'ENGLISH ELECTRIC'

Digital Computer

"Type DEUCE"

Digital Electronic Universal Computing Engine

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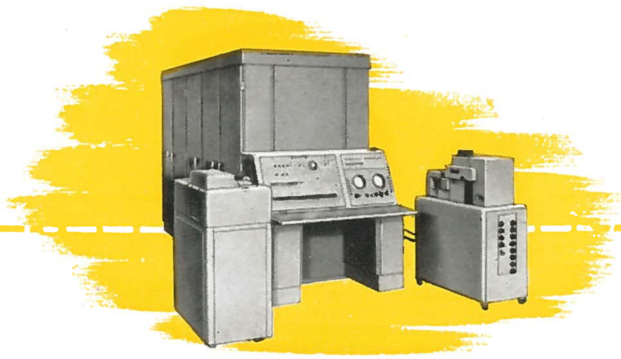
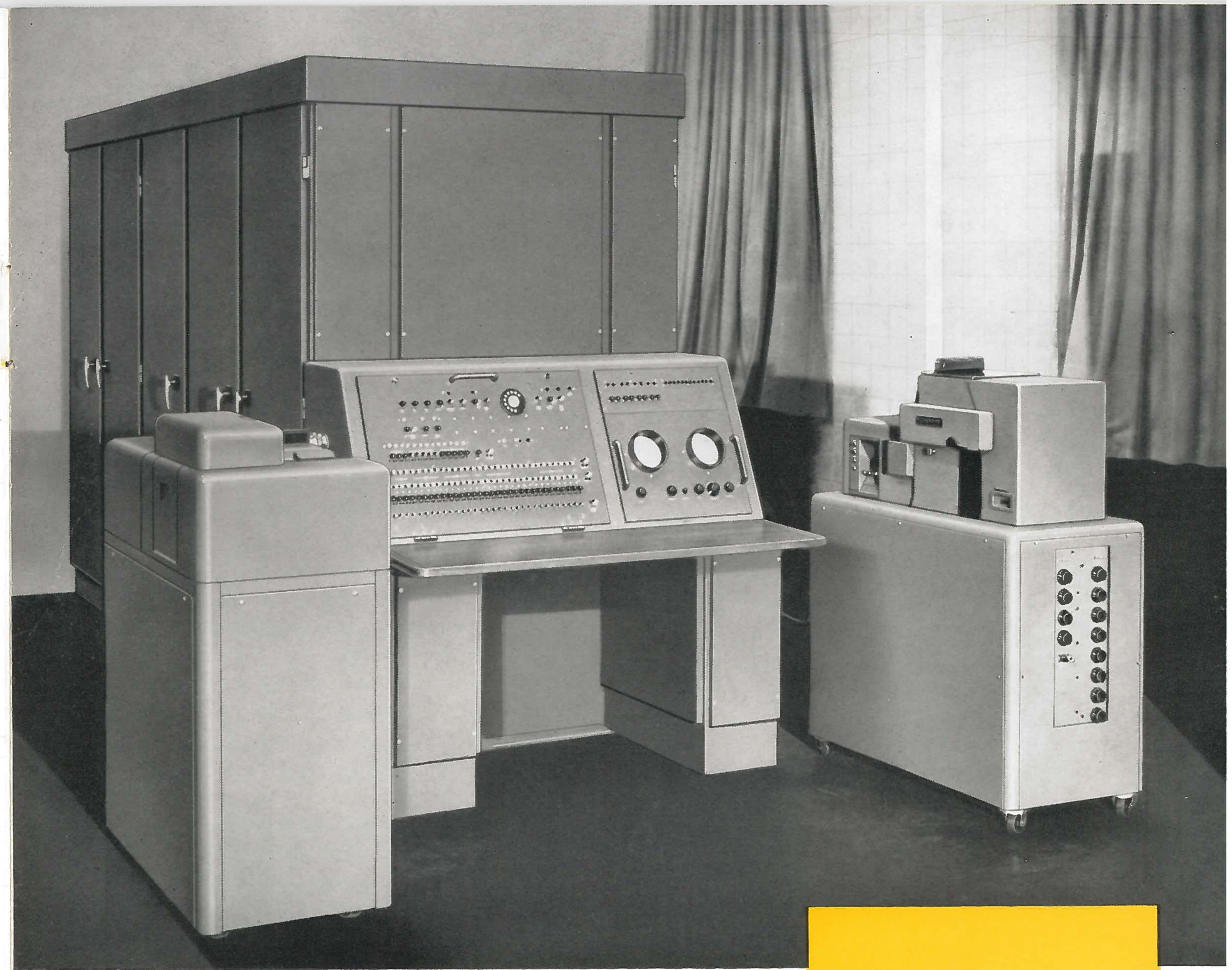


