AUTOMATIC INTERCEPT SYSTEMS
GENERAL BALANCING INFORMATION

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1. GENERAL

1.01 This section covers general balancing information applicable to all types of offices. It is designed to assist those persons who perform balance tests to have a source of information about the equipment, terminology and theory of office transmission balancing. Transmission balancing is the adjustment, measurement and evaluation process employed to control echo and singing in trunks that convert from 2-wire to 4-wire (or vice versa) operation.

1.02 Whenever this section is reissued, the reasons for reissue will be given in this paragraph.

1.03 A change in format of presenting balance procedural information has been developed. References to BSP section numbers pertain to this new format that is now available. Unless significant changes require the reissue of a subdivision, those sections that were issued under the old format will not be reissued to change to the new format.

1.04 Information pertaining to equipment arrangements and special general information for a specific office or switching arrangement will be found in the -101 section for that office or switching arrangement. That section will also describe the forms used for recording the measurements. Other sections for specific offices or switching arrangement are -200 (Network Build-Out selection and Drop Build-Out selection, as required) and the -301 (Requirements and Verification Tests).

1.05 All trunks that connect to the Message Telecommunications System (MTS) must be considered for balance. They should meet the objectives specified in the requirements section. If they do not meet the requirements, they should not be connected to the MTS.

1.06 Terminology used in this general section is described in such a manner as to include all types of offices or switching arrangements, although such terminology has previously been excluded from such services not connected to the MTS.

2. BALANCE TERMINOLOGY

2.01 A brief definition of terms used in this section is provided to acquaint the reader with balancing terms. A more detailed explanation is given in the information provided in the paragraphs which follow.

Echo—The undesired acoustical interference when sufficient power is returned with sufficient delay so that a user will hear his own voice repeated and cause disturbance over a telephone connection.

- ***Echo Return Loss*** (ERL)—The measurement of return loss within a band of frequencies (usually 560 to 1965 Hz).

Singing—Usually a single frequency at which a telephone connection will oscillate when the gains exceed the losses in the

4-wire portion of a trunk which is converted to 2-wire operation.

Singing Return Loss (SRL)—The measurement of return loss within a band of frequencies (260 to 500 Hz) at which singing will usually occur. The SRL-HI is the measurement within a band of higher frequencies (2200 to 3400 Hz).

Return Loss (RL)—The returned power reflected to a trunk when a 2-wire to 4-wire conversion device is used. When the returned power to loss ratio is small, singing or echo will result.

Four-Wire Terminating Set (4WTS)—A device by transformer arrangement to convert 4-wire to 2-wire or vice versa.

Build-Out Capacitor (BOC)—Adjustable capacitors used to increase the capacitance of a cable pair or termination.

Terminal Balance—Balance measurements on trunks terminating at an office, such as intertoll (IT) to toll connecting (TC) — both incoming and outgoing.

Through Balance—Balance measurements on trunks through a 2-wire class 3 or higher class switch such as IT to IT.

3. TRANSMISSION CONSIDERATIONS

A. General

3.01 The initial performance and subsequent maintenance of the through and 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 MTS, and it is essential because of the present extensive 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). The VNL theory is discussed in Section 800-100-100, Part 6.

3.02 Either through or terminal balancing or both may be necessary to completely balance an office. Class 3 or higher switching machines serving one or more class 5 offices switch IT to both IT and TC trunks, in which case both through and terminal balancing are required, whereas a class 4 switching office switches IT only to TC trunks and requires terminal balancing only. (Refer to Section 800-100-100, Parts 3 and 6, for a detailed explanation of the MTS switching hierarchy.)

3.03 IT trunks are assigned to 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 IT or IT and TC trunks. The termination of the 4-wire facility and the conversion to 2-wire 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.

3.04 Figure 1A 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. 1A 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. 1B. 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. 1B; 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, that is, 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 within a toll switching office. 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 trunk 4WTSs.

B. Echo and Singing

3.05 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. When the returned power is received at the distant end with sufficient magnitude (that is, the loss to the returning power is small), return-loss (RL) impairments to transmission can occur.

3.06 Subjective testing has shown that when sufficient power is returned with sufficient delay, a talker hearing his own voice repetitions 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 return losses are small and power is returned at a single frequency with sufficient magnitude to start self-sustained oscillations. This impairment is called singing or near singing. This condition always exists where the gains exceed the losses in the 4-wire portion of a circuit. The energy paths for both types of impairments are shown in Fig. 2.

3.07 The voiceband frequencies in MTS 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 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 voiceband.

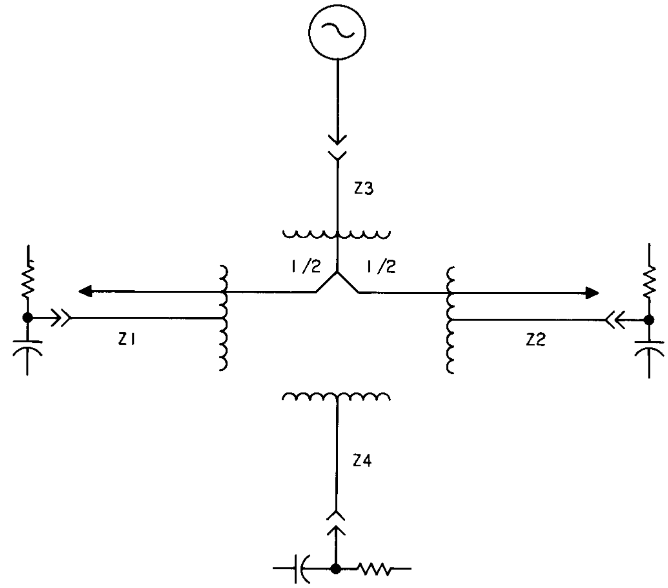
3.08 Singing will generally occur in the frequency ranges from 200 to 500 Hz and 2500 to 3200 Hz. Singing or near singing occurring in these ranges will be noticed by a talker before he will complain of any echo. Figure 3 indicates the echo and singing frequency ranges within the voice frequency (VF) band.

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

3.10 It should be noted in the energy paths illustrated in Fig. 2 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 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, it should be 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, both through and terminal balancing include separate test methods for each of the RL impairments, ie, echo return loss (ERL) and singing point (SP) or, equivalently, singing return loss (SRL). The 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, regardless of the balancing process used. A further consideration that should be noted is that the magnitude of returned power in a connection is an enhancement factor to echo and singing impairments and not the absolute cause.

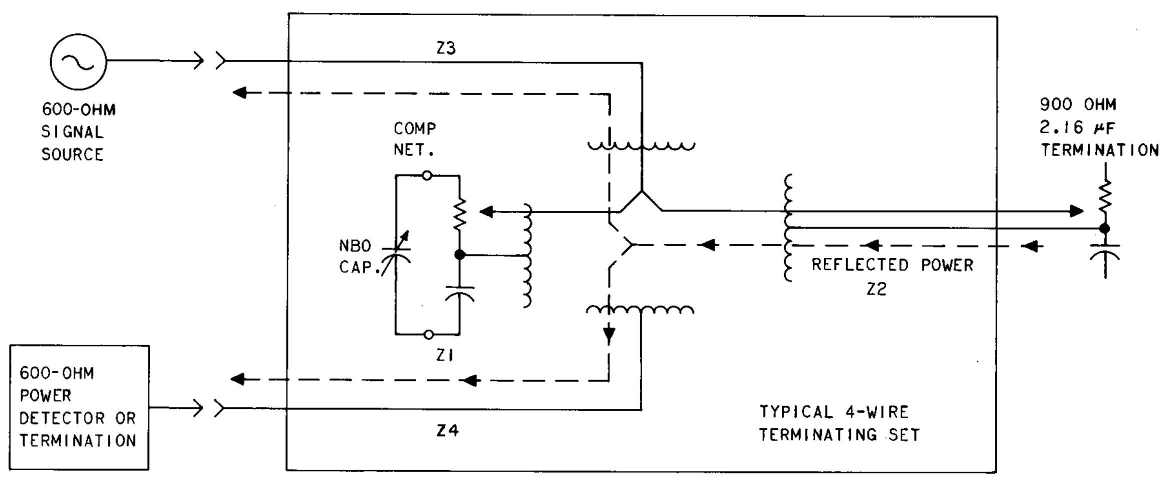
RETURN LOSS

3.11 Specifically, RL is the measure of an impedance match between circuits at the point of their



NOTES:
1. Z1 = Z2, Z3 = Z4
2. PARAMETERS ARE COMPARED TO PARAMETERS OF FIG. 3B 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. 1—Hybrid Power Division and Application

