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Paper 34

Overhead Equipment: Insulators

C. H. W. Clark, PhD(Eng), AMIEE
Chief High Voltage Engineer, Steatite & Porcelain Products Ltd

1. Introduction

When it was decided to use 25 kV for railway electrification in Britain it was realised that the design of insulators for this comparatively high voltage would raise considerable problems. In many parts of Britain the performance of high voltage outdoor insulators is seriously affected by soiling of their surfaces with soot and other solids with which the atmosphere becomes polluted in heavily industrialised areas. Such deposits contain a proportion of conducting material such as carbon and also a good deal of material which, while non-conducting when dry, becomes conducting in moist conditions. In addition to industrial pollution, salt may also be blown on to insulators near the coast and this forms a highly conductive deposit when moist.

The fact that Britain is an island with large industrial areas and is frequently subject to mists makes conditions for high voltage insulators worse than in most parts of the world. Steam locomotives are necessarily in service during trial running and on certain electrifications some will continue in use for a few years. These provide intense local pollution and moisture condensation and thus still further aggravate the problem for insulators installed over railway tracks.

The problem of suitable insulators was therefore referred by British Transport Commission and their main contractors to the British Electrical and Allied Manufacturers Association who formed a small Committee of manufacturers having wide experience of the problem of high voltage insulators required to operate under polluted conditions. In addition to the author's firm, those represented were Bullers Ltd., Doulton's Industrial Porcelains Ltd. and Taylor, Tunnicliff & Co. Ltd. Factors such as permissible overall size and details of mechanical loads to be sustained were agreed as a basis for design after discussion with the Commission's Chief Electrical Engineer and contractor. Stress was laid on the need to avoid radio and television interference and to ensure reliable operation for long periods without cleaning. If possible cleaning was to be avoided altogether, for the reasons stated in Paper 6. Reference should also be made to Paper 33 for further particulars of the way the insulators are used.

2. General Description

With the problem and requirements clearly recognised, the committee of insulator manufacturers agreed on basic type of insulator design. It was the desire of the Commission to standardise insulators as much as possible.

The cylindrical (or rod) type of insulator was chosen, partly because it has a superior radio interference performance. This type gives complete freedom in dry weather and it has the advantage over the cap and pin type of avoiding concentration of leakage currents near the pin and so minimising surface sparking in damp and polluted conditions. It is also very suitable for applications such as at the base of cantilevers (fig.1), mounting over the booms (fig.2) and horizontal mounting (fig.3), all of which involve bending stresses.

Details of insulator size and shape required careful judgment in the face of conflicting requirements. Other things being equal a long insulator will give better electrical performance but is itself more expensive and may increase the cost of other parts of the overhead equipment. The insulator should have the longest possible creepage distance but this must not be obtained by shapes which make the insulator difficult to clean either by natural rain or, when necessary, artificially. The provision of too many sheds closely crowded together may also lead to sparking across the gaps between sheds while large diameter sheds increase the cost and weight of the insulator. With all these factors in mind a basic design with eight sheds giving a minimum creepage distance of 42 in. was chosen as suitable for inclined mounting at the track side. The same insulator would of course be suitable in the less polluted areas when mounted under less favourable conditions.

Table 1 gives the dimensions, test voltages and working loads adopted as standard or minimum requirements. Over-rigid standardisation was avoided thus permitting individual variations where possible provided interchangeability and certain minimum characteristics were maintained.

This freedom permitted the use of a considerable number of hollow core insulators with stabilising glaze with a creepage distance of 27 ins. for 25 kV.

TABLE 1.

Insulator Characteristics	25 kV			6.25 kV		
Porcelain length (approx.) (ins.)		19½			9	
Creepage distances (minimum) (ins.)		42			16	
Insulation level (impulse withstand test voltage) (kVp)		200			100	
Dry withstand test voltage (kV)		130			70	
Wet withstand test voltage (kV)		110			50	
Mechanical Strength	(a)	(b)	(c)	(a)	(b)	(c)
Tensile withstand load (lbs.)	8,000	15,000	—	8,000	15,000	—
Cantilever withstand load (lbs. ins.)	15,000	30,000	60,000	15,000	30,000	60,000
Mechanical routine test load						
Tension (lbs.)	4,000	8,000	11,000	4,000	8,000	11,000
Maximum Working Loads						
Tension (lbs.)	3,200	6,000	—	3,200	6,000	—
Cantilever (lbs. ins.)	6,000	12,000	24,000	6,000	12,000	24,000

