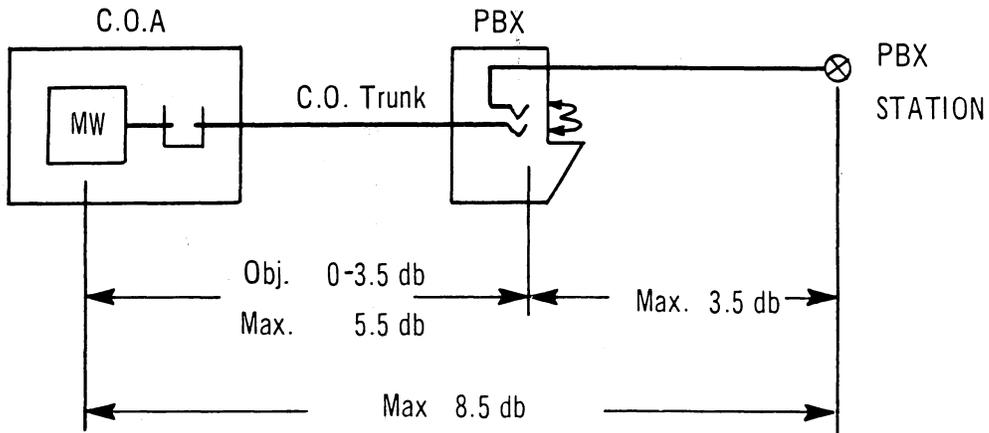
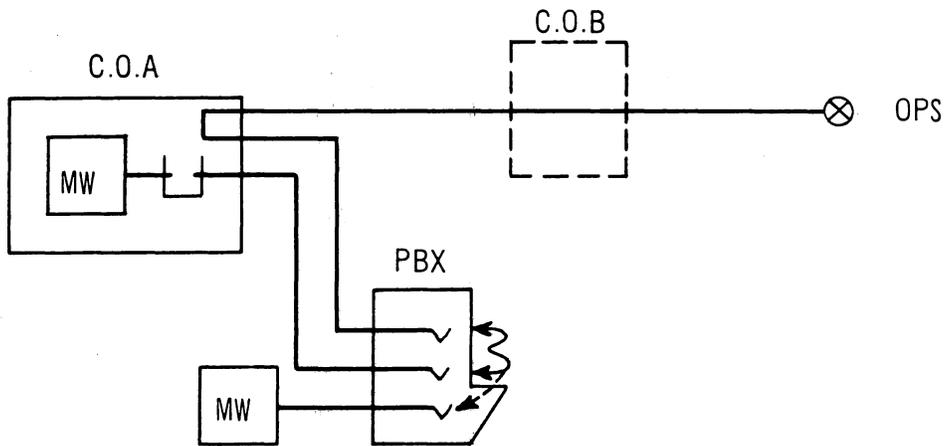
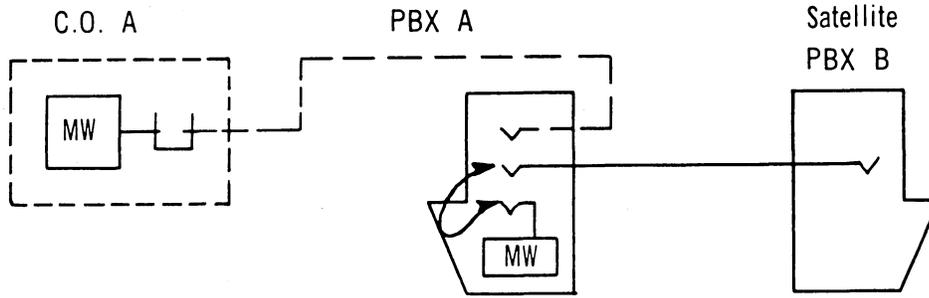


Fig. 14 – On-Premise PBX Stations



| From              | To  | EML (1000~) |                         | Data Objective                          |
|-------------------|-----|-------------|-------------------------|-----------------------------------------|
|                   |     | Short Haul  | Long Haul               |                                         |
| MW supply at PBX  | OPS | Obj.        | 0-3.5 db (VNL + 4.5) db | Same as DATA-PHONE loop per AB27.425.00 |
|                   |     | Max.        | 5.5 db 6.5 db           |                                         |
| MW supply at C.O. | OPS | Obj.        | 0-3.5 db                |                                         |
|                   |     | Max.        | 5.5 db 8.5 db           |                                         |

