TERMINAL BALANCE
GENERAL DESCRIPTION AND CONSIDERATIONS

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1. GENERAL

1.01 This section covers the general aspects of terminal balance. Terminal balance testing is required in each toll switching office (class 4 and higher) switching at via net loss (VNL) and having at least one class 5 office homing on it.

(A) Comparison of Via Net Loss and Switch Pad Switching

1.02 To meet present over-all transmission objectives, intertoll trunks are being designed to operate as close to zero db loss as possible. This low loss is called via net loss (VNL). *Via net loss* may be defined as the lowest loss at which a facility (cable, carrier, etc) may be operated as an intertoll trunk without objectionable interference from echo and singing.

1.03 Via net losses are based on having adequate balance at all points where trunks are connected (switched) together. When two intertoll trunks are switched together, the resultant balance is called office balance. When an intertoll trunk is switched to a toll connecting trunk, the resultant balance is called terminal balance. *Terminal balance* is defined as the balance between the impedance of the network in the intertoll trunk 4-wire terminating set (or its equivalent) and the impedances of the toll connecting trunks connected to subscriber loops. It should be noted that the term "toll connecting trunk" as used in this practice means any trunk that may be used to connect subscriber loops to intertoll trunks.

1.04 At major switching centers (class 3 and higher), past designs used an S pad (usually 2 db) which was switched into each built-up connection between the intertoll trunk and the toll connecting trunk. This happened at both ends of the connection. The S pads were required as an adequate loss margin or safeguard against echo and singing. When two intertoll trunks were switched together, the pad loss was not required as adequate balance was obtained on this type of connection without the benefit of the pad. Thus a switchable S pad was used — in on terminating connections and out on through connections.

1.05 The S pad was switched in on all terminating calls regardless of the transmission loss of the toll connecting trunk. The result of this was that subscribers in class 5 offices located close to the toll switching office (for example in the same building) always received a better grade of transmission on built-up connections than did the subscribers served by the more remote class 5 offices.

1.06 In class 4 offices where the S pads would have had to be switched in on all connections (because there is no through switching in a class 4 office), the equivalent loss of the S pad was included by increasing the allowable design loss of the intertoll trunk. This type of design is called terminal net loss (TNL) design.

1.07 Switching pads (S pads or their equivalent loss) will generally no longer be part of the intertoll trunks. (Note: This does not apply to the A pads in 4-wire switching systems. The A pads are used for a different purpose.) Omitting the S pads from the designs means that intertoll trunks will switch at VNL whether the switch is made to another intertoll trunk or to a toll connecting trunk. Simply removing the S pads (or losses) from the intertoll trunks does not, however, do away with the reasons for which these losses were originally required. Echo and singing margins must still be provided.

1.08 In 2-wire switching, toll connecting trunks having less than 2 db switch-to-switch loss will have a 2 db fixed pad added in the trunk. This pad will now provide the required echo and singing margins. With this arrangement, these trunks will have a loss of roughly VNL +2 db. The longer (more loss) toll connecting trunks will also be designed to VNL +2 db but no fixed pad will be used. With these longer trunks, the 2 db loss (equivalent to the 2 db pad added to the shorter trunks) will be part of the normal over-all trunk loss. For example, if VNL +2 db for a given trunk is 3 db and the losses of the equipment and cable facilities of the trunk add up to 7 db, then only 4 db (7 − 3 = 4 db) will be "overcome" by repeater gain in the trunk.

1.09 Transmission on connections to toll connecting trunks with fixed 2 db pads will be the same as it was with the previous switch pad arrangement. Transmission on connections to toll connecting trunks without 2 db fixed pads will, however, be at least 2 db better. As these latter trunks are in the over-all majority, this is the principal reason for eliminating S pads or their equivalent loss, from the intertoll trunks.

1.10 The benefits of the loss reductions resulting from VNL design and the omission of switch pads have been bought, however, at the expense of reduced echo and singing margins. In other words, the probability of echo and singing occurring on built-up connections has been increased. Steps must be taken to maintain and, where necessary, improve the margins. This is the purpose of terminal balancing.

(B) Balance and Return Loss

1.11 With the extensive use of carrier systems, intertoll trunks are operated on a 4-wire basis. Each direction of transmission is electrically separated from the other direction. The bulk of the toll connecting trunks and all the local loops are 2-wire. Both directions of transmission are handled over the same 2-wire path.

1.12 In order to interconnect a 4-wire path and a 2-wire path, a hybrid coil is used. In 2-wire switching offices, the 4-wire intertoll trunks are brought down to 2-wire through a hybrid coil arrangement which is part of a 4-wire terminating set. Fig. 1 shows a typical arrangement.

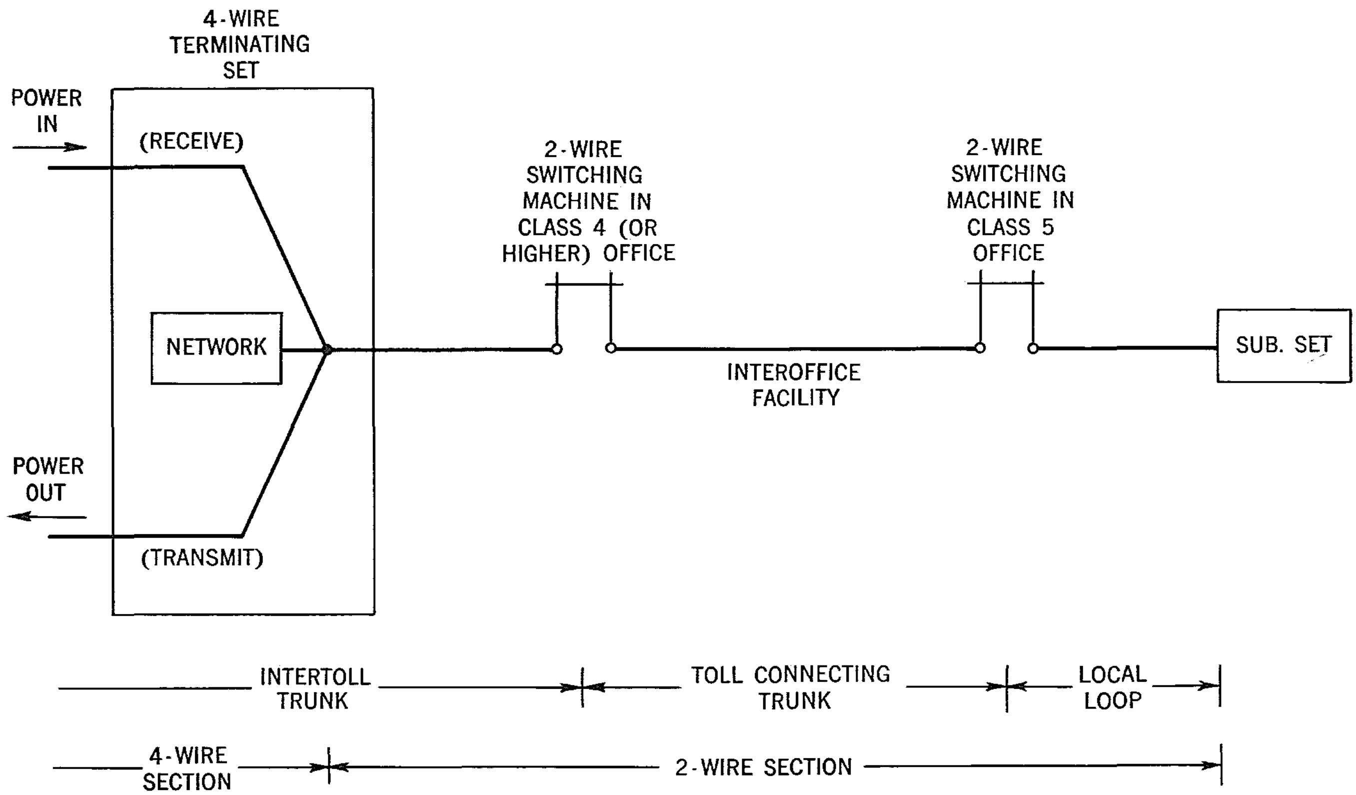

Fig. 1 – Simplified Sketch Showing a Typical Connection of an Intertoll Trunk to a Toll Connecting Trunk at a 2-Wire Switching Office

