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Paper 6

The Overhead Line Equipment

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1 Introduction

Considerations of overriding importance for electrification in Great Britain, which do not exist elsewhere, control the design of overhead line equipment. It has been thought useful to describe the more important.

1.1 *Traffic Considerations*

While the traffic density on the principal lines in this country is heavy in terms of ton miles per single track running mile per annum, being sometimes as high as 8 million, the average train is not heavy so the number of trains daily is very large, ranging from 50 to 150 or more in each direction over the 24 hours. Consequently, the maintenance of supply on the overhead line equipment without interruption is of the first importance, quite apart from any consideration of cost of maintenance.

For the same reason equipment which can be easily and quickly erected and adjusted and which will require the minimum of maintenance is needed to minimise track occupation. Traffic considerations prohibit special 'white' periods in the Working Time-table set aside for overhead equipment maintenance and demand that advantage be taken of possessions required by the civil engineers for maintenance.

This explains the decision to provide, wherever practicable on running lines, mechanical as well as electrical independence of each track equipment. In some complex areas mechanical and electrical independence has been accepted between groups of tracks.

1.2 *Physical Limitations*

A striking point about the railways of this country as compared with many other countries is the generally more restricted space available in which to install trackside equipment.

The large number of roads and frequent train service which makes level crossings unattractive results in many overbridges. These average $1\frac{1}{2}$ to 2 per route mile. Further, the small rolling stock loading gauge is very little smaller than the structure gauge. Tunnels also are frequent and of restricted clearance. In many cases the cost of providing sufficient clearance is heavy and in some cases the consequences of doing so are unacceptable.

1.3 *Atmospheric Conditions*

The degree of atmospheric pollution, especially in the neighbourhood of railway lines, is still frequently heavy. This is due to the density of industrial development, the use of coal, and the frequency of the train service, still predominantly steam hauled, as well as to the island climate. While the situation is improving the equipment must not become seriously corroded by the time the conditions have improved.

1.4 *Performance of Equipment*

Because of the considerations mentioned above, and the intention of operating at high speeds, up to 100 m.p.h. on some sections, excellence of performance to minimise pantograph wear, wire wear and line adjustment has been a major aim.

1.5 *Aesthetic Design*

To ensure structure designs which are individually and collectively satisfying, a Design Consultant has been employed to examine and advise on all basic proposals with beneficial results. The effect will be noticed particularly on later sections, where this consideration has not had to give way to the need to work to a very close programme.

2 Clearances and Line Voltage

The provision of clearance is met at bridges by lifting or reconstructing the bridge, or lowering the track and in tunnels by reconstruction or track lowering; at most bridges minimum clearance equipment with twin contact wires is required.

The normal nominal line voltage is 25 kV but a reduced nominal line voltage of 6·25 kV is used when absolutely essential, principally on sections in and around large cities to avoid intolerable clearance provision. This facility, due to the complexity of its introduction, has not been used for isolated bridges but only where a succession of difficulties occur.

Neutral sections are inserted between sections of different voltage just as between sections with a different source of supply.

The clearances adopted at the start for the two voltages for all atmospheric conditions were:

		25 kV	*6·25 kV†*
Load gauge to live equipment Live equipment to structure (static)		11″*	4″
Live equipment uplifted to structure Pantograph to structure	(passing)	8″*	3″
Load gauge to structure (minimum)		1′ 11″	11″
PLUS pockets at support points		3″	3″
Rolling stock loading gauge		13′ 1″ to 13′ 6″ above rail	

* These are substantially the same as U.I.C. figures.

† These are the same as those used on 1,500V D.C.

As a result of experience and decline in the amount of steam traffic it is hoped to reduce the 25 kV clearances as mentioned in Paper 1.

In other cases on 25 kV sections where provision of adequate clearance is costly or difficult and where operating conditions permit, dead and earthed sections of wire are installed under bridges requiring only 9 in. total clearances; insulation is effected by a form of neutral section.

Alternatively, secondary insulation of the underside of the bridge can be used in suitable cases where the overall cost is thereby reduced or where provision of clearance is exceptionally difficult and continuous current collection is necessary. A saving of some 7 in. on the 1 ft 11 in. clearance normally required can be obtained by its use and long bridges can be equipped. An installation has been in trouble-free service for some nine months.

The further development of secondary insulation for bridges associated with a reduced air clearance may lead to its effective use in difficult cases and reduce the extent of 6·25 kV sections. Particulars are given in Papers 1 and 14.

3 Wind and Ice Loadings

The wind and ice loadings assumed in the design of the equipment, are as follows:

(*a*) *On the Conductors*

	Main Catenary lbs./sq. ft at 60°F	*Main Catenary lbs./sq. ft at 22°F*	*Auxiliary Catenary lbs./sq. ft at 60°F*	*Auxiliary Catenary lbs./sq. ft at 22°F*	*Contact Wire lbs./sq. ft at 60°F*	*Contact Wire lbs./sq. ft at 22°F*
Wind loading on projected area	11	8	11	8	10	7
Ice loading	3/8″ radial		3/16″ radial		None	

(*b*) *On the Structures*

	Rolled Steel Sections lbs./sq. ft at 60°F	*Rolled Steel Sections lbs./sq. ft at 22°F*	*Tubular Members lbs./sq. ft at 60°F*	*Tubular Members lbs./sq. ft at 22°F*
Wind loading on projected area	18	12	12	8
Ice loading	None		None	

4 Scheme Particulars

The following are brief particulars of the electrification schemes completed or under construction:

Scheme	*Route Miles 25 kV*	*Route Miles 6·25 kV*	*Single Track Miles*	*High Speed Equipment Type*	*Structures Type*	*Fittings Type*
Manchester – Crewe	44	Nil	217	Simple stitch weight tensioned	Rolled sections	Non-ferrous
Liverpool – Crewe	37	Nil	155	Compound weight tensioned	Rolled sections	Non-ferrous
Crewe – Euston	371	48	1,408	Compound weight tensioned	Part-rolled sections	Non-ferrous and ferrous
Colchester – Clacton – Walton	24	Nil	50	Simple stitched weight tensioned	Rolled sections	Non-ferrous
Liverpool Street – Chelmsford – Southend Conversion	10	42	174	Compound fixed (existing D.C.)	Rolled sections painted (existing)	Non-ferrous (part existing)
Liverpool Street – Enfield – Chingford – Hertford – Bishop's Stortford	23	22	105	Simple stitched weight tensioned	Rolled sections	Non-ferrous
London – Tilbury – Southend	62	13	172	Simple stitched weight tensioned	Rolled sections	Non-ferrous
Glasgow Suburban Stage I	41	30	163	Nil	Rolled sections	Non-ferrous
Chelmsford – Colchester	22	Nil	49	Compound weight tensioned	Tubular	Non-ferrous

5 General Description

5.1 *Supports and Foundations*

All supports are of galvanised steel although trials are being made with metal spraying to compare costs and durability. Aluminium B.F.B., pre-stressed concrete masts and wood poles have been tried but they have not shown any worthwhile advantages.

