Government of India
Railway Department

(Railway Board)

Control of Railway Traffic Operations

by

Telephone and Teleprinter

with 18 illustrations

by

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Technical Paper No 317

Delhi
Manager of Publications
1945

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New Delhi,
20th April 1 1945.

W. S. BENTON,
Director, Civil Engineering,
Railway Board.

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Sam Hallas, Jan 2010

Control of Railway Traffic Operation by Telephone and Teleprinter

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PREFACE

The writer has prepared the following text with some degree of trepidation. In the first place he has attempted to deal somewhat exhaustively with a subject of primary and vital importance to modern railway operation which, however, has achieved little recognition in printed form. Indeed, a student of railway operation would probably search in vain for text-books on the subject of Train Control.

In the second place he is fully conscious of the temerity of attempting to write on a railway operating subject without due credentials. However, a railway signal engineer, as an onlooker to many facets of railway development and operation, can hardly fail in the course of a lengthy experience, to assimilate some of the inner mysteries of transportation. In any event the writer can justifiably claim to be steeped in railway lore and tradition by family associations which go back, in unbroken succession, to the earliest days of the Great Western Railway. In this work, therefore, he has attempted to use this inborn native intuition to the full rather than to trade on the professional knowledge of a railway signal engineer.

Earlier work of the writer has been criticized on the reasonable grounds that he too frequently used abstruse illusions and words that necessitated constant reference to a compendious dictionary. While this work cannot be covered by the limited vocabulary of Basic English, the text has been prepared with care to avoid technicalities to the greatest possible-extent and with the most simple English, compatible with the subject.

It has been necessary, in certain instances, to quote specific examples from ordinary practice on Indian Railways to illustrate points in the text. The writer craves the indulgence of the Administrations of these Railways and would hasten to add that any inferences to be drawn from these illustrations are certainly not intended to be long-range criticism of existing practice.

The writer's grateful acknowledgements are extended to the Managements and Officers of the British Railways who facilitated his short tour in 1944, by giving him exceptional opportunities of an intensive study of modern Train/ Traffic Control practice in Great Britain.

He also expresses his thanks to the Drawing Office Staff of the Additional Chief Engineer, Posts and Telegraphs Department, for the preparation of Illustrations and to his colleagues who have given him generous assistance in the preparation of this work for the press and he particularly acknowledges his indebtedness to P. Scott Bennett, Esq., Signal Engineer, Oudh and Tirhut Railway, for much helpful criticism, and to Colonel C. M. Scott, O.B.E., Chief Engineer, Posts and Telegraphs Department, Burma, for the period of happy collaboration which greatly helped to lay the original foundations for this work and for the preparation of much of the text and data included in Part III.

New Delhi. H. L. C.
March 1945.

PART III

Design and Operation of Train/ Traffic Control Circuits

CHAPTER XIII

Control Circuit Transmission Problems

112. The following technical information is intended to assist all who are concerned with the maintenance of Train/ Traffic Control circuits. To many, much of this information may not be new, but having regard to the fact that the basic design of one of the principal systems of telephone train control was carried out in the year 1917 and subsequent experience has necessitated few alterations to the original design, it is thought that a brief recapitulation of the design problems which had then to be overcome, may give the younger generation of engineers a more complete appreciation of their problems in maintaining Control circuits.

113. The telephone was first used for "Train Controlling" about the year 1907.. Very little technical information has been published on Train Control Systems.. It will be found that the Manufacturers' Descriptive Bulletins while giving much information on the selective ringing equipment associated with the system, offer little information on the telephone transmission problems overcome in the design of the equipment. These transmission problems are described fully in a paper by Wm. H. Capen of the Engineering Department, Western Electric Company, which he presented at the Annual Convention of the Telegraph and Telephone Section of the American Railway Association on September 19, 1923. The title of the paper was "Recent Developments in Telephone Equipment for Train Dispatching Circuits", and it describes the design work which led to the successful installation in America of the new type of train control system in October 1917. The help obtained from this paper in compiling these notes is gratefully acknowledged.

114. A satisfactory train control system must provide

a) A circuit with a maximum transmission equivalent to. the most distant: station of about 20 decibels. (See explanation of transmission equivalent at the end of paragraph 115).

b) A fool-proof selective ringing device from a control centre.

c) Satisfactory telephone communication between the Controller and any one way-station, any group of way-stations or all way-stations on the section controlled. .

d) Facilities for any way-station to call the Controller or to call any other way-station on the section through the Controller.