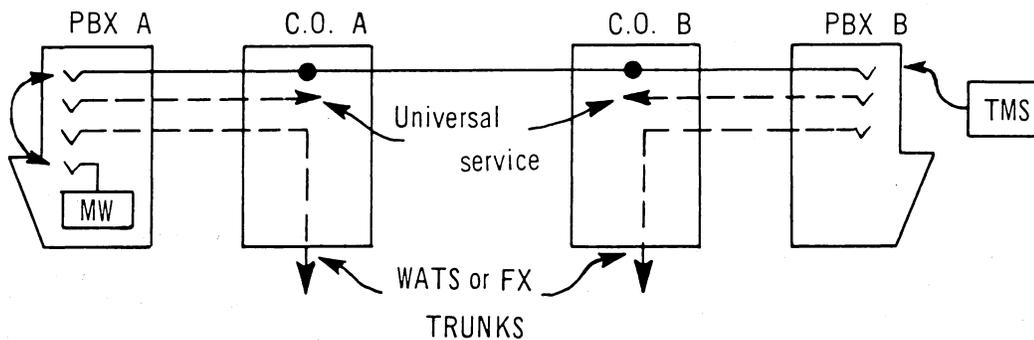
Fig. 15 – Off-Premise PBX Stations



| <u>From</u>    | <u>To</u> | <u>EML (1000~)</u>                                    |
|----------------|-----------|-------------------------------------------------------|
| MW at<br>PBX A | PBX B     | <u>Short Haul only</u><br>Obj 0-3.5 db<br>Max. 5.5 db |

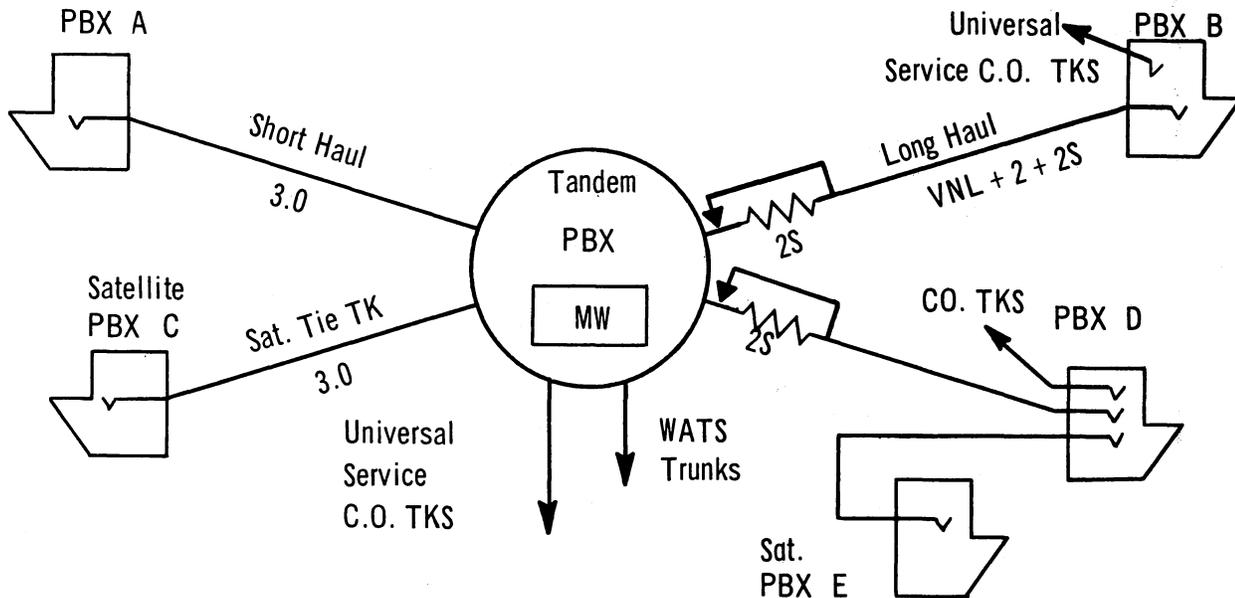
Note: No station at the satellite PBX should be more than 8.5 db from the milliwatt supply at the central office (C.O.A ).