THE introduction of the DEUCE has created a new era in the field of large scale digital computing.

Developed by the Nelson Research Laboratories of The English Electric Company, the DEUCE is based on the ACE Pilot Model at the National Physical Laboratory, which was designed and built by a combined team of mathematicians and engineers from the two laboratories. This Pilot Model was intended as a fore-runner to a much larger computer but since its completion early in 1952 it has proved itself to be a very powerful full-scale computer in its own right.



THE DEUCE

The DEUCE incorporates a number of improvements and additions to facilities, whilst a thorough overhaul of circuit design, a completely new physical lay-out and additional equipment for checking circuit operation have led to an extremely high reliability in DEUCE production models.

The achievements of these computers (a few of which are listed in this brochure) are unique in the field of automatic computation. The considerable programming experience which led to these achievements is made available to all users in the form of a library of sub-routines and programmes.

Description of Computer

Digital Computers are designed and constructed to produce automatically the numerical solution of any type of mathematical calculation at extremely high speed.

There are four basic component parts in the design of any Digital Computer :

(1) Storage for holding instructions and numbers.

(2) Equipment for transferring information into and out of the Computer.

(3) A Control Unit to interpret the instructions and to ensure that they are obeyed in the correct order.

(4) Arithmetic circuits for performing the calculations.

The diagram, Figure 1, indicates the arrangement of these components in the design of the DEUCE.

Mode of Operation

The DEUCE operates in the binary notation. This means that digits have only two states—either a 'zero' or a 'one' value. Thus two binary digits have four possible arrangements, three binary digits have eight arrangements and, in general, *n* binary digits have 2^n arrangements.

In the DEUCE, binary digits are represented by sequences of electrical pulses, separated in time by one microsecond. Machines which employ this principle are said to operate in the serial manner and in this respect the DEUCE is considered to be the fastest serial computer in use in Europe.

The DEUCE deals normally with sequences of 32 binary digits, these groups of digits being termed "words", and the time taken to pass such a sequence from one location to another is known as a 'word time' or 'minor cycle'.

A word may represent either an instruction or a number, the number varying in size from 0 up to 2^{31} (about 10^9), even if one digit is regarded as representing the sign.

Storage

An ideal computer would have a single high-speed store (i.e., one to which access to numbers and instructions is extremely rapid) of unlimited capacity. A perfect storage system, however, would be very expensive and, therefore, it is necessary to achieve an optimum design for high-speed storage capacity.

The high-speed store of the DEUCE has a capacity of 402 words and is backed by a lower-speed store of capacity of 8,192 words arranged in such a way that it may be considered merely as an extension of the high-speed store.

(1) High-speed Store

Pulses fed into one end of a five-foot column of mercury are received at the other end about one millisecond later. If the ends of the column are linked, there will be a continuously circulating pattern of pulses. (Fig. 2.)

The high speed store of the DEUCE consists of 12 such delay lines, each holding 32 words, and shorter lines, 2 of which hold 4 words, 3 of which hold 2 words and 4 holding single words.

(2) Backing Store

Binary digits may be stored in the form of magnetised spots (about 80 to the inch) around the surface of a rotating magnetic drum. The recording and sensing are effected by means of 'reading' and 'writing' heads spaced at intervals along the drum. The information is therefore stored in a number of circumferential tracks (Fig. 3).

