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Paper 1

Electrification in the Modernisation of British Railways: The Choice of the 50 Cycle System

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1 Introduction

The Modernisation Plan provided for a great supersession of steam traction and accepted the principle that for the main routes of British Railways electric traction was the ideal method to be employed. Concurrently, route modernisation required a considerable engineering effort on track works, signalling and telecommunications. It was thus evident that the electrification programme would be of a long term character, so that, in order to introduce more immediate benefits, a complementary diesel traction programme was simultaneously initiated.

In other words, it was considered that there was room for two forms of traction, each being applied in the appropriate conditions, on the grounds that considerable scope existed for either system.

The purpose of this introductory Paper is to explain why electrification is regarded by the Commission as the ultimate objective for the movement of its main traffic, and Part I will deal with the reasons which have led to the choice of the 25,000V A.C. 50 cycle system.

PART I

2 Why Electrification?

The reason must satisfy every one of the three prime conditions – economic, technical and operational – and one of the great difficulties has always been the determination of a common basis where the new method could be compared on a like for like basis with the old. The difficulty lies in the fact that with electrification the prime mover is removed from the train. This is its technical strength but its economic weakness. Its strength, because it removes items which can fail and are costly to maintain, while unlimited power most efficiently produced is always on tap. The weakness, if it is really a true weakness, is the cost of providing fixed installations capable of providing energy greatly in excess of that previously utilised by an inferior type of tractor in the movement of fewer ton miles.

Consequently, electrification can only be justified where the traffic is heavy or frequent. There are also many cases when electrification by itself has created its traffic by its own efficiency, and our own Southern Region electric services are an outstanding example of producing the revenue for its extension by its own success. Thus it still grows and flourishes, and can continue still further in its own special way to provide a service not yet matched anywhere.

Over the years the success of the Southern Region electrification has not been sufficient to convince those who had to find the money, that it could be repeated elsewhere because of differing conditions, and scheme after scheme has been deferred either because of war, lack of finance, the possibility of improving existing methods.

What has not stopped, however, is technical development, and this has led to what has been called the ‘ battle of the systems ’. The problem of getting the current to the train and the precise point at which the electrical energy should be converted to the requirements of the driving motors has been the issue. While British conditions have, up to now, preferred the use of direct current at comparatively low voltages for distribution to the train, as compared with the Continental and American example of high voltage low frequency A.C. current, the situation has changed dramatically since World War II.

We have the example before us that what is right for one region of British Railways is not necessarily suitable for another, and that once committed to its course the policy must be pursued to its natural boundary. No arbitrary line can be laid down which permits two forms of motive power operating over the same tracks.

3 Historical Note

Three committees have, at various intervals over a period of 30 years, recommended that the most suitable system for British Railways conditions, other than on the Southern Region east of Salisbury, was the 1,500V D.C. overhead system. For the reasons already mentioned very little was achieved in creating a physical reality from these recommendations, and ultimately it was discovered that the inflation of the 1950's had made the 1,500V D.C. system financially less attractive than had previously been supposed.

Technical developments had made a 3,000V D.C. system more attractive and this was tending to gain favour.

In 1954 the International Railway Congress met in London, and among other subjects, the question of the Choice of System was again debated. Of immediate interest it was of significance that no railway administration at that time was interested in changing its system of electrification, which in the main comprised the high voltage low frequency A.C., or the two D.C. systems of 1,500 and 3,000V. Was there to be a new system, which should have all the advantages of all systems and none of the disadvantages?

These possibilities were recognised in the combination of the light fixed equipment permissible with 25,000V, associated with a newly available method of A.C./D.C. conversion to permit the use of a D.C. drive. But it was decided that insufficient experience existed to confirm its supremacy over all other systems.

The Congress did, however, agree that the new system was ideal where the traffic was light or infrequent, but they could not agree that the same conclusion would necessarily apply for heavily loaded lines, or where the cost of electrical clearances was excessive, because it was thought that the savings to be derived from the cheaper fixed equipment would be absorbed, not only in obtaining clearance but by the higher cost of A.C. electric tractors.

The electrification of lightly loaded lines was of little interest to British Railways since the main justification for any kind of electrification here rests on a high traffic density. Dieselisation offers a more readily available alternative in other cases.

The extent of the limited experience available of 50 cycle traction in its modern conception at this time was the experimental section of the S.N.C.F. from Aix le Bain to La Roche sur Foron completed in 1951 and to the British Railways more limited experiment on the Lancaster – Morecambe – Heysham line authorised in 1951. Two experiments, one in France and one in England, were thus proceeding concurrently, although the French experiment being larger, had greater momentum and consequently established a substantial advance on the work in the United Kingdom.

Encouraged by their success the S.N.C.F. went ahead with 50 cycle electrification and brought into service their Valenciennes – Thionville line which was the first major scheme of main line electrification to use this system, and at a gathering at Lille in May 1955, disclosed the enhanced performance of A.C. locomotives over D.C. on a ton for ton basis.

The superior performance was obtained by exploiting the advantages of parallel connected traction motors, not so readily possible with D.C., although many claim that similar advantages lie with the A.C. motors on the low frequency A.C. system. The method is, of course, used in the United Kingdom for diesel electric traction, and the high factor of adhesion obtained on the Southern Region third rail D.C. locomotives represents a similar example of high quality performance, though somewhat costly.

Superiority at equal prices of A.C. locomotives over D.C. locomotives would profoundly improve the prospects for A.C. 50 cycle electrification in conjunction with the acknowledged cheaper fixed equipment (subject to cost of clearance). **In short, the case for a re-assessment in the choice of system for this country was clearly established.**

4 The Decision

The presentation of the case with its supporting evidence took some time to assemble, since numerous interested parties had to be consulted. Finally, the consent of the Minister of Transport had to be obtained.