115. In regard to (a) above the original designers of the control system surveyed a number of controls then existing in the United States of America from a purely operational point of view and it was considered that a circuit with a grade of transmission of about 19 decibels gave satisfactory. operating conditions which imposed no strain on the operating staff. Allowing for the greater efficiency of present day transmitters and receivers it is considered that it would be reasonable to permit a degrading of control circuits to 22 decibels, without affecting operating conditions in India.

(Transmission equivalent or level is a measure of the ratio of the power at any point in a transmission line to the transmitted power. This measure is expressed in decibels. The decibel ratio is expressed by the relation

$$\text{Decibels} = 10 \log_{10} \times \frac{\text{Power Transmitted}}{\text{Power Received}}$$

The decrease in magnitude of the transmitted power, due to line or apparatus losses is known as attenuation and is expressed in decibels.)

116. In regard to condition (b) one of the Manufacturers' Descriptive Bulletins gives all the information required and up-to-date copies of these Bulletins are available from the Manager, Standard Telephones and Cables, Ltd., Calcutta. From the telephone transmission point of view it is to be noted that the ringing selector must always remain bridged across the line, ready to receive the code ring from the Controller. However, it will be noted from the Bulletins that "the coils of the selector are wound to 21,000 ohms resistance and are tuned to 3½ cycles per second by a condenser in the selector set." (The frequency of the ringing impulses is 3½ cycles per second). The impedance of the selector at 3½ cycles per second is 35,000 ohms, and the impedance at 800 cycles per second (i.e. the basic or mean speech frequency) is over 1 megohm. The loss to speech due to the selectors is, therefore, invariably considerably less than the loss due to line leakage.

117. From the telephone transmission point of view this is important. It can be assumed that for all practical purposes the losses to speech transmission caused by the selectors bridging the line may be neglected. This was done by the designers in 1917 who assumed "that the loss introduced by the selectors was negligible". It will be appreciated, however, that if any component of a selector is allowed to deteriorate or is replaced by one which alters the overall impedance characteristics of the selector, a definite defect has been introduced in the circuit, which will affect its whole operation.

118. To satisfy condition 3(c) was more difficult. Under actual working conditions there is no way of limiting the number of way-stations which may be listening on the section control at any time. The designers, therefore, assumed the worst condition with all stations listening. They also chose a section control of No. 9 American Wire Gauge, Copper Wire, 250 miles long with 40 way-stations as a typical control circuit of that period. (No. 9 AWG with the American type of line construction is roughly equivalent to 200 lbs. per mile copper wire with 12 inch wire spacing as used by the Indian Posts and Telegraphs Department). The problem to be solved was to find a bridging impedance for the way-station telephone, which with forty of them evenly spaced along the 250 miles control circuit, would produce the minimum loss at 800 cycles through the circuit up to the fortieth impedance and still leave sufficient power available at the end of the circuit to be converted to sound in a receiver. By calculation and experiment this was found to be approximately an impedance of 7500 $\angle 70°$. (This represents an impedance with a small resistance component and a large inductive component). This impedance included a 1/2 m.f. condenser in series with the bridging induction coil in order to keep down the loss of the low frequency ringing selector currents.

119. Having arrived at a suitable impedance for the way-station instrument and constructed a telephone set with these characteristics, it was found by test that unequally spaced way-stations did affect the transmission loss along the line but not to an extent which made any alteration in the impedance design necessary. It was also confirmed that transmission from the most distant way-station to the Controller was satisfactory, and also that communication between the Controller and intermediate way-stations was efficient.

120. It was found that for a circuit longer than 200 miles the number of way-station telephones with an impedance of 7500 $\angle 70°$ at 800 cycles bridged across the line had little effect on the, overall transmission loss on the circuit. In fact, an increase in the number of way-stations from ten to fifty evenly spaced on a 200 miles long circuit gives an average loss per way-station of only 0.08 decibels for fifty way-stations in circuit. For lines shorter than 200 miles the decibel loss per way-station is very variable. It depends on the length of the line and on the number of way-stations and on the spacing of the way-stations. The worst conditions occur on a line about 100 miles long when the average loss per way-station is about 0. 5 decibels. Figs. 14 and 15 graphically illustrate these transmission conditions.

121. In general terms, the decibel loss per way-station is so low that the factor limiting the number of way-stations on a control circuit of average length, say 180 loop miles of 2001b. per mile copper in India, is not the transmission loss introduced by these way-stations, but the. traffic operating load imposed on the Controller by this number of way-stations.

