# TOLL SWITCHBOARDS (CLASS 4P) OFFICES
# TERMINAL BALANCE
# GENERAL INFORMATION

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## 1. GENERAL

**1.01** Terminal balancing is the adjustment, measurement, and evaluation processes employed to control echo and singing for terminating switched trunk connections in the direct distant dialing (DDD) network. This section covers the general information pertaining to these processes and their applications in all class 4P toll switching offices. ***Terminal*** balance is required when switching intertoll (IT) trunks to toll connecting (TC) trunks via a switchboard.

**1.02** Whenever this section is reissued, the reason for reissue will be listed in this paragraph.

**1.03** The general considerations contained in this section provide a ***basic understanding*** of the purposes, requirements, apparatus, measurements, and techniques encountered in the balancing processes. Detailed information concerning specific areas within the broad scope of terminal balancing can be found in the reference material outlined in Part 9. Additional sections which concern balancing in class 4P offices are as follows:

| SECTION | TITLE |
|---|---|
| 660-475-010 | Administration and Records |
| 660-475-301 | Terminal Balance Test Requirements |
| 660-475-500 | Office NBO Selection for Terminal Balance |
| 660-475-502 | Terminal Balance—DBO Procedures and Verification Tests |
| 660-475-503 | Analysis of Poor Results and Troubleshooting Procedures (to be issued) |
| 660-475-504 | Test Equipment, Test Facilities, and Test Terminations |
| 660-475-520 | Selection of Office NBO in Large Class 5 Offices Served by Step-by-Step Office |

The information contained in these sections can be applied to balance work initially or on a circuit order work basis required to complete Form E-2545A, as outlined 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.

**1.04** The initial performance and subsequent maintenance of the terminal balance in all 2-wire toll switching offices is important and essential to present-day toll transmission requirements. It is important because balancing permits application of via net loss (VNL) design concepts to trunks in the DDD network, and it is essential because of the present use of 2-wire toll switching. The VNL design results in toll connections with the lowest practical loss (ie, which satisfies the echo requirements of basic transmission design). VNL theory is discussed in Section 800-100-100, Part 6.

**1.05** Normally, the DTO- and DSA-type operator switchboards are considered to be class 4P toll switching offices in the DDD hierarchy plan for toll office classifications. These switchboards and all switchboards associated with more than one toll switching machine require performance of the terminal balancing processes. Refer to Section 800-100-100, Parts 3 and 6, for a detailed explanation of the DDD switching hierarchy.

**1.06** Balancing in a toll switching office is directly related to the office wiring and equipment locations at the time of performing the balance work. A comprehensive system of records for all balancing work is recommended (see Section 660-475-010). These records should also reflect any subsequent balance work performed as required in circuit order work. Proper records permit periodic inspection to determine whether the uniqueness of balance conditions within an office or within a given trunk group has been disturbed by transition work or by additions to, modifications of, or removal of trunk equipment in the 2-wire line (2WL) side of 4-wire terminating sets (4WTSs) associated with IT and TC trunks.

## 2. TRANSMISSION CONSIDERATIONS

### A. General

**2.01** Today's media for IT trunk transmission are 4-wire carrier facilities. These transmission facilities are terminated and converted to 2-wire transmission facilities when 2-wire machine switching or connections by an operator switchboard are made between IT and TC trunks. The termination of the 4-wire facility and the conversion to 2-wire

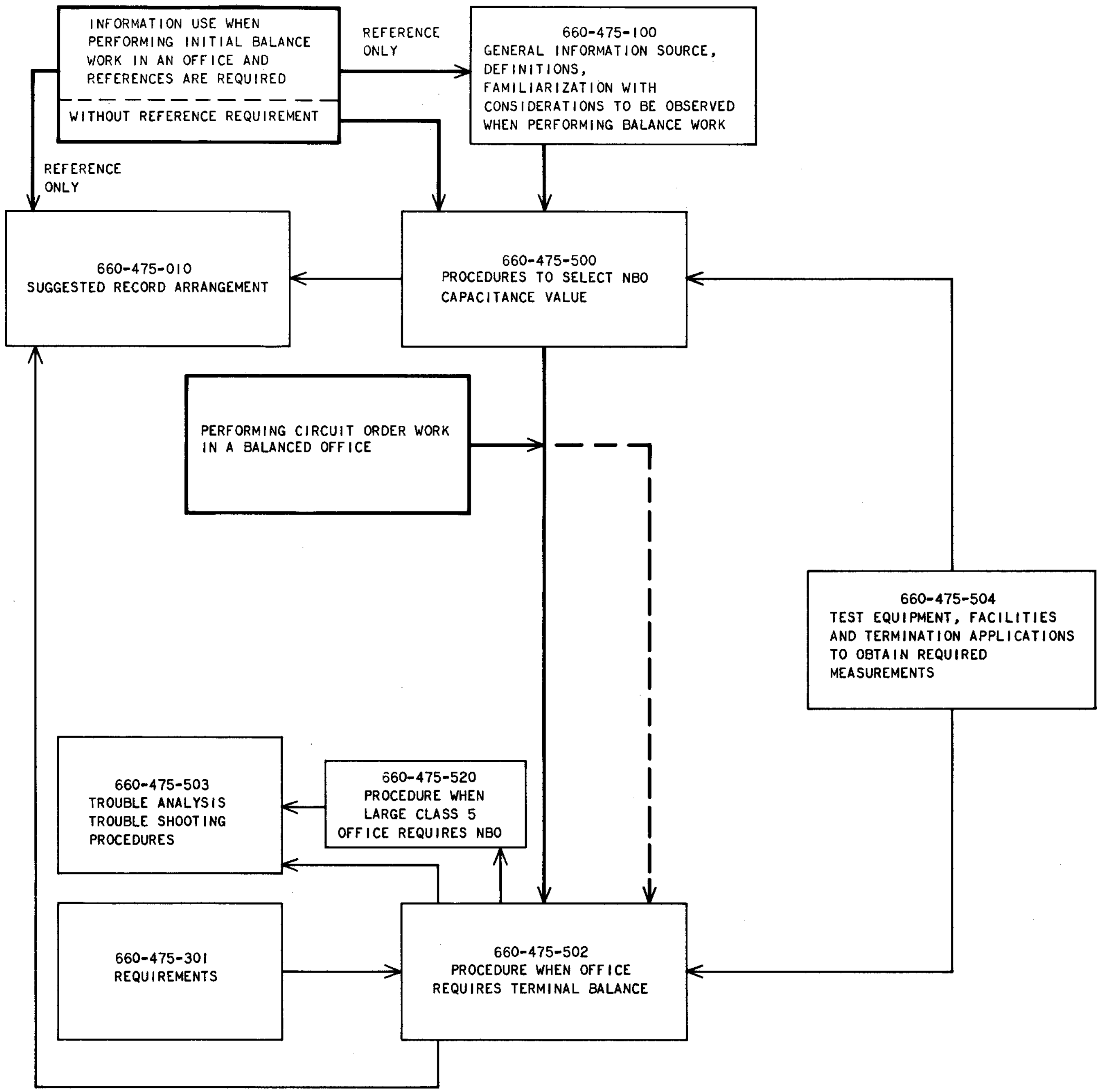



**Fig. 1—Use of Information Contained in Section 660-475-ZZZ**

facilities is accomplished with a 4WTS. The 4WTS employs a transformer-type hybrid junction between the 4-wire facility and the 2-wire facility. This type of junction permits transfer of power from the 4-wire facility receive path into the 2-wire facility and from the 2-wire facility into the 4-wire facility transmit path. Because of the transformer-type hybrid and the fact that power reflections will occur whenever impedance irregularities exist at interconnections of 2-wire circuits, control of the impedances is necessary.

**2.02** Figure 2A demonstrates the power division that occurs when a signal is applied to any port of a balanced hybrid coil arrangement such as that used in 4WTSs. 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 parameters shown in Fig. 2A to impedances Z1 through Z4 and including the hybrid coil arrangement in a typical 4WTS permits consideration of the hybrid as part of a typical 4WTS as shown in Fig. 2B. Here, the impedance value of Z1 (2-wire network line terminated with a compromise network) and that of Z2 (2-wire line 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 made. The input power continues to divide across the hybrid coils as shown in Fig. 2B; 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 reenter 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 2-wire network line (Z1). In an ideal situation where Z1 equals Z2 (impedances match), no reflections would occur. This, however, is impractical for a given 4WTS in an IT trunk and not feasible when consideration is given to all the possible variations of the 2WLs available as connections to TC trunks via a toll switchboard. Therefore, in balancing an office, compromise impedances are used to provide the best impedance matches possible across the hybrids over the greatest number of IT and TC trunk 4WTSs.

### B. Echo and Singing

**2.03** Whenever power is reflected into the 4WTS of any 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. 3). When the returned power is received at the distant end with sufficient magnitude (ie, the loss to the returning power is not sufficiently high), return-loss (RL) impairments to transmission can occur.

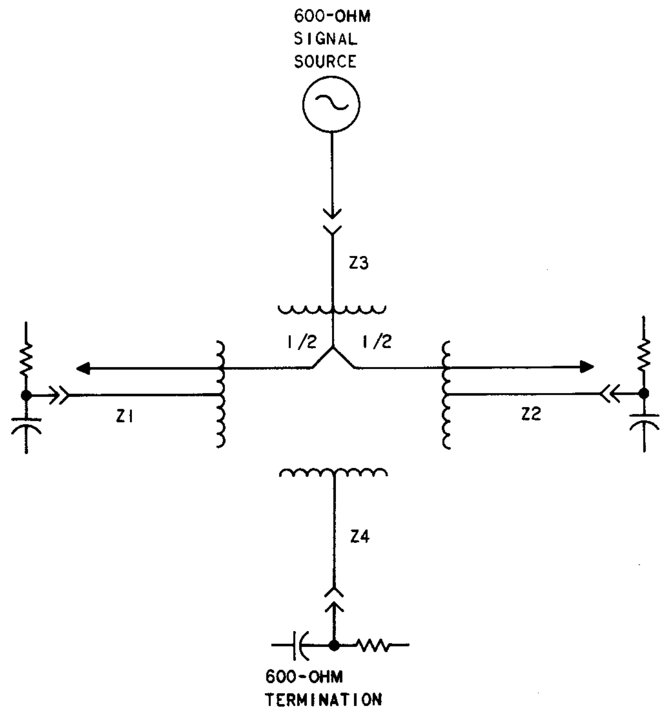
**2.04** Subjective testing has shown that when sufficient power is returned with sufficient delay, a talker hearing his own voice slightly delayed will experience disturbance with his thought processes and interference with ease of conversation. This RL type of transmission impairment is called talker echo. Another RL type of transmission impairment occurs when RLs are small and power is returned at a single frequency (SF) with sufficient magnitude to start self-sustained oscillations. This impairment is called singing. Another impairment, near singing, occurs just before singing begins. These conditions will always exist where the gains exceed the losses in the circuit from termination to termination. The energy paths for both types of impairments are shown in Fig. 3.

