

BALANCE CHARACTERISTICS OF STEP-BY-STEP CENTRAL OFFICE CIRCUITS

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1. GENERAL

1.01 This section discusses longitudinal unbalance in CO, PBX, and miscellaneous circuits from the noise standpoint. The unbalances considered are those resulting from a particular circuit or item of equipment; no attempt has been made to cover unbalance resulting from trouble or maintenance items. It is intended that the information on step-by-step circuits furnished in this section be used in conjunction with the corrective measures and data furnished in Section 873-401-100 in the solution of noise problems involving step-by-step equipment.

1.02 This section shows a number of circuits used in step-by-step offices in establishing a connection and during the talking interval. Data is also included that indicates the range of the unbalance of the items of equipment involved. Methods of decreasing the noise under the various conditions are also discussed.

1.03 Most of the information in this section was taken from the old Section AB63.241. Therefore, values given herein for the balance and longitudinal impedance of components are to be

used for comparison only; they were not obtained in conformance with modern standard measuring techniques.

2. TYPES OF OFFICES AND TYPICAL CIRCUITS

2.01 The types of Western Electric Company step-by-step COs that are most likely to be involved in long rural subscriber circuits where the balance of CO equipment is important are the Nos. 1, 350A, 355A and 360A. All these offices have similar circuit arrangements and equipment, although the resistance limits for the use of the "long line" circuit vary somewhat according to the type of CO.

A. Pretalking Interval

2.02 As shown in Fig. 1, there is a large longitudinal unbalance during the ringing condition on the called end of the circuit before the called party answers. This unbalance is present even though the long line circuit is used, since the coil of the long line equipment is shorted out during the actual ringing period. In some cases, the long line circuit may be of the repeated ringing type in which ringing current is applied directly to the line at the called side of the repeating coil and the connection toward the calling end is opened. In this case, the unbalance indicated in Fig. 1 is not present.

2.03 Inasmuch as no subscriber can be on the called line during the unbalanced ringing condition, and secondary induction effects from the circuit to other circuits in an entrance cable are not likely to be increased to an important degree by this condition, this unbalance is usually relatively unimportant. An exception would be cases having unusually high longitudinal induction that might result in the masking of the audible to ringing tone to the calling subscriber.

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B. Talking Interval

2.04 Figure 2 shows a typical circuit in a Western Electric Company step-by-step office during the talking condition where a local connector is involved.

2.05 In the circuit shown in Fig. 2, the possible sources of unbalance are the A and D relays, the 2 μ f capacitors, and certain types of coils used when the long line circuit is required. However, as explained later, if the long line circuit is used, unbalance in the local connector circuit cannot result in noise from longitudinal voltages induced on the line side of the long line equipment.

2.06 Early issues of the SD drawings covering COs of some of the types discussed in this section specified the use of tandem-wound relays of the 221A and 222 (or equivalent) types for the A and D relays, respectively. In this type of relay each winding has a d-c resistance of 200 ohms, but they are so wound that the ratio of the noise-metallic (N_M) to the noise-longitudinal (N_L) in the pair may be on the order of 15 to 30 db in the frequency range between 200 and 3000 Hz. More detailed data regarding the unbalances at various frequencies is given in Table A. (See Par. 3.12.)