The standard single track cantilever construction comprises broad flange beam masts as generally the cheapest and most satisfactory design but large quantities of tubular masts have been used initially to assist the supply position; while they are superior in torsion and will show a significantly reduced painting cost when this becomes necessary they are less satisfactory in bending and until recently first cost has been higher; current prices show them to be strictly competitive. A light tapered twin channel mast, more economical in first cost than B.F.B., is also being tried on a large scale in Scotland.

For three or more tracks portal structures are used and up to 75 ft span these have angle, welded rod braced, booms with similar, or alternatively double channel, masts. Over 75 ft span they are of rolled steel lattice construction. B.F.B. portal structures are used for fixed equipment but have insufficient resistance to the torsion produced by weight-tensioned equipment. The specially developed welded rod design has proved more than 50 per cent. cheaper in first cost than equivalent rolled steel lattice structures. Alternative designs in the tubular medium are being extensively tried in East Anglia and here the booms have four tubular main members with either welded rod or tube bracing; masts are either of similar construction or of two large diameter parallel tubes. Except for rod-braced sections these structures are galvanised before fabrication, the tubes sealed and the welded joints subsequently cold galvanised to maintain the protective zinc coating. Sections of boom are joined together and to the masts by circular-bolted flanges. The first costs of tubular designs show little difference from rolled steel designs in the smaller but are considerably cheaper for larger spans; the galvanising should last longer and painting costs in later life are expected to show a considerable saving. The trial should give valuable information. All portal type structures, whether rolled steel or tubular, are designed in standard mast and boom sections to facilitate advance ordering and special centre sections of booms are provided only where boom length is critical (fig.1).

Foundations of the side bearing type are wherever possible bored by train mounted auger, the mast or foundation bolts planted and the concrete poured in one operation. Where rock or other soil conditions or access preclude this and for large or gravity type foundations, hand excavation is employed. Special foundations have been developed for mining, bank slip, peat or other subsidence areas. In general, prefabricated foundations have not been used, effort being concentrated on mechanisation of site construction as producing the cheaper and more easily installed foundation for British conditions.

5.2 *Fittings*

In the first designs developed all fittings on the live side were non-ferrous, including copper-clad steel cantilever tubes, to meet the considerations mentioned above and a high degree of adjustment has been provided. Galvanised malleable iron fittings are employed on the structure side. The first cost is high but it is expected to reap the benefit in the years to come (fig.2).

Fittings have been developed to meet the special conditions under low bridges (fig.3) and in tunnels and maintain a high standard of performance. The success achieved may be appreciated from the fact that substantially sparkless collection is obtained with an equipment depth of less than 1 in. at minimum wire height (11 in. above load gauge) at speeds up to 100 m.p.h. Records are available to demonstrate this. Some of these fittings are illustrated in Paper 33.

Simplified fittings, predominantly galvanised on the live side have now been developed for areas of lesser pollution (fig.2). Estimated overall material cost of the overhead line equipment including structures is reduced by approximately 12 per cent. and some saving on erection and maintenance should accrue. Non-ferrous live-side fittings will continue to be used in heavily polluted areas but the designs are being simplified in line with the ferrous types to reduce first and maintenance costs.

5.3 *Insulators*

In general, the insulators are of the solid core type with normal glaze. Semi-conducting glaze has not proved satisfactory in railway service due to smoke and other deposits on the surface and heat from locomotive exhausts. It had been hoped to try out tension insulators with a reinforcing core for situations prone to malicious damage but development has not yet proceeded sufficiently to justify their use. However, the adoption of P.T.F.E. coated glass-fibre rod for terminal strain insulation in many applications is now current practice and provides a more satisfactory alternative.

Because of the design considerations mentioned in 1 above, long creepage path insulators have been used to increase intervals between cleaning. 42 in. creepage is normal for 25 kV but some insulators with 51 in. have been provided but with the same overall length between caps; there is not yet sufficient evidence to show whether the longer creepage path is desirable. A restricted trial is now being made in a clean area in the Scottish Region with insulators having a creepage path of 23 in. and 27 in. mounted beside the track. For 6·25 kV a creepage path of 16 in. has been used throughout except on D.C./A.C. converted lines where lower values have been retained in some cases to avoid change. Insulators over the track and in other smoky situations have been greased to reduce TV./radio interference and sparking and to reduce and facilitate cleaning. Ninety-five per cent. petroleum jelly plus 5 per cent. polyisobutilene has been used but does not last and a silicone grease in pressure spray packs is being adopted in the future although it is hoped that general greasing will ultimately not be required. Polythene bags are used to keep insulators clean between erection and commissioning. An energised and discharge recording test gantry on a highly polluted section of railway has given useful evaluation of a great variety of types of insulators and greases.

There has been an unusually extensive use of insulators in bending for supporting the catenary itself. A mechanical factor of safety of $3\frac{1}{2}$ in bending has been employed generally and reliability to date has been good; only four mechanical failures of this type have been reported out of some 25,000 installed and of these two are attributable to erection damage and two to manufacturing defects. The use of insulators in bending has permitted a reduction in height of structures on multi-track route, a reduction in the number of insulators and clearance required in tunnels and under bridges and a general simplification of equipment in other situations.

Three sizes of porcelain to meet differing mechanical requirements have been standardised and each is fitted with various types of end caps to meet equipment requirements.

5.4 *The Equipment*

Four types of equipment have been used; compound and simple stitched (now discontinued), weight tensioned over 60 m.p.h., simple weight tensioned for 60 m.p.h. and under and simple fixed termination for complicated layouts and under 60 m.p.h. The decision was made after trial to use compound equipment for high-speed lines to meet the special conditions in this country as described in Paper 33.

5.5 *Ancillary Conductors*

Track feeders unless short are, wherever possible, run as bare wires but space limitations and bridges in most cases make this impracticable. They are carried on brackets attached to the back of the masts. Track feeders are otherwise run as solid type paper insulated lead covered cables described later.

'Earth' wires of 7/·128 in. (0·083 in.^{2}) H.D. Cu. strand, or latterly 19/·128 in. H.D. aluminium strand are used for bonding of structures where double-rail track circuits are installed on all tracks. They are fixed to the structures with grooved clamps, are continuous and are connected to the track at intervals of approximately two miles depending on signal impedance bond spacing. Where single rail track circuits, now normal practice, are used, the requirements for earth wires is small and structures are individually bonded to rail.

5.6 *Booster Transformers and Return Conductors*

Booster transformers to reduce interference are mounted on special mid-span structures with light booms to carry across-track connections (fig.4) and the associated return conductors are attached between catenary and contact wire height to the masts or booms at the side of the tracks with cleat type insulators to give a sure insulation level of 3 kV. P.V.C. insulated aerial wires are used where necessary and, where track feeder cables at feeder stations are longer than $\frac{1}{4}$ mile, rubber insulated return conductors are laid beside them and the aerial wires omitted. Open circuit of return conductors or disconnection from rail can cause high voltages and connections to rail are duplicated for this reason.

