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Paper 23

Locomotives and Multiple-Unit Trains under Development

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1 Introduction

The fleet of locomotives and multiple-unit trains described in Papers 3 and 4, 15 to 19 and 24 to 27, together with the high speed multiple-unit train sets described later in this Paper, provide an adequate reserve of motive power for the initial stages, from Crewe to Manchester and Liverpool, of the London Midland Region main line electrification and for the authorised suburban electrification schemes. The current plans for further electrification will not require further deliveries of locomotives until about 1963/64. There is time, therefore, to assess the performance of the variations deliberately introduced into this initial fleet and to re-assess some of the parameters which controlled its design. Final re-assessment must necessarily be dependent upon experience of some duration in intensive service, but already certain trends are emerging on a short time basis.

Broadly the features which were standardised in the initial designs are giving satisfaction and no reason is at present seen to vary them. For example, the locomotive cab, the layout of its equipment and the driving technique come into this category. So do the circuit breaker and the pantograph, although accurate measurements now in progress of all the re-actions involved between the pantograph and the overhead equipment will doubtless suggest improvements in detail. In particular, serious consideration is being given to the possibility of avoiding the design restriction imposed by the requirement that transverse tilting of the pan must be avoided. In view of the rapid advances in high tensile plastics, further consideration is being given to the practicability of using insulated horn tips. The general appearance of the locomotives is considered satisfactory and here much is due to the help of the Consultant appointed by the Commission's Design Panel, who has co-ordinated the aesthetic aspect with us and with the contractors.

So far as the remainder of the equipment is concerned, the objective now, for reasons of economy in first cost and maintenance, is to reach a standard design as quickly as possible or at least to restrict the number of variables to a greater extent than in the initial fleets, whilst making suitable provision for new developments which are certain to come.

2 Locomotives: Electrical Equipment

It is convenient to consider the electrical equipment first because this largely controls the mechanical design. It is considered that the locomotives have ample power and a considerable potential to meet increased traffic demands which may arise during their life. It would not, therefore, seem likely that a major revision of the locomotive with its Bo Bo form will be required. There is in this country, where very heavy trains are the exception rather than the rule, no special incentive to adopt a design in which the gear ratio can be changed at will to permit higher tractive efforts on freight duties as an alternative to higher speeds on passenger duties.

The Papers describing these locomotives have not made specific claims in relation to adhesion. The locomotives have been designed to reduce weight transfer but there are significant differences between the various types, and tests now in progress will permit an accurate statistical assessment of their merits in regard to adhesion. Evidence already exists that for the series E3001/23 adhesions as high as 35 per cent. can be maintained with some consistency.

There is certainly not any inducement to abandon the D.C. motor for an A.C. commutator motor.

Serious consideration is being given to the use of axle-hung motors in place of the fully-suspended motors adopted for the initial fleet. Although the evidence is not yet available in a form suitable for reporting, base-plate tests in progress suggest that the reactions on the track due to the axle-hung motors are less unfavourable than has been generally supposed. These tests can be broadly based, as it will be possible to compare the performance of the axle-hung motors used on diesel-electric locomotives over the same track with those of the two types of flexible drive incorporated in the present fleet of electric locomotives. When they are complete, it will be possible for the first time to come to a logical decision on this matter, taking all the factors into account including the cost of the flexible drive and the effect on the track. This possibility is fortunately occurring at a time when, to put it at its minimum, the test-bed and the limited operating experience of the traction motors which have been developed, seem to show that there is no necessity for D.C. motors to be fully suspended to obtain good commutation. It seems highly probable therefore that by the time further contracts have to be placed, there will be adequate evidence to reach a firm conclusion on this matter and there are already what might be called strong indications that the use of axle-hung motors with roller bearing suspension will be justifiable. In that case it would seem unlikely that there would be sufficient economy by the use of one large motor instead of two per bogie or sufficient demand for higher adhesion (which is attainable at a further cost by coupling the wheels) to warrant here the use of that type of construction with the necessity of continuing to incur the relatively high cost of a fully suspended motor with flexible drive. The simplest solution of using two axle-hung motors per bogie may well prove to be the best.

