♦NO. 1/1A ESS OFFICES♦ WITH HILO 4-WIRE SWITCHING FEATURE THROUGH AND TERMINAL BALANCE GENERAL INFORMATION

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1. GENERAL

1.01 Through and terminal balance are the adjustment, measurement, and evaluation processes employed to control echo and singing in the ➧Message Telecommunications System (MTS) network.➧ All balance work performed by plant maintenance personnel is intended to be coordinated with the transmission engineering organization that has the responsibility to certify that the toll office is properly balanced. This section covers, in general, the information pertaining to these processes in class 4 or higher ranking ➧No. 1/1A Electronic Switching Systems (ESSs)➧ with the HILO 4-wire switching feature. This feature is described in Section 231-090-366. ***Through*** balance is necessary when switching intertoll trunks to secondary intertoll (IT to SI) trunks or when connecting SI to SI trunks with cord circuits by an operator at switchboards associated with class 3 and higher ➧No. 1/1A ESS➧ offices with HILO 4-wire switching feature. ***Terminal*** balance is necessary when IT or SI trunks are switched or cord connected to toll connecting (TC) trunks via a ➧No. 1/1A ESS➧ switching machine with HILO 4-wire switching feature and/or an associated toll switchboard.

1.02 This section is reissued to add information on the 1A Electronic Switching System with HILO 4-wire switching feature.

1.03 This section does not affect Equipment Test Lists.

1.04 The general considerations contained in this section provide a ***basic*** understanding of the purposes, requirements, measurements, and techniques encountered in the through and terminal balancing processes. Detailed information concerning specific areas within the broad scope of through and terminal balancing can be found in the reference material outlined in Part 11. Additional sections which concern balancing in a ➧No. 1/1A ESS➧ office with HILO 4-wire switching feature are:

SECTION	TITLE
660-470-010	Through and Terminal Balance Records
660-470-300	Through Balance Requirements
660-470-301	Terminal Balance Requirements
660-470-500	NBO Selection for Associated Switchboards for Through and/or Terminal Balancing
660-470-501	Through Balance—Drop Buildout (DBO) Procedures and Verification Tests
660-470-502	Terminal Balance—Drop Buildout Procedures and Verification Tests
660-470-503	Analysis of Poor Results and Troubleshooting Procedures (to be issued)
660-470-504	Test Routines, Test Circuits, Test Terminations, and Test Equipment Applications for Through and Terminal Balance
660-470-520	➧Selection of Office NBO in Large Class 5 Offices Served by No. 1/1A Electronic Switching Systems with HILO 4-Wire Switching Feature.➧

The information contained in the sections listed above can be applied to balance work initially, or on a circuit order work basis required to complete Form E-2545A described in Section 660-450-010. The structure of the information contained in these sections is in accordance with the sequence required in performance of balance work and can be used as shown in Fig. 1.

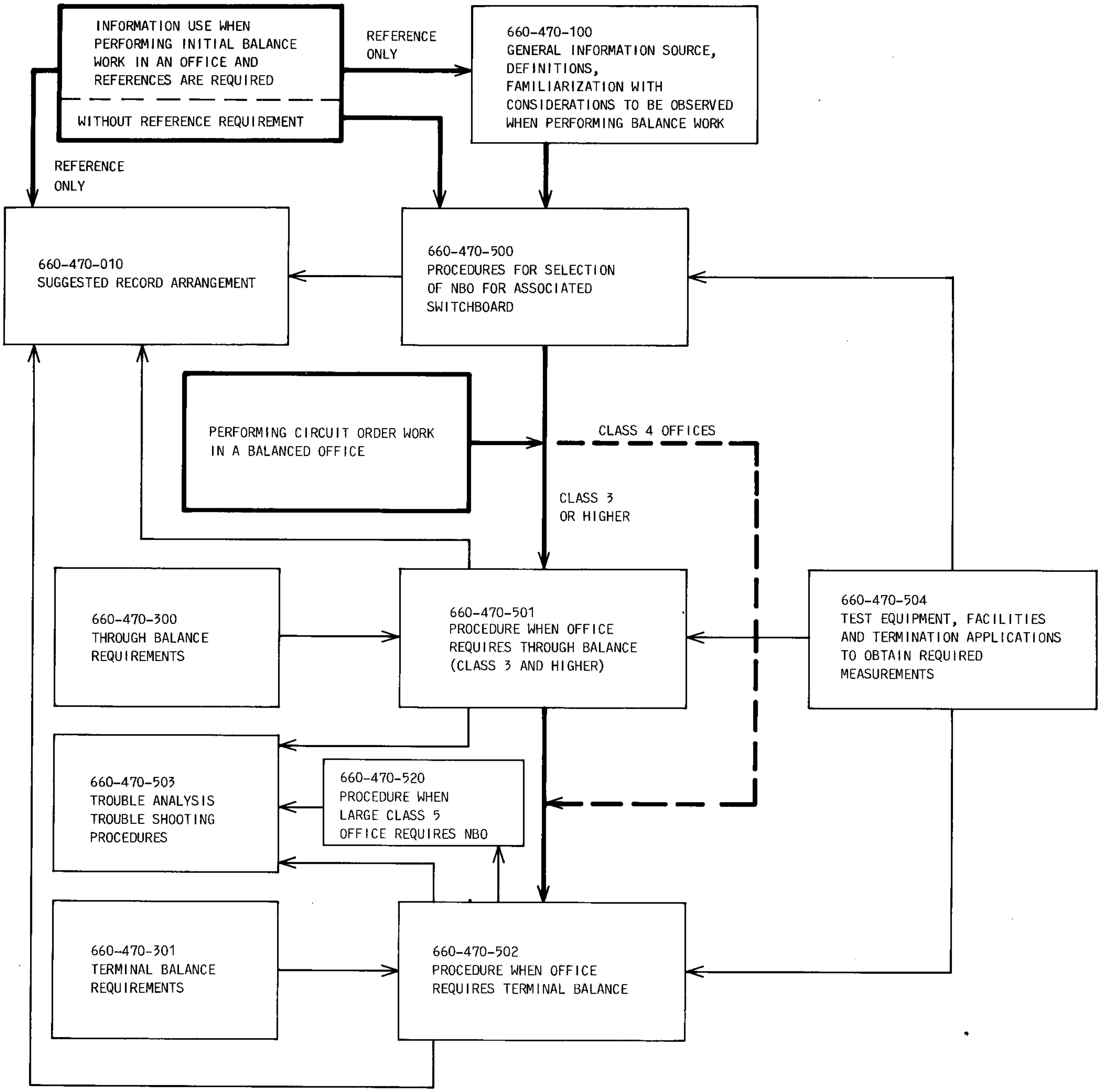


Fig. 1—Use of Information Contained in Sections 660-470-ZZZ

1.05 The classification and types of IT and TC trunks are shown in Table A. The switchboard-terminated types of trunks (SI and TC) shown in this table refer only to trunks served by toll switchboards appearing in the same building or a building adjacent to the associated switching machine. Normally, DTO- and DSA-type operator switchboards are remotely located from a switching machine and are considered to be class 4P toll switching offices in the MTS hierarchy plan for office classifications. These switchboards and those associated with more than one toll switching machine are balanced as class 4P offices using procedures in Section 660-475-ZZZ.

TABLE A

MESSAGE TRUNK CLASSIFICATIONS AND TYPES

CLASSIFICATION	PURPOSE	TYPE
Intertoll	Trunks between toll switching offices (class 4 and higher ranking)	(1) One-way (IT) (2) 2-way (IT)
Secondary Intertoll	Trunks between toll switchboards and toll switching machines (class 4 and higher ranking)	(1) Operator assistance (2) Operator junctor (3) Toll tandem
Toll Connecting	Trunks between class 5 (end offices) offices and toll switchboards or toll switching machines (class 4 and higher ranking)	*Machine Terminated* (1) Machine toll switching trunks (TC) and (TM) (2) CAMA trunks (3) ANI trunks (4) TSPS/RTA (5) Machine path of operator office trunks (00) (6) Subscriber terminating equipment (mobile radio, coastal harbor, etc) (7) CAMA junctor *Switchboard Terminated* (1) Recording-completing, flat rate (RC) (2) Recording-completing, message rate (RC) (3) Recording-completing, hotel-motel, etc (RC) (4) Toll switching, flat rate (TS) (5) Toll switching, message rate (TS) (6) Toll switching, hotel-motel (TS) (7) Subscriber-terminating (mobile radio, coastal harbor, etc) (8) Switchboard path of 2-way operator office trunks (00)
Special Service	Trunks terminated directly on toll switchboard or toll switching machine	LD, INWATS, OUTWATS, DID, DOD

1.06 When balancing a ♦No. 1/1A ESS♦ office with the HILO 4-wire switching feature and its associated toll switchboard, the selection of network buildout (NBO) capacitance and any required drop buildout (DBO) capacitance for switchboard terminating trunks may be done independently of the ESS environment. This can be accomplished if proper trunk signaling is arranged for in the switchboard end of the SI trunks. Otherwise, the ESS machine is necessary to cause proper signaling conditions in the incoming and outgoing SI trunks. The balance work for both the ESS environment and the toll switchboard must be completed before any verification tests via the switchboard can be completed. Figure 2 is typical of the trunking in ♦No. 1/1A ESS♦ toll switching offices with HILO 4-wire switching feature.

1.07 The initial performance and subsequent maintenance of the through and terminal balance in the 2-wire lines (2WL) of toll switching offices is important and essential to present-day toll transmission requirements. It is important because it permits via net loss (VNL) design concepts to be applied to trunks in the MTS network, and it is essential because of the present extensive use of 2-wire toll switchboards and 2-wire toll connecting trunks. The VNL design results in toll connections having the lowest practical loss consistent with satisfying the echo requirements of basic transmission design (see Section 781-030-100).

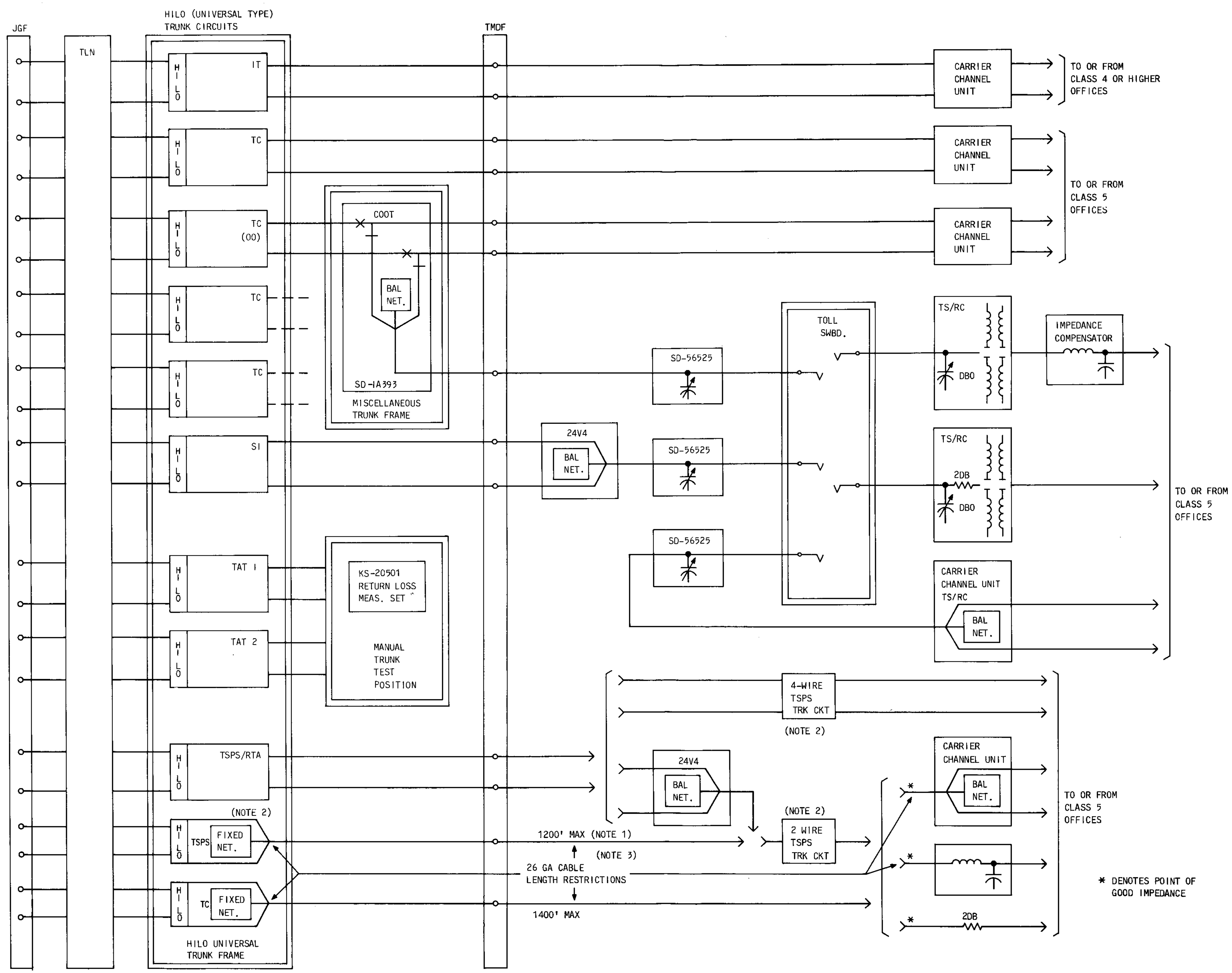
1.08 A comprehensive system of records is recommended for all balancing work (see Section 660-470-010). These records should reflect the initial balancing conditions of the office and any subsequent balancing that is required in circuit order work. Proper records are required for office certification by the certifying transmission engineer. They are also useful during periodic inspections to determine whether the balance conditions within an office or a given trunk group have changed.

2. TRANSMISSION CONSIDERATIONS

A. General

2.01 Today's media for IT trunk transmission are 4-wire carrier facilities. These 4-wire facilities are terminated as 4-wire circuits and converted to 2-wire circuits when used to make 2-wire TC trunks or when operators' switchboards are used to make IT to SI, or SI to TC connections. The termination of the 4-wire facility and the conversion to 2-wire is accomplished with a balanced transformer-type junction (hybrid coil circuit) between the 4-wire and 2-wire circuits. The hybrid junction may be a separate 4-wire terminating set (4WTS) or an integral part of the trunk relay equipment. The hybrid junction is a 4-port device where two ports are connected to the 4-wire circuit, one port is connected to the 2-wire circuit, and one port is connected to a balancing network. This arrangement permits the transfer of power from the 4-wire receive path into the 2-wire circuit and from the 2-wire circuit into the 4-wire transmit path. Because of the transformer-type junction and the fact that power reflections occur when impedance irregularities exist between the 2-wire circuit and the balancing network, control of the 2WL or network impedance is necessary.

