

DESIGN OF TOLL CONNECTING TRUNKS
 IN AREAS HAVING 4-WIRE TOLL SWITCHING

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| 3. DEFINITIONS OF LOSSES AND TYPES OF TRUNKS | 3 | 1.03 Toll connecting trunks are in most cases classified as exchange plant rather than toll plant. To facilitate transmission design it is necessary to establish the line of demarcation between toll connecting trunks and inter-toll trunks. |
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| <u>1. GENERAL</u> | | |
| 1.01 This section covers the considerations applying to the design of toll connecting trunks associated with 4-wire switching toll offices. It includes design of the toll connecting trunks required to the 2-wire toll switchboards which are retained after the installation of the 4-wire switching system since | | |

for 2-wire or 4-wire switching. In the former the connecting trunks terminate at the outward, inward or tandem toll switchboard, and in the latter case the CLR trunks similarly terminate at the switchboards and the toll switching and other trunks having permanently associated hybrids - are considered to terminate at the 2-wire side of such hybrids.

1.06 Although the loss of "S" is considered part of the intertoll trunk its physical location as part of the toll connecting trunk is discussed in Part 2. The arrangements for "S" at a 4-wire switching point from an intertoll point of view are covered in AB23.025.4 and the derivation of "S" is covered in AB23.025.6.

1.07 The losses that lie on the local side of the terminal net loss point on a toll connection are considered as toll connecting trunk losses. A limiting objective value is recommended that is low enough to permit exclusion of office or switchboard losses to simplify the design and maintenance practices. Another reason for omitting the outward operator loss is that eventual use of AMA or CAMA will remove it from a large number of calls.

1.08 The information in this section endeavors to cover many typical situations that may be encountered in toll connecting trunk design influenced by a 4-wire toll switching office. The general philosophy used in the transmission design of the cases described should lead to the proper appraisal of new and different transmission design problems as they arise. Coordination of traffic and transmission design on initial conception of the project, followed by a study of the traffic order as written and subsequent check of any changes in routings contemplated, will be of great help in keeping the transmission design problem well in hand.

1.09 Alternate routing provided on intertoll calls by the general toll switching plan with liberally engineered final groups leaves a heavy burden of service responsibility on the toll completing trunks. In recognition of this, such groups of trunks are liberally engineered as to number. However, contingencies such as cable failures should be considered as they make the provision of groups in separate cables even more desirable than on local and tandem trunk groups.

2. RELATION OF "S" TO CONNECTING TRUNK

2.01 For discussion and illustrative sketches of "S" from a toll point of view refer to AB23.025.4 and for its derivation refer to

AB23.025.6. The following Figs. 1 and 2 and paragraphs show the relation of "S" to the toll connecting trunk from the via net loss point of the toll circuit at the 4-wire switches.

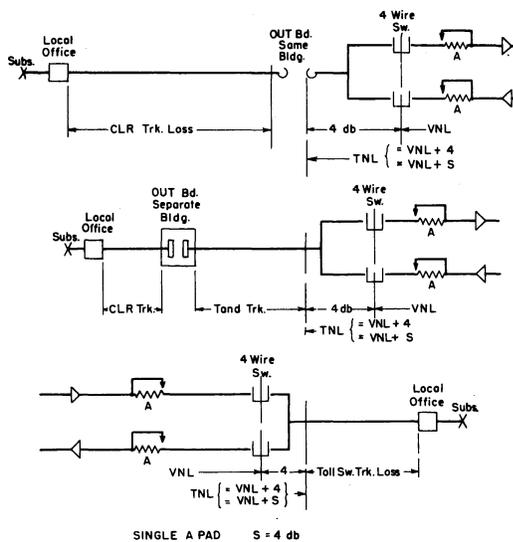


Fig. 1

2.02 Figs. 1 and 2 show the terminating arrangement for intertoll circuits at the No. 4 switching system respectively for the single A pad and the split A pad. Design of

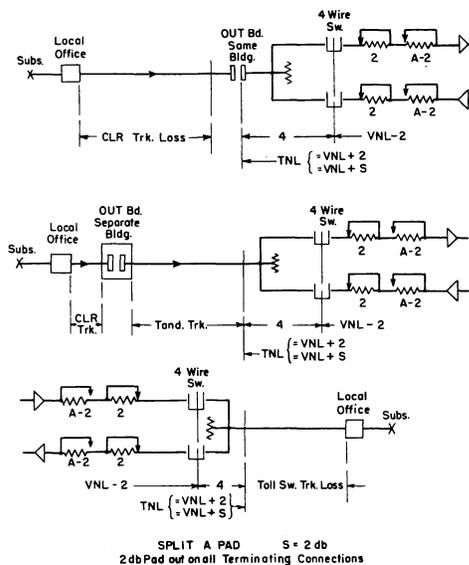


Fig. 2

toll connecting plant in this section will assume the split pad. Earlier installations equipped with single A pad generally will be modified to provide split pad operation. In some few cases it may be practicable at existing installations to continue the single pad but to make adjustment on the connecting trunk side of the hybrid in order to get the equivalent of split pad operation. In the latter case the entire A pad would drop out on all connections. (See Part 10.)

2.03 By definition the loss of "S" is part of the intertoll loss while actually it is all (4 db) or part (2 db) of the loss of the hybrid coil required for any connection between the 4-wire switches and the two wire plant.

3. DEFINITIONS OF LOSSES AND TYPES OF TRUNKS

3.01 The term "toll connecting loss" as used in this section means the loss of the trunk conductors extending between the local office and the 4-wire switching office. The loss of the outward switchboard and office losses are omitted on originating, delayed or TX traffic. The loss of an intervening tandem office, if used for the inward direction of traffic is also omitted. The loss of the hybrid in all cases where used is omitted regardless of the direction of traffic.

3.02 In the design of these trunks it is desirable that the facility loss be kept as low as practical, and preferably within a limiting value of 4 db. This does not mean that all losses be built out to the selected limiting value, nor that inordinate costs be applied to reduce small excesses in particular individual cases. This type of design is classified as low loss design. For the illustrations in this section a value of 4 db has been used as the limiting design value.

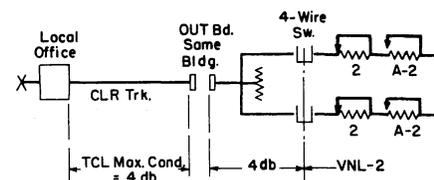
3.03 A high loss toll connecting trunk is one designed in excess of the 4 db low loss limiting value utilizing the gain derived from the A pad omission in the intertoll circuit to offset the excess loss. The gain available for this purpose is A-2 db, consequently the range of connecting trunk losses permissible for operation on a high loss basis will vary from (A-2) db to (A-2) + 4 db. Trunks with conductor losses less than (A-2) db also may be operated on a high loss basis by building them out to A-2 db by use of pads available in the hybrid coils for this purpose.

3.04 The following sketches of the different types of 2-wire connecting trunks are as-

sembled to clarify the above definitions and to show conductor transmission objectives not to be exceeded. Sketches of 4-wire trunks along with their description are included under Part 11 for simplification due to their narrower field of use. The sketches are separated into divisions of outward or originated traffic including delayed or TX calls and inward or completing traffic. The direction of origination is shown as from left to right.

Trunks Used for Outward Calls

3.05 To connect to a 4-wire dial intertoll trunk from a switchboard in the same building with the No. 4 office. (Low Loss) Fig. 3



Conventions Applying to All Sketches:

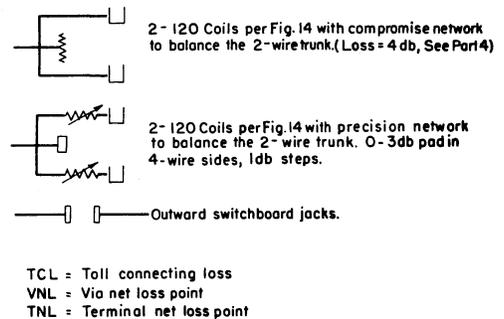


Fig. 3

3.06 To connect to a ringdown intertoll trunk through the 4-wire switches by means of a tandem trunk at OUT switchboard and the ringdown applique on the 4-wire switches. (Low Loss) Fig. 4

The A-4 pad drops out on a connection through the 4-wire switches leaving a net "S" value of approximately 2 db or the loss incurred through two opposed hybrids. On a connection from CLR trunk to the RD intertoll circuit through the switchboard multiple appearance of the RD circuit a normal "S" pad will be in the circuit.

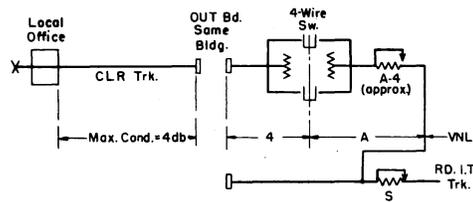


Fig. 4

3.07 To connect to a 4-wire dial intertoll trunk from a switchboard in a different building from the No. 4 office. (Low Loss) Fig. 5

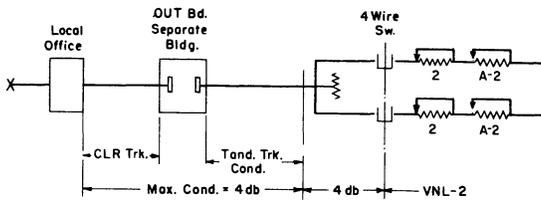


Fig. 5

A connection can be made through the 4-wire switches from a switchboard in a different building to a ringdown intertoll circuit in the same manner as shown in Fig. 4 with the same loss allocations from the local office to the 4-wire switches. On a direct connection to the RD IT trunk through a switchboard multiple appearance a tandem trunk from the switchboard in the distant building shown above to a manual tandem board in the building containing the switchboard termination of the ringdown intertoll circuit would be necessary.