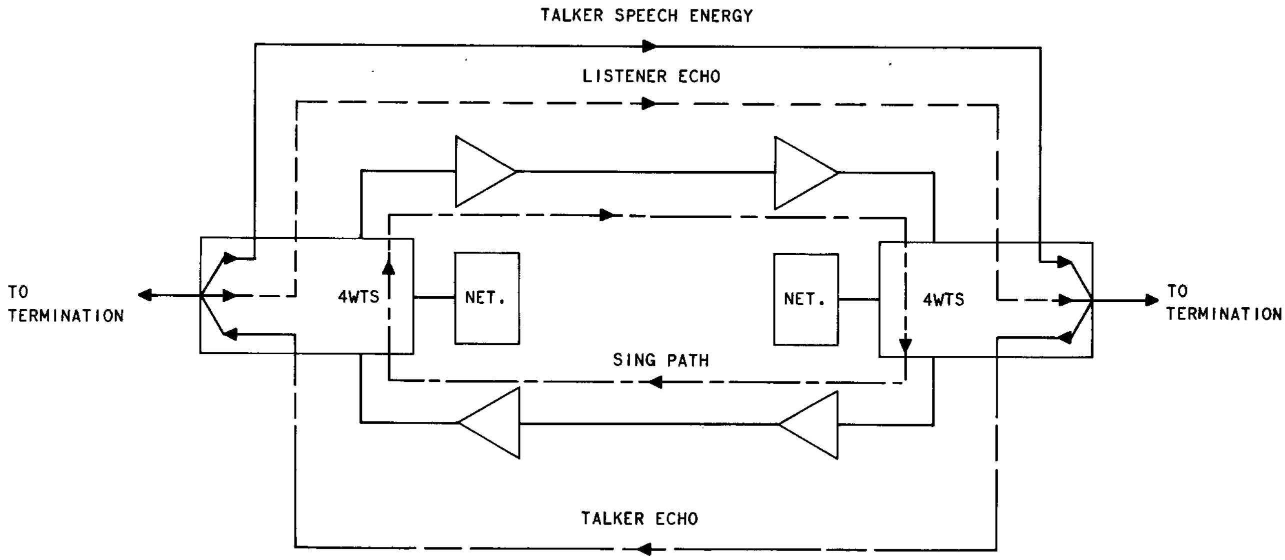


Fig. 2—One-Way Energy Paths in 4-Wire Terminated Circuits Terminating in 2-Wire Circuits

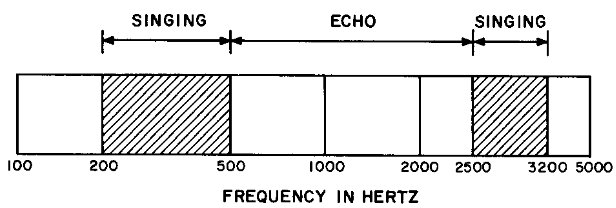


Fig. 3—Echo and Singing Ranges in a Typical Voice-Band Frequency Spectrum

interconnection. It can be expressed for any frequency as RL (in dB) = 20 $\log_{10}$ [Z1 + Z2 ÷ 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 4), 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 is infinity by definition. Conversely, a complete mismatch (imbalance) will occur when either but not both Z1 of Z2 is zero. The RL for the frequency then becomes zero, since the logarithm of 1 is zero.

ECHO RETURN LOSS

3.12 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 5). This measurement does not necessarily indicate the RL at an individual frequency.

SINGING POINT

3.13 The SP is a measure of the return loss for a single frequency in the voiceband (200 to 3200 Hz). This single frequency is usually but not always the frequency having the poorest return loss 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 impedance characteristics in 2WL apparatus, the upper and lower ends of the band will generally contain the critical frequency as previously discussed in paragraph 3.08. This measurement is also determined in a specific manner as described in Part 5. The SP frequency ranges can be considered as shown in Fig. 3.

SINGING RETURN LOSS

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

3.15 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 5). Either the SP or the SRL should meet the requirements stated in the -301 section.

C. Balance Verification Tests

3.16 When performing balance work, the following tests are required, after the network build-out (NBO) and build-out (BO) capacitor adjustments are completed:

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

(b) Echo return loss test

(c) Singing point or singing return loss tests.

Although not technically a balancing requirement, a 1000-Hz transmission measurement should be made on a test connection before measuring the ERL and SP/SRL. The measured loss should be within ±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.

3.17 The verification tests performed in the -301 section 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.

4. APPARATUS CONSIDERATIONS

A. General

4.01 Before beginning the actual through and terminal balancing 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, where possible) should be made to ensure that all apparatus affecting balance is properly installed and cross-connected.

B. Compromise Network

4.02 A compromise network (COMP NET) plays an important part in the balancing process and is the 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 or the 4WTS in which it is used. A trunk in an office may be connected to many different trunks, and while all of them have a nominal impedance of 900 ohms (600 ohms for switchboard trunks), the actual impedance will vary. This variation is due to different lengths of office cabling, the normal variation among different equipments, and/or different types of cable pairs. The network connected to the hybrid line in the 4WTS must adequately balance the impedance of any one of the possible connections to the 2WL. To do this, a COMP NET consisting of a 900-ohm resistor (600-ohm in the case of switchboard trunks) in series with a 2.16-μF capacitor is used in all 900-ohm offices with provision 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. Thus, return loss depends on both of these components of impedance. Resistance mismatch is controlled by limiting the maximum resistance of the 2-wire path. The build-out capacitor parallel to the COMP NET (see Fig. 1B) is used to control reactance mismatch.

4.03 Within the hierarchy of the MTS network incoming IT trunk COMP NETs in class 3 or higher ranking 2-wire toll switching offices are required to balance with impedances presented by outgoing IT trunks, ie, IT-to-IT trunk connections across the office. If the office also has class 4 switching, the IT trunk COMP NETs must also balance with the terminating impedance 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.

4.04 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, switchbank multiple, and switchboard and testboard multiple will cause variations in cabling capacity between different trunks. Consequently, BO capacitors are provided in 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.

OFFICE CABLING RESISTANCE LIMIT

4.05 No resistance buildout is provided in the networks of the 4WTSs. It is, therefore, necessary to limit the cross-office cabling resistance to a maximum value. Reasonable control of the resistance factor of the 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. The maximum resistance which can be permitted and still meet through balance requirements has been determined by studies which considered the following factors:

(a) The changes in capacitance with different paths through the switches

(b) The rough gradation of the steps in the adjustments on the NBO and drop build-out (DBO) capacitors

(c) The structural return loss of the hybrid circuit

(d) The effect of imperfect terminations on the 4-wire side of the 4WTS.

These studies indicate that the loop resistance of the cabling between the 4WTSs should not exceed 65 ohms in 900-ohm offices. Normally, the value of cable resistance will be exceeded before the total amount of shunt capacitance and BO capacitance (if used) in the office cabling of a through-type 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

4.06 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 voice-frequency 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 in a 900-ohm circuit 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 through the office 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.

C. 4-Wire Terminating Sets

4.07 In switching offices all 4WTSs in the IT trunks 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 and 875 ohms plus 2.16 μF for the 900-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 to 0.040 μF, depending on the amount of bridged cabling capacitance. The later issues of 120-type built-out hybrids of 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 having built-in terminating circuits will not meet the requirements for the more stringent objectives of ***through*** balancing, because of their poor 2-wire input impedance characteristics at certain frequencies. They will, however, meet the minimum objectives for ***terminal*** balance.

4.08 All 4WTS in TC trunks that terminate into a switchboard where the nominal impedance is 600 ohms must be equipped with COMP NETs having a nominal 600-ohm impedance.