The electrical equipment will still include rectifiers for converting from A.C. to D.C. and for the reasons mentioned in Paper 19, there is a strong case for incorporating a rheostatic brake. This does not necessarily involve the use of semiconductor rectifiers but the space and weight saving by so doing is considerable. Experience with this type of rectifier to date suggests that it is likely to be preferred to mercury arc rectifiers unless new difficulties, which are not at present foreseen, prevent this (see also paragraph 4 below).

Experience in the design and construction of the existing types suggest directions in which the layout of the electrical equipment can be improved. This is inevitably seriously handicapped by the limitation of loading gauge, which is very restrictive. It cannot be altered radically and detailed improvements are only possible on a long term basis, but as the experiments mentioned above are occurring at a time when there is an increase in knowledge of the real nature of the relationship between the wheel diameter, axle load and rail stress, some reduction of wheel diameter may be permissible, for example, 3 ft. 6 ins. for an 18-ton axle load which, on the evidence, seems to be attainable for Bo Bo locomotives of the type required.

The desired improvement in general accessibility can be attained if full use is made of this 6 in. additional height inside the body using the mechanical features of the body described in Paper 19. This has already shown in construction the expected advantage of being able to complete the assembly of the interior equipment before the upper part of the sides and the roof are attached.

Two further simplifications seem to be possible, (*a*) the series arrangement of ventilation described in Paper 17 commends itself for more general use in the future as not only does it reduce the number of fans and auxiliaries but it occupies the minimum of floor space; (*b*) drastic overhaul of the cabling arrangements seem to be indicated, for example, in the direction of taking most of the cables and all of the small wiring away from the floor and arranging them in racks above the equipment, as has been standard practice for some years in British Railways' static substations for conversion from A.C. to D.C. Owing to the narrow width available in our loading gauge, everything possible should be done to widen and clear the passage-way between cabs.

In addition, the experience of the next few months will determine the extent to which the present rather elaborate protection arrangements can safely be reduced. The general policy is clear, namely, to omit them unless they are essential and if necessary further to improve the quality of the equipment to avoid the need for them.

3 Multiple-Unit Trains: Electrical Equipment

A new development actually in hand since the preparation of Paper 4 is the construction of high speed multiple-unit train sets for the Liverpool Street–Clacton main line passenger trains. These comprise 15 four-coach sets and eight two-coach sets permitting the formation of eight-coach trains with two motor coaches or of ten-coach trains with three motor coaches, the latter being used during peak traffic periods.

They will include silicon rectifiers of Westinghouse Brake & Signal Co. manufacture, as sub-contractors to the General Electric Company, who are making the complete equipments. The rolling stock will be built in the Railway Works at York in the North Eastern Region. Other principal data for the four-coach unit with all seats occupied (16 passengers taken as one ton) are as follows :—

Maximum axle load	14·5 tons
Maximum service speed	100 m.p.h.
Balancing speed on level tangent track	90 m.p.h.

Acceleration on level tangent track	0·8 m.p.h.
Average accelerating tractive effort	16,500 lbs.
Continuous rating at wheel in weak field:	
Tractive effort	8,400 lbs.
Speed	54 m.p.h.
Power	1,210 h.p.
Total weight of electrical equipment	21.7 tons.

The design performance curve for the equipment under the above conditions is shown in fig.1.

The journey time from Liverpool Street to Clacton (70 miles) with 5 per cent. provision for make-up time and with four intermediate stops each of 2 minutes will be 85 minutes, an average of 50 m.p.h. and an improvement of 20 per cent. on the present steam timing, and 88 per cent. of the maximum theoretically possible speed if infinite accelerating and braking power are available and speed restrictions are observed. These trains will be brought into service on this duty in 1962. They are heavily powered for this duty but this is deliberate as they may well be prototypes electrically for even faster longer distance multiple-unit trains in the future, working over heavier ruling grades.