Fig. 16 - PBX Satellite Tie Trunks



| <u>From</u>        | <u>To</u> | <u>EML (1000~)</u>   |                  | <u>Data</u>                                                                 |
|--------------------|-----------|----------------------|------------------|-----------------------------------------------------------------------------|
|                    |           | <u>Short Haul</u>    | <u>Long Haul</u> |                                                                             |
| MW supply<br>PBX A | PBX B     | Obj . (VNL + 2.5) db | (VNL + 4.5) db   | Meet Require-<br>ments of<br>AB27.425.00<br>for Toll con-<br>necting trunks |
|                    |           | Max. 5.5 db          | (VNL + 4.5) db   |                                                                             |

Fig. 17 - Nontandem Tie Trunks



| From                    | To             | EML (1000~)                               |                       | Data                                        |
|-------------------------|----------------|-------------------------------------------|-----------------------|---------------------------------------------|
|                         |                | Short Haul                                | Long Haul             |                                             |
| MW supply at Tandem PBX | PBX A, B, or D | Obj (VNL + 2.5) db<br>Max. (VNL + 2.5) db | (VNL + 2.5 + 2S)<br>* | Toll connecting Requirements<br>AB27.425.00 |

Note: 2S is a 2 db switch pad.

\* Subject To Echo Limitations Covered In Part 3.

Fig. 18 – Tandem Tie Trunks — Single Tandem PBX

6. PAD CONTROL

6.01 The Tandem PBX serves a purpose similar to a Class 3 toll office in the DDD network when it interconnects Intertandem Tie Trunks. Since these tie trunks will be operating at VNL (equivalent to Intertoll Trunks in the DDD network) it will be necessary to meet office and/or terminal balance requirements on through or terminating calls, respectively. The echo return loss and singing point requirements to be met at the tandem PBX are shown in Table III. Through and terminal balance procedures for PBXs are covered in Plant Series Practices.

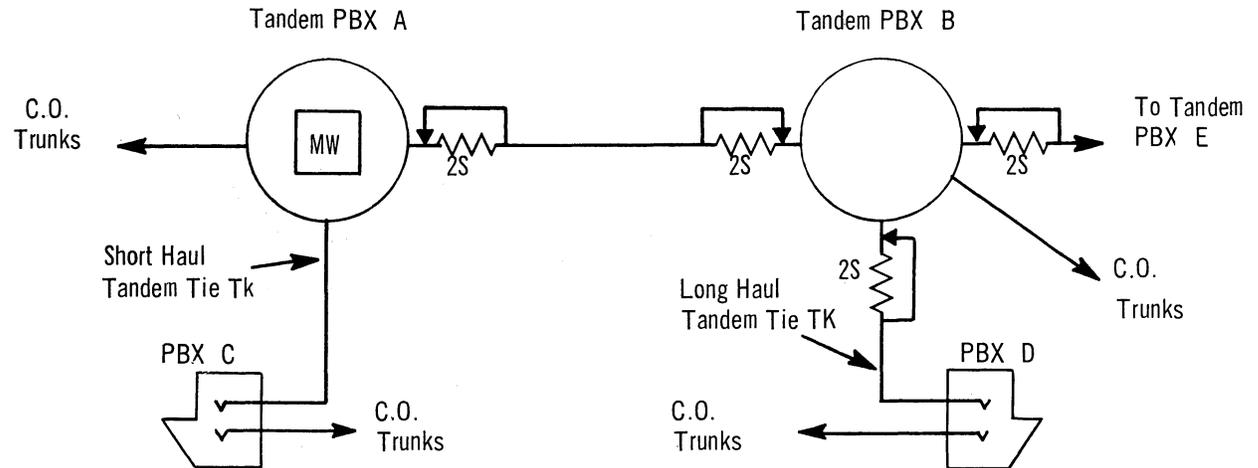
6.02 Pad switching arrangements at a Tandem SXS PBX are shown in Fig. 20. The 2 db switch pad provides adequate echo margin

on terminating connections to PBX stations and other special service circuits with facility losses less than 2 db. The switch pad can be switched **out** if a special service circuit has a facility loss greater than 2 db and if the impedance of the facility has been improved by use of impedance compensators.