D. A and B Capacitors

4.09 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 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 of the hybrid to maintain proper impedance characteristics. Referring to Fig. 4 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 paragraph 4.10(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 minature 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.

E. Trunk Relay Equipment

4.10 All intertoll-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 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 signaling relays bridged to the transmission path must have a high enough inductance (with their normal operating currents) to have a

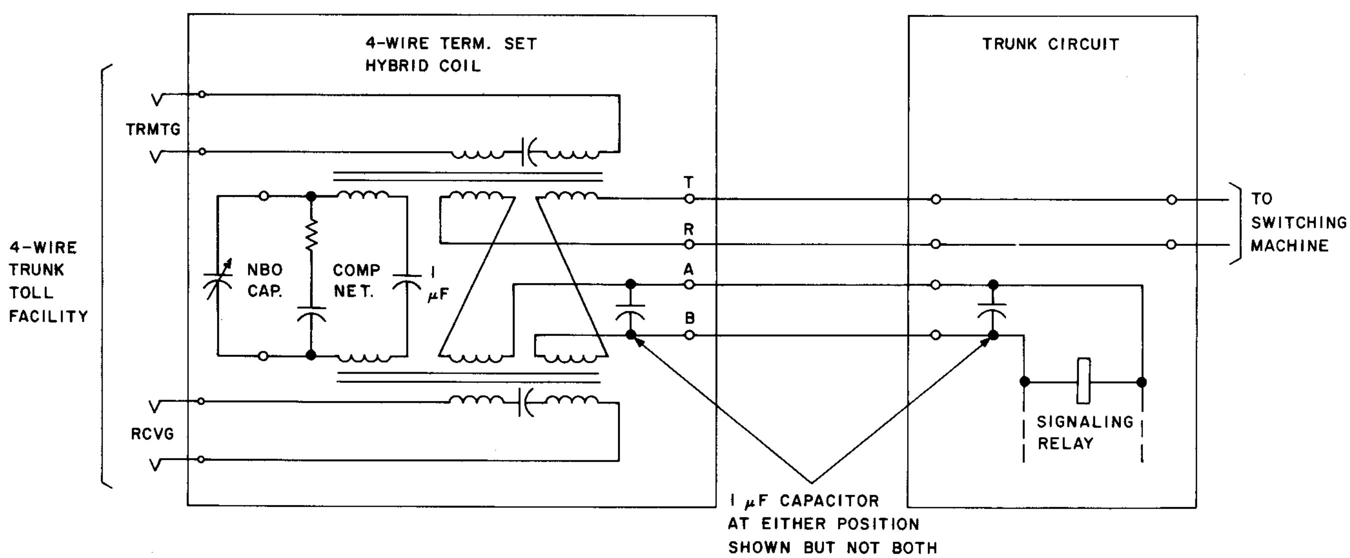


Fig. 4—Typical 1-Type or 120-Type 4WTS Hybrid Coil Arranged For DC Signaling

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, when used in auxiliary trunk circuit such as SD-27008-01, a 274AH inductor in series with the 280Y relay is provided for RL improvement.

F. Repeating Coils

4.11 Repeating coils should not be present in the transmission path connecting two IT trunks because of impedance characteristics of the coil. If the coils are present, the objectives of ***through*** balance cannot be met. In offices having secondary intertoll trunks, impedance matching between the 900-ohm switching machine impedance and the 600-ohm switchboard is necessary in the secondary intertoll trunks.

4.12 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 voice-frequency range and lower the average degree of balance obtainable against the COMP NET.

4.13 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. Therefore, trunking arrangements using repeating coils should not be employed in IT-to-IT trunk applications (through-type connections), since these connections require a high degree of balance to satisfy VNL objectives. The use of repeating coils in trunk relay circuits for impedance matching or signaling purposes should be limited to TC trunk applications. ***Trunk arrangements employing more than one repeating coil may not meet terminal balance requirements.***

4.14 In offices where the switchpoints are considered to be 900-ohm impedance and are to be connected to switchboard trunks having 600-ohm impedances, the impedance difference necessitates that (a) any 2WL path from the switchpoints to a switchboard must have an impedance transformation made with a 1.5:1 ratio repeat coil, (b) all IT trunk 4WTSs must be equipped with COMP NETs consisting of a 900-ohm resistor in series with a 2.16-μF capacitor, and (c) all 4WTSs in switchboard-terminated trunks must be equipped with COMP NETs consisting of 600-ohm resistors in series with 2.16 μF capacitors. One result of having machine and switchboards with different impedances is that the NBO capacitance value across the COMP NET of a 4WTS in a switchboard trunk will be approximately 1.5 times as large as the NBO capacitance values across the COMP NET in a machine trunk.

4.15 In offices where 121 trunks (inward operator) may be part of both through and terminal connections, current design of trunk relay units used for this application includes a repeating coil. Terminal connections involving this trunk will generally meet terminal balance requirements. Where through connections via the switchboard are completed using a 121 trunk and a 4-wire tandem trunk (see Part 6), the 4-wire tandem trunk provides impedance matching between the machine and switchboard without introducing a second repeat coil. With this arrangement, ***minimum*** through balance requirements will be met but requirements stated in Section -301 cannot be met because of the repeating coils in the 121 trunk.

4.16 In offices having two-wire tandem trunks using trunk relay equipment with repeating coils, these trunks are used to complete outgoing terminal traffic (see Part 7) from the switchboard and will generally meet terminal balance requirements. Use of the 2-wire tandem trunks to complete through connections will not meet through balance requirements. Repeating coils appearing in a 2WL path 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 midcoil capacitors provided in the secondary IT and 2-wire tandem trunk relay equipment provided in some offices are designed to obtain the best compromise in impedance transformation between the IT and TC trunk relay equipment for impedance matching and/or to derive signaling leads. At the class 4 office end, each of these trunks is provided with midcoil capacitors that 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 return loss in the voice-frequency range, is demonstrated in Fig. 5.

G. 2-dB Pads

4.17 The 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.

H. Outside Cable Plant

4.18 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 office balance results. (See references listed in Part 11 for further discussion.)

4.19 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 irregularties in cable pairs using voice-frequency sweep tests.

I. Impedance Compensators

4.20 An impedance compensator is a device used on loaded cable pairs to make the sending-end impedance of the loaded cable pair more uniform over the voice-frequency range at the toll switching office. An impedance compensator should be provided on all TC trunks utilizing loaded cable.

4.21 Two types of impedance compensators are currently in use for improving the impedance characteristics of loaded cable: the impedance compensator per SD-95756-01 and the 837-type networks shown in SD-97054-01.

