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Paper 39

Signalling Equipment (Siemens and General Electric Railway Signal Co., Ltd)

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1. Factors and Considerations influencing the Company's Equipment Design

When design investigations were first started very little was known of the actual level of 50 cycle energy – and harmonics thereof – which might arise within a signalling system. It was realised that for many pieces of equipment there were likely to be three significant levels of effect by A.C. interference:

1.1 *A level below which no change from normal performance occurs, whether the components are in the energised or de-energised state.* For example in a D.C. relay in this category neither pick-up nor release values would be changed by the superimposed 50 cycle energy, nor would it vibrate or show any other unusual effects.

1.2 *A level above that of* (1.1) *in which the component is effected, but not so seriously as to endanger either it or the system in which it works.* For example a relay coil may rise in temperature as a result of eddy currents in the copper slugs with which it is provided, and D.C. pick-up and release values may be changed, but in no case in this category would the coil burn out, nor would the operating and releasing figure be so modified that there would be a danger of non-release, or false energisation.

1.3 *An inadmissible level, characterised by failure to operate in a normal manner, to become over-heated or to burn-out, or to vibrate or chatter so badly as to effect operation or life.* The object of the Company's design work was to ensure that as far as possible equipment would operate under condition 1.1 in all normal circumstances, and only move into the second level of effect under abnormal condition of traction load. Some means had to be found to exclude the possibility of effects as violent as category 1.3 above. The use of high voltage gas-discharge surge arrestors in combination with fuses was considered to a limited extent to be acceptable as a means to this end.

2. Importance of the Track Circuit

It was expected that in the Track Circuit the greatest liability to interference by 50 cycle energy would arise because the rails form a common conductor for the signalling current and the whole of the traction current of a train which runs on them and, to a less extent, for traction currents of more distant trains. The greater proportion of development work then, has been concerned with track circuits. Three types to meet the several requirements were evolved as described hereunder.

3. D.C. Track Circuit Equipment for use in 50 cycle traction areas which are free from D.C. Traction, or Earth Currents (see fig.1 and Table 1)

Protection is afforded by the inclusion of choking coils in the connections to the rails at both ends of the section. The chokes are tapped so that alternative values of inductance and saturation levels may be selected. For most purposes the whole winding is used, but circumstances do arise where a tapping offers a better compromise. For example when a track relay of abnormally low coil resistance is used on a track circuit with heavy ballast leakage fewer turns are required on the choke to ensure a given level of immunity. The track relay is provided with a magnetic circuit which is protected by solid copper slugs. Any alternating flux set up in the iron circuit is largely balanced by counter flux produced by eddy currents circulating in the slugs, and much of what remains is diverted to flow in a path which does not include the armature.

At the feed end of the track circuit the choke protects the feed rectifier from high levels of traction voltage-drop and, for normal levels, it limits rectification of this energy which would otherwise augment the D.C. feed current and reduce the detection sensitivity of the track circuit.

Fuses of high rupturing capacity are inserted in the connections at both ends of the track and, on the side of these remote from the rails, a gas discharge tube is bridged across. In the event of a traction current surge producing a large potential the current is diverted whilst the fuses blow.

With tracks which possess the usual range of ballast resistances the greatest length of section for which this method can be employed is determined by the traction voltage drop which occurs for peak loads with the particular system of rail bonding and traction-return circuit employed. So far it has been limited on British Railways to about 500 yards. The effect of various levels of A.C. voltage drop upon this equipment is shown in Table 2.

Number of Track Circuits of this type installed .. 580
Number of Track Circuits of this type being installed 617

4. A.C. Track Circuit Equipment Immune to D.C. currents as well as to 50 cycle Traction Currents. Single Rail (see fig.2 and Table 2)

The need arose for this method at Liverpool St. and at Fenchurch St. for example, because of the necessity to install and operate the system whilst D.C. Traction was in use and for it to continue in work after conversion to A.C. Traction. This track circuit employs, to the full, the inherent advantage which the Double-element Vane Type relay offers by the necessity of there being a proper relationship in frequency and phase of the currents fed to the two elements before operation can occur. Such a relay can give equal protection against A.C. currents of non-signalling frequency as it gives against D.C. traction currents. Provided any interfering frequency in the control element differs by some 5 to 10 cycles per second from the frequency of the current in the local element no progressive movement of the vane results, and, at the most, some vibratory movement occurs.