1.13 Referring to Fig. 1, the power received from the 2-wire section at the hybrid coil divides, half of it going into the receive side where it is dissipated in the output circuits of the amplifiers and half of it going into the transmit side and being sent over the intertoll trunk to the distant end. This split in power plus a small coil loss make up the transmitting loss of the hybrid coil arrangement.

1.14 Power entering the 4-wire side of the hybrid coil over the receive leg, divides at the 2-wire point with part of the power going into the 2-wire section, part going into the network (and being dissipated in it), and the remainder going into the transmit leg of the hybrid coil and back to the originating end. This division of power comprises most of the receiving loss of the hybrid coil and is determined by the match between the impedance of the network and the impedance of the 2-wire section. If the network and the 2-wire section balance each other perfectly (impedances are identical), then the power divides equally between them and no power enters the transmit leg. If the network and the 2-wire section do not balance each other perfectly (impedances are not identical), then an amount of power determined by the degree of unbalance (or mismatch) enters the transmit leg and is returned to the originating end.

1.15 This concept can also be developed from a Wheatstone bridge. Fig. 2(A) shows the regular Wheatstone bridge arrangement. If $R_A = R_B$ and $R_N = R_L$, then there is no difference of potential across the galvanometer (G) and no current will flow in G. The bridge is balanced. If $R_A = R_B$ but R_N does not equal R_L, then an amount of current determined by the unbalance (or mismatch) between R_N and R_L will flow in G.

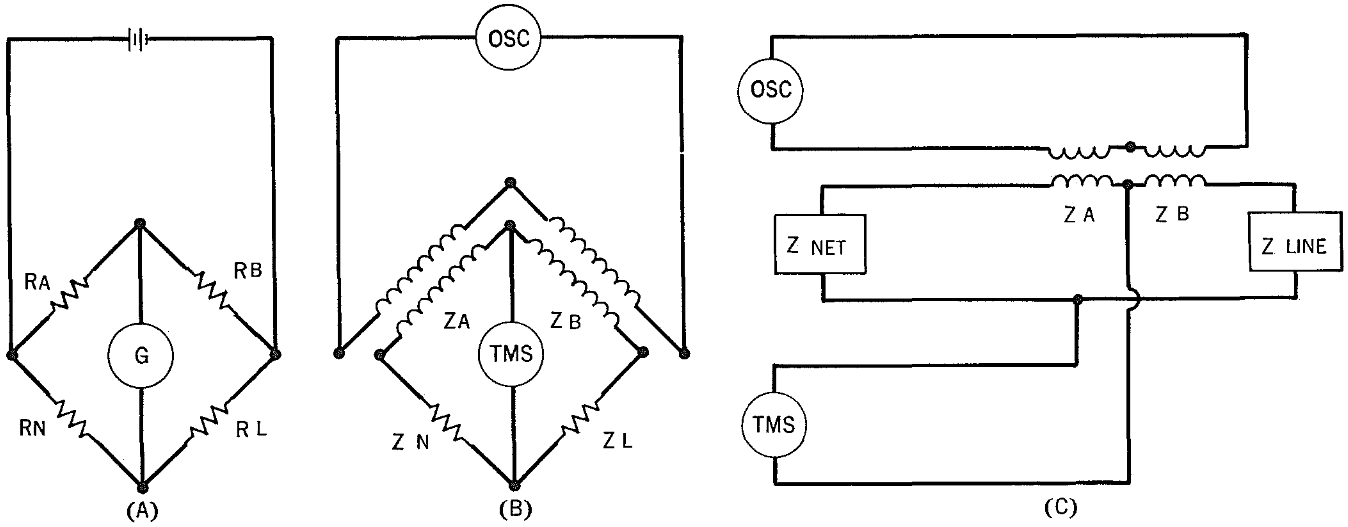

Fig. 2 – Simplified Theory of a Hybrid Coil — Transmitting 4-Wire to 2-Wire

1.16 In Fig. 2(B), ac equipment has been substituted for the dc equipment of Fig. 2(A). The battery has been replaced with an oscillator (OSC), the galvanometer with a transmission measuring set (TMS), and the resistances (R) with impedances (Z). The power from the OSC is transformer coupled to the bridge. If $Z_A = Z_B$ and $Z_N = Z_L$, then no current will reach the TMS. If $Z_A = Z_B$ but Z_N does not equal Z_L, then an amount of current determined by the unbalance (or mismatch) between Z_N and Z_L will reach the TMS. The rest of the current divides between Z_N and Z_L with the division depending upon the degree of unbalance.

1.17 Fig. 2(C) is the same as Fig. 2(B) but redrawn in a more recognizable form. Z_N and Z_L become the impedances of the network and line (2-wire section) respectively.

1.18 Referring again to Fig. 1, if the power returned to the originating end is great enough, it can degrade transmission. If sufficient power in the frequency range of 500 to 2500 cps is returned, the talker may hear his own voice repeated to him to the extent that it will interfere with his ease of conversation. This effect is called talker echo. Power returned at a single frequency may result in the connection (or part of the connection) going into self-sustained oscillations. This effect is known as singing. Although singing may occur at any frequency in the voice band, experience with built-up intertoll connections indicates that singing will usually take place in the 200 to 500 cps and 2500 to 3200 cps ranges. It should be noted that talker echo is dependent upon the balance at just one end of the connection whereas singing depends upon the balance at both ends of the connection.

> *Note:* Talker echo and singing are influenced by other factors besides the magnitude of the returned power. Echo is affected by the time required for the power to make the round trip from and back to the originating end of the connection — the longer the time (delay), the more disturbing the echo effect. Singing and the singing frequency are determined by the phase relationships of the original power and the returning power.

1.19 Because of these possible impairments, networks are designed to match the impedance of the 2-wire sections over the voice-frequency range to a degree sufficient to limit the returned power to acceptable amounts. The network is called a balancing network and the resultant degree of match (or similarity) is called balance.

1.20 The degree of balance is usually expressed in terms of return losses (in db) at certain frequencies. A return loss measured at the hybrid coil as shown in Fig. 2(C), is the amount of loss in the path of the returned power less the regular hybrid coil transmit and receive losses. If the balance between the network and the 2-wire section (line) is perfect, no power is returned to the hybrid coil transmit leg and, in effect, an infinite return loss exists. If the balance is less than perfect, some power will enter the hybrid coil transmit leg and a finite value of return loss exists. The worst match would be to short (or open) circuit the 2-wire line (or the network) at the hybrid coil. In this case there is no balance — or there is effectively zero return loss. Another way of looking at this is that due to the short (or open) no power can enter the 2-wire line and all the power is returned to the hybrid coil where it divides between the receive and transmit legs.