6.03 The switch pad is controlled as follows:

Terminating Connection

On terminating calls at a Tandem PBX over an intertandem tie trunk to a special service circuit or a station, the normal post springs of the incoming selector of the called Tandem PBX will not be arranged to cause the 2 db pad to be removed.



| <u>From</u>        | <u>To</u> | <u>EML (1000 ~)</u>                                                          | <u>Data</u>                                 |
|--------------------|-----------|------------------------------------------------------------------------------|---------------------------------------------|
| MW supply<br>PBX A | PBX B     | <u>Short Haul or Long Haul</u><br>Obj. $VNL + 0.5 + 2S^* + 2S^*$<br>Max. * * | Intertoll trunk requirements<br>AB27.425.00 |

\*2S is a 2 db switch pad

\* \* Subject to Echo Limitations Covered in Part 3.

Note: Terminal balance required at PBX A ,  
Through and Terminal balance required at PBX B

Fig. 19 – Intertandem Tie Trunks

**Tandem or Thru Connection**

When a call comes to a Tandem PBX from an Intertandem Tie Trunk and is to be connected, to a Tandem Tie Trunk or to a special service circuit which has had impedance improvement and whose loss is greater than 2 db, the normal post springs of the incoming selector are adjusted to place a resistance ground on lead "0." The resistance ground will operate relay TPC. Relay TPC operates relay PO which removes the 2 db transmission pad in the incoming circuit. As soon as the incoming selector completes the circuit through its banks, and if the connected circuit also has a switch pad, relay TSP associated with the outgoing circuit will operate causing its associated relay PO to operate

which removes the 2 db transmission pad in the outgoing circuit.

**Switchboard Connection**

On incoming calls to the attendant, the incoming selector normal post springs will be arranged to operate relay TPC. However, other relay operation in the tie trunk circuit will cause the switchboard lamp to light and the release of the incoming selector, which will cause the transmission pad to be inserted. When the attendant determines that the call will be completed via a circuit requiring a **pad out** condition, she will use the THRU jacks of both circuits. In this instance, relays ASP in both circuits operate causing the associated **PO** relays to operate. This removes the transmission pad in both circuits.

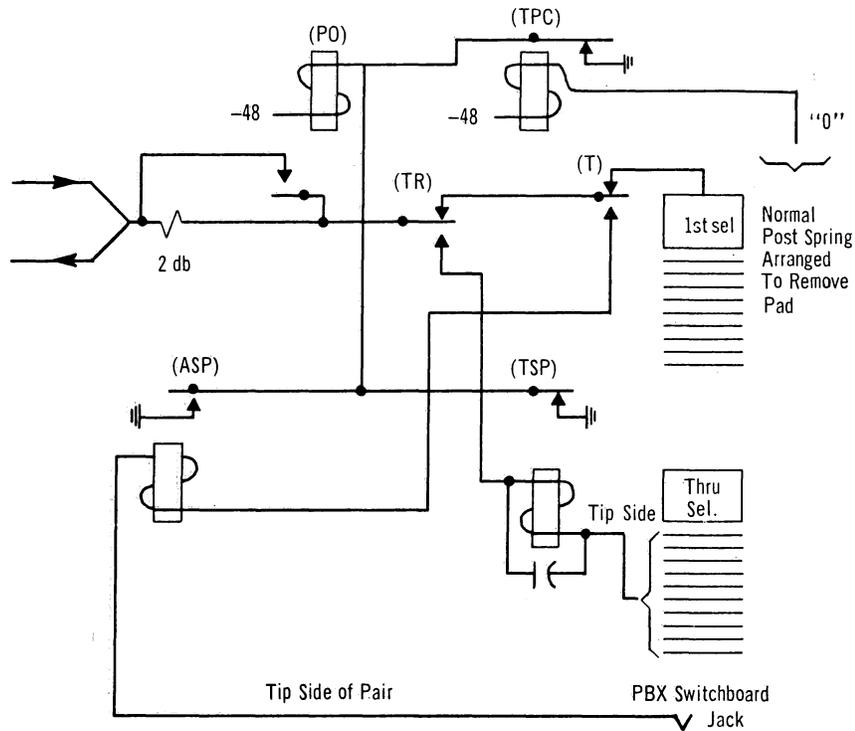


Fig. 20 – Switch Pad Control at a SXS Tandem PBX

7. DESIGN DATA

7.01 Via Net Loss factors for the types of facilities used for special services and PBX circuits are listed in Table I. The VNL formula which requires the use of these factors is discussed in Par. 3.09.

