621·331·025·1·001·42

Paper 2

The application of the 50-cycle System as proved by System Tests

J. A. Broughall, BSc(Eng), MIEE
Electrical Engineer (Development), British Railways Central Staff, British Transport Commission

F. J. Lane, OBE, MSc, MIEE
Consulting Engineer, Messrs Preece, Cardew & Rider

1 Introduction

This paper outlines the procedure, programme and method of System Tests by which performance data can be obtained for analysis while an electrified railway is rendering its normal public service of moving passengers and freight to their destinations. This is believed to be the first occasion on which such comprehensive tests of all aspects of electric traction have been attempted. The test programme is still unfinished and much more will be done in the near future as newly electrified sections, incorporating different types of equipment and providing different services are brought into commission. However, the testing equipment and the method of analysis of results are considered to be sufficiently well established to justify presentation of this preliminary report on the methods used and on certain of the results obtained.

Electrical engineering has some claim to be one of the more precise branches of engineering in that correlation of most of the phenomena is so clearly established that the performance of electrical equipment can be predicted with accuracy and reliability. In the field of electric traction accurate determination of the behaviour of the motive power units is an important advantage since the close programming of trains and the preparation of reliable time-tables are thereby greatly facilitated. This precise forecasting has been supported by assured principles of design, by Type Testing of components on the manufacturer's test-bed and, in a somewhat limited fashion, by testing of individual complete motive power units on the track and by Routine Testing of components to ensure conformity of quality in production. In the past, however, it has not always been appreciated that the integration of the performance of individual units into complete traction system involves a number of assumptions which tend to introduce margins of uncertainty and therefore detract from fully efficient operation.

2 Electric Traction Systems

An electric traction system is basically composed of three groups of equipment – firstly, fixed equipment required for bringing power from the supply point to the collecting devices on the train, secondly, the motive power units, and thirdly, other components which, although not directly part of the first and second groups, contribute to or are influenced by the conditions within these groups. Examples of the third group are the neighbouring telecommunications systems, the signalling systems and the rails on which the motive power units run. These groups have greatly differing characteristics. They also comprise many elements which are not specifically electrical in character. Examples are the physical arrangement of the overhead contact line, the mechanical and the dynamic properties of devices for current collection, the mechanical arrangement of the motive power unit. All these have their bearing on the performance of the system as a whole and have been, until recently, difficult to consider in co-ordination with the electrical groups. This is partly because the engineers concerned with them have differing modes of expression, but largely because of the difficulty of making simultaneous

measurements of the appropriate electrical and mechanical quantities and of analysing them if made. Equipment now exists which can be adapted to take and analyse simultaneous measurements through an electrified system and the other systems affected by it both under normal and abnormal conditions. The project to be described is such an adaptation.

It is appropriate to note that the presentation of the Paper by F. Busemann and W. Casson describing Full Scale Stability Tests on the British 132 kV Grid System* suggested to the authors the possibility of carrying out the present series of Traction System Tests.

Considered purely as an Electricity supply network a traction supply system is more complex than normal power supply because, whereas in a power supply transmission system the places at which the load is imposed are known and definite, the load imposed on a traction supply system by the individual motive power units moves between one point of supply and another as the trains perform their function. Normally these train movements take place according to a pre-arranged time-table but, under adverse conditions of freight working and in complicated systems of passenger and freight traffic, random features are introduced which can only be analysed on a statistical basis. This is but one example among many of factors affecting electric traction which demand such treatment.

It is the aim of System Tests to provide in a practical form bases for correct statistical assessment of all the factors involved so that individual characteristics of the various components can be satisfactorily correlated. It will be possible then to ensure that every kind of equipment is adequate for the present purpose, has the necessary margin for future development, and is the most economical with due regard to these requirements. The data should, for example, provide means by which traffic officers and eventually yardmasters may assess what loads may be safely attached to locomotives with reasonable assurance that these are being fully and efficiently employed.

The overall result should be to make possible more precise prediction of the performance of the whole system and of everything affected by it. This in turn must result in the more efficient usage of equipment and improved employment of available finance.

3 Organisation for System Tests

Clearly a System Tests programme which involves ' simultaneous ' recording of many quantities at a number of fixed points and on moving trains requires the co-operation not only of all departments of the railway organisation but also of such other bodies as the power supply authority (The Central Electricity Generating Board and the South of Scotland Electricity Board), the telecommunication authority (The General Post Office) and the many manufacturers of the traction system equipment. The Commission were therefore pleased to have the agreement of these bodies that a joint System Tests organisation should be set up in which there would be full technical collaboration, agree pooling of resources, and sharing of the financial obligations, with a promise of general availability of results. Broadly, the Commission made itself responsible for the development and costs of the special recording equipment and half the cost of translating equipment (approximately £100,000) and the contractors agreed to provide and install the other half of the translating equipment at their cost (approximately £60,000). Other organisations also made contributions of less magnitude or in kind. The planning of the operation was entrusted to a Main Committee, embracing all the above interests with the present authors as Chairman and Vice-Chairman respectively, and Mr. F. E. Stacey as Secretary. Particular phases of the work were entrusted to five Sub-Committees under the Chairmanship of Railway Officers as shown in fig.1. This also shows the three working parties established to make recommendations about and eventually control the purchase of certain special apparatus and to prepare the detailed day-to-day programme of the actual tests. Each sub-committee and working party included representatives of the interests concerned in the particular problem.

The Main Committee was finally composed of twenty-two members and, while satisfactory for information and liaison, was clearly too large to be executive. For central approval of action and expenditure therefore a small Executive Working Party was set up comprising the Chairman and Vice-Chairman of the System Tests Main Committee, and the Chairmen of the Sub-Committee and Working Parties.

4 Test Objectives

The principal objectives of the test programme can be stated as:—

(*a*) To obtain a picture of the electrical performance of the traction system as a whole.

(*b*) To obtain an operational assessment of the performance of the principal items of equipment, individually and one with another.

(*c*) To measure the external effects of the traction system, such as those on the signalling system, public communications and domestic radio and television.

In this context the term ' traction system ' means everything concerned in the electrification of a section of line and it will therefore differ from one electrification to another because arrangements for power supply and types of motive power unit are not the same for all lines, whilst different combinations of basically similar overhead line equipment occur on the different electrified lines.