1.21 One of the methods used to measure return loss is based on the above facts. A short circuit is placed on the 2-wire side of the hybrid coil and a known amount of power is sent into the hybrid coil receive leg. Returned power is measured at the transmit leg. As the short circuit results in — for all practical purposes — zero return loss, the difference between the power in and the power out is the hybrid coil loss at the frequency used for the test. This loss will normally be about 7.5 db (plus any transmit and receive pads used with the hybrid coil for transmission level adjusting purposes) depending upon the type of 4-wire terminating set used. (It should be noted that this hybrid coil and pad loss is overcome by gain in the trunk in order to meet the VNL design objectives. Thus this loss cannot be considered as part of the return loss at the hybrid coil.) The measurement is then repeated without the short circuit and with the hybrid coil connected to the line to be tested. The frequency and power input are the same for both tests. The difference between the resultants of the two measurements is the return loss at the 2-wire side of the hybrid coil of the 2-wire line under test and at the frequency used for the test.

(C) Echo Return Loss

1.22 An echo return loss is a weighted average of the return losses of all frequencies in the echo range (500 to 2500 cps). It may be determined with a "one-shot" measurement by using a 201A noise generator as the source of test power applied at the hybrid coil receive leg. The 201A noise generator provides a source of random noise whose basic energy is spread evenly over the voice band. The weighting is accomplished by means of a 455B weighting network which shapes the noise output to approximately that of a male voice from an F1 transmitter. The returned power is measured with a 2B noise measuring set (NMS) (with F1A weighting), a 3A NMS (with message weighting), or equivalent apparatus. With this arrangement, a relatively accurate picture of the return losses across the important echo range is determined with one measurement.

(D) Singing Point

1.23 A singing point is a measure of the balance (in db) between the network and the 2-wire section at the critical (or worst) frequency. This critical frequency is usually — but not always — the frequency having the poorest (lowest) return loss. Although the echo return loss test covers the important voice band, it will not necessarily indicate individual poor return losses. This is particularly true at the frequencies (200 to 500 cps and 2500 to 3200 cps) where singing usually takes place and where the F1A weighting networks would tend to mask a poor return loss. Therefore, both an echo test and a singing point test are needed to complete the balance picture. (Note that a singing frequency below 200 cps is of no importance in these tests — see Paragraph 8.09.)

1.24 The 2D singing point test set is generally used for this test.

(E) Compromise Networks

1.25 The network in the 4-wire terminating set of an intertoll trunk must balance the impedance of any toll connecting trunk (or other intertoll trunk) to which it can be connected over the frequency range from 200 to 3200 cps. The impedances of the trunks — particularly the toll connecting trunks — are not constant but change with frequency. If the intertoll trunk were to be connected to one and only one toll connecting trunk, a precision network could be designed to match the impedance of the toll connecting trunk to a fairly high degree from 200 to 3200 cps. 115-type networks are examples of precision networks designed to match (balance) specific facilities.

1.26 Intertoll trunks, however, do not switch to just one toll connecting trunk. In any office, the intertoll trunks switch to a number of different types of toll connecting trunks — each of which may have a different impedance-frequency characteristic. Therefore no one precision network could balance all the different trunk impedances and a compromise network must be used.

1.27 The compromise network is designed to match the average impedance of the trunks that may be connected to the 2-wire side of the 4-wire terminating set. The network consists of a resistor in series with a capacitor. The usual values are (depending upon the switching system impedance):

600 ohms plus 2 MF
900 ohms plus 2 MF

1.28 These compromise networks were chosen primarily to balance the impedances of the intertoll trunks and thus give good balance on through connections. However, the same compromise network must balance the impedances of the toll connecting trunks. If good (high) return losses are to be obtained on terminal connections, then the impedances of the toll connecting trunks must be close to 600 (or 900) ohms and mostly resistive over the voice band.

(F) Definition of Terminal Balance

1.29 Terminal balance is defined as the balance between the compromise network in the intertoll trunk 4-wire terminating set (or its equivalent) and the impedance of the toll connecting trunks when the toll connecting trunks are connected to subscriber loops. Terminal balance testing is the measuring of this balance and where necessary the improvement of it.

Note 1: See Part 5 for a discussion of a test termination to use in place of the subscriber loops at the class 5 offices.

Note 2: Office balance is the balance between the compromise network of an intertoll trunk 4-wire terminating set and the impedance of the 2-wire side of a 4-wire terminating set on another intertoll trunk. Office balance is concerned only with through switching — not terminating connections.

1.30 Terminal balance results are expressed in terms of echo return losses (ERL) and singing points (SP).

2. PRELIMINARY INSPECTIONS

(A) General

2.01 Before beginning the actual terminal balance tests, a certain amount of preliminary checking is usually worthwhile. These inspections may turn up troubles or conditions which would delay the completion of the terminal balance tests.

(B) Cable Plant

2.02 First — and probably foremost — is an inspection of the trunk cable acceptance test records. Satisfactory terminal balance is dependent upon the trunk cable plant being properly designed, constructed, and maintained. Irregularities (such as missing or double load coils, etc) result in power being reflected back (returned) to the originating end of the connection. These irregularities will result in poor balance at the hybrid coil because of their effect on the impedance of the cable pair. The impedance will no longer be normal but will have a series of peaks and valleys over the frequency range.

2.03 Proper cable acceptance tests, as described in other sections of the practices, should be made when trunk cables are installed or rearranged. The usually recommended tests are:

(a) loop resistance measurements,

(b) detection of loading errors using two frequencies,

(c) structural return loss measurements.

If these tests have not been made or their results are not available, then the tests should be made before starting terminal balance procedures. If the tests were made some years ago, it may be wise to make a sampling check of each loading complement.

(C) Equipment

2.04 Certain equipment in the toll switching office is required if satisfactory terminal balance is to be obtained. Visual checks (on a sampling basis where possible) should be made to insure that equipment affecting terminal balance is properly installed and cross-connected into the trunks. The following list shows the items most commonly in need of checking.

(a) Impedance compensators. (See Part 3.)

(b) Fixed 2 db pads in toll connecting trunks with less than 2 db switch-to-switch loss.

(c) 1 MF capacitors in the midpoints of the drop side of the trunk circuit repeating coils. (These capacitors are required to improve the low-frequency return losses. Standard drawings show the required options.)

(d) Trunk circuit repeating coils. (A reversed or wrong ratio repeating coil will reduce return losses and degrade transmission.)

(e) Modified operator telephone set circuits. (This is required to improve the low-frequency return losses. Standard drawings show the required options.)

(f) Network and (when required) drop building-out capacitors. (See Part 4.)

(g) Fixed 2 db pads in various test circuits such as code 102. (These pads are required to keep proper tone levels. Standard drawings show the required options.)

3. IMPEDANCE COMPENSATORS

(A) General

3.01 An impedance compensator is a device used on certain loaded cable pairs to make the sending end impedance of the loaded cable pair have a more uniform value over the useful frequency range at the toll switching office. This change in impedance is required to improve the terminal balance.