The DEUCE drum is of unique design and has 256 tracks, each holding 32 words, and 16 reading and 16 writing heads. These heads may be moved into any of 16 positions. Transfers of information may take place between the drum and the high-speed store at any time, such transfers involving one track and one delay line at a time. The time required for such a transfer is about 10 milliseconds but if a head shift is involved a further 40 milliseconds may be required. This time is not wasted, however, as computation may proceed in the meantime. Accurate planning can, in many

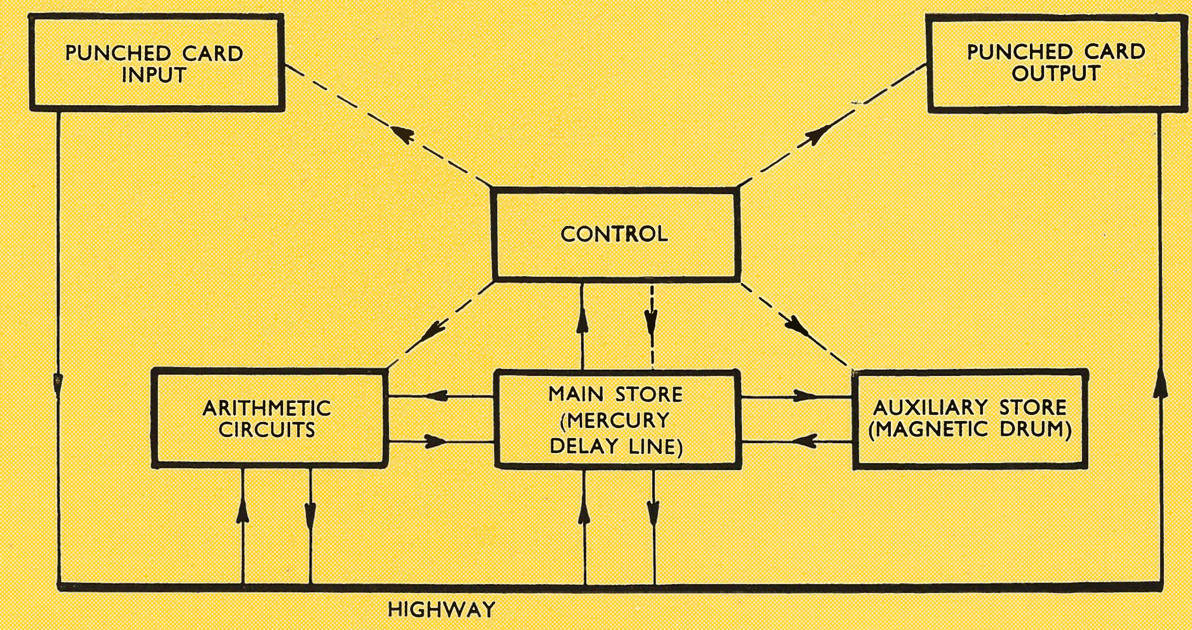


FIG. 1. BLOCK SCHEMATIC OF THE DEUCE

programmes, virtually eliminate the time spent on magnetic transfers.

Terminal Equipment

The normal method of transferring information into and out of the DEUCE is by 80-column punched cards. A card reader is supplied which will sense 32 columns of each card at a maximum speed of 200 cards per minute. Instructions may be fed in binary form, whilst by suitable programmes combinations of up to 32 decimal digits may be punched on a card and translated into binary form as the cards are read.

A separate card punch is provided which will punch a set of cards in the corresponding field of 32 columns. The punch will operate at a speed of 100 cards per minute, the cards again being punched in sterling, decimal or binary forms.

It is considered unsuitable for general purposes to attach a printing unit. The use of a punch gives an appreciably higher rate of output, whilst a separate printing unit gives greater flexibility in tabulation of results, so often required in scientific calculations.

Speed of Operation

In evaluating computing speed the following steps should be noted :

(1) Input of data to the computer.

(2) Carrying out actual computing within the machine.

(3) Output and re-input of any intermediate results (generally in binary).

(4) Output of final results.

The relative importance of these items varies with the problem and the particular machine but the DEUCE has been designed to meet these requirements in the most efficient manner. The design of the DEUCE ensures a reasonable match between the time spent on reading data and punching results and the time spent on calculation.