The conductors have been H.D. copper but H.D. aluminium has been standardised for all future work as it is at present cheaper and reduces the structure loading in some cases. Sizes used depending on circuit loading are as follows:

Cu. Equivalent Area	*Cu.*	*Al.*
·083 in.^{2}	7/·128″	—*
0·15 in.^{2}	7/·166″	19/·128″
0·23 in.^{2}	19/·128″	19/·166″

*Smaller than 19/·128 in. Al. strand is not used for mechanical reasons.

5.7 *Section Insulators*

The design of an entirely satisfactory section insulator is a difficult matter. A type using porcelain tension and compression insulation and T-section copper runners, illustrated in fig.5, has been developed and is giving satisfaction within limits of use. Porcelain fracture does not allow the line to fall. It is accepted for use in running lines at speeds up to 60 m.p.h. forward and 25 m.p.h. reverse but requires careful adjustment initially. It is also used for constructing neutral sections. It weighs 140 lbs. excluding catenary insulation and this is its principal drawback.

A simple bi-directional type of section insulator (fig.6) using P.T.F.E. coated glass-fibre insulation with toughened glass runners and weighing approximately four times the weight of the same length of contact wire has been developed and an early version operated well mechanically at over 90 m.p.h. There is every reason to hope that this section insulator will give a very high degree of satisfaction for all purposes in both directions at all speeds up to 100 m.p.h. Details will be given in Paper 33A.

5.8 *Isolating Switches and Operating Mechanisms*

The traffic conditions mentioned require a high degree of sectionalising of the overhead line equipment so that sections isolated for defect or repair may be small. As, for the same reasons, it was necessary to be able to work on a line with adjacent lines alive, induced voltages would be present on the isolated line. To reduce risks and time in applying maintenance earths and to ensure a secure earth should an electric train violate an isolated section, it was decided to provide close/open/earth switches at each end of each section. Alternative feed close/open/close switches and two position close/open switches were also required. The majority are hand operated only but in some cases remote or supervisory operation is needed as, for example, in providing rapid isolations for single-line working in association with special facing/trailing high-speed crossovers.

Several designs of horizontal, rotating pedestal switches were developed by manufacturers to a common specification which ensured that all would have the same performance and same principal dimensions so that they would be interchangeable. Each make is comprised of components which can be assembled in different ways to produce the various types, and switches are mounted on standard single or double bases to facilitate attachment to standard overhead line structures. Switches may be mounted on top of the structure masts beside the tracks or on the booms over the tracks with suitable operating gear; hand-operating mechanisms are standard for all makes in general use (fig.7).

Main design particulars are as follows:

	25 kV	*6·25 kV*
Fault level	300 MVA	150 MVA
Fault duration	12 kA 3 secs.	24 kA 1 sec.
Rating (continuous)		
normal	600 amps	1,000 amps
special D.C./A.C. conversion ..	—	1,400 amps
Post centres..	30″	30″
Minimum 1/50 positive impulse		
withstand..	200 kVp	95 kVp
Insulator creepage	45″	16″

All parts on the live side are non-ferrous, special attention has been given to operation in ice and polluted conditions and 25 kV and 6·25 kV switches have the same dimensions apart from insulator height. Contacts are of copper with silver inserts or of gunmetal and are capable of making and breaking overhead line charging current.

A single design of motor-operating mechanism has been developed to work with all types of switches. It operates on 240V A.C. and is of the motor wound, spring-operated type to ensure that operation once initiated will proceed to completion. Both parts of the movement of 3-position switches can be effected by one mechanism with a stop in the middle. Provision is made for supervisory, local and manual operation. A single mechanism will operate two switches ganged together (fig.8).

Makers and numbers so far purchased are:

	Quantities ordered	
	Isolating	*Motor*
Manufacturer	*Switches*	*Mechanisms*
Electric Transmission Ltd	20	—
Hackbridge & Hewittic Electric Ltd..	587	—
Switchgear & Equipment Ltd ..	680	425
Bertram Thomas Ltd	820	—

5.9 *Track Feeder Cables and Sealing Ends*

Both 25 kV and 6·25 kV track feeder cables are solid single core paper insulated lead-alloy 'B' sheathed, are cleated to the overhead line structures and terminate in sealing ends mounted either on the mast or boom. These sealing ends are 44 kV (25 kV to earth) and 11 kV (6·25 kV to earth) orthodox outdoor type (fig.7).

Makers and quantities so far purchased are:

	Quantities ordered			
	Cables		*Sealing Ends*	
Manufacturer	*25 kV*	*6·25 kV*	*25 kV*	*6·25 kV*
	Yds	*Yds*	*No.*	*No.*
W. T. Henley's Co., Ltd ..	30,000	—	150	80
Scottish Cables Ltd ..	—	14,000	—	—
Pirelli-General Cable Works Ltd	6,500	—	48	205
Enfield Cables Ltd.. ..	71,000	—	220	—
Aberdare Cables Ltd ..	—	53,000	—	—
	107,500	67,000	418	285

The development of 25 kV rubber- and plastic-insulated track feeder cables may in time produce an acceptable alternative for this duty and some simplification of sealing ends will result therefrom.

5.10 *Neutral Sections*

The design considerations for neutral sections on British Railways were severe. Due to the frequent location of feeder stations at junctions in congested areas the length of neutral sections had to be kept to the minimum to avoid inconvenience to traffic; the operation of multiple-unit trains of various formations postulated a multi-gap design to avoid bridging the two live sections; it was thought prudent to allow initially for locomotives operating with two pantographs raised and up to two together; it was considered necessary to make the passage through neutral sections completely automatic to reduce loss of power to a minimum.

As a consequence neutral sections were designed with four gaps and magnetic inductors were located outside the running rails on the sleepers before and after the neutral section. A receiver on the locomotive or motor coach is operated as it passes over the first inductor and this in turn cuts off and locks out the power circuits, as described in Paper 3, so that the neutral section is entered without drawing an arc at the pantograph. The lock-out is released when the receiver passes over the second inductor and the power circuits are restored under the control of line voltage selection relays. In the event of failure of this automatic power control, reliance is placed on the locomotive or motor coach no-volt relay, after breaking current on the pantograph, and restoration of circuits follows as before.

Facilities are provided in the form of supervisorily controlled isolating switches for energising the three sections from the live section ahead should a train stall.

Particulars of the two types of neutral section so far installed are as follows:

Speed limit	Up to 100 m.p.h.	Up to 60 m.p.h.
Type..	Carrier wire	Section insulator
No. of gaps..	4	4
Gap spacing	90′ approx.	40′
Inductor before	100′	75′
Inductor after	60′	60′
Total dead section ..	270′ approx.	120′
Total section over which power is cut off	430′ approx.	255′

The development of the light, high-speed section insulator will permit this type of neutral section for all speeds and it is anticipated that still further simplification and weight reduction will be achieved by using only short lengths of glass insulation in running. The cost and inconvenience of neutral sections will then be reduced to a small fraction of the present level, not least by shortening, especially if single pan locomotive working can be ensured, and so enabling them more frequently to be located close to switching stations thus reducing the length of track feeders. These developments will also permit the more extensive use of dead sections under low bridges.