Meanwhile the Commission had published in December, 1954 its Modernisation Plan, which included a programme of main line electrification, and the statement that its ultimate aim was the electrification of all lines where it could be economically justified, in order *inter alia* to take full advantage of the coming introduction of atomic power for the generation of electricity. No new decision on the system of electrification had, at that time, been taken, and even if it had no time would have been saved since no authority to proceed was forthcoming at this point of time. It was thus just possible to arrange that when instructions were given, A.C. electrification could be introduced as readily as the previously proposed D.C. system.

In the interests of a common system the Commission also decided to convert to A.C. the existing 1,500V D.C. system operating from Liverpool Street Station to Shenfield, Chelmsford and Southend (Victoria), which had to be made without delay to the adoption of A.C. on the other suburban lines in East Anglia included in the Modernisation Plan. This undertaking was given and has been substantially fulfilled.

A full account of the reasons which led to the British Transport Commission to adopt the high voltage A.C. system have already been published and it is only proposed here to refer to the more important technical aspects. These are the aspects upon which the decision to adopt A.C. really turned, but the real answer could not be forthcoming until theory had been borne out by practical results. **This Conference is thus invited to hear and see the reality following from the decisions of 1955 at the first available opportunity which marks only the beginning of a new era in British rail traction.**

5 The Study

The existing systems were giving a good account of themselves, and it would have been very convenient to continue with the 1,500V D.C. system, since it presented few technical problems to the railway engineers or to industry, and offered the advantage of continuity of practice and manufacture.

On the contrary, the A.C. system posed greater technical problems and demanded the rapid development of new designs of fixed equipment and rolling stock.

But there was another consideration. This was the long term view of the prospect of great economies coming from the wider scope for technical progress and the risk of being isolated from enjoying those possibilities in this country, to say nothing of depriving our manufacturing industry from participating in the vast expansion of an overseas market in A.C. traction that appeared more than probable would develop.

In its simplest terms, the 50 cycle A.C. system is an association of the best features of A.C. systems with the best features of D.C. systems, i.e. the high voltage and light fixed equipment associated with a particularly attractive power supply direct from the 132 kV national grid, and the rugged D.C. traction motor with its special ability for heavy and light duty and variable speed operation.

The inherent overload capacity of the system and tractors can absorb additional traffic without extra cost; on light traffic lines, or if traffic falls, the benefit of the lower expenditure on fixed equipment is realised.

It is technically superior in all respects, and overall brings economies in capital and running costs by comparison with its D.C. counterpart.

Electrification offers a sure field for development provided the system is one that has world wide application. This cannot be said for the 1,500V D.C. system, which is unlikely to be used in new schemes or be developed much further. The reverse can, however, undoubtedly be said for 25 kV 50 cycles A.C., as witness the spectacular results of the last five years in France, Turkey, Portugal, Russia, and now India. There is also the fantastic development in the use of semi-conductors as a means of rectifying A.C. current, as a switch and manifold other purposes which are only a beginning to what has been described as the electronic age.

In short, the A.C. system is more flexible than D.C. and with changing requirements it has greater possibilities of development, of useful standardisation, and of increasing economy.

PART II

6 A.C. Electrification of British Railways

The remainder of this Paper deals mainly with features that are peculiar to British Railways conditions, for which special arrangements have to be made. It deals with the equipment that has been supplied and the problems that have been met in making it possible to bring a new system of electrification into use on 184 route miles comprising 535 single track miles in 1960, followed by a further 134 route miles and 376 single track miles in 1961, as a first instalment of the A.C. electrification schemes included in the Modernisation Plan and shown in fig.1. The schemes that have been completed this year are very diverse in character. Most of them are suburban schemes and in the mileage mentioned above no account is taken of the very considerable task of converting the Liverpool Street – Chelmsford – Southend line which is giving excellent service on 1,500V D.C. to A.C. working almost overnight. The first section of the Manchester – Crewe scheme includes the whole of the Crewe complex of yards and sidings and is, of course, only a first instalment of a major main line electrification.

Some reference must be made to the cost of these works, but in the space available it is quite impossible to deal adequately either with the question of cost or justification but only to quote the total authorised expenditure on the schemes which are being commissioned this year as £32 million noting that this includes considerable elements of modernisation, e.g. re-signalling. It is tempting to give characteristic figures of the cost of different parts of the equipment but it would be misleading to do so.

In view of the wide-spread interest in the cost of suppressing interference to telecommunication circuits at the source by the use of booster transformers and return conductors, it may, however, be stated that the nett additional capital cost of doing so is assessed as being of the order of 5 per cent. of the total cost of fixed equipment, when the full scheme with return conductors is used, taking into account the economy that is possible in the screening of railway signalling and telecommunication circuits by doing so.

Only the essential features of the equipment that has been used and the problems that have been encountered are given. Subsequent Papers develop these matters and provide opportunities for their appraisal and discussion.

7 Clearance

Due to the physical limitations which exist to a far greater extent in this country than in most others, the question as to whether there was room for a high voltage contact system was perhaps the most important matter for decision.

There is not much room for any system of electrification, whether third rail or overhead, in a densely populated and industrialised country with frequent train services. Thus, for instance, overbridges of the order of two per route mile rather than level crossings, are a feature. Tunnels are also frequent and of restricted clearance. Also, the small rolling stock loading gauge is very little smaller than the structure gauge.

In practice, the majority of bridges required lifting, and in such cases it was often immaterial whether the bridge was to be lifted 10 ins. or 20 ins., i.e. the question of A.C. or D.C. system was of no significance. The problem was only acute when the bridge or obstruction could not be raised on practical grounds, or of cost. The alternative of lowering the track is not often an acceptable alternative, and other methods had to be considered. These comprised reduction of voltage, dead section, or secondary insulation – and all methods are in use where circumstances require them.

Prior to approval being given to the adoption of 50 cycle traction, British Railways were subject to clearance regulations laid down by the Minister of Transport in 1928, that is, in advance of any practical experience of what was adequate for British conditions. It was therefore necessary to seek relief from this regulation and obtain permission for new values consistent with the best information available as to the worst conditions to be expected during the transition from steam to electric traction.