Control Desk Facilities

The Control Desk of the DEUCE includes facilities to assist in the diagnosis of programme and circuit faults.

Two Cathode Ray Tube monitors are provided in order that the contents of any delay line may be

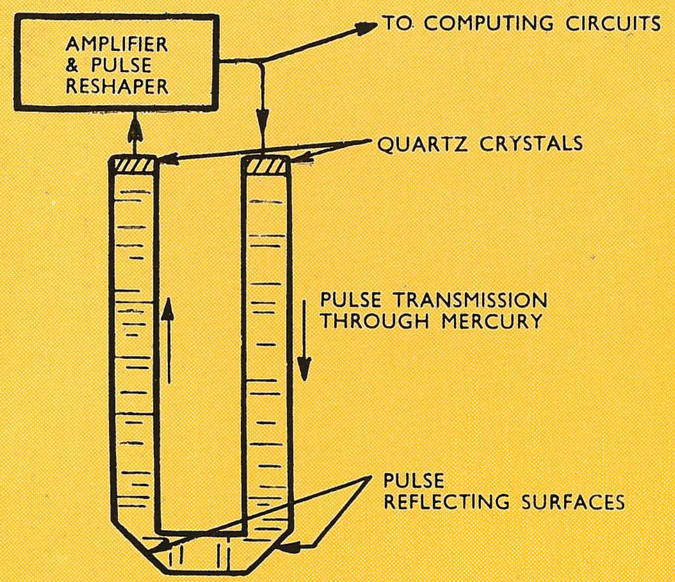


FIG. 2. MERCURY DELAY LINE

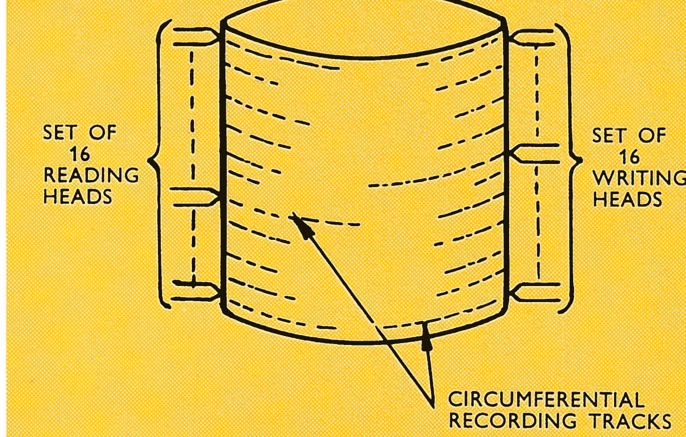


FIG. 3. MAGNETIC DRUM

seen at will, whilst the current instruction being obeyed is shown on a row of lights. It is also possible to reduce the rate of programme operation to 20 steps per second, or even to one at a time if desired.

Arrangements have been made to punch out each instruction as it is obeyed. The programmer is then free to take away a set of cards and scrutinise them without wasting valuable machine time.

Reliability

Great emphasis has been placed in the design and production of the DEUCE on the necessity to maintain reliable operation over long periods of time. Specially designed test programmes are available which enable the computer to assist in the diagnosis of its own faults, thus reducing the period of fault-finding to a matter of a few minutes.

In setting up a computer installation, it is a normal procedure to set aside a brief period daily for maintenance purposes. The test programmes may then be used in conjunction with marginal checking facilities which are provided to predict possible circuit failures before they actually occur.