6 Earthing and Bonding

Bonding is provided to ensure an adequate return path for normal return current thereby reducing impedance and avoiding excessive track voltages and to ensure an adequate return path for fault current so that dangerous potentials do not occur on grounded equipment.

All structures are bonded either to the running rail in areas with single rail or no track circuits or to a continuous 'earth' wire in double rail track circuit areas, the wire being bonded to track generally at the outer ends of consecutive track circuits. All these bonds are 0·15 in.^{2} stranded copper braided cable and have been connected to rail by gas welding and to impedance bonds by bolted lugs. Electric stud welding with bolted lugs is now superseding gas welding for rail connections facilitating the use of steel bonding cable.

Track bonding for traction purposes has been restricted to ¼ mile in each direction from railway stations and feeder stations but the provision by the Signal Engineer of extensive track circuiting extends these areas as the bonds must be capable of carrying traction current. Rail-joint bonds are stranded signalling No. 8 S.W.G. copper pin-bonded to the rail web, two per joint on track circuited rails and three per joint on common or traction rails. Cross bonding between tracks is carried out in 0·15 in.^{2} stranded copper braided cable connected as for structure bonds and the following intervals are laid down for guidance:

	No track circuits	*Single-rail track circuits*	*Double-rail track circuits*
R.R. Booster areas	800 yds	400 yds	Not more than 1,600 yds or closer than outer ends of two consecutive D.R.T.C.
R.C. Booster areas	1,600 yds	800 yds	

0·15 in.^{2} continuity, transposition and point and crossing bonds are provided as required.

Track rails are connected through links at all feeder stations and through spark gaps at all sub-feeder stations and track sectioning cabins to earth electrodes. It is, however, anticipated as has been found in other countries that following tests and experience it will generally be possible to dispense with the earth electrodes due to the track having a lower earth resistance.

At level crossings inadvertent contact between running rails and gates is avoided and the latter are insulated from rodding or signal wires. In other words the crossing is kept 'floating'. Lifting barrier type are treated in the same way except that booms and metallic skirts are earthed.

Metalwork at stations and other buildings is bonded and connected to 'earth' wire or running rails.

Bridge metalwork is bonded and connected to earth; where overhead line equipment is attached to the bridge a spark gap is fitted between the bridge earth connection and the rails.

Special rules apply to buried pipes and oil and similar installations are dealt with generally as laid down in the international regulations.

7 Design and Construction

The construction of the overhead line equipment in the field is the subject of Papers 7 and 36 but some reference is needed here to the inter-relation between design, supply and erection. Design is a central function providing standard equipment to meet the requirements of all regions of British Railways which vary greatly in the extent to which various types of equipment are required. Design of the overhead line and its supports has been done for the British Transport Commission under contract, principally by British Insulated Callender's Construction Co., Ltd and British Insulated Callender's Cables Ltd, in association with and under the direction of the Chief Electrical Engineer. Pirelli-General Cable Works Ltd have been directly concerned with special and alternative equipment designs for Scotland and Tubewrights Ltd as subcontractors with tubular structure designs. To ensure proper attention to installation, maintenance, civil engineering and local considerations, the Chief Civil Engineer (BTC) and the regional Chief Mechanical and Electrical Engineers have been associated at frequent design meetings with the Chief Electrical Engineer and the Contractors.

The planning and survey are the first moves in the process and the earlier they are finalised the quicker and cheaper the job will be. In design, however, particular attention has been paid to the provision where desirable as in the case of steelwork, of standard components in a range of sizes, which can be assembled in a variety of ways to meet differing needs. This, apart from facilitating maintenance of stocks, assists survey and allocation of equipment to particular locations. Design and development have been pursued with ease of erection in mind, as for example compound equipment, so as to meet part way the difficulty of obtaining adequate track possessions in this country. Further, the high labour cost of erection is a serious problem here and these policies have helped to keep it in check.

Mechanisation has been extensively adopted in erection and the designs of equipment, such as foundations have been developed with this in view.

8 Maintenance

Insufficient experience has been obtained to date with the equipment described in this paper to be able to give a comprehensive report on its maintenance. The only true maintenance item which has so far arisen is the necessity to clean insulators in situations near the sea and at some few locations where heavy pollution, principally from steam locomotives, occurs; in the worst places this has been at six-monthly intervals but in most places no cleaning has been done during 1½ years of service. Some greasing of insulators and also of fittings has been done to reduce very localised television interference in fringe areas (see Paper 37A).

Although no specific maintenance periods are provided in the time-table, regular possessions will be arranged at any places where abnormal maintenance may be shown by inspection to be unavoidable.

9 Conclusion

It is not practicable to measure the performance of some aspects of the equipment, such as corrosion and freedom from maintenance, except over a period of years but initial indications are that the objective will be achieved. Insulator performance, with the one exception of semi-conducting glaze, has been encouraging and its extensive use in bending justified. The current collection has been shown to be good and compound equipment has been proved superior and worth while. The sectioning devices developed and being developed show a notable advance on anything previously available.

The first British designs are more costly and elaborate than designs developed in other countries, intentionally so, to meet what are considered more onerous operating conditions but current development is in the direction of economy. The more economical and simpler constructions of overhead line fittings and line sectioning may be anticipated to be applicable in other less heavily populated and less densely industralised countries; the application elsewhere of the more expensive non-ferrous constructions is unlikely except in isolated locations where atmospheric conditions are particularly bad.

SUMMARY

Attention is drawn to special design desiderata especially traffic density in terms of the high number of trains per day, the consequent importance of minimum track occupation and the necessity for mechanical track independence. The very small clearances available in the British structure gauge, the multiplicity of over-track structures and the adverse atmospheric conditions are major factors affecting design. The necessity for excellence of performance to allow speeds up to 100 m.p.h. with the minimum of maintenance is of overriding importance.

Reference is made to the adoption of the lower voltage of 6·25 kV to meet exceptional clearance difficulties and a brief outline is included of the equipment for and method of changeover.

The development of welded-rod-braced portal structures and extensive trials with tubular structures are noted. The use of all non-ferrous fittings on the live side and long-creepage-path insulators is costly and unusual but is considered justified for the initial stages here and for polluted conditions. Compound equipment may at first-sight appear to be reactionary in imitation of D.C. practice but there is convincing evidence that its use is justified for speeds over 60 m.p.h.

The extensive use of multiple-unit trains has resulted up to now in elaborate neutral sections but current development of simpler sectioning devices will effect significant simplification and economy. Section insulators of high performance have been provided and advanced high-speed bi-directional designs have now been developed.

An outline is included of the earthing and bonding procedure adopted.

Brief description of present and anticipated future developments is given, notably the less expensive galvanised live-side fittings, simple high-speed sectioning devices and the use of glass-fibre and toughened glass.

All these developments are continuing towards economy and simplification without relinquishing durability, freedom from maintenance and excellence of performance.