The supply to the local coil of the relay is carried in screened cables and monitored at the distribution point to give an alarm if more than a very low level of potential at traction frequency appears in this 'pure' supply. The requirement that there shall be more than 10 cycles per second difference between the signalling current frequency and that of the traction current, and the principle harmonics thereof, is met by the use of a signalling current of $83\frac{1}{3}$ cycles per second. To prevent traction currents saturating the magnetic circuits of the relay, and thereby causing the relay to fall, a tuned filter circuit is included in the connection of the relay to the rails. The filter is tuned to pass $83\frac{1}{3}$ cycle current to the control coil of the relay, but to reject currents of other frequency.

As with the D.C. track circuit previously described, surge arrestors and fuses are provided at the track connections.

Number of Track Circuits of the type installed and working 428
Number of Track Circuits of the type in course of installing 26

5. A.C. Track Circuit Equipment Immune to D.C. currents as well as to 50 cycles Traction Currents. Double Rail (see fig.3 and Table 1)

The same basic arrangement is used on single-rail and on double-rail track circuits, but impedance bonds are added in the latter case. The system will operate equally well as the simpler 50 cycle track circuits hitherto used in D.C. traction areas, and remains relatively unaffected by traction currents of several hundred amperes equally shared by the two rails.

The impedance bonds used are tuned by a capacitance applied to a secondary winding; the effective rail-to-rail impedance to currents of signalling frequency being increased thereby several-fold. Control of the reactive parameter toward the inductive, or the capacitive, is achieved by the same arrangement to maintain the control current in the relay in correct phase relationship with the current in the local coils. By this means also compensation for changes in impedance of the bonds arising from the levels of magnetisation resulting from any unbalance of traction currents flowing therein is largely secured.

Number of Track Circuits of this type installed and working 196
Number of Track Circuits of this type in course of installation .. .. Nil

6. Immunisation of other Signalling Components

The remaining problems which had to be solved related to the protection or immunisation of D.C. Line Relays, D.C. Searchlight Signals, Point Machines, Point Contactors, Banner Signals, D.C. Solenoids and Solenoid Valves of Electro-pneumatic Point Apparatus, etc.

The simple slugging of solenoid cores has proved an effective method for some purposes, but the addition of a series choke raises the immunity of a slugged solenoid device by four or five times. The inclusion in the operating circuit of the resistance of the series choke winding has required the use of a slightly lower resistance solenoid coil to restore the D.C. ampere turns to the original value.

Special care in design was required to avoid damage from the heating of slugs and cores by eddy currents which circulate when A.C. currents flow through the operating windings. The design and manufacture of choking coils for immunisation purposes also called for care to minimise the possibility of breakdown, or short-circuiting of turns. Table 2 shows the extent to which the application of techniques just described has affected the immunity factor of some common signalling components supplied by the Company.

7. Utilisation of Existing Equipment

Wherever possible, existing equipment was retained in installations to be converted. Where this intention involved a compromise between overall saving of cost and efficiency of operation, a programme of bench tests was instituted to assess overall advantages of the alternatives.

The two items of greatest importance in this respect were (*a*) Impedance Bonds, (*b*) Double Element Track Relays, Double Element Line Relays and Three Position Point Detection Relays. At Liverpool St. and Fenchurch St. (to mention only two cases), a great many of each of these components were in operation. Originally produced for working on a 50 cycle signalling supply they had to be made suitable for $83\frac{1}{3}$ cycles; also whilst they would have to withstand the D.C. traction components for some months they would thereafter be subject to 50 cycle traction currents.

Impedance Bonds

Experiment showed that apart from the anticipated reduction in the setting of the tuning capacitor the existing bonds would be satisfactory, and they have so proved. Additional new bonds have been supplied where necessary and these were also suitable for working initially with the D.C. Traction Current and later with 50 cycle Traction Current.