3.08 To connect with a 4-wire dial intertoll trunk through a board in a distant building where high loss operation is used. Fig. 6

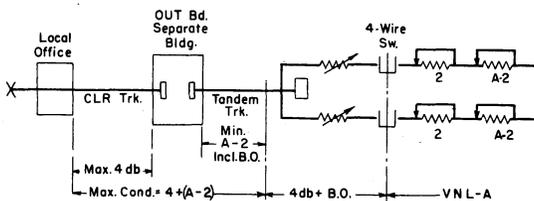


Fig. 6

This trunk is used only to connect to 4-wire dial intertoll trunks. It should not be used on account of transmission impairment with ringdown

intertoll trunks or with tributary, toll switching and TX trunks either high or low loss.

Tandem trunk conductors in db plus the transmission pad build-out in the hybrid must at least equal $A-2$ db.

If return losses will not permit this much gain, see Part 7(B), extra build-out will be necessary reducing the CLR trunk allocation of loss from 4 db by the amount of the extra build-out.

If the tandem trunk is longer than $(A-2)$ db the CLR trunk conductor maximum will be reduced by the excess over $A-2$ db.

If there are no local offices beyond the building in which the outward switchboard is located the tandem trunk can be a maximum of $(A-2) + 4$ db.

3.09 An adaptation of an intertoll pad circuit for an outward tandem trunk use is shown in Fig. 7. This might have a use where repeaters are available in the 4-wire office and the necessary simplex or composite signaling will be justified. It permits unrestricted use of the tandem trunks connected through the 4-wire switch to a ringdown applique or to a high loss toll connecting trunk.

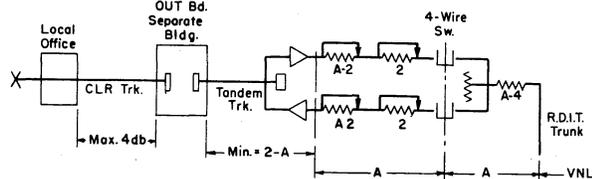


Fig. 7

Gain of repeater = $A + 2 + X$ where X is the db gain desired to reduce loss of the tandem trunk facility.

"A" pad is omitted on switch to ringdown trunk as shown. Also on a switch to a high loss connecting trunk. A-2 pad left in on a switch to a low loss connecting trunk and "A" pad left in on a switch to a 4-wire dial intertoll trunk.

TX Trunks

3.10 The use of high loss or low loss design for TX trunks from the 4-wire switches to the ticket operator handling delayed outward calls is dependent on the type of switchboard used by traffic for handling circuit requests. Where the No. 5 toll switchboard (4-wire switchboard) is used the TX trunks from the 4-wire switches may be high loss without restriction if some economies are indicated over low loss design.

However, where the No. 5-type of operation (handling circuit requests) is performed at a 2-wire switchboard, such as the No. 3 CL, and the No. 5 operator does not have a complete complement of low loss TX trunks in the switchboard multiple, but must go through the 4-wire switches, the TX trunks must be low loss and even then a penalty of (A-4) db will be encountered on the connection. This arises from the use by the operator of the through type tandem trunk which is built out to A db. Modification of the through type tandem trunk to arrange the build-out pad on relay contacts similar to that now employed with the 4-wire applique for ringdown intertoll trunks (Fig. 4) will effectively eliminate this penalty.

Where the No. 5 operator at a 2-wire switchboard has a complete complement of low loss toll switching trunks in the switchboard multiple, there will be no necessity to go through the No. 4 switches, and the TX trunks from those switches for incoming requests for TX from distant dial points may be of high loss design if economies are indicated.

A group of toll switching trunks will be required to handle delayed completion calls to local offices from the multiple in the outward board. These may be for same grade of transmission as the CLR trunks shown in Figs. 5 and 6.

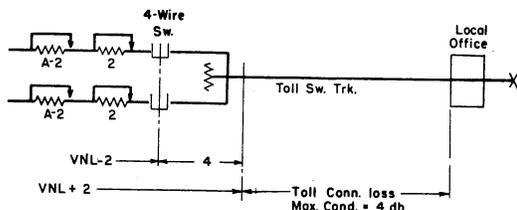


Fig. 8

Trunks Used for Inward Calls

3.11 Toll switching trunk (low loss). Fig. 8

3.12 Toll switching trunk (high loss). Fig. 9

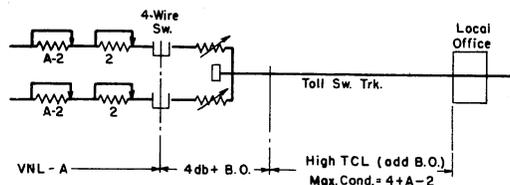


Fig. 9

High toll connecting conductor loss can vary from a low of (A-5) db to a high of (A-2) db + 4 db.

3.13 Completion via local crossbar tandem in same building with the No. 4 office. Fig. 10

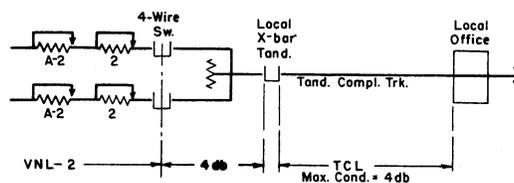


Fig. 10

3.14 Completion via local crossbar tandem of office not in same building as the No. 4 office. Fig. 11

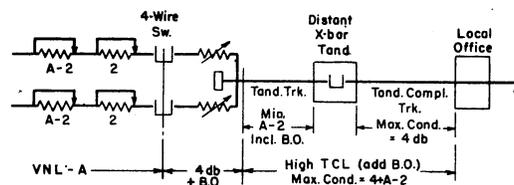


Fig. 11

The conductor loss between the No. 4 office and the distant crossbar tandem plus the B.O. must at least equal A-2 db. If return losses will not permit this much gain to be taken on a 2-wire basis, it will be necessary to resort to 4-wire operation per Part 11.

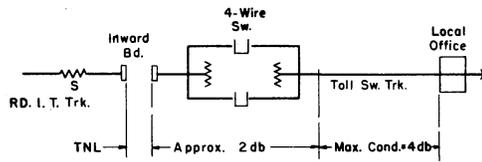


Fig. 12

3.15 Completion via outgoing trunk circuit to SxS intertoll selectors in same building. This circuit is arranged for connection to either a toll or a toll connecting trunk through the SxS switch. Fig. 12

When an intertoll circuit is selected the 2 db S pad is switched out bringing via net loss to the SxS selectors. When a connecting trunk is selected the 2 db pad is left in, giving terminal net loss at the SxS selectors, however, it may be arranged to drop the S pad on long tributary trunks.

Fig. 12 applies where both IT and TC trunks are reached by the same trunk. S pad is omitted where only IT trunks are reached. Low loss operation is used and all padding is omitted where TC trunks only are reached.

3.16 Completion from ringdown intertoll trunks.

Such connections can be handled either through a direct toll switching trunk from the IN switchboard multiple or from that point to a crossbar tandem in the same building, with a penalty of about 1 db. A third means of connection through the 4-wire switches is shown in Fig. 13.

A through type trunk from the IN board to the switches may be used in a similar manner to the terminal type shown in Fig. 13. The excess to the toll connecting losses is listed below for

the various arrangements assuming a 7 db A pad. Such uses should be avoided.

- Terminal type to Low loss trunk - 2 db excess
- Terminal type to High loss trunk - 7 db excess
- Through type to Low loss trunk - 3 db excess
- Through type to High loss trunk - 8 db excess

4. HYBRID COILS

4.01 As hybrid coils in the toll connecting plant are usually considered a part of the intertoll loss a value should be fixed to cover the amount in db. The following is a summary of the losses.

| | |
|-------------------------|---------------|
| Loss in 4-wire switches | 0.3 db |
| Efficiency loss of coil | 0.4 db |
| Other office losses | 0.1 db |
| Hybrid loss | <u>3.0 db</u> |
| | 3.8 db |

The outward switchboard multiple may have a loss of slightly more than .2 of a db in addition to that shown above. Therefore, considering both inward and outward losses, an average value of 4 db has been chosen with but slight inaccuracy to either.

4.02 Fig. 14 shows a diagram of a typical arrangement of two No. 120 coils used to make up a hybrid along with various transmission variables.

