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Paper 33.

Overhead Equipment: The Catenary System

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1. Introduction

The overhead equipment has been designed to provide high quality current collection with the minimum of maintenance. This has sometimes necessitated more expensive arrangements than are adopted in countries where availability for maintenance is less of a problem.

To achieve these aims, four general principles have been adopted, as follows:

(*a*) The conductors are in general, and certainly on lines where speeds are high, automatically tensioned by means of weights. The advantages of weight-tensioning are as follows:

(i) The tensions in the conductors are maintained substantially constant under all atmospheric conditions, thereby facilitating sparkless current collection at all times, with consequent reduction of wear of both contact wire and pantograph collecting strips.

(ii) Owing to the constant tension of the conductors, there is only one critical velocity of propagation of waves in the contact wire and this velocity is generally greater than with fixed termination equipment.

(iii) Stretch, or 'creep' of the conductors is automatically compensated.

(iv) Although the equipment becomes 'fixed' at temperatures below about 32°F, the highest tensions reached are considerably less than with fixed termination equipment, thereby permitting some economy to be made in the design of supports and terminations.

(*b*) Non-ferrous materials are used for all live fittings in areas where atmospheric pollution is pronounced or where steam traffic is likely to continue for a considerable length of time.

(*c*) The overhead equipment on each running line is mechanically and electrically independent of that on adjacent lines.

(*d*) The overhead equipment on each running line is capable of being isolated over comparatively short sections between crossovers, in order to minimise the effect of an isolation on the running of trains. Each electrical section may be earthed at both ends by means of the manually-operated switches provided.

2. Description of the Overhead Equipment

2.1 *General*

The overhead equipment is the same for 25 kV and 6·25 kV, apart from the use of smaller insulators in the latter case.

On single or double track, the overhead equipment for each track is separately supported on cantilevers which are free to swing along-track to allow for movement of the conductors as they expand or contract due to temperature changes (see fig.1).

For more than two tracks, portal structures are used, the main catenary wires being carried in pulleys attached to insulators mounted either vertically above or horizontally beneath, the structure boom. (See fig.2.)

Each contact wire is registered separately with respect to the track it serves, cross-span wire registration only being used in sidings or on minor running lines. On all running lines, registration of the contact wires is effected horizontally, the registration arms being pivoted not more than 2 in. above the level of the contact wire, thereby providing the greatest flexibility at these points.

Cadmium copper contact wire is used with all types of equipment, in preference to hard drawn copper, because of its lower elasticity and its greater resistance to abrasion, with consequently longer useful life.

The minimum contact wire height at public road level crossings is normally 18 ft. 6 in. for 25 kV and 18 ft. 0 in. for 6·25 kV, reductions in these clearances only being made in exceptional circumstances by agreement with the Ministry of Transport, subject to the provision of special road load gauges and notices in each case. The minimum contact wire height is 11 in. above the load gauge for 25 kV, or 4 in. in the case of 6·25 kV. Various load gauges are in force in different parts of the system, but the lowest is 13 ft. 1 in. above rail and the lowest permissible wire height is, therefore, 13 ft. 5 in. in areas where this load gauge applies and where the voltage is 6·25 kV.

In the case of weight-tensioned equipment, all the conductors are brought together and anchored by means of a single terminating wire which is attached to the weights through a pulley system giving a 3:1 reduction. Stops are provided so that the terminations become fixed at temperatures of about 32°F and below.

Using the wind and ice loadings quoted in Paper 6, and allowing for a maximum off-set of the contact wire of 19 in. under wind conditions, the span lengths were determined, based upon normal staggers of 9 in. on tangent and 15 in. on curved track, giving a maximum span length of 240 ft. on tangent track. In particularly exposed situations, it may prove necessary to either increase the conductor tensions or reduce span lengths in order to keep the off-set of the contact wire within the desired limit.

The maximum length of a section of weight-tensioned equipment is about 1¼ miles, or roughly 28 spans between anchor points. The main catenary is anchored on a structure at or near the centre of each length of weight-tensioned equipment, but, on gradients of 1/100 or steeper, the length of each section of equipment is reduced to half that normally allowed and it is attached to a fixed anchorage at the uphill end.

2.2 *Types of Overhead Equipment Employed*

Compound Catenary, weight-tensioned

This type of equipment is used on lines where speeds are in excess of 60 m.p.h. and consists of a main catenary, auxiliary catenary and contact wire having a total copper equivalent cross-section of 0·253 sq. in.

Particulars of the conductors are as follows:

Particulars	*Main Catenary*	*Auxiliary Catenary*	*Contact Wire*
Make-up of wire	19/·083 in. strand	7/·083 in. strand	Solid, 0·166 sq. in.
Material	Cadmium copper	Cadmium copper	Cadmium copper
Normal tension	1,950 lbs.	700 lbs.	2,000 lbs.
Maximum span	240 ft.	40 ft.	20 ft.

Before deciding upon the use of compound catenary equipment on high speed lines, consideration was given to the use of simple catenary construction with stitch wires. A considerable mileage of simple catenary, stitched, equipment has been installed for trial purposes, the stitches being 60 ft. long and at a normal tension of 350 lbs.

