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Paper 13

System Tests : Evaluation of Results

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1 Introduction

The normal procedure for planning a system for the reduction and analysis of the numerical data to be obtained from a large scale experiment starts from specifications, firstly of the derived quantities a knowledge of which is the object of the experiment, and secondly, the quantities to be measured, from which the former will be derived. The time scale imposed by the dates for introducing the new electrified services and for presenting the results of the System Tests made it necessary to start planning the data-reduction system before either of these could be specified in full detail: the system therefore had to be flexible. The object of the tests (Paper 2, para. 2) is ' 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; the overall result should be to make possible more precise prediction of the performance of the whole system and of everything affected by it '. It was taken as axiomatic that the number of measurements to be made would be so great that useful results could not be produced in a reasonable time without a digital computer.

Two things very soon became clear: the first of these was that the methods of data reduction to be employed had to be within the capabilities of equipment which could be made available before the start of the tests: the second that, owing to the differing degrees of urgency with which different types of answers were required, and to the possibility that additional analyses of the measurements might be necessary at a later date, provision would have to be made for at least two stages of data processing.

2 Digital Electronic Data Recorders

As regards equipment, the most important consideration was to avoid the bottleneck, and the introduction of mistakes, which would be caused by translating by hand the output of the measuring instruments into computer language: there was thus an immediate need for developing and manufacturing equipment which would do this translation automatically. Magnetic tape was discarded as the language medium because none of the computers easily available were equipped for magnetic tape input, and this left the choice between punched cards and punched paper tape; of these, the latter was selected because its punching speed with well proved equipment is rather higher, and the B.R. Research computer, which would be used in the first instance, accepts this form of input: machines exist for automatic conversion from punched tape to cards, for use on such other machines as only accept that form of input. A digital recording system is, by its nature, discontinuous, and the sampling interval was dictated by the effective speed of the punch of about 25 characters per second; as an accuracy of three significant decimal figures was required, a sampling speed of six quantities per second was decided on, this speed containing allowances for synchronising signals and for the fact that the punch will be running continuously; it is of course so much slower than the traction supply frequency as to be unsuitable for measuring events occurring within the A.C. cycle, such as wave form or short-period transients, and only average values (R.M.S. or other) of electrical quantities are handled, other methods described in Paper 2 being used for higher frequency events. In order to ensure a common time scale throughout the system, the recorders were to be synchronised to the supply frequency, so that the instant of sampling any one quantity would always occur at the same phase of the supply wave form, but it was considered that this would not introduce any significant error because of the smoothing effect of the averaging networks. It was next decided to feed the recording punch through a twelve-position scanner with a two-second duty cycle, so that it would be possible to sample twelve quantities every two seconds, six every second, or other similar breakdown. The considerations in this paragraph formed the basis of the requirements specification for the electronic recorder described in Paper 12 (para. 3): this also had to provide for visual monitoring, calibration, and the introduction of a bias voltage (where necessary to avoid negative readings), synchronised starting, a clock to maintain synchronisation through a short interruption of mains supply, punching of clock time at regular intervals, control of the final printing lay-out, and manual input of identification and scale factors.

3 Flow of Data

The scale of the systems tests implied the use of over 20 recorders, each punching out three figures relating to each of twelve quantities 1,800 times in a test lasting an hour: thus each test could produce 20 or more tapes, measurements of 240 or more quantities, and some half a million measurements. No computer immediately available can accept more than two tapes simultaneously or hold the contents of a larger number of tapes in a quick access internal store, so that it would not be practicable to use a computer to search all tapes for simultaneous singularities occurring in different parts of the system: it was therefore decided that the first stages of the computer analysis should consist of those operations which could be done by a single run of a single tape, such as reconciling and correcting current records of time, distance, and speed; deducing power factor from simultaneous records of voltage, current, and power; and calculating mean and peak values and frequency distribution of selected primary and derived quantities.