Double Element Relays (*of all types*)

In most cases it was necessary to rewind one element only. This had the effect of shifting the balance of energies allocated to the control element and local element, but resulted in no significant change in the release to pick-up ratio, the heating of coils or vane, or other characteristics, merely restoring the operating figure to 110V at $83\frac{1}{3}$ cycles, or appropriately according to type.

Special study was made of mechanical vibrations induced in the component parts of each type of relay under the new frequency, and where necessary steps were taken to eliminate undesirable effects.

8. Aids to Electrical Adjustments on Site

Considerable use was made of the S.G.E. A.C. Track Circuit Test Set. A photograph (fig.4) shows one such instrument. It combines a multi-range voltmeter with movable scales by which observed values can be instantly triangulated and the phase relationship of two voltages read-off. Two multi-position switches are incorporated—one to select the required voltmeter range, the other to apply the meter to either circuit A (usually the local coil of a relay), or circuit B (usually the control coil of a relay), and in a third position it connects the meter to indicate the vectorial sum of the separate voltages. The required information is then derived by the manipulation of the movable scales which apply, in a simple way, the process of phase angle determination by the 'Three Voltmeter' principle.

An advantage of this instrument is that it enables all the information required for the assessment of working conditions to be read off on the one instrument namely: (*a*) Local Voltage, (*b*) Control Voltage, (*c*) Phase relationship of these.

Table 1

Effects of various methods of immunisation against 50 cycle currents upon S.G.E. equipment commonly employed in signalling systems and approximate quantities of each used in modernisation projects

		50 Cycle Voltage* which may be applied to the Piece of Equipment without risk of damage, excessive chatter or wrongful operation. (Wattage figures show normal operating energies to produce the same degree of energisation in each case.)						Approximate Number of the Appropriate type (Columns C, D or E) involved in the Company's undertakings for British Railways Modernisation and Conversion Schemes so far; (See Key below)	
A *Item*	B *Description*	C *Non-Immunised Form*		D *Immunised by Slugs and Magnetic Shunt Paths*		E *Increased Immunity by addition of series chokes to D*		F *Already Installed*	G *To be Installed*
		Volts A.C.	Watts D.C.	Volts A.C.	Watts D.C.	Volts A.C.	Watts D.C.		
1	Track relay 2 coil 9 ohms	30	0·115	250	0·18	>450	0·22	261 on ER1, 319 on SC1 } As Col. E	309 on ER6, 311 on ER8 } As Col. E
2	Lever Locks and Circuit Controllers	250	5·75	>800	6·2	—	—	195 on ER1, 12 on ER4, 6 on ER5, 424 on SC1 } As Col D	119 on ER6 As Column D
3	Gravity Lever Locks	370	5·3	—	—	>750	8·6	36 on ER1, 7 on ER2, 33 on ER3, 10 on SC1 } As Col. E	44 on ER6, 10 on ER7, 9 on ER8, 100 on LM1 } As Col. E
4	Banner Signals 24V	250	6·1	400	8·0	750–900	12·0	Banner signals employed are of 110V input, self immune to 1,100V as Col. C	
5	D.C. Searchlight Signals 110V	>900	0·580	—	—	—	—		
6	D.C. Searchlight Signals 24V	200	0·575	—	—	>1,000	1·02	75 on ER1, 2 on SC1 } As Col. D	106 on ER6, 105 on ER8 } As Col D

Key to Columns F and G

ER1 Eastern Region, Colchester/Clacton.
ER2 Eastern Region, Shenfield/Chelmsford.
ER3 Eastern Region, Shenfield/Southend.
ER4 Eastern Region, Liverpool St./Bethnal Grn.
ER5 Eastern Region, Fenchurch St./Bow Jnc.
ER6 Eastern Region, Tilbury Loop.
ER7 Eastern Region, Stepney East.
ER8 Eastern Region, Chelmsford/Colchester.
SC1 Scottish Region, Airdrie/Kelvinhaugh.
LM1 Midland Region, Bletchley.

*Note A.C. voltage figures given are R.M.S. values for steady energies and peak values of transient impulses.

Table 2

General effects of 50 cycle Traction Current on Track Circuits described 3, 4 and 5.