In order to assess the relative merits of the two types of equipment, about seven miles of substantially level double track were equipped with simple catenary stitched construction on one track and compound catenary construction on the other, so that the installation costs and performance would be directly comparable. It was found that, although the material cost of compound catenary construction was 5 per cent. greater than that of simple catenary stitched construction, the ease of erection and reduction in track-occupation time produced a net saving. In view of this and the fact that compound catenary equipment was found to give substantially better performance, the use of simple catenary stitched equipment has been discontinued.

Fig.3 shows a section of line equipped with both compound catenary and simple catenary stitched equipment.

Simple Catenary, weight-tensioned

This type of equipment is employed as far as possible, on all running lines where speeds are 60 m.p.h. or less and consists of a main catenary and a contact wire having a total copper equivalent cross-section of 0·222 sq. in.

Particulars of the conductors are as follows:

Particulars	*Main Catenary*	*Contact Wire*
Make-up of wire	19/·083 in. strand	Solid, 0·166 sq. in.
Material	Cadmium copper	Cadmium copper
Normal tension	1,850 lbs.	2,000 lbs.
Maximum span	240 ft.	20 ft.

Fixed Termination, simple catenary

This type of equipment is used for sidings and for complex layouts on main lines where speeds do not exceed 60 m.p.h. and where the difficulty and cost of providing weight-tensioning are prohibitive. The equipment consists of a main catenary and a contact wire having a total copper equivalent cross-section of 0·222 sq. in., which are both attached to fixed anchorages, the tensions in the conductors varying according to the temperature.

Leading particulars are as follows:

Particulars	*Main Catenary*	*Contact Wire*
Make-up of wire	19/·083 in. strand	Solid, 0·166 sq. in.
Material	Cadmium copper	Cadmium copper
Normal tension (at 60°F)	1,850 lbs.	2,250 lbs.
Maximum span	210 ft.	20 ft.

Fig.4 illustrates the use of fixed termination equipment at Crewe North Junction.

2.3 *Special Forms of Construction*
Equipment beneath Overbridges and in Tunnels

Where clearances permit, the contact wire is suspended below the main catenary in the normal way, the minimum dimension between the contact and catenary wires at the supports being $6\frac{1}{4}$ in. Where necessary, the required clearance is reduced by using twin contact wire construction, wherein a length of contact wire is inserted into the catenary and is then run alongside the through contact wire (see fig.5). More frequent supports are required with this form of construction but the depth of the equipment, between supports, is reduced to less than 1 in.

Twin contact wire construction achieves the same reduction in clearance as is obtained by anchoring the catenary at each side of a bridge, but is cheaper and more satisfactory for the following reasons:

(*a*) No anchorages are required.

(*b*) No continuity connection is required to maintain the full copper section of the equipment.

(*c*) The bridge may be anywhere in the tension length. If the catenary is anchored at each face, then the bridge must become the mid-point anchor for the tension length concerned.

If, for any reason, even the limited clearance required for twin-contact wire construction is unobtainable, or would be unduly expensive to provide, this form of construction may also be used in conjunction with a dead section, secondary insulation or reduced voltage, as described in Paper 6.

The contact wire gradient to bridges is normally 1/500, but may be steeper if the bridge clearance is very restricted, or if there is a public level crossing nearby.

Neutral Sections

The four gaps required to ensure that the circuits it is desired to insulate from one another are never bridged by any of the complex combinations of pantographs, are obtained by two methods, depending upon the speeds to be allowed for, as follows:

(*a*) Carrier Wire Neutral Sections. These are used where speeds exceed 60 m.p.h. and consist of four overlap spans in series, an additional set of overhead equipment being introduced alongside the through equipment, so that they may each be lifted out-of-running in its turn to form the overlap spans (see figs.6 and 7).

The distance over which current cannot be collected is about 270 ft. The positioning of this type of neutral section with respect to signals presents some difficulty and may cause it to be a considerable distance from the feeder station with which it is associated, thereby necessitating longer feeder cables.

(*b*) Section Insulator Neutral Sections. These are used at present only where speeds are 60 m.p.h. or less and merely consist of four section insulators in series at 40 ft. intervals, the equipment being supported 6 ft. in advance of each section insulator. Not only is this type of neutral section cheap and simple to install but the length of the dead section is only 120 ft. and it is, therefore, considerably easier to position with respect to signals and near to the feeder station (see fig.8).

3. Performance

Tests have been made on simple, stitched and compound weight-tensioned equipment using a high speed test vehicle developed for the purpose.

The vehicle is fitted with two pantographs and is equipped to record, graphically, train speeds, variations in pantograph height, pantograph head pressure and acceleration, also loss of contact between pantograph and contact wire.

The 'Peak/Valley Average' of the pantograph head pressure curves (see fig.9) has been used to give an indication of the relative smoothness of pantograph travel and, therefore, of quality of current collection.

Fig.10 shows examples of the records obtained of the pantograph head pressures on various types of equipment, as follows:

Curves (A) and (B) were recorded on adjacent tracks, one (Curve (A)) having compound catenary, weight-tensioned equipment and the other (Curve (B)) having simple catenary, weight-tensioned equipment.

As may be expected, the variations in pantograph head pressure are seen to be more pronounced in the case of simple catenary equipment than with compound catenary equipment, even though the speed was 10 m.p.h. less.

The difference in performance is also indicated by the 'Peak/Valley Average' pressures of 3·4 lbs. and 5·6 lbs. respectively.

