EXCHANGE AREA TRANSMISSION PRACTICES

SECTION 6-A

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1. Introductory

This issue of section 6-A of Toll Transmission Practices describes the present standard 94-E and 94-F battery supply repeating coils for use in 24-volt and 48-volt manual and dial system offices. Mention is also made of a number of other previous standard battery supply repeating coils and their present status. The table below indicates the repeating coils which are superseded by the present standard 94-E and 94-F repeating coils.

Present Standard Battery Supply Repeating Coils	Superseded Repeating Coils
94-E (Punched steel case)	94-C, 95-C, 95-E, 94-E (Folded tin case)
94-F (Punched steel case)	94-D, 95-D, 95-F, 94-F (Folded tin case)

2. Design Features

2.1 General Design

The differences from a design standpoint between the new 94-E and 94-F repeating coils and the 94-C and 94-D repeating coils are in the winding assembly and the coil case. In the E and F coils the two halves of both the loop and the trunk windings are wound in parallel, each winding being evenly distributed over the entire winding space on the core. Windings 1-2 and 5-6 are applied next to the core, and windings 3-4 and 7-8 are applied directly over windings 1-2 and 5-6. In the 94-C and 94-D coils the two halves of the trunk or loop windings are wound individually on separate halves of the core, windings 1-2 and 5-6 being next to the core and windings 3-4 and 7-8 being on the outside.

The windings of the 94-E and 94-F coils are wound directly on the central branch of the core suitably insulated and fitted with spool heads, instead of being wound on spools and then placed on the core, as was the procedure with the superseded coils. The upper spool head is a combined spool head and terminal plate assembly which obviates the necessity of having a separate terminal plate. In order to prevent difficulties due to insulation breakdown or corrosion, which might result from the close proximity of the two halves of the trunk or loop winding, the individual conductors are insulated with black enamel and a layer of single cotton instead of a layer of single cotton only, as was used with the 94-C, 94-D, 95-C, and 95-D repeating coils.

The 94-E and 94-F coils were first manufactured with cases similar to those of the 94-C and 94-D coils described in division 5.1. The coils now being manufactured, however, have a new punched steel case instead of a folded tin plate case as heretofore used for 94-type repeating coils. The attached drawing shows an assembly of the 94-E and 94-F repeating coils. All 94-type coils mount interchangeably.

2.2 Impedance Balance

The adverse unbalance effects of battery supply repeating coils on telephone circuits in which they are used are due principally to two types of coil unbalances, series impedance unbalance and shunt impedance or admittance unbalance.

Series impedance unbalances of battery supply repeating coils are the result of resistance and inductance unbalances and are effective in causing metallic circuit noise when the loop or trunk winding of the coil is grounded at the midpoint, and voltages along the conductors or between conductors and ground are induced on the associated circuit. In the "A" cord circuit both the loop and trunk windings of the battery supply repeating coil are grounded at their midpoints, and in the "B" cord circuit the loop winding is grounded at its midpoint. The magnitude of the metallic circuit noise caused by the series impedance unbalances depends on the magnitudes of the series unbalances and the amplitudes of the induced longitudinal noise currents to ground through the coil windings.

Admittance unbalances are mainly due to capacitances between the loop and trunk windings of the repeating coils, which are unbalanced with respect to the repeating coil midpoint. Admittance unbalances are effective in causing metallic circuit noise when one winding, either the loop or trunk, is insulated from ground and when noise voltages to ground are induced on the associated circuit. The trunk winding of the battery supply repeating coil in the "B" cord circuit is insulated from ground. The magnitude of the metallic circuit noise caused by admittance unbalance depends on the magnitude of the admittance unbalance and the magnitude of the induced noise voltage to ground acting on the unbalances.

Investigation of impedance unbalances in battery supply repeating coils showed the 94-C, 94-D, 95-C and 95-D repeating coils to have average equivalent series impedance unbalances of about 8 ohms at 1,000 cycles, with a maximum unbalance of about 35 ohms. The corresponding average and maximum impedance unbalances for 25-type repeating coils are about 13 ohms and 65 ohms, respectively. Measurements made on development models of the 94-E and 94-F coils indicate that they have equivalent series impedance unbalances of about one-tenth the series impedance unbalances of the 94-C, 94-D, 95-C and 95-D repeating coils. These unbalances of the E and F coils are practically negligible from the standpoint of causing metallic circuit noise.