**2.05** The voiceband frequencies in DDD connections are normally limited by the 4-wire facilities to the 200- to 3200-Hz range. When transmission in a connection is impaired by echo, the frequencies which most talkers will notice as objectionable are in the 500- to 2500-Hz range. At these frequencies, the talker will normally complain of echo before the circuit starts to sing. Therefore, the balancing objectives for control of the RL in this frequency range are more stringent than the objectives for the control of RL at other frequencies in the voiceband.

**2.06** 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 he will complain of any echo. Figure 4 indicates the echo and singing frequency ranges within the voice-frequency (VF) band.

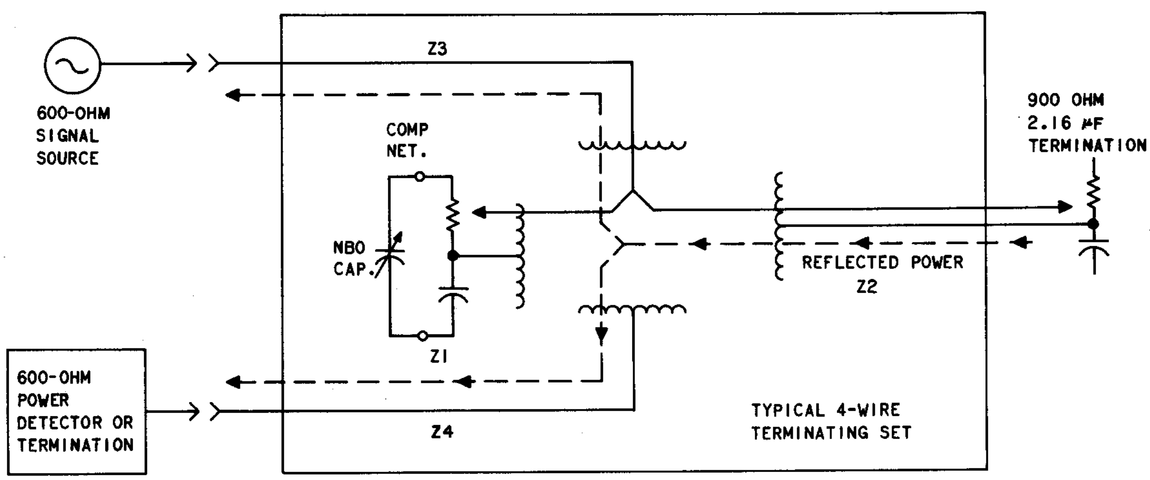
**2.07** Near singing is sometimes referred to as being a hollow sound like speaking into an empty barrel. Near singing will occur somewhat before actual singing starts.

**2.08** It should be noted in the energy paths illustrated in Fig. 3 that the talker echo path is dependent upon the RL conditions at only one end of a 4-wire facility. Another energy path also exists: this is the listener echo path which is dependent upon poor RL 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, it should be




NOTES:
1. Z1 = Z2, Z3 = Z4
2. PARAMETERS ARE COMPARED TO PARAMETERS OF FIG. 2B AS FOLLOWS:
   Z1 = NETWORK LINE
   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. 2—Hybrid Power Division and Application**

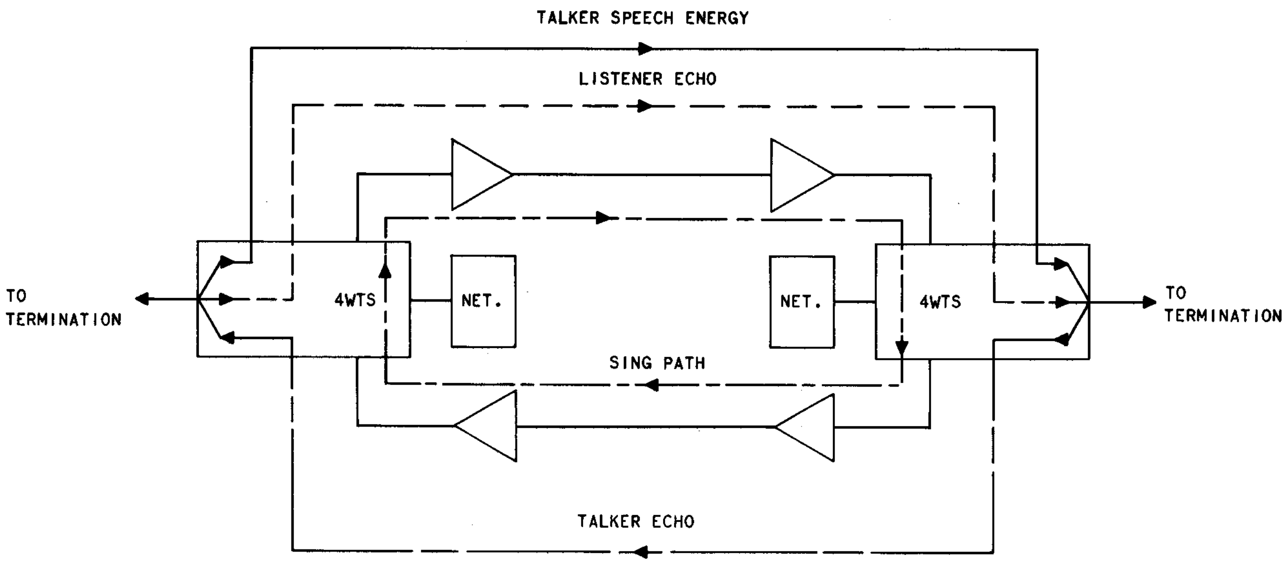



**Fig. 3—One-Way Energy Paths in 4-Wire Terminated Circuits Terminating in 2-Wire Circuits**

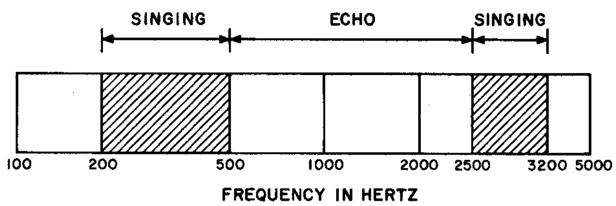



**Fig. 4—Echo and Singing Ranges in a Typical Voiceband Frequency Spectrum**

noted that singing and near singing are also dependent upon poor RL conditions at each end of a 4-wire facility; but unlike listener echo impairments which are influenced by propagation delay, they are influenced by frequency, phase relationships, gains, and power addition. Consequently, balancing consists of separate test methods for each of the RL impairments, ie, echo return loss (ERL) and singing point (SP), or equivalently, singing return loss (SRL). ERL measurements determine echo conditions and the SP/SRL measurements determine singing and near singing conditions. The results of both measurements are necessary to obtain integrity in the evaluations of balance in a given circuit. A further consideration that should be noted is the magnitude of returned power in a connection is an enhancement factor to echo and singing impairments and not the absolute cause.

### C. Definitions

#### Return Loss (RL)

**2.09** Specifically, RL is the measure of an impedance match between circuits at the point of their interconnection. It can be expressed for any frequency as RL (in dB) $= 20 \log_{10} [Z1+Z2 \div Z1-Z2]$ where Z1 and Z2 are the impedances of the interconnecting circuits. Considering this equation and the factors of impedances Z1 and Z2 (see Part 3), it can be seen that, at a given frequency, the RL is infinite at the interconnection point when the impedances are equal (balanced) since 1/0 approaches infinity by definition. Conversely, a complete mismatch (imbalance) will occur when either but not both Z1 or Z2 is zero. The RL for the frequency then becomes zero since the logarithm of 1 is zero.

#### Echo Return Loss (ERL)

**2.10** The ERL is a weighted average measurement of the RLs 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 in an IT trunk (see Part 4). This measurement does not necessarily indicate the RL at an individual frequency.

**Singing Point (SP)**

**2.11** The SP is a measure of the RL for a SF in the voiceband (200 to 3200 Hz). This SF is usually but not always the frequency having the poorest RL at the hybrid interconnection and is the critical frequency point in the voiceband at which gain and phase relationship cause a singing condition. When singing conditions exist in a circuit and the degree of balance is conducive to singing, it may occur at any frequency within the voiceband; but as a result of impedances characteristics in 2WL apparatus, the upper and lower ends of the band will generally contain the critical frequency as previously discussed in 2.06. This measurement is also determined in a specific manner as described in Part 4. The SP frequency ranges can be considered as shown in Fig. 4.

**Singing Return Loss (SRL)**

**2.12** The SRL is the actual RL in the singing bands (200- to 500-Hz SRL and 2500- to 3200-Hz SRL-HI) and is measured with a KS-20501 return loss measuring set (RLMS) or equivalent. The SRL readings obtained correspond closely with SP measurements discussed above.

**2.13** The SP and the SRL are essentially the same in a given circuit and may be considered as equivalent, the difference being in the manner in which they are obtained (see Part 4). Either the SP or the SRL should meet the requirements stated in Section 660-475-301.

**Balance Verification Tests**

**2.14** When performing balance work, the following tests are required after the network build-out (NBO) and drop build-out (DBO) capacitor adjustments are completed:

(a) 1000-Hz transmission loss and noise tests (in both directions of transmission on TC trunks working on hybrid-type repeaters or carrier facilities)

*Note:* Although not technically a balancing requirement, a 1000-Hz transmission and noise measurement should be made on a test connection before measuring the ERL and SP/SRL. The measured loss should be within $\pm$1.0 dB of the expected measured loss (EML). The purpose of the test is to ensure that the test connection has been made correctly and that the losses are within reasonable limits. (In general, trunk transmission and noise measurements are completed prior to performing any balance work.)

(b) Echo return loss test

(c) Singing point or singing return loss tests.

**2.15** The verification tests performed in Section 660-475-502 measure the amount of ERL and SP/SRL occurring in properly terminated trunks after all necessary adjustments have been made to the NBO and BO capacitors in the trunk circuits.

## 3. APPARATUS CONSIDERATIONS

### A. General

**3.01** A compromise network (COMP NET) plays an important part in the balancing process and is the basic impedance to which all 2WLs in an office are balanced. It is part of a 4WTS and provides the required termination to the 2-wire network line 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 terminations that may be connected to the 2WL of the 4WTS in which it is used. The IT trunks terminating on a switchboard will be connected to many different TC trunks; and while all of them have a nominal impedance of 600 ohms, the actual impedance presented to the IT 4WTSs will vary. This variation is due to different lengths of office cabling, the normal variation among different equipments, and/or different types of office cable pairs. The network connected to the network line in the 4WTSs must adequately balance the impedance of any one of the possible connections to the 2WL. To do this, a COMP NET consisting of a 600-ohm resistor in series with a 2.16-$\mu$F capacitor is used with provisions for adding an adjustable capacitor in parallel with the compromise network to better compensate for the capacitance of the office cabling. As stated above, in any given office the IT trunks and particularly the TC trunks will have different impedances at any frequency from trunk to trunk because of the different amounts of resistance and reactance in the office cabling. Thus, RLs depend in part on both of these components of impedance. Resistance mismatch is controlled by limiting the maximum resistance of the 2-wire path. The NBO capacitor parallel to the COMP NET (see Fig. 2B) is used to control reactance mismatch (capacitive portion).