Curves (C) and (D) show a similar comparison between compound catenary, weight-tensioned equipment (Curve (C)) and simple catenary, stitched, weight-tensioned equipment, again on adjacent tracks with identical structure spacings. Visual inspection and comparison of the 'Peak/Valley Averages' again show the superiority of the compound catenary equipment, despite the fact that the speed was 15 m.p.h. faster than in the example shown for simple catenary, stitched equipment.

Large numbers of records, such as those shown in fig.10, have been taken under a variety of conditions and these show conclusively that, while the addition of stitches to simple catenary equipment effects some improvement in performance, the use of compound catenary construction gives very much better performance than either. This improvement is expected to be even more pronounced at speeds of 90-100 m.p.h.

4. Tests in Progress

Tests, using new techniques for measuring wire movement, have recently been made. Preliminary reports of these will be found in Papers 2 and 21 and further particulars regarding them will be given at the Conference.

5. Conclusion

The general form of the three types of equipment having been established, no fundamental changes are envisaged. However, further operational experience and the results of the tests mentioned above are expected to point the way to improvements or economies which can be made in certain parts of the equipment, particularly by making full use of glass fibre and other new materials as discussed in Paper 6.

SUMMARY

The traffic density on British Railways calls for overhead equipment which will provide a high standard of current collection with the minimum of maintenance and, therefore, interruption to traffic. This requirement has sometimes demanded the use of more expensive arrangements than would otherwise have been the case. The paper describes the various types of equipment employed and their application to meet the wide range of requirements encountered. Details are given of tests carried out, the results providing a comparison between the performance of the different types of equipment.

Unusual problems have been posed by the large number of overbridges and tunnels and their generally very limited headroom, also by the need for neutral sections which would operate satisfactorily with a variety of combinations of multiple unit sets and locomotives.

The means by which these problems have been overcome are described in detail.

Having established the broad principles of the overhead equipment design, efforts are now being directed towards improvements and reductions in cost which can be gained by the use of new materials.

RÉSUMÉ

La densité de trafic des Chemins de Fer Britanniques exige des lignes aériennes de contact capables d'assurer une très bonne captation de courant avec un minimum d'entretien et, par conséquent, de dérangement au trafic. Ce besoin a quelquefois exigé l'emploi de dispositions plus coûteuses que celles que l'on aurait autrement employées. L'exposé décrit les divers types d'équipements employés et leur application pour satisfaire la gamme étendue des conditions requises. Les auteurs décrivent les essais effectués dont les résultats permettent une comparaison des performances des divers types d'équipements.

Des problèmes très exceptionnels ont été posés par le grand nombre de passages supérieurs et de tunnels, par leur tirant d'air généralement très restreint et aussi par la nécessité de fournir des sections neutres capables de fonctionner d'une façon satisfaisante avec une grande diversité de combinaisons de rames automotrices et de locomotives.

Les auteurs décrivent en détail les moyens employés pour surmonter ces difficultés.

Ayant établi les principes de base de la construction des caténaires, on oriente maintenant les efforts vers des améliorations et l'abaissement des prix de revient qui sont à obtenir en employant des matériaux nouveaux.

ZUSAMMENFASSUNG

Die Verkehrsdichte der Britischen Eisenbahnen erfordert ein Oberleitungssystem, das eine hochwertige Stromabnahme mit einem Minimum an Unterhaltung und der daraus folgenden Verkehrsunterbrechung gewährleistet. Diese Anforderung hat zuweilen zur Anwendung von kostspieligeren Einrichtungen geführt als sonst nötig gewesen wären. Der Bericht beschreibt die verschiedenen, verwendeten Arten von Ausrüstungen, sowie ihre Anwendung, um den vielseitigen Erfordernissen gerecht zu werden. Einzelheiten von ausgeführten Versuchen sind angeführt, die Ergebnisse erlauben einen Vergleich der Leistungen der verschiedenen Ausrüstungsarten.

Ungewöhnliche Probleme wurden gestellt durch die grosse Anzahl von Wegüberführungen und Tunnels, sowie ihre im Allgemeinen sehr begrenzte lichte Höhe, ebenfalls durch den Bedarf an spannungslosen Trennstrecken die einen befriedigenden Betrieb mit einer Mannigfalltigkeit von Kombinationen an Triebwagenzügen und Lokomotiven gewährleisten sollen.

Die Mittel, mit denen man diese Fragen gelöst hat, werden ausführlich geschildert.

Nach Festsetzung der allgemeinen Grundlagen der Konstruktion der Oberleitungsausrüstung, strebt man jetzt nach Verbesserungen und Kostenermässigungen, die durch die Anwendung neuer Werkstoffe ermöglicht werden können.

RESÚMEN

La capacidad de los Ferrocarriles Británicos exige una línea aérea de contacto que asegurará un sistema de alimentación de corriente de rendimiento elevado y que necesitará un minimo de conservación y, por consecuencia, ocasionará un minimo de perturbación. Este requerimiento ha algunas veces exigido el empleo de dispositivos más costosos de los que habrían sido necesarios por otra parte. El informe describe los tipos diversos de equipos empleados y su applicación para satisfacer las exigencias muy diversas encontradas. Se exponen detalles de pruebas efectuadas, los resultados de que proveen comparación de los tipos diferentes de equipos.

El gran número de pasos superiores y tunels y su generalmente muy limitada altura libre tanto como la necesidad de secciones neutras que funcionarían satisfactoriamente con una diversidad de ramas de elementos multiples y locomotoras han planteado problemas insólitos.

Se describen los medios por los cuales estes problemas se han resolvido.