The clearance figures adopted (substantially those recommended by U.I.C.) were 4 ins. for 1,500V D.C., or 6,250V A.C., 11 ins. for 25,000V A.C., which figure could be reduced to 8 ins. when the clearance is of short duration, e.g. between collector gear and any part of a structure, or is due to uplift of the wire.

Considerable experience, both experimentally and in practice, has now been obtained on this important question, with the result that these values are now considered to be more than adequate for the worst conditions. It is thus possible to seek some relaxation for the less polluted areas and for the future cleaner air conditions as the smoke laden air disappears from industrial areas.

Developments in the use of glass fibre covered with P.T.F.E. have made it possible to substitute supports in tension in place of porcelain which is providing a lighter, cheaper, stronger and cleaner arrangement. The cost of electrical clearance being such a large element in the overall cost of the fixed equipment will consequently be sharply reduced by the new techniques to be described in more detail during the week, and which would possibly have never been produced but for the necessity to meet the special circumstances of the British programme.

The special bridge insulation is another example. After considerable research (see Paper 14) a special form of synthetic rubber mat ½ in. thick, 6 ft. 6 ins. wide, reinforced by steel plates and arched for mechanical rigidity, is held in position by simple clamps.

There is no electrical connection between the contact wire and the solid insulation. Thus the air stress at 25,000V is quite low, and flashover under short time conditions is normally insufficient to cause a power arc.

It is confidently believed that many low bridges can be satisfactorily insulated, and that the 11 in. limiting clearance to earth can be approximately halved.

P.T.F.E. covered glass fibre is also being introduced into the construction of section insulators, which are used to provide an electrical interruption of the contact wire while permitting mechanical continuity of the passage of the pantograph pan. This development makes a valuable contribution to the problem of good current collection and may well warrant wider use of dead sections to assist our clearance problem.

In short, formidable problems of getting adequate electrical clearance are being solved successfully by a variety of methods which will set new standards of design and quality with overall economic benefits.

8 Overhead Line Equipment

The peculiarities of the British climate and the degree of atmospheric pollution, particularly during the final years of steam operation, have dictated the need for materials having a high resistance to corrosion and erosion. It has, therefore, not always been easy in all circumstances to take advantage of the lower cost of the lighter type of structures which the light overhead wire permits. Considerations of trouble free operation with the minimum of maintenance attention are of equal importance with first costs in railway operation. In the case of Crewe Junction for example – one of the world's greatest railway centres containing 70 miles of track within three route miles – its converging main line routes present a formidable spectacle of steel gantries spanning numerous tracks. This is a special case, probably unique, and considerable thought has gone towards maintaining the maximum accessibility to equipment without disturbance of traffic, at greater initial cost than might otherwise have been incurred. Time and experience will show to what extent the high standards that have been set have been justified and where they can be relaxed. Copper clad steel cantilever tubes and non-ferrous fittings are now giving way to cheaper materials, with considerable financial savings in prospect, all of which are dealt with fully in Papers 6 and 33A.

A neutral section is interposed in the contact system at each feeder or sectioning station throughout the system. The operation of multi-unit trains of various formations dictated a multi-gap design to avoid bridging the two live sections, and the same arrangement was used to pass between 25 kV and 6·25 kV areas. It has been considered necessary to make the movement through the neutral sections completely automatic, and Paper 3 describes the technique of doing so.

Magnetic inductors are located on the sleepers before and after each neutral section. A receiver on the locomotive or motor coach is operated by the first inductor, and cuts off and locks out the power circuits. This lock out is released by the second inductor, and the power circuits are restored under the control of line voltage selection relays. In this way it has been possible to introduce a two voltage system of electrification without creating any new operating problem. From the driver's point of view it is of no consequence to his driving duties what voltage he is receiving at the pantograph.

While first British designs have been costly in catering for more onerous conditions than normally experienced elsewhere, this phase is now passing with the introduction of more economical and simpler constructions.

9 The Interference Problem

One of the most controversial matters is the degree of electric disturbance caused to signalling and telecommunication circuits along or near the electrified lines.

It is normally accepted modern practice to replace existing open wire routes on poles by cables whose sheaths can form an adequate screen against induction, and in fact their removal is also required for locating the overhead contact system supports.

Since the Modernisation Plan provided for the modernisation of the signalling system and colour light signalling on the main trunk routes, the introduction of A.C. is not a serious additional liability and experience on the continent had shown that Post Office circuits were not unduly affected by A.C. traction. However, the British Post Office drew attention to circumstances existing in Great Britain which were different from those normally obtaining abroad, in particular to the use of unbalanced circuits for dialling and ringing. The work of altering such circuits would be of such magnitude as to make it impossible of execution within a reasonable time. It was therefore decided to restrict the interference at source.

One method employed is to introduce a return conductor with booster transformers at intervals of about two miles and the whole problem is discussed in Paper 9.

It is not proposed to install booster transformers throughout all electrified routes but only on those where the Post Office conditions require them.

The booster transformer has proved to be an effective solution to the interference problem. It will only be used where necessary. Less expensive alternative methods are under development.

10 Rolling Stock

One of the great advantages which A.C. rolling stock has is the facility of close speed control not so economically practicable with D.C. This characteristic is of greater consequence for locomotives than for multiple-unit passenger trains, but it is a quality which ranks high on the credit side of the new system.

It was also quickly decided that no entirely satisfactory A.C. commutator motor had yet established itself as being superior to a D.C. motor in conjunction with a rectifier. Fortunately a number of varieties of rectifier could be introduced from which a wealth of experience could be obtained.

A final feature that had to be catered for was the necessity, as already explained to enable the locomotives and multiple-unit sets to operate on two voltages. This was an undesirable complication from the point of view of the additional apparatus and some additional expense.

These basic considerations were the foundation of British Railway requirements around which the performance to meet operational conditions had to be designed.

The implementation of the Modernisation Plan required that A.C. suburban electrification in East Anglia and Glasgow ranked equally for completion with the first stage of the Euston – Manchester – Liverpool Main line scheme, which provided also for various suburban schemes in the vicinity of the large towns served by the through services.