The investigations must cover both normal and abnormal service conditions and fault conditions and to obtain the greatest value from the results at a particular instant it is important to be able to take account of the conditions immediately before and after each such test.

* Proc. I.E.E. Part A, Aug. 1958. P347.

Some of the factors to be measured at different degrees of loading are as follows:—

(i) Inter-action of one equipment on another, e.g. the way in which the operation of one motive power unit is affected by others working within the zone covered by the common point of supply: the actual voltage regulation on the contact line.

(ii) Amount and effect on the supply system of unbalance between phases and of distortion of wave form.

(iii) Interference effects on the Post Office circuits in terms of induced voltages and noise levels on a number of G.P.O. circuits of different types at varying distances from the line.

(iv) Interference effects on the Commission's communication circuits and on signalling circuits and apparatus.

(v) Interference effects on radio and television apparatus adjacent to the electrified line.

(vi) Induced voltages on neighbouring overhead conductors and the rise of the track voltage above earth.

(vii) The effect of troubles such as loss of supply, faulty insulator or faults on the motive power equipment; the efficacy of remedies.

Many of these can best be expressed quantitatively by histogram recording the frequency of occurrence of various values of the special factors concerned, e.g. the average voltage at a motive power unit.

Quite apart from these electrical effects it is proposed to record such other effects as:—

(viii) The reaction between the motive power units and the track, on jointed and continuously welded lengths of track.

(ix) The dynamic performance of the motive power units in terms of spring deflection and pantograph behaviour.

(x) The dynamic performance of the overhead conductors, especially at selected places where preliminary observations have shown that collection is difficult.

5 Basis of the Measurements

It is evident from the foregoing that means of measurement must enable the quantities concerned to be examined simultaneously and over a reasonable period of time in such a form that the inter-relation of the phenomena and their individual development can be examined.

Chart recording is not suitable. Most experienced engineers have in their possession many lengths of discarded record charts collected in attempts to measure precisely and at close time intervals events as they occur. Apart from the inaccuracies which were liable to occur in the past with many types of this form of measurement, the extraction of results is a formidable task and accurate determination of simultaneous events as between one part of the system and another, is nearly impossible. Electronic measuring methods, the use of which has increased enormously within the past few years can, however, provide the necessary means to permit not only the synchronised and nearly simultaneous measurement throughout the system of all the quantities in which the engineer is interested, but also the means of evaluating results and presenting them in a usable form.

Essentially the process used is to employ a direct means of measuring or 'following' the quantity concerned (voltage divider, current transformer, transducer) supplemented by a suitable type of 'translator' for converting the derived observation to a D.C. voltage proportional to it, and to connect this D.C. voltage to an electronic digital recorder in such a way that the reading is picked up by a rotary selector switch and is recorded in code form on a punched tape. This punched tape can then either be read back as figures on a decoding printer or it can be fed to a digital computer and analysed in accordance with appropriate instructions.

The recorders are provided with twelve ways and the speed of the recorder used is such that if each of the twelve ways on the rotary selector switch is associated with a different variable, each variable is recorded once every two seconds. As each test sequence is repeated at least twice during a programme period there is a very high degree of probability that all except very transient events are sampled and recorded in the course of the minimum of three hours' testing. If with some particular quantity a higher frequency of scanning should seem to be necessary, it is of course possible to connect the incoming D.C. voltage to more than one way. If it is connected to all twelve points, the frequency of reading becomes once every 0·16 seconds. Events throughout the system can therefore be regarded as being measured simultaneously for all except very short transient phenomena. The word 'simultaneous' is deemed to include this reservation when used without qualification in this Paper.

Paper 12 describes the electronic apparatus by means of which results are being recorded and Paper 13 outlines arrangements for subsequent examination and presentation.

Simultaneous recording is vital to the whole test process. Most of the measured values are changing rapidly and in random fashion and many phenomena appear at irregular intervals so that any analysis of cause and effect can only be successful if all appropriate values are ascertained at the same instant. The synchronisation of all testing equipment is therefore an essential part of the test procedure and this process has not been without its difficulties, bearing in mind that even on the initial test on the short Colchester – Clacton line the fixed test units are distributed along 18 miles of railway track, and eight recording assemblies are carried on motive power units.

The method employed is briefly as follows:—

Speech communication and remote control of all recorders from the test headquarters are by means of a wired telephone circuit for fixed positions and by the Clearcall System in which the signals are impressed on the overhead wire by carrier frequency equipment supplied by A.E.I. (Rugby) for the multiple-unit trains. A microphone and a loudspeaker are available at every position.

For the synchronisation of the tests every digital recorder is fitted with an integral accurate electronic clock. Before beginning the first test of the day, the observer synchronises his recorder clock to the correct time as announced by test headquarters. The operation of all recorders is controlled by a master recorder which is put into operation from the test headquarters. Thus the start signal of 0·5 to one second duration and the stop signal of over three seconds duration is given to the special unit which, in its turn, starts or stops all other units. Once tests begin this unit issues automatically every five minutes a signal which is transmitted to all recorders by the above means. On the reception of this signal these recorders stop the recording of measurements, record the actual time of their own clock and automatically begin again the recording of measurements. The subsequent identification of simultaneous measurements is easily done by determining on the tapes results of the same number within the 5-minute group.

The Clearcall System is based on the well-known principle of amplitude modulation of a carrier current. This carrier current at the frequency of 140 kc/s is fed to the overhead contact wire by a 0·014 μf, 25 kV condenser, one side of which is connected to earth through two 400 Ω resistors, the earth being duplicated for safety. Section gaps with low impedance power jumpers are short circuited by by-pass units comprising condensers and resistors (fig.2). It was found that the impedance presented by booster transformers was not important to the carrier current and these are not fitted with by-pass units.

Transmitting and receiving are only possible separately. Speech transmissions are automatically cut while remote control signals are transmitted. The start stop signals are in the form of audio-frequency tones obtained from a tone generator.

A further important basic requirement is the indication of train position on the track and this has been effected by using a track magnet at each mile post so as to produce a suitable mark on the tape. The marks, together with the timing marks and the recorded speeds of the train, permit the subsequent determination of the train position at any instant.