Apart from the essential changes consequent upon the substitution of silicon rectifiers for mercury arc rectifiers, the arrangement of equipment and its underframe mounting will be generally similar to that described in Paper 26. The last of the 71 equipments made for the Enfield – Chingford – Bishop's Stortford service described therein includes a rectifier of this type which has now been in satisfactory service for several months. The coaching stock for these trains will be new and although it includes a certain element of modernisation in the interior arrangement and fittings, it will not necessarily be representative of the ultimate high speed multiple-unit train of the future.

As to multiple-unit trains in general, consideration is now being given to the possibility of developing a new underframe, eliminating the trusses of the present design which restrict the layout of the electrical equipment. The question of the optimum weight is also being reconsidered. For the reasons already mentioned above, it is proposed to continue using axle-hung D.C. motors with roller bearing suspension.

Until electronic control equipment is more fully developed, really radical changes seem unlikely in the immediate future in the electrical control equipment. It is likely that the camshaft principle will be more widely adopted and that the major changes will be in the direction of simplifying circuits and layout and by embodying the newest techniques reducing the size of individual components. In spite of this assertion a considerable number of developments are actively in hand by the Commission and electrical contractors and some indication of their nature and scope is given in Appendix I.

4 Further Developments in Electrical Equipment

Three examples of progress by the English Electric Company may be cited:—

(*a*) Locomotive with silicon rectifiers, and infinitely smooth control of power.

The 15th 3,000 h.p. locomotive of series E3024/35 E3303/5 (see Paper 16), will be equipped with air cooled silicon diodes of Westinghouse Brake & Signal Company manufacture in place of the water-cooled ignitrons. It will also have a novel low-tension tap-changing scheme using transducers connected in such a way as practically to eliminate arcing at the tap-changing contacts and to allow the possibility of smooth control of traction motor voltage. The saving in space and weight due to these two features will allow rheostatic braking to be added without any increase in total weight.

This scheme has already been proved on the test bed and the locomotive equipped in this way will be on the track early in 1961.

(*b*) Motor Coach with silicon rectifier and stepless control.

The 112th motor coach equipment for the London, Tilbury and Southend lines, see Paper 25, incorporates air-cooled silicon rectifiers and a novel tap-changing scheme using a stepless regulator manufactured by Brentford Transformers Ltd., to give smooth control of traction motor voltage. The silicon rectifiers are of English Electric manufacture and occupy only half the space of the mercury-arc rectifiers they replace. The traction motors are connected in parallel and the rectifiers connected in bridge. The regulating transformer is an auto-transformer of the type in which carbon collectors are rolled axially along the windings—the whole being immersed in a nitrogen atmosphere and built with class H insulation. In spite of these additional features the weight of this equipment is no greater than that of a conventional one. This type of control provides a minimum of kW loss and reactive kVA during starts, eases tap-changer duty and eliminates notching peaks.

(*c*) Prototype equipment with infinitely smooth control of power.

A prototype equipment has been built and proved on the test-bed for another form of notchless control in which rectifier switching during tap changing relieves the tapping contactors of arc rupturing duty, thereby reducing wear and maintenance and eliminating tap-changing reactors so improving the power factor during notching. This scheme has other consequent advantages.

5 Mechanical Parts

The locomotives and rolling stock represent an acceptable level of achievement already, so far as mechanical as well as electrical design is concerned. Where variations have been introduced to gain experience, deliberate choice must in due course be made of certain features over others. In so far as nothing is already perfect, even the preferred designs must themselves be subject to continuing development, and the following sets out the different items which will call for continued experiment and new design in the future.