In order to avoid contact between dissimilar metals and the risk of electrolytic corrosion in the service conditions due to steam locomotives, it was specified that all metal work in contact with the catenary should be copper or copper alloy, the insulators providing the separation between the copper of the live metal and the galvanised steel of the supporting structures. The metal fitting at the live end of each insulator is therefore made of copper alloy (nickel gunmetal) having high corrosion resistance while the earthed fitting is galvanised malleable iron. The use of non-ferrous fittings increases the cost of the insulators and with suitable precautions galvanised iron fittings may in future be used where excessively corrosive conditions are not likely to occur.

The design of the overhead system requires in many places the use of insulators with high cantilever strength. These permit considerable economy in some situations while in others they permit space saving without which it would be impossible to meet certain of the specified requirements. One example of the use of these insulators is to facilitate the support of catenaries over several lines of track with complete electrical and mechanical independence of each catenary (fig.2). The high cantilever strength insulators are mounted vertically on a portal structure and each supports a catenary from a horizontal extension attached to its top cap. Single insulators also subjected to cantilever loads are used for side registration. Other uses for the high cantilever strength insulators are supports for catenaries under bridges or in tunnels where space may be saved by using the insulators in the horizontal position.

3. Preliminary Tests under Service Conditions

While the problem of insulating high voltage lines in damp and polluted atmospheres is one on which British engineers have special knowledge and experience, it was recognised that conditions of service for railway insulators might require additional special study. Tests were therefore made by British Railways and their contractors with the co-operation of the insulator manufacturers on insulators installed for this purpose over and alongside track used by frequent steam trains and in a district subject to considerable general industrial pollution.

Initially insulators were exposed to the pollution and were examined and tested periodically. As soon as possible arrangements were made to instal more insulators at different positions relative to the track centre line and to maintain them at their appropriate working voltage (25 or 6·25 kV). The gantry on which these insulators were installed for test is illustrated in figs.4 and 5. Eventually as many as 60 insulators were under test. Observation platforms were provided to enable the insulators to be studied closely with voltage applied and still more closely with the voltage off. The installation was eventually a considerable one but had to be removed to allow the electrification of the line in question. Reference should be made to Paper 11 for particulars of the current research programme.

Assessment of insulator performance was based on the method developed by Forrest (1). The circuit used enabled the leakage current of each insulator to be measured; all leakage current surges in excess of 25 mA were counted and the occurrence of a surge greater than 100 mA was indicated by the raising of a flag which remained up until it was re-set by hand. The hut housing the instruments was visited twice a week. On the few occasions when an insulator became dirty enough to flashover, thus tripping the circuit breaker in the 25 kV transformer primary, it was possible to see which insulator had caused the shut-down from its flag.

Many insulators will be installed in service at the side of the track and will be horizontal or inclined. Both these factors were expected to help the insulator performance. Some insulators on the test gantry, however, are vertical and directly over the track and the results give dramatic confirmation of the expected difference. More recently horizontal insulators have been installed immediately over the track in the lowest position likely to be occupied by insulators in service. These are giving a better performance than the vertical insulators. It should be stressed that the gantry is on rising gradient with a heavy steam service including both freight and suburban working and this gives an accelerated test as conditions are substantially worse than will occur in practice.

Fig.6 illustrates the differences brought out by these tests between various insulators. This graph shows the number of leakage currents surges recorded by different insulators, all installed in the worst position, i.e. vertical and directly above the funnels of steam locomotives. Greased or other specially treated insulators recorded very few surges and are represented by the group of almost horizontal lines near the bottom of the graph. The other curves all refer to untreated insulators. In general they are roughly parallel but in some cases curves cross each other showing that the long time performance is not always correctly forecast by the early results. Within the limited confines of this paper it would be unjust to particularise which design of insulator corresponds to each curve, as considerable explanations are necessary to permit a just assessment.