Transient events which take place within a small fraction of a second need a different technique and for this purpose, whilst the timing signal is still available for the check, oscillographs and high speed cameras are necessary for a proper record of the events. This form of instrumentation is well known and requires no special description, but Papers 11 and 21 refer to some of the very special techniques used in some phases of this work.

As an example of the measurements involved, attention is drawn to Appendix I which gives a list of the quantities observed during the Colchester – Clacton test. There were in all some 140 variables being measured, ranging in magnitude from voltages of 132 kV and currents of thousands of amps, to voltages of less than 1 volt, currents measured in milliamps, and movements in fractions of an inch.

6 Accuracy

With traction measurements involving great changes in the magnitude of the measured quantities, it is not practicable to adhere to the general rule of measuring in the upper part of the instrument range for all test levels. However, every effort has been made to ensure this and so to get the best possible accuracy, and all instruments have been chosen with this end in mind. The current and voltage translators are provided with tappings to adjust the range to suit the quantity measured. Small quantities like psophometric voltages are amplified by means of magnetic amplifiers before being fed to the electronic digital recorder. The long term accuracy of the latter is better than one per cent but under the conditions where calibration is carried out before each day's series of tests and with the machine in daily use (which conditions in fact applied during the tests), the accuracy of measurement is such that for the full scale input of 99V the uncertainty of the measurement is ± 0·2V. This uncertainty gradually increases rising to ± 0·5V for zero input. Thus the recorders do not sensibly decrease the accuracy with which the quantities are measured, but some loss of accuracy is involved in the use of translators. The error involved is not more than double that inevitably associated with any electrical measurement involving the use of current transformers, etc. with Class I instruments and is probably less than this. When we speak of error in this way we are really considering the range within which the true value may lie and there is a high degree of probability that most of the readings will lie at the middle of that range and be substantially accurate.

7 General Test Programme

The general plan for the tests is to operate the section to be examined in public service, timing the sets of observations and interspersing trial and empty trains among the regular traffic in such a way that results can be extracted for operational states which represent one quarter, one half, three quarters and full load conditions.

8 System Tests on the Colchester – Clacton Line

A series of preliminary tests was commenced in February 1960 but at that time not all of the equipment was free of ' teething ' troubles, nor had all the points at which measurements were desired been equipped with digital recorders and other apparatus. The first formal series of system tests was made on the Colchester – Clacton line on August 10 and 11.

The points at which measurements were made are shown in fig.3 which is to be read in conjunction with fig.4 showing in some detail the arrangements for feeding the overhead contact line on this section of route.

The graphical time-table showing the trial and public trains is shown in fig.5 from which it can be seen that the train

service was at full strength during the hour of test 2 and varied up to about half strength during tests 1 and 3. When all the results have been completely analysed, it will thus be possible to relate the various effects of the current demand of the line at the different load levels.

Control of the tests was exercised from a temporary Control Station at Colchester, with which all other test points were in touch by telephone. All tests were started from the Control Station. All the points of measurement were attended throughout the tests, and the log sheet at the Control Room shows any equipment failing to make its record. Thanks to the carefulness with which the preliminary tests had been carried out, there were few occasions of limited duration when any of the recording equipment was not functioning throughout the system.

Fig.6 shows electronic digital recorders at Colchester feeder station during the test. All tapes were collected at this point for reading on a decoding printer as a quick check that all the records were in the desired form before being sent on to the digital computer.

In this series of tests all eight multiple-unit trains required for the service were equipped with digital recorders. This is the ideal arrangement but some compromise will be necessary when System Tests are made on the bigger electrification schemes where many more trains will be operating from one power supply. However, it is considered that the total of 27 digital recorders which has been provided will permit a satisfactory proportion of the motive power units to be fully equipped and a technique is being developed to equip the remainder to supply the essential minimum measurements.

9 Analysis of Results

During the six test periods on these two days, a total of approximately seven million pieces of information were recorded.

The tests have not been completed as early as was anticipated and it will not be possible to report to this Conference the full results of the analysis.

The results are now being examined and Part II of this Paper will include samples of the test records obtained and particulars of the analysis as far as it has been completed. Arrangements will be made for inclusion in the final proceedings of the Conference of a more complete report on the test results.

An Appendix to Paper 13 lists some of the quantities that are ultimately to be determined by computation and analysis of the tapes. For the second part of this Paper, which will be handed to delegates at the Conference, it has been necessary to confine the principal analysis to one main subject and it has been decided to make an examination of the voltages induced in the railway telecommunication and Post Office circuits and their relation to the current demands of the motive power units and the flow of current to the line through the track feeders.

This analysis will be made so that the result will be in a form which will make possible later for the first time the estimation of the effective screening factor by comparing the actual results with the values calculated by the formula given therein, namely

$$e_a = -jw \sum_{\nu=1}^{n} \int_{x'}^{x''} m_{\nu a}(x) I_\nu(X)\, dx$$

This will involve a considerable mathematical exercise but as the physical relation of the telecommunication circuits on this line is not too complex in relation to the arrangement of the overhead conductors, it will be possible to make the necessary calculations notwithstanding the complication introduced by the presence of booster transformers.

10 Conclusion

The authors are, in effect, presenting this Paper on behalf of the many organisations and individuals who so readily participated in the preparatory work and the actual tests. They believe that future results will justify their faith in the methods adopted and provide an improved basis of knowledge on which still better and more economic systems and equipment may be designed and constructed in the future.

SUMMARY

This Paper outlines the procedure, programme and method of System Tests by which performance data can be obtained for analysis while an electrified railway is performing its normal public service of moving passengers and freight to their destination. This is believed to be the first occasion on which such comprehensive tests of all aspects of electric traction has been attempted. The test programme is still unfinished and much more will be done in the near future as newly electrified sections, incorporating different types of equipment and providing different services are brought into commission. However, the testing equipment and the method of analysis of results are considered to be sufficiently well established to justify presentation of this preliminary report on the methods used and on certain of the results obtained.

The Paper defines an electric traction system so as to include not only the fixed equipment and the motive power units which inherently belong to it, but neighbouring telecommunication and signalling systems and indeed the rails themselves, all of which experience the effects of electrification. Whilst the former are to some extent amenable to calculation, the new arrangements proposed for measuring effects throughout the system will improve the precision of prediction of their performance and begin to make this possible for the remainder of the system.