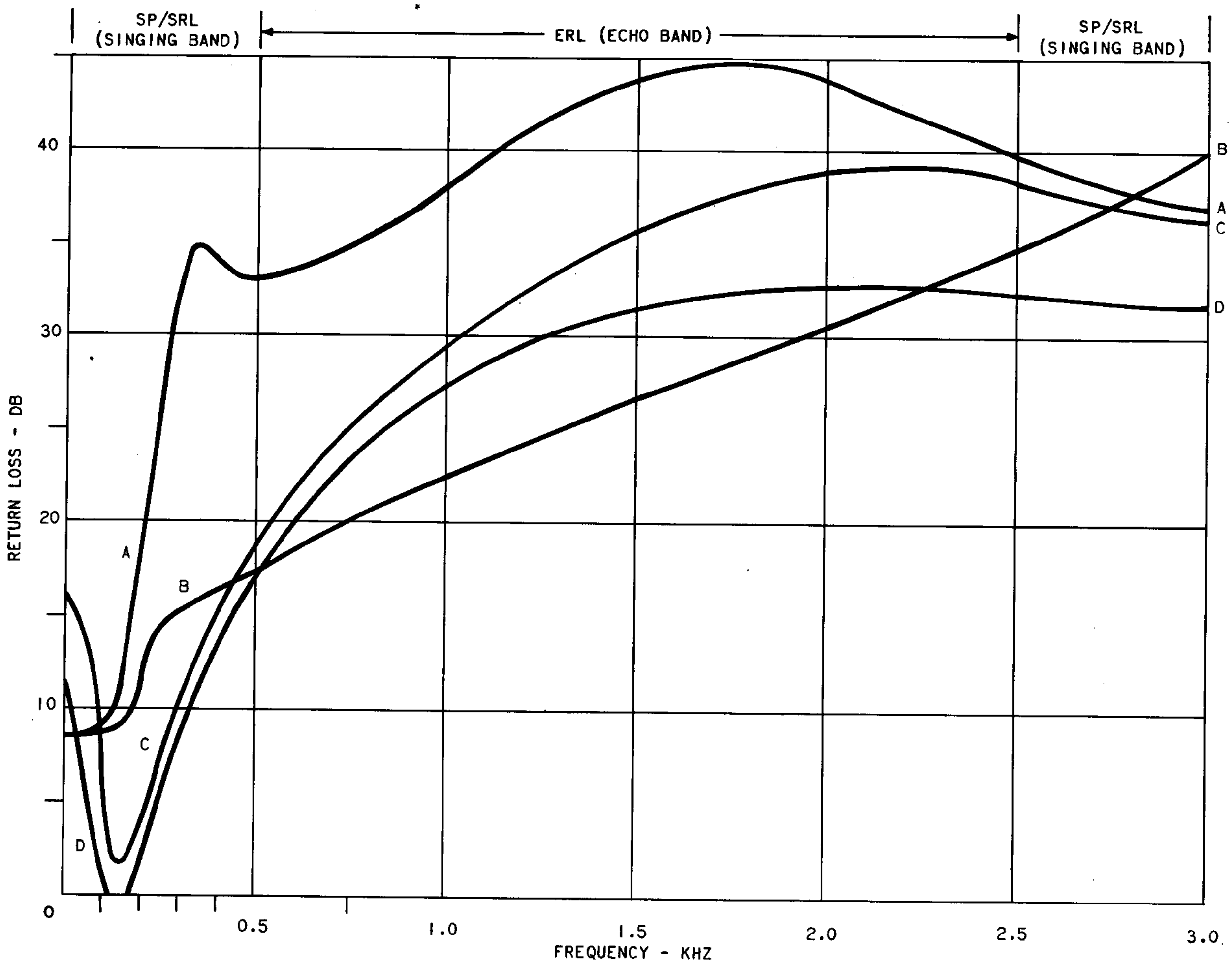
4.22 Most loaded cable has been designed with a 0.5 loading end section at the toll switching office. (This means the electrical distance from the toll office to the first load point is equal to one half the electrical length of a full load section.) A mathematical analysis of the impedance characteristic of a 0.5 loading end section will show that the impedance increases with frequency and that this impedance is predominantly resistive. The reactive component of the impedance is negative (capacitive) and very small. As the impedance of the compromise balancing network in the 4WTS is essentially constant with frequency, the increase in line impedance results in low return losses (poor terminal balance) as the upper cutoff frequency of the cable pair is approached.

4.23 The sending-end impedance of a 0.8 loading end section is much better 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 (SD-95756-01) has been designed to build out the loading end section to 0.8 and to add inductive reactance to offset the capacitive reactance.

4.24 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 return losses when this cable pair is balanced by a compromise network.

4.25 The earlier type impedance compensator shown in Fig. 6 consists of a multiunit capacitor bridged across the line and a 44-mH coil in series (on the office or switch side of the capacitor) with the line and optional low-frequency corrector network.

4.26 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)



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

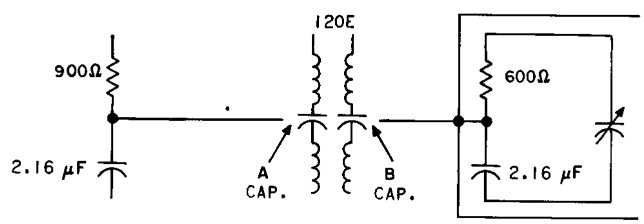


Fig. 5—Typical Return-Loss Results For Different Values of Midcoil Capacitors

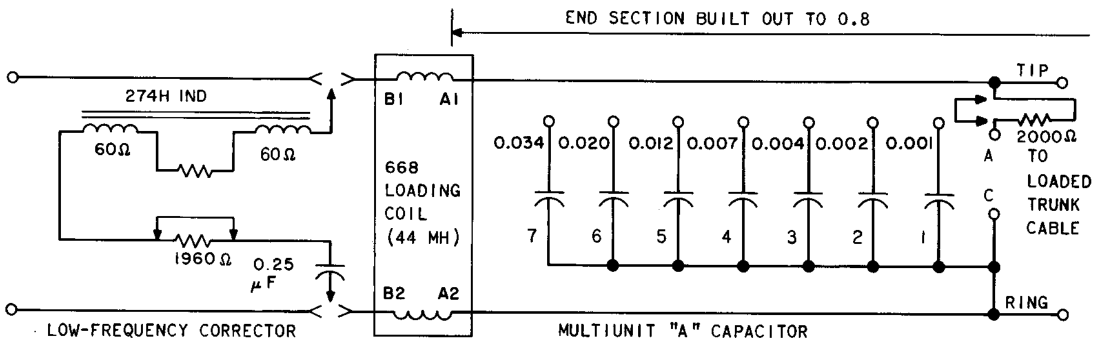


Fig. 6—Impedance Compensator—SD-95756-01

and a negligible reactive component which gives good balance against the IT compromise network.

4.27 In addition to the basic impedance compensator, the low-frequency corrector shown in Fig. 6 is normally used on 22- and 24-gauge H88-loaded cable to improve the return losses 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.

4.28 A drop build-out capacitor may also be provided for building out the office cable of the switching equipment side of the impedance compensator.

4.29 The amount of capacitance required in the impedance compensator A capacitor will usually be specified as part of the trunk design information. In some cases, E6 repeaters have been used at the toll office end of TC trunks and impedance compensation is provided by the line build-out (LBO) unit of the E6 repeater itself.

> ***Note:*** The use of E6 repeaters at the class 4 office end of TC trunks is no longer recommended.

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

4.31 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.

4.32 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 new compensator is applicable to D88 or H88 low-capacitance 19-gauge and high-capacitance 19-, 22-, or 24-gauge cable conductors.

4.33 The new compensators are 837-type networks and provide a better impedance correction on toll connecting trunks at 2-wire switching offices than the SD-95756-01 network. When inserted into a toll connecting trunk which is terminated at the far end in a precision network (115-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 voice-frequency band. All lengths of cable end sections up to 5000 feet can be built out by adjustment of the internal BO capacitors.

4.34 The 837A network shown in Fig. 7A is used for most toll connecting 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 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. 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 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 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.

4.35 The 837B network shown in Fig. 7B 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 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) Toll connecting 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 return losses toward the access line.

4.36 The 837B has adjustments for the following:

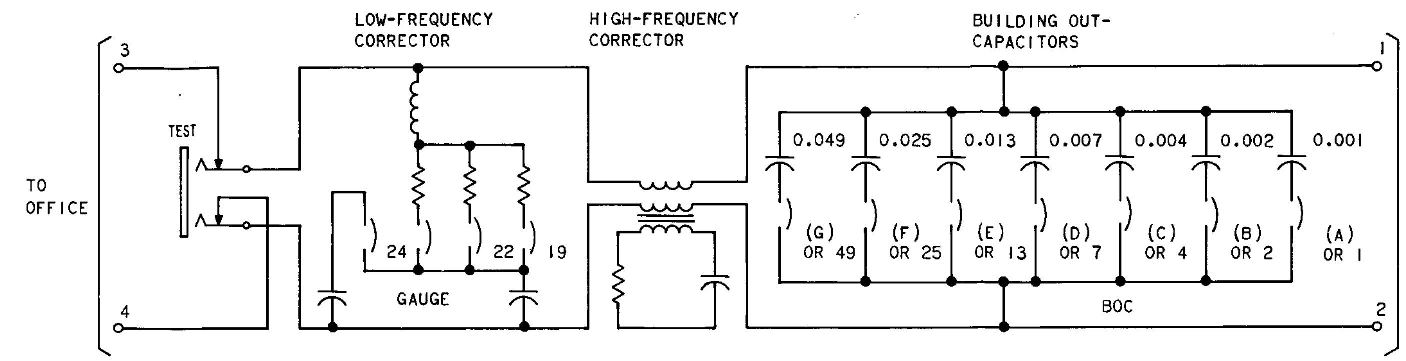
(a) Building out capacitance for office cabling (DROP BOC) from 0 to 0.064 μF in 0.002-μF steps