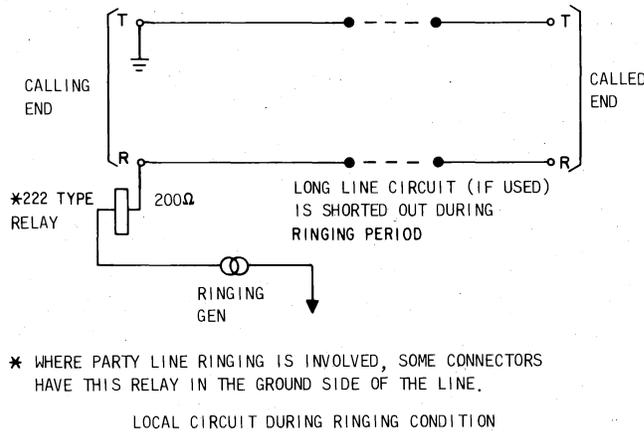
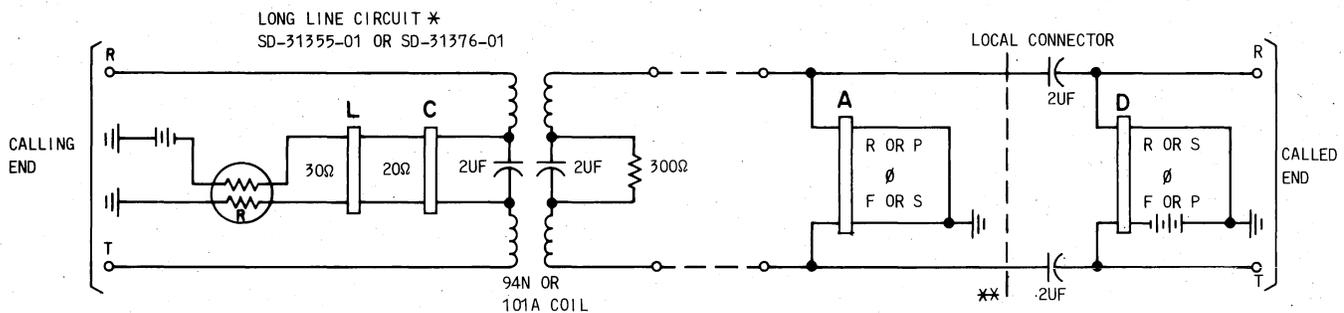


Fig. 1—Local Circuit During Ringing Condition



- * FOR SIGNALING PURPOSES, USED ON SUBSCRIBER LOOPS OVER ABOUT 635 TO 1000 OHMS, THE VALUE DEPENDING UPON THE TYPE OF OFFICE INVOLVED. THIS CIRCUIT MAY ALSO BE REQUIRED ON THE "CALLED END" OF THE LOCAL CONNECTOR.
- ** FOR A REVERTING CALL, A REVERTING CALL SELECTOR HAVING ONLY THE "A" RELAY IS USED IN PLACE OF THE LOCAL CONNECTOR, SO THE PART OF THE TRANSMISSION CIRCUIT TO THE RIGHT OF THE DASHED LINE IS NOT INVOLVED.
- Ø F AND R DESIGNATIONS APPLY TO TANDEM-WOUND RELAYS, P AND S DESIGNATIONS ARE FOR SANDWICH-WOUND TYPE.

Fig. 2—Typical Local Circuit During Talking Condition

TABLE A

| Type of Equipment | Freq. | Z (Note 1) | Average Unbalance Range | | |
|---|-------|---------------|-------------------------------|-------------------------------|-----------------------|
| | | | N_M-N_{L1} (Note 2) (dB) | N_M-N_{GC} (Note 3) (dB) | Z_u (Ohms) (Note 4) |
| Connectors | 200 | 140 + j 210 | 17 to 22 | 9 to 14 | 18 to 29 |
| Tandem-Wound Relay (Note 5, Fig. 1) | 1000 | 420 + j 850 | 22 " 27 | 2 " 7 | 30 " 51 |
| | 3000 | 980 + j 1830 | 23 " 28 | -3 " +1 | 34 " 57 |
| Tandem-Wound Relay (Reversed Conn. Fig. 3) (Note 5) | 200 | 140 + j 210 | 15 to 22 | 7 to 14 | 13 to 31 |
| | 1000 | 420 + j 850 | 14 " 4 | -6 " +4 | 12 " 36 |
| | 3000 | 980 + j 1830 | 14 " 20 | -13 " -7 | 11 " 23 |
| Sandwich-Wound Relay | 200 | 71 - j 20 | - 1.4 | +1.4 | 2.1 |
| | 1000 | 48 + j 6 | - 9.7 | -3.4 | .8 |
| | 3000 | 47 + j 44 | -11.2 | -7.4 | .7 |
| Reverting Call Selectors | | | | | |
| Tandem-Wound Relay | 200 | 268 + j 535 | 23 to 26 | 7 to 11 | 34 to 50 |
| | 1000 | 834 + j 1720 | 26 " 28 | 0 " 3 | 47 " 63 |
| | 3000 | 1970 + j 3660 | 27 " 30 | -6 " -3 | 53 " 74 |
| Sandwich-Wound Relay | 200 | 93 + j 6 | - 4.5 | - 4 | 1.4 |
| | 1000 | 93 + j 32 | - 7.6 | - 7 | 1.0 |
| | 3000 | 93 + j 96 | -10.4 | -13 | .7 |