The organisation for the System Tests which is a joint responsibility of the Commission and of numerous contractors and other organisations, such as the Central Electricity Generating Board and the General Post Office, is described, after which the objectives are set out in some detail and the method of synchronising results throughout the system is described, with references to Paper 12 which describes details of the electronic apparatus and Paper 13 which describes the method of analysing the results.

The accuracy is discussed, followed by some details of the first series of tests carried out on the Colchester – Clacton – Walton line. This part of the Paper concludes with particulars of the analyses which it is hoped to complete in time for reporting in Part II to be distributed at the Conference itself.

RÉSUMÉ

Cet exposé décrit les procédés, le programme et les méthodes pour les Essais de Système qui permettent d'enregistrer des valeurs de performance, pour l'analyse subséquente, au cours de l'exploitation normale d'un chemin de fer électrifié pour le transport publique de voyageurs et de marchandises. Il y a lieu de croire que c'est la première fois que des essais tellement complets de tous les aspects de la traction électrique aient été tentés. Le programme d'essais n'est pas terminé et beaucoup plus d'essais seront entrepris dans un proche avenir à mesure que des sections de lignes récemment électrifiées, qui seront munies de types d'équipement différents et qui assureront des services différents, seront mises en exploitation. Pourtant l'on juge que l'appareillage pour les essais et la méthode de l'analyse des résultats sont assez bien établis pour justifier la présentation de ce rapport préliminaire concernant les méthodes adoptées et certain des résultats obtenus.

L'exposé définit un système de traction électrique de telle façon à comprendre, non seulement le matériel fixe et le matériel de traction qui appartiennent essentiellement au système même, mais aussi les systèmes avoisinants de télécommunication et de signalisation et en outre les rails qui tous subissent les effets de l'électrification. Bien qu'il soit possible, à un certain degré, de déterminer les performances du matériel fixe et moteur par le calcul, les nouvelles disposition proposées pour la mesure des effets partout dans le système rendront plus précise la prédiction des performances du matérial et entameront la possibilité de prédire les performances des autres parties du système.

L'auteur décrit l'organisation des Essais de Système, pour laquelle la Commission, de nombreux entrepreneurs et d'autres organismes, tels que la Central Electricity Generating Board et le General Post Office, sont conjointement responsables. Puis il présente en détail les buts des essais et décrit la méthode adoptée pour synchroniser l'enregistrement des valeurs partout dans le système en référant le lecteur à l'exposé 12 pour des précisions sur l'appareillage électronique et à l'exposé 13 pour une description de la méthode d'analyser les résultats.

Il discute l'exactitude des résultats et puis donne quelques détails de la première série d'essais entreprise sur la ligne Colchester – Clacton – Walton. Il termine cette partie de l'exposé en donnant des précisions sur l'analyse des résultats que l'on souhaite achever assez tôt pour pouvoir en faire un rapport dans la Seconde Partie qui sera distribuée lors de la Conférence même.

ZUSAMMENFASSUNG

Der Bericht beschreibt in grossen Zügen Verfahren, Programm und Methodik der ' System Tests ', die ermöglichen, Unterlagen über das Verhalten einer elektrisierten Bahn zu bekommen, während die Bahn ihren normalen öffentlichen Dienst versieht, Fahrgäste und Fracht zu deren Zielen zu befördern. Wir glauben bei dieser Gelegenheit erstmalig eine vollständige Zusammenfassung aller Seiten der elektrischen Zugförderung versucht zu haben. Das Versuchsprogramm ist noch nicht abgeschlossen; in der nahen Zukunft werden zahlreiche weitere Untersuchungen ausgeführt werden, wenn neue elektrifizierte Abschnitte mit abweichender Ausrüstung und anderen Verkehrsbedingungen in Betrieb kommen. Unseres Erachtens sind jedoch die apparative Ausrüstung für die Untersuchungen und die Methodik für die Auswertung der Ergebnisse hinreichend entwickelt, um die Vorlegung dieses vorläufigen Berichts über die Methoden und einige Ergebnisse zu rechtfertigen.

Der Bericht definiert ein System elektrischer Zugförderung so umfassend, dass es nicht nur die ortsfesten Anlagen und die Triebfahrzeuge einschliesst, die notwendig dazu gehören, sondern auch benachbarte Fernmelde– und Signalanlagen sowie die Schienen selbst, die sämtlich den Wirkungen der Elektrifizierung ausgesetzt sind. Ein Teil dieser Wirkungen ist heute schon der Berechnung zugänglich; die neuen Einrichtungen, die wir für die Messung der Auswirkungen in dem gesamten System vorschlagen, werden die Genauigkeit der Voraussage des Verhaltens für diese Effekte verbessern und für die übrigen anfangen, Voraussagen zu ermöglichen.

Die Organisation der ' System Tests ', für die die ' British Transport Commission ' zahlreiche Fabrikanten sowie andere Organisationen, wie ' Central Electricity Generating Board ' und ' General Post Office ', gemeinsam verantwortlich sind, wird beschrieben, die Ziele werden im Einzelnen dargelegt. Die Methode, nach der Messungen in dem ganzen System synchronisiert werden, wird beschrieben, unter Bezugnahme auf die Berichte 12 (Einzelheiten der elektronischen Geräte) und 13 (Verfahren zur Analyse der Ergebnisse).

Die Genauigkeit der Messungen wird erörtert; dann folgen Einzelheiten aus den ersten Versuchsreihen an der Strecke Colchester – Clacton – Walton. Dieser Teil I des Berichts schliesst mit einem Hinweis auf die Auswertungen, die, hoffentlich, noch früh genug für Aufnahme in den während der Konferenz selbst zu verteilenden Teil II abgeschlossen werden können.