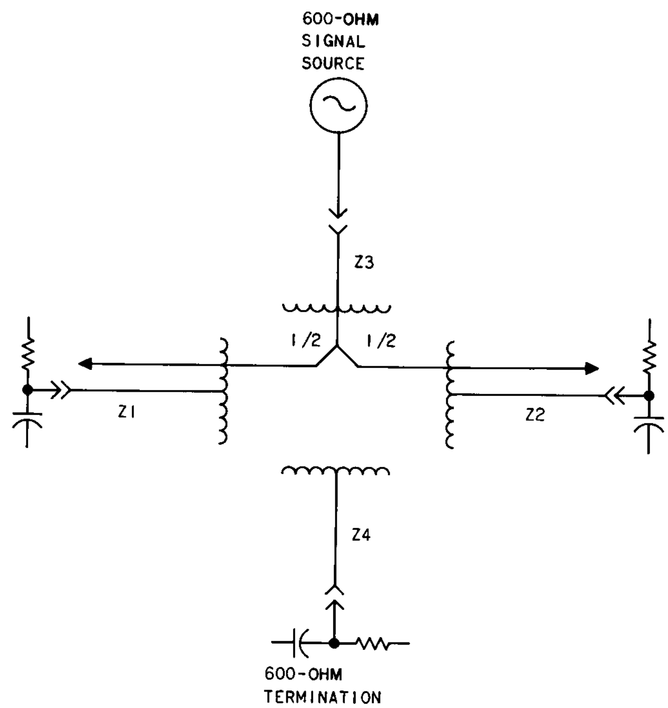
2.02 Figure 3A demonstrates the power division that occurs when a signal is applied to any port of a balanced hybrid coil arrangement such as found in the 4WTS devices. The figure assumes that all impedances including the source impedance are identical. In this assumed case, the power is dividing equally across the hybrid, and one-half of the input power is absorbed in each of the impedances Z1 and Z2. Applying the notation shown in Fig. 3A to impedances Z1 through Z4 and including the hybrid coil arrangement permits consideration of the hybrid as part of a typical 4WTS as shown in Fig. 3B. Here, the impedance value of Z1 (balancing network consisting of a 2-wire network line terminated with a compromise network) and that of Z2 (2WL terminated) are indicated to be different (impedances are not matched), which is the general case in a 2-wire switching office before any balancing is done. If the impedance Z1 is greater than the impedance Z2, the input power continues to divide across the hybrid coils as shown in Fig. 3B; however, the power absorbed in impedance Z2 is less than that absorbed in impedance Z1. This unabsorbed power from the 2WL (Z2) is reflected back into the hybrid coil arrangement as indicated by the dashed line. The reflected power will again divide across the hybrid as shown and re-enter the 4-wire facility transmit and receive paths. The magnitude of this reflected power back into the hybrid will increase (while the input power remains constant) as the difference (impedance mismatch) between Z1 and Z2 becomes greater. If the impedance conditions were reversed, ie, if Z1 were smaller than Z2, the power reflections would originate from the balancing network (Z1). In an ideal situation



NOTES:

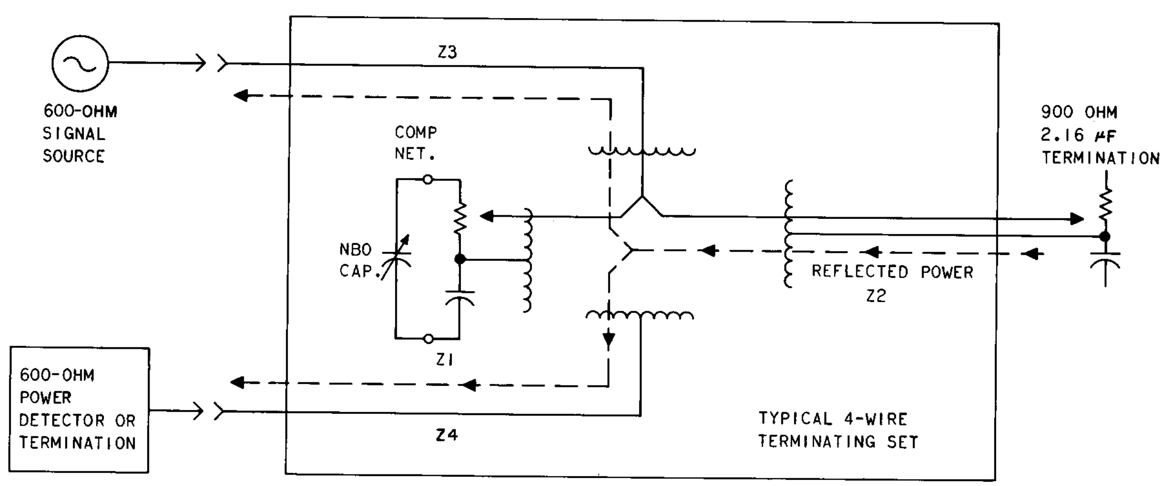
1. TSPS SECTION 852-404-100 INDICATES THAT A 0.5dB MAXIMUM LOSS IS DESIRED BETWEEN THE TSPS TRUNK CIRCUIT AND THE OUTGOING TOLL SWITCH APPEARANCE. THEREFORE THE 0.5dB MAXIMUM LOSS REQUIREMENT TAKES PRECEDENCE OVER THE TERMINAL BALANCE CABLE LENGTH RESTRICTION.
2. 2-WIRE TSPS TRUNK CIRCUITS SHOULD BE LIMITED TO EARLIER TSPS INSTALLATIONS WHERE 4-WIRE SWITCH CONVERSIONS HAD NOT BEEN CONSIDERED. 4-WIRE TSPS TRUNK CIRCUITS ARE DESIRABLE WITH 4-WIRE SWITCH AND 4-WIRE FACILITIES. THEREFORE NEW TSPS INSTALLATIONS SHOULD USE 4-WIRE TRUNK CIRCUITS WHERE 4-WIRE SWITCHING MACHINES ARE PLANNED IN THE FUTURE.
3. CABLE RESTRICTIONS ARE DISCUSSED IN DETAIL IN PARAGRAPH 3.17.

Fig. 2—No. 1/1A ESS With HILO 4-Wire Switching Toll Office Arrangements and Trunking Schematics



NOTES:
1. Z1 = Z2, Z3 = Z4
2. PARAMETERS ARE COMPARED TO PARAMETERS OF FIG. 3B AS FOLLOWS:
   Z1 = BALANCING NETWORK
   Z2 = 2-WIRE LINE
   Z3 = 4-WIRE RECEIVE
   Z4 = 4-WIRE TRANSMIT

A. POWER DIVISION IN A BALANCED HYBRID COIL ARRANGEMENT



B. INPUT AND REFLECTED POWER PATHS IN TYPICAL 4WTS

Fig. 3—Hybrid Power Division and Application

where Z1 equals Z2 (impedances match), no reflection would occur. This, however, is impractical in switchboard terminating trunks associated with the HILO 4-wire office since the balancing network is a fixed impedance and many possible variations of the 2WL impedances are available in connections within a toll switching office. Therefore, in balancing switchboard terminating trunks associated with the HILO 4-wire office, the ultimate aim is to obtain the best practical impedance matches at the hybrids over the greatest number of trunks.

B. Echo and Singing

2.03 Whenever power is reflected into the 2- to 4-wire junction of an IT trunk, the portion that returns into the transmitting path of the 4-wire facility is amplified in the carrier equipment and returned to the distant end (see Fig. 4). If the returned power is received at the distant end with sufficient magnitude (ie, the loss to the returning power is small), return loss impairments to transmission can occur.

2.04 Subjective testing has shown that when the power is returned with sufficient magnitude and delay, a talker hearing his own voice repetitions experiences thought process disturbance and interference with ease of conversation. This type of return loss impairment is called talker echo.

2.05 Singing is a return loss type of transmission impairment occurring when the return losses are small and when the power is returned at a single frequency with sufficient magnitude to start self-sustained oscillations. This impairment always exists when the gains exceed the losses in a circuit from termination to termination. However, before the circuit starts to sing, an impairment known as near singing occurs. Near singing is like the hollow sound that occurs when speaking into an empty barrel.

2.06 The voiceband frequencies in MTS connections are normally limited by the 4-wire facilities to the 200- to 3400-Hz range. When transmission in an MTS connection is impaired by echo, the frequency band which talkers will notice as objectional is 500 to 2500 Hz. At these frequencies, the talker will normally complain of echo somewhat before the circuit will start to sing. Therefore, the balancing objectives for control of the return loss in this frequency range are more stringent than the objectives for the control of return loss at other frequencies in the limited voiceband.

2.07 Singing will generally occur in the frequency ranges from 200 to 500 Hz and 2500 to 3200 Hz. Singing or near singing occurring in these ranges will be noticed by a talker before echo becomes objectionable. Figure 5 indicates the echo and singing frequency ranges within the voice frequency (VF) band.

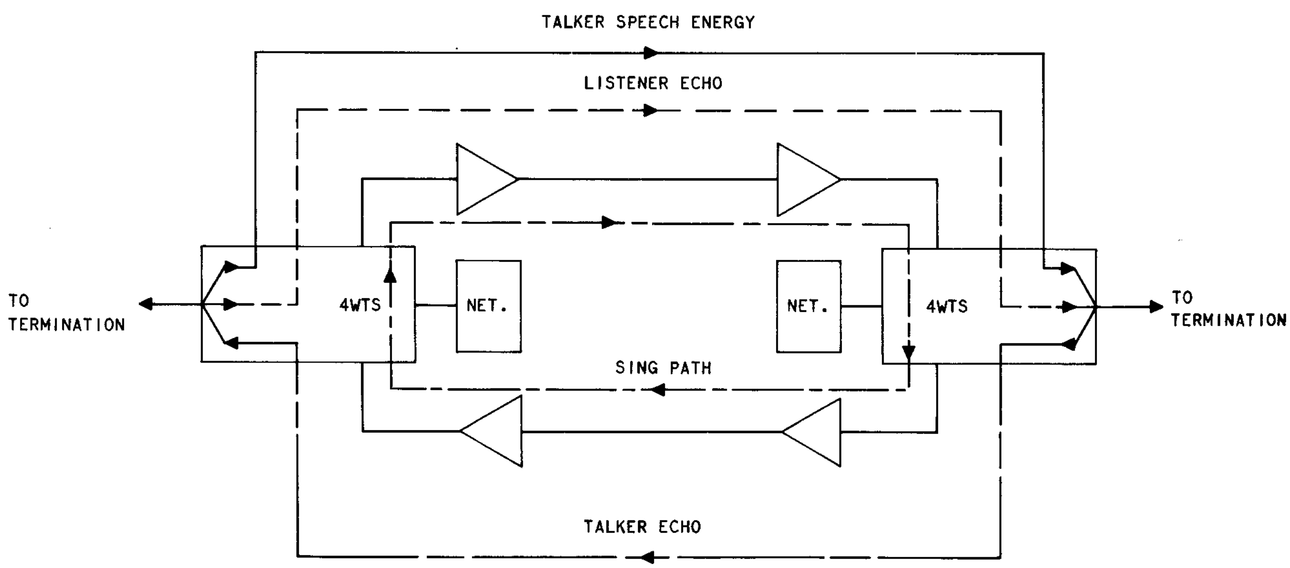


Fig. 4—One-Way Energy Paths in 4-Wire Circuits Terminated in 2-Wire Circuit

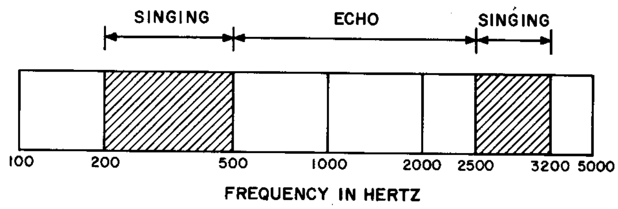


Fig. 5—Echo and Singing Ranges in a Typical Voiceband Frequency Spectrum

2.08 In the energy paths illustrated in Fig. 4, the talker echo path is dependent upon the return loss conditions at only one end of a 4-wire facility. The listener echo path is dependent upon poor return loss at both hybrid ends of a 4-wire facility. Since controlling the talker echo energy paths in both directions will also result in control of the listener echo energy paths, the listener echo paths are not considered in office balancing procedures. In addition, singing and near singing are also dependent upon poor return loss conditions at each end of a 4-wire facility; but unlike echo impairments which are influenced by propagation delay, they are influenced by frequency, phase relationships, gains, and power addition. Consequently, both through and terminal balancing include separate test methods for each of the return loss impairments, ie, echo return loss (ERL) and singing return loss (SRL). ERL measurements determine echo conditions and the SRL measurements determine singing and near singing conditions. The results of both measurements are necessary to obtain integrity in the evaluation of balance in a given circuit. A further consideration is that the magnitude of returned power in a connection is an enhancement factor to the echo and singing impairments and not the absolute cause.

C. Definitions

Return Loss

2.09 Specifically, return loss is the measure of an impedance match between two circuits at the point of their interconnection. It can be expressed for any frequency as:

$$RL = 20 \log_{10} \frac{|Z1 + Z2|}{|Z1 - Z2|} \text{ dB}$$

where Z1 and Z2 are the impedances of the interconnecting circuits.

Considering this equation and the factors of impedances Z1 and Z2, it can be seen that, at a given frequency, the return loss is infinite at the interconnection point when the impedances are equal (balanced), since n/0 is infinity by definition. Conversely, a complete mismatch (imbalance) will occur when either but not both Z1 or Z2 is zero. The return loss for the frequency then becomes zero since the logarithm of 1 is zero.

Echo Return Loss (ERL)

2.10 ERL is a weighted average measurement of the return losses for all the voice frequencies in the echo range (500 to 2500 Hz). This measurement is determined in a specific manner at the hybrid interconnection of the 4-wire and 2-wire circuits (see Part 5). This measurement does not necessarily indicate the return loss at an individual frequency.

Singing Return Loss (SRL)

2.11 SRL is the lower value of the weighted average measurement of the return losses in one of two frequency bands (200 to 500 Hz and 2500 to 3200 Hz). A measurement in the lower portion of the VF band and a measurement in the upper part of the VF band are made in a specific manner at the hybrid interconnection of the 4-wire and 2-wire circuits (see Part 5). Both measurements are made and the lower reading is taken as the SRL value.

Point of Good Impedance

2.12 The point of good impedance is that point in a switched connection where the impedance is constant. The point of good impedance is used to describe maximum office cable length and is basic to the balance plan in ♦No. 1/1A ESS♦ offices with HILO 4-wire switching feature. It is defined as the 2-wire input to a 4WTS, or the toll office side of impedance compensators or 2-db pads in 2-wire TC trunks.

2.13 The point of good impedance of 4WTSs exists when the 4-wire transmit and receive ports are properly terminated. In 2-wire TC trunks, the point of good impedance at the office side of an impedance compensator or a 2-dB pad can be substituted with a termination consisting of a 900-ohm resistor connected in series with a 2.16 μF capacitor.

Trans-Hybrid Loss (THL)

2.14 THL is the amount of loss between the 4-wire receive and transmit ports of a 2- to 4-wire hybrid junction when the 2WL is shorted at the hybrid. The THL includes the fixed loss of cable and pads in the 4-wire portion of the hybrid circuit plus the normal hybrid loss (6.5 to 8.0 dB) caused by the power division in the hybrid and the inherent loss of the coils. The measurement must be made in a specific manner (see Part 5).