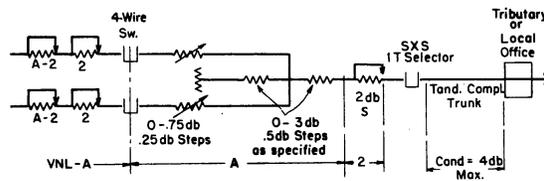


Fig. 13

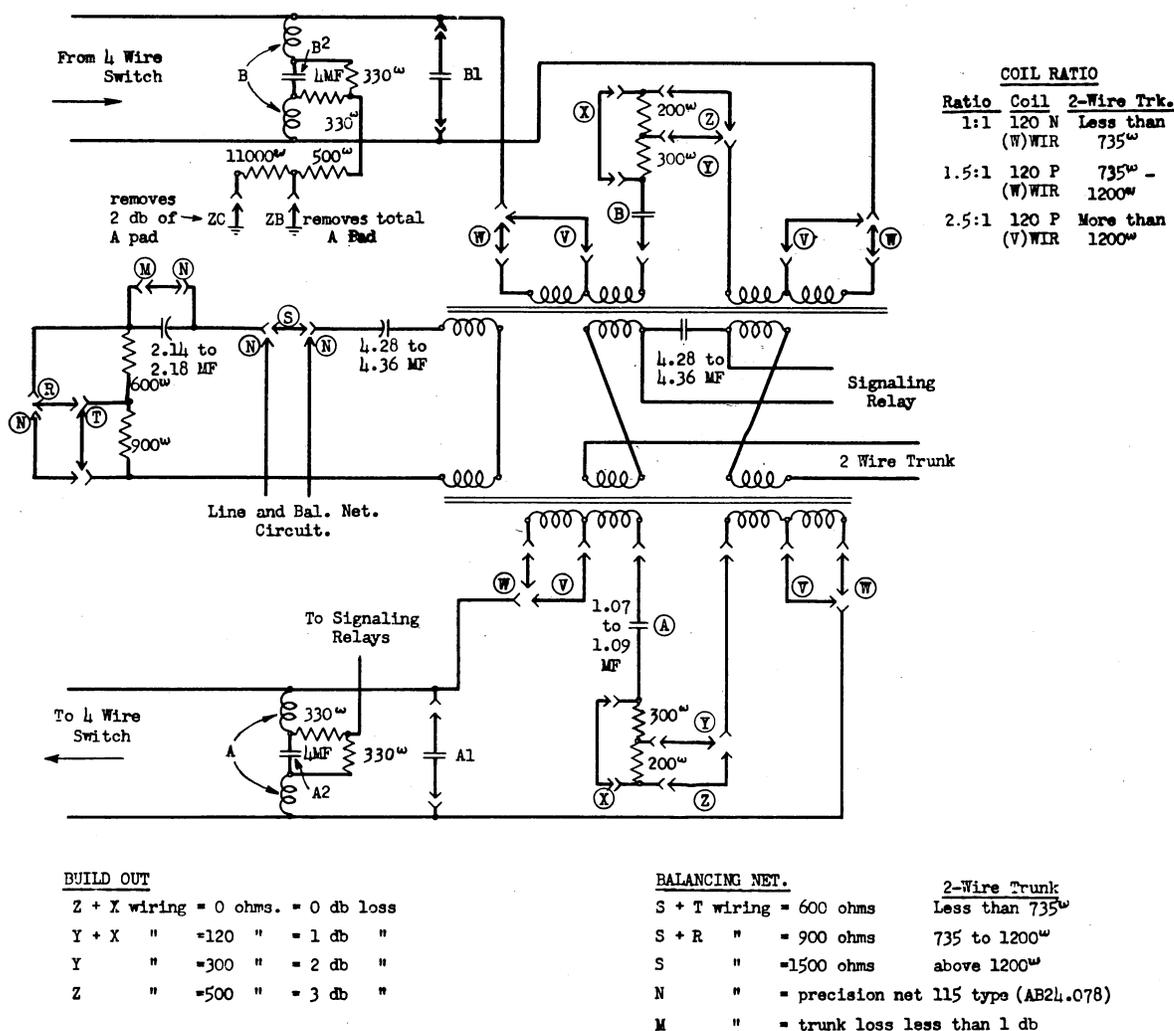


Fig. 14

4.03 The following transmission options are provided and must be specified for every trunk.

- Coil ratio.
- Balancing network.
- Series resistance build-out
- Low cutoff condensers.
- Simplex control for pad operation and signaling.

4.04 Coil Ratio: Normally only 120-P coils are provided since in metropolitan area plant to which these coils are connected only H88 or

higher impedance loading systems are encountered. The proper coil ratio must be specified for each case.

4.05 Balancing Network: With a low loss trunk the compromise networks furnished with the circuit are used. The selection of 600, 900 or 1500 is determined by the order of impedance of the 2-wire trunk to which it is connected. If it can be administered from an assignment standpoint, some small advantage can be obtained in return loss by strapping out the 2 mf condensers (M wiring) associated with the compromise network on trunks less than 1 db.

4.06 For high loss operation, the condenser and resistances of the compromise network are

strapped out and an external precision network of the proper type is connected into the circuit as indicated by N wiring. The precision network will be of the 113 or 115 series corresponding to the type of 2-wire trunk facility to be balanced.

4.07 Series Resistance Building Out: In order to provide limited transmission flexibility with a fixed A pad, the midpoint of each side of the hybrid coil is provided with a series resistance which can be adjusted to provide losses of 0, 1, 2 or 3 db. With low loss operation, the 0 db strapping must be specified.

4.08 With high loss operation the magnitude of the loss to be inserted in the series B.O. is dependent on the magnitude of the A pad and the length and return loss of each individual trunk, as shown in Part 3. Assuming adequate return losses the series pad is used to limit the gain from the A pad so that A-2 never exceeds the sum of the trunk loss plus the series pad. For example, if A pad is 7 and the trunk has a loss of 4 db, the series build-out would be 1 db or $7-2 = 4 + 1$. Where the trunk loss is A-2 db or greater the pad would be 0 db unless the return loss of the trunk was not adequate to support such a gain from the echo standpoint. In such cases the pad value would be increased thereby reducing the gain until the echo return loss requirements were satisfied. Each db change in the pad would be a 2 db credit against the echo requirements.

4.09 In using series build-outs in the 4-wire sides of the hybrids as discussed above an impedance mismatch is created. For example, a 3 db build-out consists of 500 ohms which is in series with the 600 4-wire branch so that 1100 ohms is presented to the repeating coil instead of 600 ohms. The loss values include this reflection loss due to the mismatch.

4.10 Capacitors for Low Cutoff Facilities: On the 4-wire branches in Fig. 14 are capacitors B1 and A1. Each is composed of two units .075 and .125 mf. For all low loss operation and for high loss operation involving trunk facilities with cutoff equivalent to H-88 facilities or higher, these capacitors are not connected. However, for high loss operation with trunk facilities with cutoff lower than H-88 loading, they are required to attenuate the high frequencies thus minimizing singing in the cutoff range.

4.11 Simplex Control for Pad Operation and Signaling: On the upper or inward direction of transmission of the 4-wire branch of Fig. 14 is a retard coil B and capacitor B2 combined into a simplex arrangement for controlling the

A pad in the intertoll circuit. Wiring ZC as shown removes 2 db of the A pad, wiring ZB removes the entire A pad. A dual function of the retard coils and capacitors is to provide a low frequency shunt thus improving circuit balance in that range. A similar retard coil A and capacitor A2 are provided in the lower 4-wire branch of the circuit. It performs the same low frequency shunt function as above, its simplex arrangement being used for supervision purposes.

5. LOW LOSS VS. HIGH LOSS DESIGN

5.01 Low loss plant (low toll connecting loss) is designed to meet the nominal toll connecting loss without the benefit of any gain provided by the omission of the A-2 pads in the 4-wire toll switching system. High loss plant (high toll connecting loss) may be designed to a higher value than the nominal value by an amount equal to the gain provided by the omission of the A-2 switching pads associated with the intertoll trunks.

The applications of the two types of design among the various types of toll connecting trunks are covered below. The effect of the introduction of AMA and CAMA on outward toll connecting trunks is also discussed.

(A) Low Loss Design Required

- (1) Recording-completing trunks to toll switchboards in the same building with the No. 4 office (Fig. 3).
- (2) Toll switching trunks from outward toll switchboard in the same building with the No. 4 office for completing delayed outward calls (Paragraph 3.10).
- (3) Toll tandem trunks from outward boards to 4-wire switches which may also select ringdown intertoll trunks on the 4-wire switching multiple (Figs. 4 and 5).
- (4) Toll switching trunk groups from the 4-wire switches which may be used for
 - (a) Completing either tributary or local office traffic from any outward board within the toll center area.
 - (b) Completing from incoming ringdown trunks via a through type or terminal type tandem trunk from the IN operator to the 4-wire switches (Fig. 13).
- (5) TX trunks (see Paragraph 3.10).

(B) High Loss Design Permitted

- (1) Toll tandem trunks from a toll switchboard in a different building from the No. 4 office to the 4-wire switches when ringdown inter-toll trunks are not available for selection (Fig. 6).
- (2) Toll switching trunks from the 4-wire switches to local offices.
- (3) Toll completing trunks to crossbar tandem when not used for completing from incoming ringdown intertoll trunks (Fig. 11).
- (4) TX trunks to outward toll boards located in a different building than the 4-wire office. (Same as tandem trunk in Fig. 6, see exceptions Paragraph 3.10.)

5.02 The application of high loss design is further restricted by minimum attenuation and return loss requirements. This is discussed below under high loss trunks.

(C) Effect of AMA and CAMA

5.03 Introduction of Automatic Message Accounting (AMA) or Centralized Automatic Message Accounting (CAMA) appears at this time to have no effect on the design possibilities for toll switching trunks as outlined in this section. However, the introduction of this type of operation may change design possibilities for the connecting trunks handling the originating toll calls from the subscriber to the 4-wire toll switching office. Some of these conditions are discussed below.

5.04 AMA operation uses automatic recording equipment located at and associated with a particular local office. This plan may permit high loss design of the direct trunks from the local AMA office into the No. 4 switches on exactly the same basis as toll switching trunks to the same building.

5.05 With CAMA operation, the equipment and identifying operator are centralized with respect to several local offices which they serve. This may be at a crossbar tandem situated in the same building or in one adjacent to the No. 4 office; or it may be in a building remote from the 4-wire office. In the former case the originating connecting trunk plant involved must be designed on a straight low loss basis similar to the condition where the OUT TOLL board is adjacent to the No. 4 office.

5.06 Where the CAMA equipment is associated with a crossbar tandem in a building remote from the No. 4 office, the trunks from the CAMA to the No. 4 office may be considered for high loss de-

sign on the same basis as those from an outward toll board in a building distant from the 4-wire switches.

5.07 In some instances of CAMA operation, plans for handling traffic may call for the equivalent of through intertoll switching over trunks to the No. 4 office. If this is contemplated, adequate transmission and signaling performance over such routes will require an equivalent intertoll trunk design for such facilities. Either of the following two layouts will apply.

- (1) CAMA located adjacent to or in near vicinity of the No. 4 office - arrange trunk as through type intertoll tandem trunk currently used in No. 4 switching (per AB23.025.4) and insure adequate drop balances at the CAMA.
- (2) CAMA located remote from No. 4 office; design trunk as standard intertoll trunk with repeater at CAMA end for adequate drop balance and use standard intertoll trunk circuit with amplifiers and A pads at 4-wire switching end. This is the only approach that will guarantee transmission and full switching flexibility for any initial and ultimate routing plans.

