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Paper 14

The Consulting Engineer's Contribution to 50-Cycle Electrification

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1 Introduction

While British consulting engineers have assisted in various ways in the Modernisation Plan, the contribution of consulting engineers to 50-cycle electrification has been channelled through an Advisory Panel to the Chief Electrical Engineer. This Panel was set up by the British Transport Commission following a meeting held on the 22nd October, 1956, under the chairmanship of Mr. John Ratter, then Technical Adviser to the British Transport Commission. It was arranged that the Chairman of the Panel should be Mr. S. B. Warder, Chief Electrical Engineer, and the consulting engineers appointed were Mr. J. S. Tritton of Messrs Rendel, Palmer & Tritton, Mr. G. F. Kennedy, of Messrs Kennedy & Donkin, and Mr. E. L. E. Wheatcroft, of Messrs Merz and McLellan. Membership of the Panel was subsequently strengthened by the addition of Mr. F. J. Lane, of Messrs Preece Cardew & Rider.

The services of the Panel were in the first instance directed to assisting the Chief Electrical Engineer to solve certain problems of special difficulty arising in connection with the decision to adopt the standard frequency for railway electrification at a nominal line voltage of 25 kV. These formed the subject of four specific remits as described below. In addition, on the appointment of Mr. Lane it was arranged that Preece Cardew & Rider should give special attention to the system tests which have been described in Paper 2. Merz and McLellan were further instructed to prepare schemes for the electrification of certain lines of the Western, London Midland and Scottish Regions as described later in this paper.

2 Remit No.1 – Interference (Kennedy & Donkin)

Interference with communication circuits is a problem that has been greatly accentuated by the introduction of 50-cycle traction and this important subject is dealt with fully in Paper 9. The solution so far adopted in this country has been (1) to connect booster transformers in series with the overhead conductors and rails to restrict the flow of traction current through earth, and (2) to provide heavy magnetic and electric shielding on signal and telecommunication cables which parallel the track.

One particular aspect with which the Consultant Advisory Panel has been concerned is the possibility of designing signal and communication circuits that would be immune to the effect of induced voltages and thus save the cost of providing series boosters and special shielding of cables. In February, 1958, a Committee termed the 'Hot Telecommunication Cable Committee' was formed, with Professor Kapp of Kennedy & Donkin as Chairman. On the Committee were representatives of the Chief Electrical Engineer's Department and Chief Signal Engineer's Department, British Railways, and of a manufacturer of telecommunication equipments and cables.

The Committee came to the conclusion that, so far as railway circuits were concerned, it would be technically feasible to protect terminal apparatus by the use of such devices as isolating transformers and longitudinal chokes; but that some screening would be necessary to prevent breakdown of cable insulation by high voltage induced under earth fault conditions.

The possibility of interference with Post Office circuits, however, prohibits this solution and necessitates suppression at source on approximately 30 per cent. at least of the total track mileage to be electrified at 50 cycles. Both with and without suppression at source some screening and barrier devices are necessary for the Railways' own signalling and telecommunication circuits.

The report of the Study Committee has been accepted by the British Transport Commission. It emerges from this report that no untried devices will be needed for protection of the Railways' signalling and communication circuits. In the absence of the booster transformers, which provide suppression at source, a combination of the well proven methods of screening the cables and isolating transformers in the signalling and telecommunication circuits will provide the best protection. Kennedy & Donkin have been appointed as consultants to find, in collaboration with the Commission's experts, the combination of these methods that is technically and economically most favourable.

3 Remit No.2 – Insulation of Bridges (Merz and McLellan)

The British Transport Commission has laid down a static distance of 11 in. for 25 kV as the minimum permissible dimension between a contact wire and the soffit of a bridge. There are many existing bridges over railway lines in Britain where this minimum dimension cannot be obtained without either raising the bridge or lowering the track. With bridges of relatively simple construction the cost of such modifications is reasonable and consequently many bridges have been raised (and modernised at the same time) while in other cases the track has been lowered and regraded.

Unfortunately there are a number of bridges where neither of these solutions is practicable or economic, and for such cases it was suggested that dimensions lower than 11 in. could be permitted if a suitable form of solid insulating material could be interposed between the contact wire and the bridge soffit.