It will be evident that the simultaneous electrification of substantial areas in four separate railway regions required the production of substantial quantities of rolling stock. There was also the matter of converting the existing 1,500V system Liverpool Street services and the important question of timing. The only way that this could be achieved was to build the rolling stock for the Liverpool Street – Tilbury and Southend line in advance of the line being electrified and use it for the Shenfield and Chelmsford services whilst those trains were withdrawn for alteration.

It was a fortunate coincidence that the respective fleets were about the same size and a very difficult operation should be accomplished with the minimum of dislocation and interference to the travelling public.

11 Multiple-Unit Trains

It has been explained that one of the merits of electrification is the removal from the train of items that can go wrong. Therefore, it is somewhat of a paradox with the A.C. system equipment formerly in a lineside substation now forms part of the electric tractor. In a sense it is a retrograde step since each unit virtually becomes a mobile substation. However, the saving grace is that those items which are additional are static, having no moving parts, i.e. transformer and rectifier, and consequently little maintenance.

About 400 sets of either three or four cars have been built during the last three years and the introduction of such quantities of new equipment, mostly of a prototype character, must be unique. They have not the glamour of the locomotive but the concentrated work they must do require the highest standard of reliability.

Recent trends favour semi-conductors such as germanium or silicon for the rectification of A.C. current. They lend themselves to underframe mounting, require the minimum of accessories and there are no problems of starting in cold weather.

The first high speed multiple-unit train sets for non-stop services from Liverpool Street to Clacton with corridor stock and refreshment facilities have recently been authorised, and will be capable of a maximum speed of 100 m.p.h. Built into 8 or 10-car trains with two or three motor coaches per train the total available horse-power will be adequate to give spectacular results.

Silicon rectifiers are being employed for these trains.

12 Locomotives

The locomotives will no doubt attract the greatest interest. These are more powerful than any other locomotives in use on British Railways and incorporate features which are new to British Industry.

Basically they represent four different approaches to two kinds of duty laid down by British Railway specifications. These duties were necessary to fulfil the intentions of the Modernisation Plan for faster and more intensive train schedules and consistent punctuality.

It was intended that trains would be normally operated at the following maximum speeds:—

Express Passenger	100 m.p.h.
Local Passenger	75 m.p.h.
Express Freight	60 m.p.h.
Mineral Freight	55 m.p.h.

and the following loads were required:—

Express Passenger	475 tons trailing
Express Freight	500 ,, ,,
Heavy Mineral	1,000 ,, ,,

Two types of locomotives can cover the whole range of work, one for mixed traffic and the other for heavy mineral work. In the event, both types were identical in appearance and equipment, but a different gear ratio limits the speed of the freight locomotives to 80 m.p.h. whereas the mixed traffic locomotive has a maximum speed of 100 m.p.h.

A combination of difficulties has developed in regard to the declared policy of fitting all freight wagons with brakes, both in regard to the equipment and its operation. The result has been to slow down this part of the Plan and this will for the present restrict the opportunities of utilising fully the capacity of the freight locomotives.

For this and other reasons all but five of the first 100 prototype locomotives have been built as mixed traffic locomotives, known as type 'A'.

The difficulties of load gauge and of speed restrictions on British Railways are well known, and in spite of a large programme of track improvement and re-alignment on the London Midland Region route from Euston to Manchester, the effect of speed restrictions which will still continue, because of curves and junctions, precludes a speed in excess of 75 m.p.h. if infinite power, acceleration and braking are available. The proposed average speed of 67 m.p.h. including 4 per cent. make-up gives an improvement of 9 per cent. over a steam hauled 475 ton passenger train.

The locomotives are four axle BoBo units, which due to the limitation imposed by the Chief Civil Engineer must not exceed 20 tons axle weight, nor have a wheel diameter less than 48 ins.

It was decided to incorporate flexible drives and to provide a free issue to the manufacturers of Brown Boveri air blast circuit breakers, and the improved Faiveley Pantograph manufactured by Messrs. J. Stone & Co. (Deptford) Ltd., which are also standard on multiple-unit sets.

The difficulties of the loading gauge made the task of the manufacturers exceedingly difficult, and it is therefore something of a triumph that all designs eventually came out well within the stipulated limit of 80 tons, with a rating, when assessed on the U.I.C. Code 614.0 based on the one hour test, of 4,260 S.H.P.

The previously mentioned decision with regard to the use of D.C. motors and rectifiers left the manufacturers free to offer various designs and arrangements. Similarly, no preferences were expressed either for high or low voltage tap changing for speed control. Both methods were chosen for trial and a considerable measure of freedom was also given in respect of mechanical design.

It was, however, required that all driving cabs should be substantially similar and that the driving technique should be standardised.

All these decisions were taken several years ago when the semi-conductor rectifier, already acceptable for multiple-unit operation, was not thought to be sufficiently developed for locomotive work where operating conditions cannot be so accurately determined. However, the advance in technique has been even swifter than anticipated with the result that the second part of the prototype locomotive delivery consisting of the 40 to be built in Railway Workshops, and one by The English Electric Company, will have either germanium or silicon rectifiers.

The saving in weight and space compared with the mercury arc rectifier arrangement has permitted the use of rheostatic braking to secure economies from reduced brake wear and tyre maintenance.

13 System Tests

In recent years, great advance in electronic measurement techniques has stressed the lack of knowledge of system performance, and made it possible to acquire it.

It is one thing to test an individual machine but quite another to show that a whole system conforms to the performance predicted by the designer. Hitherto most tests of traction systems have been of a piecemeal character relying on numerous assumptions which were not always appreciated. Often maximum conditions were stipulated which were entirely artificial and did not represent the position correctly. It is a matter of history that much harm has been done by such misleading information and progress has consequently been arrested thereby.

In the case of the introduction of 50 cycle traction in the usual atmosphere of doubt as to certain consequences which could not be precisely predicted, the new testing techniques have been called into service. It is no less than a mammoth computing exercise – not in one place, but in many both fixed and mobile.