Track Circuit type	*Traction Voltage drop over the length of the common rail**	*Effects*
	Up to 100V approx.	No change in Performance
	Above 150V	Moderate changes in detection sensitivity
	Above 250V	Breakdown of gas discharge devices, blowing of fuses and isolation of relay from rails
Single Rail D.C. fed (See 3)	Up to 400V and assuming fuses fail to blow	(a) *With Section occupied at any point* Relay remains unoperated (b) *With Section Clear* Relay remains energised but releases upon the application of a Test Shunt > 0·2 ohms across rails
Single Rail A.C. $83\frac{1}{3}$ cycles (See 4)	Up to 60V	Sensitivity increases
	Above 100V	
	(1) Momentary	No effect
	(2) Sustained	Fuses blow and relay releases
Double Rail A.C. $83\frac{1}{3}$ cycles (See 5)	Up to 50 amperes unbalance of current in the two rails	No effect
	Traction current in one rail only (broken rail condition)	Relay releases when breakage occurs, fuses blow if voltage drop over intact rail exceeds 250

* Figures shown are to be taken as R.M.S. values for steady energies or peak values for transient conditions.

SUMMARY

The paper treats with the three forms of 50 cycle-immune track circuits employed by the Company in work so far undertaken, and also briefly refers to measures taken to protect other components of the signalling system. A D.C.-fed track circuit with protection applied at both ends of the section is described. Single rail and double rail track circuits using $83\frac{1}{3}$ cycle signalling current and double element relays are also described. The effect of moderate and heavy levels of 50 cycle energy upon each type of track circuit is discussed. Preference is shown for a capacitive, rather than a resistive feed, for the track circuits using separate in-phase $83\frac{1}{3}$ cycle supplies for track feeds and relay local coils. If necessary (to facilitate interworking with supplies employed by other manufacturers' equipment at system boundaries) the equipment is easily arranged to operate with supplies in quadrature. The S.G.E. phase-angle measuring instrument is described. It enables rapid assessment of phase-relationship between local and control currents in double element relay circuits, at the same time making available the R.M.S. voltage values of the two components.

RÉSUMÉ

On décrit les trois types de circuits de voie pour 50 Hz qui sont insensibles aux courants de traction et employés par la S.G.E. dans le travail réalisé jusqu'ici, et on discute brièvement les mesures prises pour protéger d'autres éléments du système de signalisation. On décrit également un circuit de voie alimenté en courant continu et protégé aux deux extrémités, des circuits de voie isolés sur une file de rails et sur deux files de rails dans lesquels on emploie le courant de signalisation à $83\frac{1}{3}$ Hz et des relais à élément double, l'effet exercé sur chaque type de circuit de voie par les niveaux moyens et élevés de l'énergie provenant des circuits 50 Hz. Pour les circuits dans lesquels on emploie pour les voies et pour les bobines des relais locaux une alimentation indépendante 83,3 Hz de même phase, on préconise l'alimentation capacitive plutôt que l'alimentation résistive. On fait remarquer qu'il serait facile d'installer l'équipement de manière à assurer son fonctionnement en quadrature de phase avec le courant d'alimentation de l'équipement éventuellement monté par d'autres fabricants et situé sur les lignes de démarcation entre les différents systèmes (si cela s'avérait nécessaire pour faciliter leur fonctionnement simultané). On décrit, en outre, l'instrument construit par la S.G.E. pour mesurer les angles de déphasage, instrument qui constitue, en effet, un moyen de déterminer rapidement la phase entre les courants locaux et les courants de commande dans les circuits à relais à élément double, tout en permettant de disposer de la valeur efficace des tensions des deux composantes.