To meet this problem Merz and McLellan put forward two proposals for interposing solid insulation material as well as an alternative proposal of a metallic shield so designed as to improve the electric stress distribution in the air gap. These are referred to respectively as silicone rubber sandwich insulation, butyl rubber secondary insulation and the electrostatic shield.

3.1 *Insulation Levels*

Under standard ambient conditions the peak impulse withstand voltage of an 11 in. gap will be about 170 kV and the 50-cycle r.m.s. breakdown voltage will be about 120 kV. These values may be exceeded under the most favourable conditions but when subjected to smoke, steam, water vapour and sparks from passing locomotives values 30 per cent. lower than those given above have been measured.

In the development of bridge insulation the puncture strength of solid insulation has been made substantially higher than the above values but the breakdown strength of air gaps has been allowed to fall below these values in certain instances.

3.2 *The Electrostatic Shield*

This is shown on fig.1 (sketch B), and consists of an open mesh shield with its upper surface shaped to give an approximately uniform electrostatic field to the soffit of the bridge. The shield is supported along its edges by conventional post insulators and is made of stainless steel or titanium in order to withstand the highly corrosive operating conditions. An experimental shield of this design has been successfully tested under extreme service conditions and has also withstood repeated arc-over with fault currents up to 10,000 amps without serious damage.

Although the shield is relatively cheap, the effect is to save rather less than 3 in., and therefore its field of application is somewhat limited.

3.3 *Silicone Rubber Sandwich Insulation*

This proposal, which is not illustrated, made use of a sandwich consisting of three layers of silicone rubber. The silicone rubbers used have excellent electrical properties and are resistant to high temperatures and chemical attack, but they have the disadvantage of poor mechanical properties. They are also very difficult and costly to manufacture in large sheets. As a result, the experience gained in making the silicone rubber sandwich was used to develop an alternative proposal which utilises a much cheaper material, butyl rubber.

3.4 *Butyl Rubber Secondary Insulation*

In this design, which is shown in fig.1 (sketch C), there is no electrical connection between the contact wire and the solid insulation, and the air gap is therefore subjected to a slightly higher stress than would occur without the presence of the solid insulation. Nevertheless the air stress under normal 25 kV excitation is quite low and sparkover to the solid insulation will occur only under short-time transient conditions, such as perhaps during the passage of a steam train or during switching or lightning overvoltage conditions. High surface resistance is incorporated in the rubber so that if the air gap breaks down, as described above, the current is limited and the sparkover is not followed by a power arc.

3.4.1 *Practical Application*

The first practical application of this form of insulation was on the Colchester – Clacton – Walton line of the Eastern Region of British Railways when a bridge on this line was equipped on 15th November, 1959, and the insulation has been in successful operation since that date. The method of construction is shown in figs.2 and 3.

The butyl rubber sheet is reinforced by steel plates which are arched for mechanical rigidity and held in position by simple compression clamps. The thickness of the rubber is 0·41 in. and the total thickness including the steel reinforcing plates is 0·6 in. Originally the width of the pad was limited by manufacturing consideration to 6 ft but improvements in manufacturing facilities have enabled the width to be increased to 6 ft 6 in. overall. This width is desirable to provide an adequate voltage withstand level. The upper surface of the pad is coated with high conductivity butyl rubber which is brought over the edges and turned $\frac{3}{4}$ in. on the underside of the pad. The purpose of this layer is to provide an earthy upper surface to the pad and to provide a low resistance contact to the earthed clamps at the side of the pad.

To obtain sufficient clearance to the front and rear edges of the pad at the ends it is swept up at an angle of 15 degrees for a distance of approximately 3 ft from the faces of the bridge.

Weather shields (not shown) are provided to protect the ends of the pad where it protrudes beyond the bridge. Clamps along the sides of the pad perform the dual function of locating the edges of the pad at the correct distance from the soffit and from each other, and of holding the pad in the appropriate position above the conductor. The design of clamp shown in fig.1 (C) includes provision for longitudinal adjustment.

3.4.2 *Conclusions on the application of solid insulation*
Development is still proceeding but the following conclusions seem possible:

(i) It seems fairly certain that low bridges of up to about 39 ft in length can be satisfactorily insulated with butyl rubber secondary insulation.