In the older types of battery supply repeating coils, the series impedance unbalances have usually been much more important than the admittance unbalances as a cause of metallic noise in circuits exposed to induction; and, consequently, the reduction of the series unbalances has been the principal objective in the development of the coils described in the present section. In this connection it may be noted that the series unbalances which occurred in the older types of battery supply repeating coils were due to irregularities and variations in materials and manufacturing processes, and not to any dissymmetry in the coil design. By the use of parallel windings in the new coils, the effects of these irregularities and variations in causing series impedance unbalances have been practically eliminated.

The admittance unbalances of the 94-E and 94-F coils are somewhat lower than those of the 94-C, 94-D, 95-C and 95-D repeating coils and are materially less than those of 25-type repeating coils. The admittance unbalances of the E and F coils are of about the same importance as their low series impedance unbalances, and therefore may also be considered negligible as a cause of metallic circuit noise.

2.3 Impedance Relations

Aside from impedance balance, the only difference in essential electrical characteristics between the 94-E unity ratio repeating coil and the 94-C and 95-C unity ratio repeating coils is that the nominal d-c. resistances of both the loop and trunk windings are each about 40 ohms instead of 42 ohms. This is a result of the omission of the winding spool, as described in division 2.1 the mean length of turn of the winding being reduced about 5 per cent. In the 94-F repeating coil which is the 1.5:1 ratio repeating coil superseding the 94-D and 95-D repeating coils, the nominal d-c. resistance of each loop winding is also 40 ohms. The nominal d-c. resistance of each high or trunk winding is 60 ohms instead of 63 ohms as for the 94-D and 95-D coils. As indicated above the 94-E coil is of unity impedance ratio and the 94-F has an impedance of 1.5:1, trunk to loop winding.

2.4 Prevention of Compound Exudation

The coil windings of the 94 and 95-type repeating coils are impregnated with a rosin compound to prevent moisture penetration. No additional compound is used to fill the cases, however, as is done for the 25-type coils. The seams of the case are water-tight so that it will catch and hold any impregnating compound which may flow from the coil when and if the temperature becomes high enough to melt the compound, as the result of the flow of abnormal currents during circuit trouble conditions.

2.5 Heating Characteristics

The 94 and 95-type coils are somewhat smaller than the corresponding 25-type coils. Due to their smaller size and to the fact that they must dissipate the same amount of heat under service conditions as the 25-type coils, the temperatures reached by the 94 and 95-type coils under 24-volt trouble conditions are somewhat higher than those of the 25-type repeating coil under corresponding conditions but they do not constitute a hazard.

The use of external current control resistances with the 94 and 95-type repeating coils in 48-volt battery supply service results in the coil and case temperatures being much lower under trouble and severe service conditions than temperatures reached under similar conditions for the 25-type repeating coils used in 48-volt service.

3.0 Transmission Features

3.1 Transmission

Except for the improved balance, the transmission characteristics of the 94-E and 94-F coils are practically equivalent to the 94-C, 94-D, 95-C and 95-D coils. A small improvement (about 0.05 db) is obtained in voice frequency transmission due to the lower d-c. resistance, the average loss for currents of speech frequencies being about 0.7 db for both coils.

The impedance of the loop winding (4-3, 8-7) of the 94-F (inequality ratio) coil is the same as that of the corresponding winding of the 94-E (unity ratio) coil; consequently the transmission losses for the two coils are equal when used under the particular combinations of loop and trunk impedance for which they are designed.

Since the 94-E and 94-F repeating coils have the same direct-current resistance in the loop windings as the 25-type coils, the battery supply losses are identical under similar loop and subscriber's set conditions. Consequently, the transmission loss data which have been issued to the Associated Companies regarding losses in common battery conditions involving the 25-type coils apply also to the 94-type coils.

3.2 Coil-to-Coil Crosstalk

Crosstalk between adjacently mounted repeating coils of the new designs of 94-E and 94-F types is lower than for the older designs of these coils and for the 95-type coils and is considerably lower than that between the corresponding 25, 26 and 27-type repeating coils used under similar conditions. An average reduction of from about 40 crosstalk units for 25-A coils to 20 crosstalk units for 94 and 95-type repeating coils was accomplished by adjusting the thickness of the coil case walls involved in the crosstalk exposures. For the new designs of the 94-E and 94-F repeating coils it is expected that the coil-to-coil crosstalk will be reduced to about 5 crosstalk units by using the steel case.