Information from all sources of interest will be simultaneously recorded and synchronised by electric recorders which are capable of sampling up to twelve different electrical inputs every two seconds. The values are produced in the international teleprinter code as punched tapes. While these recorders can only accept inputs as D.C. voltages they can be used in association with translators where the values originate in other forms, e.g. movement of vehicles and overhead equipment. Thus information under all conditions of service is recorded throughout the system, including the interaction of the pantograph and the overhead catenary, spring deflections, etc. In the signalling and telecommunication circuits, interference effects are being measured whilst other instruments display the fundamental and eleven selected odd harmonics of the wave forms submitted to it.

I should perhaps refer to the absence of particulars of the wave form, power factor or the power consumption of the motive power units. Measurements of all these quantities are being taken but they were not completed at the time of going to press with the Papers concerned; some will be included in Part 2 of Paper 2 and the remainder will be given in the published proceedings.

A fuller description of the work done so far (and it has only just begun) will be given during the week by lecture and demonstration.

The system test programme represents a great step forward in providing speedily accurate information of the greatest importance to designer and user.

14 Research in Electric Traction

The ever quickening march of science has demanded an ever increasing expansion in research. The demands in all fields have been considerable and so far the effort in the traction field has not been commensurate with its importance to the community or potential value, insofar as this country is concerned.

The Modernisation Plan has provided the opportunity for reviewing and expanding the research programme, which has provided for a special research branch in the electric traction field. The large capital investment required justifies every means by which the performance can be improved concurrently with a reduction in cost, and the opportunity has been provided by the adoption of the 25 kV 50 cycle system.

Already tangible results are forthcoming following the increased research interest that has been directed to the many fundamental matters which, but for this major decision, would not have been studied. Particulars of these will be described in Papers during the Conference, but it is already clear that the work being done in this country on adhesion, current collection, and semi-conductor control is as advanced as anywhere else in the world.

Whatever the outcome of these researches, the A.C. overhead system cannot help but benefit more than most. **Thus so long as railways continue to be one of the largest users of single phase power they have a responsibility in fostering the developments which must inevitably take place.**

15 Conclusion

The British Transport Commission adopted the 25 kV 50 cycle A.C. system after a searching enquiry, and came to the conclusion that it was the most suitable system for British Railway conditions as a whole.

It was fortunate that it was cheaper in both first cost and operating cost than the only alternative of 1,500V D.C. but the cost margin was not significant and could only be appreciable in long term when a major section of the system had been converted.

Of course, a valuable export incentive was present, and subsequent events have shown that this country can now make an impressive contribution in this field overseas.

However, the overriding consideration which this Conference has been convened to demonstrate, is the noteworthy developments in electrical engineering which have been stimulated by A.C. traction, in which British industry and the Commission are playing their part.

SUMMARY

After explaining that both Dieselisation and Electrification have their place in the Modernisation Plan for British Railways, the Paper discusses the circumstances in which electrification is desirable, with particular reference to the historical aspects in this country. The circumstances which led to a re-assessment of earlier decisions to standardise 1,500V D.C. overhead (with the exception of the Southern Region electrification at 600/750V D.C. third rail) and the decision in 1955 to adopt the 25 kV 50 cycle A.C. system are stated briefly.

A description of the extent of electrification now in hand on this system – 535 single track miles to be completed in 1960, 376 single track miles in 1961 is then given, with a reference to the cost of the works explaining the absence of detailed figures of the cost of components in the Papers.

The second part deals in general terms with the technical problems of applying the system, of which further details are given in the Papers to be discussed at the Conference. Mention is made of the special problem of getting sufficient clearance, of the use of secondary insulation, of new insulating materials and of the possibility of reducing air clearances in the near future, and of the dual voltage 25/6·25 kV system developed for use when the higher voltage is impracticable. There is reference to modification of some of the original designs as the electrifications are reaching the stage where less expensive solutions are permissible. The circumstances in which it has been necessary to use booster transformers with or without return conductors as a means of suppressing interference at the source are described. The major design parameters for motive power units, 100 3,300 H.P. locomotives and about 400 multiple-unit train sets, are given, together with brief particulars of the major features of the equipments now coming into service, all of which use D.C. motors after rectification on the locomotives or trains by mercury arc or, increasingly, semi-conductor rectifiers.

The Paper ends with references to the scope of the System Tests project designed to provide information about the behaviour of all parts of the system, and to the steps being taken to ensure that British Railways play their part in a comprehensive Research programme directed particularly to matters affecting the most efficient use of the single phase system.

The British Transport Commission adopted the 25 kV 50 cycle A.C. system after a searching enquiry, and came to the conclusion that it was the most suitable system for British Railway conditions as a whole.

It was fortunate that it was cheaper in both first cost and operating cost than the only alternative of 1,500V D.C. but the cost margin was not significant and could only be appreciable in long term where a major section of the system had been converted.

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RÉSUMÉ

Après avoir expliqué que la dieselisation et l'électrification ont toutes les deux leur place dans le plan de modernisation des Chemins de Fer britanniques, l'exposé discute les circonstances dans lesquelles l'électrification est désirable et rappelle particulièrement ses aspects historiques en Grande-Bretagne. Les circonstances qui ont amené à la revue des décisions antérieures d'unifier l'électrification en courant continu 1500 V avec caténaires (à l'exception de l'électrification de la Southern Region avec troisième rail à 600/750 V.) et la décision en 1955 d'adopter le système en courant alternatif 25 kV, 50 Hz sont exposées brièvement.

On décrit l'étendue de l'électrification actuellement en cours avec ce système: 535 miles de voie sont à compléter en 1960 et 376 miles de voie en 1961. On parle aussi du coût des travaux et on explique l'absence dans les exposés de chiffres détaillés sur le coût des différentes parties.