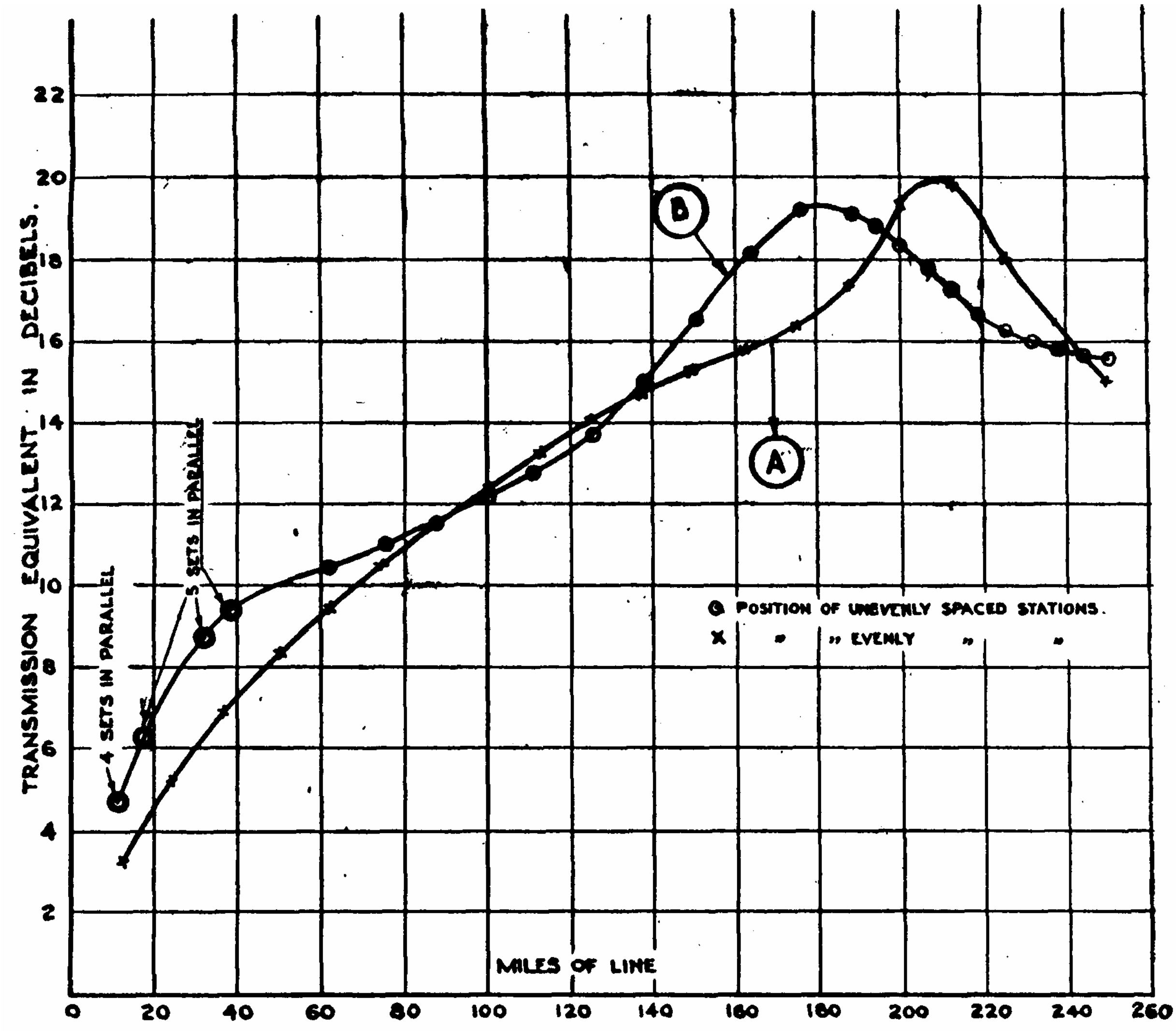

Fig 14 Transmission equivalent of typical control circuits

Curve A shows variations of transmission equivalent for 40 way-stations evenly spaced along the line.

Curve B shows variations of transmission equivalent for 40 way-stations unevenly spaced along the line.

Line under test - 250 miles. No. 9 A.W.G. Copper. Test frequency 800 cycles.