**3.02** Within the hierarchy of the DDD network, IT trunk COMP NETs are required to balance impedances presented by the terminating impedances of TC trunks. The NBO adjustment, therefore, permits establishing an impedance value in the COMP NETs that will satisfy some mean value of the 2WL terminating impedances. The 2WL impedances themselves can also be affected by a similar adjustment to capacitance with BO capacitors bridged across the 2WL.

**3.03** 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 by the office would be quite similar to the impedance of the 4WTSs COMP NET. Long cable lengths, bridged service observing cabling, and switchboard and testboard multiple will cause variations in cabling capacity between different trunks. Consequently, BO capacitors are provided in all 2WLs to permit making their impedances more alike by changing reactance in the same manner as the COMP NET impedances are varied in the 2-wire network lines with the NBO capacitors. In other words, the function of the BO capacitor is to narrow the range of 2WL impedance presented to the 4WTS hybrids.

**3.04** Figure 5 demonstrates the typical trunking to and from a toll switchboard. The apparatus shown in the figure is representative of that found in most offices of this type.

**Office Cabling Resistance Limit**

**3.05** No resistance buildout is provided in the networks of the 4WTS. Reasonable control of the resistance factor of the 2WL 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 2WL paths are made, the impedances may change and the effect on the balance in the office should be investigated. Normally, the values of cable resistance that will affect impedance will not be exceeded before the total amount of shunt capacitance and BO capacitance (if used) in the office cabling of a connection becomes larger than a maximum permissible capacitance value. One exception to this is when there is a large amount of bridged cabling in the connection such as may be present in large multiples.

**Office Cabling Capacitance Limit**

**3.06** In all cases, the maximum permissible value of capacitance in office cabling for any connection is limited by attenuation-frequency distortion characteristics and is specified as 0.080 μF. Large values of capacitance introduce increased attenuation distortion at the upper part of the VF spectrum (2000 to 3000 Hz). Therefore, the NBO should ***not*** exceed 0.080 μF in any office, and a ***lower*** value is desirable. For example, a shunt capacitance of 0.080 μF will produce a difference in loss between 1000 and 3000 Hz of about 1.2 dB. It should be remembered that this difference in loss for a connection is also affected by capacitance of the 4-wire paths between the 4WTSs and the facility terminals (eg, channel banks). However, this capacitance is not reflected in the value of the NBO.

**3.07** 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, 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.

**3.08** If the coil has other than a 1:1 impedance ratio, an additional limitation exists. For instance, in a 1.5:1 ratio coil interconnecting a 900-ohm plus 2.16-μF circuit and a 600-ohm plus 2.16-μF circuit, the capacitance parts of the impedances will not be in a proper ratio. That is, the 600 ohms and 2.16 μF transformed through an ideal 1.5:1 coil will be equivalent to 900 ohms and 1.44 μF. This capacitance imbalance will be in addition to that caused by leakage reactance, series reactance, and self-inductance effects in the repeating coil itself. ***Due to these limitations the requirements of terminal balance on trunk arrangements employing more than one repeating coil may be impossible to meet.***

NOTES

1. TRK EQPT ASSOCIATED WITH #5XB OFFICE.

VNL DESIGN NOTES

A. ALL FOUR-WIRE TERMINATING SETS MUST BE COIL TYPE AND EQUIPPED WITH NET BUILDOUT CAPACITORS

B FOUR WIRE TERM SETS ARE NOT HARD WIRED TO TRUNK CIRCUITS

C THE 1 UF CAPACITOR SHALL BE CONNECTED ACROSS THE 2-WIRE SIDE OF THE 4-WIRE TERM SET (IF TERM SET IS PRESENT)

D ALL INTRABUILDING TOLL CONNECTING TRUNKS WILL BE EQUIPPED WITH 2 db PADS

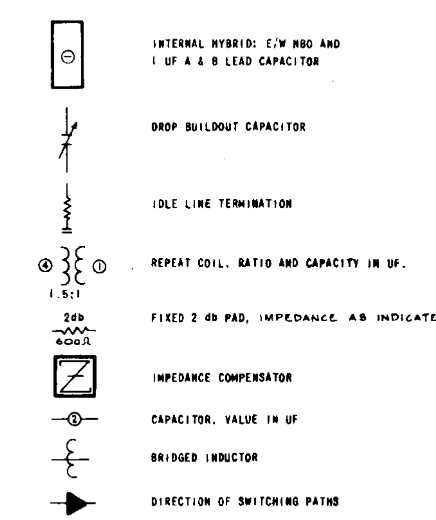
E. ALL 2-WIRE TRUNK GROUPS TO END OFFICES WILL BE EQUIPPED WITH IMPEDANCE COMPENSATORS.

F. TERMINAL BALANCE TESTING - CLASS 4 OFFICE AND HIGHER:

BSP 660-470-100
BSP 660-470-500
BSP 660-470-502

G OFFICE NBO 0.024 MICROFARADS

LEGEND



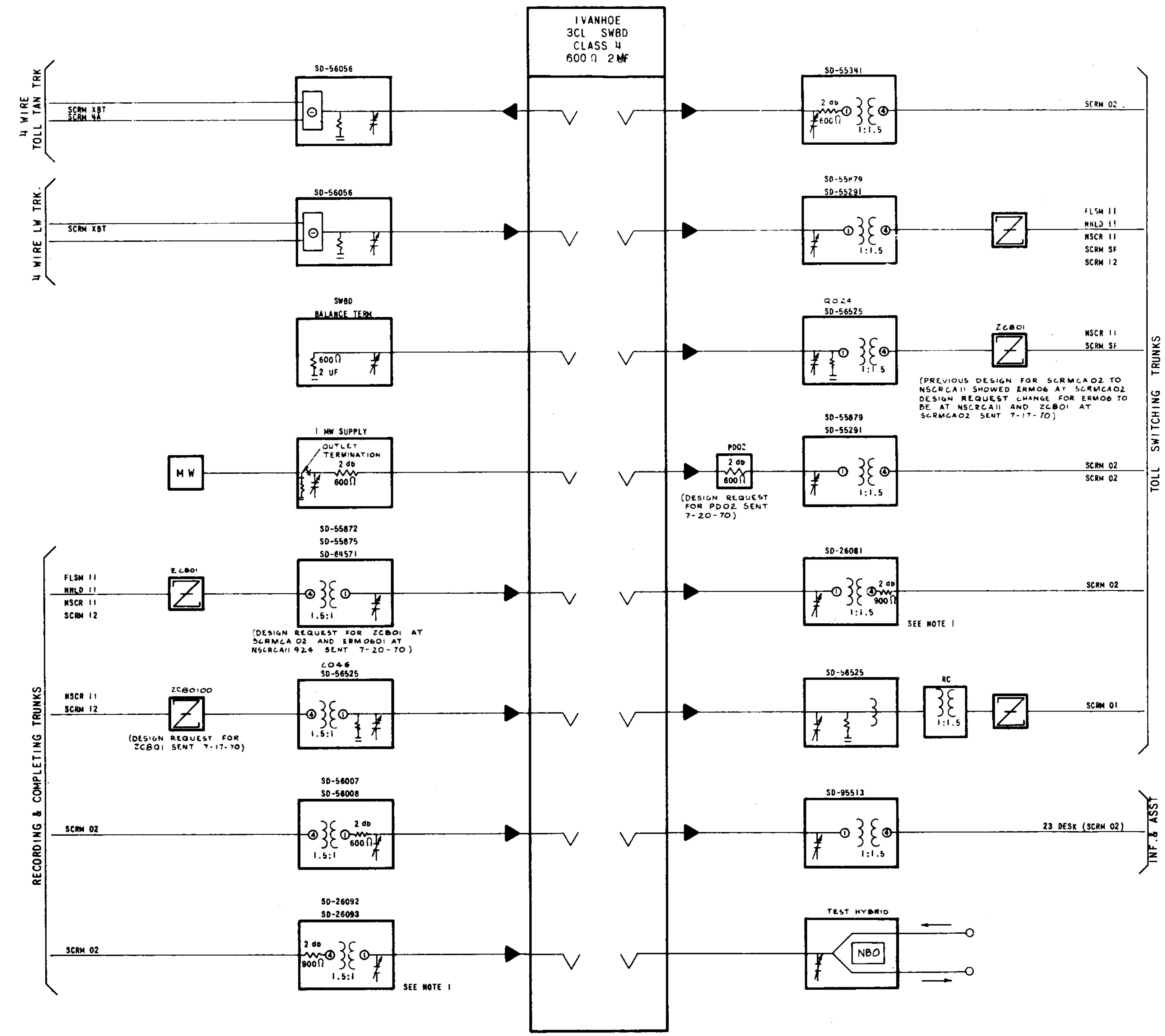




**Fig. 5—Trunking Schematic for Typical Class 4P Switchboard Toll Switching Office**

**3.09** Before beginning the actual terminal balancing adjustments and measurements, a certain amount of preliminary checking is usually worthwhile. These inspections may reveal apparatus or conditions which will hamper or invalidate balancing measurements. Visual checks (on a sampling basis) should be made to ensure that all apparatus affecting balance is properly installed and cross-connected.

### B. 4-Wire Terminating Sets

**3.10** In class 4P switching offices, all 4WTSs in the IT and tandem trunks terminating on the switchboard must be equipped with COMP NETs and NBO capacitors. The 4WTSs must have the proper nominal 2-wire input impedance. This impedance is 575 ohms plus 2.16 μF for 600-ohm hybrids. These values allow for an average resistance of 25 ohms in the office cabling. With mostly 22-gauge wire, this is equivalent to approximately 800 feet of cabling and requires an NBO of 0.030 or 0.040 μF, depending on the amount of bridged cabling capacitance. The later issues of 120-type built-out hybrids, F-type signaling units, and D2 channel banks (SD-96463-01) will meet this requirement. The older varieties of 120-type, the miniature type (SD-95137-01), N- and T-type carrier, and E-type SF signaling units that have built-in terminating circuits will meet the minimum objectives for ***terminal*** balance.

### C. A and B Capacitors

**3.11** The 2WL hybrid coil windings in 4WTS are frequently used to develop dc signaling on the 2WL path in an office. 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 the following:

(a) The capacitor value is 1 μF.

(b) Only one capacitor exists in the 2WL.

(c) A 1-μF capacitor is also provided in the 2-wire network line of the hybrid to maintain proper impedance characteristics.