La seconde partie de l'exposé traite, en termes généraux, des problèmes techniques de l'application du système, dont les détails sont donnés dans les rapports soumis à la Conférence. On mentionne le problème spécial du dégagement de gabarit suffisant, l'emploi d'isolation complémentaire, de nouveaux isolants et la possibilité de réduire les gardes d'air dans un futur proche, et le systéme de double tension 25 et 6,25 kV développé pour les cas où la tension de 25 kV n'est pas praticable. On mentionne aussi quelques modifications de certaines constructions originelles au fur et à mesure que l'électrification atteint le stade où des solutions moins chères sont permises. On décrit les circonstances dans lesquelles l'emploi des transformateurs-suceurs avec ou sans conducteurs de retour a été nécessaire comme un moyen de supprimer à l'origine les perturbations. Les principaux paramètres de construction des unités de force motrice, 100 locomotives à 3,300 H.P. et environ 400 rames automotrices, sont donnés avec de brefs caractéristiques des équipements entrant actuellement en service. Ceux-ci ont tous des moteurs à courant continu alimentés par des redresseurs à vapeur de mercure ou, de plus en plus, à semiconducteurs, les redresseurs étant placés sur les engins.

L'exposé se termine en donnant des indications sur l'envergure du projet ' Essais de Système ' destiné à fournir des informations au sujet du comportement de toutes les parties du système d'électrification, et sur les dispositions prises pour assurer que les Chemins de Fer britanniques jouent leur rôle dans un large programme de recherches dirigées surtout aux questions relatives à l'emploi le plus efficace du système monophasé par courant industriel.

La British Transport Commission a adopté le système d'électrification par courant alternatif 25 kV., 50 Hz à la suite d'investigations qui montrèrent que ce système était le meilleur dans son ensemble pour les Chemins de Fer britanniques.

Le fait qu'il est moins cher tant pour les dépenses d'établissement que pour les dépenses d'exploitation par rapport à la seule alternative au courant continu 1500 V est un heureux résultat. Mais la différence de dépenses entre les deux systèmes n'était pas très significative et ne pourra être apprécié qu'à long terme quand une section importante du réseau sera électrifiée.

Evidemment les perspectives d'exportations ont stimulé aussi et les évènements suivants ont montré que la Grande-Bretagne peut fournir dans ce domaine, une contribution impressionnante dans les pays d'outre-mer.

Cependant la raison prépondérante pour l'organisation de cette Conférence est de montrer les développements remarquables de l'électrotechnique stimulés par la traction à courant alternatif, et dans lesquels l'industrie Britannique et la British Transport Commission remplissent leur rôle.

ZUSAMMENFASSUNG

Nach einer Erläuterung, dass Diesel– sowohl als elektrische Zugförderung ihren Platz in dem Modernisierungsplan der ' British Railways ' finden, erörtert der Bericht die Verhältnisse, unter denen Elektrifizierung wünschenswert ist, unter besonderer Bezugnahme auf die geschichtlichen Gesichtspunkte in Grossbritannien. Die Umstände werden kurz erwähnt, die zu einer Nachprüfung der früheren Entscheidung, 1500V Gleichstrom mit Fahrleitung zu normen (mit Ausnahme der Elektrifizierung mit 600/750V Gleichstrom und Stromschiene im Gebiet der ' Southern Region '), und zu der Entscheidung im Jahre 1955, das 25 kV 50 Hz Wechselstromsystem anzunehmen, geführt haben.

Der Umfang der derzeit laufenden Elektrifizierung nach diesem System – 535 Gleismeilen sollen 1960, weitere 376 1961 fertiggestellt werden – wird angegeben, unter Bezugnahme auf die Kosten der Arbeiten und mit einer Erklärung für das Fehlen von Einzelangaben über die Kosten der Bestandteile in den diesbezüglichen Berichten.

Der zweite Teil befasst sich in grossen Zügen mit den technischen Problemen bei der Verwirklichung des 25 kV- Systems, über die sich Einzelheiten in den während der Konferenz zu diskutierenden Berichten finden. Erwähnt werden: Das Sonderproblem, für die Fahrleitungen hinreichenden Lichtraum zu schaffen, Anwendung zusätzlicher Isolation, neue Isolierstoffe und die Möglichkeit, den Luftüberschlagsweg in Kürze herabzusetzen, schliesslich die Entwicklung des Zweispannungssystems (25/6,25 kV) für Fälle, wo die höhere Spannung nicht benutzt werden kann. Es wird auf Änderungen einiger der anfangs benutzten Konstruktionen hingewiesen, da die Elektrifizierung jetzt ein Stadium erreicht hat, das preiswertere Lösungen gestattet. Die Verhältnisse werden beschrieben, unter denen es notwendig war, Saugtransformatoren mit oder ohne Rückleitung zwecks Unterdrückung von Beeinflussung an der Quelle zu verwenden. Die wesentlichen Konstruktionsdaten für die Triebfahrzeuge – 100 Lokomotiven von 3300 HP und etwa 400 Triebwagenzugeinheiten – werden gegeben, ausserdem in Kürze Einzelheiten der wesentlichen kennzeichnenden Merkmale der Ausrüstungen, die jetzt in Betrieb kommen. Sie benutzen alle Gleichstrommotoren und Gleichrichtung auf den Triebfahrzeugen mit Quecksilberdampf- oder, in zunehmendem Umfang, Halbleiter – Gleichrichtern.

Der Bericht schliesst mit Hinweisen auf den Zweck der ' System Tests ', die Unterlagen über das Verhalten aller Teile des Systems liefern sollen, sowie auf die Schritte, die unternommen wurden, um sicherzustellen, dass ' British Railways ' ihre Rolle in einem umfassenden Versuchsprogramm spielen, das besonders auf alle die Fragen abgestellt ist, die auf die möglichst erfolgreiche Verwendung des Einphasensystems Einfluss haben.

Die ' British Transport Commission ' hat das 25 kV 50 Hz Wechselstromsystem nach einer tiefschürfenden Untersuchung angenommen, die zu der Folgerung geführt hat, dass es, im Ganzen genommen, für die Bedingungen der ' British Railways ' am geeignetsten ist.