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

3.03 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% of the cutoff frequency. At 0.8 end section, however, the capacitive reactance component becomes important. Thus the impedance compensator has been designed to build out the loading end sections to 0.8 and to add inductive reactance to offset the capacitive reactance.

3.04 As an example of the effectiveness of an impedance compensator, consider a 19CNB H88 loaded cable pair. At 0.5 end section, the sending end impedance has a magnitude of 1017 ohms at 1000 cps and of 1400 ohms at 2500 cps. After application of an impedance compensator, the sending end impedance has a magnitude of 975 ohms at 1000 cps and of 970 ohms at 2500 cps. 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.

(B) Description

3.05 The basic impedance compensator (see Fig. 3) 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.

3.06 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% of the cutoff frequency) and a negligible reactive component which gives good balance against the intertoll trunk compromise network.

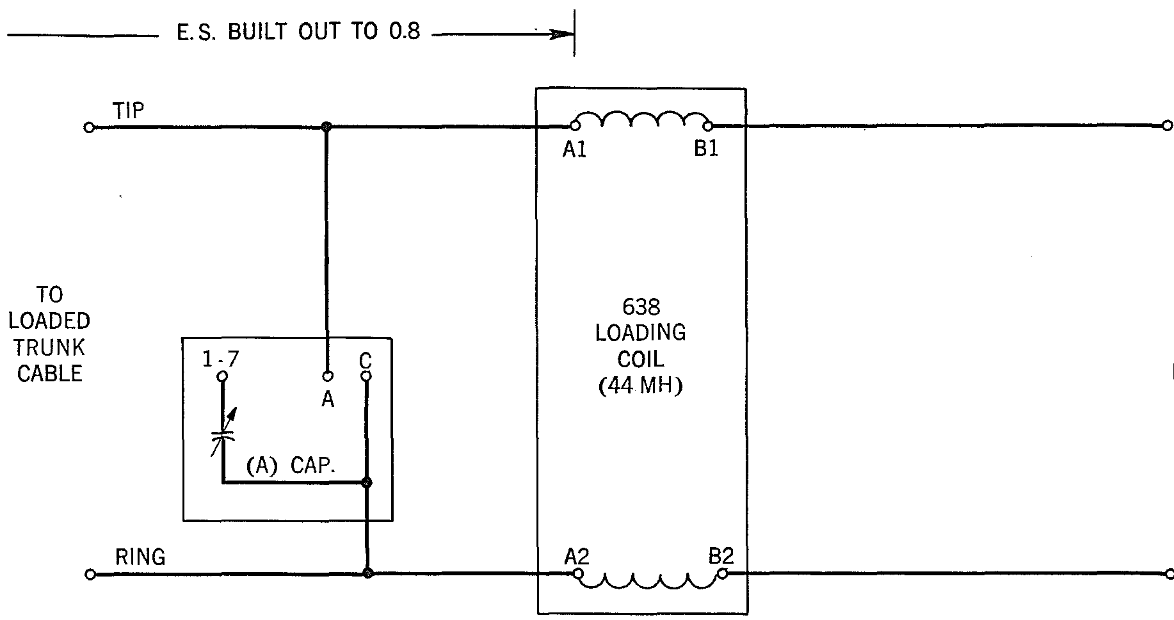

Fig. 3 — Impedance Compensator (SD-95756-01)

3.07 In addition to the basic impedance compensator, a low-frequency corrector is normally used on 22- and 24-gauge H88 loaded cable to improve the return losses at the lower frequencies (300 to 500 cps). 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.

3.08 A high-frequency corrector may be provided for use on low cutoff facilities such as H135 and H175 loaded cable pairs. There are no adjustments on the high-frequency corrector.

3.09 A drop building-out (BO) capacitor may be provided for building out the office cable on the switching equipment side of the impedance compensator. (See Part 4(B).)

3.10 Fixed 2 db pads are shown on the drawing with the impedance compensator. They are used on certain trunks having less than 2 db switch-to-switch loss and where a fixed 2 db pad cannot be provided in the trunk relay equipment.

(C) Adjustment Considerations

3.11 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 factors involved in such a computation are:

Imp. Comp. "A" Cap. = 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 located in the toll office (if used).

Note: See Paragraph 3.15 for example.

3.12 In the event terminal E23 repeaters located in the toll office are used on a trunk, they are connected between the cable pair and the impedance compensator. 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 section for each db of gain provided by the repeater. This, of course, reduces the amount of building-out capacitance required in the impedance compensator.

3.13 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 used in the test (at the toll office) plus the capacitance of the cable length given as the basic end section of the precision network.

3.14 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.

3.15 An example of the computation method follows:

22-gauge H88 loaded cable pair

Cable capacitance = 0.082 MF per mile

Average loading section = 6000 feet

Actual loading end section at the toll office = 2700 feet

100 feet of office cable and cross connections (at 0.000025 MF/foot) from the impedance compensator through the E23 repeater to the termination of the outside plant cable.

Note: Office cable capacitance varies from one type of cable to another. (The value of 0.000025 MF/foot is an average value chosen for this example.) Section E43.401 (AB23.331) shows office cable capacitance per foot for the various types. Accurate data on the types and lengths of cables used can usually be obtained from impedance compensator installation records. In some cases, sample measurements of the cable capacitance may be warranted. This would be where the type of cable used is unknown or doubtful or where long (in excess of 100 feet) runs of cable are involved. Measurements should be made with a capacitance bridge or its equivalent.

E23 repeater (at the toll switching office) gain = 3.5 db

From Paragraph 3.11

$$\text{Imp. Comp. “A” Cap.} = (0.8\text{x}\frac{6000}{5280}\text{x}0.082) - (\frac{2700}{5280}\text{x}0.082) - (0.000025\text{x}100) - (0.05\text{x}3.5\text{x}\frac{6000}{5280}\text{x}0.082)$$

$$\text{Imp. Comp. “A” Cap.} = 0.014 \text{ MF}$$

4. BUILDING-OUT CAPACITORS

(A) Network Building-Out (NBO)

4.01 The compromise network in an intertoll trunk 4-wire terminating set should provide satisfactory balance against the impedances of the trunks which may be connected to the intertoll trunk.

4.02 These impedances, however, are not connected directly to the 4-wire terminating sets of the intertoll trunks. There is always some office cabling between the two. Office cables, like outside cables, have distributed capacitance throughout their lengths. This distributed capacitance acts as a capacitor bridged across the trunk and thus has a modifying effect on the impedance of the trunk. This effect can be balanced in the network of a 4-wire terminating set by bridging an equal amount of capacitance across the compromise network. The network building-out (NBO) capacitors are provided for this purpose.

4.03 Just as there is only one compromise network in a 4-wire terminating set, so there can be only one value of NBO capacitance strapped into a 4-wire terminating set. But the office cabling capacitance connected to the 2-wire side of the 4-wire terminating set is not a constant value. The amount of capacitance is determined by the types, lengths, and number of multiples of the cables in the connection and thus varies from one switched connection to the next. A compromise value of the capacitance of all the toll switching connections in an office must be determined. This compromise value is then used as the NBO capacitance for the office and is strapped into the networks of all the 4-wire terminating sets used on message traffic trunks — both intertoll and toll connecting trunks.

Note: There are certain exceptions to this general rule for the use of the office NBO capacitance value. They are:

(a) Where the line-to-network impedance ratio of the 4-wire terminating sets in an office are not all the same. (See Paragraph 4.14.)