The purely mechanical parts of our large fleet of diesel locomotives of a number of different designs have given little trouble in service, and little merit of one type over another so far as performance is concerned, is emerging. The same can be expected to be true of the five mechanical designs described in Paper 3. Development of mechanical parts need only concentrate, therefore, on three main points:—

(*a*) Minimum maintenance attention and costs.
(*b*) Optimum interior layout.
(*c*) Best relationship between weight and cost.

(*a*) *Minimum Maintenance*

Subject to adequate corrosion protection, the maintenance problems centre round the moving parts, concentrated on the bogies. Mileage between tyre turning and minimum removal of material at each turning are an essential goal, the former controlling locomotive availability. All aspects of tyre wear, therefore, require continued research and development in the direction of:—

Reduction of slipping and incipient slipping.
Flange lubrication.
Review of flange and tread profiles in relation to average track condition.
Geometry of vehicle and track regarding attitude of wheel sets to rail.
Harder tyre steels.

There is obviously more latitude in riding quality in a locomotive than a coach, and acceptable riding, within the known rules of suspension design can probably be obtained by more economical means in a locomotive. Although experience has yet to confirm its efficiency, simple inspection of the four bogie designs on these particular locomotives, indicates that one A.E.I. (Rugby) already has the least number of components and a minimum of metallic wearing surfaces. The steel coil spring, of suitable material and not stressed too highly, is a component calling for no maintenance, and use of rubber to replace metallic rubbing surfaces is likely to increase, subject to the arrival of no unpleasant surprises in the nature of the rubber after the passage of years. Controlled damping in the different directions of movement is an essential to good riding, and a whole field of development is waiting here on the improvement of the kind of dampers available today, whose long term behaviour under railway conditions is yet to be found out, or the substitution of others.

The foregoing holds good for M.U. trains, except that a very high standard of riding for the sake of passenger comfort comes first, and the engineer must supply the means, even at the expense of greater complexity. Fortunately the whole trend of the intensive experimental and development work now proceeding here with carriage bogies, is tending towards simplification. Improvement in the riding of M.U. stock in this country is likely to be attained by bogie designs or modifications, which include features likely to reduce maintenance periods and costs.

A weak point in both locomotive and M.U. vehicle design is undoubtedly the brake rigging, and in none of the existing designs can maintenance costs in this respect be expected to be a minimum. This is another subject calling for intensive development in the direction of frictionless and wear free pin joints, and overall design of the brake system to reduce these joints and associated rodding to a minimum. The cast iron brake block on the tyre tread has served us well, but under increasingly intensive operating conditions it is the arbiter of availability and gives rise to undue man hour maintenance costs. The disc brake, already under development in various forms, would, if successful, reduce at one stroke both brake rigging and brake block maintenance.

(*b*) *Optimun Layout for Equipment*

In no case on the existing locomotives and M.U. vehicles is it possible to be completely satisfied with layout and accessibility of equipment inside or under the vehicle. In so new a technique this is a feature calling for a good deal of thought in future development. The electrical equipment itself is under continued development and as its components become smaller and more compact, so better design to simplify cables and conduiting, and the fitting in of the necessary brake piping will be possible.

On locomotives this will be facilitated by a body design which permits assembly of equipment to be carried out to completion in the open as it were, and the arrangement described in Paper 19 or something like it, commends itself for future development.

So far as M.U. motor coaches are concerned, equipment which must be placed under the floor is best served by a form of body and underframe construction without trussing, and this is already being developed.

(*c*) *Best Relationship between Weight and Cost*

For the reasons mentioned in Paper 3, some of the underframe and superstructure designs included in the first fleet of locomotives, are far from being as economical as could be desired. In both locomotives and carriages, the money which can be spent on reduction in weight is strictly limited in relation to the lower traction costs of moving the reduced weight, and use of expensive light alloys in casting and sheet form cannot always be justified economically in this field. In certain of the locomotives, material savings in weight of steel have resulted from using of forms of integral design, but here again even steel construction can be too expensive if the man hour content of the welded sub-assemblies is too great. Once the overall dimensions of the locomotive of the future can be seen more clearly, an intensive investigation into the most economical construction is very desirable. This is already in train in this country so far as coaching stock is concerned, the results of which will be applicable to future designs of M.U. stock.