122. Figure 15 on the next page shows theoretical circuit loss curves for evenly spaced way-stations on a No. 9 A.W.G. copper line. It is of technical interest to note that, for a particular length of line, a certain critical number of way-stations of the designed impedances when evenly spaced, produced minimum overall loss in the circuit. For example, 40 way-stations involved a loss of about 9.5 decibels over 160 miles of No. 9 A.W.G., while the same number of way-stations caused a loss of 13.5 decibels over a similar circuit 65 miles long, and a loss of 13 decibels over a circuit 250 miles long. Similarly 30 way-stations evenly spaced produced minimum loss. on a line 120 miles long, and 50 way-stations minimum loss on a line 200 miles long.

123. From these results it will be noted that if the way-stations happen to be evenly spaced at 4 miles intervals throughout a control circuit the best transmission conditions are obtained. This is explained by the fact that the telephone bridging impedances load the aerial line and, theoretically, it can be shown that spacing of 4 miles produces the maximum loading effect on a No. 9 A.W.G. open wire copper line.

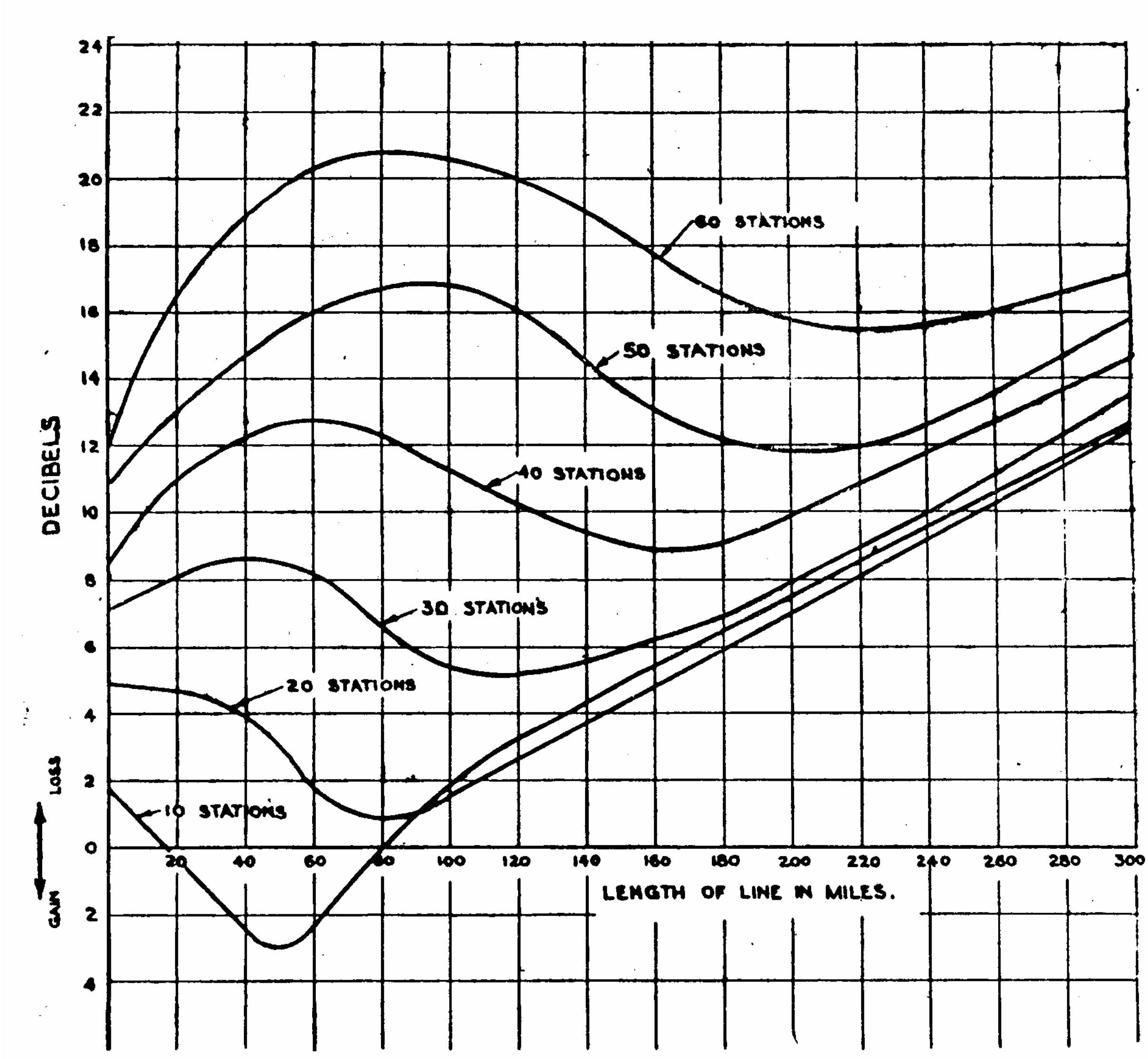

Fig. 15. Theoretical Circuit Loss Curves. Evenly spaced way-stations on a 9 A.W.G. Copper line (Non-loaded)