(b) Crossbar tandem offices are considered to have a nominal impedance of 900-ohms. Toll switchboards have a nominal impedance of 600 ohms. Impedance matching between the two is done through repeating coils. ***Toll connecting*** trunks with a switchboard appearance will use 600-ohm 4-wire terminating sets. The NBO value used in these 600-ohm sets will normally be 1.5 times the NBO value used in the 900-ohm sets.

4.04 It is not necessary to actually measure the capacitance of each switching path in an office. Measurements made on a sampling basis are adequate. In class 3 (or higher) offices, the NBO capacitance is determined by the more stringent requirements imposed on through switching — intertoll trunk to intertoll trunk. Class 3 (or higher) office procedures are covered in other sections of the practices. Fig. 4 shows in simplified form how the NBO measurements are made in a class 4 office.

4.05 In a class 4 office, a connection is set up through the switching machine and/or the switchboard to a toll connecting trunk. The selected trunk is then opened up and terminated (as indicated in Fig. 4) at the point where the trunk impedance is considered to be constant and resistive. With the NBO capacitor open and bridged with a variable capacitor, a return loss measurement at 2000 cps is made. The variable capacitor is then adjusted until the point of maximum return loss is obtained. The amount

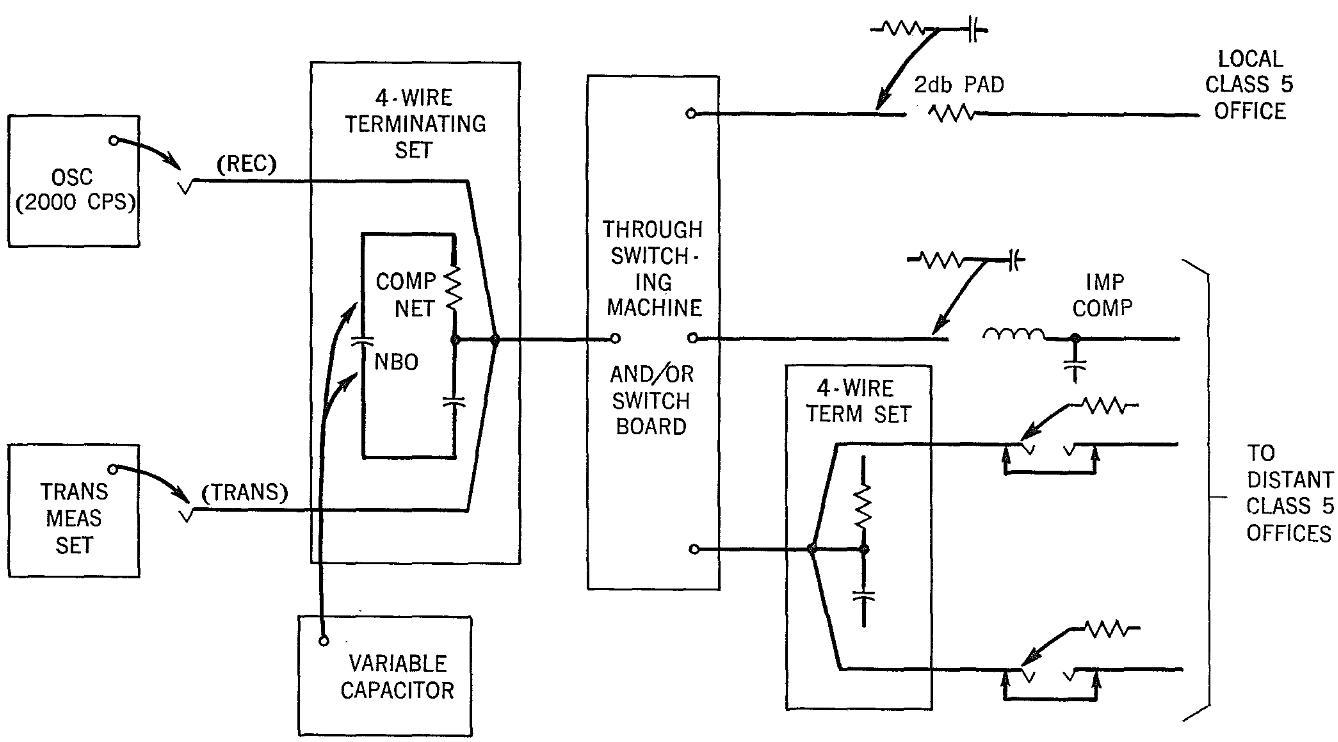

Fig. 4 — Simplified Sketch Showing One Step in Process of Adjusting NBO Capacitors in a Class 4 Office

of capacitance added in the network is equivalent to the distributed capacitance of the office cables in the connection. This test is repeated to other toll connecting trunks until all trunk groups and access paths have been sampled.

4.06 There will probably be no semblance of an over-all normal distribution to these office cable capacitance measurements. The measured values will tend to separate into two groups — a group of smaller 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.

4.07 In order to obtain an average of these measured values, a system of weighting (size of groups, size of samples, traffic usage, etc) would have to be used. Because of this, a figure midrange between the longest and shortest paths can generally be accepted as the value used for the compromise NBO capacitance. For example, if the longest measured paths were 0.032 MF and the shortest were 0.014 MF, then the accepted compromise (midrange) path would be 0.023 MF (the sum of 0.032 and 0.014 divided by 2). Thus, the NBO value for the office would be 0.023 MF. Care must be taken that the actual longest and shortest paths were measured and then used to determine the final compromise value.

4.08 More accurate measurements of the office cabling capacitance are obtained if 2000 cps is used than if a lower frequency were used. This is due to the presence in the trunk relay equipments of various series capacitors and bridged inductances (such as retardation coils and relays). The effects of these components 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 easily measured at the higher frequencies.

(B) Drop Building-Out (DBO)

4.09 Using a compromise (midrange) NBO value means that return losses somewhat less than maximum can be expected on the longest and shortest switching paths (those paths with more or less capacitance than the midrange path). As this reduction in return losses can become serious if the deviations in switching path capacitance are too great, the capacitance differences should be held within a relatively narrow range.

4.10 In a class 4 office, the difference in capacitance between the longest and shortest switching path should not exceed 0.025 MF. If this range is exceeded, then the measured values of the shorter paths outside the range are excluded from the computation made to determine the midrange path capacitance. Capacitance is then added to the shorter paths to bring them up to the midrange value. This process of adding capacitance is known as drop building-out (DBO).

4.11 Fig. 5 is an example of the method used to determine the office NBO and the switching paths requiring DBO. In the example, the longest path measured is 0.040 MF and the shortest is 0.005 MF. All measured values below 0.015 MF (0.040-0.025 = 0.015) are excluded and the midrange path is determined to be 0.028 MF (sum of 0.040 and 0.015 divided by 2 equals 0.028) and 0.028 MF becomes the NBO value for the office. Now capacitance is added to all the paths measuring less than 0.015 MF to bring them up to the midrange path capacitance of 0.028 MF.

4.12 In a class 3 (or higher) office, the NBO capacitance as determined by the office balance procedures will usually be larger than required for best balance on connections to toll connecting trunks. It is usually necessary to add DBO capacitance to some or all toll connecting trunks in this class of office. These DBO capacitors are adjusted for maximum return loss when the toll connecting trunks are connected to an intertoll trunk. It should be noted that in class 3 (or higher) offices, the office balance work should be completed before starting the terminal balance tests.