3. ♦NO. 1/1A ESS♦ OFFICE WITH HILO 4-WIRE SWITCHING FEATURE AND ASSOCIATED TOLL TRANSMISSION EQUIPMENT AND CABLE CONSIDERATIONS

A. ESS Trunk Relay Circuits

3.01 Two types of trunk relay circuits are provided by ♦the No. 1/1A ESS♦ when arranged with the HILO 4-wire switching capability. They are universal type plug-in trunk circuits and miscellaneous type trunk circuits. The miscellaneous type trunk circuits which connect to the switching network are always required to do so via a universal type interface plug-in trunk circuit. Two types of universal trunk circuits are available: a 4-wire trunk circuit and a 2-wire trunk circuit. The 4-wire trunk circuits are used for IT, SI, and TC trunks, while the 2-wire trunk circuits are only used for TC trunk applications. The 2-wire trunk circuit incorporates a hybrid coil circuit and is equipped with a fixed balancing network. Certain cable length restrictions must be observed when interconnecting the 2-wire line of the 2-wire trunk circuit to its associated point of good impedance; eg, impedance compensator, 2-dB pad, or 4WTS. These cable length restrictions are described in paragraph 3.17.

B. 4-Wire Terminating Sets

3.02 The 2WL input of 4WTSs used in 4-wire TC trunks terminating on the ♦No. 1/1A ESS♦ switch (Fig. 2) is the point of good impedance that is used to determine cable length. These 4WTSs must have the proper nominal 2-wire input impedance (900 ohms plus 2.16 μF) and a compromise network (COMP NET) connected in the hybrid network line. ***These 4WTSs require no network build-out adjustment.*** Note that these 4WTSs differ from the 4WTSs in 4-wire TC trunks terminating on the ***switchboard*** and those in the ***switchboard end*** of SI trunks where the proper nominal 2-wire input impedance is 600 ohms in series with 2.16 μF and both a COMP NET and some value of NBO capacitance must be considered.

C. Impedance Compensators

3.03 An impedance compensator is a device used on loaded cable pairs to make the sending-end impedance at the toll switching end of the loaded cable pair more uniform over the VF range. The office side of the impedance compensator is the point of good impedance used to determine cable lengths in 2-wire TC trunks. The impedance compensator must be properly adjusted before the terminal balance verification measurements are made. If the impedance compensators are being adjusted in conjunction with an office conversion, due consideration must be given to the capacitance added by cable halftap and/or by office cable associated with cutover devices. Final terminal balance measurements should not be made until the halftaps and cutover devices have been removed.

3.04 Most loaded cables have been designed with a 0.5 loading end section at the toll switching office. (This means the electrical distance from the toll office to the first load point is equal to one-half the electrical length of a full load section.) A mathematical analysis of the impedance characteristic of a 0.5 loading end section shows that the impedance increases with frequency and that this impedance is predominantly resistive. The reactive component of this impedance is capacitive and very small. Since the impedance of the balancing network in a 4WTS is essentially constant with frequency, the increased line impedance of a 0.5 loading end section results in a lower return loss (poor terminal balance) as the upper cutoff frequency of the cable pair is approached. Therefore, an impedance compensator should be provided on all 2-wire TC trunks utilizing loaded cable.

3.05 The sending end impedance of a 0.8 loading end section is much better for terminal balance purposes since its impedance is substantially constant up to about 85 percent of the cutoff frequency. With a 0.8 loading end section, however, the increased capacitive reactance component is important. Thus, the impedance compensator is designed to build out the loading end section to 0.8 and to add inductive reactance to offset the additional capacitive reactance.

3.06 Two types of impedance compensators are currently in use for improving the impedance characteristic of a loaded cable pair: the impedance compensators given in SD-95756-01 and the 837-type networks given in SD-97054-01. Descriptive information and the method of adjustment are given in Sections 332-205-100 and -500.

3.07 The 837A network shown in Fig. 6A will appear in most toll connecting trunks connecting directly to a ➧No. 1/1A ESS office with the HILO 4-wire feature➧ and, in general, where the NBO capacitor is located in the trunk relay equipment of trunks terminating on an associated toll switchboard. All adjustments are accessible on the front of the network. The adjustments are for the following purposes:

(a) Building-out capacitance (BOC) from 0 to 0.101 μF in 0.001 μF steps

(b) Low frequency (below 1000 Hz) impedance correction for 19-, 22-, or 24-gauge cable conductors.

Screw-down adjustments are used. The screws short out or connect in the network components as required. A jack designated TEST is provided on the front of the network for use in making measurements of return loss of the impedance compensator and cable pair. An open plug, such as the 258D plug, inserted into the TEST jack disconnects the network and outside cable from the office equipment. Terminals 3 and 4 on the office side of the network are the points of good impedance in office cabling.

3.08 The 837B network shown in Fig. 6B contains two built-in features not furnished in the 837A network. One feature is a line building-out resistor (LINE BOR) to correct end section resistance of loaded cable in order to improve return losses. The second feature consists of drop building-out capacitors (DROP BOC) for use where the trunk relay equipment is not provided with BO capacitors.

Note: When the 837B is used in TC trunks connecting directly to the ➧No. 1/1A ESS HILO 4-wire➧ switch, the DROP BOC screws should be up.

3.09 The 837B has adjustments for the following:

(a) Building-out capacitance for office cabling (DROP BOC) from 0 to 0.062 μF in 0.002 μF steps.

(b) Low frequency (below 1000 Hz) impedance correction for 19-, 22-, or 24-gauge cable conductors

(c) Building-out capacitance for the cable (LINE BOC) from 0 to 0.101 μF in 0.001-μF steps

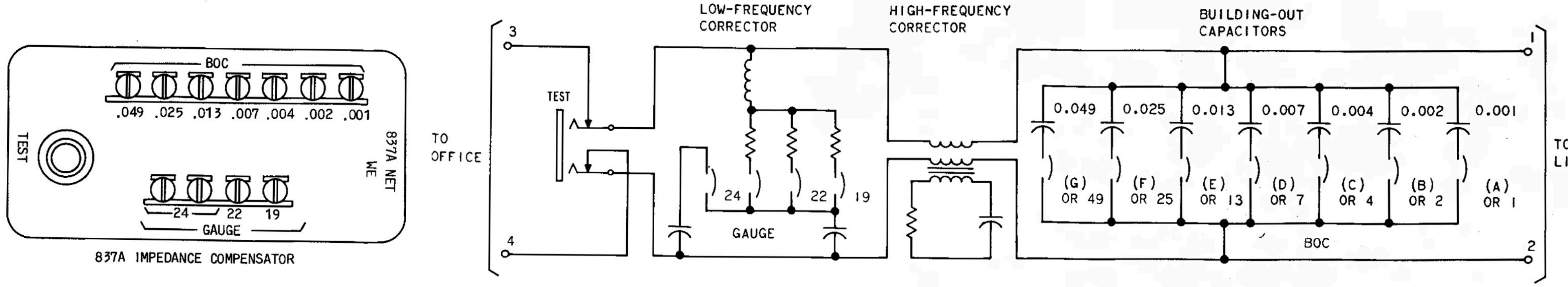
(d) Building-out resistance for the cable (LINE BOR) from 0 to 196 ohms in 28-ohm steps.

All adjustments are made by operating the screw-type switches on the front of the 837B network (Fig. 6B). In addition, a jack designated TEST 2 on the front of the network provides access to the impedance compensator and cable pair for making return loss measurements. An open plug, such as the 258D plug, inserted into the TEST 2 jack, disconnects the network and outside cable from the office cable. Pin jacks designated TEST 1 are the point of good impedance for office cabling.

3.10 The loss of the 837A and 837B networks at frequencies above 700 Hz is 0.5 dB maximum. With the low frequency corrector set for 24-gauge cable, the loss will not exceed 1.4 dB at frequencies between 200 and 700 Hz. When the low frequency corrector is arranged for 19- or 22-gauge conductors, the loss is somewhat less over the same frequency range. The above values of loss do not include attenuation caused by adding the 837B network LINE BOR in series with the cable. When the 837B network LINE BOR is used, the values of loss will increase approximately as follows:

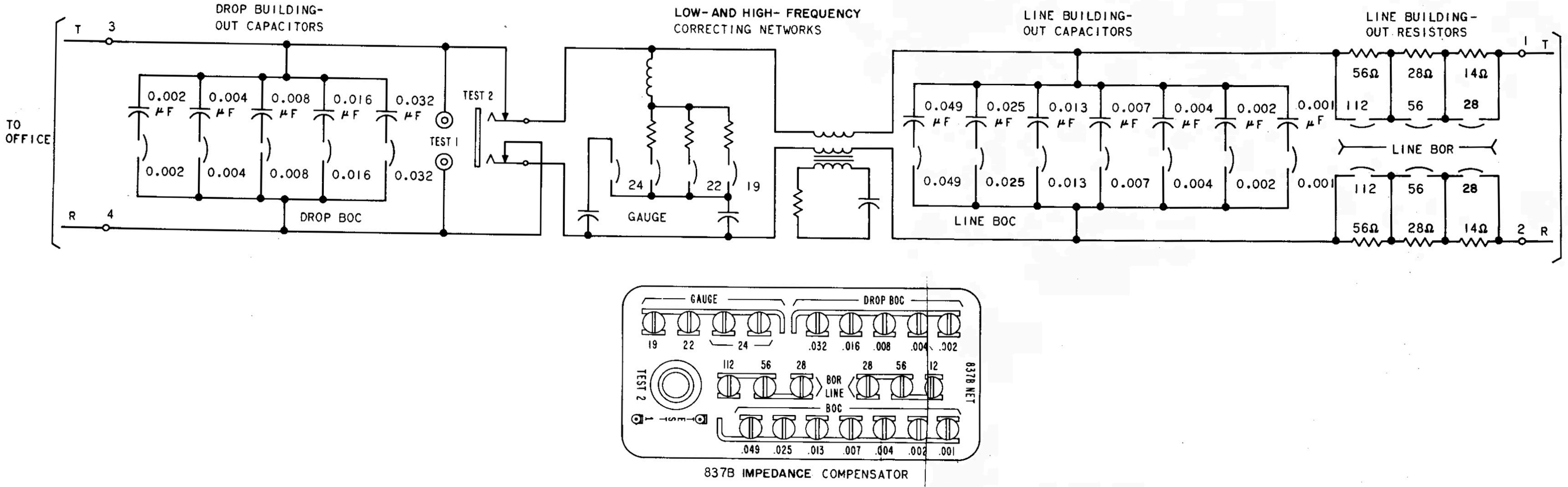
VALUE OF LINE BOR (OHMS)	INCREASE IN INSERTION LOSS (dB)
26	0.13
56	0.27
112	0.50
196	0.90

3.11 The amount of capacitance required in an 837A network BOC or an 837B network LINE BOC will usually be specified on the Circuit Layout Record (CLR) card as part of the toll connecting trunk design information. The LINE BOC should be set in accordance with the CLR or the adjustments tabulated on SD-97054-01 for all end sections of 19-, 22-, or 24-gauge conductors. The low frequency corrector should be set for the particular cable gauge used. Screws should be turned down for

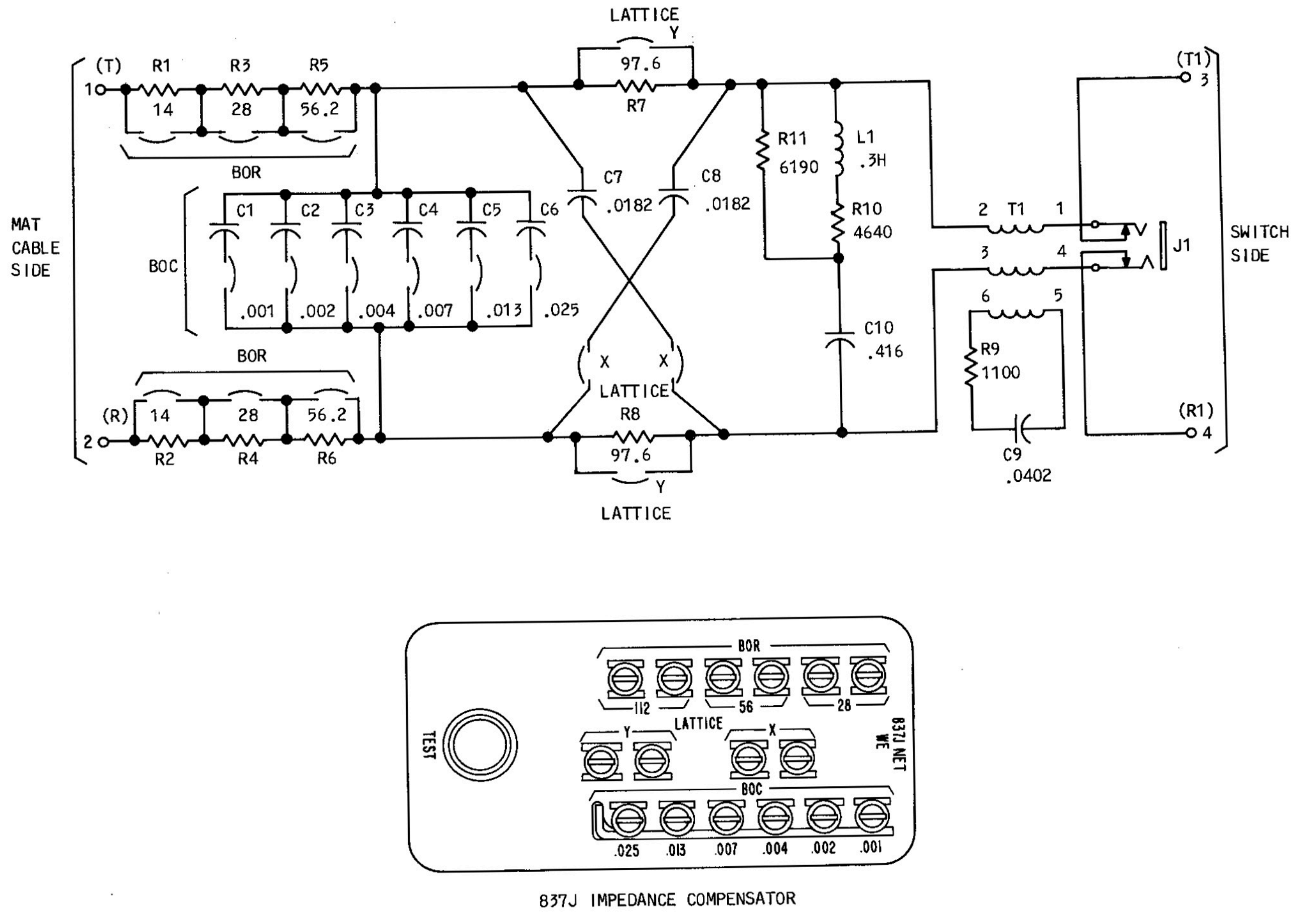


( ) IN SOME EARLY NETWORKS THE BOC CAPACITORS WERE DESIGNED WITH LETTERS.