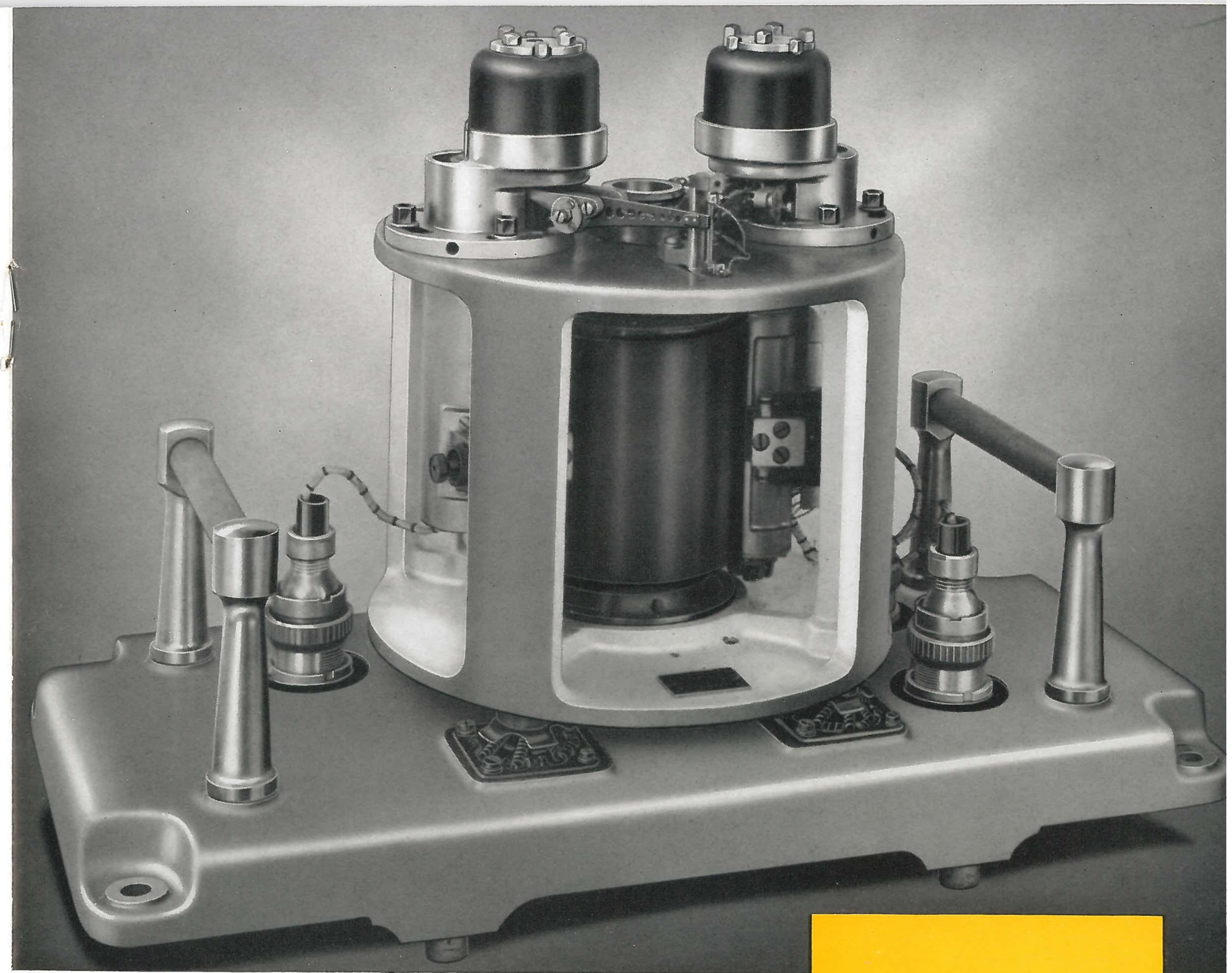
The computer has been designed in compact form, yet all components are conservatively rated and are easily accessible while the computer is in operation. Consequently, fault location and repair may be carried out with all units in position thus removing the necessity of complicated test equipment.

Installation Requirements

The dimensions and approximate weight of each of the main assemblies is given in the following table :

	Length.	*Breadth.*	*Height.*	*Weight.*
Card Reader	3′ 0″	1′ 5″	3′ 8″	4 cwt.
Card Punch	3′ 3″	1′ 7″	4′ 1″	4 cwt.
Electronic Units and Control Desk	14′ 0″	4′ 6″	7′ 4″	25 cwt.
Mercury Delay Line Store	2′ 9″ diameter.		3′ 4″	3 cwt.
Power Supply Unit ...	6′ 0″	2′ 2″	6′ 3″	10 cwt.

The entire equipment has been designed to operate satisfactorily without provision of forced cooling. However, since heat dissipated in the main assembly is about 7 kW it may be desirable to provide ventilation for the machine in order to avoid discomfort to operators.