Although at present not notably cheaper than light alloy, suitable forms of steel reinforced plastic show great promise, even for complete vehicle construction, because the weight reductions which are possible will no longer be marginal, but substantial – as much as 10 to 12 tons per vehicle possibly. Starting already in a small way in passenger coaches, this is a development which may one day be applicable to locomotives.

In the meantime, to an increasing extent, plastics are coming into use to replace sheet metal detail components, and as described in the Papers, there are many such components on the locomotives now under review.

Reduction in weight of power units is the goal of all railway development everywhere, but in this country at any rate, a conservative view is preferred, firstly because weight saving if pursued with excess of zeal can undoubtedly cost too much – more than can ever be recovered by reduction in traction costs. Secondly, the operation of a railway depends upon reliable adhesion, and until a lot more results are available from the current intensive research programme covering conditions in this country, extensive reduction in adhesive weights of locomotives, even with A.C. traction, is a matter for great caution.

6 Electro-Diesel

Six electro-diesel locomotives are at present under construction for use on the Southern Region, developed in the first place to allow the Civil Engineer to have possession of the track for maintenance purposes at night. The combination of a 600 h.p. diesel engine with a standard 1,500 h.p. electrical equipment permits continuation of freight traffic. The equipments are being made by the English Electric Co. Ltd.

Consideration is now being given to the extent to which such a dual purpose locomotive on both third rail and overhead system would be economical for handling certain classes of traffic, a considerable part of whose journey may be over electrified lines, but which need free access to sidings in which the traffic is not sufficiently large to warrant electrification.

7 Conclusion

Although Electric Traction is now well over 50 years old, neither in this country nor in any other has the last word been said. Indeed there never was a time when the promise of new materials, new techniques and new thinking offered more for the future.

So far as mechanical parts are concerned, it is true that the vehicles required are little more than boxes on wheels. But amongst many new possibilities two items alone could revolutionise costs and weight. These are better understanding of adhesion and the development of structural plastics. Another aspect is that, of the combined machine, vehicle and track, the former may be paying more than its fair share of the combined capital and maintenance charge – we do not know yet.

Electrically, elimination of moving parts from control gear and simplification of cabling as we know it now on board the vehicles would bring big changes to overall design.

While, therefore, we must be bold and choose systems and establish standards which have best expectation of avoiding too early obsolescence, and which will give economical production and use for a sufficient period, another part of our minds and activities must always be well out in front sounding and testing new possibilities as they dawn.

SUMMARY

This Paper explains that a pause in the ordering of equipment will permit at least a preliminary assessment being made of the merits of the different varieties of electrical and mechanical equipment incorporated in the initial fleet of locomotives and multiple-unit trains described in other Papers.

It expresses the view that the features which have been standardised in the initial designs are likely to be maintained in the next fleet, for which the design will be standardised to a greater extent.

The electrical equipment of locomotives is considered next as largely controlling the mechanical design and the view is expressed that if experiments now in progress maintain their present trends, the Bo Bo form of locomotive is likely to be maintained, probably with axle hung motors, semi-conductor rectifiers and a rheostatic brake. The hope is expressed that a smaller wheel diameter will be permissible on a lighter locomotive giving additional headroom in the very restricted body controlled by the limited loading gauge. Proposals are being made for making the best use of the space so gained.

The section dealing with the electrical equipment of multi-unit trains begins with a statement of equipments recently ordered for high speed main line service between Liverpool Street and Clacton, including semi-conductor rectifiers and looks forward to a more convenient type of underframe for future equipments.

Examples are given of three further developments in hand or in the prototype stage.