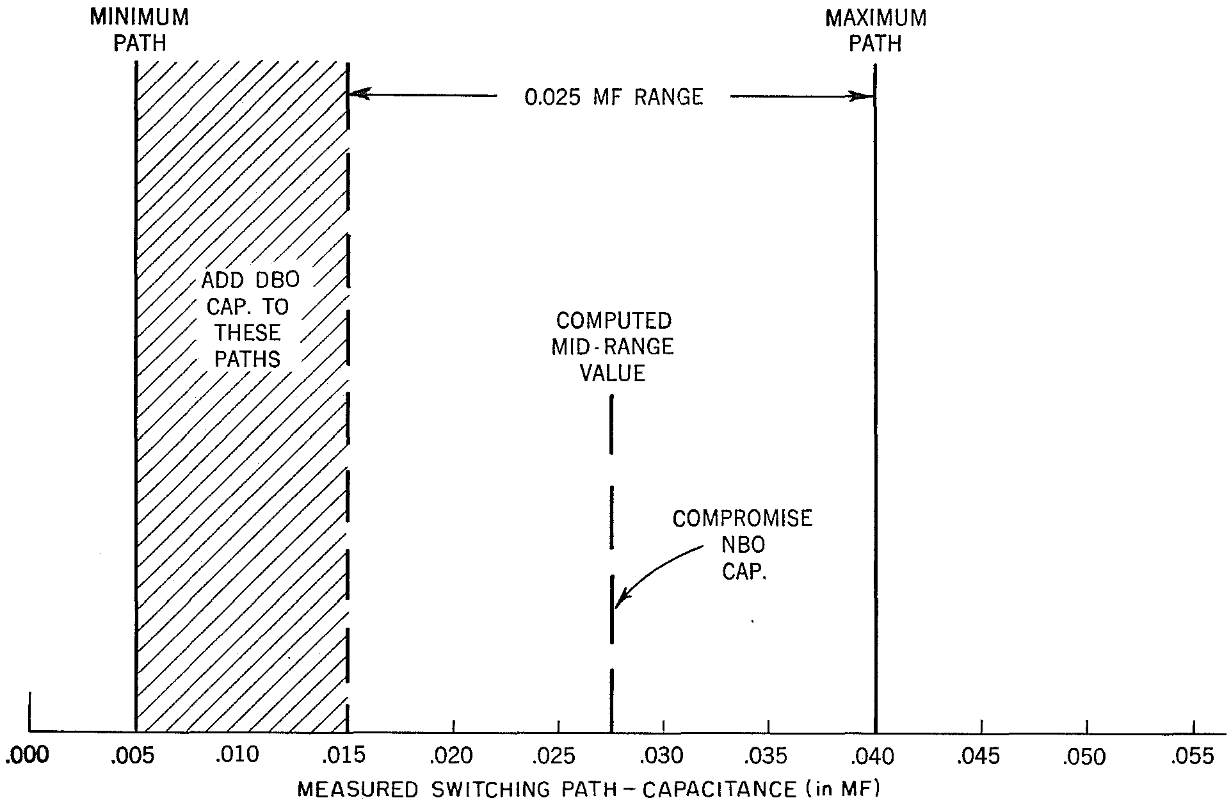

Fig. 5 — Example of Determination of NBO Capacitance in a Class 4 Office

4.13 DBO capacitance causes some transmission loss at the higher frequencies. Because of this, excessive amounts of DBO should be avoided where possible. This is done by limiting, wherever possible, the amounts of office cable associated with the trunks. For example, some equipments are cabled directly rather than being cross-connected together. This results in a lower NBO value and hence a lower DBO value.

(C) Effect of Impedance Ratios in 4-Wire Terminating Sets

4.14 The network building-out (NBO) capacitance ranges and adjustments are based on a 1:1 network-to-line impedance ratio in the 4-wire terminating sets. In some 4-wire terminating sets, a ratio other than 1:1 has been used. Probably the most common of these is the miniature 4-wire terminating set (4TT) where a 2:1 network-to-line impedance ratio is used. In the 4TT, the compromise network is 1200 ohms plus 1 MF rather than the usual 600 ohms plus 2 MF. It will be noted that the capacitor is only half the normal value. This is due to the fact that capacitive reactance is inversely proportional to the capacitance. It follows then that the NBO capacitance will be only half the actual office cabling capacitance. Because of this, the range of capacitance differences as given in Paragraph 4.10 must be halved (to 0.0125 MF) when working with values measured in the network of this type of 4-wire terminating set.

(D) Estimated Building-Out Capacitance Values

4.15 If an office is to be cut over at 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.

4.16 In this event, an estimated value of NBO capacitance based on terminal switching (in a class 4 office) should be strapped into the networks of the 4-wire terminating sets. In class 3 (and higher) offices, through switching requirements determine the NBO value. This is covered in other sections of the practices.

4.17 Terminal balance testing should be completed as soon as possible after the cutover and the estimated NBO and DBO capacitances replaced with final values.

5. CLASS 5 OFFICE 900-OHM TEST CIRCUIT

5.01 Terminal balance data used in the VNL design of intertoll and toll connecting trunks is the average (and distribution grade) of the echo return losses and singing points to all the subscriber loops in a class 5 office. Obviously it is impracticable to test each toll connecting trunk to all the subscriber loops. To permit a quick check of each trunk's performance, a compromise termination has been selected for use at the class 5 offices in place of the subscriber loops.

5.02 This termination consists of a 900-ohm resistor in series with a 2 MF capacitor. These values are considered representative of the wide array of loops radiating from a class 5 office. Terminal balance objectives as set forth in Paragraph 7.03 are based on using this test termination.

5.03 A temporary arrangement providing a test termination should be provided when the standard 900-ohm plus 2 MF termination (SD-96000-01, Fig. 9 or SD-98100-01, Fig. 6) is not available in the class 5 office. A temporary arrangement should also be provided for testing one-way incoming trunks.

6. TEST HYBRID COIL CIRCUIT ARRANGEMENTS

(A) General

6.01 In 2-wire switching offices, terminal balance tests are made "across" a hybrid coil similar to the type used to terminate the intertoll trunks in the office under test. In 4-wire switching offices, the tests are made "across" the hybrid coils associated with the individual toll connecting trunks. In some of the smaller 2-wire switching offices, a working intertoll trunk may be turned down and the measurements made using this trunk's drop equipment. In most cases, however, it will be more convenient to set up a test hybrid coil arrangement which duplicates the drop equipment of an intertoll trunk.