ZUSAMMENFASSUNG

Dieser Bericht beschreibt die drei gegen 50 Hz immunen Gleisstromkreise, die in den von diesem Unternehmen bisher gebauten Anlagen zur Anwendung kamen, wobei auch die zum Schutz von anderen Teilen des Signalsystems getroffenen Massnahmen kurz berührt werden. Ein an beiden Enden geschützter, mit Gleichstrom gespeister Gleisstromkreis, sowie einschienige—und zweischienige Gleisstromkreise für $83\frac{1}{3}$ Hz Signalstrom und Doppelelementrelais werden beschrieben. Der Einfluss von niedrigen oder hohen 50 Hz Strömen auf die verschiedenartigen Gleisstromkreise wird diskutiert. Werden die Gleisstromkreise und die Ortsrelaissputen an unabhängig phasengleiche $83\frac{1}{3}$ Hz Speisung angelegt, so ist die kapazitive—der Widerstandsspeisung vorzuziehen. Wenn nötig (um das Zusammenwirken an Stosstellen mit Stromversorgungen für Anlagen anderer Herkunft zu gewährleisten) kann die Anlage leicht so angeordnet werden dass sie mit Speisungen in Quadratur arbeitet. Das von der S.G.E. entwickelte Instrument zur Messung des Phasenverschiebungswinkels wird ebenfalls beschrieben. Es dient zur schnellen Abschätzung der Phasenlagen zwischen Orts- und Steuerströme in Doppelelementrelais-Stromkreisen; gleichzeitig zeigt es die Effektivwerte der Spannungen der beiden Komponenten an.

RESÚMEN

Este discurso trata de los tres tipos de circuitos de vía imunizados contra los efectos de corriente alternada de 50 ciclos, empleados hasta la fecha en obras ejecutadas por esta compañía y también incluye unas notas sobre las medidas tomadas para proteger los demás aparatos que forman parte del sistema de señalización. Un circuito de vía de corriente continua con protección en los dos

extremos, circuitos de vía de corriente alternada de 83⅓ ciclos con un riel aislado, y con dos rieles aislados respectivamente con sus relevadores de dos elementos, son explicados. Los efectos producidos por interferencia por corrientes medianas y pesadas de 50 ciclos son examinados. Es evidente la preferencia para alimentación por capacidad en vez de resistencia para los circuitos de vía con dos fuentes distintas pero sincronizadas de corriente de 83⅓ ciclos, una para la alimentacion y la otra para el arrollamiento local del relevador. Si es necesario utilizar fuentes de energía ya usadas para equipo de otros fabricantes (por ejemplo en puntos donde se ligan dos sistemas) es fácil arreglar utilizar las fuentes en cuadratura. Se explica el instrumento de marca S.G.E. para medir el angulo de fase. Este instrumento facilita el estudio de la diferencia en las fases de las corrientes locales y de control en los circuitos de los relevadores de doble elemento, así mismo midiendo la raíz cuadrada de la media de los cuadrados del valor del voltaje de los componentes.