6. DESIGN OF LOW LOSS TRUNKS

6.01 Low loss design corresponds to that in effect with 2-wire switching in the toll connecting plant and involves no change in the basic design considerations. Where low loss operation is indicated today for trunk groups which ultimately might be candidates for high loss operation, consideration should be given the use of repeater and fine gauge cable to meet the low loss requirements and at the same time anticipate the copper economies available with high loss operation. Also, the use of cable carrier should be considered for ultimate application of permanent low loss trunk groups where transmission design is tight even with coarse gauge conductors and repeaters.

6.02 With improvements in transmission tools such as repeaters and carriers, the resistance ranges on trunks may become limiting. Any possible extension of such ranges should be investigated. The same will be the case in high loss design.

7. DESIGN OF 2-WIRE HIGH LOSS TRUNKS

(A) A Pad Determination

7.01 Since some gain is available in the inter-toll trunks due to A pad usage in intertoll switching, it can also be taken advantage of to lower toll connecting trunk losses. 2 db of the

A pad has been used to reduce the equivalent S value of the hybrid coil from 4 db to 2 db as discussed in Part 2 leaving A-2 available as gain to offset part of the connecting trunk loss.

7.02 It is necessary to choose some value for A in advance and, therefore, a selection should be made that will permit the use of the most economical grade of plant. In many of the larger areas an A value of 7, the maximum, would be the choice as the A-2 value of 5 db can easily be used for savings in connecting trunks. There are several factors that might influence the choice of a smaller value of A such as:

- (1) The output level of the toll office.
- (2) The resistance limit of toll connecting trunks subject to high loss design.
- (3) The maximum usable gain on immediately proposed or possible future high loss trunks.

7.03 The output level of the No. 4 office as a toll office will in some cases limit the value of A (see AB23.025.4). For example, if the output level is +7 db an A value of 7 can be selected; however, if the output level is +4 a lesser A value may be required. Should the economies resulting from the use of 7 db against a lesser value be large it may be desirable to change the output level of the office from +4 to +7 db.

7.04 An analysis of the connecting trunk candidates for high loss use may indicate that the resistance limit of the trunk, usually limited by pulsing, will hold down the high loss gain that can be utilized. In such cases the cost of extending the signaling range may be less than the savings in outside plant realized. Another factor is that future development will probably have a trend toward extended signaling ranges. Therefore, before limiting the A pad on signaling alone careful consideration should be given any possible future savings.

7.05 Analysis of connecting trunks for the maximum usable gain may indicate that the A value can be less than 7 db. With the build-

out possibilities in the sides of the hybrid (see Part 4) and reasonably high return losses in the two wire trunks, a value of 7 db will give high loss connecting trunks a transmission range of from 2 to 9 db. However, build-out provided in the hybrid coil must be specified for each trunk on assignment on all high loss trunks of less than 5 db. If a lesser value of A is chosen some saving in administration of the proper build-outs may be gained.

7.06 The groups adaptable to high loss design are determined from comparison with those described in Part 3. Each of these groups can be analyzed for the benefits derived such as transmission improvement and gauge reduction. The attached heading of an analysis sheet (Fig. 15) is offered to cover the items to be considered on each trunk group considered for high loss operation.

7.07 Having thus determined the theoretical benefits of high loss design to individual groups the theoretical over-all copper saving can be determined. Generally the substitution of finer gauge will result in savings. The substitution of 22, 24 or 26 gauges for 19 will be most advantageous, while the substitution of 24 or 26 gauges for 22 will give lesser savings. Against such copper savings should be charged the cost of the precision network needed in the hybrid to balance the trunk.

7.08 The summarization of all groups subject to high loss design by their various trunk routes may have an important influence on immediate relief projects. On routes where ample heavy gauge is available for low loss design of connecting trunks, the application of high loss design may permit allocating of heavy gauge for long interlocal trunks or tandem trunks thus saving the use of repeaters on such trunks. Where a relief project is proposed, high loss will generally permit savings through the use of finer gauge on the entire relief cable. In cases where there is a shortage of heavy gauge conductors and ample fine gauge, the use of high loss design may result in a saving of repeaters or placing more heavy gauge.

| TOLL SW. OR TX TRUNK GROUP | INCOMING OFFICE | | LOW LOSS DESIGN | | | HIGH LOSS DESIGN | | | REMARKS |
|----------------------------|-----------------|------------|-----------------|------------|----|------------------|----|---------------|---------|
| | TYPE | INC.SUPV.ω | LENGTH K F | FACILITIES | db | FACILITIES | db | GAIN REQUIRED | |
| | | | | | | | | | |

Fig. 15

(B) Net Gain on High Loss Trunks

7.09 On high loss trunk design due to the introduction of gain by the switching out of the A pad a higher degree of hybrid balance is necessary. To accomplish this an appropriate precision network is used in the hybrid instead of the compromise network.

7.10 Much of the existing loading is spaced on former limits which in some cases were exceeded, resulting in low structural return loss.

Limits

| | <u>Old</u> | <u>New</u> |
|---------------------------------|------------|------------|
| Variation of ave. from standard | 3% | 2% |
| " " individual from ave. | 5% | 3% |

If loading is spaced on the new limits (see AB22.125) on cable of reasonably uniform capacitance throughout, high structural return losses

should result. With such return losses gains within the range of the A-2 pads can usually be realized in high loss design. A family of curves shown in Fig. 16 indicates the gain that may be taken against various structural return losses. However, such values obtained by assumption or calculation should be verified by test as soon as possible after the cable is available for test. Calculations of return losses for existing or proposed load spacing systems can be made and if results fall short of requirements for gain desired, remedial measures should be included as part of the project.

7.11 Part 8 discusses balance considerations on connecting trunks and the derivation and use of the family of curves indicating the gain that can be taken. It also gives a method of calculating the theoretical structural return-loss of a loaded facility from the plant layout.

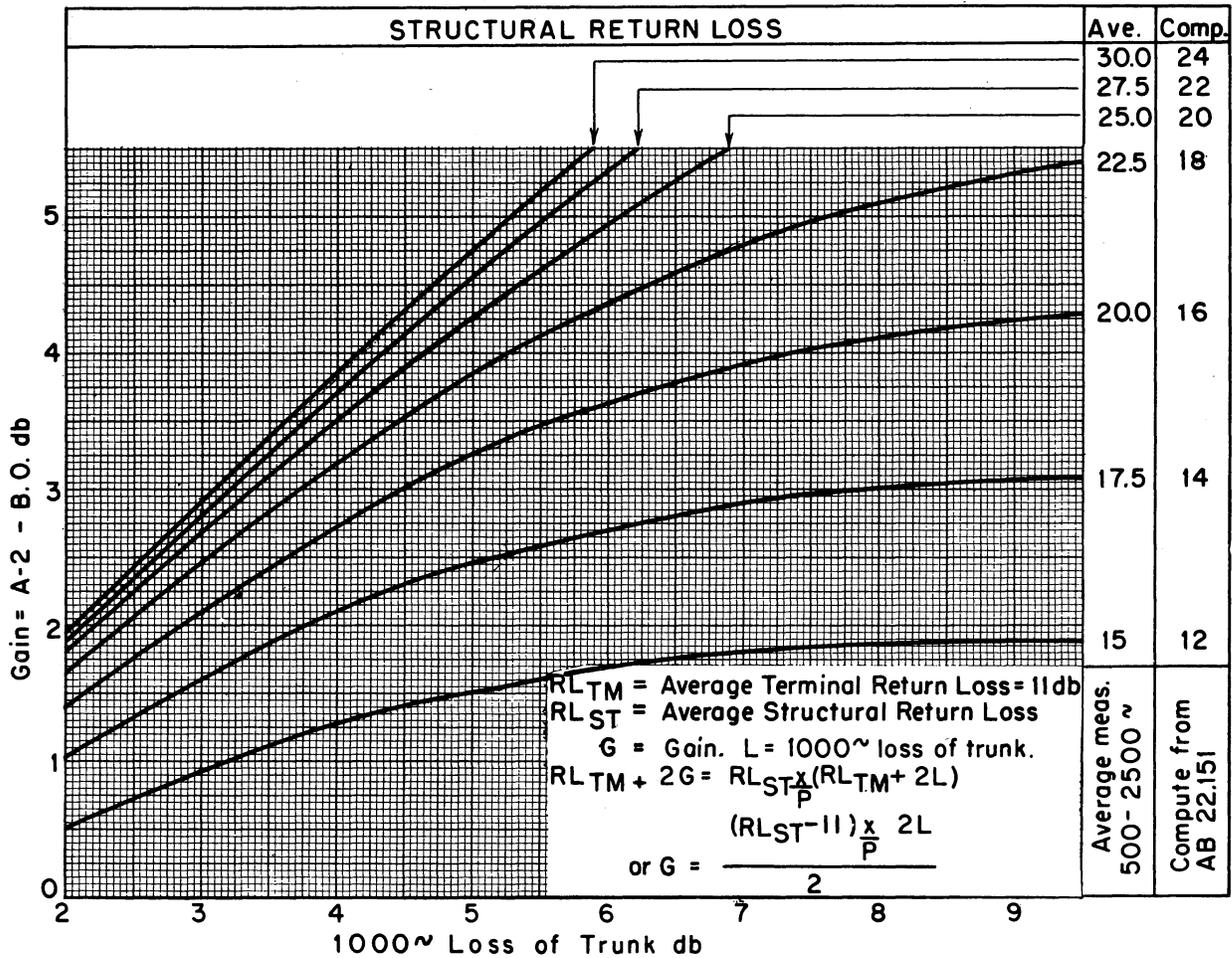


Fig. 16

7.12 Appendix A shows a method of measurement for structural return loss of loaded trunk conductors. It includes an explanation of the tie in of such measurements to theoretical calculations recognizing variations from the average. It also indicates a method of establishing a bogey for measurements of the trunks when connected to the standard balance and noise test line.