A. 837A NETWORK INCLUDES ADJUSTMENTS FOR CABLE CAPACITANCE (BOC) AND GAUGE OF CABLE PAIRS



B. 837B NETWORK INCLUDES ADJUSTMENTS FOR OFFICE CAPACITANCE (DROP BOC), CABLE CAPACITANCE (LINE BOC), CABLE RESISTANCE (LINE BOR) AND GAUGE OF CABLE PAIRS



C. 837J NETWORK INCLUDES ADJUSTMENTS FOR CABLE BUILDOUT (BOC, BOR, LATTICE) AND A FIXED IMPEDANCE COMPENSATING NETWORK

Fig. 6—Impedance Compensators 837A, 837B and 837J

one cable gauge only. It should be noted that there are two screws for 24 gauge. If the end section contains mixed gauge cable or differs from the predominant gauge of the line, set the low frequency corrector by means of return loss measurements. Final adjustments, whenever deviation from the trunk design information is made, should be determined by return loss measurements as covered in Section 332-205-500.

3.12 The 837J network is an impedance compensator for use on 25-gauge H88 loaded metropolitan area trunk (MAT) cable. A schematic of this compensator is shown in Fig. 6C. The network contains all passive components. It is made up of three adjustable networks (BOR, BOC, LATTICE buildout) and a fixed impedance compensating section.

3.13 The BOR and BOC adjustable networks may be set to complement lengths from 0 to 3 kft of H88 loaded MAT cable. The LATTICE section represents a fixed 3-kft length and can be adjusted to be fully in or out. End sections of any length from 0 to 6 kft can be made to appear like a full 6-kft loaded section by appropriate settings of the networks.

3.14 The minimum insertion loss of the 837J network is 1.45 dB. The maximum loss is 3.46 dB.

3.15 Installation and prescription setting information for the 837J network is given in Section 332-206-258.

D. 2-dB Pads

3.16 VNL design provides fixed 2-dB pads in all 2-wire TC trunks having a loss that is less than 2 dB without the pad. These pads are provided to improve the ERL and the SRL performance. Individual pads which can be cross-connected into 2-wire trunks external to the ESS office are shown in SD-95756-01. In switchboard terminated trunks, the pads may be included in the trunk relay equipment as options or externally connected. The office wiring side of a 2-dB pad is considered to be the point of good impedance.

E. Office Cable

3.17 The wire size of the cabling normally used in an ESS office is 26 gauge. Between 900 ohm terminations, the maximum 1000 hertz loss of 1050 feet of this cable is 0.5 dB. Correspondingly, the maximum cable pair resistance of this length is 100 ohms. As stated in paragraph 3.01, the 2-wire ESS HILO trunk circuit incorporates a hybrid (4WTS) with a fixed balancing network. In order to ensure that the terminal balance requirements as stated in Part 6 can be met, cable length restrictions are required between the 2-wire line of the ESS 2-wire HILO trunk circuit and its associated point of good impedance at the TC trunk terminating on the ESS switch. This restriction is that 50 percent of the cable lengths between the 2-wire HILO ESS trunk circuits and their associated points of good impedance must be equal to or less than 800 cable feet and none exceed 1400 cable feet.

3.18 Since the Hybrid Balancing Network of the 2-wire HILO ESS trunk circuit is fixed (has no adjustment capability), it is important that the cable length restrictions given above be maintained. Figure 7 shows the ERLs that can be expected when the ESS 2-wire HILO trunk circuit and its associated 2-wire line cable is terminated at the point of good impedance with 900 ohms in series with 2.16 μF. The ERL curves are for ESS 2-wire trunks which employ either E&M or loop-type signaling. The ERL values shown are higher than required by the terminal balance requirements. This is because the ERL of the trunk (terminated at the class 5 office with a balanced termination) must be added (on a power basis) to the ERL shown on the curves in Fig. 7.

F. Outside Cable Plant

3.19 Cable loading irregularities, such as missing or double load coils, wrong load coils, irregular spacing of load coils, etc, result in poor return loss performance and will degrade terminal balance results. (See references listed in Part 10 for further discussion.)

3.20 The cable completion tests outlined in Section 330-300-500 should be made when trunk cables are installed or rearranged. Section 330-450-100 describes the general theory and techniques for location of impedance irregularities in cable pairs using VF sweep tests.

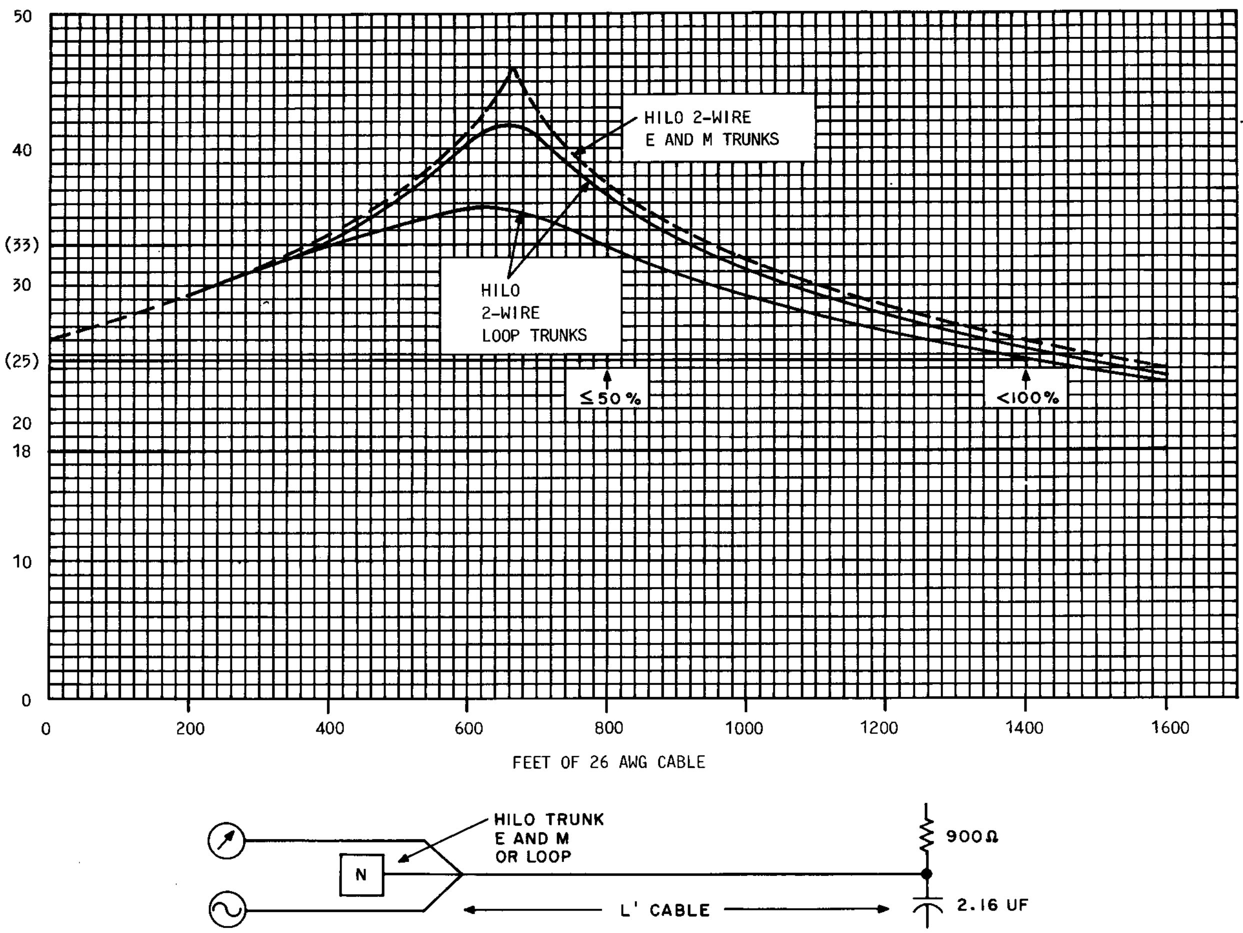


Fig. 7—HILO 2-Wire Trunk Terminal Balance

4. APPARATUS AND CABLE CONSIDERATIONS IN ASSOCIATED SWITCHBOARD TERMINATING TRUNKS

A General

4.01 The COMP NET plays an important part in the balancing process and is the impedance to which all 2WLs terminating on the switchboard are balanced. It is part of a 4WTS and provides the required termination to the balancing network of the 4WTS hybrid coil arrangement. It has designed impedances over the VF range (200 to 3200 Hz) and will match the nominal impedance of circuit terminations that may be connected to the 2WL of the 4WTS. A trunk terminating on the switchboard will be connected to many other trunks, and while all of them have a nominal circuit impedance of 600 ohms, the actual impedance will vary. This variation is due to different lengths of office cabling, and the normal variation among different equipments and/or different types of trunks. The resistance mismatch of the 2WL impedances is controlled by limiting the maximum resistance of the 2WL. The NBO capacitance, connected in parallel to the COMP NET, is used to control reactance mismatches and establish an impedance value in the COMP NETs that will satisfy some mean value of most all the 2WL terminating impedances.

4.02 The ideal 2WL would have office cable and apparatus causing little or no modification to a terminating impedance and the impedance presented to a 4WTS hybrid junction would be quite similar to the impedance of the 4WTSs COMP NET. Cable lengths, multiple, and bridge-connected circuits will cause variations in cabling capacity between different trunks. Consequently, drop building-out (DBO) capacitors are provided in all 2WLs to permit making their impedances more alike. Adjustment of the DBO capacitors changes the reactance in the same manner as the COMP NET impedances are varied in the balancing network with the NBO capacitors. The DBO capacitors are used to narrow the range of 2WL impedance presented to the 4WTS hybrids.

4.03 No resistance buildout is provided in the networks of the 4WTSs. It is, therefore, necessary to limit the office cabling resistance to a maximum value. Reasonable control of the office cabling resistance factor of impedance is accomplished by equipment design, office layout, and maximum use of 22-gauge office cabling in the transmission path. As a result, when equipment rearrangements, additions, deletions, and modifications which change the amounts of office cabling and/or apparatus in switchboard terminating 2WL paths are made, the impedances may change and the effect on the balance at the switchboard should be investigated.

4.04 When repeating coils are present in a 2WL to derive signaling or transform impedances, the degree of balance that can be obtained is limited. For instance, a 1:1 ratio coil has some leakage reactance and lowering of inductance because of saturation which is particularly noticeable at the lower frequencies. The repeating coil will also add to the series resistance of a circuit. These effects will modify the 2WL impedance presented to the 4WTS by different amounts over the VF range and lower the average degree of balance obtainable against the COMP NET.

B. A and B Lead Capacitors

4.05 The 2WL hybrid coil windings in 4WTSs are frequently used to develop dc signaling on the 2WL path. When this is done, the 1-μF capacitor bridged across the A and B leads of the 4WTS is utilized to provide ac continuity for the voice path and dc isolation for the signaling path. A value of 1 μF is the capacitance that gives the 2WL side of the 4WTS hybrid junction the desired impedance characteristic for interconnection to another 4WTS. When used for signaling, this capacitor may be located in the 4WTS itself or in the trunk relay equipment, depending upon specific equipment arrangements. In all cases, it is necessary to ensure that (a) the capacitor value is 1 μF, (b) only one capacitor exists in the 2WL, and (c) a 1-μF capacitor is also provided in the 2-wire network line (balancing network) of the hybrid to maintain proper impedance characteristics. Referring to Fig. 8, note that when the 1-μF capacitor is located in the trunk circuit, the loop resistance of the A and B leads from the 4WTS to the trunk circuit is included in the total cabling resistance of the 2WL. Some equipment also includes inductors in the A and B leads for additional impedance isolation. To improve signaling, class 5 office ends of 4-wire TC trunks generally have a 4-μF capacitor across the A and B leads. However, the difference in the impedance characteristic in these cases can be ignored since no connection is required to other 4WTSs. The older varieties of 120-type or the miniature type (SD-95137-01) 4WTS, N- and T-type

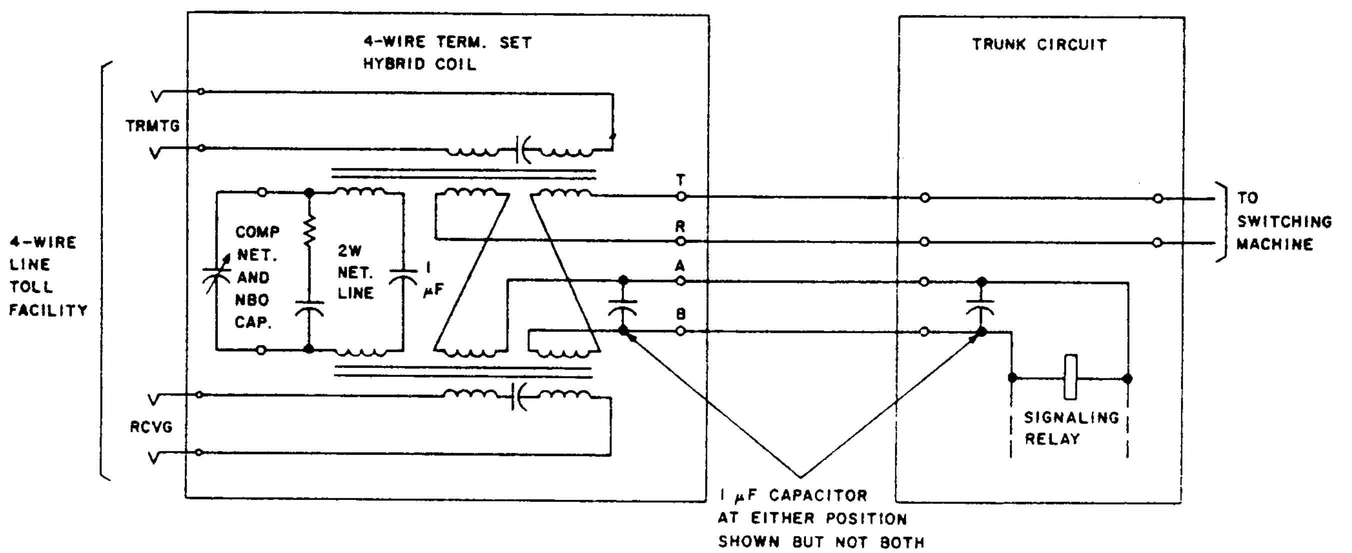


Fig. 8—Typical 1-Type or 120-Type 4WTS Hybrid Coil Arranged For DC Signaling

carrier, E-type and F-type signaling units, and D2 channel banks may have still a different A and B lead capacitor value. These values should be verified by SD information in each case.

C. Trunk Relay Equipment

4.06 All trunk relay equipment should have the following features provided:

(a) Adjustable DBO capacitors bridged across the transmission path. (If a 2-way trunk or multiple access trunk is involved, a DBO capacitor is required in each transmission path.)

(b) Idle circuit terminations to provide the same nominal impedance as a 2WL termination when the trunk relay equipment is not seized. (Because of the low-loss design of MTS trunks, the termination is provided to prevent possible singing in the idle condition.)

(c) Any signal relays bridged to the transmission path should have a high enough inductance (with their normal operating currents) to have a negligible effect on the path impedance from 200 to 3200 Hz. For example, 280BP or 280Y relays do not meet this requirement unless they are isolated by a separate high-impedance inductor; therefore, a 274AH inductor in series with the 280Y relay is generally provided for return loss improvement.