RESÚMEN

En este documento se esboza el procedimiento, programa y método de las Pruebas de la Red mediante las cuales se pueden obtener datos sobre el rendimiento, para fines de análisis, mientras un ferrocarril electrificado presta el servicio público normal de transportar pasajeros y mercancías a su punto de destino. Se estima que éste es el primer caso en que se ha tratado de conseguir una integración tan completa de todos los aspectos de la tracción eléctrica. Todavía no se ha puesto fin al programa de pruebas y mucho queda por hacer en un futuro cercano, a medida que se vayan poniendo en servicio nuevas secciones electrificadas provistas de diferentes tipos de material y que ofrezcan distintos servicios. No obstante, el equipo de prueba y los métodos de analizar los resultados se hallan lo suficientemente avanzados y establecidos para justificar la presentación de un informe preliminar sobre los métodos empleados y, en ciertos casos, los resultados obtenidos.

En el documento se describe un sistema de tracción eléctrico y abarca no solamente el equipo fijo en las unidades de fuerza motriz que forman parte integrante del mismo, sino al sistema de telecomunicaciones y señalización adyacente, así como los carriles propiamente dichos, todos los cuales acusan el efecto de la electrificación. Aun cuando todos estos elementos son susceptibles, hasta cierto punto, de cálculo, los nuevos métodos propuestos para medir los efectos por todo el sistema mejorarán la exactitud de predicción en torno a estos elementos y empezará a hacerla aplicable al resto del sistema.

La responsabilidad de organizar las Pruebas de la Red recae conjuntamente sobre la Comisión y numerosos contratistas, así como otras organizaciones tales como la Central Electricity Generating Board y la General Post Office, que son objeto de detallada descripción, tras de lo cual se esbozan los objetivos sistemáticamente y se describe el método de sincronizar los resultados obtenidos por todo el sistema, haciendo particular alusión al documento 12, que se ocupa de los aparatos electrónicos, y al documento 13, en el que se describen los métodos de analizar los resultados.

Se enfoca el problema de la precisión y a continuación se dan ciertos detalles acerca de la primera serie de pruebas realizadas en la línea Colchester – Clacton – Walton. Esta sección del documento concluye facilitando información de los análisis que se espera llevar a cabo a tiempo para que figuren en la Sección II, que se distribuirá a los delegados en la Conferencia misma.