RÉSUMÉ

On attire l'attention sur les desiderata spéciaux de la construction des caténaires, surtout sur la densité de traffic en trains par jour, l'importance de l'occupation minimum de voie qui en résulte, et la nécessité de l'indépendance mécanique des caténaires. Les gardes d'air très petites du gabarit anglais, la multitude des passages supérieurs et les conditions atmosphériques défavorables sont les facteurs essentiels de la construction. La haute qualité des performances nécessaire pour la réalisation des vitesses atteignant 100 m.p.h. avec un minium d'entretien est d'une importance capitale.

On mentionne l'adoption de la tension réduite de 6,25 kV pour faire face aux difficultés exceptionnelles de gabarit et on donne un aperçu de la méthode et de l'équipement adoptés pour la commutation. On signale aussi le développement des portiques armés de verges soudées et les essais étendus des supports tubulaires. L'emploi des accessoires non-ferreux pour les parties sous tension et des isolateurs de grande résistance aux courants de cheminement est coûteux et exceptionnel, mais dans ce pays on le considère comme justifié au début et dans le cas de la pollution de l'atmosphère. L'adoption des caténaires composées peut à première vue sembler quelque peu rétrograde à l'imitation du courant continu, mais il existe des preuves convaincantes montrant que son emploi est justifié lorsqu'il s'agit des vitesses de plus de 60 m.p.h.

L'utilisation très étendue des rames automotrices a entraîné jusqu'à présent l'introduction des sections neutres complexes, mais le développement actuel d'un sectionnement moins compliqué aura pour conséquence un système simplifié et plus économique. On a utilisé des isolateurs de section de haute qualité, et on vient de développer des dispositifs à double entrée pour les grandes vitesses dans les deux sens.

On donne aussi les grandes lignes du processus adopté en ce qui concerne la mise à la terre et la liaison au rail. On décrit les développements actuels ainsi que ceux que l'on envisage pour le futur, notamment les accessoires galvanisés peu coûteux pour les parties sous tension, les dispositifs simples de sectionnements pour les grandes vitesses, l'emploi de la fibre de verre et de verre durci.

Tous ces nouveaux développements tendent vers l'économie et la simplification sans réduire l'endurance, l'absence de maintien et la haute qualité des performances.

ZUSAMMENFASSUNG

Die Aufmerksamkeit wird zuerst auf spezielle Entwurfsbedingungen gelenkt, besonders auf die Verkehrsdichte ausgedrückt durch die hohe Zahl der Züge pro Tag, die daraus folgende Bedeutung einer möglichst geringen Gleisbesetzung und die Notwendigkeit der mechanischen Gleistrennung. Die sehr kleinen verfügbaren Spielräume in der Britischen Lichtraumumgrenzung, die Vielfältigkeit der Oberleitungen und die ungünstigen atmosphärischen Bedingungen sind Hauptfaktoren, die die Konstruktion beeinflussen. Die Notwendigkeit von Geschwindigkeiten bis zu 100 m.p.h. für sehr gute Leistungen mit einem Minimum an Unterhalt ist von grösster Bedeutung.

Die Wahl der niedrigeren Spannung von 6.25 kV um den aussergewöhnlichen Spielraum-Schwierigkeiten zu begegnen, wird erwähnt, ferner sind die Grundzüge des Systems und die Ausrüstung der Umschaltung erklärt.

Die Entwicklung von geschweissten, versteiften Portal-Fahrleitungsmasten und ausgedehnte Versuche mit Röhrenmasten werden erwähnt. Die Verwendung von Nichteisenteilen auf der stromführenden Seite und von Isolatoren mit langem Kriechweg ist teuer und nicht üblich, wird aber für das hiesige Anfangsstadium und in Anbetracht der verunreinigten Luft als gerechtfertigt betrachtet. Die Anwendung eines Hilfstragseiles mag beim ersten Anblick in der Nachahmung der Gleichstrom-Technik als reaktionär erscheinen, doch es gibt überzeugenden Beweis, dass ihre Anwendung für Geschwindigkeiten über 60 m.p.h. gerechtfertigt ist.

Der ausgedehnte Gebrauch der Triebwagenzüge hat bis heute die Anwendung von komplizierten Streckenabschnitten zur Folge gehabt, doch laufende Entwicklungen von einfacheren Vorrichtungen für die Streckentrennung werden bedeutsame Vereinfachungen zur Folge haben und die Wirtschaftlichkeit beeinflussen. Trennisolatoren von hoher Güte wurden eingebaut und neuzeitliche, in beiden Richtungen befahrbare Konstruktionen für hohe Geschwindigkeiten entwickelt.

Das angewendete Verfahren der Erdung und der Schienenverbindungen wird gezeigt.

Die gegenwärtigen und kommenden Entwicklungen, vor allem die billigeren, galvanisierten Verbindungsteile auf der stromführenden Seite, einfache Streckentrennvorrichtungen für hohe Geschwindigkeiten und die Anwendung von Glasfaser und gehärtetem Glas werden kurz beschrieben.

Alle diese Entwicklungen werden in Richtung der Vereinfachung und der Wirtschaftlichkeit fortgeführt, ohne die Dauerhaftigkeit, Unterhaltfreiheit und hohen Stand der Leistung zu beeinträchtigen.

RESÚMEN

El autor se refiere a los deseos particulares en cuanto al proyecto, especialmente con referencia a la densidad de trafico en términos de circulación diária, la importancia consiguiente de ocupación mínima de vía, y la necesidad de independencia mecánica de vía. La pequeña tolerancia permitida por el gálibo de paso libre Británico, el gran número de estructuras sobre las vias y las condiciones atmosféricas desfavorables, son factores mayores que influyen sobre el proyecto. La necesidad de un funcionamiento excelente que permita velocidades hasta 100 m.p.h. junto con un minimo de mantenimiento es de la mayor importancia.

Se hace mención de la adopción de la tensión reducida de 6.25 kV para hacer frente a las dificultades excepcionales para proveer distancia dielectrica *desplazamiento*, y se delinean brevemente el aparato y el método adoptados para el cambio de tensiones.

El autor llama la atención al desarrollo de las estructuras de portal soldadas y a los ensayos realizados con estructuras tubulares. El empleo de todo accesorios no ferrosos en la parte bajo tensión y de aisladores de largo camino para corrientes de fuga es costoso y poco común, pero en este país se considera como justificado al principio y bajo condiciones de suciedad. A primera vista el empleo de catenaria doble puede parecer reaccionario en comparación con corriente contínua, pero hay mucha evidencia mostrando que es justificado cuando se trata de velocidades de más de 60 m.p.h.

El empleo extenso de unidades múltiples ha necesitado hasta ahora la introducción de secciones neutras complejas, pero el desarrollo actual de un seccionamiento menos complicado resultará en un sistema simplificado y más económico. Se han introducido aisladores de sección de muy alta calidad, y se han desarrollado dispositivos bi-direccionales de alta velocidad.