The Paper concludes with a statement of work in hand on mechanical parts to ensure minimum maintenance, optimum interior layout and the best relation between weight and cost. It mentions the special attention that is being paid to problems associated with braking and the use of plastics. It concludes with a brief reference to electro-diesel locomotives under construction for use on the Southern Region and to investigation in progress as to the possibility of these being used beneficially on lines being electrified on the 25 kV system.

RÉSUMÉ

Dans cet exposé on explique qu'une intervalle entre les commandes de matériel permettra de juger, du moins d'une façon préliminaire, les mérites des différents types d'équipement électrique et mécanique qui ont été incorporés dans les unités du premier parc de locomotives et de rames automotrices lesquelles sont décrites dans d'autres exposés.

On exprime l'opinion que, selon toute probabilité, les particularités normalisées pour les constructions initiales seront retenues pour les unités du parc prochain, pour lesquelles la construction sera encore plus largement normalisée.

Ensuite on traite l'équipement électrique des locomotives du point de vue que cet équipement controle en grande partie l'étude des parties mécaniques et il exprime l'opinion que si les tendances des expériences actuellement en cours continuent dans leur présente voie, les futures locomotives seront, comme celles déjà construites, du type Bo-Bo, et comprendront probablement des moteurs suspendus par le nez, des redresseurs semi-conducteurs et le freinage rhéostatique. On souhaite qu'il s'avérera practicable de construire une locomotive plus légère avec des roues de diamètre moins grand laquelle, de ce fait-ci, aurait une plus grande hauteur libre dans la caisse dont les dimensions sont limitées par le gabarit restreint. On est en train de formuler des propositions pour le meilleur emploi de l'espace ainsi gagné.

La section de l'exposé qui traite l'équipement des rames automotrices commence par une précision des équipements récemment commandés pour le service haute vitesse de la grande ligne entre la gare de Liverpool Street et Clacton, lesquels comprendront des redresseurs semi-conducteurs. Ensuite elle prévoit un type de chassis plus commode pour le futur matériel.

On donne trois autres exemples de développements en cours ou au stade de prototypes.

On termine l'exposé en précisant le travail actuellement en cours quant aux parties mécaniques pour réduire au minimum l'entretient nécessaire et pour obtenir les meilleurs dispositions intérieures et le rapport le plus avantageux entre le poids et le coût des véhicules. On mentionne les soins spéciaux consacrés aux problèmes posés par le freinage et par l'emploi de matières plastiques. Enfin on traite brièvement les locomotives electro-diesels en cours de construction pour l'usage sur la Southern Region et les recherches actuelles concernant la possibilité d'employer avantageusement de telles locomotives sur les lignes en cours d'électrification en courant monophasé 25 kV.

ZUSAMMENFASSUNG

Dieser Bericht erklärt, wie eine Unterbrechung in den Aufträgen auf Ausrüstungen endlich erlauben wird, die Vorzüge der elektrischen und mechanischen Einrichtungen vorläufig zu beurteilen, die in den ursprünglich bestellten und in anderen Berichten beschriebenen Lokomotiven und Triebwagenzügen enthalten sind.

Es wird die Meinung vertreten, dass die in den ursprünglichen Entwürfen bereits genormten Merkmale auch für weitere Lieferungen beibehalten werden sollten und die Normung weiter auszudehnen ist.

Es wird dargelegt, dass die elektrische Ausrüstung von Lokomotiven ihre mechanische Konstruktion weitgehend bestimmt und dass, falls die zur Zeit laufenden Versuche weiter gleichartige Resultate liefern, die Bo Bo Form der Lokomotiven wahrscheinlich beibehalten werden wird, voraussichtlich mit Tatzenlagermotoren, Halbleitergleichrichtern und Widerstandsbremsung. Der Hoffnung wird Ausdruck gegeben, dass bei leichteren Lokomotiven ein kleinerer Raddurchmesser erlaubt sein wird; dies würde einen Gewinn an Höhe in dem durch das enge Ladeprofil sehr eingeengten Wagenkasten ergeben. Vorschläge werden gemacht, den so gewonnenen Raum möglichst gut auszunützen.