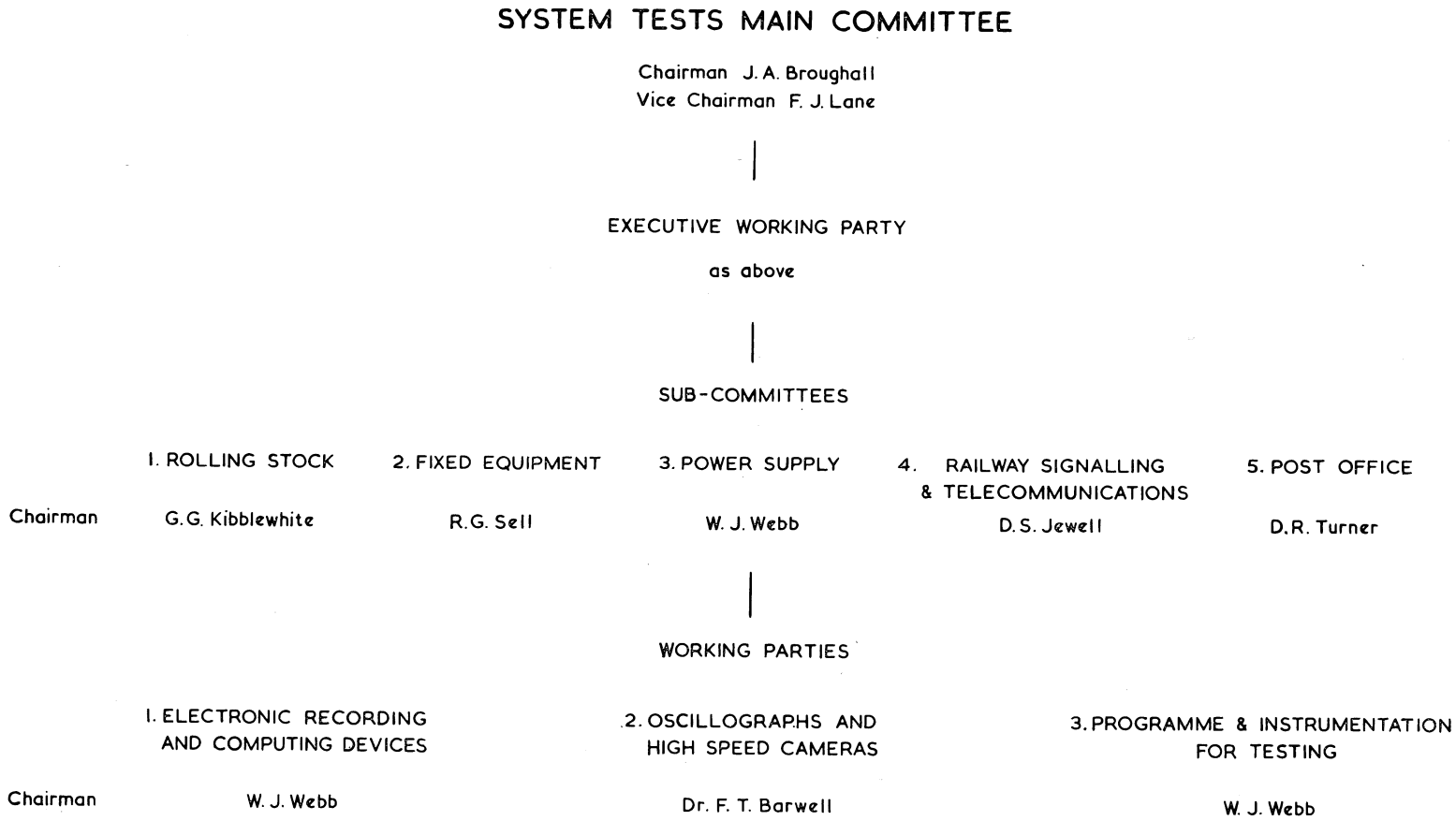

Fig.1 Organisation for system tests

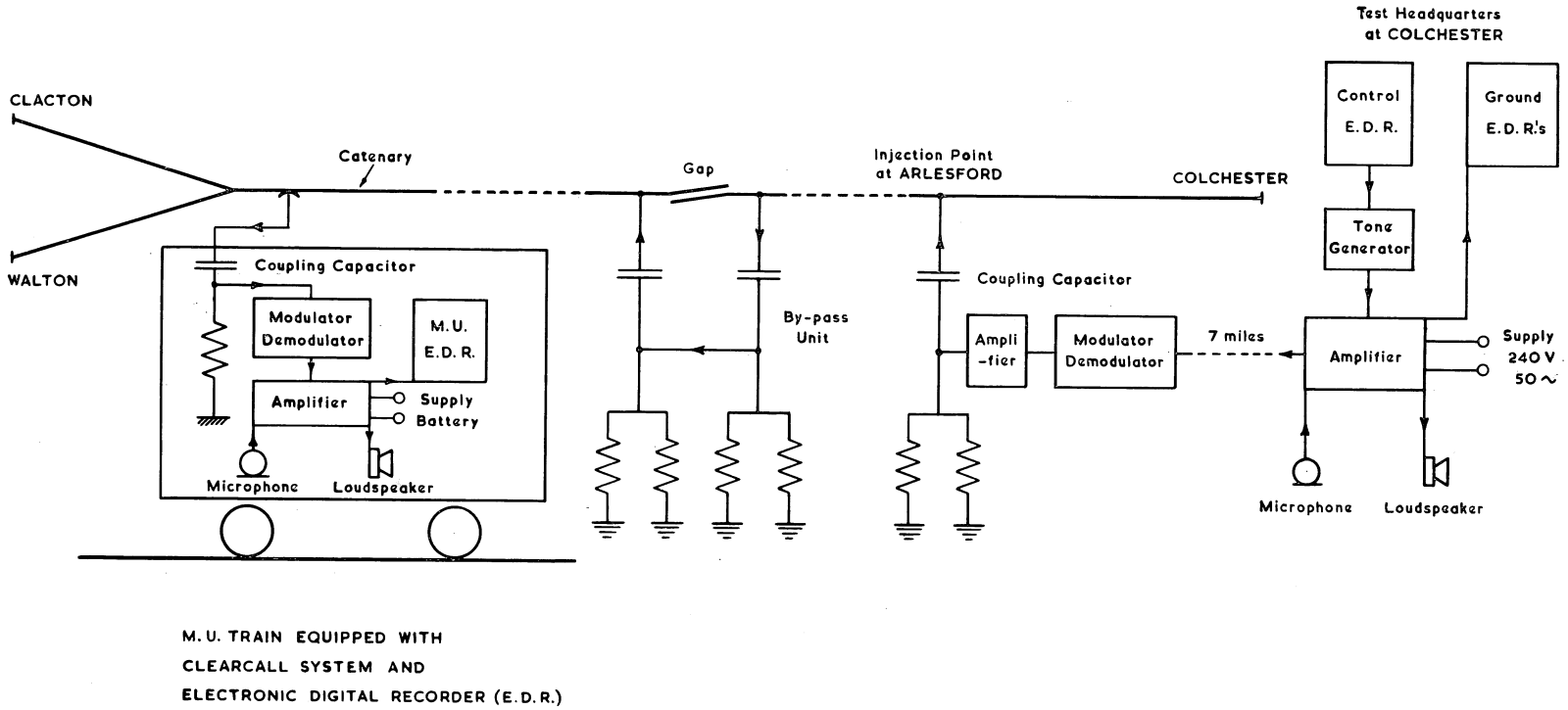

Fig.2 Arrangements of equipment for timing signal