Verificados los principios generales del proyecto de la línea aérea de contacto, los proyectistas se esfuerzan actualmente a realizar mejoras y rebajas de coste que consiente el empleo de materiales nuevos.

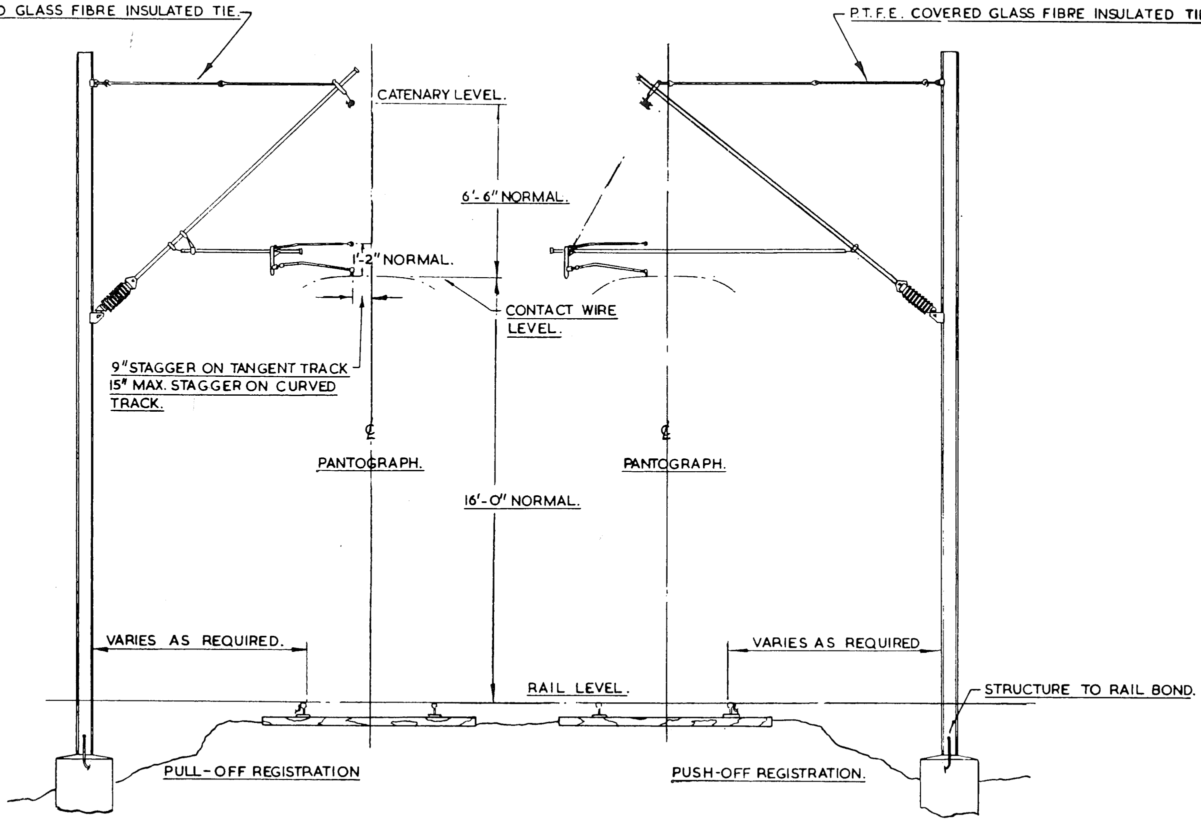


Fig.1 Single Track Cantilevers – Open Route Balance Weight Tension Equipment 25 kV and 6·25 kV (Compound Catenary)

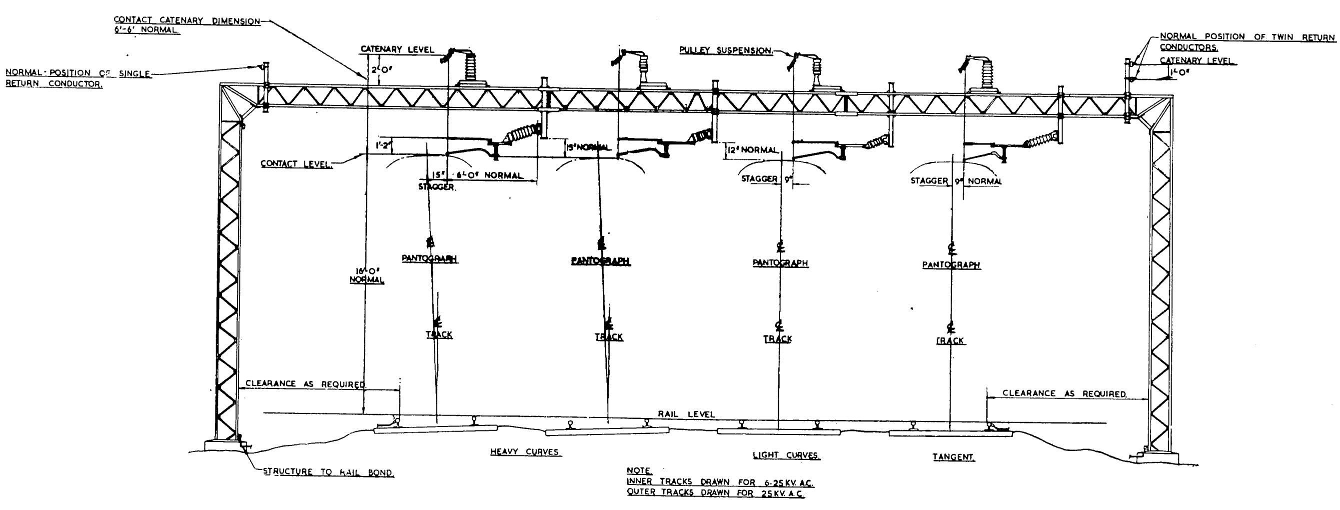


Fig.2 Multi-Track Portal Construction. Balance Weight Tensioned Equipment 25 kV and 6·25 kV A.C. (Compound Catenary)