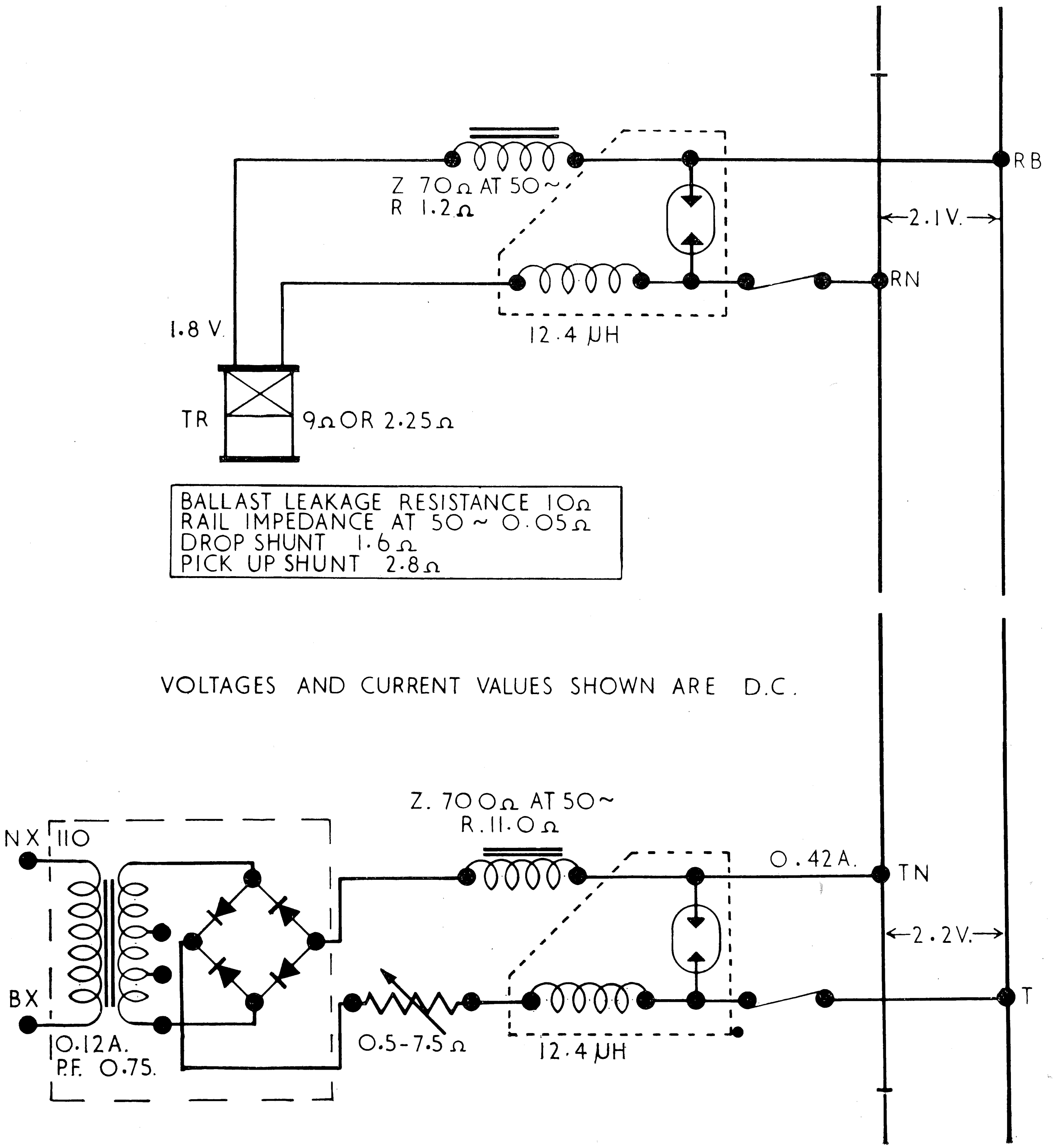

Fig.1 Protected D.C. Track Circuit

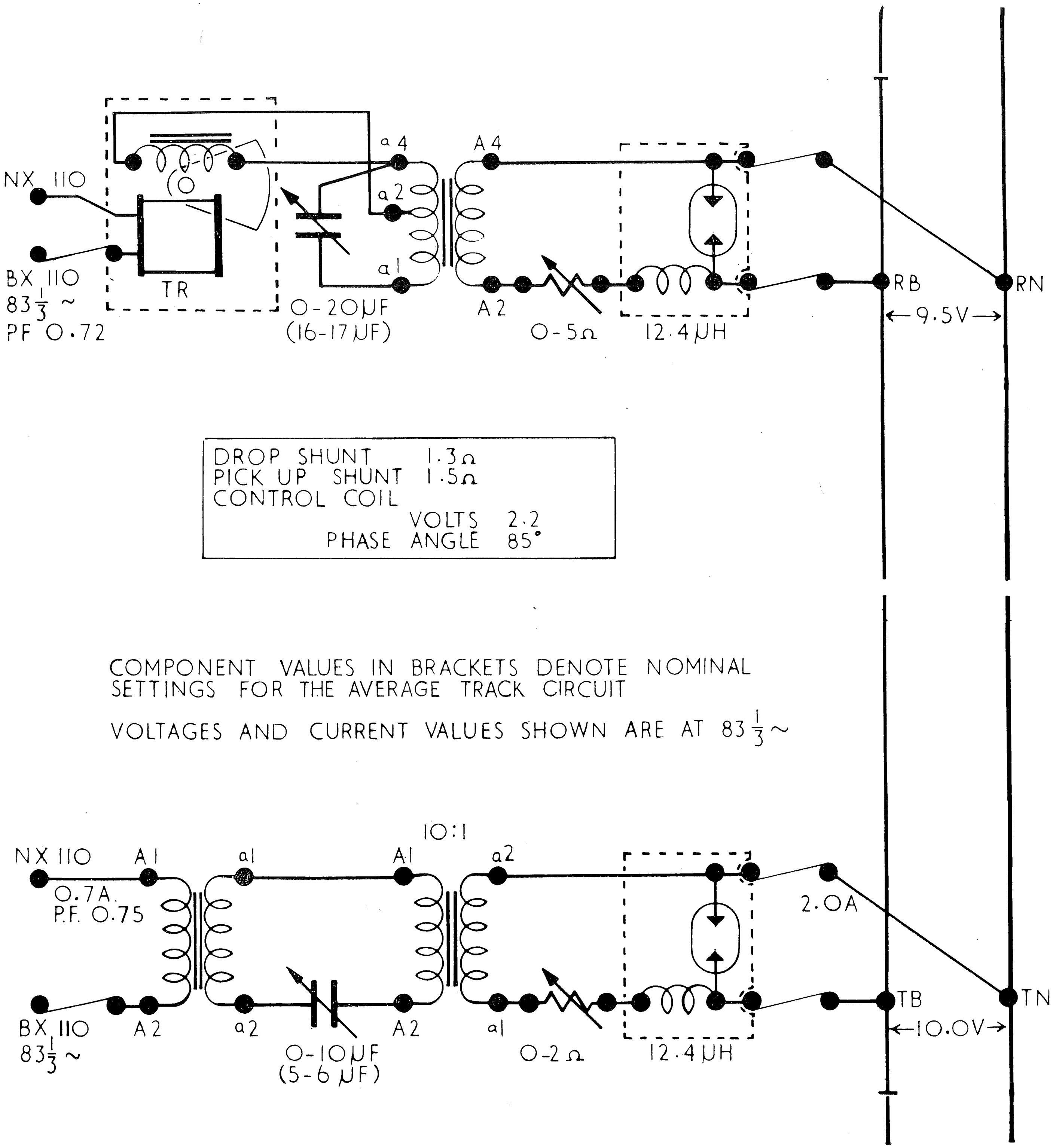