4. Details of Insulators in Service

In standardising certain overall dimensions of insulators latitude was left for individual makers to propose variations. The insulators now in use at 25 kV include some with a creepage distance of 51 ins. obtained by the use of eight deeply ribbed sheds. Others have eight sheds giving creepage distances of 42 ins. or 49 ins. The diameter of the sheds varies from $6\frac{3}{8}$ ins. to $9\frac{1}{2}$ ins. On track isolators post insulators with 12 plain sheds have been used giving a creepage distance of 45 ins. For 6·25 kV solid core insulators with 2, 3 or 4 sheds giving a creepage distance of 16 ins. have been used for line supports and isolators. All insulators have their fittings attached by means of Portland cement. Fig.7 illustrates the shed shapes of different insulators, some of which are shown in their service positions in earlier illustrations.

Though the demand on the British insulator makers has not been very great in relation to the capacity available for all types of insulator there has at times been a need for special efforts to avoid delays in delivery which could hold up carefully planned construction work. The build up of insulator requirements is shown in the following table:—

Half Yearly Period	*Quantity of Insulators*	
	25 kV	6.25 kV
1957 1st half	8,500	—
1957 2nd ,,	7,700	1,700
1958 1st ,,	23,200	9,000
1958 2nd ,,	5,000	1,200
1959 1st ,,	10,000	5,300
1959 2nd ,,	33,000	11,200
1960 1st ,,	22,600	500
1960 2nd ,, (Estimated)	50,000	5,000
TOTAL	160,000	33,900

5. Performance in Service

On the two trial sections, namely, the Colchester-Clacton line and the Styal loop of the Manchester-Crewe section, approximately 6,000 insulators have been in service for 22 months. On the trial section of the Glasgow Suburban electrification, approximately 1,200 insulators have been in service for 15 months. Particularly over the former of these lines there has been a considerable service of steam-hauled trains throughout the service period. Most of the constructions illustrated earlier in the paper occur on these lines and all the 25 kV types of insulator illustrated have been in use. All of them have performed satisfactorily except those with stabilising glaze. Failures on these occurred initially in places where steam locomotives tended to stand below the insulators and were attributed to the high negative temperature coefficient of this type of glaze. Some months later, a few insulators failed in other positions and it became necessary to decide that this type was not satisfactory for the duty and to replace them. All the other types have given satisfactory service but there are naturally a few places where the conditions as regards local pollution by steam locomotives are at present particularly severe and here it will be necessary to resort to cleaning. This is also the case in a limited area on the Colchester-Clacton electrification where there is exceptionally heavy salt pollution, but experiments with protective greases continue and it is too early to say how frequently cleaning in these special areas will be necessary.

A few complaints of television interference have arisen in this area, where the signal strength is weak and the receivers concerned are exceptionally close to the track. Further details in regard to this are given in Paper 37a.

6. Conclusion

It is clearly too early to pronounce a firm conclusion but satisfaction may be felt with the general report of service given above, implying as it does general absence of failures of the normal types of insulator in use under conditions which are without doubt more arduous than they will be when the electrification is complete.

SUMMARY

In Britain, an industrialised island with a humid climate the effect of surface contamination on high voltage insulators is a well known problem. Insulators for 25 kV electrification are also subjected to pollution from steam locomotives and the insulator makers were asked to put forward designs for these difficult conditions. The designs include two sizes mainly for use in tension. Another suitable for high cantilever loads was required to permit economical arrangements for mechanically and electrically independent support for catenaries over multiple tracks. Tests were made under actual railway conditions near a London terminus to supplement previous knowledge of insulator performance under heavy pollution. Insulators are required to give reliable service without surface discharges which might cause radio interference or flashover and on the present electrified lines the majority are giving excellent performance. The solution of the 25 kV insulator problem has been achieved mainly by the use of designs of porcelain with adequate margins and the small extra initial cost should be justified by a reduction of the amount of cleaning required later and by improved reliability.

RÉSUMÉ

En Grande-Bretagne qui est une île très industrialisée avec un climat humide, la contamination de la surface des isolateurs haute tension est un problème bien connu. Les isolateurs pour les lignes électrifiées à 25 kV étant aussi sujets à la pollution de la part des locomotives à vapeur les fabricants d'isolateurs ont été invités à proposer des isolateurs pour ces conditions difficiles. Deux modèles de grandeur différente, prévus surtout pour travailler en tension ont été construits. Pour les caténaires sur les voies multiples, un autre isolateur convenant pour de fortes charges de flexion était demandé pour permettre une disposition économique des supports mécaniquement et électriquement indépendants.