8. RETURN LOSS

(A) Balance Considerations on Connecting Trunks

8.01 The return loss characteristic of exchange plant including connecting trunks is of vital importance in setting the lowest practicable loss at which intertoll trunks can be operated from the standpoint of talker echo. This is covered in detail in AB23.025.6.

- (1) A talker at A in Fig. 17 will be tolerant of the echo he hears as his own voice travels to B and is partly returned to him through the distant hybrid - provided the sound of his returned voice is not too loud for the particular time interval of round trip delay.

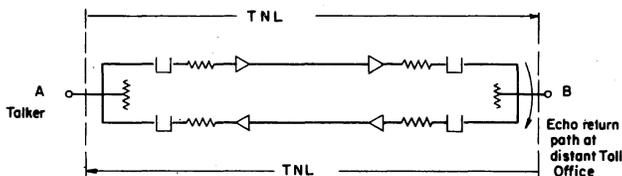


Fig. 17

- (2) It is assumed in the intertoll trunk design practices that return losses in the echo frequency range, as seen looking into the exchange plant, will approximate a normal probability distribution with an average of 11 db and a standard deviation of 3 db; that is, considering all loop and connecting trunk conditions 68 per cent lie between 8 and 14 db and 96 per cent lie between 5 and 17 db. This should not be confused with the singing requirements which are 6 db with a standard deviation of 2 db.

8.02 With high loss operation some of the loss in the 4-wire circuit of Fig. 17 is switched out by removal of A pads. In order to preserve the round trip loss of the echo path, the return loss across the hybrid or the hybrid balance associated with the high loss connecting trunks must be correspondingly increased. This requires that the average of the exchange plant return losses as seen from the 2-wire side of the hybrid be increased from the values assumed in the preceding paragraph by twice the gain taken from the intertoll trunk by pad removal.

(B) Structural Return Loss

8.03 Return losses presented by the exchange plant at the 2-wire side of the hybrid are (1) the variety of return losses of the subscriber loops where no trunk is involved or (2) the power summation of the structural return loss of the trunk and the terminal return loss to which the trunk connects. Given the connecting trunk loss and the gain that is to be taken by pad removals in the intertoll trunk it is possible to arrive at the required structural return loss. The terminal return loss is a necessary factor, but no method for improving the return loss of loops is contemplated. In Fig. 16 a family of curves has been plotted showing the permissible gain that can be utilized by A-2 pad removal in the intertoll trunk less hybrid build-out, in terms of the structural return loss of a connecting trunk facility and its loss in db.

8.04 An average value of terminal return losses was used in preparation of the curves along with an average value for the structural return losses. This means that actual measurements would fall both above and below the averages. Terminal return losses are assumed to have a standard deviation from average of approximately 3 db and structural return losses usually have a somewhat larger standard deviation. For example, with structural return losses having an average of 30 db a standard deviation of 6 db is common. This means that 68% of the structural return losses at all frequencies between 500 and 2500 cycles would lie between 24 and 36 db and 96% between 18 and 42 db.

8.05 Means are available for calculating the structural return loss that can be expected by reference to the trunk loading layouts as they are shown in the plant records. AB23.016 provides a method for theoretical calculations and AB22.151 gives tabular information that is based on AB23.016 and serves as a simplified means of gaining the same answer. The structural return loss derived from the above practices is, however, not the average loss but the 63% at critical frequency value (assumed to be .7 of cutoff).

8.06 As a result of limited experience it appears that the measured structural return losses over the echo range (500-2500 cycles) are often better than calculations at a critical frequency would indicate. This is particularly true on 24-gauge H-88 facilities and to a lesser degree on 22 gauge. As a result of this experience it is suggested that the engineer lean toward the use of slightly higher gains for such complements than load spacing irregularities indicate. Later verification of such judgment can be gained by sampling tests per Appendix A.

8.07 In order to provide an approximate method of utilizing the theoretical calculations with the curve in Fig. 16 a cross reference of measured average and computed theoretical values is shown on the curve. If the loaded count for example is 22-gauge H-88 and has a reference deviation of 4% as found from the plant records and Fig. 7 in AB22.151, the 63% structural return loss is 21 db per Table A in the same practice. This means that an average measured structural of at least 26 db can be counted on and gains as shown can be realized by removal of the A-2 pad. Interpolation between the 25 and 27.5 curves on Fig. 16 indicate that were the trunk 1000 cycle loss 6 db a gain of 5 db could be taken.

8.08 The curves in Fig. 16 will assist the engineer to judge the gain that can be taken if he knows the return loss of the trunk either from measurement, calculation or assumption. The curves are a guide and are more accurate as the length of trunk increases. On the shorter lengths particularly, as the gains increase the curves never reach the point where gains and trunk loss are equal. However, where the average return loss is 30 db or above, it can be assumed that it is for all practical purposes little worse than perfect. In a combination of structural return loss and terminal return loss at the end of a short trunk, the structural as high as 30 db would have so little effect on talker echo as to be insignificant. Therefore, it would be reasonable to expect that gains equal to trunk loss could be taken where the average structural return loss was in the order of 30 db.

9. HIGH LOSS DESIGN (CONCENTRATOR TRUNKS)

9.01 Concentrator trunks have many of the earmarks of the No. 4 office toll connecting

trunks though not connected to it. They are used for outward business only and serve primarily to connect to large terminal intertoll groups to distant cities. A typical unit is 100 toll connecting trunks from various offices having access through concentrator switches to 40 intertoll trunks to either a distant crossbar tandem or No. 4 office. The trunks are 2-wire from the local office to the concentrator office where they become 4-wire by means of a hybrid. On the 4-wire side of the coils there is a fixed pad of either 0 db or 4 db plus a 3 db variable pad in steps of 1 db, the latter being the same as shown in Fig. 14. By this arrangement padding of from 0 to 7 db is possible in 1 db steps (see Fig. 18).

9.02 The intertoll circuits are lined up similarly to those terminating in the 4A machine with the exception that the A pad is missing. They, therefore, appear in the 4-wire concentrator switch at a VNL-7 level.

9.03 On zero length trunks 2 db is left out of the 7 db available padding resulting in an equivalent A-2 pad of 5 db remaining and an equivalent S of 2 db, i. e., $VNL-7 + 5$ (pad reduced by 2) + 4 (hybrid loss) = $VNL + 2$. All toll connecting trunks can be served by this arrangement and compromise nets can be used in the hybrid to balance the 2-wire conductor. However, trunks between 2 and 4 db can be reduced to or near 0 db by use of a precision net and strapping out of additional pad loss. Return losses of the trunks should meet requirements of Part 8.

9.04 If the trunk exceeds 4 db, the 4 db pad should be removed and a precision net provided to match the trunk conductor. The return loss of the trunk should be of a satisfactory value as dis-

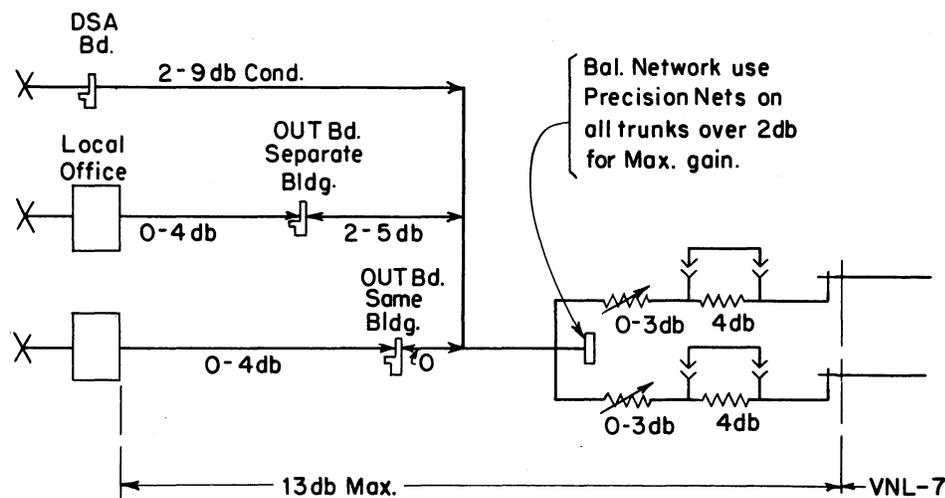


Fig. 18

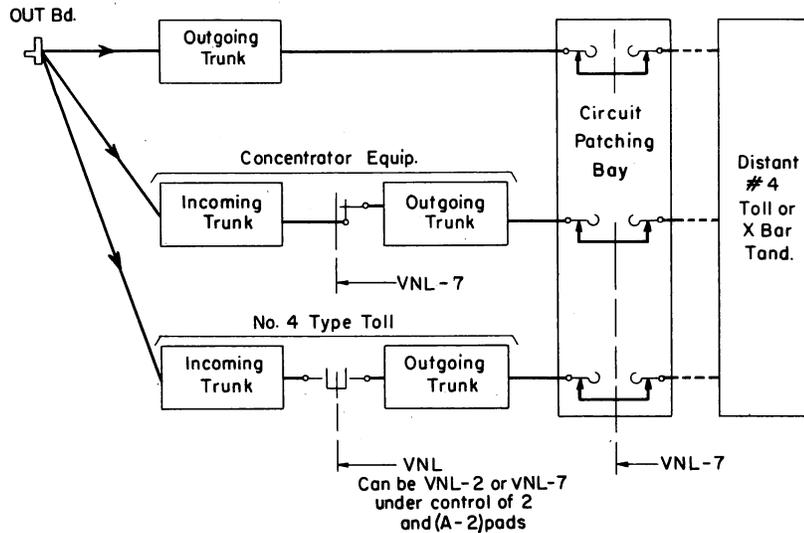


Fig. 19

cussed in Part 8. Where an outward board in an outlying building handles tributaries, the variable pad in the hybrid circuit and the outside conductors from the concentrator office to the outward toll board must add up to at least 5 db to satisfy return loss limits. If they add up to more than 5 db the loss between the switchboard and the local office should be correspondingly reduced from 4 db.