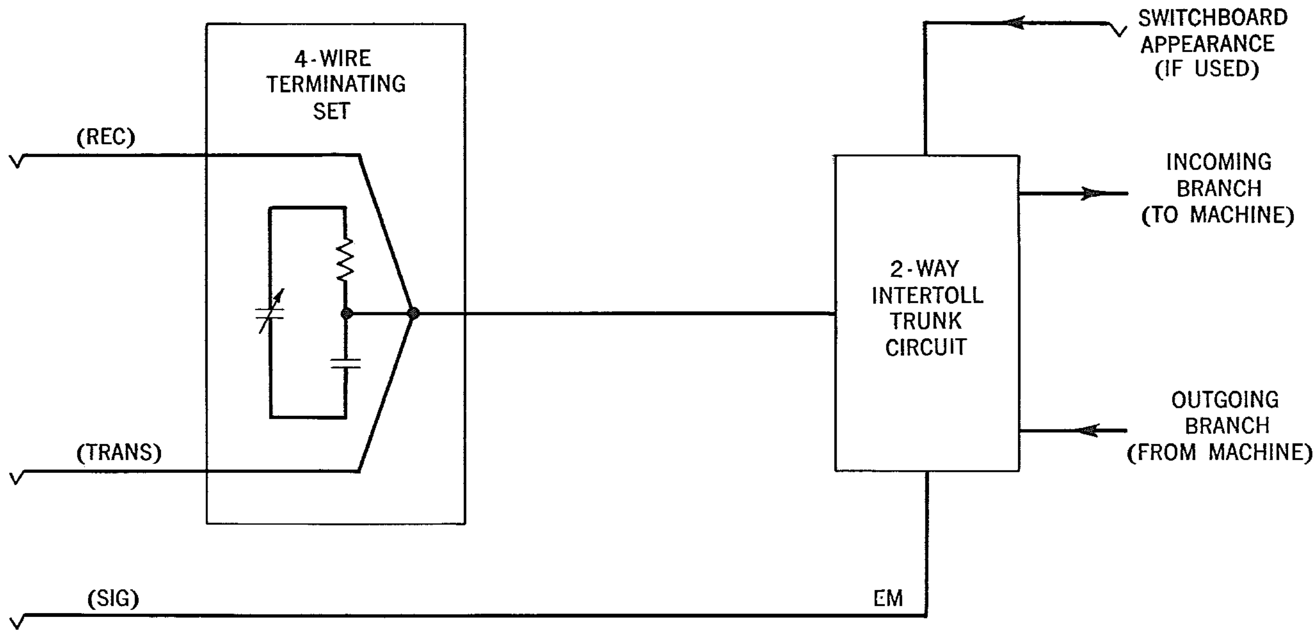

Fig. 6 – Simplified Sketch of Test Hybrid Coil Circuit

6.02 A special directing code (970) has been made available for use in balance testing. This code permits selection of the trunks to be tested. In crossbar tandem offices, the test hybrid coil circuit will make use of this code. The test hybrid coil will also provide a convenient test point for future maintenance testing of terminal balance.

(B) Typical Test Hybrid Coil

6.03 The arrangement of the test hybrid coil circuit will vary according to the type of office being tested. Fig. 6 shows the general arrangement. The various types of 4-wire terminating sets have somewhat different balance characteristics. This is also true of the various trunk relay equipments. Because of this, care must be taken that the equipment used in the test hybrid coil circuit is actually representative of the intertoll trunks in the office.

(C) Use of the Test Hybrid Coil

6.04 Fig. 7 shows how the test hybrid coil circuit is used to measure terminal balance.

6.05 To measure the echo return loss (ERL) of a toll connecting trunk, the test hybrid coil is switched to the desired trunk and a 900-ohm plus 2 MF termination is placed at the class 5 office. The 201A noise generator and 2B or 3A noise measuring set (NMS) are connected as shown in Fig. 7 and the reading of the NMS is recorded. A short circuit is then placed on the 2-wire side of the 4-wire terminating set and the resultant reading of the NMS is recorded. This latter reading corresponds to zero return loss. The difference between the two readings is the ERL of the toll connecting trunk under test.

6.06 By substituting a 2D singing point test set for the noise generator and the NMS, a trunk singing point test may be made. Sub-

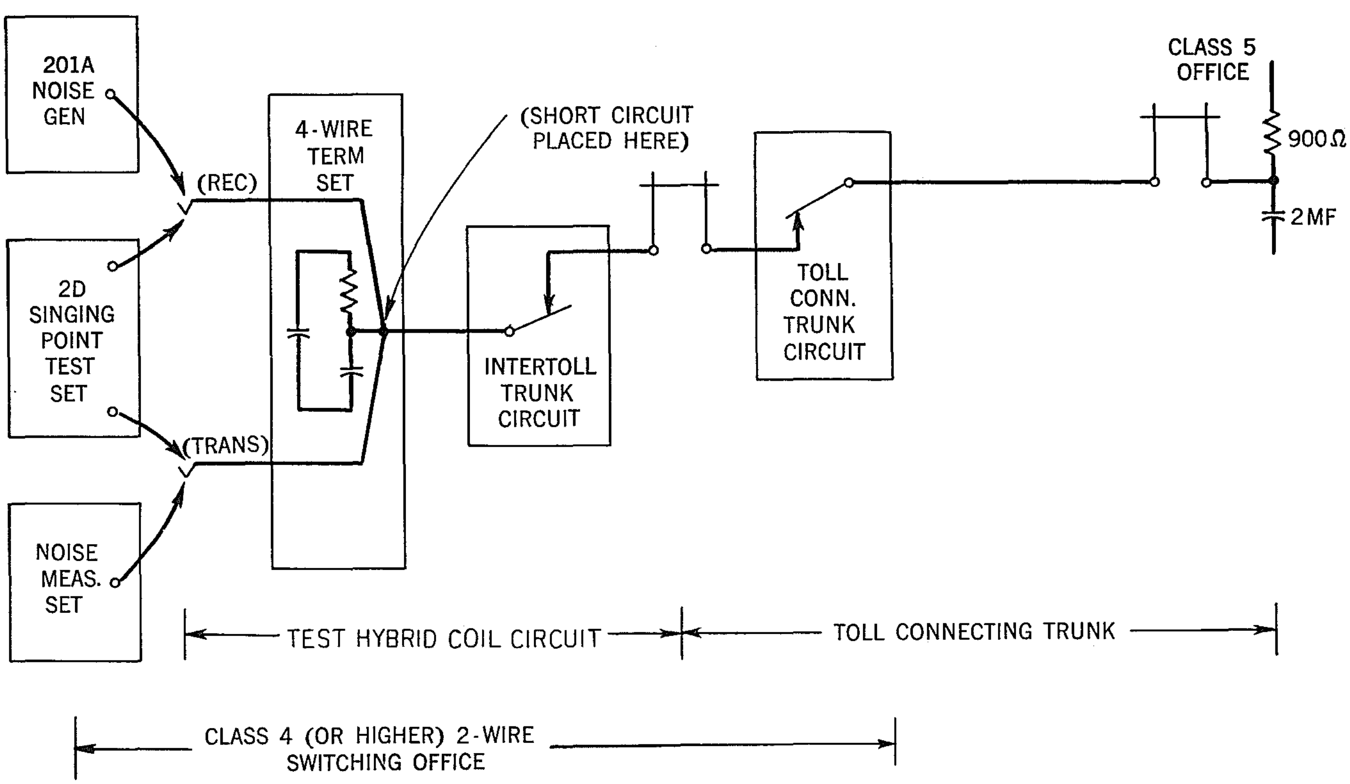

Fig. 7 — Method of Measuring Terminal Balance

tracting the 1000 cps hybrid coil transmit and receive losses from this measured singing point results in the corrected (final) singing point for the toll connecting trunk.

6.07 With the application of correction factors, the test hybrid coil arrangement may be used to measure the 1000 cps over-all transmission losses of the built-up test connections.