Ein günstiger Umstand war, dass dies System hinsichtlich der Anlage- sowohl als der Betriebskosten billiger war als die einzige Alternative, nämlich 1500V Gleichstrom. Der Kostenunterschied war jedoch nicht wesentlich und könnte nur auf lange Sicht, nach Umstellung eines grösseren Teils des Netzes, merklich werden.

Naturgemäss hat auch die Aussicht, die Ausfuhr wertvoller Güter zu fördern, mitgespielt, und spätere Ereignisse haben gezeigt, dass Grossbritannien nun übersee einen eindrucksvollen Beitrag hierzu leisten kann.

Wie dem auch sei, die Erwägung, die für die Einberufung dieser Konferenz ausschlaggebend war, ist, die bemerkenswerten elektrotechnischen Entwicklungen aufzuzeigen, die durch die Wechselstromzugförderung angeregt worden sind und in denen die britische Industrie und die ' British Transport Commission ' ihre Rolle spielen.

RESÚMEN

Despues de explicar que tanto dieselización como electrificación tienen su lugar en el plan de modernización de British Railways, este folleto, discute las circunstancias en las cuales electrificación es deseable, refiriendose en particular a los aspectos históricos en Gran Bretaña.

Se manifestan brevemente las razones que provocaron una revaluación de decisiones anteriores para la normalización por catenária a 1500V corriente contínua (excepto la electrificación de la Southern Region por tercer carril a 600/750V corriente contínua) y la decisión en 1955 de adoptar el sistema de 25 kV 50 Hz corriente alterna.

Se describe seguidamente la escala de electrificación actualmente en mano con este sistema – 535 millas de via a completar en 1960, 376 millas de via en 1961 (equivalente a via única) y se refiere al costo de las obras, explicando la ausencia en los folletos del costo detallado de los componentes.

La segunda parte trata en términos generales de los problemas técnicos para la aplicación del sistema, cuyos detalles se encuentran en los folletos bajo discusión durante la conferencia. Se mencionan el problema especial para obtener tolerancia elétrica, el empleo de aislamiento segundário, materiales aislantes nuevos y la posibilidad de reducir las tolerancias eléctricas en un futuro próximo, y el sistema de tensión duple 25/6·25 kV desarrollado para uso cuando la tensión mas alta fuere impracticable. Se menciona la modificación de parte de los proyectos originales a medida que la electrificación toma aspectos que permiten soluciones mas baratas. Se describen las circumstancias bajo las cuales el uso de transformadores compensadores ha sido necesario, con o sin conductores de retorno, con el fin de suprimir interferencia en la fuente de suministro. Se dan los parámetros principales del proyecto de las unidades de fuerza, 100 locomatoras de 3300 C.V. y unas 400 composiciones de unidades múltiples, junto con detalles breves de los rasgos principales de los equipos entrando actualmente en servicio, todos los cuales usan motores de corriente contínua tras rectificación en las locomotoras o unidad multiple por medio de arco de mercurio o, cada vez mas, semiconductores.

Acaba el folleto refiriendose al campo cubierto por el proyecto de pruebas del sistema, ideado con el fin de obtener datos acerca del comportamiento de todas las partes del sistema, y a las medidas tomadas para asegurar que British Railways contribuyen lo suyo dentro de un programa comprensivo de investigación dirigido en particular hacia materias que afectan el empleo mas eficaz del sistema monofásico.

La British Transport Commission adoptó el sistema de corriente alterna a 25 kV, 50 Hz tras profunda investigación y concluyó que era el sistema mas adecuado para las condiciones de British Railways.

Afurtunadaments resultó mas barato que la otra alternativa de corriente continua a 1500V tanto en costo inicial como en el de explotación. Sin embargo el margen de costo no era significativo y podia ser apreciable sólamente a largo plazo al convertir una sección importante del sistema.

Naturalmente, existia un incentivo importante con vistas a la exportación y acontecimientos posteriores han demostrado que Gran Bretaña puede actualmente contribuir notablemente en este campo en el extranjero.

Sin embargo la concideración mas importante para cuya demostración este congreso se ha convenido es el desarrollo notable que tracción por corriente alterna ha estimulado en la industria eléctrica, en el cual la industria Británica y la British Transport Commission contribuyen su parte.