124. The foregoing explains why it is observed sometimes in practice that when efforts are made to improve a control circuit by shortening the length controlled without materially reducing the number of way-stations, the anticipated improvement in transmission may not be obtained; in fact the overall transmission loss may increase.

125. Reverting to Fig. 14 it will be noticed that the transmission equivalent in each curve rises to a peak at a point about 180 to 200 miles from the controlling point and the transmission equivalent beyond this actually decreases. This apparently abnormal result is due to reflection from the end of the circuit. It has been noted previously that both the selector and the telephone bridging impedances have a high value at 800 cycles per second. They are also high in comparison with the characteristic impedance of the open, wire line which is approximately 650 ohms. At the last way-station on the line, therefore, the line is practically open-circuited notwithstanding the impedance bridged across it.

126. It is suggested that on circuits longer than 200 miles where this reflection is marked, the open wire line should be terminated with its characteristic impedance of 650w so that the transmission loss curve is smoothed out at the distant end. An improvement of two or three decibels in the transmission loss up to the way-stations near the distant end may be obtained in this way. To avoid losses to ringing selector currents it would be necessary to connect a 1 m.f. condenser in series with the resistance of 650 ohms.

CHAPTER XIV

Control Telephone Design

127. The principal operating and technical requirements affecting the design of a way-station control telephone are as follows -

(a) There should be a ‘Listen and Speak’ key. In the ‘Listen’ position the transmitter should be disconnected.

(b) The circuit should have good ‘Break-in’ efficiency. - That is, the side tone in the way-station receiver should not drown incoming speech from the controller, who can therefore cut in.

(c) When the ‘Speak’ key is operated, the transmitting circuit should be arranged for maximum efficiency.

(d) The receiver and the transmitter must be insulated from the line by an induction coil.

(e) The impedance in the ‘Receive’ or ‘Listen’ position of the key, must be as close as practicable to the desired theoretical value of 7500 $\angle 70°$.

128. The way-station control telephone circuit is shown in Fig. 16 below. When the receiver is hung up the primary of the induction coil remains bridged across the line in series with the 0.25 m.f. condenser. In this condition the secondary of the induction coil is not in circuit and the bridging impedance is slightly higher, than 7500 $\angle 70°$. This produces less loss at a way-station not “listening” and improves transmission to way-stations which may be listening. When the receiver is removed to listen, the listen circuit is arranged for maximum efficiency, and this combined circuit most nearly simulates the theoretical impedance of 7500 $\angle 70°$.