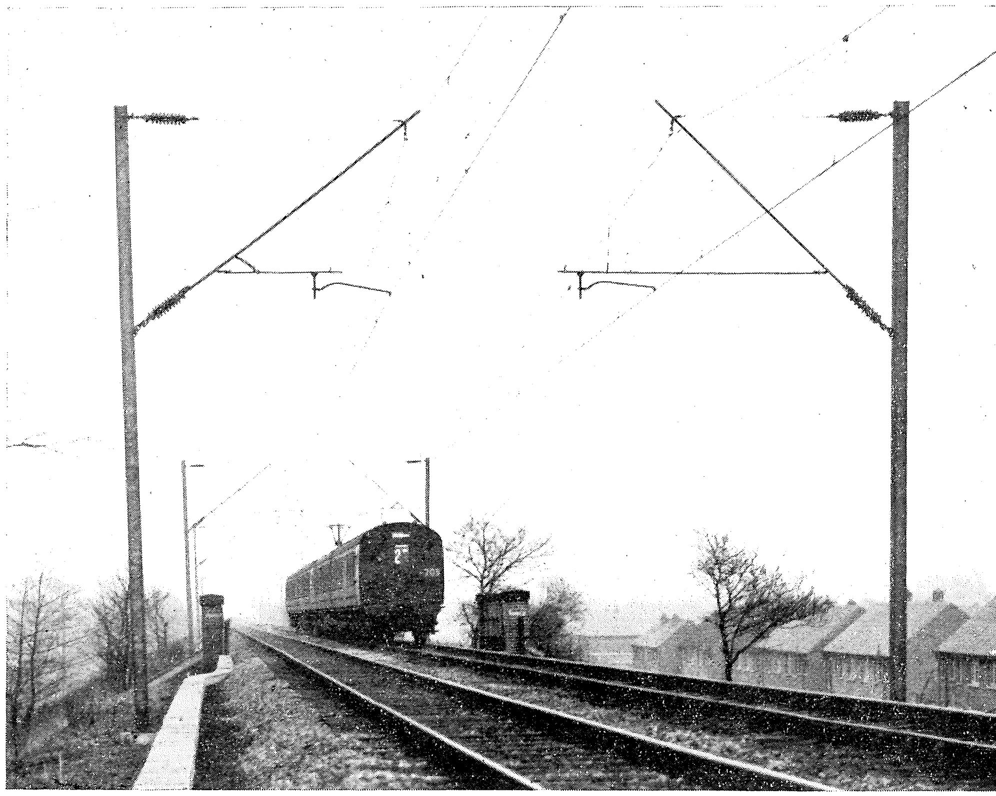


Fig.3 Compound Catenary (L.H. Track) and Simple Catenary, Stitched, Equipment (R.H. Track)