THE MAGNETIC DRUM

The main power unit is designed to be fed direct from a 400-440 volt, 50-60 c.p.s. 3-phase supply and the total consumption is approximately 9 kVA. The power unit may be situated at any convenient distance from the main assembly.

Maintenance Facilities

Computing installations of all types require a degree of maintenance dependent, of course, upon the complexity of the equipment involved. In order to ensure trouble-free operation with the DEUCE and to provide optimum service facilities for those who wish to service their own machine, The English Electric Company are prepared to train customers' personnel in the operational and maintenance aspects of a computer installation. Training courses are conducted regularly by The English Electric Company for this purpose, both for Home and Overseas customers.

Many of the components are of standard manufacture but replacements for all components will be available from The English Electric Company.

Use of Computer

The usefulness of any electronic digital computer is very largely dependent upon the amount and type of experience which has been built up in the *programming* and operation of machines of that particular design.

A great deal of operational experience lies behind the application of the DEUCE to many technical calculations and this fact should be considered in evaluating any proposed computer.

In order to programme any problem the following steps are usually noted :

(a) The most suitable mathematical treatment for the problem must be selected or devised ;

(b) The mathematical procedure must be translated into a computational scheme suitable for employment on the machine ;

(c) Routines for carrying out numerical operations must be selected or prepared ;

(d) The routines, together with other instructions, must be assembled.

Library of Programmes and Sub-routines

One very important aspect of programming is the accumulation of a library of routines and programmes and great emphasis has been placed on this aspect of DEUCE programming.

In order to obviate the necessity of preparing parts of programmes, for example, to read a decimal number from a card, or to calculate log.x, every time it is required, these functions are written in "sub-routine" form. Sub-routines are designed so that they may easily be integrated into any programme.

The experience on the ACE Pilot Model has given rise to a large number of complete programmes and sub-routines, which have been translated for use with the DEUCE. Copies of all such programmes will be available with coding details and complete instructions for use.

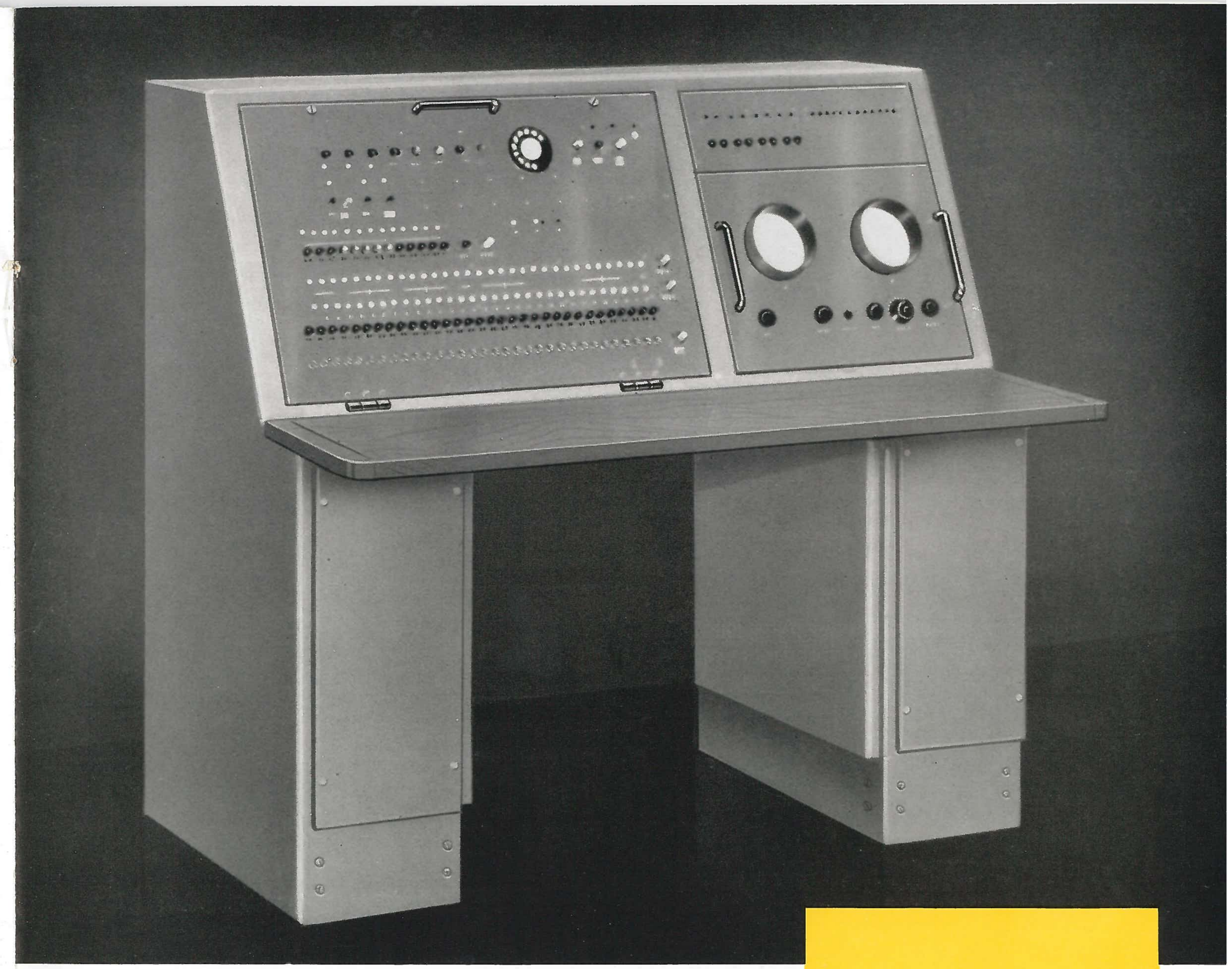
In addition, facilities exist for the exchange of information between the various groups operating these computers and consequently the library will continue to expand.