4.0 Signaling Characteristics

4.1 " Non-Ring Through " Characteristics

For practically all purposes a battery supply repeating coil is desired to have a " non-ring through " characteristic at 20 cycles. The 25-type repeating coil has a very low efficiency for the transmission of 20-cycle ringing signals. The 94-type repeating coil is less efficient at 20 cycles than the 25-type coil, and therefore, is better than the 25-A repeating coil from a " non-ring through " standpoint.

4.2 Direct-Current Signaling and Battery Supply

In order that the new coils may operate satisfactorily with standard direct-current signal and battery supply circuits which have been designed for operation with the 25-A repeating coils, approximately the same direct-current resistance requirements are specified for 94-E coils as for 25-A repeating coils. The direct-current resistance of the high windings of the inequality ratio 94-F repeating coil is approximately 8 ohms greater than the resistance of the high winding of the 25-R inequality ratio repeating coil.

The 94-E and 94-F coils are superior to the corresponding 25-type coils from the standpoint of interference with signaling relays resulting from interruptions of the battery current through the windings.

4.3 Signal Tones

The 94-E and 94-F repeating coils have about the same efficiency as the 25-type repeating coils for the transmission of the high tone (460 cycles—check and order tone), low tone (153 cycles—dial and busy tone), and audible ringing signal tone.

5.0 Other Battery Supply Repeating Coils

5.1 Nos. 94-C, 94-D, 95-C and 95-D Repeating Coils

The 94-C, 94-D, 95-C and 95-D repeating coils were designed to have approximately the same transmission characteristics as the 25-type repeating coils. Also, as noted in division 3.1 and except for impedance balance, the transmission characteristics of these coils are practically equivalent to the 94-E and 94-F coils described above.

The Code No. 94 applies to a single coil in an individual mounting and No. 95 to a two-coil combination in a twin mounting. The 94-C and 94-D coils are similar electrically to those of the 95-C and 95-D combinations, respectively. The 94-C and 95-C coils have impedance ratios of the windings of 1 to 1 and the 94-D and 95-D coils have impedance ratios of 1.5 to 1 (trunk to loop winding).

The principal novel feature of these coils was that the overall dimensions were such as to make them suitable for mounting on standard vertical racks and frames in the same manner as relays and condensers, the 95-type coil requiring exactly twice the mounting space as the 94-type coil. This was for the purpose of effecting savings in cabling, cable racks, coil racks, and in installation costs by making it possible to concentrate electrically associated equipment. In order to take full advantage of such equipment savings these coils were designed to mount on 1¾ inch horizontal centers and 3½ inch vertical centers. This made it possible to mount ten single coils per strip on 19½ inch or 32½ inch relay racks in a vertical space equal to that occupied by two relay mounting plates. Also it is possible to mount five single coils in a horizontal position in a vertical space equal to that occupied by one relay mounting plate.

Although these coils were designed primarily for installation on standard relay racks under the conditions noted above, the design is such as to permit the coils to be installed associated with other apparatus in switchboard sections, desks or iron frameworks.

The desirable mounting characteristics above described are obtained by using a rectangularly shaped core built up of silicon steel laminations on which spools having copper windings are assembled. In the 94-C, 94-D, 95-C and 95-D coils short air gaps are used at the junctions of the branches of the magnetic circuit.

The 94 and 95-type coils are interchangeable on the same mounting plate, one 95-type coil employing the same space and drillings as two 94-type coils. The 94-type coil is 1$^{11}/_{16}$ inches wide and the 95-type coil is 3⅜ inches wide. The overall height of the case is 3⅛ inches and its length is 4$^{7}/_{16}$ inches.

Manufacture of the 94-C, 94-D, 95-C and 95-D repeating coils was discontinued when the 94-E, 94-F, 95-E and 95-F repeating coils were made available.

5.2 Nos. 95-E and 95-F Repeating Coils

The 95-E and 95-F repeating coils and the 94-E and 94-F coils were made available at the same time to supersede the 95-C, 95-D, 94-C and 94-D coils respectively. The 95-type coils are all twin mounted arrangements as discussed in division 5.1, the cases for all the coils being alike. In electrical characteristics the 95-E and 95-F coils are similar to the 94-E and 94-F coils. Due to the savings realized for the 94-E and 94-F coils in connection with the punched steel case described in Division 2.1 the 95-E and 95-F coils can no longer be used economically and manufacture is discontinued in favor of the 94-E and 94-F coils.