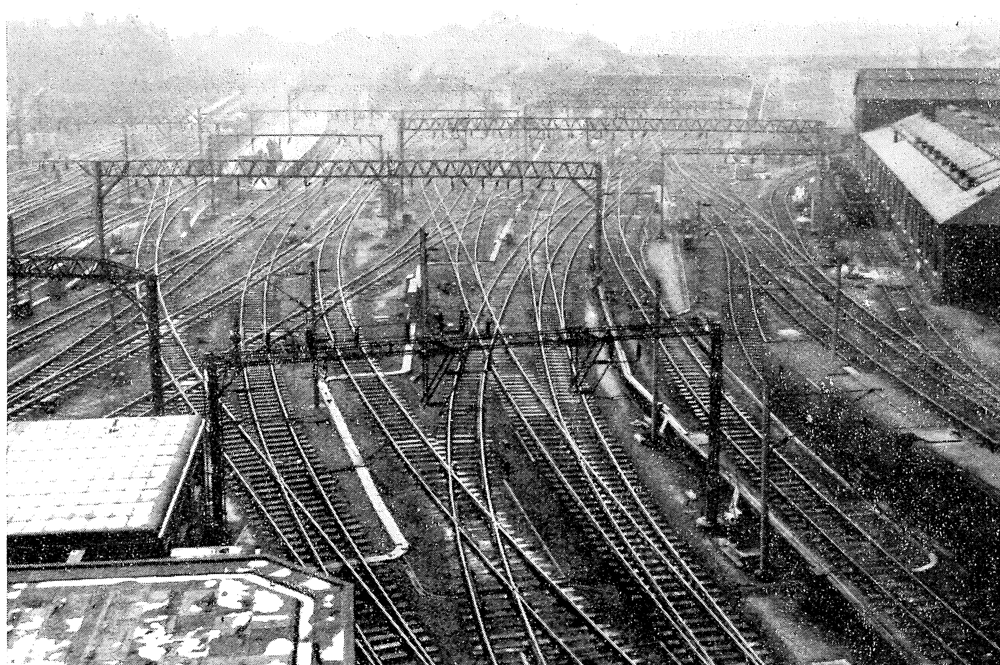


Fig.4 Fixed Termination, Simple Catenary. Equipment at Crewe North Junction

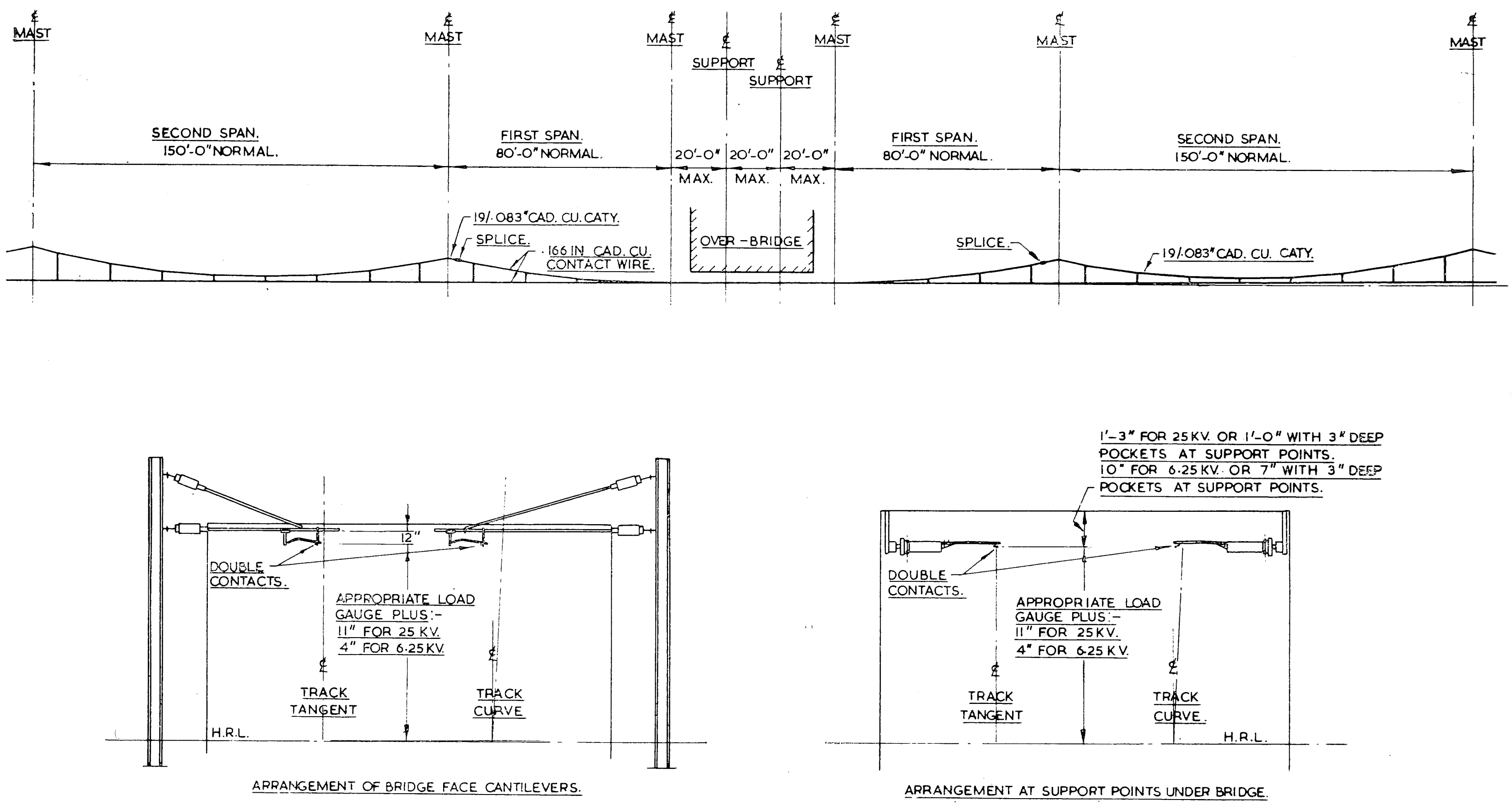


Fig.5 Arrangement of Two Contact Wires at Bridges. Balance Weight Tensioned Equipment 25 kV and 6·25 kV A.C. (Compound Catenary)