Notes:

1. Longitudinal impedance of C.O. equipment. (These impedances are based on an average measured value of 2.2 mf for each of the nominal "2 mf" condensers shown for the "local" connector in the right-hand part of Fig. 1.)
2. N_{L1} signifies the "noise-longitudinal" (namely, 1/100 of the total longitudinal noise current expressed in dba) which flows by way of the particular item of C.O. equipment, from any individual exposed pair to which that specific connector or selector is connected. Note that N_M is the noise-metallic with the pair normally terminated in 600 ohms in each direction.
3. N_{GC} indicates noise-to-ground measured across C.O. equipment. (Note that this is NOT the total noise-to-ground but only that part of it which is represented by the noise-voltage drop across the C.O. equipment itself.)
4. Z_u represents the equivalent series unbalance in ohms, where

$$\frac{N_M}{N_{L1}} \text{ (numerical ratio) } = .42 Z_u \text{ and } \frac{N_M}{N_{GC}} = \frac{42 Z_u}{Z_L}$$

5. Unbalances for tandem-wound relays depend on amount of direct current in relay. The lower figures in the range given are the average of the minimum unbalances observed in the individual connectors or selectors, and the higher figures are the average of the maximum unbalances. The spread of individual values is ± 4 db in the case of the maxima and +3 to -8 db in the case of the minima.

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2.07 On subscriber lines where reverting calls are involved, the circuit is substantially the same as shown in Fig. 2 except that the reverting call selector uses only an "A" relay, and the part of the circuit to the right of the dashed line is not in the transmission circuit.

3. REMEDIAL MEASURES

3.01 One of the first steps in the study of any noise problem is to ensure that maintenance conditions are not contributing unduly to the noise. Next, one must determine whether the noise is in the CO or the loop plant. Tests for determining such conditions are outlined in Section 331-850-502. General discussions of the longitudinal balance of circuits are given in Sections 873-401-100 and 873-400-100.

3.02 In correcting a noise problem due to CO unbalance, two methods are available. One method requires the reduction of the longitudinal current flowing through the unbalanced CO circuits and the other involves the improvement of the longitudinal balance of the CO circuits. The method to be employed depends, to a considerable extent, upon the number of subscriber lines having excessive noise.

A. Reduction of Longitudinal Current

3.03 In most cases where noise is experienced on CO connections, the number of subscriber lines involved will be relatively small and the reduction of the longitudinal current flowing from these lines through the office equipment will prove to be the most economical solution. The most effective way of reducing the longitudinal current through the CO equipment in severe cases of induction is by the use of a long line circuit on each of the subscriber lines involved. The repeating coil of the long line circuit completely isolates the CO equipment from the longitudinal line induction.

3.04 The long line circuit is ordinarily used to provide satisfactory supervision only on subscriber loops over about 635 to 1000 ohms, the value depending upon the type of office involved. However, it is usually on circuits with extra long loops requiring the long line circuit for supervision that the exposure conditions are severe and a high degree of CO balance is important from the noise standpoint. In a few cases, the long line circuit has been used to improve noise conditions on shorter

loops. Where this circuit is used, unbalance in the local connector circuit (as shown in Fig. 2) is made ineffective in producing noise due to longitudinal voltages induced in the outside plant on the long line circuit "loop" end, since the coil prevents the induced longitudinal voltages from reaching the unbalanced CO equipment. However, longitudinal voltage induced in the loop on the other side of the CO equipment would act on the connector circuit unbalance unless another long line circuit were used on that other loop.

3.05 The equipment in the long line circuit has a high degree of balance. All recent SD drawings for the types of offices discussed specify the use of the 94N repeating coil which is well balanced. However, some of the earlier drawings specified the use of the 101A coil, which may have an equivalent series-impedance unbalance of 5 to 30 ohms (N_M/N_{L1} numerical ratio of 2 to 13) for the frequency range of 200 to 3000 Hz, the larger unbalance being at the higher frequencies. In the older offices where the unbalance in 101A-type repeating coils contributes to noise problems, consideration should be given to the replacement of the 101A coils with the 120C type, which is even better balanced than the 94N.