Referring to Fig. 6, it should be noted 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 [see 3.12(c)]. 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, the miniature types (SD-95137-01), N- and T-type 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.

### D. Trunk Relay Equipment

**3.12** All IT-type trunk relay equipment should have the following features provided:

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

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

(c) Any signaling relays bridged to the transmission path must 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 relay is provided for RL improvement.

### E. Repeating Coils

**3.13** Repeating coils appearing in a 2WL path for impedance matching or signaling purposes

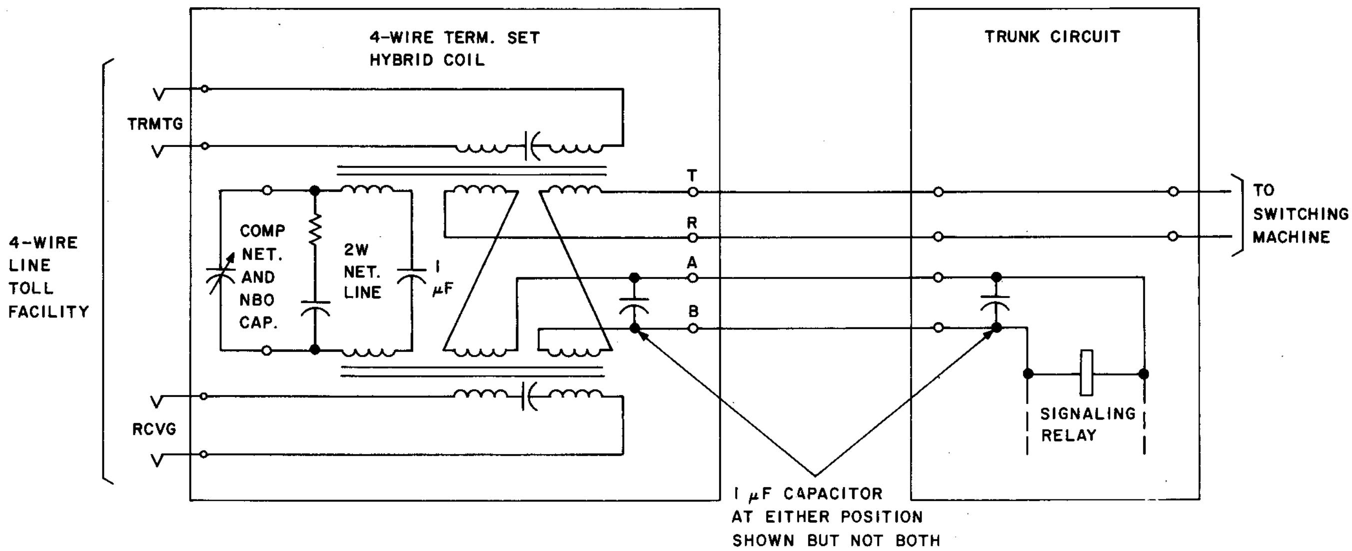



**Fig. 6—Typical 1-Type or 120-Type 4WTS Hybrid Coil Arranged for DC Signaling**

must also be equipped with properly valued midcoil capacitors to obtain optimum impedance characteristics. The VNL objectives for both ERL and SP/SRL are based on this criterion. The repeating coils and their midcoil capacitors are designed to obtain the best compromise in impedance transformation and impedance matching. The midcoil capacitors obtain the best impedance presentation in the IT trunk direction. This results in reduced ERL and SP/SRL performances in the TC 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 RL in the VF range, is demonstrated in Fig. 7.

### F. 2-dB Pads

**3.14** VNL design provides fixed 2-dB pads in all TC trunks having a loss of less than 2 dB without the pad. These pads are provided to improve ERL and SP/SRL performance. Pads are provided as options in some types of trunk relay equipment. External pads which can be cross-connected into certain trunks are shown in SD-95756-01.

### G. Outside Cable Plant

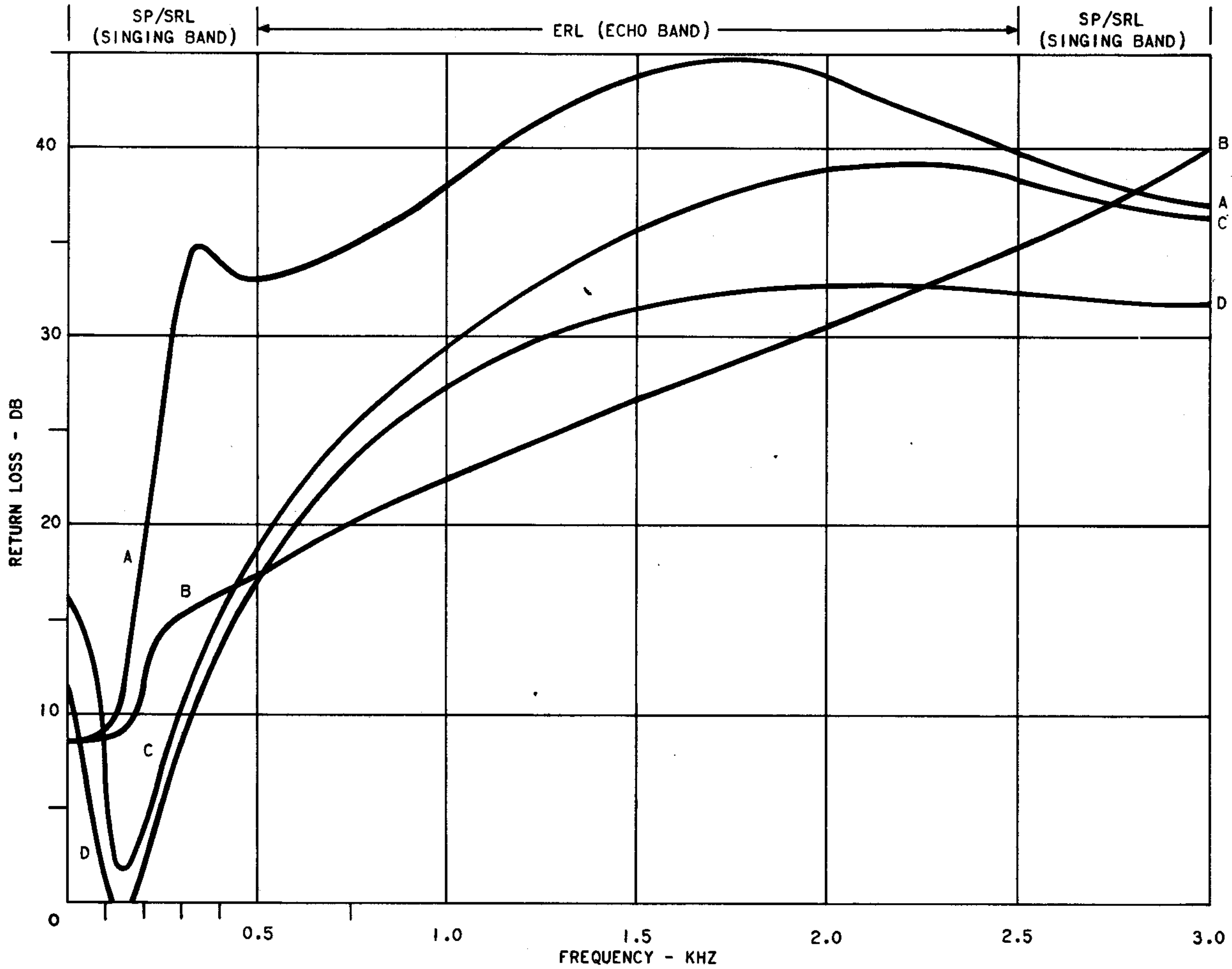
**3.15** Cable loading irregularities, such as missing or double load coils, wrong load coils, irregular spacing of load coils, etc, result in poor RL performance and will degrade office balance results. See references listed in Part 9 for further discussion.

**3.16** 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.

### H. Impedance Compensators

**3.17** Impedance compensators are necessary in all TC trunks assigned to loaded cable facilites. Each impedance compensator must be properly adjusted to cause the loaded cable pair to have the proper sending end impedance. Two types are currently in general use: the impedance compensator shown in SD-95756-01 and the 837-type networks shown in SD-97054-01.

**3.18** The designs for cable loading normally provide a 0.5 loading end section at the toll switching office. (This means that the electrical length between the first load point and the office is one half the electrical length of a full load section.) Using mathematical analysis, it can be shown that the sending end impedance of a 0.5 loading end section is not constant over the VF range and that the sending end impedance of 0.8 loading end section is approximately constant over the VF range. The




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

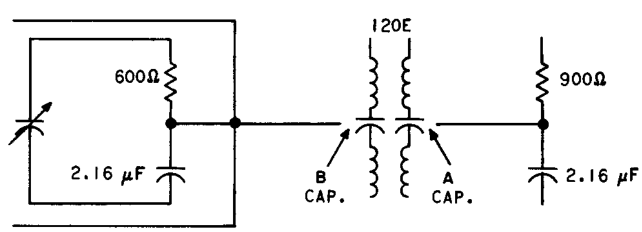



**Fig. 7—Typical Return-Loss Results for Different Values of Midcoil Capacitors**

same type of analysis on the impedance of the compromise balancing networks of 4WTSs used in IT trunks will also show these impedances to be approximately constant for the VF range.

**3.19** The sending-end impedance of a 0.8 loading end section approaches the ideal for terminal balance purposes, since the resistive component of this impedance is substantially constant up to about 85 percent of the cutoff frequency. At a 0.8 loading end section, however, the capacitive reactance component becomes important. Thus, the impedance compensator functions to build out the loading end section to 0.8 and to add inductive reactance to offset the capacitive reactance.

**3.20** As an example of the effectiveness of the impedance compensator, consider a 0.5 end section of a 19CNB H88-loaded cable pair. The sending-end impedance has a magnitude of 1017 ohms at 1000 Hz and of 1400 ohms at 2500 Hz. With proper application of an impedance compensator, the sending-end impedance has a magnitude of 975 ohms at 1000 Hz and of 970 ohms at 2500 Hz. This smoothing out of the impedance-frequency curve will result in a substantial improvement in the high-frequency RLs when this cable pair is connected to a properly balanced 4WTS.

**3.21** The earlier type impedance compensator shown in Fig. 8 consists of a multiunit capacitor bridged across the line and a 44-mH coil in series (on the office side of the capacitor) with the line and an optional low-frequency corrector network.

**3.22** The multiunit A capacitor is used to electrically build out the loading end section to 0.8. Positive (inductive) reactance is provided by the 44-mH coil to offset the negative (capacitive) reactance. The net result is a sending-end impedance with an essentially constant resistive component (up to about 85 percent of the cutoff frequency) and a negligible reactive component which gives good balance against a 4WTS compromise network.

**3.23** In addition to the basic impedance compensator, the low-frequency corrector shown in Fig. 8 is normally used on 22- and 24-gauge H88-loaded cable to improve the RLs at the lower frequencies (300 to 500 Hz). There are no adjustments in the low-frequency corrector other than a wiring option for the use of either a 22- or 24-gauge cable pair.