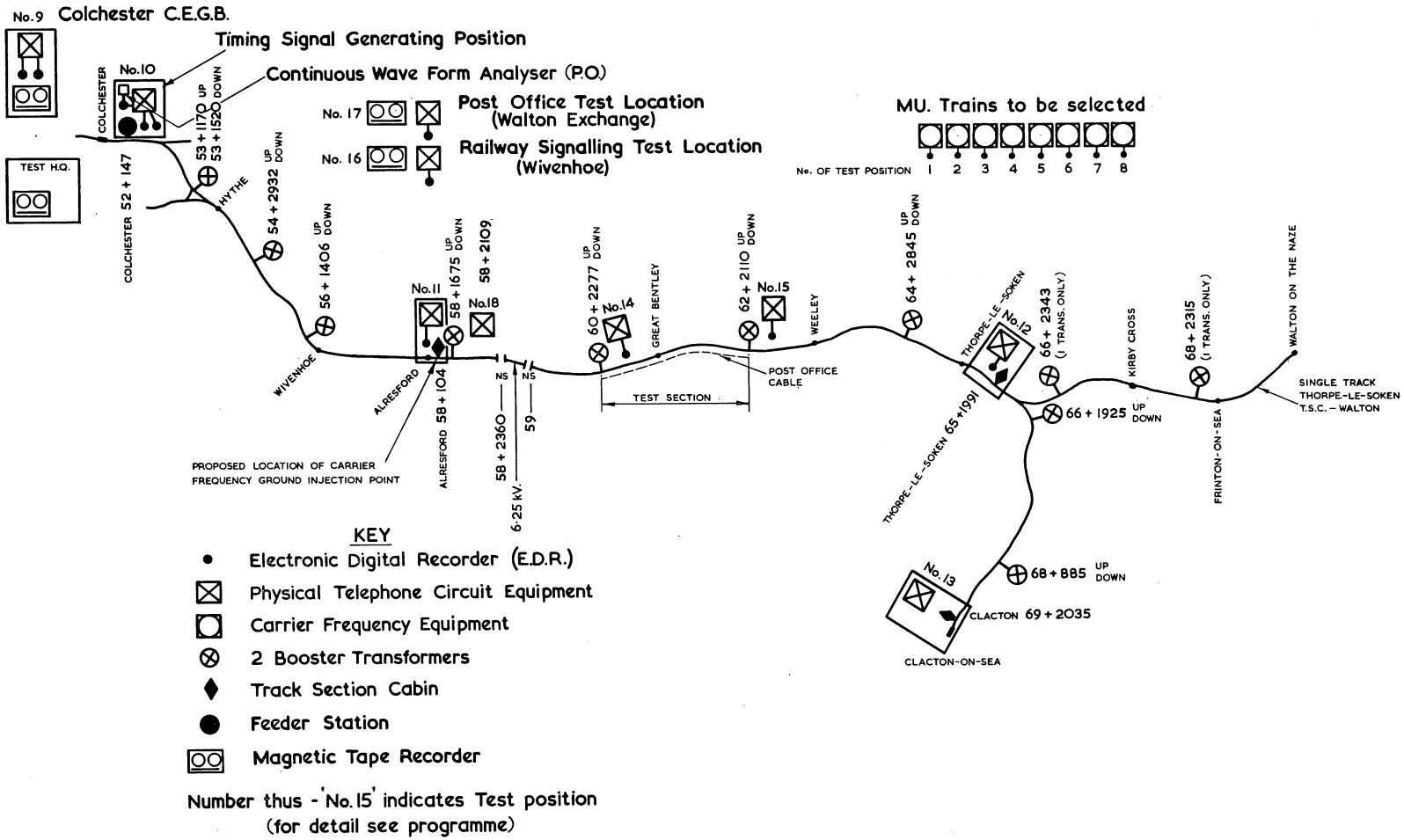

Fig.3 System tests Colchester – Clacton – Walton. Location of electronic digital recorders and timing signal receiving equipment