(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

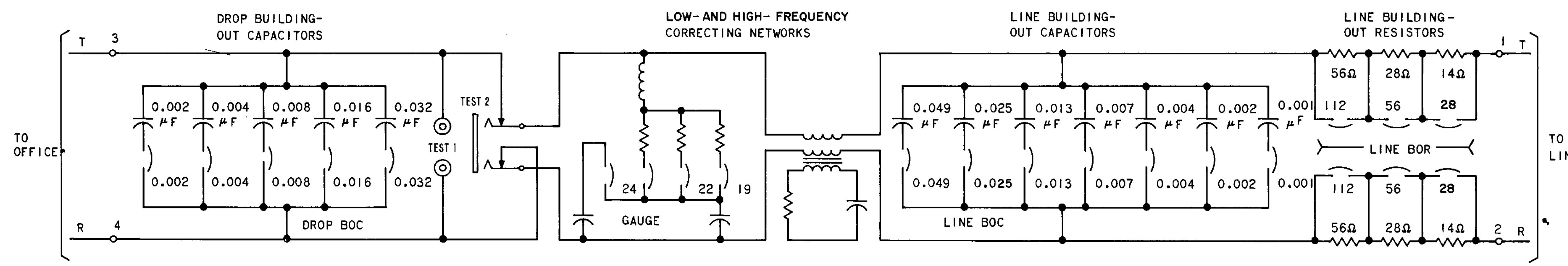
(d) Building out resistance for the cable (LINE BOR) from 0 to 196 ohms in 28-ohm steps.

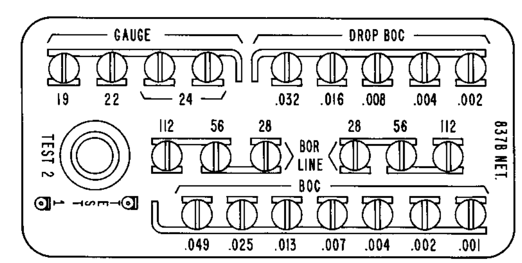
All adjustments are made by operating the screw-type switches on the front of the 837B network (Fig. 7B). In addition, a jack designated TEST 2 on the front of the network provides access to the impedance compensator and cable pair for making return-loss measurements. An open plug, such as the 258D plug, inserted into the TEST 2 jack, disconnects the network 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





837B IMPEDANCE COMPENSATOR

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

Fig. 7—837A and 837B Impedance Compensators

4.37 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

4.38 The amount of capacitance required in an 837A network BOC or an 837B network LINE BOC will usually be specified as part of the toll connecting 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 return-loss measurement as covered in Section 332-205-500.

4.39 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 return-loss measurement.

4.40 The 4066-type network is an adjustable 2-terminal network. It is normally used in conjunction with a 1-type 4WTS for precision balancing of its hybrid when the 2-wire circuit consists of 19-, 22-, or 24-gauge cable facilities. The circuit diagram for the 4066A network is shown in Fig. 8. The 4066A network is described in Section 332-852-101 and adjustments in Section 332-205-500.

J. Building-Out Capacitors

NETWORK BUILDOUT (NBO)

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

4.42 Office cables have distributed capacitance throughout their lengths. This distributed capacitance modifies the terminating impedance presented to the 2WL or 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.

4.43 In class 3 and higher offices, ***through*** balance on the longest IT-to-IT path through the office is used to determine the value of capacitance required for network buildout; whereas in class 4 offices, ***terminal*** balance on the average IT-to-TC path is determined and used as a compromise value of network buildout (refer to -200 Section).

4.44 In order to obtain a true average 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 for the office 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.

4.45 A new method of determining the office NBO value by optimizing the ERL and SRL measurements has been developed and is explained in the -200 section and engineering section of the particular office.

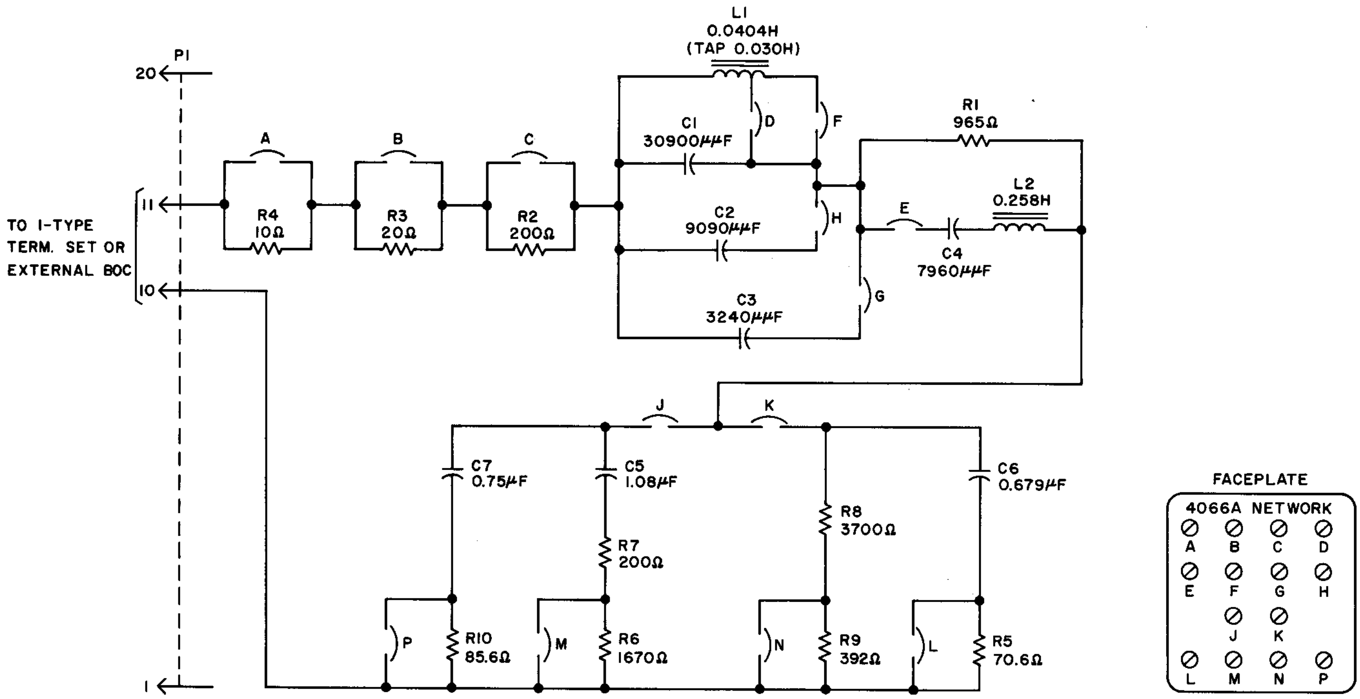


Fig. 8—4066A Network—Schematic

4.46 When measuring office cabling capacitance, it is not necessary to actually measure the capacitance of each switching 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). Usually, connections through just the switching machine will be among the shorter paths and connections through the switchboard will make up the longer paths.

4.47 When a compromise (midrange) value of office cable capacitance is used to determine an NBO value, return losses somewhat less than maximum can be expected on the longest and shortest switching paths, ie, those paths with more or less capacitance than the midrange path. This reduction in return losses can become serious if the difference in office cable capacitance is too great; therefore, capacitance differences must be held within a relatively narrow range.