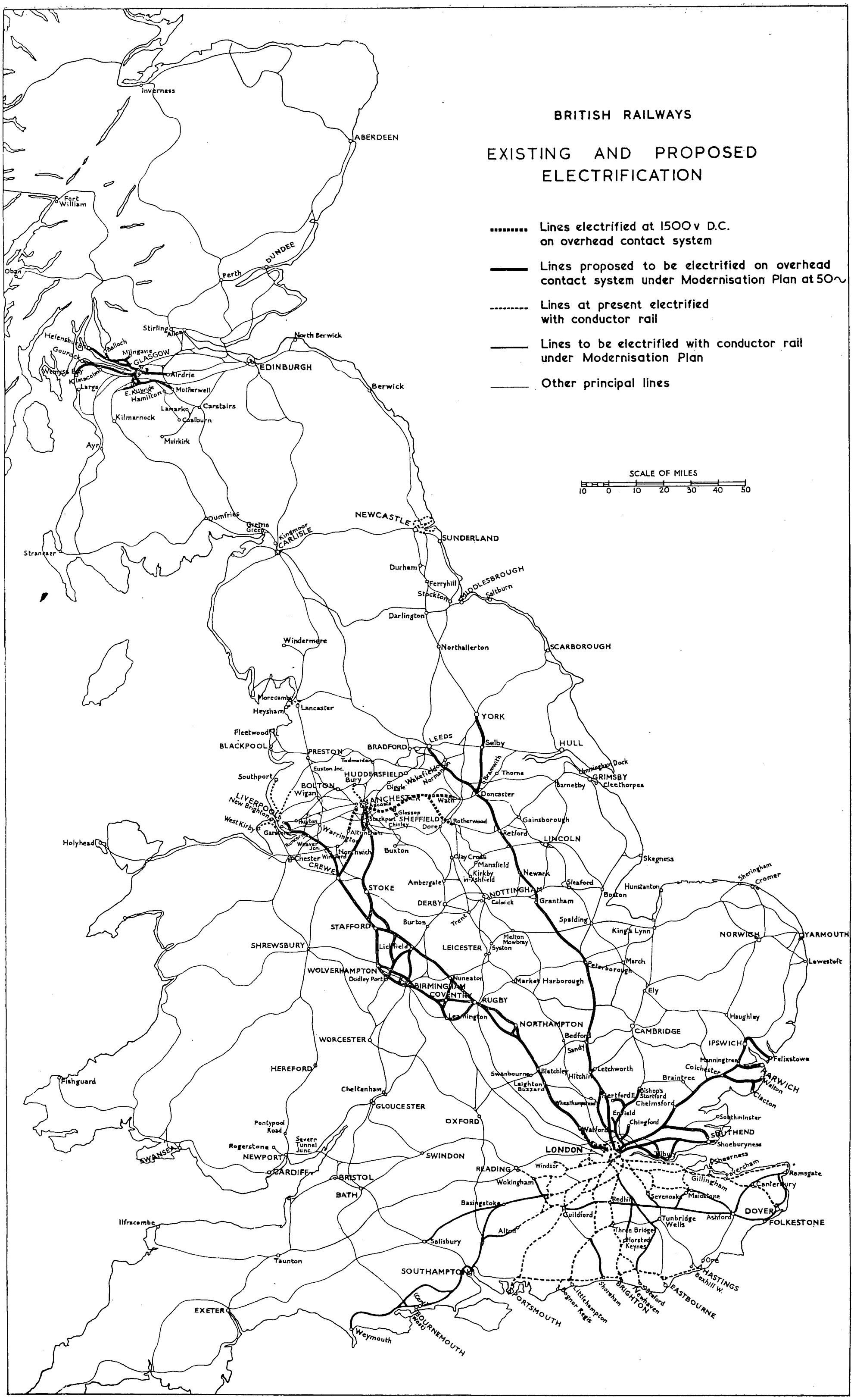

Fig.1 Existing and proposed electrification

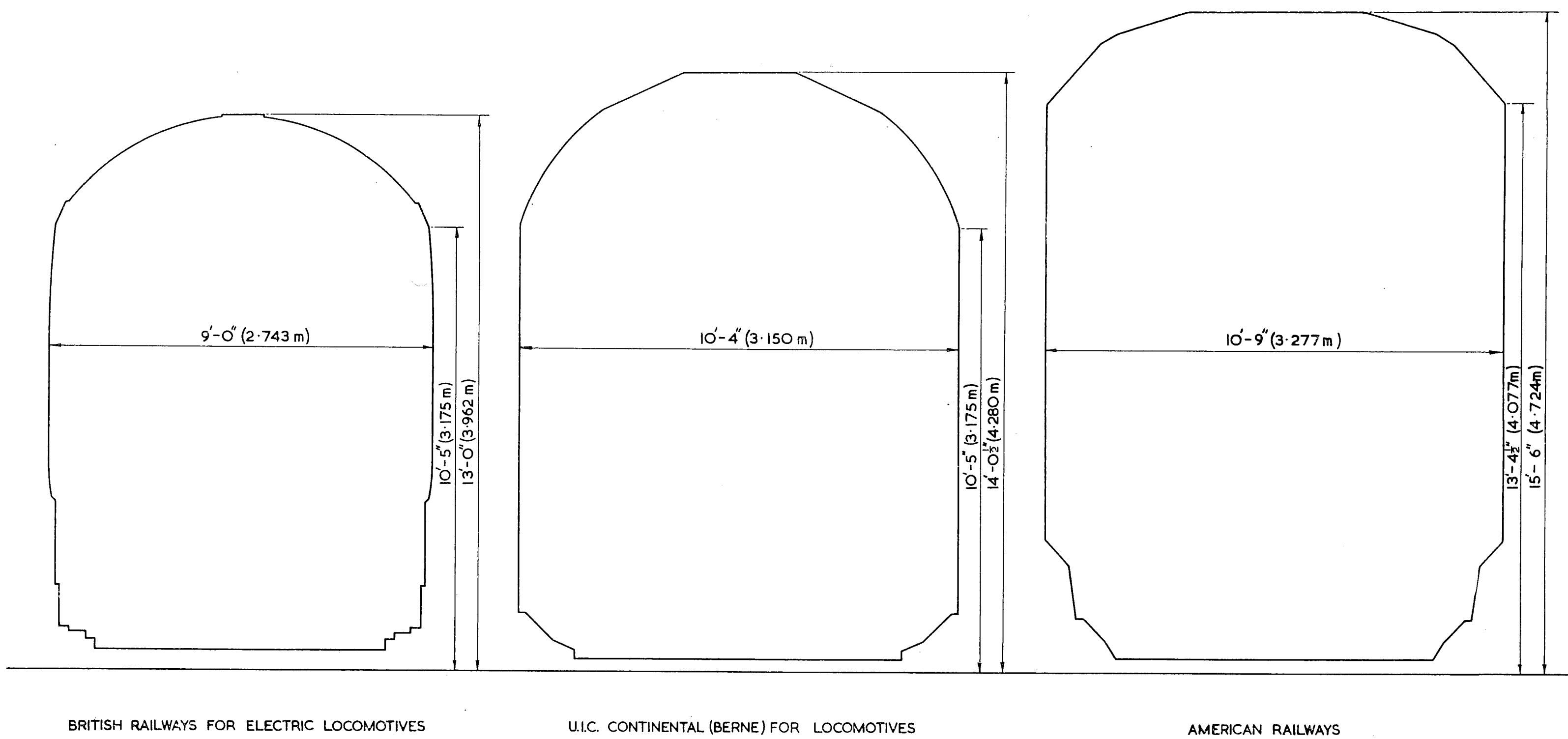

Fig.2 Comparison of loading gauges