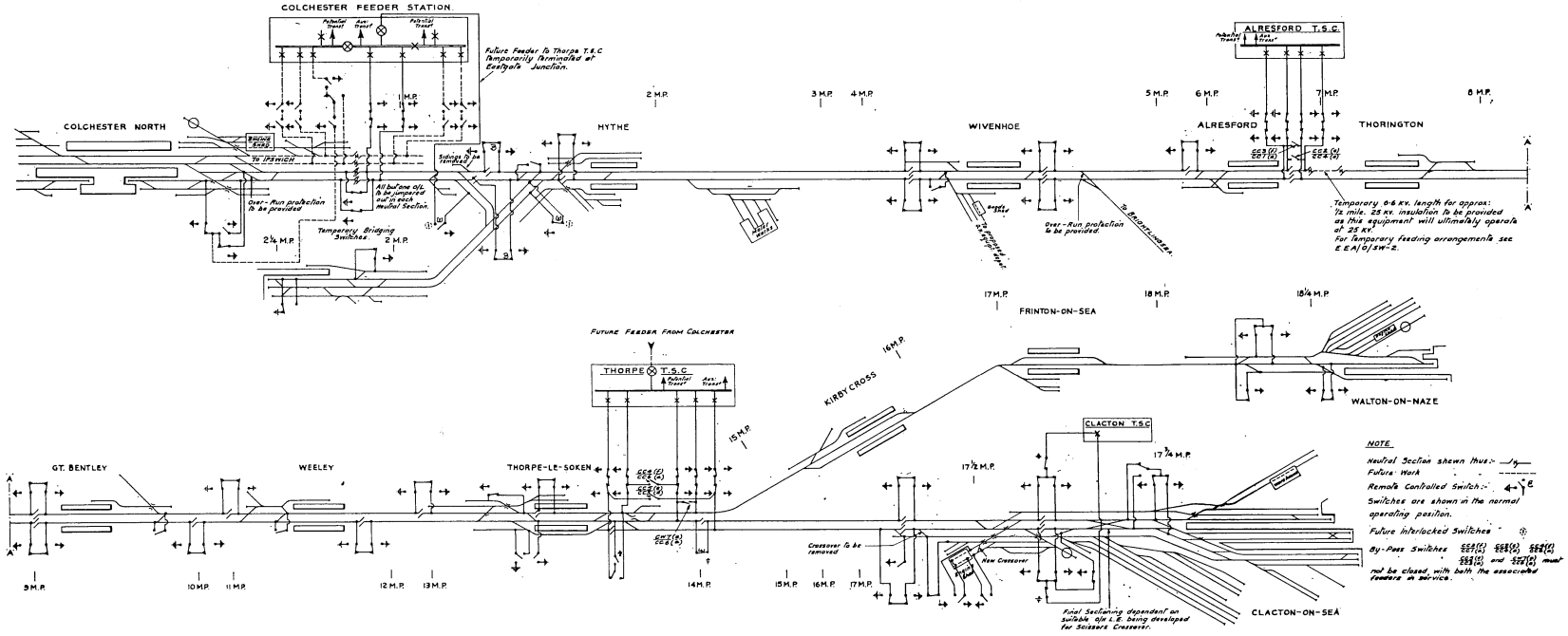

Fig.4 Colchester – Clacton – Walton electrification. Arrangement of supply

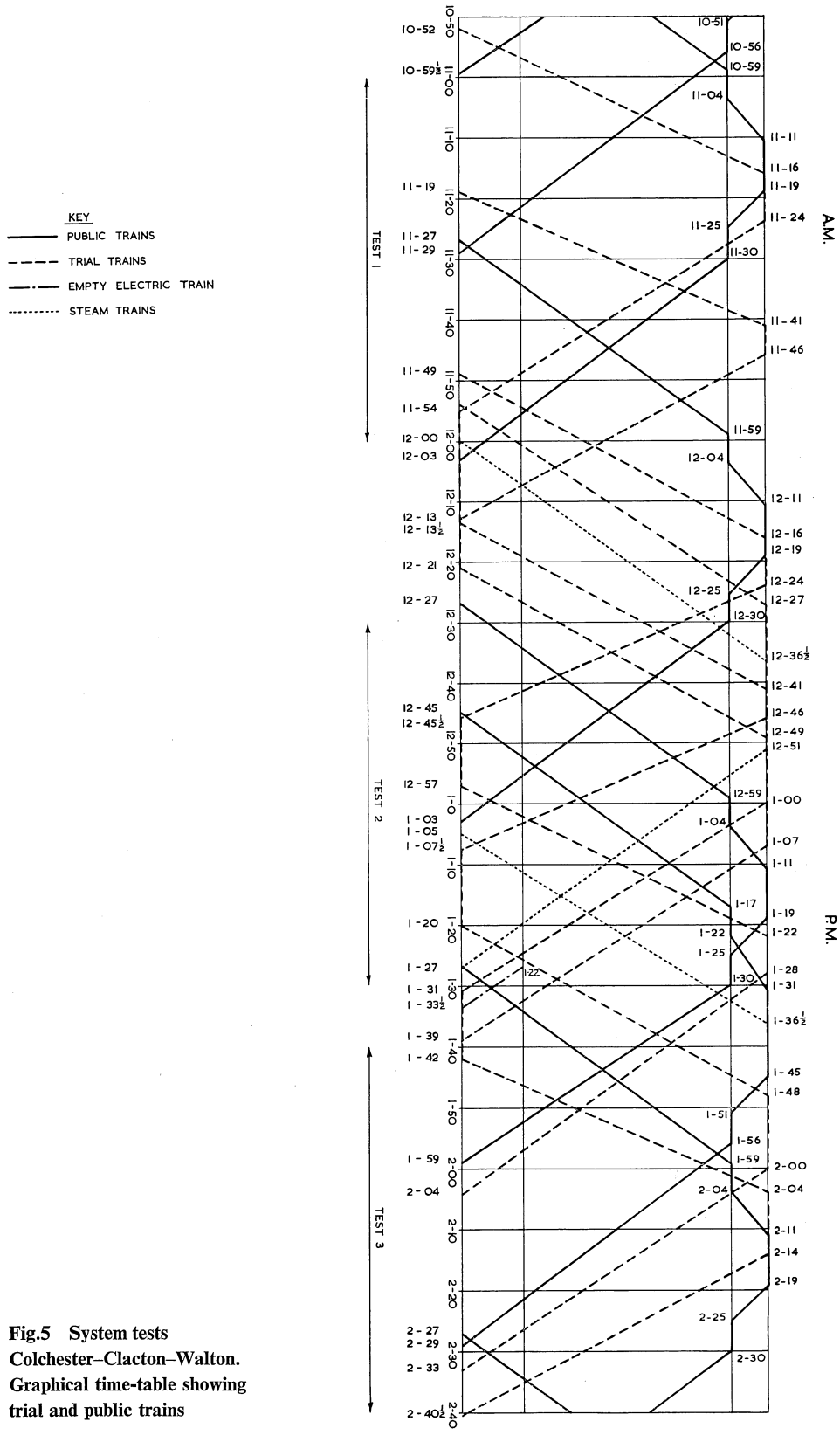

Fig.5 System tests Colchester–Clacton–Walton. Graphical time-table showing trial and public trains

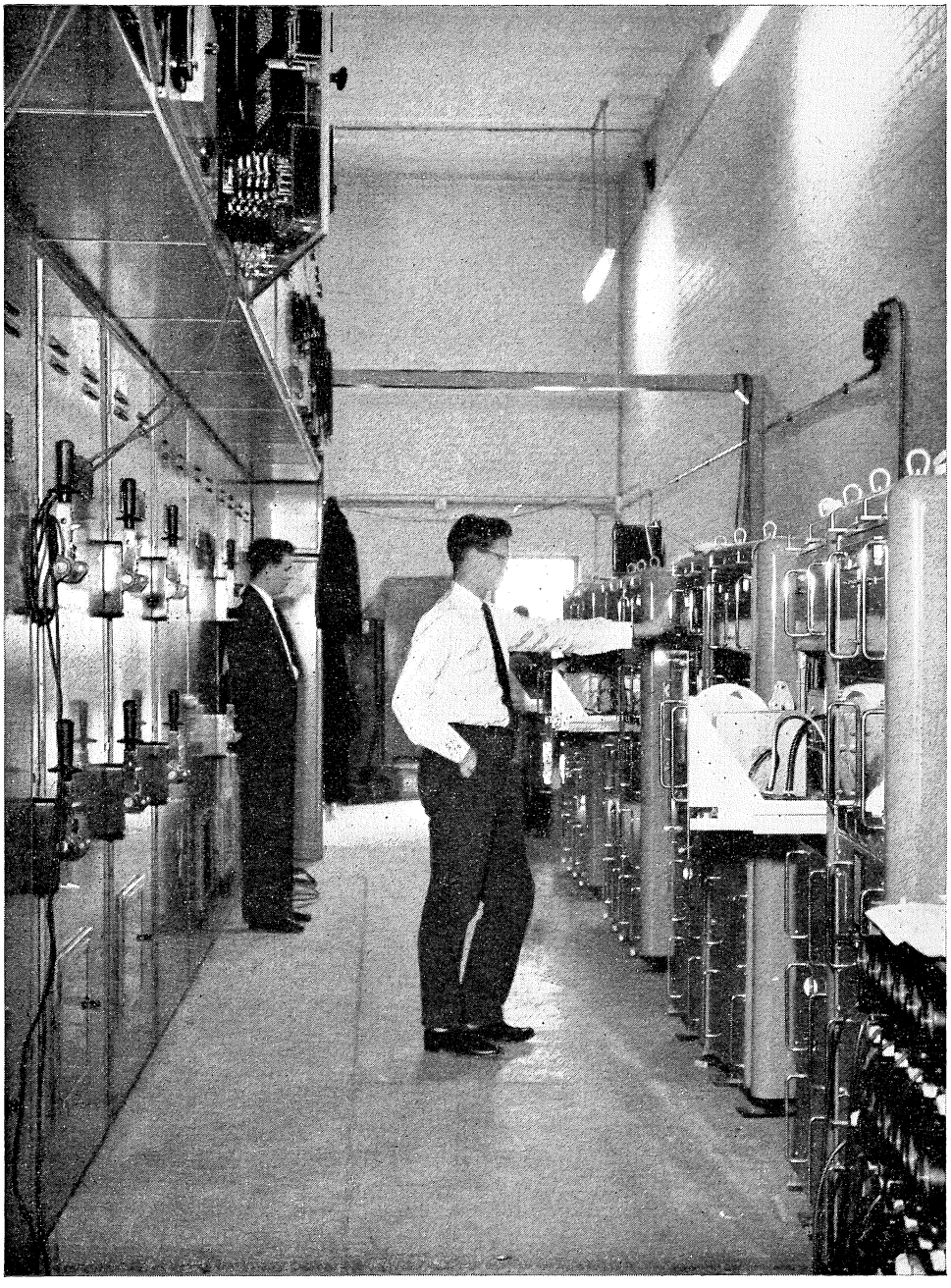

Fig.6 Electronic digital recorders