(ii) In this event the limiting dimension of 11 in. specified by British Transport Commission can be approximately halved.

(iii) Promising proposals exist for dealing with the problem of bridges exceeding 39 ft in length in which the contact and catenary wires may require mechanical support underneath these longer bridges.

4 Other Remits

4.1 *Lightning Arrestors* (*Kennedy & Donkin*)
This remit was investigated and answered comparatively quickly. By the second meeting with the Panel in July, 1957, it was decided to adopt the consultants recommendation to fit lightning-arrestors on the existing locomotives of the Manchester – Sheffield – Wath electrification.

4.2 *Voltage Changeover* (*Merz and McLellan*)
The consultants reported that the only practical solution available which met all the conditions laid down was that developed by the Chief Electrical Engineer's staff and known as the 'three neutral section scheme'. The scheme has been adopted not only at locations where a changeover takes place from one voltage to another at speed, but also at phase change locations. It is described in Paper 3.

4.3 *System Tests* (*Preece Cardew & Rider*)
These are dealt with fully in Paper 2.

5 Schemes for Electrification (Merz and McLellan)

5.1 *Western Region*
In addition to the consideration of the special problems mentioned, Merz and McLellan were asked to prepare a scheme for comparing the economics of diesel and electric traction for the routes between London, Bristol and Cardiff on the Western Region comprising about 200 route miles, and they reported on this in May, 1959.

On the operating side the study required a detailed assessment to be made of the tracks to be equipped as well as the traffic pattern associated with these main routes and several subsidiary lines in order that electric operation could be applied to the highest possible traffic density over the wired lines without leading to uneconomical locomotive changes. A careful assessment was made of the locomotive and multiple unit motive power requirements, as well as the power supply arrangements in order to implement the improved train performances required after the modernisation plan was complete.

On the technical side the scheme was based on electric overhead line equipment and rolling stock designs which had at that time been provisionally standardised by the British Transport Commission. Among the problems involved were those associated with bridge and tunnel clearances and the effect of 50-cycle electrification on signalling and telecommunication equipment, including the automatic train control system in use by the Western Region. All bridges and tunnels on the routes were gauged so that estimates could be prepared for the cost of modification where restricted clearances existed. Similarly estimates were prepared for the immunisation of various types of track circuits, signal interlockings and telecommunication circuits. For comparative purposes estimates were also prepared for an equivalent scheme using diesel motive power.

After examination by the appropriate Chief Officers of the British Transport Commission and the Western Region, the conclusion was come to that the difference between the estimated costs of diesel and electric operation although slightly in favour of the latter, was not large enough to warrant giving immediate consideration to electrification on these lines in preference to those on which electrification has been programmed. Further consideration has, therefore, been deferred until electrification on authorised schemes has progressed sufficiently to warrant it.

5.2 *London Midland and Scottish Regions*
Merz and McLellan have also been instructed to prepare schemes for 50 cycles A.C. electrification of certain lines of the London Midland and the Scottish Regions. These form extensions from Weaver Junction to Glasgow of the electrification already authorised and proceeding on the main line between Euston, Liverpool and Manchester as well as several connecting lines north of Crewe. The procedure for the study is similar to that described above for the Western Region although in this case it comprises some 900 route miles. Estimates are required not only for the electrification of the main lines but also individually for the connecting lines for the purpose of deciding which of these should be electrified. The latter include conversion of the Manchester – Sheffield – Wath section and the Manchester – Altrincham section from D.C. to A.C. The investigation is still proceeding and is due for completion in April, 1961.

6 Relative Economics of Electric and Diesel Traction (Merz and McLellan)

This study was made for the purpose of establishing a general criterion, applicable to British Railways conditions, for prima facie determination whether electrification would be justified on a particular railway. The results are given in terms of:

(1) Traffic density expressed as locomotive miles/annum/route-mile.
(2) Average number of tracks along the routes.
(3) Locomotive user expressed in miles/annum/locomotive-on-line.

The limitations on its applicability are mentioned and the effect of variations in basic data, e.g. cost of fuel or electricity and interest rates are given. The conclusions are presented graphically over a range of the above-mentioned parameters.