9.05 Outgoing traffic from a switchboard may be routed to an important distant city in as many as 3 ways. The first of these is a direct high usage group where the traffic density justifies it. The second is the concentrator group where a large intertoll group is shared with other switchboards. The third route is through the No. 4 office where intertoll trunks are shared on a final basis in the controlled switching plan. Of the three methods of routing traffic to a distant city the second and third have been discussed but not the first.

9.06 Fig. 19 has the direct trunk at the top and shows a comparison between it and the other types of trunks. The direct group has hybrid coils and 4 db removable pads plus 3 db variable pads in steps of 1 db in the 4-wire sides. It contains compromise or precision nets as required. These and all other transmission features are similar to the concentrator trunks. If the same grade of trunk conductors are used for the direct group and concentrator group the padding can be the same. However, it is not essential that they be so. Assuming the intertoll parts of the three

types to be at a level of VNL -7 db at the circuit patching bay that part of the circuits can be interchanged. Up to a certain point differences in the connecting trunk can be compensated by padding in the direct trunk and concentrator trunk or by A pad removal and B.O. for calls via the No. 4 office. Return loss requirements will be the same as called for in Part 8.

9.07 The return loss test procedure outlined in Appendix A will apply to concentrator trunks and the exchange plant part of direct toll trunks. The same method of return loss sampling tests should be applied. In the event that all three outgoing groups, direct, concentrator and No. 4A are high loss design, sampling can be spread over the counts involved in such a way as to give best assurance that low return loss troubles are spotted well in advance. Service protection afforded by having circuits assigned in different sheaths should be considered with the group through the No. 4A office rated the most important to split as it is the final outgoing route and is suitable to reach all points.

10. S OF 2 DB WITH NON-SPLIT A PAD

10.01 This method may have application in a few No. 4 offices now equipped with the single (non-split) A pad where almost all intertoll trunks have been provided. All new offices and additions to existing No. 4 offices are being equipped with the split A pad. It will cost something to accomplish the equivalent $S = 2$ with the single A pad by the high loss method, i.e., the extra pad-

ding required in trunks along with extra precision networks. The relative economy should be determined for each office. It can only be used in areas where high loss design can be used universally, i.e., no tributary-to-tributary connections through the 4-wire machine and no ringdown trunks applied to the 4-wire multiple to which connection will be made by trunks without A pads.

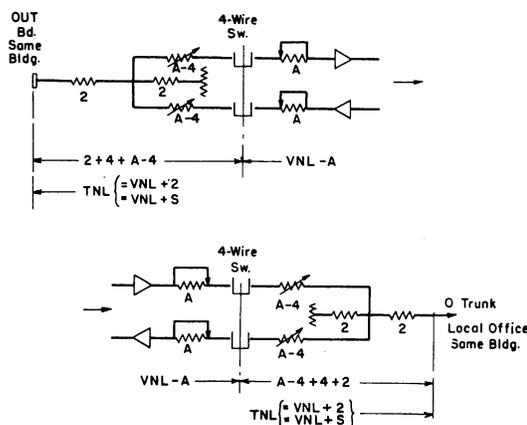


Fig. 20

10.02 The method consists of always omitting the

A pad when switched to connecting trunks including tandem trunks in the same building and padding out trunks less than A-2 to meet the A-2 value. Thus zero length tandem trunks and toll switching trunks would be padded out in accordance with Fig. 20. The 2 db pad is inserted on both tandem and toll switching trunks and the 0 to 3 db pads in the 4-wire sides in the toll switching trunks. Tandem trunks are not equipped with the latter 0 to 3 db pads which will have to be specially provided.

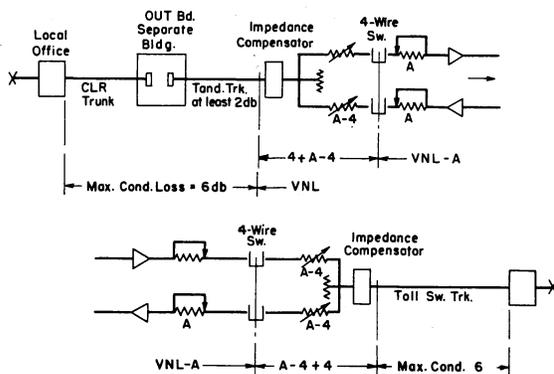


Fig. 21

10.03 Where the local trunk is in excess of 2 db the pad in the 2-wire side would presumably be left out and a precision network be provided to balance the 2-wire line. Figs. 6, 9 and 11 show the arrangement. The gain taken by the removal of A pad less two and minus the B.O. left in the sides of the hybrid will be the net gain taken. Structural return losses of the 2-wire trunk must be adequate to meet this gain per part 8.

10.04 In a few cases an impedance compensator and a compromise net (Fig. 21) can be provided in place of the precision network. This arrangement may be used to take 2 to 3 db of the A pad gain beyond the 2 db allocated to S. The structural return loss of the 2-wire trunk before application of the compensator should be the same as if a precision network were to be used per Part 8.

11. DESIGN OF 4-WIRE HIGH LOSS TRUNKS

11.01 Four-wire trunks connecting to the 4-wire switches are designed on a high loss basis only.

11.02 Terminal type 4-wire toll connecting trunks (Fig. 22) are designed to an over-all 1000-cycle loss of A-2 db, excluding the 4 db hybrid coil circuit allowance.

11.03 Four-wire design has application only where desired transmission allocations cannot be realized by use of 2-wire arrangements. The two principal uses for this design are (1) for the toll tandem trunks from a central OUT toll switchboard to a 4-wire switching office in a different building where the outside plant losses (which increase the loss of this trunk over the definition 4 db) cannot be offset by 2-wire design and (2) for completion of incoming calls from the 4-wire switches via a local crossbar tandem in a different building (Fig. 23) where it is also necessary to offset the additional loss of the outside cable facilities.

11.04 Fig. 23 could be considered as a means of overcoming trunk losses less than 2 db where it is essential to obtain TNL at the switchboard or crossbar-tandem office.

11.05 Generally, 4-wire operation for toll switching trunks and toll tandem trunks from outward toll boards in buildings separate from the No. 4 office is uneconomical as compared to 2-wire high loss operation, since it would involve twice the copper usage plus increased trunk circuit costs.

11.06 The hybrid coil circuit and balancing network on the 4-wire trunks are located at the outlying office rather than at the 4-wire switching center as in the 2-wire case.

SECTION AB22.128.2

11.07 Building-out arrangements provided with 4-wire trunks permit insertion of pad losses of 0-6.75 db by 0.25 db steps. Circuit drawings for these trunks now provide for the building-out pads in the 4-wire sides, located at the 4-wire office. Earlier arrangements provided for these pads in the 2-wire branch partially associated with the hybrid coil circuits. The amount of build-out to be used in each case is the difference between

the A-2 pad value and the 1000-cycle loss of the 4-wire cable pair.

11.08 The cable pairs in the 4-wire legs should be loaded to preserve the nominal toll impedance-frequency and attenuation-frequency relationship, and proper ratio repeating coils should be used.

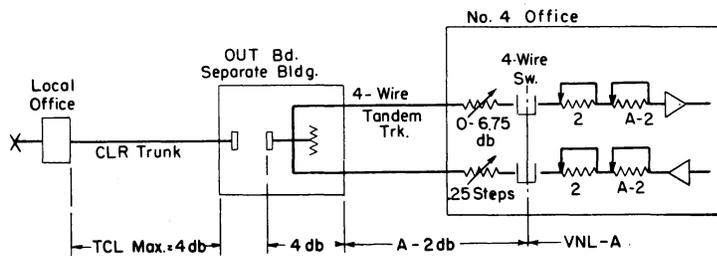


Fig. 22

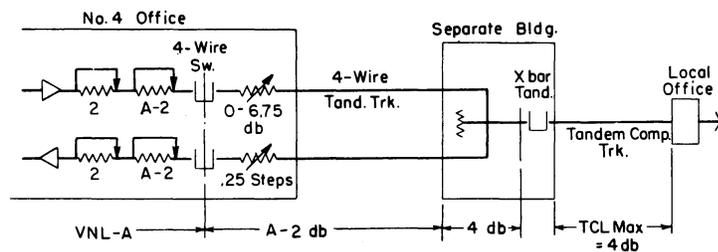


Fig. 23

Attached:

Appendix A - Structural Return Loss Tests

Appendix B - References

STRUCTURAL RETURN LOSS TESTS

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| 3. SERVICE RETURN LOSS TESTS | 5 |
| (A) General | 5 |
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1. GENERAL

1.01 The following method for return loss tests is included for optional use as a means of obtaining return loss measurements on high loss connecting trunks. It was devised by one Company and used with satisfactory results as far as the sampling tests in Part 2. The service tests described in Part 3 is a suggested method and is more in outline form.

1.02 The sampling test is arranged to be completed without the use of any of the 4-wire switching office equipment such as hybrid coils, routine test frames and switches. The test results on a sample should provide a reasonably true picture of the return losses that may be expected on the particular complement from which the sample was chosen. The test is arranged for 24, 22 or 19-gauge conductors with H-88 loading. Application to other types of loading can be made by substitution of the proper types of coil or coil ratios and balancing networks in the built up hybrid arrangement.

1.03 The test equipment and general hook up may be varied considerably and it is suggested that any Company devise its own arrangements. It is the intent of this section to record what one Company used for whatever assistance it may be.

Provision of lists of various optional test equipment and test hookups to cover all conditions is outside the scope of this appendix.

1.04 The service test outline assumes the use of the outgoing toll connecting trunk test frame and the 4-wire switches. In it means are suggested for testing the return loss of the combination of the 2-wire toll connecting trunk and the balancing network when permanently associated through their hybrid coil arrangement. Result are compared against those obtained in the sampling tests.