Fig.2 $83\frac{1}{3}$ **c/s Single Rail Track Circuit**

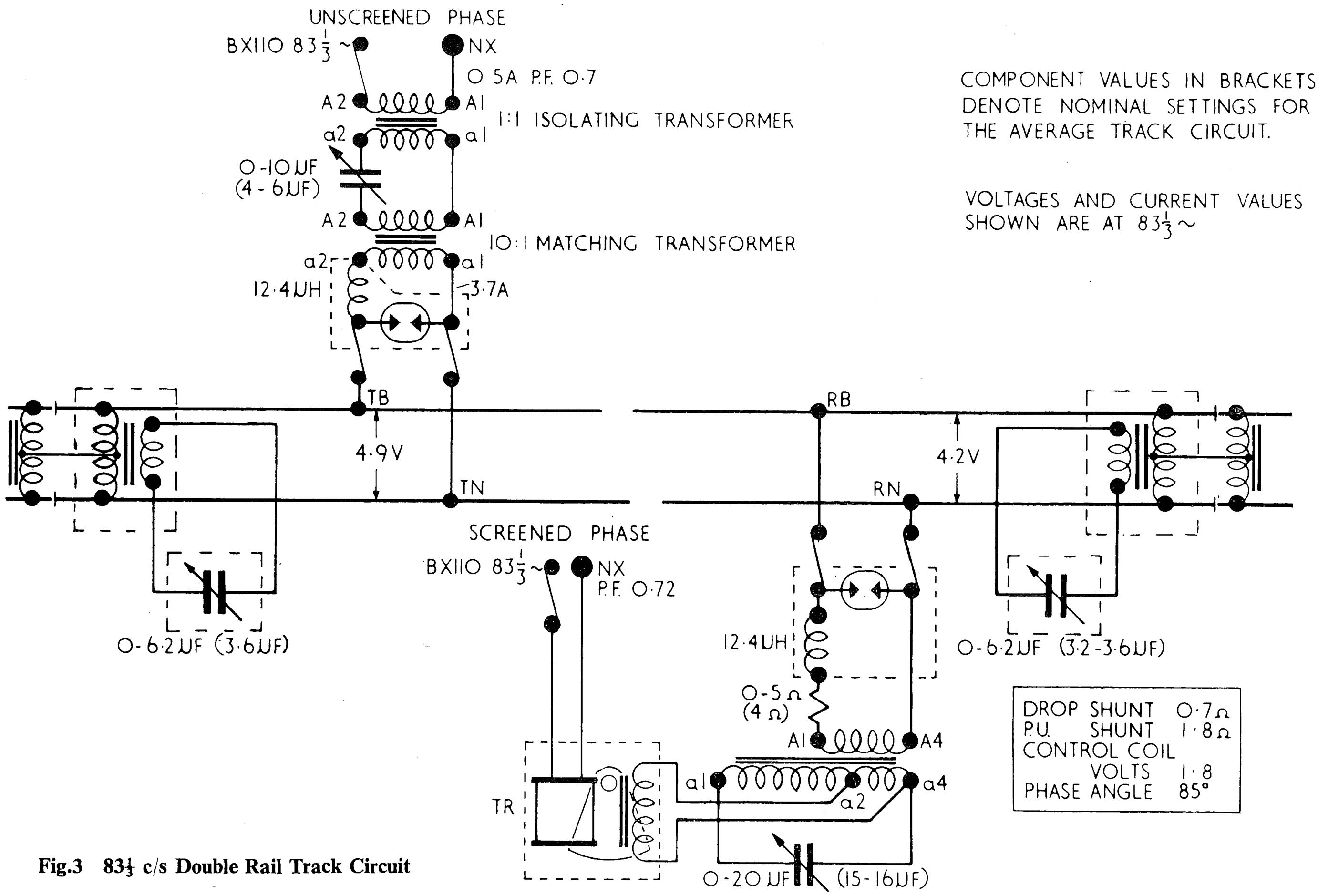

Fig.3 83⅓ c/s Double Rail Track Circuit