SUMMARY

The paper records the setting up of a panel of Consulting Engineers to advise the Chief Electrical Engineer, British Transport Commission, on matters remitted to it. It describes important contributions arising therefrom, in particular the development to a successful conclusion of means to avoid in certain cases the lifting of bridges or the lowering of tracks. This is achieved by the installation of reinforced butyl rubber insulation attached in a convenient manner to the bridge in question. It is probable that, following successful use on a short bridge, this technique can be now extended to long bridges and even certain tunnels.

The paper records valuable contributions made to the solution of the interference problem leading to a new *modus operandi* for dealing with this matter. It also records the preparation of reports on the relative merits of diesel and electric traction and an investigation in progress on the economics of extending into Scotland the electrification authorised from Euston to Manchester and Liverpool.

RÉSUMÉ

Cet exposé mentionne la formation d'une commission d'Ingénieurs-Conseils pour conseiller l'Ingénieur Électricien en Chef de la British Transport Commission sur les questions qui sont soumises à la dite commission. Les contributions importantes qui en decoulèrent sont décrites, notamment le développement satisfaisant des procédés qui, dans certains cas, permettent d'éviter de surélever les ponts ou d'abaisser les voies. Ceci est obtenu grace à l'isolation en caoutchouc butyle renforcé qu'on fixe d'une façon appropriée au pont. Il est probable qu'à la suite du succés de son emploi sur un pont court, cette technique puisse maintenant être étendu à des ponts longs et même à certains tunnels.

La rapport décrit aussi les contributions importantes apportées à la solution du problème des effets d'induction qui ont conduit à une nouvelle façon de traiter ces questions. Il rend compte également de la préparation de rapports sur les mérites relatifs de la traction Diesel et de la traction électrique et d'une enquête actuellement en cours sur problème sur la rentabilité de l'extension jusqu'en Écosse de l'électrification déjà autorisée de Euston à Manchester et Liverpool.

ZUSAMMENFASSUNG

Der Bericht beschreibt die Aufstellung einer Kommission von beratenden Ingenieuren, die dem Chef Elektro-Ingenieur der British Transport Commission über die Fragen, die ihr zugewiesen werden, Rat erteilt. Bedeutende Beiträge, die entstanden sind, werden beschrieben, im Besonderen die Entwicklung zu einer erfolgreichen Lösung um das Erhöhen von Brücken oder das Senken von Geleisen in gewissen Fällen zu vermeiden. Dies wird durch eine Zwischenlage von verstärkter Butyl-Gummi Isolation erreicht, die in einer passenden Art an der betreffenden Brücke befestigt wird. Es ist wahrscheinlich, dass als Resultat einer erfolgreichen Anwendung an einer kurzen Brücke diese Methode jetzt auch auf lange Brücken und selbst auf gewisse Tunnelle ausgedehnt werden kann.

Der Bericht beschreibt ferner wertvolle Beiträge zur Lösung von Störungsproblemen die in der Behandlung dieser Fragen zu einer neuen Arbeitsmethode führten. Er beschreibt auch die Vorbereitung von Berichten über den relativen Wert von Diesel- und elektrischen Betrieb, weiter eine gegenwärtige Untersuchung über die Wirtschaftlichkeit der Ausdehnung der Elektrifizierung nach Schottland, die bereits von Euston bis Manchester und Liverpool genehmigt ist.

RESÚMEN

En el documento se hace constar el establecimiento de un cuadro de Ingenieros Consultores para asesorar al Ingeniero Electricista en Jefe, Comisión Británica del Transporte, sobre los problemas que se planteen. Se describen las importantes contribuciones que se han aportado, en particular el desarrollo de los medios apropiados para evitar, en ciertos casos, el levantamiento de puentes o el descenso de las vias, lo cual se puede conseguir instalando un aislamiento a base de caucho de Butilo reforzado acoplado de manera conveniente al puente en cuestión. Es muy probable que, de surtir resultados satisfactorios en puentes cortos, esta técnica se haga extensiva a los puentes largos e incluso a ciertos tuneles.