5.3 Nos. 94-A, 94-B, 95-A and 95-B Repeating Coils

The Nos. 94-A, 94-B, 95-A and 95-B repeating coils are the initial commercial results of the development work on the 94 and 95-type coils and have been used to a limited extent. Structurally these coils are identical to the 94-C, 94-D, 95-C and 95-D coils, respectively, in all details except the magnetic circuit. In the "A" and "B" coils, the core branches come together with butt-joints whereas on the "C" and "D" coils short air-gaps are provided at the junctions.

These coils have the same equipment features and very closely the same transmission characteristics as the 94-C, 94-D, 95-C and 95-D repeating coils, respectively. The principal service difference between these two groups of coils is in respect to their signaling characteristics, the "C" and "D" type coils being better than the "A" and "B" coils from the standpoint of reducing signaling interference. In this matter the "C" and "D" coils are particular satisfactory for the service conditions encountered in 48-volt service and provide a desirable margin over the performance of the "A" and "B" coils in 24-volt service. The 94-A, 94-B, 95-A and 95-B repeating coils were, of course, discontinued when the 94-C, 94-D, 95-C and 95-D coils were made available.

5.4 Nos. 86-A, B, C and D Repeating Coils

These repeating coils are modifications of 25-type repeating coils, and were developed as temporary standards for use on vertical racks and frames in dial system and manual offices, pending completion of the development of the 94 and 95-type repeating coils. This procedure made it possible to secure promptly a large part of the potential economies associated with vertical rack and frame installations of battery supply repeating coils.

The differences between these coils and the standard 25-type repeating coils are solely in the assembly and mounting arrangements. The cases used and mounting arrangements are similar to those subsequently used with the 94-A type coils, the differences being principally in dimensions, the 86-type coils being appreciably larger than the 94-type coils.

The following table gives general data:

Code No.	Impedance Ratio (Trunk to Loop) Windings	Battery Supply Voltage	Electrically Identical to
86-A	1:1	24	½ No. 25-A
86-B	1:1	48	½ No. 25-S
86-C	2:1	24	½ No. 25-R
86-D	2:1	48	½ No. 25-M

The 86-type repeating coils are potted in individual folded sheet-iron cans of rectangular cross-section. The case height is 3$^{13}/_{16}$ inches, width 2$^{1}/_{16}$ inches, and length 3$^{15}/_{16}$ inches. Due to the case width the 86-type coil requires a horizontal mounting space of 2⅛ inches between centers and, therefore, has been used chiefly on panel incoming and district frames. It has also been used on step-by-step toll incoming selectors and to some extent on straightforward trunk units.

The 86-type coils are similar to the 94-type coils in the design features which prevent exudation of coil impregnating compound from the case.

5.5 Nos. 25-A, 25-S, 26-A and 86-B Repeating Coils with Improved Balance

The 25-A, 25-S, 26-A and 86-B repeating coils supplied to the Companies from coils in the Western Electric Company's stock have, for some time, been selected on an impedance unbalance basis to give results when used in unbalanced relay circuits, comparable to the results obtained with 94-type coils as discussed in P.E.L. No 329. The maximum series inductance limits employed for selecting the coils are 4 millihenries for the 25-A and 26-A coils and 2 millihenries for the 25-S and 86-B repeating coils. In order to obtain these results with new coils of these code numbers, the manufacturing specifications have been changed to specify a bifilar winding arrangement. These modified repeating coils retain their same code numbers but are designated by the letter "T." In the case of the 25-A, 25-S and 26-A coils, this letter is stamped on one of the long edges of the wood base and for the 86-B coil the letter is stamped on the end opposite the terminals.

5.6 125-A and 126-A Repeating Coils

In order to further realize upon the manufacturing economies which it has been possible to obtain for the type of coil construction employed for the 94-type coils manufacturing information has been made available for the 125-A and 126-A repeating coils to replace the 25-A and 26-A coils, respectively. The 125-A coil consists of two 94-E repeating coils mounted on a wood base for coil rack mounting and the 126-A coil consists of one 94-E repeating coil mounted in the same manner. The new designs are, of course, mechanically interchangeable with the coils which they replace. Manufacture of the 125-type repeating coils will not be started until repeating coil stock conditions permit.

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MODIFIED 94 TYPE REPEATING COIL