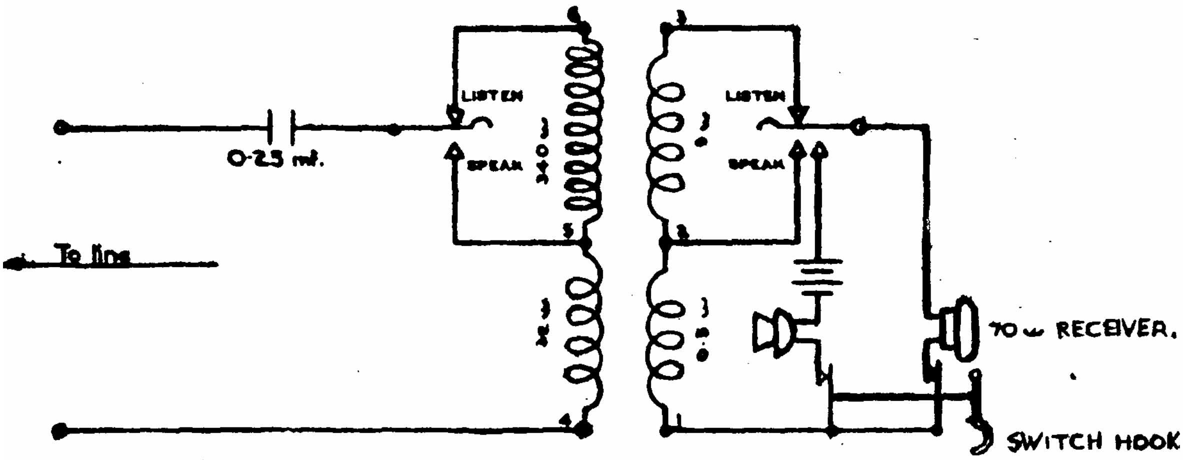

Fig. 16. Way-station Control Telephone Circuit

129. It is necessary to impress on all traffic staff who use the control circuit, that, when listening the circuit should be in the “listen” condition, i.e. the ‘Speak’ key should not be operated. It is realized that in an ordinary conversation it causes a certain inconvenience to keep on releasing the ‘Speak’ key when the controller is talking to the way-station, but practice should make the operation instinctive.

130. When the operator at the way-station wishes to speak to the Controller; the ‘Speak’ key alters the circuit to provide a high transmission efficiency into the line. It will be seen that the ratio of the turns in the induction coil is changed. At the same time the transmitter battery circuit is closed. Maintenance engineers do not have to be reminded to impress on the traffic staff using the control equipment, that unnecessary operation of the ‘Speak’ key, e.g. when the Controller is dictating a message, not only reduces the listening efficiency of the circuit, but drains the transmitter battery unnecessarily.

131. When the circuit is arranged for “Speaking” the receiver is bridged directly across the transmitter winding of the induction coil (Secondary). This is necessary to give the `break-in' efficiency mentioned in paragraph 127(b). The impedance of the receiver is relatively high compared to that of the transmitter coil winding so that no serious loss of transmission occurs, but the side-tone is unavoidably greater than is to be found in telephones fitted with anti-side-tone circuits. This side-tone imposes little strain on the operator at the way-station as he is not using the telephone continuously.

131. The Controller’s telephone set differs from the way-station control telephone and is designed to give both the maximum practicable transmission and receiving efficiency. The “break-in” efficiency. must be as high as possible in order that when a Controller is talking to a way-station, the side-tone in his receiver will not drown speech from a distant station who may require to impart urgent information. While the side-tone must be sufficient to enable the Controller's own speech to sound natural, it should be sufficiently low to prevent amplification of extraneous room noises or otherwise impose a strain on the Controller.

132. The circuit employed for the Controller’s telephone set is shown in Fig. 17 below. It incorporates an anti-side tone device. This circuit has a transmitting efficiency approximately 2 decibels less than the way-station control telephone, but the receiving efficiency is approximately 6 decibels better than the way-station control telephone in the “Speak” condition.

133. Maintenance engineers will appreciate that since way-station sets and Controllers’ sets have been specially designed for the service required of them, no alterations to their circuits or components can be made without the risk of causing serious deterioration in the operation of the control system. It is realized that during the war, when it has been difficult to obtain spare components for maintenance purposes, temporary expedients may have been made, pending replacement by standard components when this becomes possible.