En el documento se anotan asimismo las valiosas contribuciones que se han hecho para tratar de resolver el problema de la interferencia con miras a conseguir un nuevo metodo de acción con que abordar esta cuestión. Tambien se ocupa de la preparacion de informes sobre el valor relativo de la dieselización y electrificación, asi como del estudio que actualmente se lleva a cabo sobre el aspecto económico en torno a la ampliación hasta Escocia de las lineas de Euston a Manchester y Liverpool, cuya electrificación ya se ha autorizado.

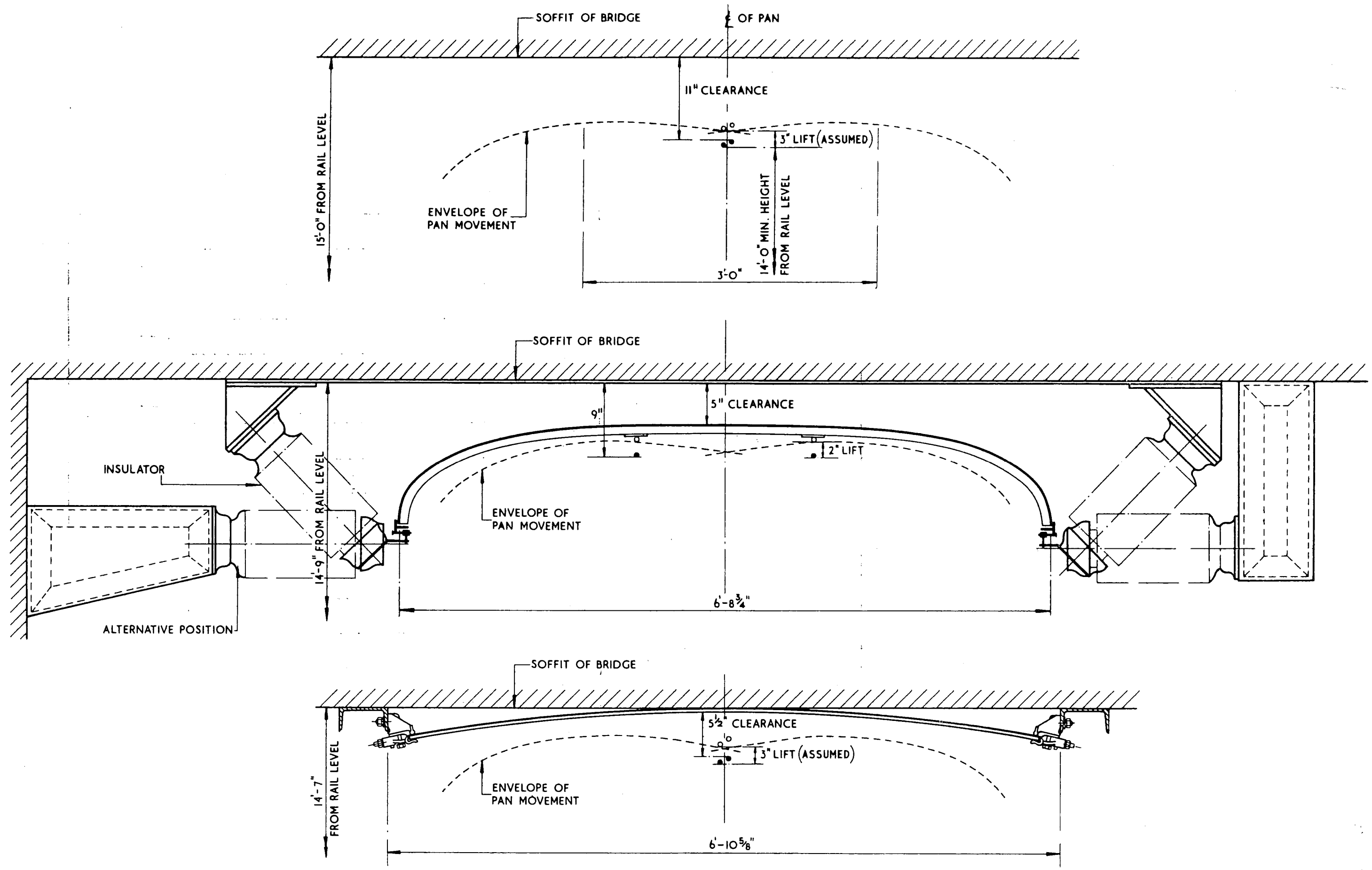

Fig.1 Comparison of clearance under bridges

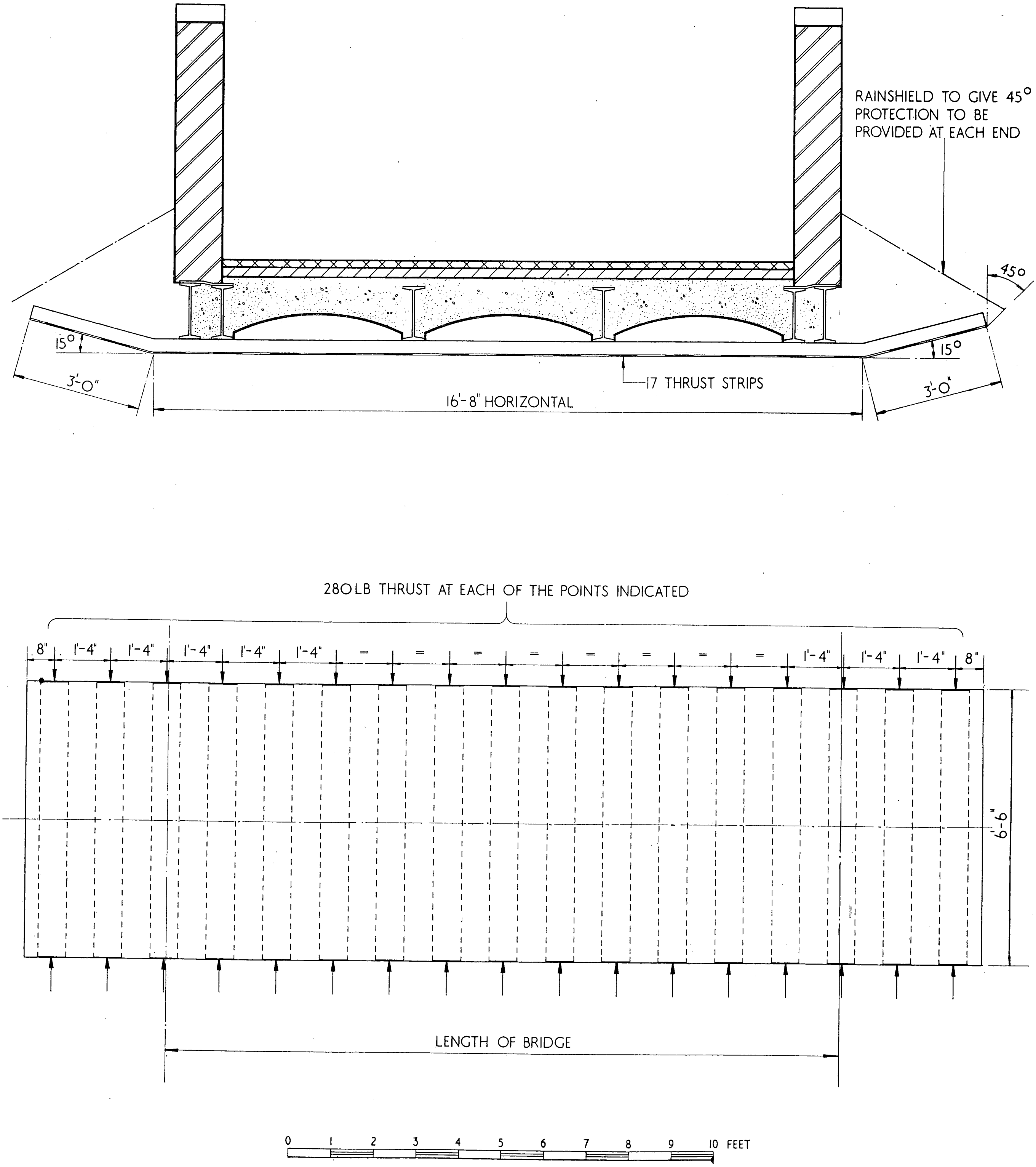

Fig.2 Details of Mark VI butyl insulation at bridge 1039 (Colchester – Clacton – Walton Line, Eastern Region)