7.02 Loss data, at 1000 cycles, for all commonly used facilities is listed in Table VIII. Typical loss values are included for many of the standard equipment components which are used to provide special service circuits.

7.03 Resistance data for various cable gauges and equipment items are given in Table IX.

CHART A  
ROUND TRIP DELAY VS LENGTH  
CABLE FACILITIES

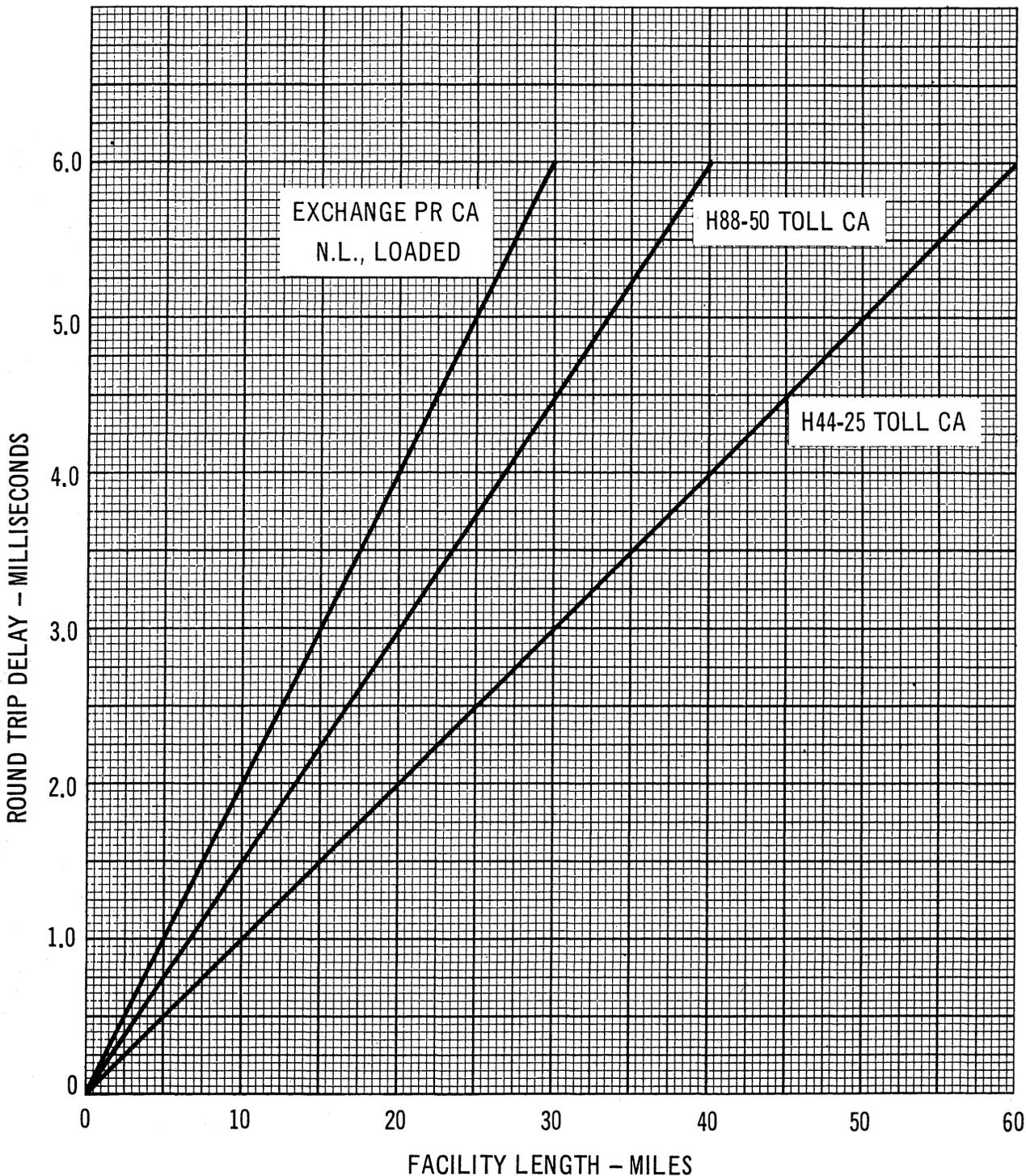


CHART B  
ROUND TRIP DELAY VS LENGTH  