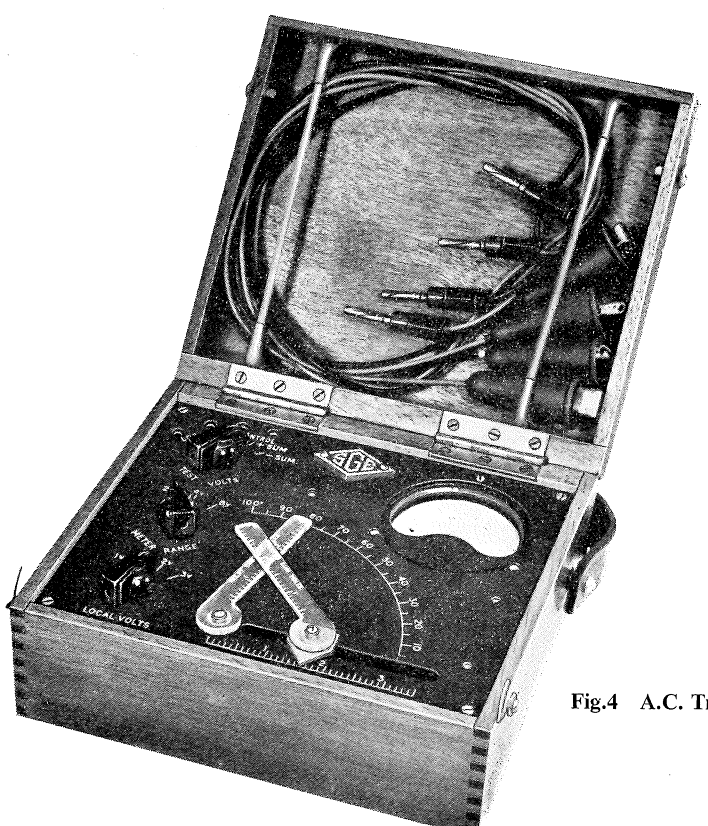

Fig.4 A.C. Track Circuit Test Set

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