Se incluye en este artículo una descripción breve del procedimiento adoptado en cuanto a la puesta a tierra y la conexión eléctrica entre carriles.

Se describen también brevemente los desarrollos actuales así como los anticipados para lo futuro, especialmente los accesorios galvanizados poco costosos para la parte bajo tensión, los dispositivos sencillos de seccionamiento, a alta velocidad y el empleo de fibra de vidrio y vidrio reforzado.

Todos estos desarrollos resultan en economías y en simplificación sin rebajar durabilidad y buen funcionamiento, ni aumentar mantenimiento.

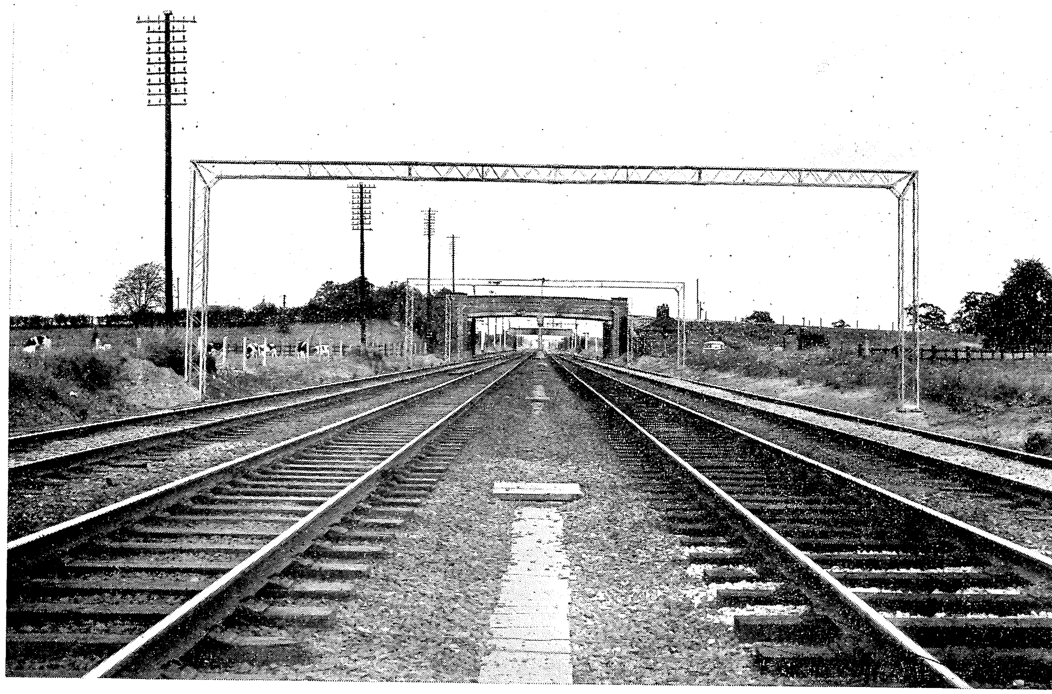


Fig.1a Welded rod portal structure

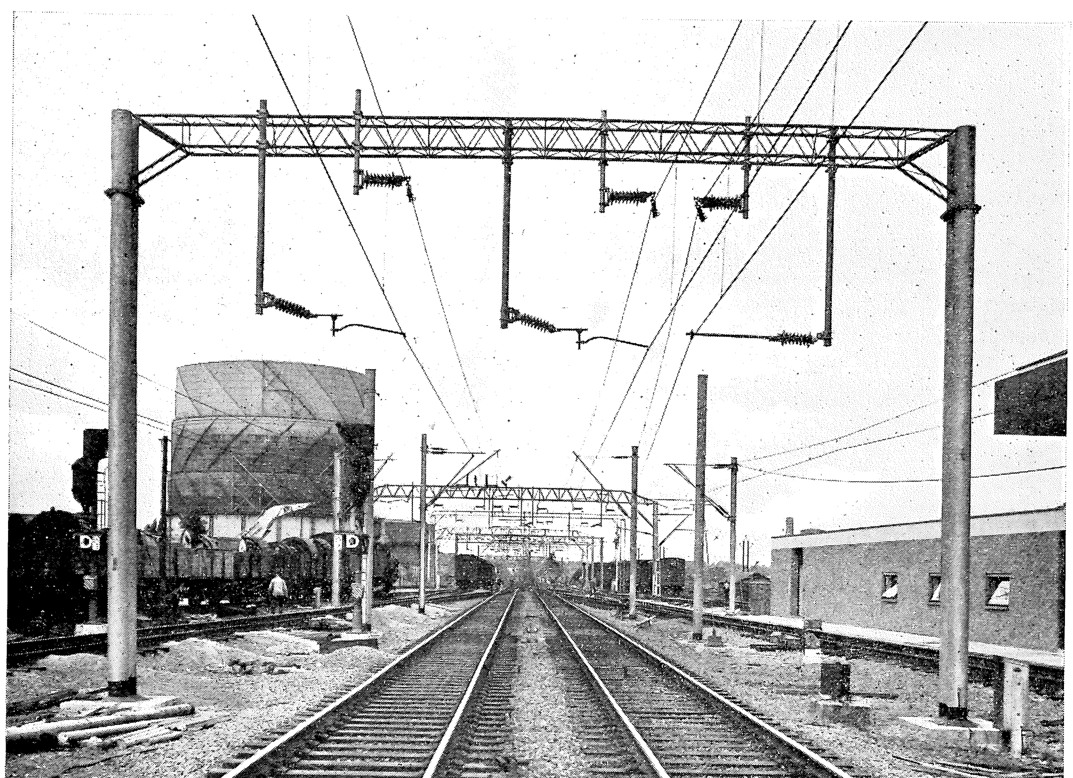


Fig.1b Tubular portal structure

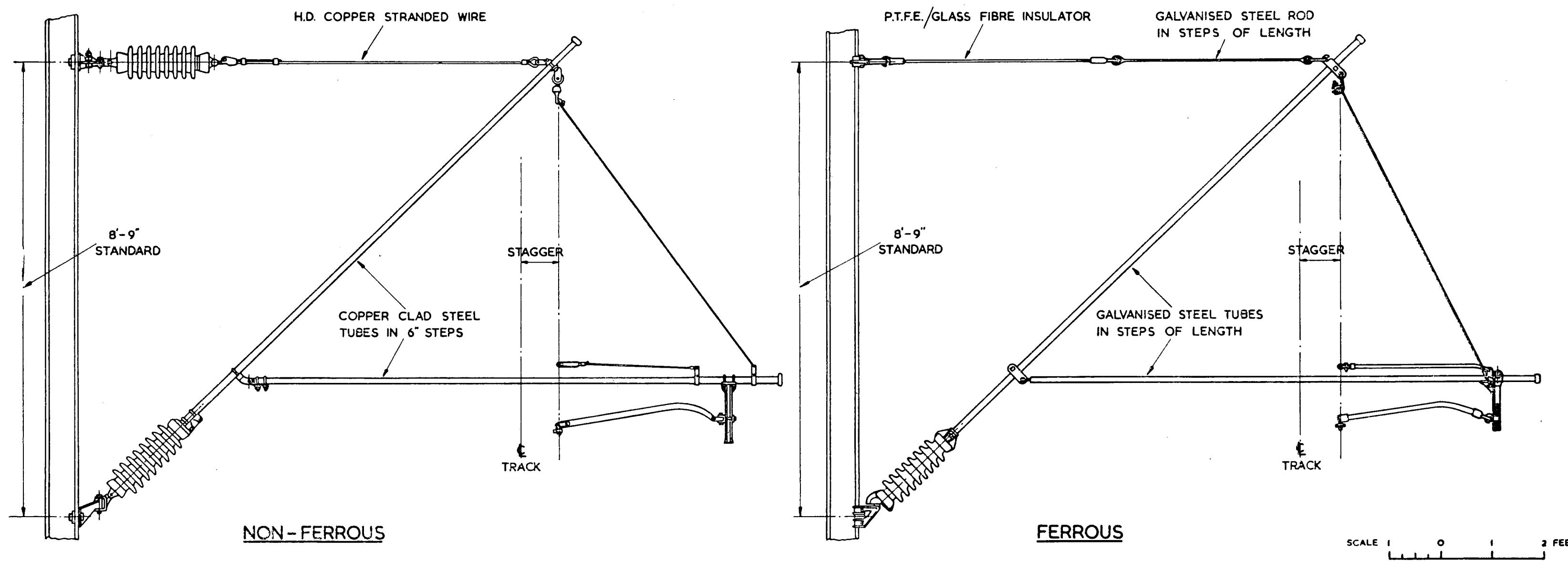


Fig.2 Cantilever Construction

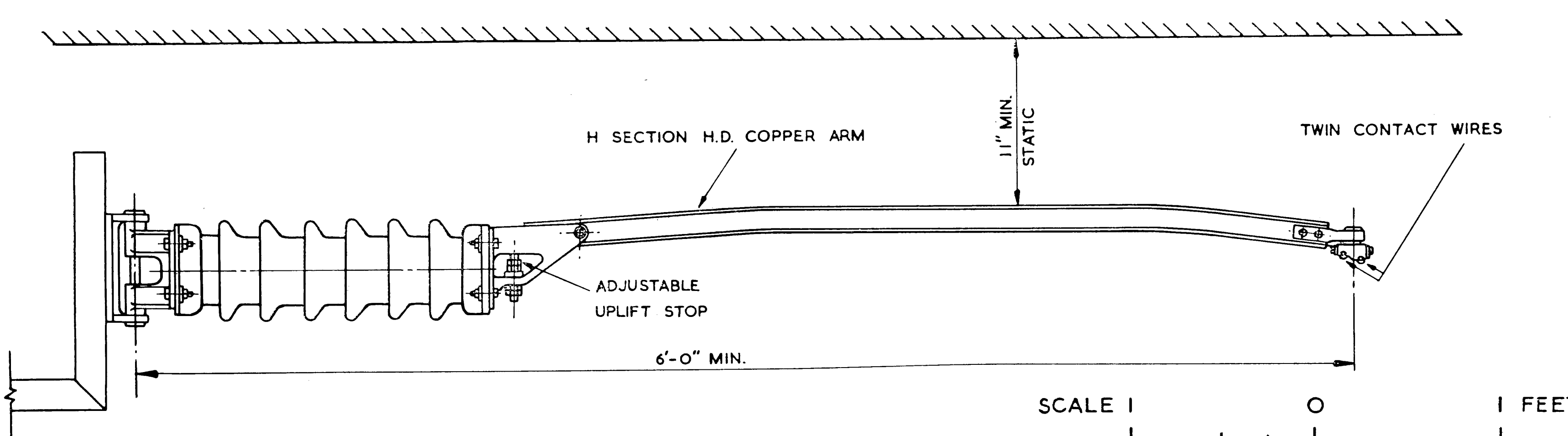


Fig.3 Bridge Support and Registration Fitting

Fig.4 Booster Transformer mounted on structure