Der Abschnitt, der sich mit der elektrischen Ausrüstung von Triebwagenzügen befasst, beginnt mit Angaben über vor kurzem bestellte Ausrüstungen mit Halbleitergleichrichtern für den schnellen Fernverkehr zwischen London, Liverpool Street, und Clacton, und stellt für die Zukunft eine zweckmässigere Form des Untergestells in Aussicht.

Drei Beispiele weiterer Entwicklungsarbeiten werden angeführt, die in Angriff genommen wurden oder bereits zu einem Prototyp gediehen sind.

Der Bericht schliesst mit Angaben über derzeit laufende Arbeiten an mechanischen Teilen, mit dem Ziel, ein Minimum an Unterhaltungsarbeiten, eine möglichst gute Anordnung im Wagenkasten und das günstigste Verhältnis zwischen Gewicht und Kosten sicherzustellen. Den Problemen der Bremsung und der Benutzung von Kunststoffen wird besondere Aufmerksamkeit gewidmet. Die diesel-elektrischen Lokomotiven, die für die 'Southern Region' gebaut werden, werden zum Schluss kurz erwähnt; die Möglichkeit wird untersucht, solche Maschinen auf Strecken zu benutzen, die mit Wechselstrom 25000 V. elektrifiziert sind.

RESÚMEN

Este documento se refiere a la fase relacionada con la adquisición del equipo que se va a emplear y, por lo menos, permitirá hacer un estudio preliminar de los méritos que tienen las diversas clases de equipo eléctrico y mecánico de que están dotadas las locomotoras y trenes de unidades múltiples iniciales que se describen en otros documentos.

Expresa la opinión de que es muy probable que las características que distinguen a los diseños iniciales se adopten para los nuevos tipos de máquinas, cuyo diseño se generalizará todavía más.

Se expresa, asimismo, el parecer de que el equipo y locomotoras eléctricas influirán, en gran medida, en el diseño mecánico y se prosigue arguyendo que de persistir la tendencia actual lo más probable es que se mantenga el modelo Bo Bo de locomotoras, posiblemente con motores suspendidos por un extremo, rectificadores semiconductores y un freno reostático.

Se expresa la esperanza de que se implante una rueda de diámetro más reducido en los modelos más livianos de locomotora para obtener mayor espacio libre en el armazón sumamente reducido supeditado al gálibo de carga limitado. Se han presentado ciertas propuestas tendentes a facilitar el aprovechamiento de este mayor espacio.

La sección que se ocupa de los trenes eléctricos de unidades múltiples empieza describiendo el equipo que se acaba de encargar para el servicio por línea principal a alta velocidad entre Liverpool Street y Clacton, incluídos los rectificadores semiconductores, y se expresa la esperanza de que en el equipo del futuro se empleen bastidores más convenientes.

Se dan ejemplos de otras tres realizaciones actualmente en producción en la etapa prototipo.

El documento concluye aludiendo al trabajo que se está efectuando con miras a reducir al mínimo el servicio de mantenimiento, conseguir la óptima ordenación del interior y las relaciones más favorables entre el peso y el costo. Hace referencia a la especial atención que se ha dedicado a los problemas relacionados con el equipo de frenado y al uso de los materiales de plástico. Termina, asimismo, refiriéndose sucintamente a las locomotoras electro-diesel en construcción destinadas para la Southern Region, y al estudio que se está haciendo sobre la posibilidad de emplear a éstas ventajosamente en las líneas electrificadas por el sistema de 25 kV.