2. SAMPLING TEST (H-88 TRUNK FACILITY)

(A) Test Equipment

2.01 The following equipment items and test sets were assembled for tests of H-88 trunk facilities.

2.02 Aparatus:

- 2 - 120P Coils
- 2 - 115H Balancing Networks
- 2 - 115AL Balancing Networks
- 1 - 2D Singing Point Test Set (J94002D)
- 1 - 354E Volume Indicator
- 1 - 19C Oscillator

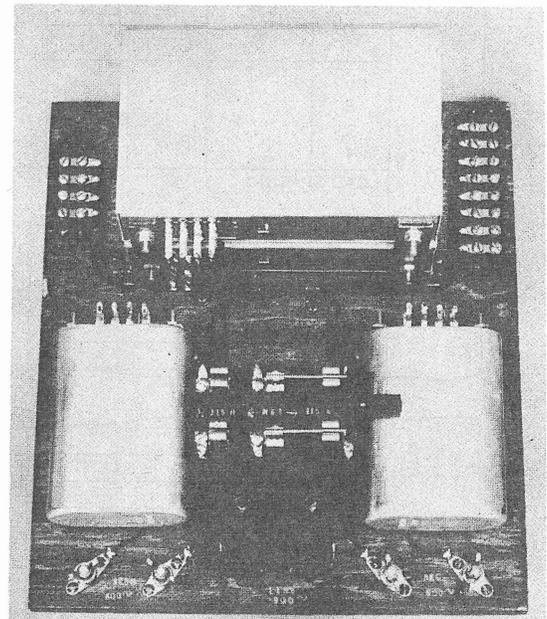


Fig. A-1

SECTION AB22.128.2

2.03 The necessary cords, keys, jacks, etc., shown in the sketch of the test hookup (Fig. A-3) were obtained locally.

2.04 The two 120P coils and the networks were mounted on a board with a convenient arrangement for switching as shown in the photograph (Fig. A-1).

(B) Preparation for Test

2.05 Strapping of balancing networks. The type of 19 gauge or 24 gauge was ascertained from the plant records and in cases of doubt verified by test. In order to use the proper strapping in the 115AL network as shown below, it was necessary to test for the actual mutual capacity of either DSM or CSM. In case of doubt in this measurement a median value was used without serious error. The method of testing capacity of loaded cable conductors is included in E-31.020. The local test-boards, in the area of this company had previously been modified to make similar tests.

2.06 The balancing networks were strapped in accordance with the following data.

115H 22 H88 No strapping

115H 19 CNB H88 Straps 2, 3 and 4

| | | Cap/Load Sect. | Strap |
|-------|------------|----------------|---------------|
| 115AL | 24 DSM H88 | Below -.0927 | 2-4, 5-6 |
| | | .0927-.0945 | 2-4, 1-3, 5-6 |
| | | .0945-.0964 | 2-4, 3-6 |
| | | .0964-Upward | 2-4, 1-6 |
| | 24 CSM H88 | Below -.0798 | 6-8 |
| | | .0798-.0811 | 6-8, 1-3 |
| | | .0811-.0825 | 6-8, 3-5 |
| | | .0825-Upward | 8-8, 1-5 |

2.07 The balancing network in the hybrid was built out so the basic section plus the build-out equaled the equivalent capacitance of the cable pair from the main frame to the first coil (see AB24.078).

Build-Out Data in Networks

| 115H Network | 22 H88 | 19 CNB H88 |
|--------------------|----------|------------|
| Basic section | .15 | .15 |
| feet | 900' | 900' |
| B.O. Cap/1000' in) | | |
| excess of basic) | .0155 mf | .0159 mf |
| section) | | |

| RETURN LOSS TESTS FOR 4-A HIGH LOSS TRUNKS | | | | | | | | | | TESTER. DATE | |
|--|--------|-----------------|----|-----------|-----|-------------|----|--------------------|--------------------------|--------------|--|
| SECT. NO. | CA NO. | LOCATED BETWEEN | | LENGTH | GA. | END SECTION | | COMP 1000' LOSS DB | MEAS. CAP. m.f. PER MILE | | |
| | | OUT | IN | | | OUT | IN | | | | |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| LOAD SPACING | | | | | | | | | | | |
| PAIR | | | | | | | | | | | |
| 300 | | | | | | | | | | | |
| 400 | | | | | | | | | | | |
| 500 | | | | | | | | | | | |
| 2900 | | | | | | | | | | | |
| 3000 | | | | | | | | | | | |
| SP | | | | | | | | | | | |
| NET NEAR END | | STRAPPING | | B.O.COND. | | REMARKS: | | | | | |
| NET FAR END | | | | | | | | | | | |

Fig. A-2

| 115AL Network | 24 DSM | 24 CSM |
|---|----------------|----------------|
| Basic section feet | .1915 1150' | .2083 1250' |
| B.O. Cap/1000' in) excess of basic) section) (nominal)) | .0159 | .0136 |

2.08 The balancing network used to terminate the facility in the distant office was built out to full section, i.e., the basic section and the equivalent capacitance from the last coil to the main frame plus the build-out was made to equal a full section.

2.09 The above build-out and strapping data were figured in advance and entered in the form for recording the test results, thus providing a ready record for all concerned. (A copy of the sample form used by the Company where this test was made is shown in Fig. A-2.)

(C) Calibration of Test Equipment

2.10 The test equipment set up is shown in Fig. A-3 except that it is not yet con-

nected to a trunk. Sending from the oscillator with the 900 line connected to 900 and the network open or shorted gave a pure trans-hybrid loss of approximately 7 db. The gain of the variable 19C oscillator was adjusted to get a zero reading on the volume indicator scale. During this test all gain was cut out of the 2D singing point test set. Changing the frequency of the oscillator throughout the test frequency range showed less than a db variation in the volume indicator readings. If the variation had been more than a db a correction factor would have been added or subtracted from all subsequent readings. When the 900 termination and open condition to line and net respectively were reversed, no material change was noted.

(D) Sample Selection and Return Loss Tests

2.11 A sample of five trunks was selected from each complement proposed for high loss use. A separate sample can be taken where there are differences in cable makeup. Where complicated trunk plant conditions exist such as complements passing in and out of various cable sheaths a larger sample may be desirable.

2.12 The following is a description of the structural return loss tests made on each

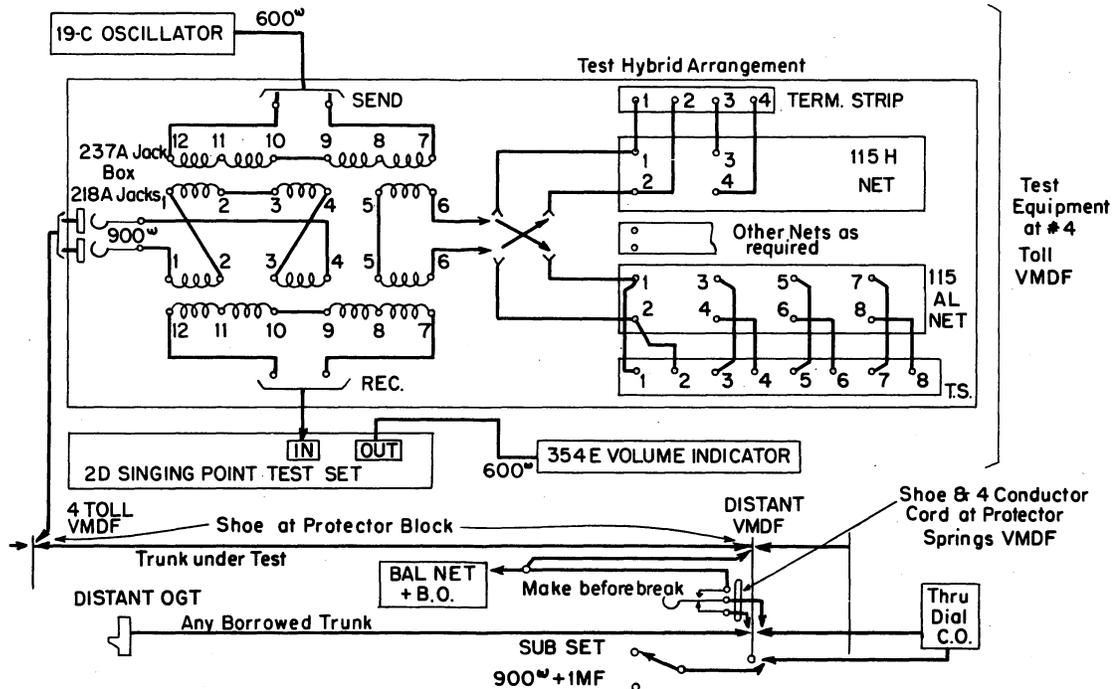


Fig. A-3

trunk in the sample. The network at the distant end was connected to the conductors of the first trunk to be tested by means of a shoe and cord at the protector springs of the main frame. At the testing end the proper network was switched into the test hybrid with the strapping and B.O. arranged as described above. The latter was then connected to the circuit under test by means of a shoe at the protector springs in the main frame as shown on Fig. A-3. Return loss tests were made at 100-cycle intervals from 300 to 3000 cycles. After tests were made on all the trunks in the sample, one trunk was selected as typical.

2.13 Return loss measurements of this trunk terminated in $900 + 1 \text{ mf}$ through a CO talking circuit were made. These tests covered the frequency range from 300 to 3600 cycles at 100-cycle intervals in order that they might serve as a reference standard for service tests as discussed later. Such measurements varied with frequency from values quite similar to those terminated in a precision network to much poorer results. The explanation may probably be found in the variety of end sections and the insertion of repeating coil equipment as well as the fact that the $900 + 1 \text{ mf}$ is a compromise for the precision network.