D. Repeating Coils

4.07 Repeating coils appearing in TC trunks must be equipped with properly valued midcoil capacitors to obtain optimum impedance characteristics. The VNL objectives for both ERL and SRL require this criterion. At the class 4 office end, TC trunks having repeating coils should be provided with midcoil capacitors that obtain the best impedance presentation in the IT network direction. This results in reduced ERL and SRL performance in the class 5 office direction, but the requirements are less stringent and can be met. An example of the effects that the midcoil capacitance has on impedance transfer, with resulting effect to return loss in the voice-frequency range, is demonstrated in Fig. 9.

E. Building-Out Capacitors

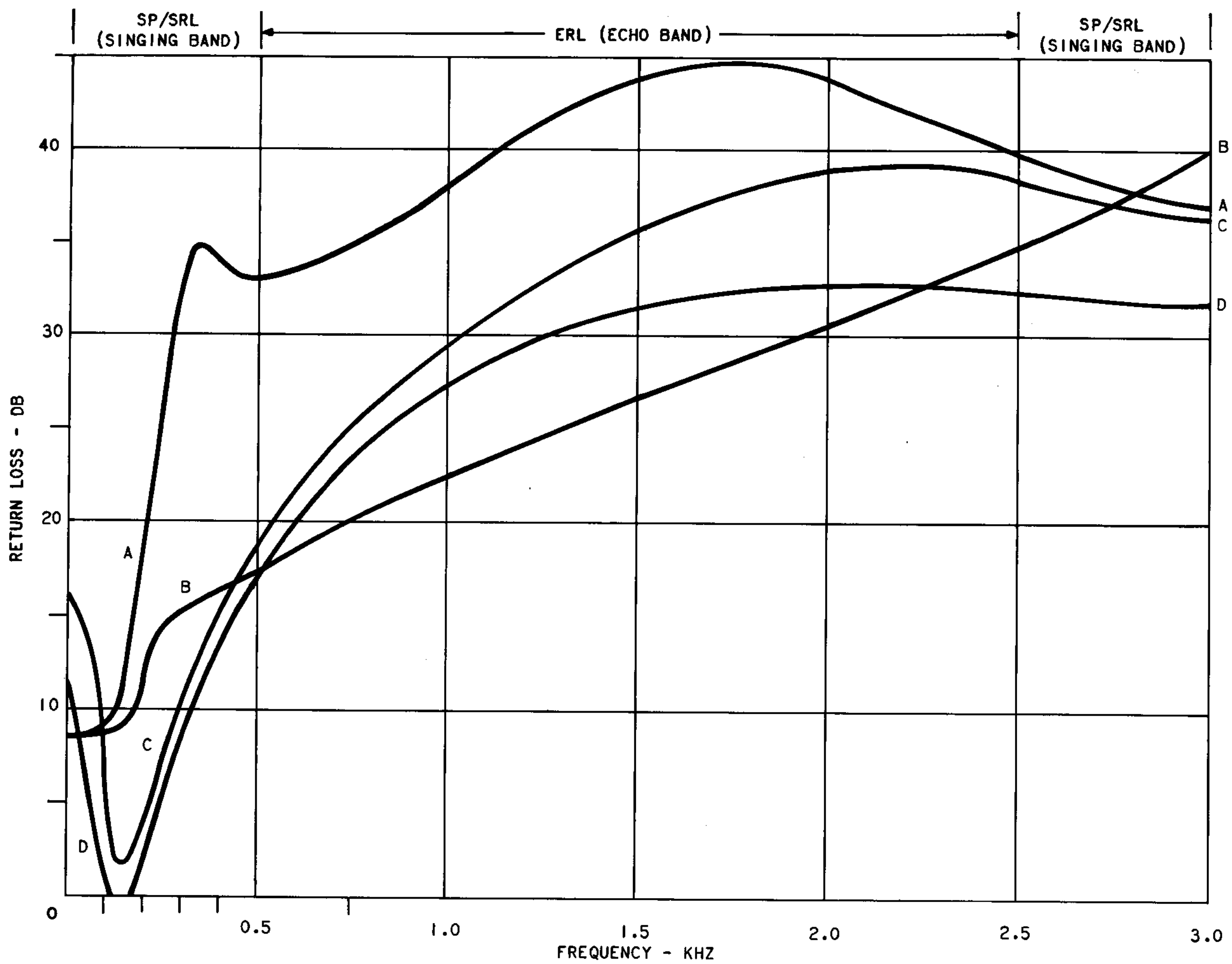
Network Buildout

4.08 The compromise network in 4WTSs of SI and TC trunks terminating on the switchboard should be made to provide satisfactory balance against the impedances presented by other SI or TC trunks which may be connected to the 2WL at the switchboard. This requires choosing some value of NBO capacitance equal to the office cable capacitance in the longest path through the office (class 3) or a suitable range of average capacitance (class 4).

4.09 Office cables have distributed capacitance throughout their lengths. This distributed capacitance modifies the terminating impedance presented to the 2WL of a 4WTS hybrid at the upper frequencies of the voiceband and must be balanced in the network of the 4WTS by bridging an equal amount of capacitance across the COMP NET. The NBO capacitors are provided for this purpose. When initially balancing switchboard terminating trunks, according to procedures of Section 660-470-500, a single NBO capacitance value is selected for all 4WTSs. Therefore, the impedance of the COMP NET will be modified by a fixed capacitance amount in all 4-wire trunks terminating on the switchboard.

4.10 When performing balancing of a switchboard associated with class 3 and higher ➧No. 1/1A ESS offices with HILO 4-wire switching➧ where ***through*** balance is generally required, the longest SI-to-SI path via the switchboard is used to determine the value of NBO capacitance unless trunks requiring terminal balance are longer by more than 0.0125 μF. When performing balancing of a switchboard associated with a class 4 ➧No. 1/1A ESS office with HILO 4-wire switching➧ ***terminal*** balance on the switchboard end of the average SI-to-TC path via the switchboard is determined and used as a compromise value. The procedures for NBO capacitance selection are contained in Section 660-470-500.

4.11 In order to obtain a true average SI-to-TC path length when selecting a terminal balance NBO value, a system of weighting (size of groups, size of samples, traffic usage, etc) would have to be used. This would be a difficult and complex procedure; therefore, a figure midrange between the longest and shortest path is generally accepted as the compromise value of office cable capacitance.



CURVE	A CAP. μF	B CAP. μF
A	4	1
B	1	1
C	1	2
D	1	4

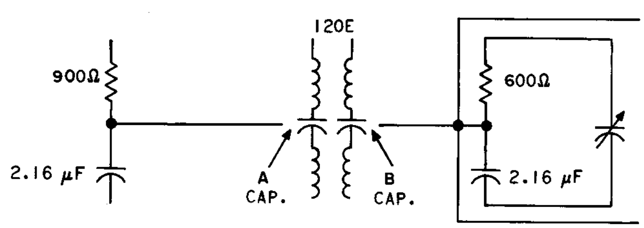


Fig. 9—Typical Return Loss Results For Different Values of Midcoil Capacitors

For example, if the longest measured path was 0.032 μF and the shortest measured path was 0.014 μF, the accepted compromise (midrange) path would be 0.023 μF (the average of 0.032 and 0.014). Thus, a compromise NBO value for the switchboard terminating trunks would be 0.023 μF. Care must be taken that the actual longest and shortest paths are used to determine the final compromise value. No paths used in the determination can exceed 0.080 μF, since large values of capacitance introduce increased attenuation-distortion at the upper part of the voice-frequency spectrum (2000 to 3000 Hz).

> ***Note:*** The difference in capacitance between the longest and the shortest operator connected SI-to-TC paths should not exceed 0.025 μF. If this range is exceeded, the shorter paths outside the range are excluded from the computation made to determine the midrange office cable path capacitance.

4.12 Figure 10 is an example of the method used to determine the office NBO capacitance value for a class 4 toll switchboard. In the example, the actual measurements for the longest path is 0.040 μF and the shortest is 0.005 μF. All measured values below 0.015 μF (0.040 - 0.025 = 0.015) are excluded and the midrange path is then determined to be 0.028 μF, (0.040 + 0.015)/2 = 0.0275 0.028 μF. In most cases, some growth factor (up to ten percent of actual values) should be added to the actual values. The result of adding a maximum growth factor is shown in the figure.

4.13 On switchboards associated with class 3 and higher offices, the NBO capacitance, as determined by the through balance procedures, will ***usually*** be larger than required on connections to TC trunks. It is usually necessary, in this case, to add build-out capacitance to some or all TC trunks to give a maximum return loss when the TC trunk is connected to an SI trunk that has been adjusted to meet through balance test requirements. It should be noted that ***terminal*** balance testing on the class 3 switchboard terminating TC trunks cannot be started until the ***through balance NBO capacitance value for the switchboard has been established.***

Drop Buildout (DBO)

4.14 To obtain balance across 4WTSs that have been assigned a fixed NBO capacitance, the variance of the office cable capacitance in the 2WL of the 4WTS plus the variance of capacitance in the office cable of any connected trunk must be considered. DBO capacitors are used for this purpose. When performing the ***through*** balance DBO procedure of Section 660-470-501, buildout is used to make all SI trunk office cabling have the same capacitance. When performing terminal

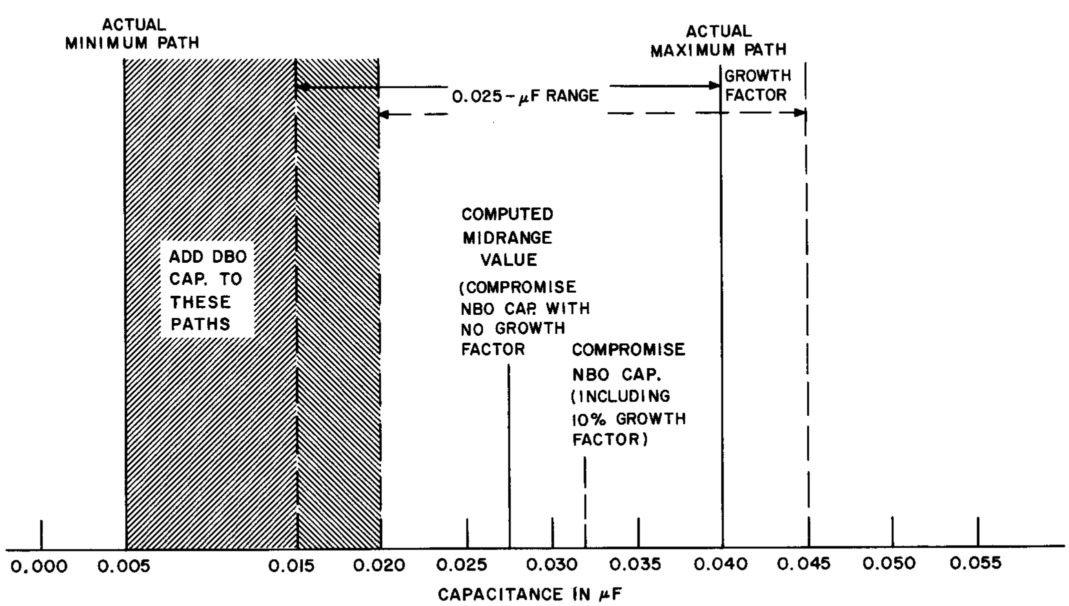


Fig. 10—Example of Determination of NBO Capacitance in Class 4 Offices

balance in Section 660-470-502, the capacitance variance in SI-to-TC connections is measured. Once the range is known and evaluated capacitance is added with DBO capacitors in the shorter TC trunks only. No buildout is generally made in the SI trunks.

> ***Note:*** In class 4 offices where a difference of 0.010 μF or greater exists in the 2WL office cable capacitance of the 4WTSs in the switchboard end of SI trunks, capacitance buildout is required in those SI trunks having more than 0.010-μF capacitance difference from the longest trunk.

Office Cable

4.15 Office cable resistance and capacitance is limited in switchboard terminating trunks. The limits apply only to the switchboard ends of SI trunks and TC trunks terminating on toll switchboards associated with the ESS toll office. The maximum loop resistance between 4WTSs or a 4WTS and a point of good impedance is 45 ohms. The maximum total shunt and DBO capacitance is 0.080 μF. In general, the resistance limit will be exceeded before the capacitance limit.

> ***Note:*** Office cable capacitance varies from one type of cable to another. A value of 0.000025 μF/foot is an accepted average value.

Outside Cable Plant

4.16 On 2-wire TC trunks, cable loading irregularities (such as missing or double load coils, wrong load coils, irregular spacing of load coils, etc) result in a poor return loss and will degrade terminal balance results.

4.17 The cable completion tests outlined in Section 330-300-500 are generally made when trunk cables are installed or rearranged. Section 330-450-100 describes the general theory and techniques for locating impedance irregularities in cable pairs by using VF sweep tests.

5. MEASUREMENT CONSIDERATIONS

A. General

5.01 The ERL and SRL requirements for through and terminal balancing are specified to satisfy VNL operation of toll trunks. These requirements are stated and measured in terms of a specific degree of balance (impedance match, see Part 2A) at all 4-wire hybrids in any toll connection. The requirements are expressed in dB and are a value over and above the THLs (see part 2C). Switchboard terminating TC trunk requirements do not include 4WTS hybrid losses. The THL of these hybrids must be accounted for when measuring ERL and SRL since the requirements are based on specific measurement techniques which include using a 4WTS.

5.02 Transmission performance objectives in the telephone plant can be construed in different ways. In one sense, objectives for performance can be thought of as the ideal arrangement, ie, the best we can visualize. In this sense, VNL objectives for through balance are to have no echo or singing paths at intermediate switching points in a connection. This could be accomplished with all 4-wire switching, including switchboards. This, however, is impractical. Since ideal situations are seldom attained, we frequently use objectives in another sense, that of defining requirements that allow satisfactory performance. This permits judgment of the necessary degree of performance which is feasible to obtain in view of both economic and technical considerations. These considerations are included in the overall performance requirements for through and terminal balance as specified in Sections 660-470-300 and 660-470-301. The method of expressing the objectives requires that the measured values be evaluated. If the distribution of the measurements is reasonable and the requirements are met, the overall objectives will be met. When any trunks fall below the median requirements, a careful check may show that the balance can easily be improved. The given turndown limit indicates balance irregularities severe enough that the trunk cannot be left in service and corrective action should be taken. In an office certified for balance, any trunk added by circuit order work which does not meet median requirements should be noted, and the condition referred to transmission engineering for determination of cause and for evaluation of any effects to the total office balance.

5.03 The transmission type measurements necessary to perform balance work (both adjustments and verification measurements) are made with the KS-20501 Return Loss Measuring Set (RLMS) or equivalent. The RLMS transmits a specific level of weighted noise across the voiceband of frequencies and measures a resultant return loss of all frequencies in the echo range and both singing ranges selectively. Section 660-470-504 shows the applications of the RLMS in making balance measurements. Balance measurement indications made while making any adjustments should respond to the capacitance and/or resistance change being made. Maximum measurement indications in these types of measurements will coincide with the optimum adjustments. Overall verification measurements of complete connections are measured for ERL, SRL, and SRL HI. When making these measurements, the THL must be accounted for. An additional measurement that is required when balancing switchboard terminating trunks is office cable capacitance.