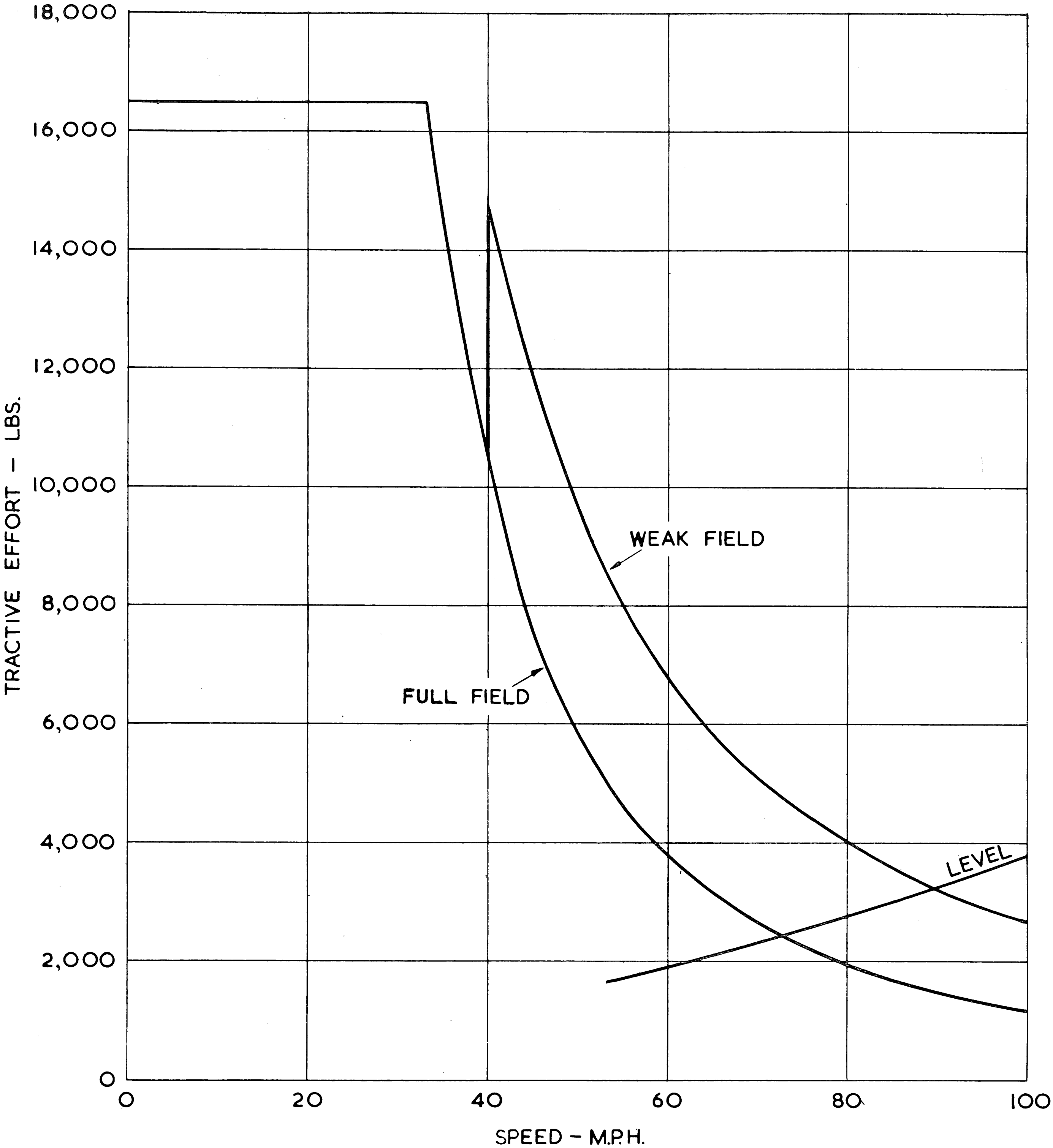

Fig.1 Performance curves for a 4-coach express multiple unit train based on 22·5 kV line voltage and half-worn wheels

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