Form of Instruction

DEUCE instructions nominate three storage locations. Two storage locations are specified as containing 'operands' ; a further storage location is specified as containing the next instruction.

For example, were it required to transfer a number from location A to location B, both of these locations would have to be nominated in the instruction. The instruction would be obeyed in the manner described below :

During the first word time, the instruction is sent to staticisors which perform the necessary electronic circuit switching. In the particular instruction



THE CONTROL DESK

envisaged, a route will be cleared between the two locations in order to enable the transfer of information to take place. The transfer actually takes place during the second word time and simultaneously the next instruction is fed into the instruction register. Thus the complete operation takes two word times, or 64 microseconds.

In the case of the longer delay lines, it will be appreciated that as there are 32 words to a delay line some arrangement has to be made to select the appropriate word. Each instruction actually states the number of word times which must elapse before the instruction or number is in the correct position to be transferred.

DEUCE Programming

The fundamental principles of DEUCE programming are quite straightforward. It has already been stated that an instruction has three main component parts specifying :

Source.

Destination.

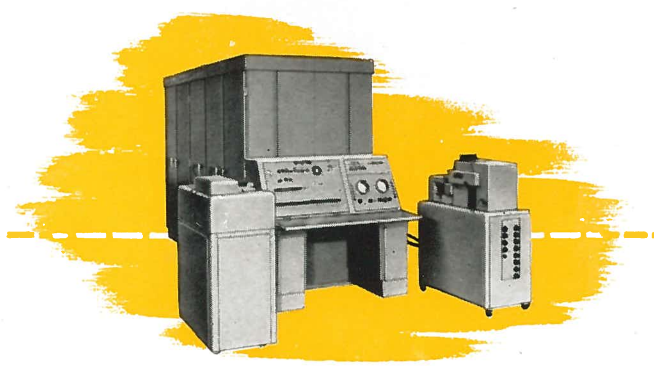
Next instruction.

The source may specify a number contained simply in a storage location, or it may operate as a 'functional source' providing a combination of two numbers, or a fixed constant.

Similarly the destination may be called upon to employ functional properties. Numbers selected by the source part of the instruction may be simply copied or, for example, added or subtracted into the storage location specified by the destination part.