5.04 All trunks being measured for balance must have met the required noise limits and 1000-Hz transmission loss as specified in applicable trunk transmission testing practices. All 4-wire trunks should meet the noise and loss transmission requirements in both directions.

B. 4WTS Trans-Hybrid Loss

5.05 At 2-wire switchpoints (3CL switchboards), where the hybrid adjacent to the RLMS is used to convert from 2-wire to 4-wire for testing purposes, a THL adjustment is required. The THL measurement is made from the 4-wire receive to the 4-wire transmit port of a 4WTS with the 2WL of the hybrid short circuited ***immediate*** to the hybrid circuitry. The return loss of the 2WL in this case is zero (see Part 2) and the indicated ERL value on the RLMS is adjusted to read 0.0 dB using the THL switches. The value of the THL switch settings when the RLMS meter indicates zero is the THL of the 4WTS being tested. This value is unique to each hybrid.

5.06 ♦When making balance measurements at the MTTP using the KS-20501 RLMS provided, it is necessary to make THL adjustments in the TAT 1 circuit when the TAT 1 circuit is used in the 2-wire mode. ***In the 2-wire mode, the RLMS is only connected to TAT 1.*** When the THL key is pressed, a short is placed across the 2-wire port in the hybrid of the 2-wire test access circuit (SD-1A322) by the machine. The return loss of the 2-wire port in this case is zero (see Part 2) and the indicated ERL value on the RLMS must be adjusted to read 0.0 dB using the THL switches. The value of the THL switch settings when the RLMS meter indicates zero is the THL of the 4WTS of the 2-wire test access circuit. This value is unique to each 2-wire test access circuit hybrid. In the 4-wire mode, a THL adjustment in the 4-wire test access circuit will not be made since there is no balance test hybrid present. But it will be necessary to compensate the gain already induced in the RLMS described above in the 2-wire mode. This test access trunk compensation will be done by pressing the THL key at the TAT being used. By pressing the THL key, the machine will cause a short between the transmit and receive paths at the RLMS or a loop-back effect. Once this is done, locate the COM 1 potentiometer (circuit pack location 30-31; FB-625) at the MTTP. Adjust the potentiometer until the RLMS reads 0.0 dB. ***The procedures described above should be done initially before making any balance measurements.***

> ***Note:*** When in the 2-wire mode, the TEST LOCATION switch on the RLMS should be on +0 dB. In the 4-wire mode, ***do not*** change the TEST LOCATION switch on the RLMS. The TEST LOCATION switch should remain on +0 dB.♦

C. Echo Return Loss

5.07 The ERL is the measurement of the amount of received power relative to the transmitted power of the weighted average for all frequencies in the echo range (500 Hz to 2500 Hz). This measurement is indicated in dB and is obtained with an RLMS at the 4-wire transmit and receive ports of a test hybrid or 4WTS.

D. Singing Return Loss

5.08 The SRL measurement is the lower value of two measurements made with the RLMS (SRL and SRL HI). The SRL measurement indicates the amount of power in the weighted average of return loss at frequencies from 200 Hz to 500 Hz. The SRL HI measurement indicates the amount of power in the weighted average of return loss at frequencies from 2500 Hz to 3200 Hz. In general, the critical frequency for singing (that frequency having the lowest return loss) will be in the upper band (SRL HI) if the reactance of the circuit impedance is negative (capacitive) and in the lower band (SRL) if the reactance is positive (inductive). Both measurements must be made to evaluate the SRL of a trunk.

E. Office Cable Capacitance

5.09 Measurements for capacitance of office cable is necessary in switchboard terminating trunks and is measured with the RLMS and the hybrid of an SI trunk or a balance test hybrid terminated on the switchboard. When using an SI trunk, a connection from or to the ♦No. 1/1A ESS♦ HILO TAT 1 or TAT 2 test trunk and the switchboard is necessary. Test box signaling or manual relay operations in the switchboard end of the SI trunk may be required. The RLMS is connected to the hybrid in the switchboard end of the SI trunk or to the 4-wire transmit and receive ports of the test hybrid. The hybrid 2WL must be terminated in the switchboard balance test termination, another trunk, or a portable termination. If connected to a TC trunk, a termination at the point of good impedance in the office cable is required. This may be the input to another hybrid, a 600 ohm plus 2.16 μF or a 900 ohm plus 2.16 μF portable termination. The termination must include all office cabling up to the point of good impedance in the trunk.

5.10 The internal signal of the RLMS with an SRL HI function switch setting or an external oscillator (set to 2000 Hz) and the EXT OSC setting of the RLMS is used to measure office cable capacitance. The NBO capacitor can be readjusted or a variable capacitance box (7A or equivalent) can be connected across the COMP NET of the hybrid being used for testing. When the NBO capacitor or variable capacitance box is adjusted to produce a maximum indication of SRL HI (or 2000 Hz if an external oscillator is used), the value of the capacitance is approximately equal to the capacitance of the office cable being measured. ♦(For test equipment setup refer to the Applications Chart, Test 1, in Section 660-470-504.)♦

6. THROUGH AND TERMINAL BALANCE IN THE ENVIRONMENT OF THE ♦NO. 1/1A ESS♦ WITH HILO 4-WIRE SWITCHING

A. General

6.01 The majority of the balancing effort in the environment of the ♦No. 1/1A ESS♦ with HILO 4-wire switching feature involves making verification measurements for through and terminal balance.

B. Through Balance

6.02 Through balance verification measurements are made from ♦No. 1/1A ESS♦ 4-wire HILO Test Access Trunks (TAT 1 or TAT 2) incoming to an SI trunk, and to a balanced termination (Code 100) outgoing from an SI trunk. Thus, through balancing can be thought of as cross-office testing. No through balance requirements exist on machine switched connections direct from IT trunks to IT trunks.

C. Terminal Balance

6.03 Terminal balance verification measurements are made to or from ♦No. 1/1A ESS♦ 4-wire HILO test access trunks (TAT 1 or TAT 2) through terminated toll-connecting (TC) trunks. Thus, terminal balancing can be thought of as terminating or originating-office testing as opposed to the cross-office type of testing for through balance.

6.04 Before verification measurements are started, certain preliminary investigations and adjustments must be made to the transmission equipment in the TC trunk. The investigations include determining if the cabling length restrictions from the 2-wire line of the ♦No. 1/1A ESS♦ HILO hybrid trunk circuit to its "point of good impedance" have been adhered to and that 2-dB pads have been included in intrabuilding TC trunks. For 2-wire interbuilding trunks employing impedance compensators, the impedance compensators must have been adjusted or prescription set to maximize the return loss of the TC trunk to which they are connected.

D. ♦No. 1/1A ESS♦ HILO 4-Wire Test Facilities and Circuits

6.05 A ♦No. 1/1A ESS♦ office with HILO 4-wire switching feature is equipped with at least one Manual Trunk Test Position (MTTP). For return loss balance testing, this test facility enables operating personnel to accept or generate test calls. When a test call has been established, it can be transferred to return loss measuring equipment (KS-20501) associated with the MTTP. At the completion of testing, the test connection can be released from the MTTP. Operation of the MTTP is described in Section 231-130-320.

6.06 Associated with the MTTP are three test trunk circuits which interface with the HILO switching network. (For HILO interface circuitry refer to SD-1A397-01.) Only test access trunk circuits TAT 1 and TAT 2 per SD-1A418-01 are used for return loss balance testing.

6.07 A combined termination and milliwatt test circuit per SD-1A386-01 provides the Code 100 test function in the No. 1/1A ESS with HILO 4-wire feature. For balance testing this circuit provides a 4-wire 600 ohm balanced termination.

7. THROUGH AND TERMINAL BALANCE OF TOLL SWITCHBOARDS ASSOCIATED WITH THE ♦NO. 1/1A ESS♦ OFFICE WITH HILO 4-WIRE SWITCHING

A. General

7.01 Balancing methods for toll switchboards differ from the balancing methods of the ESS environment. Since the SI trunks between the ESS HILO office and their associated switchboards are interconnected with 4-wire facilities, balancing of switchboards with exception of the verification measurements are independent of the ESS office. Switchboards assume the same class as the toll office and, where associated with class 3 and higher ranking offices, require ***through*** balance if "IN" and "OUT" (through) functions are performed with the SI trunks. Terminal balance is required on all TC trunks terminating on the switchboards.

> ***Note:*** Balance ***verification*** measurements for SI to TC trunk connections via the switchboard ***cannot*** be made until the ESS office balance work is complete. However, the NBO selection and DBO on the switchboard end of SI trunks and the switchboard terminating TC trunks can be completed if "off hook" signaling conditions are provided by test set signaling or manual relay operations in the switchboard end of the SI trunks used for testing. Otherwise, the TAT 1 or TAT 2 circuit in the ESS office with HILO 4-wire switching must be available.

7.02 Office cabling of switchboard terminating TC trunk groups will, in general, have significant differences in capacitance and resistance due to considerable length variations, multiple appearances, service observing bridging, etc. In addition, the trunks may have repeat coils, signaling relays, and other devices that affect impedances. Furthermore, the 4WTSs in the switchboard end of SI trunks and in the 4-wire TC trunks are not provided with an adjustment for resistance. Therefore, all balance work is accomplished with capacitance, by first adjusting the NBO capacitors in parallel with the 4WTS COMP NETs to a single value, and then adding capacitance with BO capacitors to the 2-wire paths. The required value of NBO capacitance is determined by procedures in Section 660-470-500.

7.03 The NBO capacitance value for the switchboard ends of SI trunks for class 3 and higher ranking switchboards, as determined by the through balance procedures in Section 660-470-500, will usually be larger than that in TC trunks. Since all the SI trunks must be built out to equal ***one-half*** the longest through connection path, it is usually necessary to add BO capacitance to some or all TC trunks in order to meet terminal balance requirements. In the class 3 offices where through balance is required and SI trunks are shorter than the TC trunks, it may be necessary to build out the SI trunks to equal the compromise (midrange) capacitance value of the office cable in the TC trunks before determining the NBO value required for through balance.

7.04 The compromise (midrange) value of office cable capacitance in SI-TC connections is used to determine an NBO capacitances value for switchboards associated with class 4 offices where only SI to TC or TC to SI connections are made. In these offices, ERL and SRL values, somewhat less than the maximum values obtainable on the trunks near the midrange lengths, can be expected on the longest and shortest paths, ie, those paths with more or less capacitance than the midrange path. This reduction in the ERL and SRL values can become serious if the difference in office cable capacitance is too great. Therefore, capacitance differences should not be greater than 0.025 μF (a relatively narrow range).

7.05 The measurements for determining office cable capacitance are made using an RLMS as described in Section 660-470-504. The SRL HI setting of the RLMS or an alternate method using an external oscillator set to 2000 Hz and the RLMS set to EXT OSC is specified because of the various series capacitors and bridged inductors (coils and relays) that are placed in the line by the trunk relay equipment. The impedance effects of these components are negligible at the higher voice frequencies, but may control measurements at the lower voice frequencies. In addition, the office cabling capacitance is a shunt capacitance which when changed is easily detected and measured at the high frequencies. ***Through*** office path capacitances are measured from the 4WTS of an SI trunk to the 4WTS of another SI trunk. ***Terminal*** office path capacitances are measured from the 4WTS of an SI trunk to a termination inserted at the point of good impedance in a connected TC trunk. The termination(s) in the TC trunk must be placed at (a) the 4-wire side of the 4WTSs (located nearest the toll office) on 4-wire facilities, (b) the toll office side of impedance compensators in loaded cable, or (c) the toll office side of 2-dB pads.

7.06 When measuring for a ***through*** balance NBO value, the longest path value (not to exceed 0.080 μF) must be found. When measuring for a terminal balance NBO value, an average path must be determined. In order to obtain a true average of office cable capacitance values in TC trunks or an average path length in the class 4 offices, a system of weighting (sizes of groups, size of samples, traffic usage, etc) would be necessary. This would be a difficult and complex procedure, therefore, a figure midrange between the highest and the lowest value measured is generally accepted as the compromise value. For example, when determining the average path in a class 4 office; if the longest path was measured to be 0.032 μF and the shortest path measured was 0.014 μF, the accepted compromise (midrange) path would be 0.023 μF (the average of 0.032 and 0.014). Care must be taken that the actual longest and shortest paths are used to determine a compromise value. No paths used in the computation can be greater than 0.080 μF nor can the difference between the longest and shortest paths exceed 0.025 μF. When the difference is greater than 0.025 μF, all paths measuring less than the longest path minus 0.025 μF should be excluded from computations to determine a midrange path.

7.07 When measuring the office cabling capacitances, it is not necessary to actually measure the capacitance of each TC trunk or SI to TC connection. Measurements made on a sampling basis are adequate. As a general rule, no semblance of an overall normal distribution to office cable capacitance measurements will be obtained. The measured values will tend to separate into two groups—a group of small values and a group of large values.

7.08 The total office cable capacitance in any connection via the switchboard including any buildout should not exceed 0.080 μF; and a lower value is desirable. Large values of capacitance introduce increased attenuation-distortion of the upper part of the VF spectrum (2000 to 3000 Hz). For example, a shunt capacitance of 0.080 μF in a 600-ohm circuit will produce a difference in loss of approximately 1.2 dB between 1000 and 3000 Hz.

7.09 In all cases, consultation with the responsible transmission engineering organization is necessary when selecting the office NBO value for the 4WTSs in switchboard terminating SI and TC trunks. It should be noted that terminal balance testing on TC trunks terminating on the switchboard can be started as soon as the NBO value has been established.

7.10 To obtain adequate balance across 4WTS hybrids having fixed (adjusted) NBO capacitance, the variance in office cable capacitance must be considered. The capacitance of all incoming SI paths to the switchboard should be made approximately the same and in a like manner, outgoing SI paths from the switchboard should be made approximately the same. In class 3 offices where "IN" and "OUT" (through) connections are made by the operator, it is necessary that the incoming SI paths equal the outgoing SI paths and the total capacitance equal the NBO value. In class 4 or class 3 offices where the operator does not perform both "IN" and "OUT" (through) functions, it is desirable, but not necessary, that the incoming or outgoing SI and the average TC paths be equal; however, the total capacitance of the two should equal the NBO value for best balance conditions. This is generally accomplished by adding fixed DBO capacitance in the TC paths.

7.11 Since a growth factor is generally added to the NBO capacitance, through balancing procedures require that DBO capacitance be added to all SI paths. However, terminal balancing requires that DBO capacitance be added only to the shorter paths excluded from the computation of the compromise NBO value. When adding the DBO capacitance in terminal balancing, the shorter trunks are built out to equal the compromise value of office cable plus any growth factor that has been included in the office NBO capacitance.

Note: In practice, the office NBO value may be increased by additional capacitance for growth. This growth factor (generally ten percent of the compromise office cable value) will be included in the final office NBO selection made by the responsible transmission engineer. When a growth factor is included in the NBO value, the compromise NBO value must also be increased by the growth factor.

B. Through Balance Considerations

General

7.12 The through balance verification measurements are made from the ESS testing facilities and an SI trunk connected to an SI trunk, ie, class 3 switching (via the machine and switchboard). The verification measurements are made after the NBO and DBO capacitances at the switchboard have been determined and adjusted. Thus, through balancing can be thought of as cross-office testing.