**3.24** A DBO capacitor may also be provided for building out the office cable of the switching equipment side of the impedance compensator.

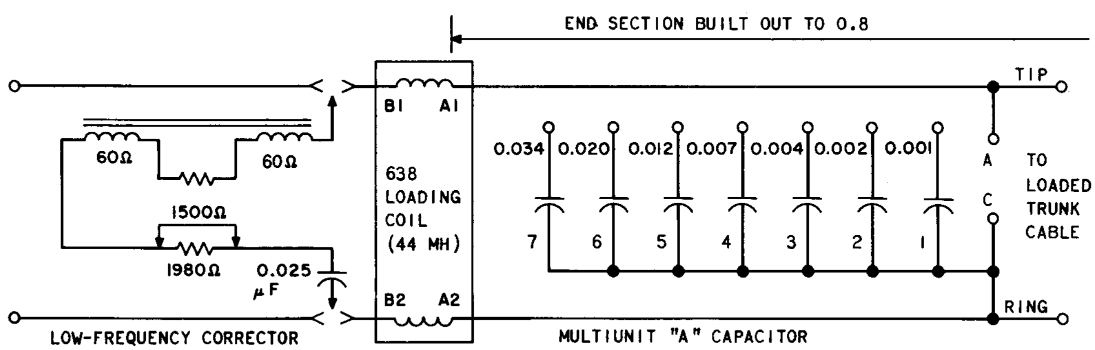



**Fig. 8—Impedance Compensator—SD-95756-01**

**3.25** The amount of capacitance required in the impedance compensator A capacitor will usually be specified as part of the trunk design information. The A capacitor value required for a particular cable pair may be computed. In most cases depending upon the accuracy of the data, the computation method is satisfactory. The results of a computation are such that:

| | | |
|---|---|---|
| Impedance Compensator A Capacitor | = | Cable capacitance for 0.8 of average loading section *Minus* Capacitance of the actual end section *Minus* Capacitance of office cable *Minus* Capacitive effect of the E23 repeater (when used) located in toll office |

As an example, assume the following parameters for a 22-gauge H88-loading cable pair:

| | |
|---|---|
| Cable capacitance | =0.082 μF/mile |
| Average loading section | =6000 feet |
| Actual loading end section to toll office | =2700 feet |
| Office cable and cross-connections from impedance compensator through E23 repeater to termination of outside plant cable | =100 feet |
| E23 repeater gain | =3.5 dB. |

The resulting computations would be as follows:

Impedance Compensator A Capacitor =

(0.8) × (6000/5280) (.082)
− (2700/5280 × 0.082)
− (0.000025 × 100)
− (0.05 × 3.5)
× (6000/5280 × 0.082)
=0.014 μF

> ***Note:*** Office cable capacitance varies from one type of cable to another. A value of 0.000025 μF/foot is an average value chosen for this example. Accurate data on the types and lengths of office cable can usually be obtained from impedance compensator installation records. In some cases, sample measurements of the cable capacitance may be warranted when the type of cable is unknown and long (in excess of 100 feet) runs of cable are involved. When measurements are necessary, they should be made with a capacitance bridge.

**3.26** When terminal E23 repeaters located in the toll office are used on a TC trunk, they are connected between the cable pair and the impedance compensators. The E23 repeater has the effect of lengthening the loading end section. On an H88-loaded facility, this effect is approximately equal to 0.05 loading end section for each dB of gain provided by the repeater. This reduces the amount of building-out capacitance required in the impedance compensator. In the case of E6 repeaters, impedance compensation is provided by the line build-out (LBO) unit of the E6 repeater itself.

> ***Note:*** The use of E23 or E6 repeaters at the class 4 office end of TC trunks is no longer recommended because of RL degradation. They should be installed at intermediate points or at the class 5 office end.

**3.27** An accurate value of the capacitance of the actual loading end section may be obtained from the cable structural RL test data. This capacitance is equal to the building-out capacitance added to the precision network (115-type or 4066-type) used in the structural RL tests plus the capacitance of the cable length given as the basic end section of the precision network.

**3.28** If the impedance compensators are being adjusted in conjunction with an office conversion, due consideration must be given to the capacitance added by cable halftaps 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.

**3.29** The 837-type impedance compensator shown in SD-97054-01 has been made available as a standard replacement for the impedance compensator shown in SD-95756-01. The 837-type compensator is applicable to D88 or H88 low-capacitance 19-gauge and high-capacitance 19-, 22-, or 24-gauge cable conductors.

**3.30** The new compensators are 837-type networks and provide a better impedance correction on TC trunks at 2-wire switching offices. When inserted into a TC trunk which is terminated at the far end in a precision network (115-type or 4066-type), the impedance compensator may be adjusted to build out the trunk cable pair impedance to appear as a 900-ohm resistor in series with a 2.16-μF capacitor over the VF band. All lengths of cable end sections up to 5000 feet can be built out by adjustment of the internal BO capacitors.

**3.31** The 837A network shown in Fig. 9A is used for most TC trunks where the BO capacitor is located in the trunk relay equipment of the trunk. 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 $\mu$F in 0.001-$\mu$F steps

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

Screw-down adjustments are used. Each screw bridges a gap between two conductors. 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 measurement of RL of the impedance compensator and cable pair. An open plug, such as the 258D plug, inserted into the TEST jack disconnects the network from the office equipment. Office capacitance up to the 837A network may then be measured through test clips connected to terminals 3 and 4 on the office side of the network.

**3.32** The 837B network shown in Fig. 9B 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 RLs. The second feature consists of drop building-out capacitors (DROP BOC) for use in trunks which have no trunk relay equipment or where the trunk relay equipment is not provided with BO capacitors. The 837B is a modified version of the 837A network and is primarily used on the following:

(a) TC trunks at offices which are not provided with BO capacitors.

(b) TWX and DATA-PHONE® access lines which require line building out of resistance and capacitance to obtain higher echo RLs toward the access line.

**3.33** The 837B has adjustment for the following:

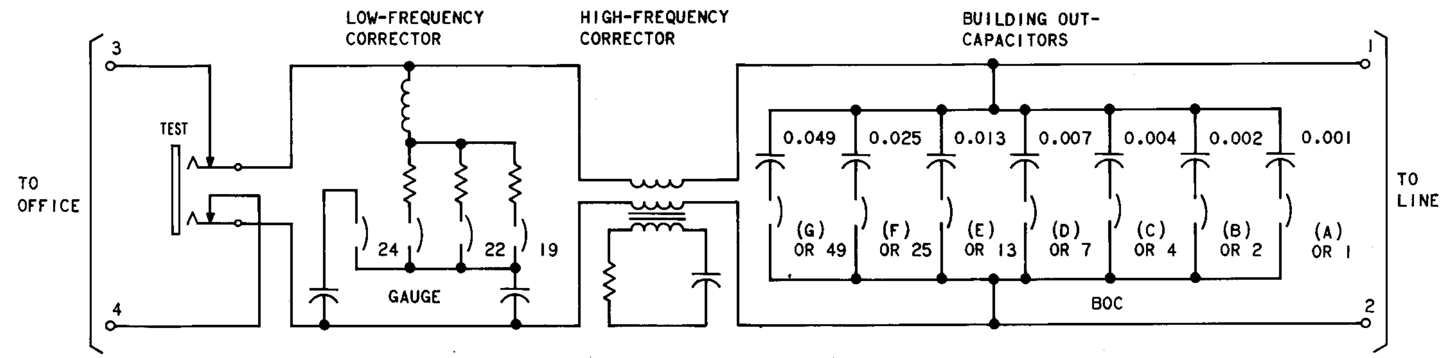
(a) Building-out capacitance for office cabling (DROP BOC) from 0 to 0.062 $\mu$F in 0.002-$\mu$F steps

(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 $\mu$F in 0.001-$\mu$F steps

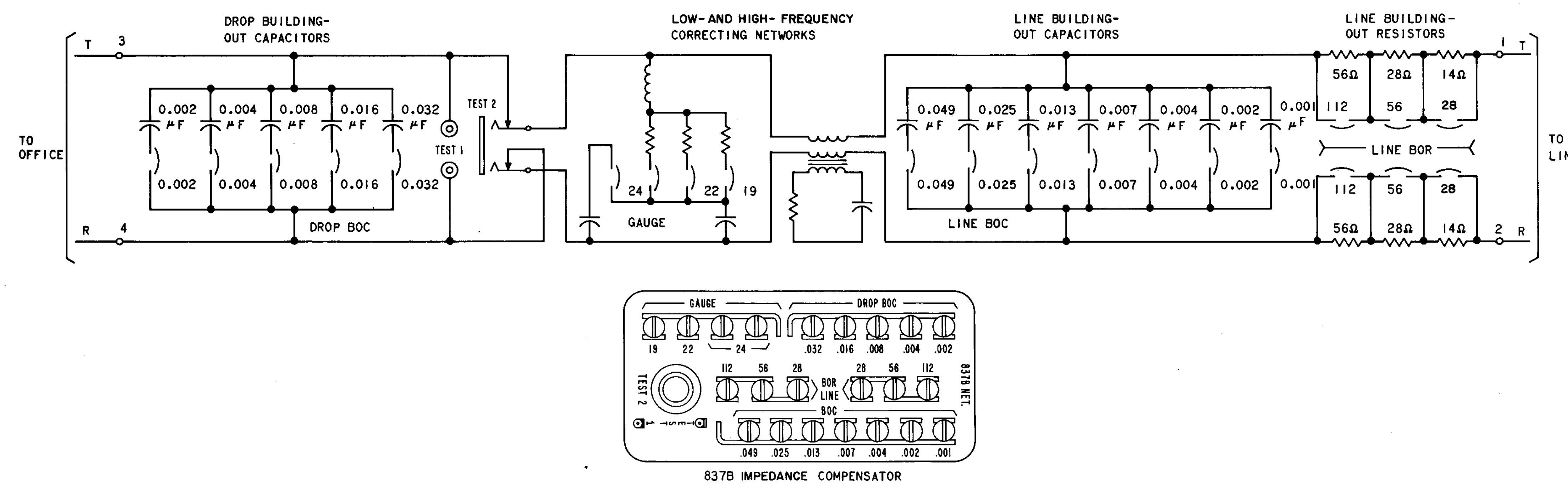
(d) Building-out resistance for the cable (LINE BOR) from 0 to 196 ohms in 28-ohm steps.

All adjustments are made by operating the screw-type switches on the front of the 837B network (Fig. 9B). In addition, a jack designated TEST 2 on the front of the network provides access to the impedance compensator and cable pair for making RL measurements. An open plug, such as the 258D plug, inserted into the TEST 2 jack, disconnects the network from the office equipment. Office capacitances up to the network may then be measured and adjusted by using pin jacks designated TEST 1.