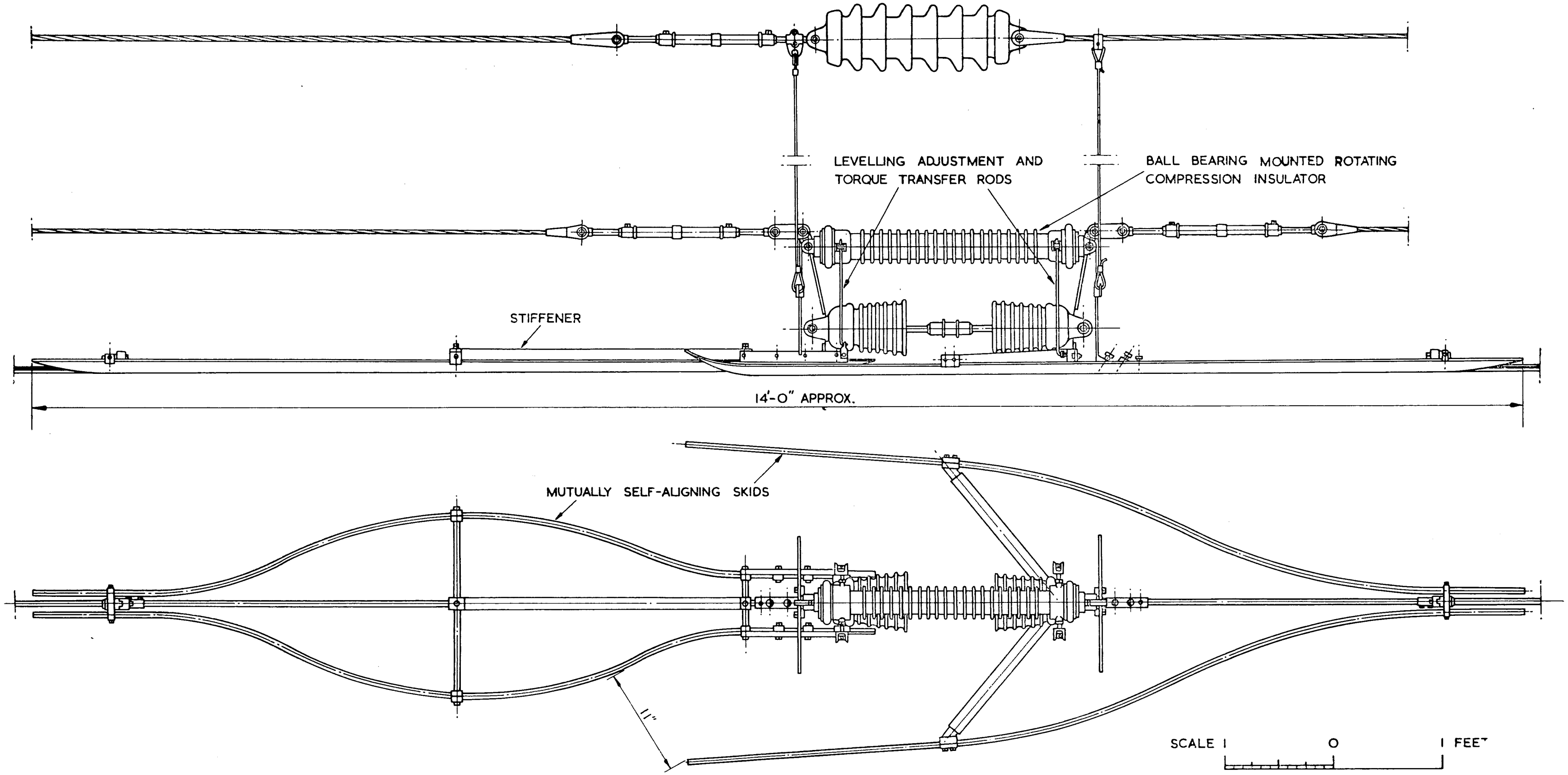


Fig.5 25 kV Section Insulator – porcelain type

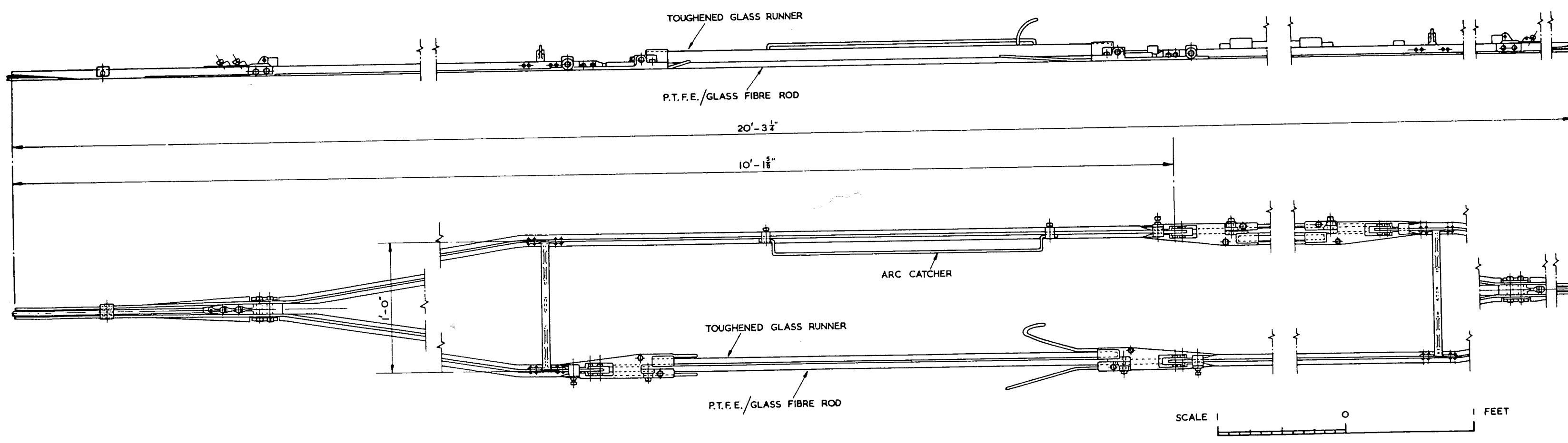
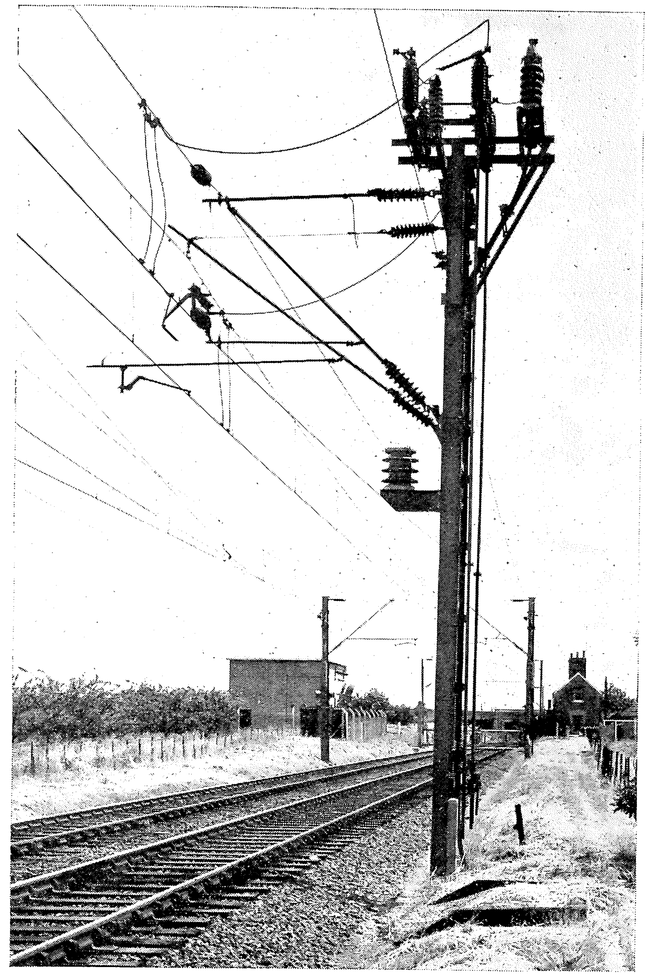


Fig.6 25 kV Section Insulator – glass type

Fig.7 Track feeder structure with isolating switch



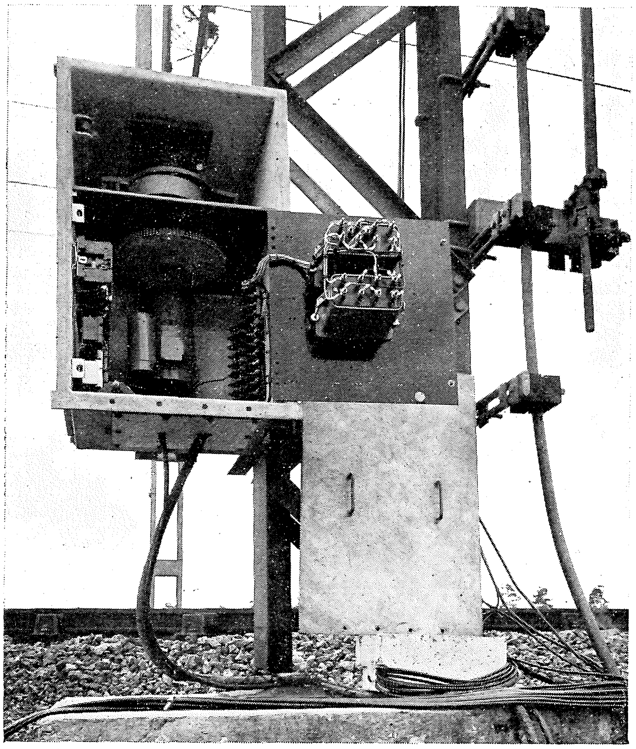


Fig.8 Motorised mechanism for isolating switch (prototype), cover removed

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