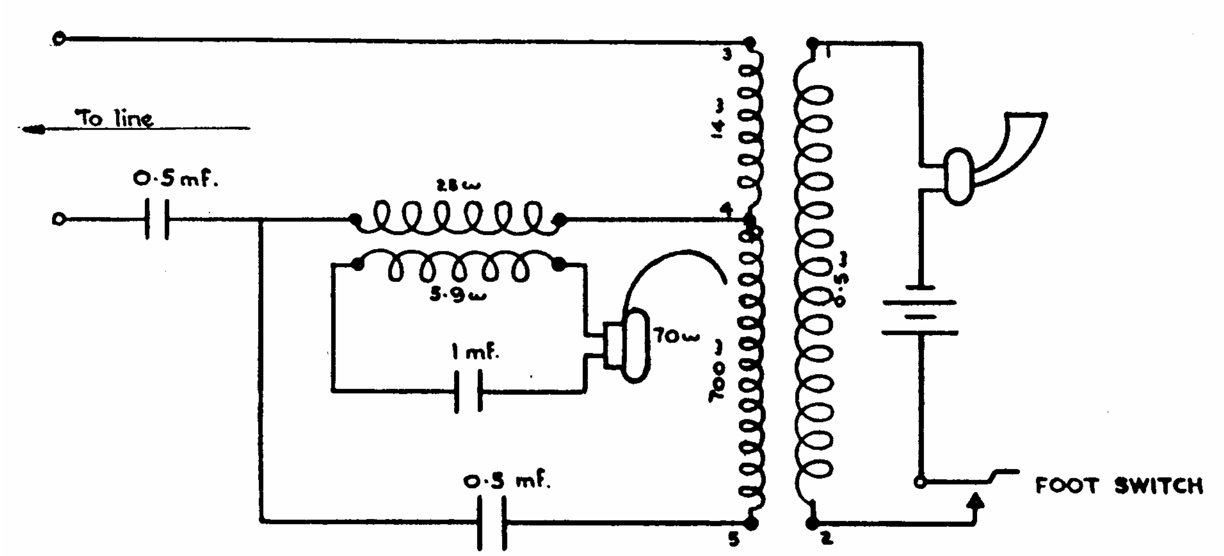

Fig. 17. Controller's Telephone Circuit

CHAPTER XV

Train/ Traffic Control Circuits

134. The planning of individual Train/ Traffic Control circuits requires careful consideration. From some of the data given in Chapter XIII it has been shown that it is not easy to predict the effect on overall transmission of a required number of way-stations on a certain length of line, more particularly if these way-stations are at irregular spacing. It is equally difficult to predict the effect which abnormal grouping or bunching of way-stations will produce on a line. Additional complications may accrue if branches, several miles in length, are combined with the main circuit (particularly if these branches are 'T' connected) or if sections of cable are inserted in the circuit without due regard to loading.

135. From its fundamental design, it is desirable that a control circuit should be controlled from one end. Attempts to control circuits from intermediate points or to incorporate long branches to the main circuit may meet with little success. In India, a number of cases of abnormal but comparatively short Control circuits do operate with fairly satisfactory results but it may be remarked that there are other abnormally arranged Control circuits which do not operate satisfactorily.

136. Unless adventitious assistance in the form of a terminal repeater or amplifier is provided the total permissible overall length of a Control circuit, if the transmission loss is limited to 22 decibels, will be governed by the decibel loss due to (a) line resistance and capacitance between the two conductors and (b) way-stations.

137. Taking an average number of way-stations as 40 and the average loss per way station as 0.1 decibels, the permissible length of a Control circuit would be as follows -

Circuit	Attenuation Decibel/ Mile	Way-Station losses.	Permissible length.
200 lb. per mile copper	.064	4 db.	281 miles.
300 lb. per mile copper	.044	4 db.	409 miles.

138. On Indian Railways it has not always been found possible to limit the overall length of Control circuits to the permissible lengths suggested in the previous paragraph. As an operating facility it was found convenient to centralize the control circuits of a District/ Division for operation from a main Control office. In many instances this involved the practice of linking an outlying control circuit to the central control office by trunk lines, frequently of considerable length.

139. There are technical objections to the use of trunk connections to an outlying circuit which may be briefly stated as follows:-

(a) Transmission losses which occur on the trunk portion of the circuit added to the losses of the outlying "controlled" section of the circuit frequently cause the overall transmission loss to exceed 22 decibels.
(b) Trunk lines necessarily increase risk of interruption and if failure occurs at any point in the trunk line section the entire section control circuit in automatically suspended. In such a case there is no opportunity of cutting out the faulty section and continuing control working with a portion of the circuit suspended.
(c) Unlike a section control where switches are provided at each station and the localisation of failure is a precise and simple operation, trunk lines are only provided with testing points at long intervals, say of 25 miles, making localisation of a failure only very approximate, inevitably resulting in longer duration of failures.
(d) Signalling (i.e. ringing and selector operation) batteries have to be increased to cover the increased resistance added by trunk lines.

140. In order to overcome these marked disadvantages several of the Indian Railways have adopted the policy of Control decentralisation where this has been found necessary. Detached Control offices are provided at suitable locations from which radiate compact and comparatively short Control circuits covering only the actual routes controlled, and in order to maintain administrative control between the outlying Control office and the District/ Divisional Headquarters Office, a separate telephone circuit is provided.

141. In certain cases, where decentralisation is found to be impracticable for special reasons, an improvement in the operation of a long trunk-linked Control circuit can be effected by the provision of a standard telephone repeater installed at the Controller's end of the circuit as a 2 wire/ 4 wire terminal repeater, the arrangement being shown diagrammatically in Fig. 18 below.