2.14 In making measurements advantage can be taken of the $900 + 1 \text{ mf}$ termination in the balance and noise test line per SD-96000-01, Fig. 9, if available. A method of reaching either the permanent test line or a temporary one as well as what to provide for the latter is shown on Fig. A-3 and is described as follows:

For a temporary test line a number was assigned and a termination was prepared consisting of a choice of a subset or $900 + 1 \text{ mf}$ under control of a key. Any trunk from a second distant office was appropriated and taken out of service and connected by a shoe and 4-conductor cord at the M.D.F. to a transfer key with a make before break contact as shown. The trunk under test was now connected in the distant office to this key arrangement. With the key normal, thus using the appropriated trunk, the assigned test number was dialed from the distant OGT board. After the called number was reached the key was operated and thus the line under test cut through to the termination selected. When the temporary test line was used it was necessary to trip ringing by removal of the subset receiver and then to switch to the $900 + 1 \text{ mf}$ termination for tests. It should be noted that the connection is held by the shunt in the test hybrid coil arrangement and will fall down if any part of that side of the circuit is momentarily opened.

(E) Interpretation of Test Results

2.15 In the event of very low return losses in one or more of a sample obviously out of line with calculations or other good trunks it was found desirable to enlarge the sample to cover the entire complement. Extremely low structural return losses are usually a result of a missing load coil. Such can be discovered by a correctness of loading test at .8 of cut-off frequency and located by means of an impedance run. In general, the procedure for such tests is covered in AB45.175. These pairs were either repaired or marked as unfit for high loss use and as carrying a transmission penalty for ordinary trunk use.

2.16 Where test results between 500 cycles and 2500 cycles, considered as the echo range, are all above the value of the calculated structural needed for the gain to be used per Fig. 16, it can be assumed that the trunks are satisfactory for high loss use. Subsequent tests for service should uncover no marginal troubles, tests on the five sample trunks being adequate evidence of the quality of the lot. Any real troubles will be picked up on the service tests as covered in Part 3.

2.17 Where tests results between 500 and 2500 cycles show part of the circuits with satisfactory return losses at all frequencies and part with unsatisfactory at some frequencies, it may be necessary to enlarge the sample to find if there are enough pairs in the complement suitable for high loss use. The lower grade conductors could thus be marked unsuitable similar to those mentioned in Paragraph 2.14.

2.18 Where test results show the trunk conductor to be generally on the line between good and bad, examination of the plant records was resorted to in order to uncover any irregularity in spacing or type of cable not formerly noticed. For example, 19 gauge DNB and CNB have different nominal capacities as well as 24 gauge DSM and CSM or there may be outside plant changes that have not yet been posted. Remedial steps such as build-out or moving a loading coil can be considered. Another alternative might be to take less gain by increasing the series B.O. in the hybrid.

2.19 Given a group of measurements, the average structural return loss and the standard deviation may be obtained by methods outlined in AB91.027. Analysis of sets of measurements have been made at 500-cycle intervals and at 200-cycle intervals between 500 and 2500 cycles. The former is simpler and is very close in results to the latter, therefore, is recommended as a time saver. Should the average fall at a value that is just

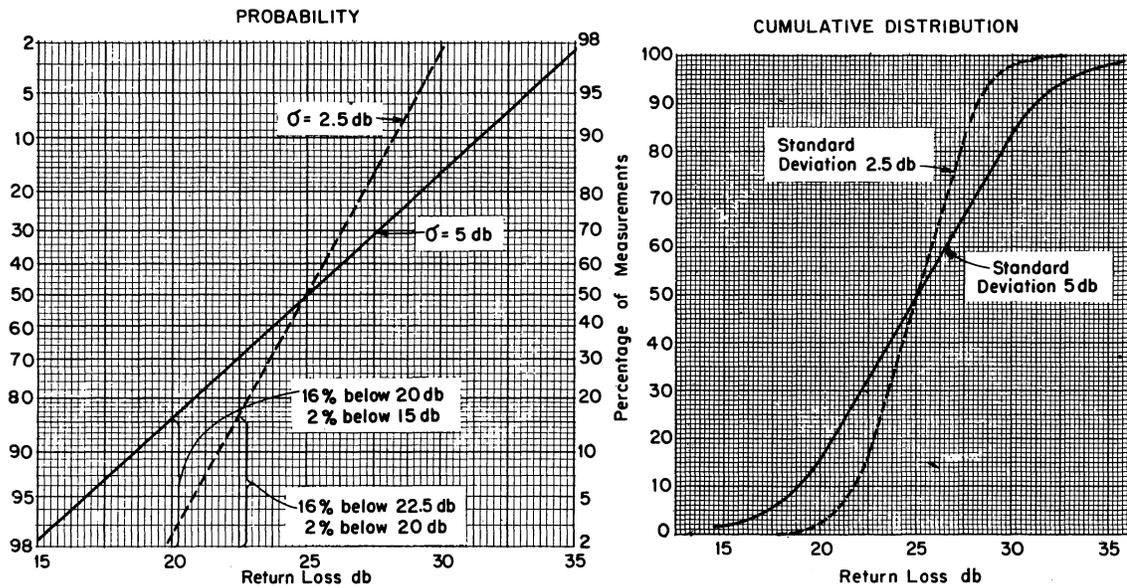


Fig. A-4

suitable to take the gain indicated in Fig. 16 and the standard deviation be equal to or less than the difference between the average and calculated columns in Fig. 16, some measurements will be less than the corresponding calculated value. According to the statistical analysis method 16 per cent or less of the measurements can be expected to fall below the calculated value.

Fig. A-4 shows such a case where the average is 25 and the standard deviation figures out to be 5. The results are plotted on probability paper which indicates that 2 per cent of the measurements would fall below 15 db.

2.20 From Fig. A-4 it is evident that with an average of 25 db if the standard deviation turned out to be some such figure as 2.5 db very few measurements (2%) would be less than 20 db and the circuits would be clearly usable.

3. SERVICE RETURN LOSS TESTS

(A) General

3.01 It is assumed that a fair sample of each cable complement terminated in a precision network has been tested for structural return loss. Further that return loss measurements of a typical trunk chosen from the sample and terminated in the balance and noise test line (900 + 1 mf through a CO coil circuit) have been made. This outline of a test procedure is written to cover the test of

the trunk circuit from the 4-wire multiple through the hybrid coils and their various optional connections for transmission and balance. The 2-wire conductors are terminated at the distant office successively in two test lines. Return loss is checked against the balance and noise test line and transmission against the 1 milliwatt test line.

3.02 Connection of transmission features on the hybrid of each trunk circuit should be specified at the appropriate time and will be the same as ascertained during the sampling test with the exception of (1) the extra capacitance build-out to be added in the network to compensate for the office cabling between the M.D.F. and the hybrid coil, (2) the series resistance pads in each side of the hybrid to build-out transmission loss in 1 db steps up to 3 db. The use of the latter is specified where the trunks conductor loss is less than the gain provided by the removal of the A-2 pad or where return loss is too low to take all the gain.

(B) Singing Point Tests for Return Loss Verification

3.03 Structural return losses having been judged satisfactory on the sampling test, it is proposed to use the corresponding return loss test of a typical trunk selected from the sample when terminated in the balance and noise test line (900 + 1 mf) as a standard. The advantage

of this method over termination of the trunk conductors in a precision network is that no assistance will be required from the distant office.

3.04 A second simplification of the test is to use a singing point test rather than a return loss test. It has an added advantage that it can be used to set the value of the build-out condensers to match the extra unknown building cable capacity. Use of singing as a test of balance in the echo range is discussed below.

3.05 Return loss was first measured against a perfect termination, then against a 900 + 1mf termination which is somewhere between perfect and poor. The low point in a return loss against frequency curve will be the point at which the circuit will sing when tested with the 2-D singing point test set. The value will be the return loss of the facility at that frequency plus approximately 8 db for the trans-hybrid loss plus series resistance B.O. pads where used. With the low point lying between 500 and 2500 cycles and singing occurring at a value commensurate with the values on the curve there is practically positive assurance that the return loss of the circuit under test is satisfactory. With the low point outside the 500 to 2500-cycle range, and singing occurring at a value commensurate with it there is reason to believe the circuit is satisfactory.

3.06 In the absence of a filter in the 2-D singing point test set to cutoff at 2500 cycles it may be necessary to identify the point of low singing should it be below a safe value of return loss. The typical circuit return loss curve may also have such a low at some higher frequency such as 3400 cycles. If singing occurs at approximately the same frequency and at a commensurate value it may be safe to assume the circuit is still satisfactory as were the samples in the echo range.

(C) Outline of Test Procedure

3.07 To make singing point tests the 2-D singing point test set can be used at the automatic outgoing toll connecting trunk test frame (see A229.831). This frame has facilities for manually picking any toll completing trunk and for dialing a test line number to reach the balance and noise test line (SD-96000-01, Fig. 9) or its equivalent in the distant office. This test line provides a termination of 900 and 1mf in the on-hook condition. If it is found that a satisfactory singing point can be obtained, the variable condenser value should be strapped into the network of trunk hybrid as a permanent value and singing point again checked. All similar circuits, that is in the same sample, can be strapped with the same build-out.

3.08 If the trunks have a satisfactory singing point, other features of the circuit such as variable pads can be checked against the 1 milliwatt test line in the distant office (see A229.831). This test verifies both sides of the hybrid and the respective variable pads if used, as well as the 1000-cycle loss of the trunk conductors.

3.09 High loss tandem trunks from out toll boards can be checked in somewhat the same manner, the distant outward operator calling up the local test line and then connecting it to the 17C testboard by dialing 101 over the tandem trunk. Singing point tests are then made at the testboard.

3.10 If return loss tests in addition to singing point tests are necessary to justify the use of otherwise doubtful facilities, they can be made either from the main frame or from the same points from which the singing point tests described above were made.

REFERENCES

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|------------|--|------------|---|
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| AB22.151 | Design of Circuits Using E-1 Repeater | AB23.190 | Toll Cable Completion Tests |
| AB23.010 | Transmission Considerations in Laying Out Toll Circuits | AB24.078 | Exchange Line Balancing Network Data |
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| | | E40.539 | 2D and 2E Singing Point Test Sets |