Two methods were to be used for presenting the data in such a form that it is possible to search for simultaneities in singularities. In the first instance all recorder tapes will be offered to standard ' teleprinter ' page printers, to produce a permanent plain language record of all quantities which have been directly recorded: this will be a formidable quantity of paper, but search therein will be simplified as clock time will be printed at regular intervals. It is hoped later to be able to use an automatic graph plotter, operated directly from computer tape, to produce timed plots of selected quantities, either directly measured or derived.

The requirement for printed tables of all results influenced the choice of code for the output punch of the electronic recorder: as this was being specially designed, we had a free hand in this respect. It will be appreciated that there is no standardisation of paper tape codes for computer inputs, although many accept five-hole tape which is identical in physical form with some teleprinter tapes: and whereas a translation from one tape code to another can be done inside a computer under programme control, a teleprinter would have to be extensively modified to accept tape punched in a computer code. It was therefore decided to use unmodified teleprinter equipment, and to incorporate the International Teleprinter Code in the recorder equipment. One result of this decision is that the teleprinter cannot be used for the computer output of derived quantities, as the output punch of the B.R. Research computer operates only in the Elliott code, which alone is acceptable by the computer's output printer.

A diagram is given (fig.1) showing the flow of data indicated in the preceding paragraphs.

4 Computer Reduction

The computer most readily available for the purpose of processing the data tapes is an Elliott 402F computer located in the Research Department at Derby (fig.2). In terms of data processing on the scale envisaged, the total storage capacity, consisting of approximately 5,000 locations of 32 binary digits, is not great. The output tape from a single recorder for one hour contains over 21,000 3-decimal-digit numbers. If need arose, it would be possible to store a full set of values for up to six quantities. This could be done most economically by storing three 3-decimal numbers in each storage location. However, it was decided that, in order to reduce storage and sorting within the machine, the use of the computer should in the first instance be confined to calculating the subsidiary quantities which could be derived from the twelve individual readings in one 2-second section of tape. Tests for the validity of the recordings, and for missing values, will be incorporated.

The derived values will be printed out in such a form that they can be pasted on to the original sheets containing the print-out of the twelve initial recorded quantities. This will save translating the Elliott computer code of the output into International teleprinter code.

In view of the large amount of data, a very fast input routine is clearly required, and one has been devised which will read a single block of twelve numbers into the store.

For the purposes of planning it was estimated that one tape, representing one hour's testing and recorded on one E.D.R. would take about one hour to run through the computer, but in practice it has been found that it may take from one to three hours, depending on the amount of processing required. This is computer time only, and does not include page printing of recorded output tapes, page printing of results, or any graph plotting: these processes can go on simultaneously with computer operations.

5 Test Records and First Analysis

On a typical day's testing on the Colchester – Clacton line, with three test periods each of one hour, 17 E.D.R.'s were in operation, located as follows:

- 8 on multiple-unit trains,
- 5 at power supply positions,
- 2 at booster transformers,
- 1 at railway signalling and telecommunication test site,
- 1 at G.P.O. test site.

The quantities actually recorded on the trains and at the railway signalling and P.O. test sites (taken as typical) are listed in the Appendix.

It was decided that the first analysis to be undertaken would be to determine the magnitudes and times of occurrence of the real peaks in the interference voltages induced in the rail and post office signalling cables, and the positions of the M.U. trains and the magnitudes of the electrical quantities therein at the corresponding times. This analysis is proceeding at the time of writing.

The tapes are checked for the correctness of the labelling. The data are fed into the computer in blocks of twelve quantities, corresponding to the twelve different channels on the E.D.R. equipment. If the number of digits in the block is not correct, the normal procedure is then to neglect that particular block. The digits appearing on the tape are then multiplied by the appropriate calibration factors or other instrumental corrections made to obtain the true value of the quantity. A check is also made of the time. Each block of information represents a lapse of two seconds and at intervals through the tape a synchronised time signal appears. If the recorded time does not agree with that calculated from the number of lines, the computer stops. The operator can then choose whichever value appears to be correct, and restart the programme.