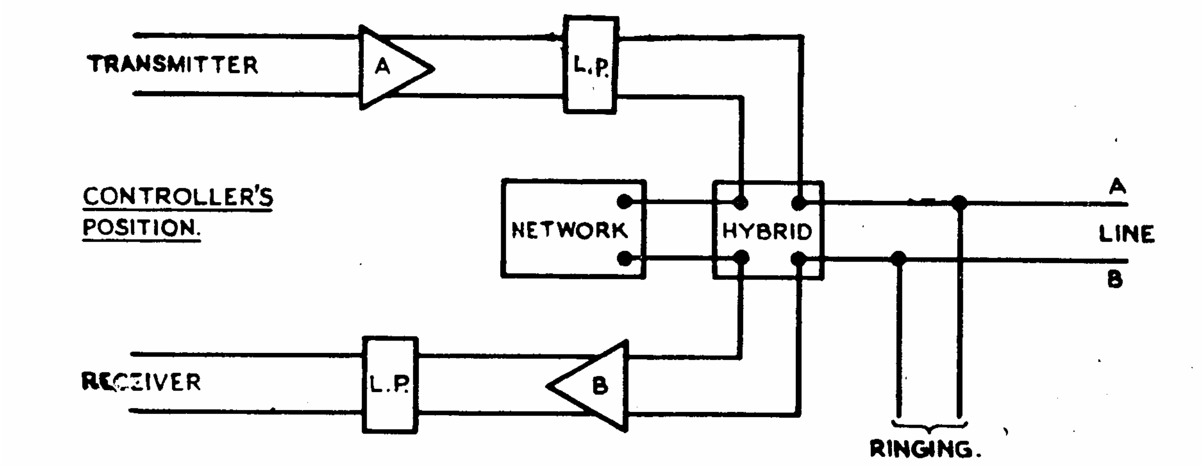

Fig. 18. 2 wire/ 4 wire Terminal Repeater

142. It may be emphasized that a correctly designed and installed Control circuit of reasonable length should not normally require the installation of a repeater to overcome line transmission losses. Abnormal transmission losses may be due to defective way-station equipment which should be eliminated by careful testing with suitable transmission loss measuring equipment.

143. The introduction of intermediate telephone repeaters to Control circuit operation is a new departure which is still in an experimental stage. Until further data is available the writer is chary of advancing an opinion on the successful practicability of the development though it would seem, from analogous telephone practice, that there should be no insurmountable difficulty in linking two adjacent Control circuits by an intermediate 2-wire repeater for end-to-end speech.

Train Control Circuits in large yards

144 In large station yards with a complicated line network of telephone, telegraph, block and Control circuits linking various cabins and offices there is a risk of frequent line faults particularly in the nesting season when odd pieces of wire, &c. found too frequently in larger yards, are picked up and dropped on the open wire lines by birds. Much can be done to eliminate those faults by simplifying the line networks. It is clear that the greater the length of a circuit in a railway yard the greater is the risk of faults developing and vice versa.

145. In the case of a control office situated at a large headquarters, the outgoing line wires are generally looped into several cabins and offices before reaching the “open line”. In the other words the circuit has to run the gauntlet of the “vulnerable area” and any fault occurring within that area will automatically involve suspension of working of the entire circuit.

146. Where practicable, it is desirable that a control circuit should proceed direct from the control office to the “open line”, the local offices and cabins being connected to the control office by a subsidiary loop. In this case should a fault occur in the complicated network of the subsidiary loop, only work on this loop will be suspended, the main control circuit being unaffected. It is realised that this means an increase in the total mileage of control

line for which rent is aid but this increase will generally be small. The length of wire in the main circuit where it passes through the vulnerable area is reduced.

147. A control circuit entering a large station area should invariably be led direct into the cabin or office of most importance from the point of view of train controlling. The circuit should then proceed to cabins and offices of lesser importance which can be cut off if a fault develops beyond the main cabin or office, thus keeping the main circuit working between the control office and the most important cabin or office.

Conclusion

148. On most Indian Railways the line wires for Control circuits are provided and maintained by the Indian Posts and Telegraphs Department, while the office and way-station equipment is provided and maintained by the Railways. Experience has all too frequently shown that if line wires and office equipment are treated as two separate responsibilities, there has been a constant tendency, in the past, on the part of the two authorities, to blame each other for unsatisfactory operation. It is quite certain that unless the staff of each Department, i.e., Railways and Indian Posts and Telegraphs, can regard a control circuit as an entity; a complete electrical device in the efficient operation of which they are as keenly interested as their colleagues in the other Department, really efficient maintenance of Control circuits cannot be attained. The writer urges the utmost degree of liaison and collaboration between the officials of the Railways and the Indian Posts and Telegraphs Department to this worthy end.