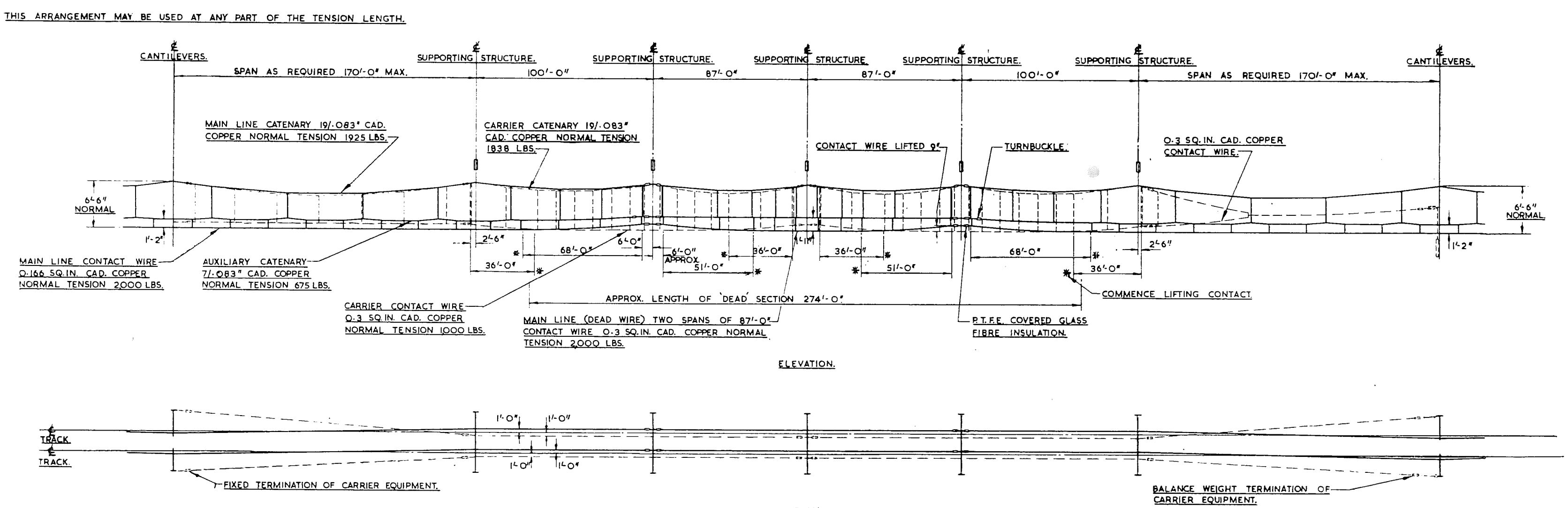


Fig.6 Two Track Carrier Wire Neutral Section using Glass Fibre Insulation. Balance Weight Tensioned Equipment 25 kV and 6·25 kV A.C. (Compound Catenary)

Fig.7 Carrier Wire Neutral Section

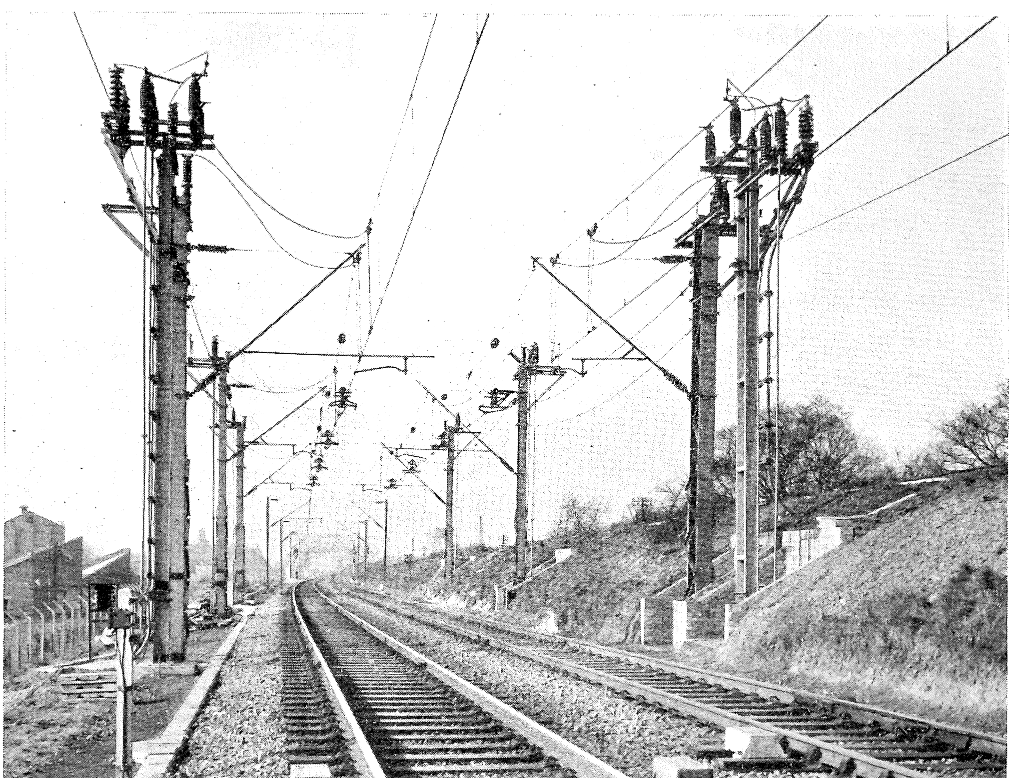
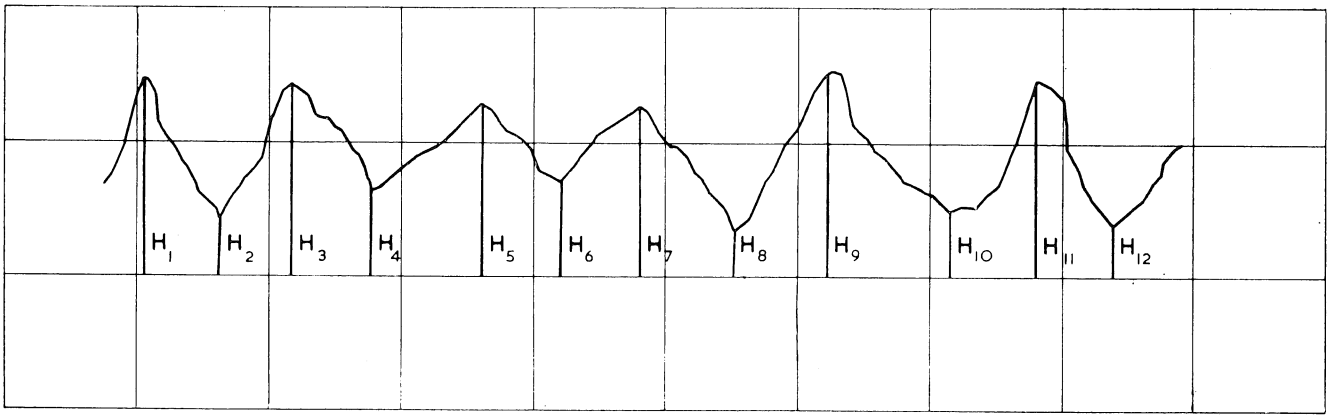