( ) 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

**Fig. 9—837A and 837B Impedance Compensators—SD-97054-01**

**3.34** 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 |

**3.35** The amount of capacitance required in an 837A network BOC or an 837B network LINE BOR will usually be specified as part of the TC trunk design information. The LINE BOC should be set in accordance with the adjustments tabulated on SD-97054-01 for all end sections of 19-, 22-, or 24-gauge conductors. An average value should be used for a mixed-gauge end section. Final adjustment is determined by RL measurement as covered in Section 332-205-500.

**3.36** The low-frequency corrector should be set for the particular cable gauge used. Screws should be turned down for 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 RL measurement.

### I. Building-Out Capacitors

#### Network Buildout (NBO)

**3.37** The compromise network in an IT 4WTS should provide satisfactory balance against the impedances presented by all TC trunks which may be connected to the 2WL.

**3.38** Office cables have distributed capacitance throughout their lengths. This distributed capacitance modifies the terminating impedance presented to the 2WL of a 4WTS by a trunk at the upper frequencies of the voiceband. This effect can be balanced in the network of a 4WTS by bridging an equal amount of capacitance across the COMP NET. The NBO capacitors are provided for this purpose.

**3.39** In general, the selected value of NBO capacitance required for the network buildout in a class 4 office is the capacitance value of the average IT to TC connections. When the difference between the average value and the longest IT to TC path is greater than 0.0125 μF, the general case is not applicable and the NBO value must be calculated.

**3.40** In order to obtain a true average terminating path length for NBO purposes, 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. For example, if the longest measured path were 0.032 μF and the shortest measured path were 0.014 μF, the accepted compromise (midrange) path would be 0.023 μF (the average of 0.032 and 0.014). Thus, the NBO value (excluding any growth factor) for the office would be 0.023 μF. Note that the value satisfies the condition that the difference between the average and the longest path measurement is less than 0.0125 μF, or in other words, the range (or difference) between the longest and shortest path measurements is less than 0.025 μF. This method of selecting the office NBO value also depends on the following conditions:

(a) The actual longest and shortest IT to TC connections are used.

(b) The longest path does not exceed 0.080 μF.

(c) The variance in office cable capacitance of IT to switchboard portions of the IT to TC connections is negligible.

**3.41** When measuring office cabling capacitance, it is not necessary to actually measure the capacitance of each connection path. Measurements made on a sampling basis are adequate. As a general rule, no semblance of an overall normal distribution to the measurements will be obtained. The measured values will tend to separate into two groups—a group of small values (shorter paths) and a group of larger values (longer paths).

**3.42** Figure 10 is an example of the method used to determine the office NBO capacitance value in a class 4 office plus any growth factor (see note). In the example, the longest path measured (IT to TC trunk connection via switchboard to a termination at a point of good impedance, ie, 2-dB pad, impedance compensator, or hybrid) is 0.040 $\mu$F and the shortest path measured is 0.005 $\mu$F. All measured values below 0.015 $\mu$F ($0.040 - 0.025 = 0.015$) are excluded and the midrange path is then determined to be 0.028 $\mu$F [$(0.040 + 0.015)/2 = 0.0275 \approx 0.028$)]; therefore, 0.028 $\mu$F becomes the compromise office cable capacitance. The excluded trunks are then built out to equal the compromise office cable value (0.028 $\mu$F) since buildout is required and the midrange value provides the best balance when the office NBO in the hybrid network line is made to equal the compromise cable value.

> ***Note:*** In practice, the office NBO value may be increased by an additional amount of capacitance for growth. The growth factor (generally ten percent of the compromise office cable value) will be included in the final office NBO selection made by the transmission engineer responsible for office certification. When a growth factor is included in the NBO, the compromise cable value must also be increased by the growth factor as shown in Fig. 10.

**3.43** In general, there is no necessity for adding build-out capacitance in the IT trunk to switchboard multiple office cabling. In some offices, however, the preliminary inspections and measurements to determine the paths for use in the NBO selection may show significant variance in the IT trunk portions of terminating toll connections (class 4) via the switchboard. In these offices, some buildout will be required before the NBO value is determined.

**Drop Buildout (DBO)**

**3.44** When the NBO capacitance value is determined for an office and has been strapped on all IT and TC trunk 4WTS NBO capacitors, DBO capacitance can be added with the BO capacitors in the various trunk relay equipments. (This also applies to the balance test terminations.) The procedures for this are in Sections 660-475-502 and -504.

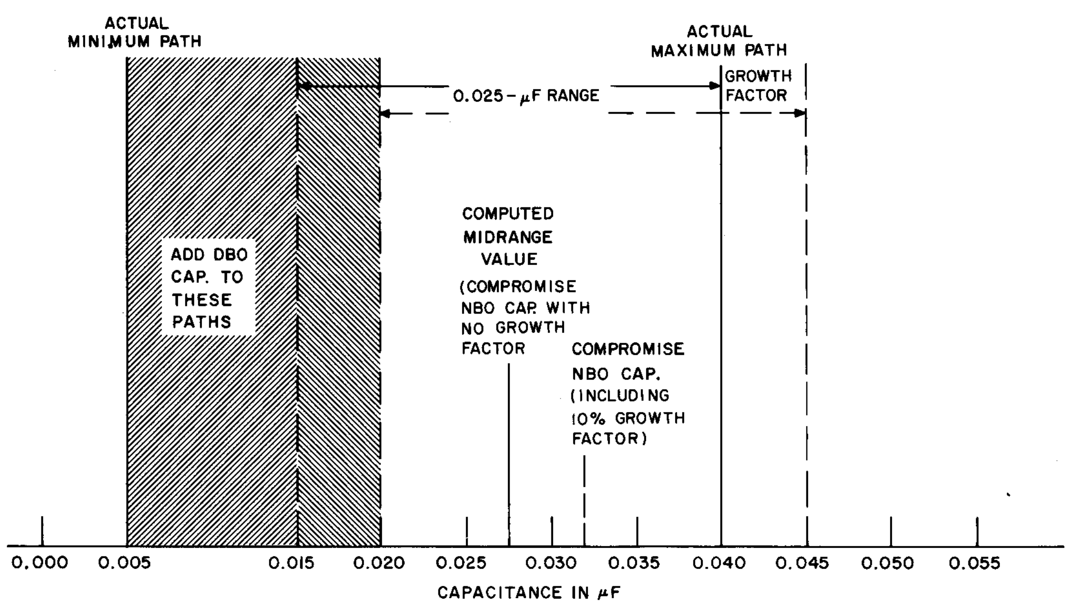



**Fig. 10—Example of Detemination of NBO Capacitance in a Class 4P Office**

**3.45** Terminal balancing requires that DBO capacitance be added only to the shorter paths excluded from the computation of the compromise office cable value. When adding the DBO capacitance in terminal balancing, the shorter trunks are built out equal to the compromise value of office cable paths plus any growth factor that has been included in the office NBO.

## 4. MEASUREMENT CONSIDERATIONS

### A. General

**4.01** The ERL and SP/SRL objectives for terminal balancing are specified to satisfy VNL operation of IT trunks. These objectives are measured and stated as a specific degree of balance between the COMP NET of an IT 4WTS and a 2WL impedance connected to the 4WTS. The objectives are expressed in dB and are a value over and above the inherent losses of the 4WTS hybrid (iron core coil, pad, and circuitry losses). These additional losses must always be subtracted from the indicated measurements as stated in the following text, since the objectives are assumed to be the results of specific measurement techniques which include using a 4WTS. The 4WTS used may be one associated with an IT trunk or a test 4WTS simulating an IT trunk. The 4-wire transmit and receive ports of a 4WTS are, or can be made in most cases, accessible at a jack field and provide convenient connection points for the transmission-type testing equipment required in measuring the balancing objectives. The use of a 4WTS makes it necessary to measure the transmission loss which exists between the receive and transmit ports. This loss is sometimes referred to as "trans-hybrid loss". This loss must be measured for weighted noise and a 1000-Hz test tone (when using general purpose test equipment) or calibrated by adjustment of the SRL HI setting (when using the KS-20501 RLMS test set or equivalent) before the ERL and SP/SRL, respectively, can be determined.

**4.02** 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 it is feasible to obtain in view of economic and technical considerations. These considerations are included in the overall performance requirements for terminal balance as specified in Section 660-475-301. The method of expressing the objectives requires that the measured values be analyzed. If the distribution of the measurements is reasonably normal and the requirements are met, the overall objectives will be met. ***When any trunks fall below the median requirements, the trunks should be investigated for the source of poor balance to prevent skewing the measurement results distribution.*** The given turndown limit indicates balance irregularities severe enough that the trunk cannot be left in service and corrective action must be taken. Also, any trunk having an ERL or SP/SRL decidedly poorer than one with similar equipment should be investigated. A careful check may show that the balance can easily be improved.

**4.03** The measurements for determining office cable capacitance are made with a test equipment setup using a 2000-Hz test tone or the RLMS TEST TYPE switch set to SRL HI as described in Section 660-475-504. The 2000-Hz test tone or SRL HI setting on the RLMS gives a more accurate indication than a lower frequency because of the various series capacitors and bridged inductors (such as coils and relays) that may be present in the trunk relay equipment. The impedance effects of these components are negligible at high frequencies, whereas they may control measurements at the lower frequencies of the voiceband. In addition, the office cabling capacitance is a shunt capacitance with greater effects more easily measured at higher frequencies. Terminal office path capacitances are measured from the 4WTS of an IT trunk to a termination. The termination(s) are placed at points of good impedance such as:

(a) The 4-wire sides of the 4WTSs (located nearest the toll switching office) on 4-wire facilities

(b) The office side of impedance compensators in loaded cable

(c) The toll switching office side of 2-dB pads when these are required in nonloaded cable.

**B. 4WTS Loss (Trans-Hybrid Loss)**

**4.04** The 4WTS loss (trans-hybrid loss) is a measurement for noise or a SF across the 4WTS itself. A known amount of weighted noise or SF power is applied to the 4WTS receive port and a short circuit is placed on the 2WL ***immediate*** to the hybrid coil arrangements. The RL in this case will be zero (see Part 2). A power detector is connected to the transmit port and a measurement is made. Since the RL is zero, the measurement will be the input power ***minus*** 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) ***plus*** the fixed loss of the cable and pads circuitry associated with the 4WTS receive and transmit ports from the point of measurement to the hybrid. When using general purpose test equipment, the loss as measured for weighted noise is used as the correction factor when determining the ERL, and the loss as measured for 1000 Hz is used as the correction factor when determining the SP/SRL.

> ***Note:*** When using the KS-20501 RLMS, no separate calculation is needed to compensate for the trans-hybrid loss (THL). Rather, the RL readings are automatically compensated for in all measurements after the THL adjustment (refer to Section 660-475-504).