4.48 In addition, it is desirable to introduce distortion in direct machine-switched connections with extra capacitance in order to get a high balance via a switchboard. Therefore, switching path cable capacitance, including any buildout, should not exceed 0.080 μF in any office; and a lower value is desirable, since large values of capacitance introduce increased attenuation-distortion at the upper part of the voice-frequency spectrum (2000 to 3000 Hz). For example, a shunt capacitance of 0.080 μF in a 900-ohm circuit will produce a difference in loss of approximately 1.2 dB between 1000 and 3000 Hz.

4.49 In a class 4 office, the difference in capacitance between the longest and the shortest switching paths should not exceed 0.025 μF. In some offices, this value has been decreased to 0.015 μF for better control of balance. If this range is exceeded, the shortest paths outside the range are excluded from the computation made to determine the midrange office cable path capacitance, that is, the NBO value.

4.50 Figure 9, is an example of the method that has been used to determine the office NBO capacitance value in a class 4 office. In the example, the longest path measured 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)]. In some offices, a growth factor (up to ten percent of actual value) should be added to the actual values. The result of adding a maximum growth factor is shown in the figure.

4.51 In class 3 and higher offices, the NBO capacitance, as determined by the through balance procedure, will usually be larger than required for best balance on connections to TC trunks. In this class of office, all IT trunks are built out to equal the longest path. It is usually necessary, in this case, to add build-out capacitance to some or all TC trunks. The capacitance is added to give a maximum return loss when the TC trunk is connected to an IT trunk that has been adjusted to meet through balance test requirements. It should be noted that terminal balance testing on TC trunks can be started just as soon as the NBO value for an office has been established.

DROP BUILDOUT (DBO)

4.52 To obtain balance across 4WTS hybrids having fixed NBO capacitance, the variance in switching path office cable capacitance must be considered. The capacitance of incoming paths should be made approximately the same and the outgoing paths should be made approximately the same. It is not necessary that the incoming paths equal the outgoing paths; however, the total capacitance of the two should equal the NBO value for best balance conditions. This is accomplished by adding fixed DBO capacitance in the switching paths. (Refer to the -200 section.)

4.53 When the NBO capacitance value is determined for an office and has been strapped in all IT 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.)

4.54 Through balancing requires that DBO capacitance be added to all switching paths, whereas terminal balancing requires that DBO capacitance be added only to the shorter switching paths. When adding the DBO capacitance in terminal balancing, the shorter trunks are built out to equal the compromise value.

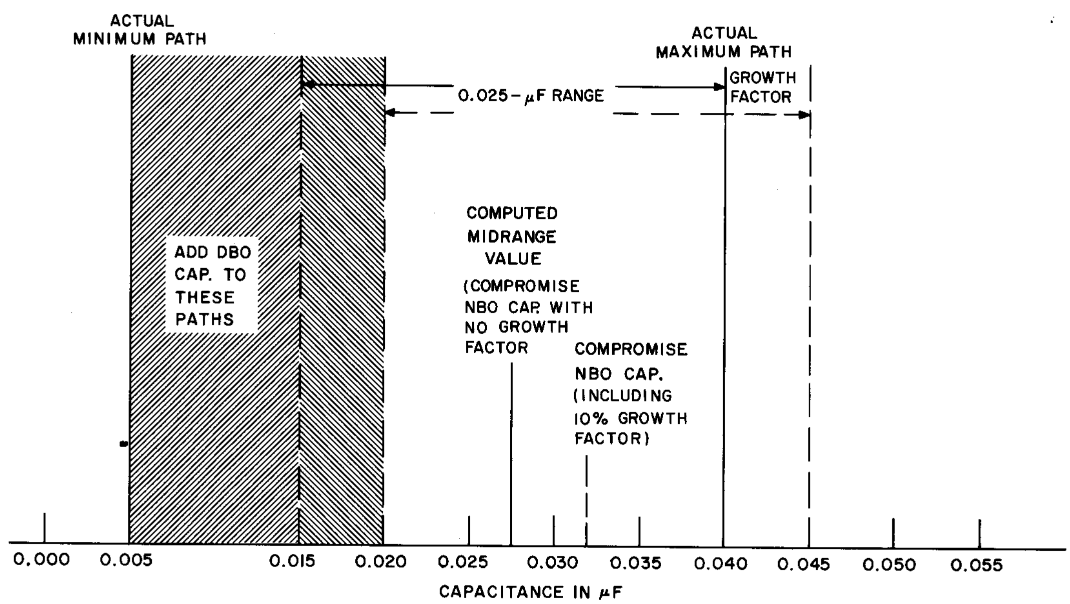


Fig. 9—Example of Determination of NBO Capacitance in a Class 4 Office

5. MEASUREMENT CONSIDERATIONS

A. General

5.01 The ERL and SP/SRL objectives for through and 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 as previously mentioned. This loss is sometimes referred to as "trans-hybrid loss". This loss must be measured using the KS-20501 RLMS test set or equivalent before the ERL and SP/SRL, respectively, can be determined. The dial of the RLMS is set to SRL/HI for this measurement and the THL dial adjusted to obtain a zero reading on the RLMS meter.

5.02 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 is feasible to obtain in view of economic and technical considerations. These considerations are included in the overall performance requirements for through and terminal balance as specified in -301 section. 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. In the requirements presented in the -301 section, only one requirement is presented. The tester should try to meet this value. Results of the measurements are given to a transmission engineer or supervisor who will determine if the trunk which has failed to meet the stated requirement should be turned up for service. This person will determine minimum and turn-down values from the engineering section. When any trunks fall below the minimum requirements, these trunks should be investigated for the source of poor balance. The given turndown limit indicates balance irregularities severe enough that the trunk cannot be left in service and corrective action should 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.

5.03 The measurements for determining office cable capacitance are made with a test equipment setup as described in -200 section. The 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. Through office path capacitances are measured from the 4WTS of an incoming IT trunk to the 4WTS of an outgoing primary or secondary IT trunk. The only exception to this is in an office that uses a time division switch or has buffers that will not switch capacitive reactance. However, the resistive reactance of the trunk attached to the other side of the switch does affect balance measurements and is required for proper termination. Terminal office path capacitances are measured from the 4WTS of an incoming IT trunk to a termination. When the TC trunk serves a class 5 office in the same building with the switching machine, the connection is completed to the class 5 office balance test termination. When the TC trunk serves a distant class 5 office, a termination(s) must be placed at (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, or (c) the toll switching office side of 2-dB pads when these are required in nonloaded cable.

5.04 Through balance verification measurements are made on connections from the 4WTS of an incoming IT trunk or a balance test circuit (refer to -301 section) to the 4WTS of an outgoing primary or secondary IT trunk. The connections are established through the switching machine and may include a switchboard. Terminal balance verification measurements are made on connections from the 4WTS of an incoming IT trunk or the balance test circuit to a ***terminated*** TC trunk.

B. 4WTS Loss (Trans-Hybrid Loss)

5.05 The 4WTS loss (trans-hybrid loss) is a measurement for noise across the 4WTS itself. A known amount of weighted noise generated in the RLMS is applied to the 4WTS receive port and a short circuit is caused on the 2WL ***immediate*** to the hybrid coil arrangements. The return loss in this case will be zero (see Part 3). The power detector of the RLMS (receive side) is connected to the transmit port and a measurement is made. Since the return loss 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). The measurement also includes the fixed loss of the cable and pads circuitry associated with the 4WTS receive and transmit ports. The loss as measured for weighted noise is used as the correction factor when determining the ERL. The loss is measured with the TEST TYPE dial at the SRL HI setting when using the RLMS and is the correction factor when determining the SP/SRL.

5.06 Once the trans-hybrid loss correction factors are measured, 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, since the factors are unique to the 4WTS itself.

C. ERL Determinations

5.07 The ERL in a 2WL is a determined amount of power for the weighted average of the RL at all frequencies in the echo range, 500 to 2500 Hz. This determination is the difference between the weighted noise correction factor (trans-hybrid loss for weighted noise) and a weighted noise measurement obtained in the same manner as described in Part 5B, but with no short circuit at the 4WTS and with the trunk under test terminated. ERL = weighted noise power measurement (trunk terminated) ***minus*** weighted noise correction factor (trunk shorted at the hybrid coils of the 4WTS).