Des essais ont été effectués près d'une gare terminus de Londres sous les conditions réelles des chemins de fer pour compléter les connaissances antérieures sur les performances d'isolateurs sous une forte pollution. Les isolateurs sont tenus à rendre un service sûr sans décharges de surface, ce qui peut causer des perturbations sur la radio ou des amorçages. Sur les lignes actuellement électrifiées la majorité des isolateurs montrent des performances excellentes. Le problème des isolateurs 25 kV a été résolu surtout en employant des coefficients de sécurité adéquats et les petits frais supplémentaires du début peuvent être justifiés par la réduction des nettoyages et l'amélioration de la sécurité.

ZUSAMMENFASSUNG

Die Auswirkung der Oberflächenverunreinigung der Hochspannungsisolatoren ist in Grossbritannien, einer industrialisierten Insel mit feuchtem Klima, ein bekanntes Problem. Die Isolatoren für die 25 kV- Elektrifikation sind auch Verunreinigungen durch Dampflokomotiven ausgesetzt. Von den Isolatoren-Fabrikanten wurden Entwürfe zur Lösung dieser schwierigen Bedingungen angefordert. Die Entwürfe enthalten zwei Modellgrössen, hauptsächlich für die Anwendung unter Zugspannung. Isolatoren einer dritten Grösse wurden bei hohen Biegungsbeanspruchungen angewendet, um wirtschaftliche Anordnungen der mechanisch und elektrisch unabhängigen Träger der Fahrleitungen über mehrere Geleise zu erreichen. Prüfungen unter Betriebsbedingungen wurden in der Nähe eines Londoner Bahnhofes gemacht, um die bisherigen Kenntnisse über Isolatorleistungen unter starker Verschmutzung durch neue Erfahrungen zu ergänzen. Von Isolatoren wird erwartet, dass sie zuverlässig und ohne Oberflächenentladungen, welche Radiostörungen oder Ueberschläge verursachen können, arbeiten.

Die Lösung des 25 kV- Isolatorenproblems wurde hauptsächlich durch die Anwendung von Spezial-Porzellankonstruktionen erreicht. Die anfänglichen geringen Extrakosten sollten durch Reduktion des späteren Reinigungsaufwandes und durch erhöhte Zuverlässigkeit gerechtfertigt werden.

RESÚMEN

En la Gran Bretaña, país industrializado con un clima húmedo, el efecto de la contaminación superficial en los aisladores de alto voltaje es un problema bien conocido. Los aisladores para la electrificación de 25 kV también son objeto de contaminación procedente de las locomotoras a vapor, y se instó a los fabricantes de aisladores a que presentasen diseños capaces de superar semejantes condiciones. Los diseños presentados comprenden dos tamaños, destinados principalmente a uso con tensión. Otro de los diseños apropiados para elevadas cargas de cantilever debía permitir la instalación económica de soportes mecánica y eléctricamente independientes para catenarias sobre vías múltiples. Se realizaron pruebas en las condiciones propias del servicio ferroviario cerca de una terminal de Londres para completar el conocimiento de que hasta entonces se disponía con respecto al rendimiento de los aisladores sujetos a una intensa contaminación. Los aisladores deben dar un servicio seguro sin descargas superficiales que podrían causar interferencias en la radio o saltos de arco, y en las actuales líneas electrificadas, la mayoría de éllos está produciendo resultados excelentes. La solución al problema en torno al aislador de 25 kV se ha logrado recurriendo al uso de diseños especiales a base de porcelana con márgenes adecuados. El reducido costo adicional quedaría compensado por la menor cantidad de trabajo de limpieza que exigen posteriormente y por su rendimiento más seguro.