7.13 The verification results of through balancing are measurable as the ERL and SRL at the ESS test facilities. These results should meet the VNL performance objectives.

7.14 The use of successive steps and intermediate evaluations as prescribed in Section 660-470-501 is recommended when performing through balance via the switchboard using test equipment and techniques prescribed in Section 660-470-504. The prescribed step methods simplify the balancing process, and specify that intermediate ERL and SRL evaluations be obtained in relation to the required objectives to substantiate completed steps and verify portions of the balanced work. When performing through balance work, any trunks having ERL and/or SRL values below the median requirements, as specified in Section 660-470-300, should be investigated for trouble.

7.15 Before starting the through balance at the switchboard, a certain amount of preliminary work is usually required. Apparatus should be verified, traffic flow should be sketched, records prepared, etc. In addition to test planning, verify that the 1000-Hz transmission loss and noise limits of all trunks to be balanced have been measured and are acceptable. The actual measured loss (AML) and noise measurements ensure that the trunk equipment meets transmission requirements. Through balance measurements are of little value when the 1000-Hz transmission and noise requirements are not met.

7.16 Figure 11 illustrates the typical through office connection that must meet through balance objectives.

7.17 Whenever adjustments to the NBO and DBO capacitors are made to obtain through balance, it is necessary that the final capacitance adjustments be optimized by trial adjustments to maximize the measured ERL since the 2WL of each trunk will be slightly different in length. It may sometimes be advantageous to put initial strapping on the capacitors; however, the final adjustments should be made by measurement.

7.18 As a result of the through balance process, all NBO capacitors will be strapped for the same value and all network line impedances will be approximately equal. The 2WL impedances in the hybrids of all incoming and outgoing SI trunks that must meet through balance requirements will also be approximately equal. Therefore, the impedances to be connected at the switchboard interconnection in all through path connections will be similar.

NBO Capacitance Selection (Class 3 and Higher Ranking Offices)

7.19 To initially perform the through balance, a value of capacitance must be selected for the NBOs of all 4WTSs involved in through office connections via the switchboard. The same value of NBO capacitance must also satisfy terminal balance requirements on the TC trunks originating and terminating at the switchboard. The procedures for making the NBO selection are contained in Section 660-470-500.

DBO Capacitance Adjustment (Class 3 and Higher Ranking Offices)

7.20 After the NBO capacitance for through balance of the SI trunks to and from the switchboard has been selected and installed in the 4WTSs of the trunks, the 2WL of each SI trunk path must be built out with capacitance and verified. Since the longest incoming and longest outgoing trunks are used in the NBO selection and a ten-percent growth factor is generally added whenever 0.080 μF will not be exceeded, DBO capacitance is necessary on all trunks.

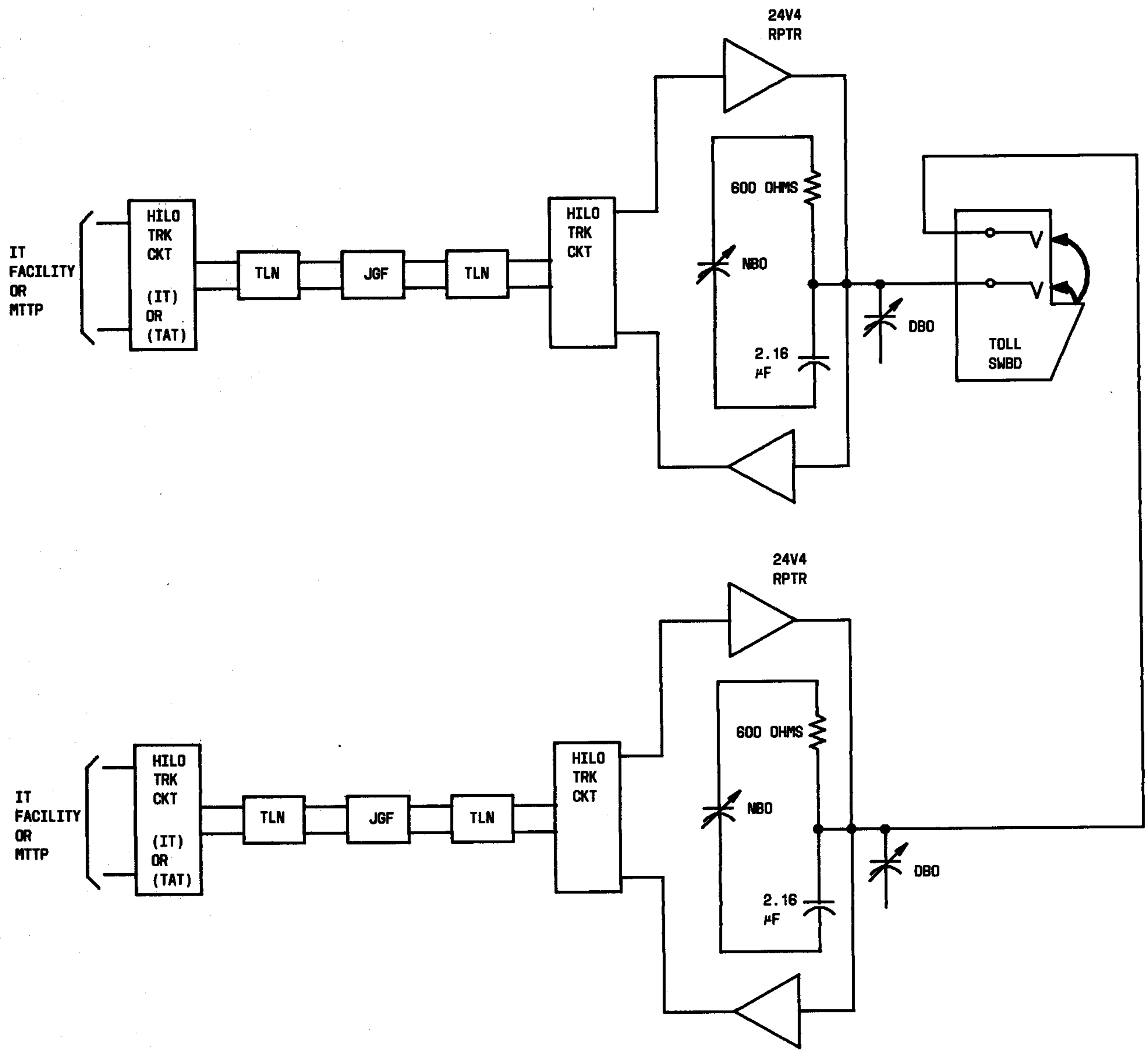


Fig. 11—Typical Through Connections Via Switchboard

7.21 In the adjustment of the DBO capacitors, the ultimate consideration is to make all paths through the switchboard have the same capacitance as the longest path. This results in all incoming trunks and all outgoing trunks being equal to their longest counterpart with respect to capacitance. The procedures for DBO adjustments and verification tests are contained in Section 660-470-501.

7.22 In the performance of the procedures, the actual DBO adjustments are made with the incoming or outgoing SI trunks connected to the switchboard balance test termination.

Verification

7.23 Verification tests should be performed on all SI trunks requiring through balance after the through balance capacitance buildout has been completed. These verification tests should be performed using test equipment and test routines specified in Section 660-470-504 and following the procedures given in Section 660-470-501. The results should be recorded as shown in Section 660-470-010. All measurements should meet requirements as given in Section 660-470-300.

C. Terminal Balance Considerations

General

7.24 The terminal balance verification measurements in class 4 offices or class 3 and higher ranking offices are made from the ESS test facilities via the switchboard to terminated TC trunks (class 4 switching). Thus, terminal balancing can be thought of as terminating or originating office testing as opposed to the cross-office concept of through balancing.

7.25 The verification results of terminal balancing are measurable as the ERL and SRL incoming or outgoing from the ESS test facilities on all combinations of connections between SI and TC trunks. ➧These results must meet the balance requirements as specified in Section 660-470-301.➧

7.26 The use of successive step techniques and the intermediate evaluations as prescribed in Section 660-470-502 is recommended when performing terminal balance tests. Terminal balance testing should be performed using test equipment, test routines, and techniques prescribed in Section 660-470-504. The prescribed step methods simplify the balancing process. In order to verify the completed steps, the prescribed step methods specify that the intermediate ERL and SRL evaluations be performed in relation to the required objectives.

> ➧***Note:*** It is advantageous during the balancing process to verify portions of the balanced work before the total dynamic structure of the office balancing can become distorted by improper analysis or adjustments.➧

When performing terminal balance work, any trunks having ERL and/or SRL values below the median requirements as specified in Section 660-470-301 should be investigated for trouble. Trouble should also be suspected if poor test results are obtained on some trunks which are similar in design to other trunks having good test results.

7.27 When an office is to be cut over to switch intertoll, terminal balance testing on the switchboard terminating TC trunks should be completed before the switching system goes into service. Conditions such as too short a turnover-cutover time or the use of a large number of cutover devices and/or halftaps may sometimes preclude the completion of the terminal balance tests until after the actual cutover. In this event, an estimated value of NBO capacitance based on terminal or through balance requirements should be strapped into the 4WTS of all switchboard terminating 4-wire TC trunks. The terminal balance testing should be completed on switchboard terminating TC trunks as soon as possible after the cutover and the estimated NBO and DBO capacitances replaced with the final values.

7.28 Before starting the switchboard terminal balance tests and adjustments, a certain amount of preliminary work is usually required. This includes verifying that outside plant cable acceptance testing is complete, impedance compensators are adjusted, 2-dB pads are present where required, and impedance matching is provided where required. The preliminary work also includes checking repeat coils for proper ratios, proper midcoil capacitance, and correct orientation of the ratio with respect to the impedances being matched. Traffic flow sketches, record preparation, bay locating, and other test planning should also be made part of the preliminary work. In addition to test planning, verify that the 1000 Hz transmission loss and noise-limit measurements of all trunks to be balanced have been measured and are acceptable. The actual measured loss (AML) and noise measurements are to ensure that the trunks meet the transmission requirements. Where TC trunks employ carrier or 4-wire facilities, both directions of transmission must be measured. Terminal balance measurements are of little value if the TC trunks do not meet their 1000-Hz transmission loss and noise-limit requirements.

7.29 Figure 12 illustrates the typical TC trunk connections that must meet balance objectives. The illustration is typical for incoming and outgoing TC trunks.

7.30 When performing balance work on class 3 switchboards where class 4 switching is also performed (a class 5 office is served directly by the switchboard), the incoming and outgoing SI trunks are generally required to meet the through balance objectives. (The through balance objectives are more stringent than the terminal balancing objectives.) When this is the case, the SI trunk portions of a connection have already been balanced

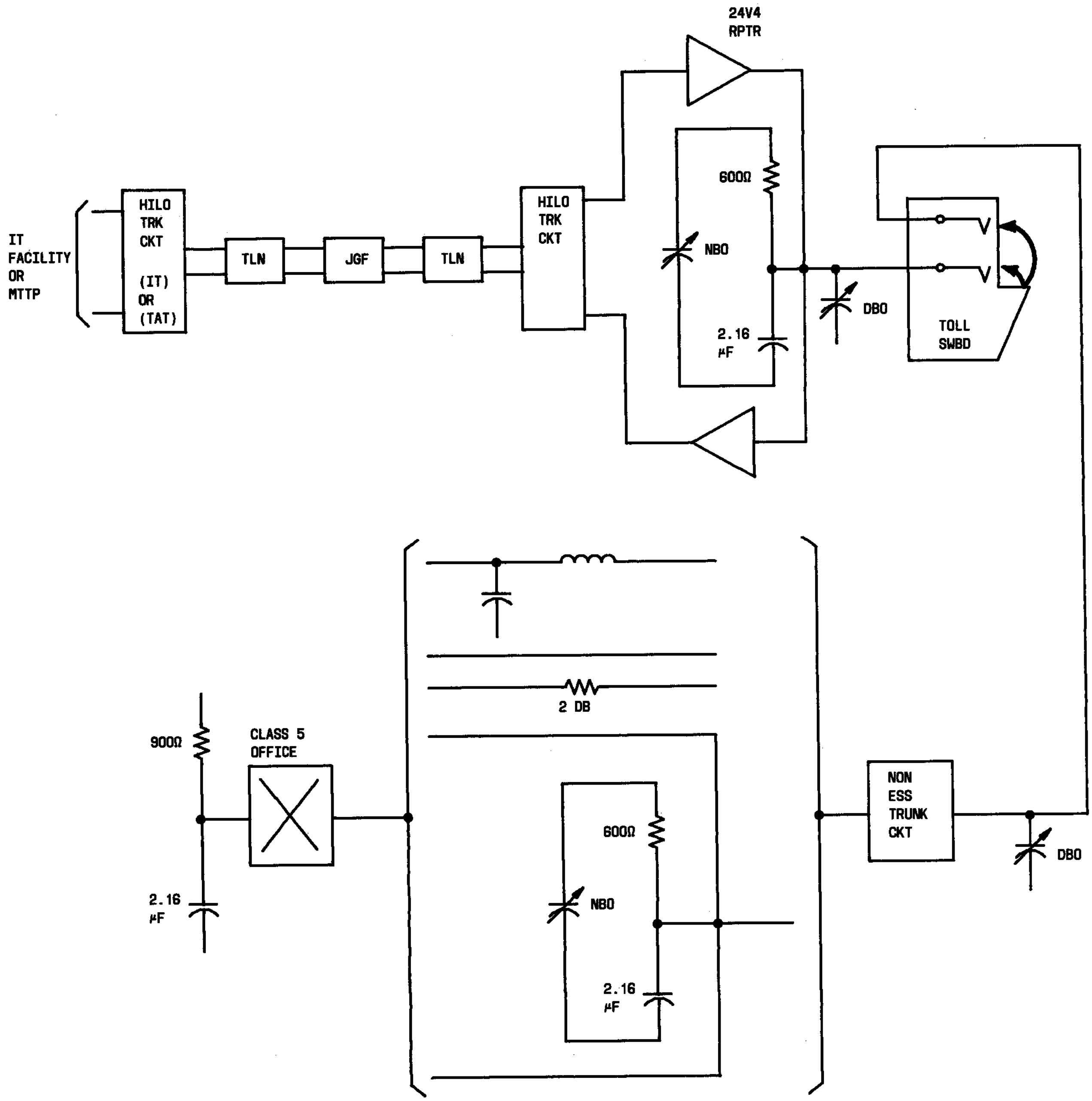


Fig. 12—Typical Terminal Connections Via Switchboard

for through connections and drop build-out work is made only on the TC trunk portion of the connection (refer to Section 660-470-502).

7.31 The strapping of NBO and the DBO capacitors (when required) and the adjustment to impedance compensators must be completed before performing terminal balance verification tests given in Section 660-470-502. To meet overall TC trunk balance objectives, the interoffice facilities to class 5 offices must meet certain criteria. In the case of loaded cable, this includes the structural return loss criteria of the cable and impedance compensator adjustments. In the case of TC trunks with 4-wire facilities, the 4WTS hybrid in the TC trunk at the class 5 office should have a COMP NET option provided. In some cases where large class 5 offices exist, NBO capacitance is also required (refer to

Section 660-470-520). Where the class 5 office is in the same building, provision of a fixed-pad option (when required) as discussed in Part 3 should be verified.