D. SP/SRL Determinations

5.08 The SP 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 3. The determination of the SP is the difference between the correction of trans-hybrid loss and a measurement made with a singing point test set into the terminated trunk under test; or, stated differently, SP = SP test set measurement (trunk terminated) ***minus*** trans-hybrid loss (trunk shorted). When determination of SRL is made with the RLMS, trans-hybrid loss is compensated for in the test set calibration and the SRL indication for SRL or SRL HI is read directly without correction.

E. 2-Wire Switching Path Capacitance Determinations

5.09 The capacitance of 2-wire switching paths is measured in the following manner. The 2-wire path to be measured is connected by machine switching, 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, the RLMS is adjusted with the SRL HI output switch setting and applied to the 4WTS receive port. The RCV side of the RLMS is connected to the transmit port. The RLMS is used to indicate an RL value without consideration of the trans-hybrid loss 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 return loss, and the NBO capacitance value is approximately equal to the cable capacitance. Detailed explanations for the techniques are given in -200 section.

6. THROUGH BALANCE CONSIDERATIONS

A. General

6.01 The through balance verification measurements are made from the 4-wire facilities of incoming IT trunks to the 4-wire facilities of outgoing IT trunks, ie, class 3 switching (via a machine or switchboard). The through balance verification measurements are completed after NBO and DBO capacitances have been determined and adjusted. Thus, through balancing can be thought of as cross-office testing.

6.02 The verification results of through balancing are measurable as the ERL and SP/SRL incoming or outgoing from the toll facilities on all combinations of connections between IT trunks. These results should meet the VNL performance objectives.

6.03 The use of successive step techniques and intermediate evaluations as prescribed in the -301 section is recommended when performing through balancing using test equipment and techniques as prescribed. When performing through balance work, any trunks having ERLs and/or SP/SRLs below the requirements as specified in -301 section 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.

6.04 Before starting the through balance tests and adjustments, a certain amount of preliminary work is usually required. Apparatus should be verified, traffic flow in the office should be sketched, records prepared, etc. In addition to test planning, the 1000-Hz loss of trunk relay equipment to be balanced should be measured. The actual measured loss (AML) ensures that the trunk equipment meets transmission requirements. Through balance measurements are of little value when the 1000-Hz transmission requirements are not met.

6.05 Whenever adjustments to the NBO and DBO capacitors are made to obtain through balance in an office, it is assumed that the capacitance adjustments will be optimized by trial adjustments to maximize the measured return loss. This assumption is based on the fact that the 2WL of each trunk will be at least 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 of return loss.

6.06 As a result of the through balance process, all NBO capacitors are strapped for the same value and all COMP NET impedances are approximately equal. The 2WL impedances of all incoming and outgoing IT trunks are similar but the incoming and outgoing 2WL BO capacitances are not necessarily the same values. That is, all incoming IT trunks are built out to a similar impedance and all outgoing trunks are built out to a similar impedance. Therefore, the impedance match at the switchpoint of switchboard interconnection in all through path connections will be similar.

B. NBO Selection and Adjustment

6.07 The procedures for making the NBO selection are contained in -200 section.

6.08 When the NBO selection procedures per -200 section are completed in an office, the 4WTS in all primary IT trunks and the machine end of secondary IT trunks should have the same value of NBO capacitance. The NBO values in the switchboard end of the secondary IT trunk should be 1.5 times greater than the NBO values in 4WTSs of the machine end.

C. DBO Adjustment

6.09 After the NBO for an office has been selected and installed in the 4WTSs of all primary IT trunks and in offices containing secondary IT trunks, the 2WL of each trunk path must be built out with capacitance and verified. Since the longest incoming and longest outgoing primary IT trunk is used in the NBO selection (see exception in paragraph 5.03) and a ten percent growth factor is added (in those offices where growth is expected), whenever 0.080 μF will not be exceeded, drop buildout is generally necessary on all trunks.

6.10 In the adjustment of the DBOs, the ultimate consideration is to make all paths through an office have the same capacitance as the longest path. This results in all incoming trunks being similar, all secondary IT trunks in some offices being similar, and all outgoing trunks being similar to their longest counterpart with respect to capacitance.

6.11 In the performance of the procedures, the actual DBO adjustments are made with the incoming trunks connected to a code 100 balance test termination or to the outgoing side of the balance test circuit which is measured and built out to simulate the outgoing trunks. The outgoing trunks are adjusted when connected to a balance test circuit which is measured and built out to simulate an incoming trunk. With exception of 121 trunks, the secondary IT trunks in some offices are adjusted after adjustments are complete on the incoming and outgoing primary IT trunks.

D. ERL and SP/SRL Verification Tests

6.12 Verification tests should be performed on all primary IT trunks and in offices containing secondary IT trunks after capacitance buildout, using test equipment and procedures of the -301 section.

7. TERMINAL BALANCE CONSIDERATIONS

A. General

7.01 The terminal balance verification measurements are made from the 4-wire facilities of incoming IT trunks 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.

7.02 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 meet VNL performance objectives.

7.03 The use of successive step techniques and intermediate evaluations is prescribed in the -301 section. Trouble should be suspected if poor test results are obtained on some trunks which are similar in design to other trunks having good test results.

7.04 When an office is to be cut over to VNL, terminal balance testing 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 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 switching or through switching, depending on the class of office, should be strapped into the 4WTSs. In class 3 and higher ranking offices, through switching requirements will generally determine the NBO value that is required. Terminal balance testing should be completed as soon as possible after the cutover and the estimated NBO and DBO capacitances replaced with the final values.

7.05 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 then 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 ratios, proper midcoil capacitance, and correct orientation of the ratio with respect to the impedance being matched. Traffic flow sketches, record preparation, bay locating, and other test planning should also be made part of the preliminary work. In addition, 1000-Hz loss measurements are required on trunks before the ERL and SP/SRL are measured. The AML measurement is to 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 be measured. Terminal balance measurements are of little value if the TC trunks do not meet their 1000-Hz requirements. Standard methods of measuring 1000-Hz trunk losses are given in other sections of the practices.

7.06 In the class 3 and higher switching offices where class 4 switching is done (a class 5 office is served directly by the class 3 machine), the incoming and outgoing IT trunks are required to meet the through balance objectives, which are more stringent than the terminal balancing objectives. When this is the case, the IT trunk portions of a connection have already been balanced for through connections, and drop build-out work is made only on the TC trunk portion of the connection.

7.07 The strapping of NBO and DBO capacitors (when required) and the adjustment to impedance compensators must be completed before performing terminal balance verification tests. To meet overall TC trunk balance objectives, the intraoffice facilities to class 5 offices must also meet certain criteria. In the case of loaded cable, this includes the structural return-loss 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 option provided. In some cases where large class 5 offices exist, NBO capacitance is also required. Where the class 5 office is in the same building, provision of a fixed-pad option, when required as discussed in Part 4, should be verified.

7.08 The description and use of impedance compensators and the method of adjusting earlier types by computation are discussed in Part 4. 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 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, 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. When the return-loss measurements are made, the distant end of the cable pair under test should be terminated with a precision (115-type or 4066-type) network at the class 5 office. The precision network is used at the class 5 office instead of the balance test termination to avoid spurious reflections that may result in inaccurate adjustments of the impedance compensator.

7.09 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 average loop impedance. The terminal balancing processes 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 the -301 section. The method of terminating in the various types of class 5 offices is covered in Section 660-576-500.

B. NBO Selection—Class 3 and Higher Offices

7.10 In a class 3 or higher ranking office, the NBO capacitance is determined by the through balance procedure and will usually be larger than required for best balance on connections to TC trunks. It is usually necessary to add DBO capacitance to some or all TC trunks in this class office. The DBO capacitors are adjusted for maximum return loss when the TC trunks are connected to an IT trunk that has been adjusted to meet the through balance requirements. It should be noted that terminal balance testing on TC trunks can be started as soon as the NBO value for the office has been established.

C. NBO Selection—Class 4 Offices

7.11 When a toll switching machine is class 4, a compromise NBO value of capacitance is used. This value is a compromise value of capacitance determined from capacitance measurements made for the various paths, from both machine and switchboard, in the office. 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 intertoll and toll connecting. When using the optimization method described in the sections containing the new format, better results are obtained.