The tapes to be first examined are those containing induced interference voltages on Signal and Telegraph and Post Office equipment recorded at Wivenhoe and Walton respectively. Three of the quantities are psophometric readings, which are converted according to a non-linear characteristic incorporated in the computer programme. As the tape is fed in, the computer keeps a record of the ten highest values occurring for each quantity, together with the time of occurrence. Of these ten values, a few will be true maxima and the remainder should be values lying immediately to one side or the other of the true maximum. A histogram showing the frequency of occurrence of values in different ranges is also compiled for the complete tape. There are, therefore, two possible checks on the genuineness of the maxima (neglecting transients) so revealed; first of all it should be accompanied by a few neighbouring values, and it should be a value which is consistent with the general pattern of values as revealed by the histogram. A maximum value which failed to conform to one or other of these requirements would be scrutinised outside the machine before being accepted as genuine and not due to instrumental or other error or as being a transient for which other techniques are needed.

The remaining tapes are to be scrutinised to pick out the values which correspond in time to the ten highest values recorded for each of the fourteen quantities on the Signal Engineer's and P.O. tapes. For the moment this operation will only be carried out by the computer for M.U. tapes applicable to the rolling stock. For other tapes the necessary information will be taken from the printed out record. For the M.U. tapes, however, a further computation will be carried out in order to locate the position of the train concerned at the required times. The speedometer readings every two seconds can be integrated and compared with a periodical check by mile-posts. This is the primary information required from the tapes, but histograms showing frequency of occurrence of values in the various channels will also be taken, as well as average values where appropriate.

The results of these analyses will be reported in part 2 of Paper 2.

APPENDIX

QUANTITIES RECORDED AT TYPICAL TEST SITES

I On M.U. Trains

Line Voltage
Line Current
Power
Speed
Position (from mile-post indicator: on 6 channels).

II At Railway Signalling and Telecommunications Test Sites

Longitudinal induced voltage in unscreened signal cable: 2 routes
Longitudinal induced voltage in screened audio signal cable: 4 routes.
Longitudinal weighted noise voltage (psophometer).
Transverse weighted noise voltage (psophometer).
Rail to earth voltage.
Rail to rail voltage.
Signal supply voltage.

III At G.P.O. Test Site

2 psophometric readings } each on
2 measures of direct induced voltage } three channels.

SUMMARY

The concept of a system test in which a very large number of measurements were to be made of many different quantities had two immediate consequences, firstly, that the reduction and presentation of the results in a reasonable time would be impossible without the use of a high speed computer, and secondly, that the highest possible proportion of the measurements should be generated at source in computer language. The system for data reduction was kept flexible, so that results could be obtained in the priority required, and further analyses could be made at a later stage if necessary.

These considerations dictated the method for the collection and the flow of data, using punched paper tape as an intermediate medium: provision is made for monitoring the tape during the course of a test, for printing out the raw data as recorded for the first stage of the analysis, and the display of the results: all data, both original and derived, are retained as paper tape, ready for such further analysis as may later be required.

This Paper also gives the considerations leading to the specification for the versatile ' electronic data recorders ' which have been designed and built specially for these series of tests; and it contains an outline of the computer procedure for carrying out one of the analyses.

RÉSUMÉ

Deux conséquences s'ensuivent du concept d'essais de système où un grand nombre de mesures de maintes quantités différentes sont à faire. Premièrement, l'analyse et la présentation des résultats dans un délai raisonnable seraient impossible sans l'emploi d'une calculatrice haute vitesse. Deuxièmement, la plus grande proportion possible des mesures devraient être enregistrée lors des essais sous la forme exigée par la calculatrice. Un système flexible fut adopté pour l'analyse des valeurs enregistrées, pour que les résultats pussent être obtenus selon la priorité voulue et que des analyses supplémentaires pussent être faites si besoin était.