**4.05** Once the THL correction factors are measured or the THL adjustment is made when using the KS-20501 RLMS, the ERL and SP/SRL of a terminated 2WL connected to the 4WTS can be determined, provided the 2-wire network line is properly terminated with a COMP NET of the correct impedance. In the case of a balance test circuit 4WTS, the ERL and SP/SRL of any 2WL in an office, terminated in an impedance, can be determined with the same correction factors or THL adjustment since the factors are unique to the 4WTS itself.

**C. ERL Determinations**

**4.06** The ERL measurement is determined indirectly as the difference between two measurements for weighted noise, which are taken between the receive and transmit ports of a 4-wire and 2-wire circuit hybrid interconnection. One measurement (THL) must be made with the 2WL of the hybrid short-circuited (see 4.04). The other is made with the short circuit removed and the 2WL properly terminated at the class 5 office. The difference between the two measurements is the RL to the transmitted noise in the VF echo range. When general purpose test equipment is used, the ERL must be calculated. When the KS-20501 RLMS is used, no calculations are necessary.

**D. SP/SRL Determinations**

**4.07** The SP of a terminated trunk is a determined amount of power at a critical frequency in the frequency range of 200 to 3200 Hz. The critical frequency will usually be in the upper or lower end of this range as mentioned in Part 2. The determination of the SP is the difference between the correction factor measurement for a SF (1000-Hz THL) and a measurement made with a singing point test set (see note) into the terminated trunk under test; or, stated differently, SP = SP test set measurement (trunk terminated) ***minus*** SF power measurement (trunk shorted at the hybrid coils of the 4WTS). When determination of SRL is made with the KS-20501 RLMS, the THL is compensated for in the THL calibration and the SRL indications for SRL and SRL HI switch settings can be read directly without correction. The lower value of the two indications is considered to be the SRL for a trunk.

> ***Note:*** The SP test set described in Section 103-106-105 measures the result of connecting a VF amplifying device between the 4-wire receive and transmit ports of a 4WTS and increasing its gain. A sing will commence when the gain at some frequency becomes greater than the RL at that frequency. This is similar to microphone feedback in a public address system. The test set indication is the measurement of the gain required for the singing to occur.

**E. 2-Wire Switching Path Capacitance Determinations**

**4.08** The capacitance of 2-wire connection paths is measured in the following manner. The 2-wire path to be measured is connected via a toll operator switchboard connection or a testboard connection to the 2-wire side of a working IT trunk or balance test circuit 4WTS. The far end of the 2-wire path must be connected to a termination that includes all the office cable. When the connection is complete, a 2000-Hz test tone (when using general purpose test equipment) or the SRL HI output switch setting (when using the RLMS) is applied to the 4WTS receive port and a power detector is connected to the transmit port. The detector is used to indicate a RL value for the test tone without consideration of the THL while capacitance is added to the 4WTS COMP NET impedance. The capacitance is added by strapping the NBO capacitance, or by making a selection on an external variable capacity device substituted for the NBO capacitor. When the COMP NET impedance is similar to the 2-wire path impedance, the detector will indicate a maximum RL, and the NBO capacitance value is approximately equal to the cable capacitance. The techniques of measuring are dependent on types of test equipment used. Detailed explanations for the techniques are given in Section 660-475-504.

## 5. TERMINAL BALANCE CONSIDERATIONS

### A. General

**5.01** The terminal balance verification measurements are made from the 4-wire facilities of IT trunks to TC trunks terminated in a class 5 office (class 4 switching). Thus, terminal balancing can be thought of as terminating- or originating-office testing.

**5.02** The verification results of terminal balancing are measurable as the ERL and SP/SRL incoming or outgoing from the toll facilities on all combinations of connections between IT trunks and TC trunks. These results should follow a normal distribution curve and meet VNL performance objectives.

**5.03** The use of successive step techniques and intermediate evaluations as prescribed in Sections 660-475-500 and -502 are recommended when performing terminal balancing using test equipment and techniques prescribed in Section 660-475-504. The prescribed step methods simplify the balancing process and specify that intermediate ERL and SP/SRL evaluations be obtained in relation to the required objectives to substantiate completed steps and verify portions of balance work before the total dynamic structure of office balancing can become distorted by improper analysis or adjustments. When performing terminal balance work, any trunks having ERLs and/or SP/SRLs below the minimum requirements as specified in Section 660-475-301 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.

**5.04** When a switchboard is to be cut over to VNL, terminal balance testing should be completed before the switchboard 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 sometimes preclude the final completion of the terminal balance tests until after the actual cutover. In this event, an estimated value of NBO capacitance based on sampling of the terminal connections should be strapped into the 4WTS. Terminal balance testing should be completed as soon as possible after the cutover and the estimated NBO and any necessary DBO capacitances replaced with the final values.

**5.05** Before starting the 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 (in toll switching trunks having less than 2-dB switch-through-switch loss and in the various test circuits and test lines), and impedance matching is provided where required. The preliminary work also includes checking for proper repeating coil ratios, proper midcoil capacitance, and correct orientation of the ratio with respect to the impedance being matched. Traffic-flow sketches, record preparation, bay locations, and other test planning should also be made part of the preliminary work. In addition, noise and 1000-Hz loss measurements should be complete on trunks before the ERL and SP/SRL are measured. The noise and loss measurements ensure that the trunks meet the transmission requirements for the particular type of trunk being tested. Where TC trunks employ carrier or 4-wire facilities, both directions of transmission must have been measured. Terminal balance measurements are of little value when TC trunks do not meet their 1000-Hz loss and noise limit requirements. Standard methods of measuring 1000-Hz trunk losses and noise limits are given in other sections of the practices.

**5.06** Figures 11A and 11B illustrate the typical incoming and outgoing TC connections that must meet balance objectives. Figure 11A shows the typical incoming TC connections, whereas Fig. 11B shows the typical outgoing connection via toll switchboards.

**5.07** In some offices buildout is required on short incoming IT trunks when the difference

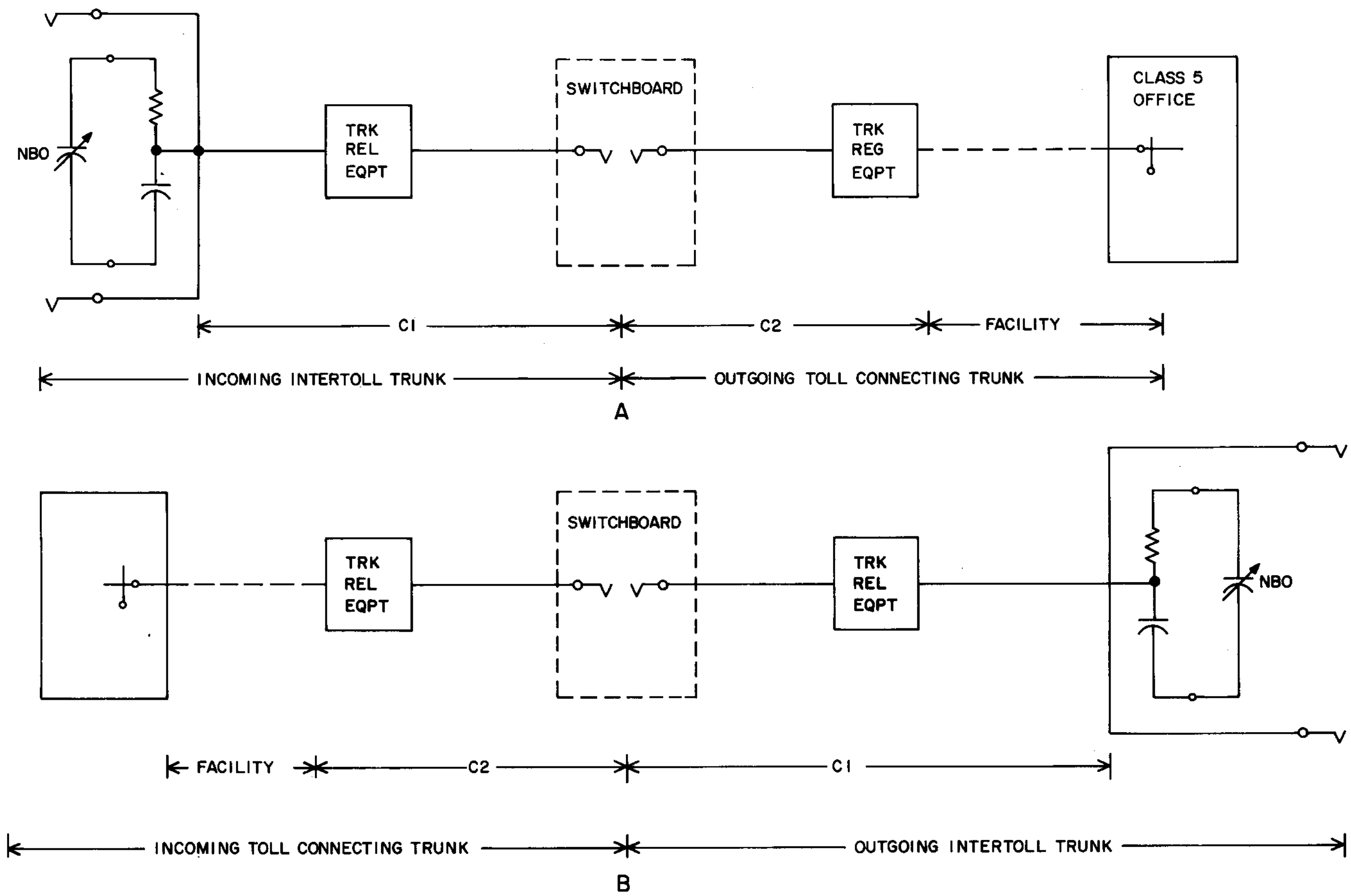



**Fig. 11—Typical Toll Connecting Paths in Class 4P Toll Switching Office**

between the longest and shortest paths is greater than 0.025 μF. This also applies to the outgoing IT trunks. This buildout (when required) must be completed before determining the office NBO capacitance value.

**5.08** The strapping of the NBO capacitors and any required DBO capacitor strapping must be completed before performing terminal balance verification tests given in Section 660-475-502. To meet the TC trunk balance objectives, the facilities to class 5 offices must also meet certain criteria. In the case of loaded cable, this includes the structural RL criteria 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 provided. In some cases where large class 5 offices exist, NBO capacitance is also required (refer to Section 660-475-520). Where the class 5 office is in the same building, the provision of 2-dB fixed-pad option, when required as discussed in Part 3, should be verified.

**5.09** The description and use of impedance compensators and the method of adjusting the earlier types by computation are discussed in Part 3. The computation method 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 building-out capacitor will usually be specified as part of the trunk design information. In most cases, the computation method is satisfactory; but if the computation data is not available or is questionable, RL measurements should be made to ensure that the impedance compensators are properly adjusted. Impedance compensator adjustments require that RL measurements be made at the impedance compensator in a specific manner (see Section 332-205-500).