3.06 In installations where a small number of exposed lines are involved, the use of drainage coils, neutralizing transformers, or longitudinal chokes will probably be less expensive than changes in the various transmission circuits. However, these measures usually require special engineering to determine the lines affected, as well as extra space which is not ordinarily provided in the central office. Any rearrangements in the power and telephone systems will make it necessary to reconsider the coordination problem and the drain, transformer, or choke installations. Section 873-505-101 and -107 give details regarding the specific uses and installation of these mitigative devices.

B. Reduction of Central Office Unbalance

3.07 In relatively few cases, objectionable noise may be experienced on connections involving a large number of subscriber lines. In a situation of this kind, it may prove economical to reduce the noise by improving the balance of the CO circuits involved. Since on an outgoing call a group of circuits is available to any given line for each of the circuit conditions previously described, it will be necessary to balance all the circuits in a

group for each of the circuit conditions where noise exists. Then, through proper assignment, the subscriber lines having high longitudinal induction should be associated with this balanced group of circuits. Where noise is experienced on incoming calls to subscriber lines, all of the incoming circuits involved in noisy conditions must be included since all of these circuits are available to the subscriber lines with high induction.

3.08 This section does not detail corrective measures for each of the unbalanced conditions in the CO circuits. Section 873-401-100 outlines measures for similar circuits and conditions, and by the use of that section, corrective measures can be obtained for any unbalanced condition. Any corrective measures involving the modification of CO equipment should be made on the basis of tests and only after ample consideration has been given to the possible effects of the modifications on all features of the circuit. This is especially true in those cases where a capacitor is added to a circuit or the value of the present capacitor is increased to shunt out an unbalance. Where such a capacitor is shunted across a relay, the operating time of the relay is altered considerably. This fact eliminates this method of improving the balance of many circuits where the relay is required to repeat dial pulses.

Sandwich-Wound Coils

3.09 The sandwich-wound coil consists of three concentric windings with the inner and outer windings connected in series and serving as a primary, and with the middle winding serving as the secondary. Sandwich-wound coils provide much better longitudinal balance than do tandem-wound relays. This improvement in balance is particularly desirable in the case of battery supply relays associated with the transmission circuits of community dial offices in rural areas, where the outside plant is likely to be involved in inductive exposures to power systems.

3.10 The sandwich-wound relay coil (designated as P252419) has been provided since about

1942 in the manufacture of new step-by-step offices of the Nos. 1, 350A, 355A and 360A types. It may be substituted for the tandem-wound coil in existing offices where the improved balance would be advantageous. The 370A and 370B offices which are no longer standard (and only a few are in existence) employ parallel-wound relays which are well balanced, so no replacements are necessary.

3.11 The lower longitudinal impedance of the sandwich-relay circuits has the advantage that capacitively induced currents are drained from the circuit and, consequently, have less effect on any shunt unbalance present in the line or station equipment. Also, the possibility of resonance effects in the longitudinal circuit between the reactive component of the connector impedance and the capacitance of the outside plant is minimized by the use of the sandwich relays. These effects are shown in Table A.

Optional Transposed Connection of Tandem-Wound Relays

3.12 An important factor in the longitudinal balance of step-by-step office connectors with tandem-wound relays is an unbalance, largely independent of the effects of minor production variations in relays or capacitors, which occurs between the front and rear windings of each relay, because the magnetic structures at the front and rear ends of the relay are dissimilar.

3.13 In Fig. 2, the connections of the front and rear windings to the tip and ring conductors are the same for both the "A" and "D" relays. The unbalance effects of the two relays are consequently additive. Transposition of the tip and ring wires between the "D" relay and the series capacitors as shown in Fig. 3 provides improved balance at higher frequencies by opposing the effects of the impedance difference between the front and rear windings of the "A" relay against the similar effects in the "D" relay.