7.32 The description and use of impedance compensators and the method of adjustment are discussed in Part 3. The computation method, however, depends upon the accuracy of the loading-end section and the office cabling data. The use of a low-frequency corrector, if provided, and the amount of capacitance required in the BO capacitor will usually be specified as part of the trunk design information. When balance verification measurements (ERL and SRL) indicate that the impedance compensator adjustment in a trunk is questionable, return loss measurements should be made to ensure that the impedance compensators are properly adjusted. Impedance compensator adjustments require that return loss measurements be made at the impedance compensator with the distant end of the cable pair under test terminated with a precision (115- or 4066-type) network to avoid spurious reflections that may result in inaccurate adjustments of the impedance compensator.

> ***Note:*** The terminal balance verification measurements are made through the switching machine to balance test terminations in class 5 offices. Consideration of these terminations as a source of poor ERL or SRL measurements should be given before any readjustment of the impedance compensators.

7.33 To permit a more practical method of measuring ERL and SRL on TC trunks, a compromise termination has been selected for use at class 5 offices in place of the subscriber loops. This termination consists of a 900-ohm resistor in series with a 2.16 μF capacitor. These values are considered to be representative of the average loop impedance. The terminal balancing procedures are based on using the class 5 office termination. Detailed procedures for making terminal balance tests and the use of this termination are covered in Sections 660-470-502 and -504. The method of terminating in the various types of class 5 offices is covered in Section 660-576-500.

NBO Capacitance Selection (Class 4)

7.34 When the ESS toll switching machine and switchboard are class 4, a compromise NBO value of capacitance is used in the 4WTSs in the switchboard ends of the SI trunks and the 4-wire TC trunks. This value is a compromise value of capacitance determined from capacitance measurements made on connections of the incoming SI trunks to outgoing TC trunks and incoming TC trunks to outgoing SI trunks via the switchboard. This compromise value (which should not exceed 0.080 μF) is then used as the NBO capacitance for the office and is strapped into the networks of all the 4WTSs—both SI and TC (refer to Section 660-470-500).

> ***Note:*** An exception to this general rule for strapping the office NBO capacitance value into all 4WTSs is (a) where the line-to-network impedance ratios of the 4WTSs in the TC trunks are not all the same, or (b) where TC trunks have E-type SF signaling circuits with built-in 4WTSs and adjustable or fixed values of NBO capacitance.

7.35 The NBO capacitance ranges and adjustments are based on a 1:1 network-to-line ratio in the 4WTSs. In some 4WTSs, a ratio other than 1:1 is used. This is the case in the miniature 4WTSs, where a 2:1 ratio is used, and the compromise network is 1200 ohms plus 1 μF rather than 600 ohms plus 2.16 μF. Note that the capacitor is less than half of the normal value because capacitive reactance is inversely proportional to the capacitance. Hence, the NBO capacitance in these 4WTSs will be approximately half the actual office cabling capacitance.

7.36 Some of the E-type SF circuits contain built-in 4- to 2-wire termination circuits. The 2-wire side of the circuit is designed for a nominal 900-ohm and 2.16-μF impedance while the 4-wire side is designed to match 600-ohm facilities. The 2-wire side has a 10:1 impedance ratio instead of the usual 1:1 ratio. Building-out capacitors are included in these circuits as part of the compromise network portion and any combination may be necessary to obtain the required NBO value for balance. However, because of the 10:1 ratio, the actual value will be approximately one-tenth of the office NBO capacitance value.

7.37 In some of the later versions of E-type SF circuits, the NBO portion of the compromise network circuit is equipped with a fixed capacitance value equivalent to 0.040 μF. If a trunk uses E-type signaling circuits with a fixed value of NBO, the requirements for ERL and SRL will be marginal and should be brought to the attention of the transmission engineering organization.

7.38 When TC trunks are equipped with V-type repeaters or carriers, other than T1, equipped with D1 channel units, capacitance measurements for NBO determinations should be made with the 4-wire side of the trunk terminated with 600 ohms at the repeater patch bay, circuit patch bay, voice-frequency patch bay, or equivalent 4-wire location serving the class 5 office. When the TC trunks have a 2-wire facility with an impedance compensator, a termination of 900 ohms in series with 2.16 μF should be placed on the office side of the compensator. (The earlier types of impedance compensators necessitate disconnecting and terminating the office cable pair; however, the later types are provided with a jack for this purpose). When the facility is nonloaded and involves a 2-dB pad, the office cabling connected to the pad is disconnected and terminated with 600 ohms in series with 2.16 μF.

7.39 Digital channel banks for T-carrier facilities between a toll office and a class 5 office have built-in hybrids. The 4-wire legs of these hybrids are terminated or accessed for balance testing purposes in a manner that is unique to the particular type of channel bank. The current types of channel banks in use are the D1, D2, (both MD), D3, and D4. (Refer to Sections 365-1YY-ZZZ when performing measurements on TC trunks equipped with the D1-, D3-, or D4-type channel banks, or 365-4YY-ZZZ when performing measurements on trunks equipped with D2 channel banks.)

7.40 When making capacitance measurements to select an NBO value, more accurate measurements of the office cabling capacitance can be obtained when a high-frequency signal (2000 Hz) is used rather than a lower frequency. The effects of various series capacitors and bridged inductances (such as retardation coils and relays) are negligible at the higher frequencies, whereas, they may control the measurements at lower frequencies. In addition, the office cabling capacitance, being shunt capacitance, has more effect and is, therefore, more accurately measured at the higher frequencies. This same effect is obtained when using the SRL HI output ➧(frequency range from 2200 Hz to 3400 Hz)➧ of the KS-20501 RLMS. A 2000-Hz signal source can also be used externally with the KS-20501 RLMS. This is accomplished by setting the TYPE TEST switch to EXT OSC and connecting an oscillator to the EXT OSC jack or binding posts.

7.41 There will, in general, be no semblance of an overall normal distribution in the measurements of office cable capacitances. The values will tend to separate into two groups, ie, a group of smaller values (shorter paths) and a group of larger values (longer paths).

7.42 In order to obtain a true average of these measured values, a system of weighting (size of groups, size of samples, traffic usage, etc) would be necessary. Since this is impractical, a compromise value must be determined. This value is the average of trunk sample measurements which include the longest and the shortest paths.

7.43 The capacitance measured on the connections in a given sample should have similar values. Whenever a wide excursion within a sample occurs, it could be indicative of improper connections or that too wide a distribution of connections is covered by the sample. If the latter case exists, additional samples should be taken.

7.44 When using a compromise value of NBO capacitance, a somewhat less than maximum value of ERL and SRL can be expected on the longest and shortest paths (those paths with more or less capacitance than the computed midrange path). This reduction in ERL and SRL values can become serious if the deviations in path capacitance are too great; therefore, capacitance differences should be held to within a relatively narrow range by adding DBO capacitance to the shorter paths (ideal range being no more than 0.025 μF difference between the longest and shortest path). This may require additional sampling to determine the shorter paths that require build-out capacitance to reduce the range.

7.45 Capacitance measurements made on a sampling basis are adequate provided that the samples are chosen with care to be representative of all trunks in the office. As a general rule, where the total number of trunks to be represented by a sample is five or less, all trunks are included in the sample. When the total number of trunks is more than five, the following sample sizes are recommended.

TOTAL NUMBER OF TRUNKS	NUMBER IN SAMPLE
5 or less	All trunks
6 to 10	5
11 to 15	6
16 to 25	7
26 to 50	8
Over 50	Approximately 18 percent of total

7.46 At least one sample should be tested for each category of trunking (see Table A). Furthermore, each of these categories should be subdivided according to the type of trunk equipment and the facilities used on the trunks, and at least one sample from each subdivision should be tested. For example:

(a) Trunks with fixed 2-dB pads

(b) Trunks employing loop signaling on voice-frequency loaded facilities

(c) ♦Trunks employing E&M leads with DX signaling on 2-wire voice-frequency loaded facilities♦

(d) ♦Trunks employing E&M (SF or DX signaling) or loop (E- or F-type signaling units) signaling and 4-wire voice-frequency loaded facilities or carrier channels.♦

7.47 If an inspection of the physical locations of trunk circuits, impedance compensators, switchboard appearances, etc, indicate that large differences in central office cable lengths may be expected within one of the above subdivisions, the sample size should be increased or additional samples should be taken. Consideration should also be given to the differing amounts of bridged capacitance in a trunk having cabling from service observing equipment, multiple switchboard lineups, etc.

DBO Capacitance Adjustment (Class 3 and Higher Ranking Offices)

7.48 In class 3 and higher ranking switchboards where through connections are made by the operator, all SI trunks and some of the TC trunks require DBO capacitance. This is because the required NBO capacitance value in these offices is, as a rule, fairly large so as to satisfy through balance for the longest through office path plus a growth factor. In these offices, the shorter TC trunks must be built out with DBO capacitance to obtain adequate return loss against the office NBO value. The procedures are contained in Section 660-470-502.

DBO Capacitance Adjustment (Class 4)

7.49 In class 4 offices, DBO adjustments will usually be quite limited because the NBO capacitance value is selected as a compromise to the range of capacitance measured on connections involving both the SI and the TC trunks. The shorter connections of SI and TC trunks may require buildout; this is determined when establishing the compromise NBO value for the office. The procedures for determining the DBO capacitance in these offices are given in Section 660-470-502.

Verification

7.50 To complete the terminal balance work of switchboard terminating trunks after the impedance compensators, NBO capacitors, and (where necessary) DBO capacitors have been adjusted, the following verification tests should be made on all switchboard terminating TC trunks from the TAT 1 or TAT 2 for:

(a) Echo Return Loss

(b) Singing Return Loss.

> ***Note:*** The ESS office balance work must be completed or has progressed to the point that the TAT circuits and the SI trunk used for testing have been balanced.

7.51 It is extremely important that the ERL and SRL verification tests be made from the 4-wire side of all 4WTSs in switchboard terminating TC trunks. These tests should be made on all TC trunks in all toll switching offices irrespective of their rank in the MTS hierarchy. These tests will uncover any balance troubles such as open NBO capacitors, compromise networks, or incorrect wiring in the 4WTS or other equipment within the individual trunks and ensure proper return losses toward the class 5 office.

8. CERTIFICATION OF OFFICE BALANCE

8.01 The certification of an office as balanced is the responsibility of the transmission engineer. The requirements for certification are given in Section 853-500-110. The following is a summary of these requirements:

(a) The office NBO capacitance value must not exceed 0.080 μF and must be approved by the transmission engineer. (This applies to switchboard trunks only.)

(b) Trunks that do not meet VNL design objectives (as specified in Section 781-030-100) are classified as not meeting minimum balance requirements.

(c) Intertoll trunks are assigned to 4-wire facilities. (Those that are not must be classified as not meeting minimum balance requirements.)

(d) Trunks for which recorded measurements are not available are classified as below minimum requirements for ERL and SP/SRL.

(e) At least 50 percent of all measurements for each class of trunk (SI, intrabuilding TC, intra-processor TC trunks, 4-wire interbuilding TC, and 2-wire interbuilding TC) must be equal to or greater than the median requirement. Similarly, not more than 2 percent of the measurements for each class of trunk may be below minimum requirements.

(f) All trunks with measurements below the turndown limit have been removed from service.

8.02 The ERL and SRL measurements for trunks working on 2-wire VF loaded cable facilities should be summarized separately from trunks working on 4-wire facilities and from trunks that are equipped with 2-dB pads. This is desirable because higher ERL values are expected from the latter types of circuitry.

9. TEST ARRANGEMENTS AND TERMINATIONS

A. General

9.01 All test sets used in balancing must be calibrated in accordance with standard instructions before they are used. The calibration should be rechecked during the testing period. Ample warm-up time should be allowed for all test sets to ensure that they have been stabilized.

9.02 ♦Communication and test line circuits between testing locations should be established as required. The codes 101 and 970 (where available) provide communications as well as test lines to the MTTP over any trunk incoming to the No. 1/1A ESS HILO office from the class 5 office.♦

9.03 The transmit and receive ports of 4WTSs associated with TC trunks appear in a variety of jack fields. To avoid misunderstanding, the 4WTS ports, when considered in the balancing sections, are established with reference to the facilities; ie, the transmit port transmits to the facility; the receive port receives from the facility. In 4-wire voice-frequency patching jack fields, the transmit port designation is EQ OUT and connects to the RLMS RCV jack. The receive port is designated EQ IN and connects to the RLMS TRMT jack.

B. Switchboard Balance Test Terminations

9.04 The testing of connections to toll switchboards involves a switchboard balance test termination (SWBD BAL TST TERM). The SWBD BAL TST TERM consists of a nominal 600 ohms in series with 2.16 μF and is bridged with a BO capacitor provided to change the reactance component of its impedance. The impedance of the SWBD BAL TST TERM is adjusted to represent, at its switchboard jack, the impedance presented by SI trunks or the average TC trunk (class 4 office only) which terminate at the switchboard.

10. TESTING ANALYSIS AND TROUBLESHOOTING

10.01 The method of stating objectives requires that the measured values be analyzed. If the distribution of the measurements is reasonably normal and the requirements are met, the overall objective will be met. If any of the trunks fall below the median requirements, these trunks should be investigated for the source of poor balance. Similarly, any trunk having a decidedly poorer ERL or SRL than one with similar equipment should be investigated. A careful check may show that the balance can easily be improved. Where all the trunks measured have ERL values well above the requirements shown in Section 660-470-300 or 660-470-301, an error in the method of measurement may exist. In offices where all trunks have been designed to meet the median requirements, a large percentage of balance measurements can be expected to exceed the median. In a new office with well-designed trunks, it is probable that 100 percent of the measurements will meet median requirement values. If requirements are marginal or not met and the causes of the poor balance results cannot be determined, the results should be referred to the transmission engineering organization for further investigation.

11. REFERENCES

11.01 The following references are given to provide detailed information with regard to through and terminal balance.

SECTION	TITLE
231-090-366	HILO 4-Wire Switching Feature 2-Wire No. 1 and No. 1A Electronic Switching System
231-130-320	Manual Trunk Test Position
330-300-500	Completion Tests of Exchange-Area Cables - Introduction
330-450-100	Fault Location on Cable Pairs Using Voice-Frequency Sweep Test Sets - General Theory
332-015-100	Simplified Theory of Singing Point Tests
332-205-100	Impedance Compensators - Description
332-205-500	Impedance Compensators - Tests and Adjustments
332-206-158	837J Network—Description
332-206-258	837J Network—Installation and Prescription Settings
660-576-500	Class 5 Offices - Methods of Terminating at Class 5 Direct Distance Dialing Offices for Terminal Balance Measurements
781-030-100	Notes on Direct Distance Dialing
820-009-150	Limiting Conductor Conditions

Other References:

Transmission Systems for Communications,
Bell Telephone Laboratories, Inc., 1970.

Principles of Electricity Applied to Telephone and Telegraph, Long Lines Dept.,
American Telephone and Telegraph Co., 1961.