> ***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 TC trunks and switchboard ends of 4-wire tandem trunks terminate at switchboard appearances which have 600-ohm impedance hybrids requiring an NBO value less than that of the office NBO

(c) When E-type single-frequency (SF) signaling circuits with built-in 4WTSs are provided with adjustable or fixed values of NBO capacitance

(d) When the switch is incapable of switching capacitive reactance, an NBO value of a different value may be required on each side of the switch.

7.12 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 900 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 and the NBO capacitance in these 4WTSs is approximately half the actual office cabling capacitance.

7.13 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 faclities. 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 for balance. However, because of the 10:1 ratio, the actual value will be approximately one-tenth of the office NBO value.

7.14 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 of 0.004 μF. If a trunk uses E-type signaling circuits with a fixed value of NBO, the requirements for the return loss and singing points have been reduced.

7.15 When TC trunks are equipped with V-type amplifiers or carrier other than T1 equipped with D1 channel units, 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, voice-frequency patch bay, or equivalent 4-wire location serving the class 5 office. When the TC trunks are a 2-wire facility with an impedance compensator, 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 900 ohms plus 2.16-μF in series.

7.16 In the measurements of office cable capacitances, the values will tend to separate into two groups, ie, a group of smaller value (shorter paths) and a group of larger values (longer paths). Usually, connections through just the switching machine will be among the shorter paths and connections through the switchboard will make up the longer paths.

7.17 The capacitance measured on the connections in a given sample should all have approximately the same value. A wide range within a sample could be indicative of trouble on a 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.

7.18 It is not necessary to actually measure the capacitance of all switching paths in an office. Return-loss measurements made on a sampling basis are adequate, provided 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 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

7.19 At least two samples 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 at least a 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 or CX or DX signaling on 2-wire voice-frequency loaded facilities

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

7.20 If an inspection of the physical locations of trunk circuits, impedance compensators, etc, indicates 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.

D. DBO—Class 3 and Higher Offices

7.21 In class 3 and higher ranking switching offices, some DBO capacitance is generally required in all IT, TC, and in offices containing secondary IT trunks. 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 the ten percent growth factor when specified.

7.22 The DBO capacitor on each type of IT and TC trunk should be adjusted so that the capacitance of all trunks is approximately the same, provided the maximum DBO does not exceed 0.080 μF. If there is an impedance conversion between the machine and switchboard or trunk, the actual capacitance values will be adjusted automatically in the process of making adjustments. If the NBO has been established at the maximum value of 0.080 μF, DBO capacitance cannot be used to improve return loss on the longer trunks. In some instances, rearrangement of trunking may be required in order to meet terminal balancing requirements.

E. DBO—Class 4 Offices

7.23 In class 4 offices, DBO adjustments will usually be quite limited because the NBO value is selected as a compromise to the range of capacitance measured on the TC trunks. The shorter TC trunks (having less capacitance) may require buildout; this is determined when establishing the compromise NBO value for the office (see Part 7C).

F. ERL and SP/SRL Verification Tests

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

(a) 1000-Hz transmission loss test (in both directions if trunks work on hybrid-type repeaters or carrier facilities)

(b) Echo return loss test

(c) Singing point or singing return loss test.

Although not technically a balance objective, a transmission measurement should be made on the trunk connection before the ERL and SP/SRL are measured. The measured loss should be within ±1.0 dB of the EML for the trunk. The purpose of the test is to ensure that the test connection has been made correctly and that the losses are within reasonable limits. Procedures for the ERL and SP/SRL tests are given in the -301 section.

G. Class 5 Office 900-Ohm Test Terminations

7.25 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 (off-hook condition). The termination consists of a 900-ohm resistor in series with a 2.16-μF 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.

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 value must not exceed 0.080 μF and must 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) 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 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

(g) Balance records must be complete as specified in the -101 section.

9. TESTING ARRANGEMENTS AND TERMINATIONS

A. Test Hybrids

9.01 In order to make accurate balance measurements and to make balance measurements practical in offices in which random connection prevents connection of specific incoming trunks to specific outgoing trunks, it has been found necessary to set aside a hybrid coil and trunk relay which duplicate the drop equipment of an IT trunk. 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 strapped for the office NBO value of capacitance.

9.02 The test hybrid may be connected to the 101 test trunk using a patch cord or a special switch or the hybrid may be wired to a code 970 trunk.

B. Reference Trunks

9.03 In offices having program control and teletype command to connect specific incoming and outgoing trunks, "reference" trunks may be used to perform balance tests. The reference trunks should be electrically equal to the longest incoming and longest outgoing trunk. A record must be kept as to the identify of the reference trunks.

C. Test Apparatus

9.04 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 time should be allowed for all test sets requiring warm up to ensure that they have stabilized.

9.05 Local talking circuits between testing locations should be established as required.

9.06 Several combinations of test equipment may be employed in measuring the objectives of balancing. The ERL is obtained with test equipment capable of sending and receiving weighted random noise. The SP/SRL measurements require test equipment capable of sending and receiving 1000-Hz test tone or an RLMS.

9.07 The KS-20501 RLMS described in Section 103-106-115 or the Wiltron-type RLMS, 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. In addition, the Wiltron 9041 has the NBO and DBO decade capacitors in the lid of the set. It also has the capability of making 1000-Hz loss measurements.

9.08 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 switching office (toll drop). To avoid misunderstanding, the 4WTS ports are established with reference to the toll facilities: that is, the transmit port transmits to the toll facility; the receive port receives from the toll facility. In 4-wire voice-frequency patching jack fields, the transmit port designation related to the toll drop is EQ OUT and the receive port is designated EQ IN.

D. Balance Test Terminations

9.09 The balance test termination (BAL TST TERM) in offices for all incoming IT trunks and the machine-switched end of 4-wire tandem trunks is accessed by dialing code 100. The BAL TST TERM consists of a nominal impedance termination for a 2WL (900 ohms in series with 2.16 μF) and is bridged with a BO capacitor provided to change the reactance component of its impedance. In the new circuit pack arrangements, access to build out certain office code equipment has been restricted. The impedance of the BAL TST TERM is adjusted to present the same value of impedance to the switchpoints as that presented by the outgoing IT trunk in class 3 and higher offices and outgoing TC trunks in class 4 offices (see Part 7). The testing of connections through 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 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 present at its switchboard jack the impedance presented by the outgoing TC trunks in class 4 offices (see Part 7), which terminate in the switchboard and outgoing IT trunks in class 3 and higher offices.

9.10 The BAL TST TERM and SWBD BAL TST TERM provide a means of establishing test connections for incoming trunks to the outgoing switchpoints or to the switchboard.

9.11 In some class 3 offices, a working IT trunk or spare equipment assigned to provide a BAL TST circuit is used as the incoming side of the office to perform tests on the outgoing IT trunks. In some class 4 offices, a ***selected*** machine-switched TC trunk is used to test the outgoing IT trunks. In some offices, the ***selected*** TC trunk should be a CAMA or AMA trunk having office cable capacitance equal to the average length of the CAMA or AMA trunk paths in the office. Selection of the trunk is made after the NBO selection and DBO procedures are completed.

10. TESTING ANALYSIS AND TROUBLESHOOTING

10.01 All trunks having ERLs and SP/SRLs below the requirements 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 which have good test results.

10.02 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. A careful check may show that the balance can easily be improved. Where all the trunks measured have ERLs well above the requirements, 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 channels for further investigation.

10.03 The ERL and SP/SRL measurements for trunks working on 2-wire voice-frequency 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.

10.04 It is extremely important that ERL and SP/SRL 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 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 individual trunks and ensure proper return losses toward the class 5 office.

11. REFERENCES

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

SECTION	TITLE
103-106-115	Western Electric Company Model KS-20501 Return Loss Measuring Set—Description and Operation

SECTION	TITLE
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 and General Information
332-205-500	Impedance Compensators Tests and Adjustment
332-852-101	4066A Network—Description
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).