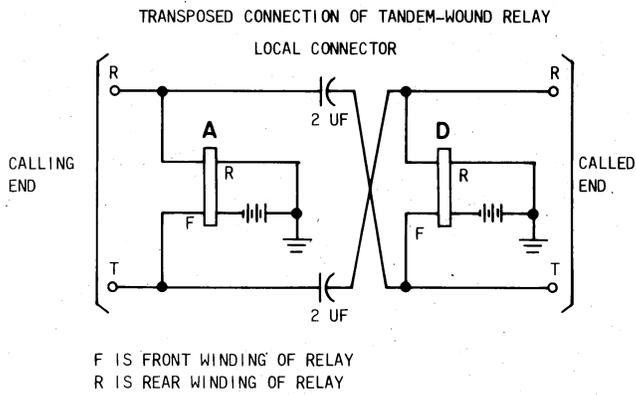


Fig. 3—Transposed Connection of Tandem—Wound Relay

3.14 Because of the advantages to be gained in the balance of existing offices in certain cases, the wiring of Fig. 3 is shown as an option on the connector drawings applying to certain offices using tandem-wound relays, and the change may be made rather simply in the field. A check should be made of the connections of each type of connector in a particular office in order to avoid changes in circuits which already have the most favorable connection. The relative advantages of connectors with sandwich-wound relays and with the transposed connection of the tandem-wound relays are shown in Table A. Tables B through H list relays that can be used to replace older unbalanced relays.

TABLE B
STEP-BY-STEP RELAY INTERCHANGEABILITY

| W.E. CO. CODE (UNBALANCED) | A.E. CO. CODE (EQUIVALENT UNBALANCED) | W.E. CO. CODE (BALANCED) | REMARKS |
|----------------------------------|--|--|--|
| *221A *221P *221R | *R99A1 *41089A1 | 221ND 221NE 221NE | |
| 221BB | | | With minor range reduction 221NJ relay may be substituted |
| *221EB | | 221FAK | |
| 221EU | | | With minor range reduction 221NJ relay may be substituted |
| *221FS | | | Replace winding with P252419 |
| 221JH | | | With minor range reduction relay winding may be replaced with P252421 |
| *221NK | | | Replace winding with P252419 |
| | | 221FAA 221FAB | |
| | | 221FAC | Replace relay or winding if date coded prior to 1-53 (P252151) winding |
| | | 221FAE 221FAF 221FAJ 221FAK 221FAM | |
| *222W *222Y *222AA | *R1364-A2-A *R1338-A-1 *R1892A-1 | 222KM 222KR 222KP | |
| *222GM *222GW *222JW | | 222LC 222KS 222KN | |
| *223D | | 223DA | |
| | | 223DB | |
| | *R1364-A2 *R5124A1 *R5169A1 | | Replace winding with P252419 |

* A.E. Co. relay windings D280026 and D285004 or W.E. Co. relay winding P251478 may be replaced with W.E. Co. relay winding P252419 to correct unbalance.

W.E. Co. relay winding P251479 used in 221BB, 221EH and 221JH relays may be replaced with a P252421 winding with slight reduction in range.

TABLE C

IMPROVEMENT OF BALANCE OF CONNECTOR CIRCUITS

| CIRCUIT DRWG. NO. | OPTION CHOICE, STATUS, ED OR J DRWG. NO. |
|---|---|
| ES 241615-01 ES 241813-01 ES 254468-01 ES 254470-01 ES 30034-01 ES 30036-01 ES 30069-01 ES 30131-01 ES 30185-01 | Replace relay windings with P252419 Replace relay windings with P252419 |
| SD-30208-01 | Replace relays per Table A or replace relay windings with P252419 |
| SD-30215-01 SD-30220-01 SD 30228-01 | Use "T" option ED 30215-34 Use "T" option ED 30220-35 Use "T" option ED 30228-35 |
| ES 30254-01 ES 30310-01 | Replace relay windings with P252419 Replace relay windings with P252419 |
| ES 30400-01 ES 30460-01 ES 30462-01 | Use "U" option or replace relay windings with P252419 Use "P" option or replace relay windings with P252419 Use "P" option or replace relay windings with P252419 |
| ES 30563-01 ES 30564-01 ES 30699-01 | Replace relay windings with P252419 Replace relay windings with P252419 Replace relay windings with P252419 |
| SD 30904-01 SD 30911-01 SD 30912-01 SD 30922-01 SD 30928-01 SD 30939-01 SD 30944-01 SD 30946-01 SD 30950-01 | Satisfactory Satisfactory Satisfactory Satisfactory Satisfactory Satisfactory Satisfactory Satisfactory Satisfactory |
| SD 31088-01 SD 31192-01 SD 31193-01 SD 31210-01 | Use "Y" option ED 31088-36 Use "ZC" option Use "T" option ED 31193-34 Use "S" option ED 31210-34 |
| SD 31219-01 SD 31297-01 | Replace relay windings with P252419 Replace relay windings with P252419 |