Fig.8 Section Insulator Neutral Section



PEAK VALLEY

$$\text{P.V.A.} = \frac{2\left\{\left(H_1 + H_3 + H_5 + \ldots H_{(n-1)}\right) - \left(H_2 + H_4 + H_6 \ldots H_n\right)\right\}}{n}$$

Fig.9 Method of Determining Peak and Valley Average (P.V.A.). B.S.1134 for Surface Roughness

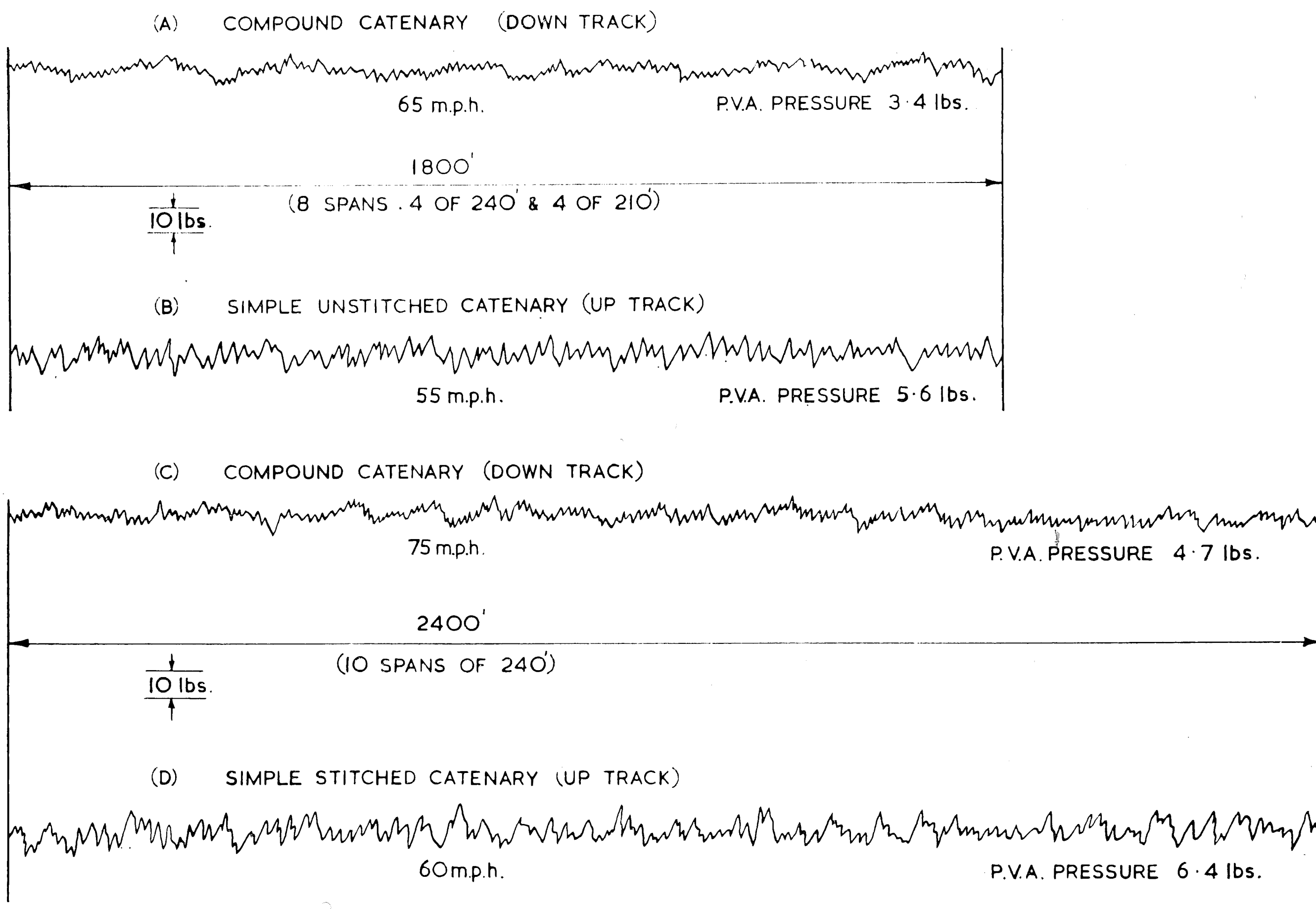


Fig.10 Examples of Pantograph Head Pressure. Records Obtained on Open Route, Tangent Track, with Various Types of Overhead Equipment

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