CARRIER FACILITIES

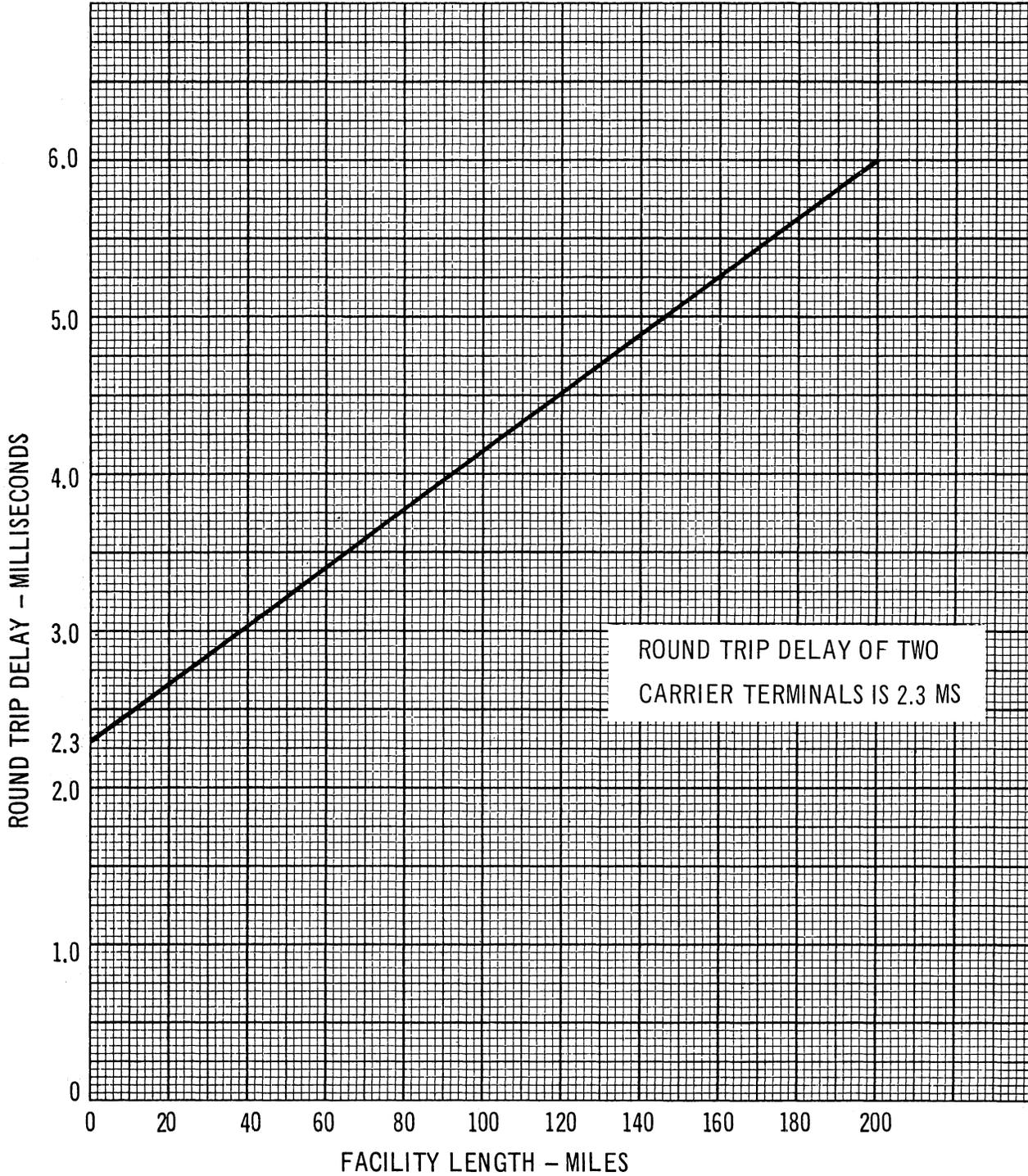
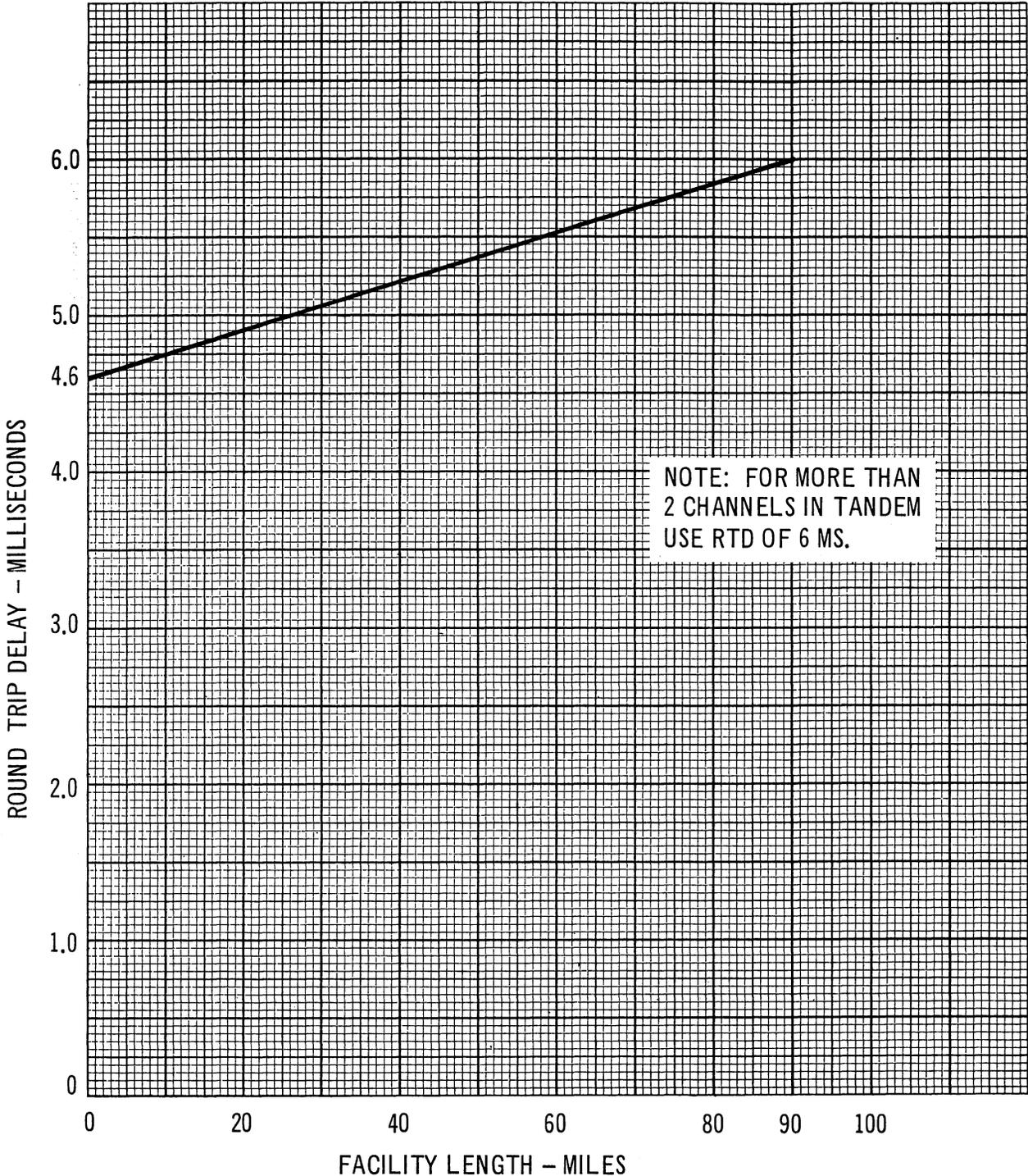


CHART C

ROUND TRIP DELAY VS LENGTH  
TWO CARRIER CHANNELS IN TANDEM  
(ANY TYPE SYSTEM OR CHANNEL UNITS)