TABLE C (Cont)

IMPROVEMENT OF BALANCE OF CONNECTOR CIRCUITS

| CIRCUIT DRWG. NO. | OPTION CHOICE, STATUS, ED OR J DRWG. NO. |
|-------------------|---|
| SD 31526-01 | Use "Q" option |
| SD 31598-01 | Use "Q" option ED 31598-32 |
| SD 31656-01 | Use "Y" option |
| SD 31737-01 | Use "Y" option ED 31737-30 |
| SD 31738-01 | Use "T" option ED 31738-30 |
| SD 31739-01 | Use "Y" option ED 31739-30 |
| SD 31740-01 | Use "Y" option ED 31740-30 |
| SD 31741-01 | Use "Y" option ED 31741-30 |
| SD 31742-01 | Use "T" option ED 31742-30 |
| SD 31810-01 | Use "B" and "Y" options ED 31810-30 |
| SD 31811-01 | Use "U" option ED 31811-30 |
| SD 31818-01 | Use "W" option ED 31818-30 |
| SD 31832-01 | Use "Y" option ED 31832-30 |
| SD 31833-01 | Use "Y" option ED 31833-30 |
| ES 32136-01 | Use "F" option or replace relay windings with P252419 |

TABLE D

IMPROVEMENT OF BALANCE IN OUTGOING TRUNK CIRCUITS

| CIRCUIT DRWG. NO. | OPTION CHOICE, STATUS, ED OR J DRWG. NO. |
|----------------------------|--|
| SD 30921-01 SD 30974-01 | Satisfactory Satisfactory |
| SD 31711-01 SD 30205-01 | Replace 221 FAC relays dated before 1/53 Replace winding of 221P relay with P252419 |
| SD 31147-01 SD 31428-01 | Use "K-S" option or replace winding of 221BB relays with P252421 Use "R" option |
| SD 31541-01 SD 31609-01 | Satisfactory Satisfactory |
| SD 31648-01 SD 31693-01 | Replace winding of 221P relay with P252419 Replace 221 FAC relays dated before 1/53 |
| SD 31699-01 | Satisfactory |
| SD 31779-01 | Replace 221 FAC relays dated before 1/53 |
| SD 31874-01 SD 31929-01 | Satisfactory Satisfactory |
| SD 31892-01 | Replace 221 FAC relays dated before 1/53 |
| SD 32008-01 SD 32087-01 | Satisfactory Satisfactory |

TABLE E

IMPROVEMENT OF BALANCE OF INCOMING TRUNK CIRCUITS

| CIRCUIT DRWG. NO. | OPTION CHOICE, STATUS, ED OR J DRWG. NO. |
|----------------------------|--|
| SD 30974-01 SD 31542-01 | Satisfactory Satisfactory |
| SD 31648-01 | Replace winding of 221P relay with P252419 |
| SD 31919-01 SD 32008-01 | Satisfactory Satisfactory |

TABLE F

IMPROVEMENT OF BALANCE IN TWO-WAY TRUNK CIRCUITS

| CIRCUIT DRWG. NO. | OPTION CHOICE, STATUS, ED OR J DRWG. NO. |
|----------------------------|--|
| SD 30900-01 | Use "T" option inductor if measured noise is too high |
| SD 30921-01 | Satisfactory |
| SD 30938-01 | Replace 221 FAC relays dated before 1/53 |
| SD 31602-01 | Use "H" option |
| SD 31658-01 SD 31674-01 | Replace winding of 221P relay with P252419 Replace 221 RAG relays dated before 1/53 |
| SD 31747-01 | Satisfactory |
| SD 31748-01 | Use "R" option or replace winding of 221P relay with P252419 |
| SD 31754-01 SD 31775-01 | Replace 221 FAC relays dated before 1/53 Replace 221 FAC relays dated before 1/53 |
| SD 31842-01 SD 31874-01 | Satisfactory Satisfactory |