7. TERMINAL BALANCE OBJECTIVES

(A) General

7.01 When the impedance compensators, the NBO capacitors, and (where necessary) the DBO capacitors have been adjusted, the following tests should be made on *all* toll connecting trunks:

(a) 1000 cps Transmission Loss Test (in both directions if trunks work on hybrid-type repeaters or carrier facilities).

(b) Echo Return Loss Test.

(c) Singing Point Test.

7.02 Although not technically a terminal balance objective, a transmission measurement should be made on each test connection before measuring the echo return losses and singing points. The measured loss should be within ±1.0 db of the connection's computed loss. This computed loss would include the losses of the test hybrid coil arrangement, office wiring (drop), operator service trunks, toll connecting trunk and the measuring equipment. The purpose of the test is to insure that the test connection has been made correctly and that the losses are within reasonable limits.

(B) Objectives

7.03 Balance test objectives are:

		AVERAGE	DISTRIBUTION GRADE (DG)
(a) Echo Return Loss (ERL)	—	18.0 db	2.5 db
(b) Singing Point (SP)	—	10.0 db	2.0 db

Note: The above ERL and SP objectives are general for 2-wire switching systems switching at VNL. Because of the A pad, hybrid coil, and testing arrangements, different test objectives are used for 4-wire switching systems. Specific test objectives are given for each type of switching system in the sections covering terminal balance tests.

7.04 The ERL and SP objectives are based on using a 900-ohm plus 2 MF test termination in the class 5 office. The ERL objective is further based on using a 201A noise generator equipped with a 455B weighting network and a 2B noise measuring set (NMS) with F1A weighting, a 3A noise measuring set with message weighting, or equivalent apparatus.

7.05 A 128A filter is built into the 2D singing point test set. If the singing point test is made using test equipment other than the 2D set, a 128A filter should be used in conjunction with the other equipment. This filter cuts off those high frequencies which will not ordinarily pass through the intertoll network (because of repeater filters and carrier-filtering action) and which would thus give an erroneous picture if taken as the final trunk singing frequencies.

7.06 Averages and distribution grades may be determined in a manner similar to that described in Section E15.300. An average of 18.0 db and a distribution grade (DG) of 2.5 db may be defined approximately as:

84.0% of the trunks should equal or be better than 15.5 db (18.0-2.5 or 1 DG).

98.0% of the trunks should equal or be better than 13.0 db (18.0-5.0 or 2 DG).

100.0% of the trunks should equal or be better than 10.5 db (18.0-7.5 or 3 DG).

In a like manner, an average of 10 db and a DG of 2 db may be defined approximately as:

84.0% of the trunks should equal or be better than 8 db.

98.0% of the trunks should equal or be better than 6 db.

100.0% of the trunks should equal or be better than 4 db.

7.07 All trunks having echo return losses below 13 db and/or singing points below 6 db 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. (See also Part 8.)

(C) Special Considerations

7.08 ERL and SP averages and distribution grades for trunks working on voice-frequency, 2-wire, loaded cable facilities should be summarized separately from trunks working on hybrid-type repeaters or carrier and from trunks that have been treated with 2 db pads. This is due to the inherently higher return losses expected from the latter types of circuitry. All of these excluded trunks should be measured, however, in order to detect transmission and balance troubles.

7.09 Toll connecting trunks working on open wire leads with large quantities of supplementary equipment (e.g., carrier line filters, autotransformers, etc) may have poor balance. These trunks should all be measured but should be excluded from the office averages.

(D) Individual 4-Wire Terminating Sets in Class 4 Offices

7.10 After satisfactory terminal balance has been obtained in an office, ERL tests should be made from the 4-wire side of all 4-wire terminating sets used on traffic message trunks. The tests should be made to a balance test termination such as code 100 (built out if necessary). These tests will uncover any balance troubles (for example: open NBO capacitors, compromise networks, incorrect wiring in the 4-wire terminating sets, or other equipment) on the individual trunks. The balance objectives for these tests vary with the type of termination used in the tests. Specific objectives are given in the sections covering terminal balance tests.

Note: In class 3 and higher offices, this test should be made on those 4-wire terminating sets used on toll connecting trunks.

(E) Records

7.11 It is desirable to prepare and maintain a record of both the return loss and singing point test results. This will aid in determining later whether any irregularities have developed should it be necessary to investigate the cause of transmission difficulties. Also, future measurements made in connection with trunk additions and plant rearrangements can be added to provide a continuing record of the over-all terminal balance condition for the office.

8. ANALYSIS OF POOR TEST RESULTS

(A) General

8.01 Test results for the various toll connecting trunks will not all be the same. The differences in test results are due to many factors. One of these factors is the structural return loss (SRL) of the individual cable pairs. A structural return loss is a measure of the similarity of an actual cable pair and a nearly ideal line (a precision network). Any departure from the ideal line (such as manufacturing tolerances, the use of mixed gauges, irregular load spacing, etc) naturally reduces the SRL. Minimum acceptable SRL objectives have been established. Measured structural return losses will also vary from complement to complement and from pair to pair.

8.02 Another factor affecting test results is the use of a compromise NBO capacitance on the intertoll trunks. When a compromise NBO is used, it will not be ideal for all connections.

8.03 If the structural return loss objectives are met, if the building-out capacitors are adjusted properly, and if there are no troubles in the plant, then the test results should conform to the patterns established by the objectives given in Part 7.

8.04 Test results which are below the objectives are indicative of troubles. The following paragraphs summarize a number of conditions which may be found upon closer investigation of trunks with poor terminal balance test results.

(B) Echo Return Losses

8.05 Return loss tests which are uniformly poor across the entire voice-frequency band usually indicate a serious impedance mismatch. This may be caused by a repeating coil with an incorrect impedance ratio, with the primary and secondary windings reversed, or with a physical trouble in the coil itself or its wiring.

8.06 Return loss tests which are poor at the lower voice frequencies only may indicate series capacitor or shunt inductor trouble. The series connected capacitors at the repeating coil midpoints may be the wrong value. If the trunk works on 22- or 24-gauge conductors with H88 loading, a low-frequency corrector may be required in addition to the impedance compensator.

8.07 Return loss tests which are poor at the higher frequencies only may indicate impedance compensator or capacitance building-out trouble. The impedance compensator may be wired in backwards or its "A" capacitor may be open or incorrectly adjusted. The trunk drop building-out capacitor may be open or improperly adjusted.

8.08 Poor return losses on trunks with a normal 1000-cycle switch-to-switch loss of less than 2 db may indicate 2 db fixed pad trouble. This may be an open resistor, an omitted pad, or a pad with the wrong impedance option.

(C) Singing Points

8.09 If the singing point is low, it will be helpful if the approximate singing frequency is determined. Poor singing points at frequencies below 200 cycles are not significant because normal built-up toll connections will cut off below 200 cycles while the 2D singing point test set will not. This type of singing frequency could, however, mask a poor singing point at a higher frequency. If singing points below 200 cps are found, a 207G high-pass filter (to add loss to frequencies below 200 cps) should be used in conjunction with the 2D singing point test set.

8.10 If the singing point is in the low-frequency range above 200 cycles, the trouble may be due to an improperly wired coil; if it is poor and is in the middle frequency range, the trouble may be due to a cable loading irregularity; and if it is poor but in the high-frequency range, the trouble may be due to having a wrong value of capacitance in the impedance compensator.

8.11 Low singing points may also be caused by trouble in the equipment in the class 5 office.