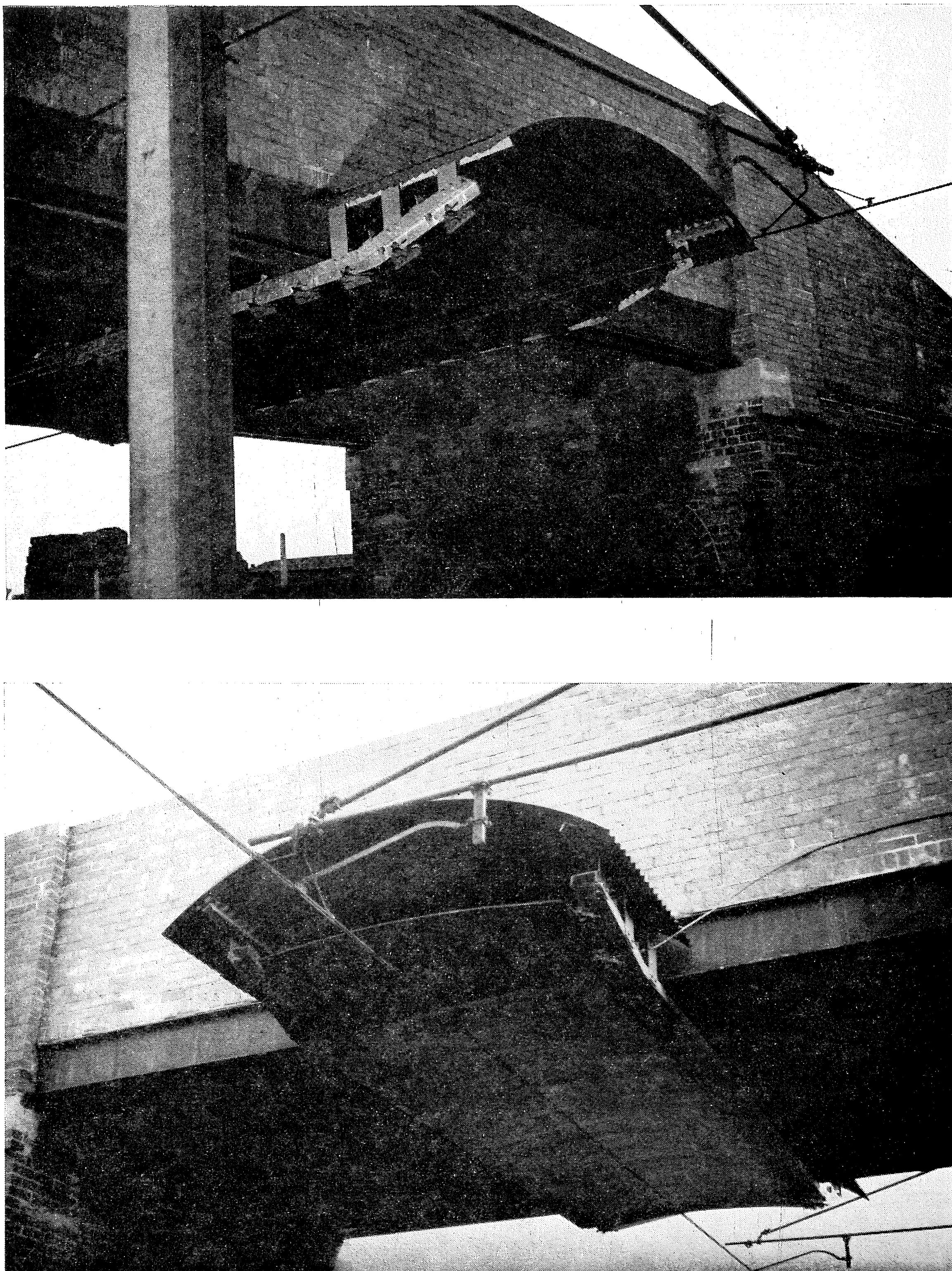

Fig.3 Two views of bridge No.1039 fitted with butyl rubber secondary insulation

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