Ces considérations déterminèrent la méthode à adopter pour l'assemblage et le débit des valeurs enregistrées et on utilise une bande de papier perforé comme stage intermédiaire. Des moyens sont prévus pour pouvoir vérifier, au cours de l'essai, les valeurs enregistrées, pour imprimer ces valeurs en chiffres comme première phase de l'analyse, et pour présenter les résultats. Tous les résultats, originaires aussi bien que dérivés sont retenus sous forme de bandes perforées pour faciliter telle analyse supplémentaire qui puisse s'avérer nécessaire plus tard.

Cet exposé précise en outre les considérations qui déterminèrent les prescriptions pour les adaptables ' enregistreurs électroniques ' qui ont été mis au point et construits exprès pour les séries d'essais et il décrit le procédé adopté pour faire une des analyses à la calculatrice.

ZUSAMMENFASSUNG

Der Gedanke ' System Tests ' auszuführen, bei denen eine sehr grosse Anzahl von Messungen vieler verschiedener Grössen zu machen ist, führt zu zwei unmittelbaren Konsequenzen: Einerseits würde Auswertung und Vorlegung der Ergebnisse innerhalb annehmbarer Frist ohne Benutzung einer schnell arbeitenden Rechenanlage unmöglich sein, anderseits sollte ein möglichst grosser Teil der Messwerte direkt in einer für die Rechenanlage verständlichen Form anfallen. Das Auswertungsverfahren wurde elastisch gehalten, so dass Ergebnisse in der gewünschten Reihenfolge gewonnen werden konnten, unter Zurückstellung einer etwa notwendigen weiteren Analyse.

Diese Erwägungen bestimmten das Verfahren für Sammlung und Weitergabe der Werte, unter Benutzung von Lochstreifen als Zwischenträger. Vorkehrungen wurden getroffen für Kontrolle der Lochstreifen während der Versuche, Ausdrucken der Ablesungen für die erste Stufe der Auswertung, und Darstellung der Ergebnisse. Alle Werte, ursprüngliche und abgeleitete, werden als Lochstreifen aufgehoben, bereit für etwa später erforderliche weitere Auswertung.

Der Bericht enthält weiter die Erwägungen, die zu der Spezifikation der vielseitigen ' electronic data recorder ' geführt haben, die speziell für diese Versuchsreihen konstruiert und gebaut worden sind, sowie einen Abriss des Verfahrens für die Durchführung einer Auswertung mittels der Rechenanlage.

RESÚMEN

El concepto de prueba de un sistema que suponía un número muy grande de medidas de muchas cantidades diferentes tuvo dos consecuencias immediatas: primera, que la reducción y presentación de los resultados dentro de un espacio de tiempo normal sería imposible sin el empleo de un computador de alta velocidad, y segunda, que la mas alta proporción posible de las medidas fuese generada al origen en lenguage de computador. Se mantuvo el sistema para la reducción de datos flexible, de forma a obtener los resultados según su requerida prioridad y poder efectuar, caso necesario, otros análisis mas tarde.

Estas consideraciones dictaron el método de recolección y de flujo de datos, empleando cinta de papel taladrado como medio intermediario. Se toman medidas para supervisar la cinta durante el transcurso de una prueba, para imprimir los datos en crudo tal y como fueron grabados para la primera etapa del análisis, y para la exposición de los resultados. Se guardan todos los datos, tanto originales como derivados, en forma de cinta de papel, dispuestos a otros análisis que puedan necesitarse mas tarde.

Este folleto da tambien las consideraciones que dieron lugar a las especificaciones para los versátiles grabadores electrónicos de datos, que se idearon y construyeron especialmente para esta série de pruebas; y contiene un bosquejo del procedimiento del computador para llevar a cabo uno de los análisis.