The functions available on the DEUCE include all the arithmetic operations of addition, subtraction, multiplication and division, as well as logical operations, shift and discrimination facilities. Certain codes are reserved for magnetic and input-output instructions, whilst double length working and modification of instructions are provided for.

Every instruction has one digit position reserved to indicate whether the operation of the programme should stop. Operation may be continued by depressing a key on the control desk. This facility provides a useful warning if an arithmetical check fails, although the programme may arrange to repeat the calculation automatically. An audible alarm is included as an additional warning feature.



Applications of the Deuce

MATHEMATICAL PROBLEMS

Mathematical problems of the following types are a few examples of those which have been solved on the ACE Pilot Model and the DEUCE.

1. Simultaneous Equations

Programmes have been written to solve sets of simultaneous equations by three different methods, viz., Pivotal Condensation, Gauss-Seidel and Choleski. These programmes have been used in a wide range of problems and the largest set of equations solved by the Pivotal Condensation method contained 115 equations, solution being made for 37 right-hand sides.

2. Matrix Problems

A programme is being developed to simplify the manipulation of matrices. Programmes already exist independently for the multiplication of two matrices for inversion and for the determination of real or complex latent roots. Matrices up to order 90 can be conveniently handled in the various calculations.

3. Differential Equations

The solution of sets of simultaneous linear differential equations may be carried out using a programme based on the Runge-Kutta method. The results of the calculation may be produced after every step, or after every *n* steps, as required.

4. Harmonic Analysis

A programme for carrying out harmonic analysis is in use. It determines sine and cosine coefficients and amplitudes. As well as its application to the analysis of electrical and mechanical vibrations, it has been used in conjunction with other programmes for fitting algebraic functions to graphs.

SCIENTIFIC APPLICATIONS

1. Aircraft Engineering

Programmes which represent many months of programming effort exist for the solution of the following problems in the Aircraft Industry :

(a) Calculations of Aircraft structural resonance modes and frequencies.

(b) Calculation of flutter coefficients for use on a flutter simulator.

(c) Digital prediction of flutter speeds for systems with up to 16 degrees of freedom.

(d) Calculation of stability coefficients from flight test data.

(e) Calculation of flutter derivatives for both subsonic and supersonic wings.

(f) Stressing of fuselage cut-outs by the Liner-Jupe method.

Many new basic routines to extend the use of the DEUCE on these and similar problems are in course of construction and include such problems as lift (involving matrix inversion) and drag (involving double integration).

The reduction and analysis of wind tunnel data is yet another way in which industry may use the DEUCE.

2. Light Engineering

Solution of sets of differential equations forms a necessary and absorbing application in the field of engineering. Problems in electron optics and in filter design have been carried out.

3. Heavy Engineering

The calculations of surge tank oscillations in Hydro-Electric schemes have been evaluated. The determination of critical speeds of flexible shafts have been completed and, in particular, this programme has been applied to the multi-span shaft of the largest turbo alternator yet ordered in this country.

Problems in the design of transformers are being investigated, in order to indicate the optimum design dimensions.

4. Government Research

The DEUCE is being used on an ever-increasing scale for the solution of problems arising in modern research and statistics indicate that a saving of many man-years of mathematical effort will be achieved.

COMMERCIAL PROBLEMS

The DEUCE was primarily designed for scientific work. This does not, however, mean that it is unsuitable for commercial problems, as is shown by the following examples :

1. Payroll

(a) **Gross Wages.** The calculation of gross wages involving a variety of bonus schemes, in addition to time and overtime earnings, applying to Staff and check workers.

(b) **Net Wages.** The deductions of tax (for all codes) and standard deductions (National Insurance, National Savings, etc.) from the Gross wages obtained by part (a).

The above programmes may be amalgamated to operate as a single programme.

2. Overhead Distribution

The distribution of factory overhead expenses to pre-assigned bases for various shops or production lines has been programmed.

3. Share Distribution

A programme has been produced illustrating the allocation of shares to applicants of an over-subscribed issue, including the production of figures indicating the money over or underpaid, and the next instalment due.

NOTE:—Due to the introduction of improvements from time to time the right is reserved to supply goods which may differ slightly from those illustrated and described in this publication.

The ENGLISH ELECTRIC Company Limited

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