**TABLE VIII**  
**1000-Cycle Loss Data**  
**for Representative Facilities and Equipment**  
**Used in Special Service Circuit Design**

| FACILITIES               | 1000-CYCLE LOSS IN DB |          | 2300-CYCLE LOSS IN DB |          |
|--------------------------|-----------------------|----------|-----------------------|----------|
|                          | KF.                   | PER MILE | KF.                   | PER MILE |
| 19H88-50 Side            | —                     | .35      | —                     | .36      |
| 1944-25 Phantom          | —                     | .30      | —                     | .30      |
| 19H44-25 Side            | —                     | .47      | —                     | .48      |
| 19H44-25 Phantom         | —                     | .39      | —                     | .40      |
| 19H44 Paired Cable (CNB) | .11                   | .56      | .11                   | .57      |
| 22H44 Paired Cable (BSA) | .20                   | 1.05     | .21                   | 1.08     |
| 24H44 Paired Cable (DSM) | .27                   | 1.57     | .32                   | 1.68     |
| 26H44 Paired Cable (BST) | .42                   | 2.20     | .42                   | 2.5      |
| 19H88 Paired Cable (CNB) | .08                   | .42      | .083                  | .44      |
| 22H88 Paired Cable (BSA) | .15                   | .79      | .15                   | .80      |
| 24H88 Paired Cable (DSM) | .23                   | 1.21     | .23                   | 1.23     |
| 26H88 Paired Cable (BST) | .34                   | 1.80     | .35                   | 1.86     |
| 19 ga. N.L.              | .24                   | 1.27     | .35                   | 1.84     |
| 22 ga. N.L.              | .34                   | 1.80     | .51                   | 2.7      |
| 24 ga. N.L.              | .44                   | 2.31     | .64                   | 3.4      |
| 26 ga. N.L.              | .54                   | 2.85     | .84                   | 4.41     |

| EQUIPMENT                               | 1000-CYCLE LOSS           |
|-----------------------------------------|---------------------------|
| Dial Long Lines Circuit (DLL)           | 0.4                       |
| Repeating Coils                         | 0.5 (nominal)             |
| Dial Repeating Tie Trk Ckt.<br>(2-wire) | 0.5                       |
| Terminating Sets (nominal)              | 4.0 (Trgs, and Rec.)      |
| Line Units                              | See SD-95144-01           |
| 837B Impedance Compensator              | Depends on BOR adjustment |

| COMPONENTS                | 1000-CYCLE LOSS |
|---------------------------|-----------------|
| PBX Office Cabling Loss   | 0.2 (nominal)   |
| Central Office Cabling    | 0.3 (nominal)   |
| Connector Loss to MW Test | 0.5 (nominal)   |

**TABLE IX**  
**Resistance Data**  
**for Representative Cable Wire Gauges and Equipment**  
**Used in Special Service Circuits**

| NONLOADED CABLE          |      | RESISTANCE OHMS PER                     |  |
|--------------------------|------|-----------------------------------------|--|
| GAUGE                    | MILE | KF.                                     |  |
| 19                       | 85   | 16                                      |  |
| 22                       | 171  | 32                                      |  |
| 24                       | 274  | 52                                      |  |
| 26                       | 440  | 83                                      |  |
| <br>                     |      |                                         |  |
| LOADED CABLE             |      |                                         |  |
| 19H88                    | 93   | 18                                      |  |
| 22H88                    | 179  | 34                                      |  |
| 24H88                    | 282  | 53                                      |  |
| 26H88                    | 448  | 85                                      |  |
| <br>                     |      |                                         |  |
| EQUIPMENT                |      | RESISTANCE (ohms)                       |  |
| E-6                      |      | 65 terminal<br>90 intermediate plus LBO |  |
| E-6 disabler             |      | 120                                     |  |
| <br>                     |      |                                         |  |
| STATION SETS             |      |                                         |  |
| 500                      |      | 150 (nominal)                           |  |
| Other                    |      | 115                                     |  |
| <br>                     |      |                                         |  |
| D.L.L. (nominal)         |      | 125                                     |  |
| SD-96234-01 and 96555-01 |      | 231                                     |  |
| SD-95435-01              |      | 471                                     |  |