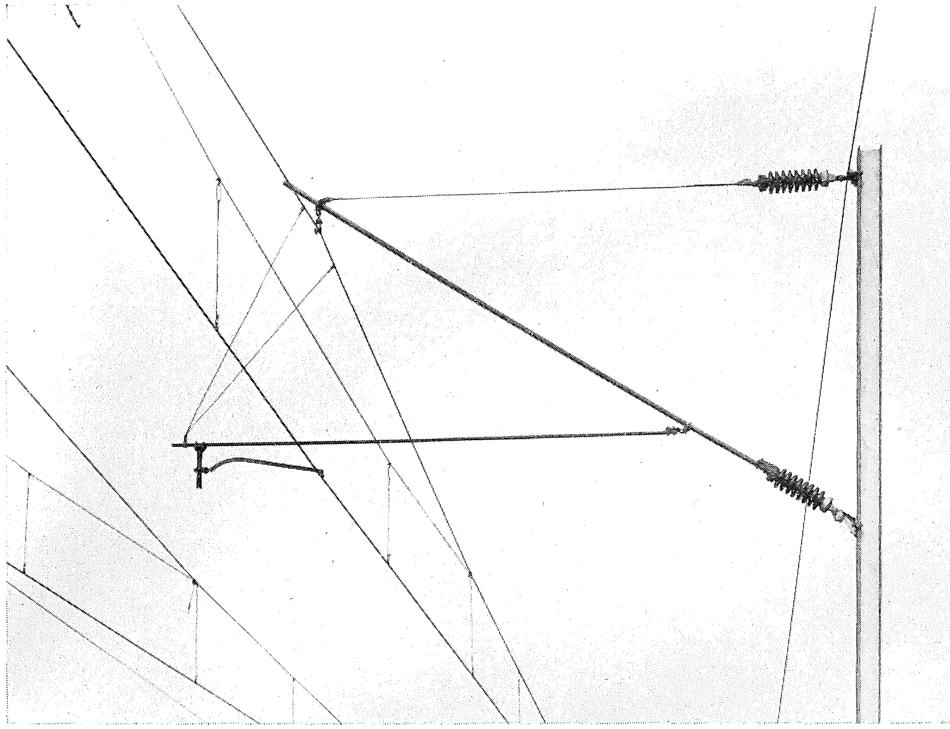
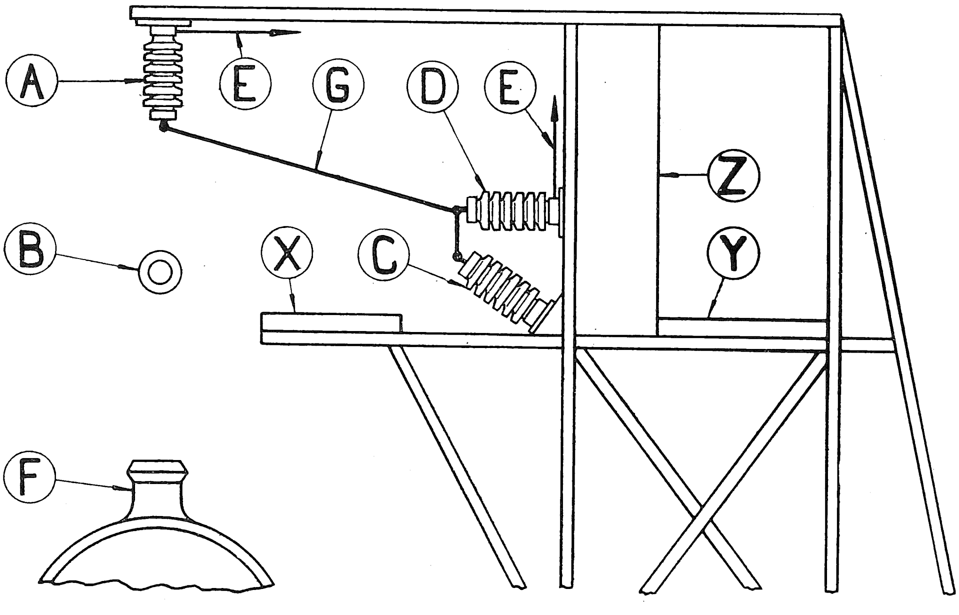


Fig.1 Insulators on single track cantilever

Fig.2 Catenary supporting insulators mounted above structure boom

Fig.3 Catenary supporting insulator mounted horizontally



A Vertical Insulator over centre of track.
B Horizontal Insulator over centre of track.
C Inclined Insulator 3 ft from centre of track.
D Horizontal Insulator 3 ft from centre of track.
E Typical insulated lead to leakage current meters.
F Position of locomotive funnel.
G High Voltage Bus Bar 25 or 6·25 kV.
X Live inspection platform.
Y Dead inspection platform.
Z Safety Screen.