TABLE G

IMPROVEMENT OF BALANCE IN REVERTING CALL CIRCUITS

| CIRCUIT DRWG. NO. | OPTION CHOICE, STATUS, ED OR J DRWG. NO. |
|----------------------------|--|
| ES 30195-01 | Replace relay windings with P252419 |
| ES 30230-01 | Satisfactory |
| SD 30917-01 SD 30978-01 | Satisfactory Satisfactory |
| SD 31213-01 SD 31647-01 | Use "U" option Use "Y" option |
| SD 31754-01 | Replace 221 FAC relays dated before 1/53 |
| SD 31762-01 SD 31831-01 | Use "U" option Use "W" option |

TABLE H
IMPROVEMENT OF BALANCE IN PBX CIRCUITS

| CIRCUIT DRWG. NO. | OPTION CHOICE, STATUS, ED OR J DRWG. NO. |
|---|--|
| SD 65721-01 | Satisfactory |
| SD 66002-01 SD 66005-01 | Replace windings of 221A/223E relays with P252419 Replace relay windings with P252419 |
| SD 66049-01 SD 66050-01 SD 66143-01 SD 66144-01 SD 66496-01 SD 66595-01 SD 66596-01 | Use 222KS (D) relay Use "N" option and replace winding of 221A relay with P252419 Use "T" option ED 66134-34 Use "Q" option ED 66144-34 Use "W" option Use 221NE relay option Use "U" option |
| C.O. TRUNK CIRCUITS | |
| SD 65657-01 | Use "ZD" option J58824A-3 |
| SD 66607-01 SD 66592-01 | Satisfactory Satisfactory |
| DIAL LONG LINE CIRCUITS | |
| SD 66057-01 SD 66060-01 SD 66087-01 SD 66462-01 SD 96010-01 SD 96034-01 | Satisfactory Use "T" option J58824AK — ED 68060-33 Satisfactory Use "T" option J58817K Satisfactory Use "V" option J99234A |
| TIE TRUNK CIRCUITS | |
| SD 65531-01 SD 65535-01 | Replace 221 FAC relays dated before 1/53 Replace 221 FAC relays dated before 1/53 |
| SD 65718-01 SD 65739-01 SD 66029-01 | Satisfactory Satisfactory Satisfactory |
| SD 66041-01 | None — Install Longitudinal Choke (149E inductor) to treat specific circuits after measurement |
| SD 66042-01 | Replace 221 FAC relays dated before 1/53 |
| SD 66578-01 | Satisfactory |

TABLE H (Cont)

IMPROVEMENT OF BALANCE IN PBX CIRCUITS

| CIRCUIT DRWG. NO. | OPTION CHOICE, STATUS, ED OR J DRWG. NO. |
|----------------------------------|--|
| TIE TRUNK CIRCUITS (Cont) | |
| SD 66066-01 SD 66622-01 | Use "M" option Use "A" option |
| SD 6635-01 | Replace 221 FAC relays dated before 1/53 |
| SD 66709-01 | Use "M" option |
| CONFERENCE CIRCUITS | |
| SD 66434-01 | Use "P" option J53120AJ — ED 66434-01 |
| SD 66461-01 | None — Install Longitudinal Choke (149e inductor) to treat specific circuits after measurement |
| SD 66693-01 | Satisfactory |
| MISCELLANEOUS CIRCUITS | |
| SD 66604-01 | Satisfactory |

3.15 An alternative method of reducing unbalance is to shunt the relay coil with a large value capacitor. This technique is discussed in Section 873-401-100.

Balance of Series Capacitors

3.16 The balance of the series capacitors is usually the controlling factor in the overall balance of connectors equipped with sandwich-wound relays. In offices equipped with these relays during manufacture, the capacitors are within the limits of 2 to 2.5 μF and the two units of a pair are now so selected that their capacitance will not

differ by more than 0.11 μf . The average unbalance data given in Table A for connectors with sandwich relays were obtained in offices where the capacitors had been paired to be balanced within 5 per cent (about 0.11 μf) or better. However, in existing offices equipped with tandem-wound coils that may be replaced by sandwich-wound coils, the maximum unbalance between the two capacitors may sometimes substantially exceed 5 per cent. In such cases, the balance of connectors equipped with sandwich-wound coils may be further improved by pairing the capacitors. The selection may be made on the basis of the tests discussed in Section 873-401-100.