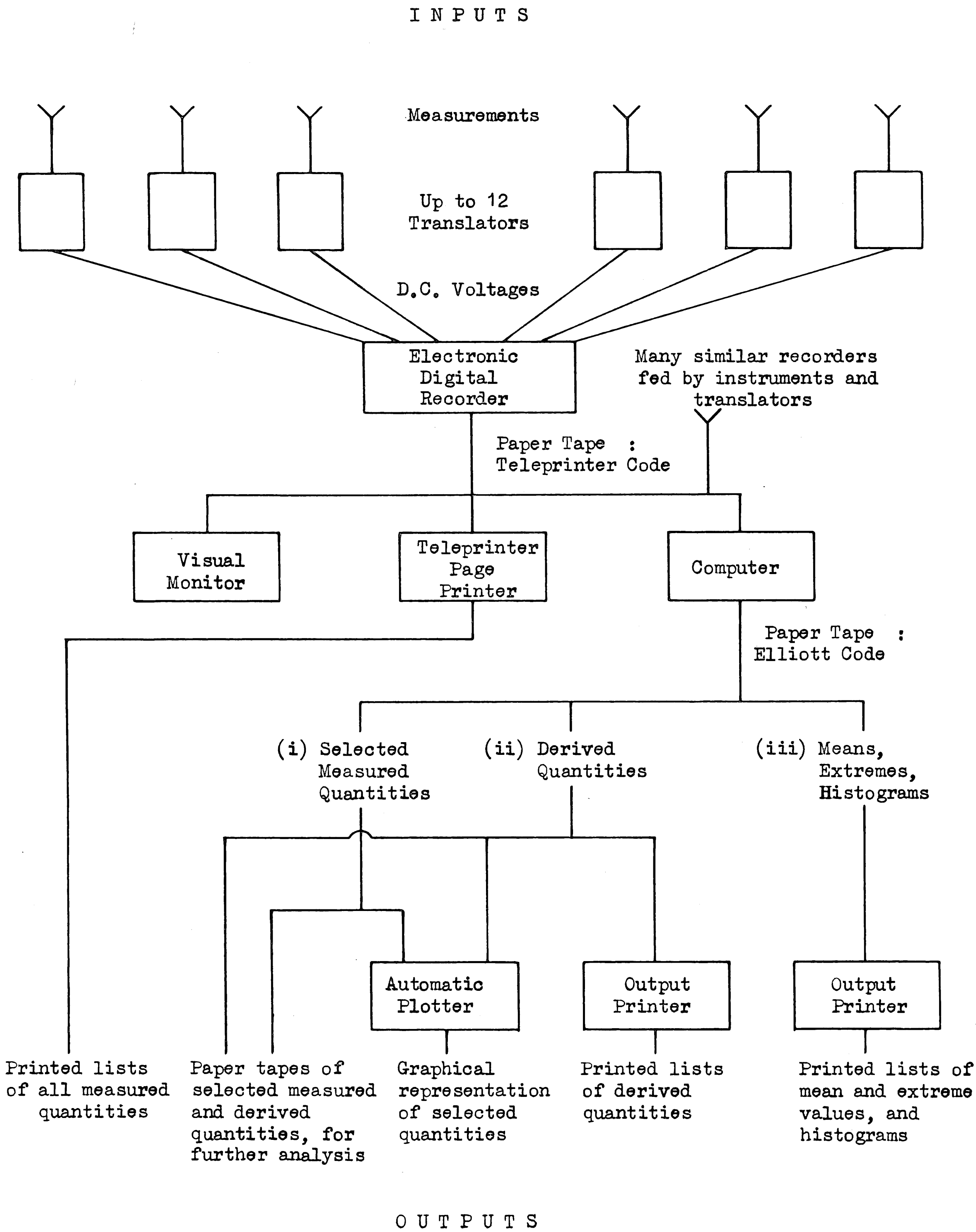

Fig1. Data flow diagram

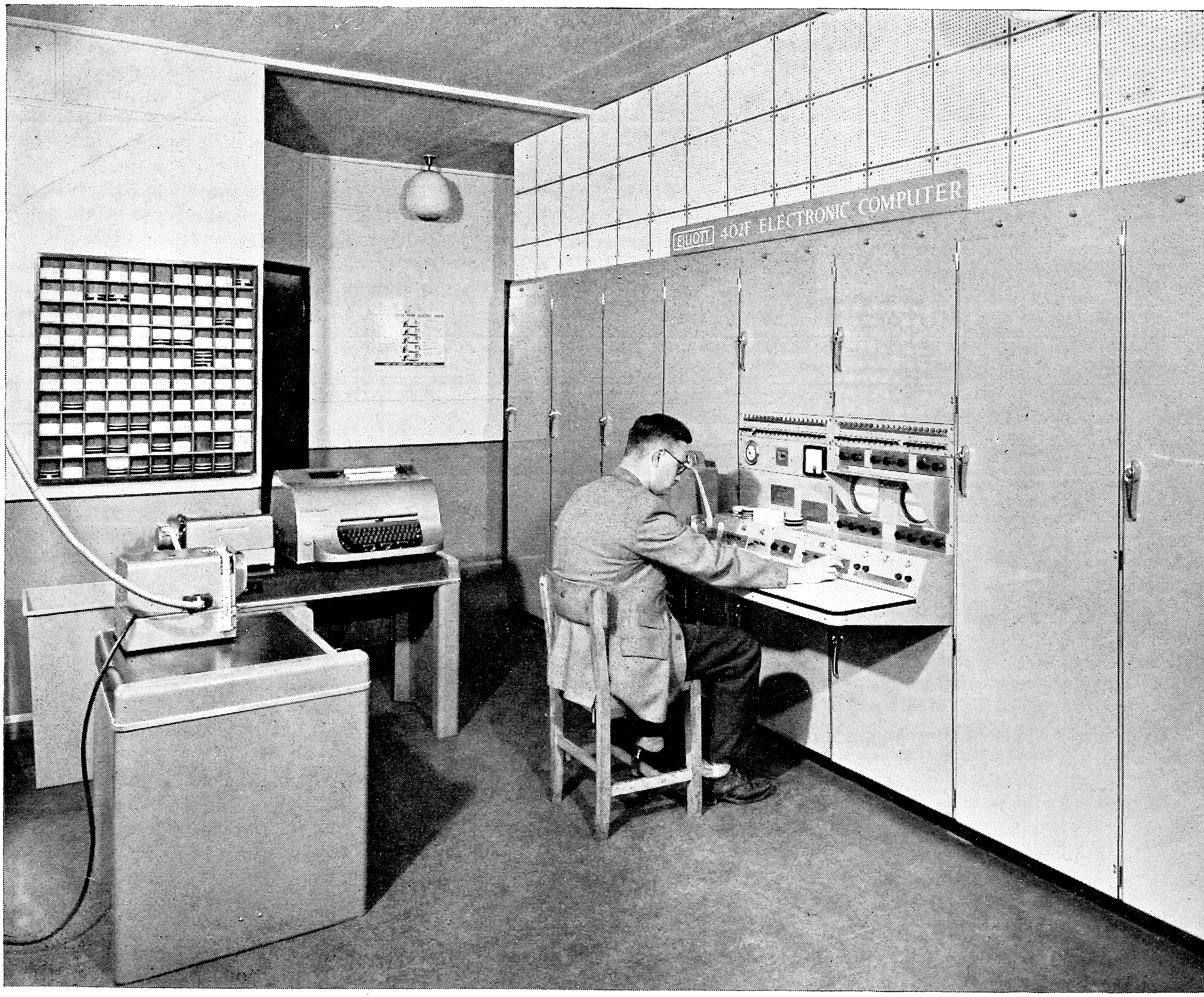

Fig.2 The British Railways research computer, with output printer

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