Fig.4 Test gantry

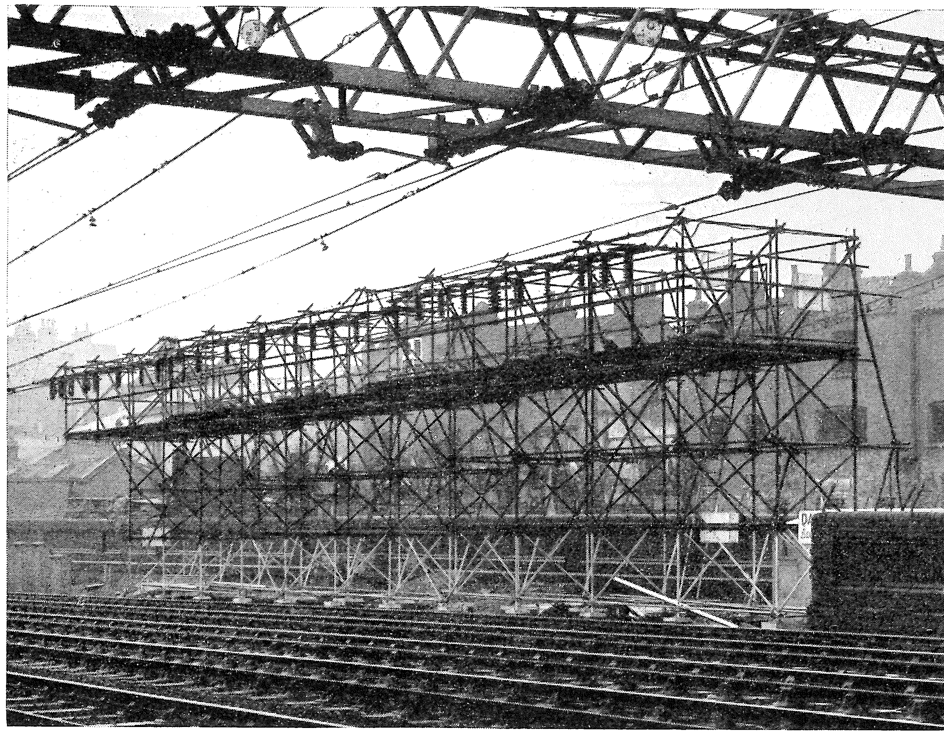


Fig.5 Insulator test gantry

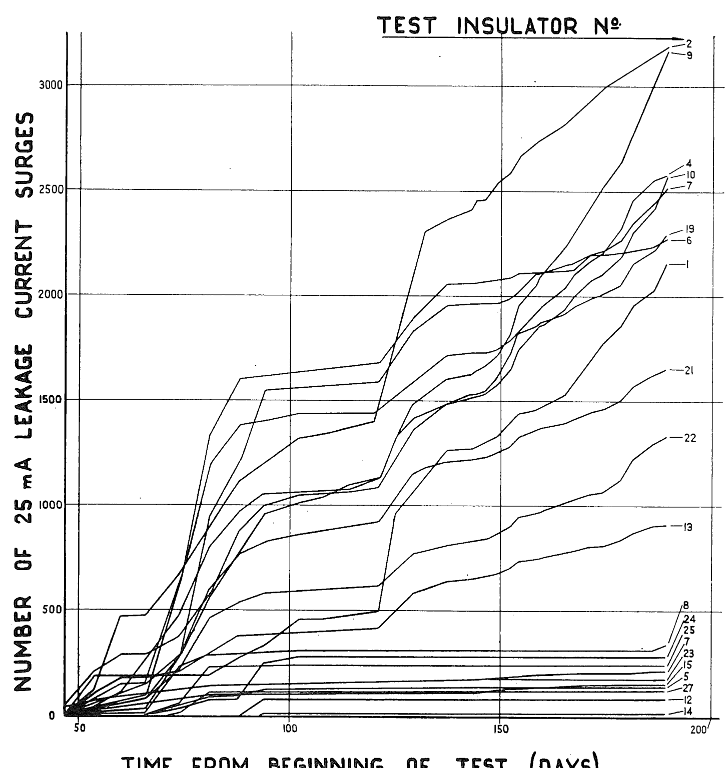
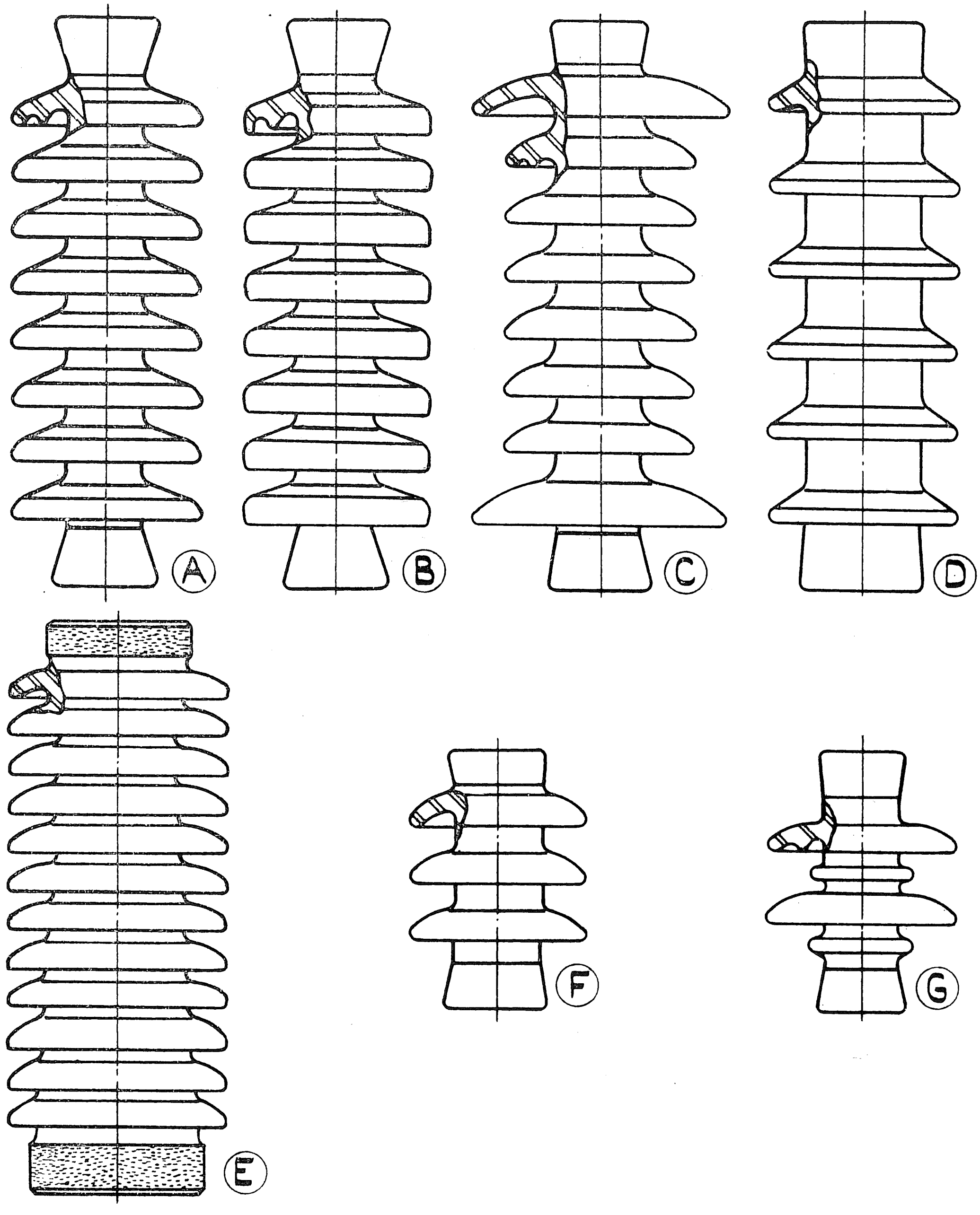


Fig.6 Typical graphs illustrating results of gantry tests



A 25 kV Line Insulator, 8 sheds, 42″ Creepage.
B 25 kV Line Insulator, 8 sheds, 51″ Creepage.
C 25 kV Line Insulator, 8 sheds, 49″ Creepage.
D 25 kV Line Insulator, 6 sheds, 27″ Creepage, Stabilised.
E 25 kV Post Insulator, 12 sheds, 45″ Creepage, for track Isolators.
F 6·25 kV Line Insulator, 3 sheds, 16″ Creepage.
G 6·25 kV Line Insulator, 2 sheds, 16″ Creepage.

Fig.7 Shed shapes of various insulators

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