**5.10** To permit a more practical method of measuring ERL and SP/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 representative of the average loop impedance. The terminal balancing requirements are based on using the class 5 office termination. Detailed procedures for making terminal balance verification tests and the use of this termination are covered in Section 660-475-502 and 660-475-504. The method of terminating in the various types of class 5 offices is covered in Section 660-576-500.

**B. NBO Selection**

**5.11** In class 4P toll switching offices, a compromise NBO value of capacitance is used in all IT trunks and those TC trunks having 4-wire facilities to the class 5 office. This value is a compromise value of capacitance determined from capacitance measurements of the various IT to TC paths via the switchboard. This compromise value (which should not exceed 0.080 μF) is the NBO capacitance for the office and is strapped into the networks of all the 4WTSs—both IT and TC trunks (refer to Section 660-475-500).

> ***Note:*** There are certain exceptions to this general rule for strapping the office NBO capacitance value into all 4WTSs. They are as follows:
>
> (a) When the line-to-network impedance ratios of the 4WTSs in an office are not all the same
>
> (b) When E-type SF signaling circuits with built-in 4WTSs are provided with adjustable or fixed values of NBO capacitance.

**5.12** 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 has been 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. This is 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.

**5.13** When TC trunks are equipped with V-type amplifiers or carrier other than digital transmission systems equipped with D-type channel units, the capacitance measurements for NBO determinations should be made with the 4-wire sides of the trunk terminated with 600 ohms at the repeater patch bay, circuit patch bay, VF patch bay, or equivalent 4-wire location serving the class 5 office. In the case of digital transmission systems, proper termination of the VF inputs must be made in the manner precribed for the D-type channel units. When the TC trunks are a 2-wire facility with an impedance compensator, a termination of 900 ohms plus 2.16 μF in series should be placed on the office side of the compensator. (The earlier types of impedance compensators necessitate disconnecting and terminating the office cable pair, and 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 connecting to the pad is disconnected and terminated with 600 or 900 ohms plus 2.16 μF in series (value of resistance in termination depends on which side of the repeat coil the pad is located.)

**5.14** When making capacitance measurements to select an NBO, more accurate measurements of the office cabling capacitance are obtained when a high VF signal (2000 Hz) is used rather than a lower frequency. The effects of various series capacitors and bridged inductances 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 more accurately measured at the higher frequencies. This same effect is obtained when using the SRL-HI output of the KS-20501 RLMS. A 2000-Hz signal source can also be used externally with the KS-20501 RLMS. This is accomplished using the EXT OSC function switch selection. Discrete values of capacitance change can be observed more readily with this method than with the SRL-HI output.

**5.15** The preliminary measurements to determine path capacitances for calculating the NBO value are made using specified sample sizes. There will, in general, be no semblance of an overall normal distribution between sample 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).

**5.16** 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. In general, this value will be the average of the greatest and least measurements.

**5.17** When determining the compromise value, a wide range of capacitance within a sample could be indicative of trouble, improper termination or connection, or could indicate that too wide a distribution of connections is covered by the sample. If the latter case exists, additional samples should be taken.

**5.18** Using a compromise NBO value means that RLs somewhat less than maximum can be expected on the longest and shortest connection paths (those paths with more or less capacitance than the midrange path). This reduction in RLs can become serious if the deviations in path capacitance exceed 0.025 μF; therefore, capacitance differences should be made to fall within a relatively narrow range by adding BO capacitance to short paths (ideal range being no more than 0.025 μF difference between the longest and shortest paths). This may require additional sampling to determine all the shorter paths that require build-out capacitance to reduce the range since the requirement objectives are based on a distribution with an ideal range.

**5.19** RL measurements made on a sampling basis are adequate provided the samples are chosen with care to be representative of all trunks in a trunk group. 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 there are more than five, the following numbers are recommended for the sample size:

| 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 |

**5.20** At least one sample should be tested for each category of trunking. Furthermore, each of these categories should be subdivided according to the type of equipment and facilities used on the trunks, and a sample from each subdivision should be tested. For example:

(a) Trunks with fixed 2-dB pads

(b) Trunks employing loop signaling on VF loaded facilities

(c) Trunks employing E&M or CX or DX signaling on 2-wire VF loaded facilities

(d) Trunks employing E&M, SF, CX signaling, or loop (E-type signaling units) signaling, and hybrid-type repeaters or carrier channels.

**5.21** The physical locations of trunk equipment impedance compensators, the use of tie cables, etc, may cause large differences in central office cable lengths to exist within a trunk group or one of the above subdivisions. When this is true, 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.

### C. DBO

**5.22** In class 4P offices, DBO adjustments will usually be quite limited because the NBO value is selected as a compromise to the range of capacitances measured on IT to TC trunk connections. The shorter TC trunks (those having less capacitance) may require buildout; this is determined when establishing the compromise NBO value for the office (see Part 5B). The procedures for DBO, when required, are given in Section 660-475-502.

### D. ERL and SP/SRL Verification Tests

**5.23** To complete the balance work in an office after the impedance compensators, NBO capacitors, and (where necessary) BO capacitors in the trunk circuits have been adjusted, the following tests should be made on all TC trunks:

(a) Echo return loss test

(b) Singing point or singing return loss test.

Although not technically a balance objective, the 1000-Hz loss and noise limit measurements must have been completed on all trunk connections before the ERL and SP/SRL are measured. The transmission measurements ensure that the test connections are made correctly and that the losses and noise are within the prescribed limits given in the trunk transmission testing practices. Procedures for ERL and SP/SRL tests are given in Section 660-475-502.

### E. Class 5 Office 900-Ohm Test Terminations

**5.24** To permit more practical methods of testing the ERL and SP/SRL on TC trunks, a compromise termination has been selected for use at class 5 offices. This termination is used to represent terminated subscriber loops with the present design of telephone sets in an off-hook condition. The termination consists of a 900-ohm resistor in series with a 2.16-$\mu$F capacitor. These values are considered to be representative of an average subscriber loop. Terminal balance test requirements are based on the use of this termination and class 5 offices should have the termination available on a dialed number basis.

## 6. CERTIFICATION OF OFFICE BALANCE

**6.01** The certification of a class 4P switchboard 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 value must not exceed 0.080 $\mu$F and be approved by the transmission engineer.

(b) Trunks that do not meet VNL design objectives (as specified in Section 800-100-100) are classified as not meeting minimum balance requirements.

(c) IT 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, ie, IT and tandem, intrabuilding TC, 4-wire interbuilding TC, and 2-wire interbuilding TC must be equal to or greater than the median requirement. Similarly, not more than two percent of the measurements for each class of trunk may be below minimum requirements.

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

## 7. TESTING ARRANGEMENTS AND TERMINATIONS

### A. General

**7.01** In order to make accurate balance measurements and to make balance measurements practical, local arrangements should be made to set aside a hybrid coil and trunk relay which duplicate the drop equipment of an IT trunk. The arrangements of the test hybrid coil and trunk relay equipment are covered in Section 660-475-504. The various types of 4WTSs have somewhat different balance characteristics. This is also true for the various trunk relay equipments; and because of this, care must be taken that the equipment used in the test arrangements is actually representative of the IT trunk equipment used in the office. It is also extremely important that the NBO capacitors in the test arrangements be properly adjusted.

**7.02** All test sets used in balancing an office 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 stabilized.

**7.03** Either general purpose or the KS-20501 RLMS test equipment may be employed in measuring the objectives of balancing (refer to Section 660-475-504). When using general purpose test equipment, the ERL is obtained by sending and receiving weighted random noise. The SP/SRL measurements are obtained using a singing point test set and test equipment capable of sending and receiving 1000-Hz test tone. The weighted noise required in the ERL measurements can be obtained with a noise generator capable of producing evenly spread random noise over the voiceband and a 455B weighting network to shape the noise to approximately represent a male voice from an F1 telephone transmitter. The noise measuring instrument used to measure the weighted noise must have its input circuit equipped with a C-message weighting network.

**7.04** The RLMS, described in Section 103-106-115, is specifically designed for making balancing measurements. This test set integrates all the transmission test equipment and techniques of obtaining balance measurements into a single, simplified operation with a single test set.

**7.05** The transmit and receive ports of a 4WTS, associated either with an IT or TC trunk or with a test hybrid arrangement, appear in a variety of jack fields. Designations at the jacks may be oriented toward the IT facility (toll carrier) or toward the toll office (toll drop). To avoid misunderstanding, the 4WTS ports are established with reference to the toll facilities: ie, the transmit port transmits to the toll facility; the receive port receives from the toll facility. In 4-wire VF patching jack fields, the transmit port designation related to the toll drop is EQ OUT and the receive port is designated EQ IN.

### B. Balance Test Terminations

**7.06** The testing of connections to an operator switchboard 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 $\mu$F 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 present at its switchboard jack the impedance presented by the average TC trunk which terminates in the switchboard.

## 8. TESTING ANALYSIS AND TROUBLESHOOTING

**8.01** All IT to TC trunk connections having ERLs and SP/SRLs below the minimum requirements should be investigated for trouble. It should be noted that 50 percent of the trunks in each category in an office should exceed the median requirements. Trouble should also be suspected if poor test results are obtained on some trunks which are similar in design to other trunks which have good test results.

**8.02** 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 SP/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 ERLs well above the requirements shown in Section 660-475-301, an error in the method of measurement may exist. If requirements are not met and the causes of the poor balance results cannot be determined, the results should be referred through proper administration channels for further investigation.

**8.03** The ERL and SP/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 inherently higher ERLs are expected from the latter type of circuitry.

**8.04** It is extremely important that ERL and SP/SRL verification tests be made from the 4-wire side of all 4WTSs used in TC trunks. These tests should be made on all TC trunks in all toll switching offices irrespective of their rank in the DDD hierarchy. The tests should meet the requirements given in Section 660-475-301 so as to present adequate balance toward the class 5 office. These tests will aid in identifying balance troubles, such as open NBO capacitors, compromise networks or incorrect wiring in the 4WTS, or other equipment within individual trunks and ensure proper RLs toward the class 5 office.

## 9. REFERENCES

**9.01** The following references are given to provide detailed information with regard to terminal balancing.

| SECTION | TITLE |
|---|---|
| 103-106-105 | J94002D (2D) and J94002E (2E) Singing Point Test Set—Description (manufacture discontinued) |
| 330-300-500 | Completion Tests of Exchange-Area Cables—Introduction |

| SECTION | TITLE |
|---|---|
| 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 and General Information |
| 332-205-500 | Impedance Compensators—Tests and Adjustments |
| 660-576-500 | Class 5 Offices—Terminal Balance Procedures |
| 800-100-100(Part 6) | Notes on Direct Distance Dialing |

Other References:

Transmission Systems for Communications—Chapter 2 (BTL Publication)

Principles of Electricity Applied to Telephone and Telegraph—Chapter 28 (Long Lines Department of AT&TCo).