AUGUST 1958.

GENERAL DESCRIPTION OF "DEUCE" DIGITAL ELECTRONIC UNIVERSAL COMPUTING ENGINE.

THE ENGLISH ELECTRIC COMPANY LIMITED

GENERAL

The "DEUCE" Computer was developed by the Nelson Research Laboratories of The English Electric Co. Ltd. It was based on the ACE pilot machine, which was designed and built at the National Physical Laboratories by a combined team of mathematicians and engineers from the two Laboratories. The English Electric Company have now manufactured 18 "DEUCE" Computers. No fewer than six of these machines are being used by the Aircraft Industries for design work and performance study. Two machines are engaged in Reactor and Atomic Weapon design and the remainder on General Engineering, Scientific and Commercial time hire work.

One machine has been installed by the New South Wales Institute of Technology in Australia. This machine has neither needed the services of an English Electric engineer nor a spare magnetic drum since its installation over 18 months ago. No fewer than three customers have returned to English Electric for a repeat order and one customer is shortly to install a third machine.

A high order of reliability is being obtained and the average serviceability of all machines in use is of the order of 95%. The machine installed at Short Brothers and Harland, Ireland, has averaged over 98% serviceability since its installation over 10 months ago. It should be noted that these figures do not include the Preventative Maintenance time, averaging two hours per day, but they do take into account 'spoilt' computing time and the time taken to repair faults, including such minor occurrences as card jams. Recent orders for computers have been received from the Norwegian Government and from our own Central Electricity Generating Board.

The English Electric Company is the only British Computer Manufacturer who has been delivering machines on the scheduled delivery date for the last two years. This fact and the serviceability figures obtained may be readily checked up with any of our users.

Two versions of 'DEUCE' are now available differing only in respect of input and output. It should be noted that although the Mk.II is a later development than the Mk.I full compatability exists between the two and all programming work which has been carried out in the past for the Mk.I is still usable on the Mk.II.

It is estimated that over 250,000 man hours of programming work have been carried out by the combined user force and the majority of this work is available to new customers. This includes a very comprehensive subroutine library. The interchange of information between users is carried out through the medium of our 'DEUCE' Users Association, which has been in existence for over 2 years.

GENERAL CHARACTERISTICS

The 'DEUCE' is a serial machine operating in the binary mode. It uses a word length of 32 digits and a word time of 32 microseconds; successive instructions may be obeyed at intervals as little as 64 microseconds. Multiplication and Division times are 2 milliseconds and the Addition and Subtraction times are 64 microseconds. All arithmetic operations are fixed point. A single length and a double length accumulator are provided . The latter may be used as two single length accumulators. Numerous floating point subroutines are available.

Three types of storage are provided. The High Speed Store immediately associated with the computing circuits, is of the acoustic delay type using mercury delay lines, the reliability of which is now conclusively proven. A large capacity store of long access time is provided by a magnetic recording drum, information being transferred in blocks between these two systems. The third type of storage is on magnetic tape. The equipment for this is available as an optional extra.

The 'DEUCE' is a transfer machine and all the arithmetic and logical facilities are associated with parts of the high speed store. Thus instructions specify the transfer of words from a specified source to a specified destination, indicating at the same time the location in the high speed store of the next instruction. The code can therefore be described loosely as "2 + 1 address". There are 32 sources and 32 destinations.

Instructions are stored in the computer store in exactly the same manner as numbers, each occupying one word length. Optimum programming is used to achieve maximum speed of operation. This system is most flexible and it is sufficient to say that the majority of programming work on 'DEUCE' is carried out by programming assistants, generally female, leaving the work of logical analysis to the programmers themselves. Programme input is in binary on cards. This system is regarded as being simpler as well as more efficient than decimal input of programme though a system for the latter method is available.

THE MAIN STORE

The acoustic mercury delay line storage consists of 12 long lines each having a delay of 1,024 microseconds and therefore accommodating 32 words with an average access time of 496 microseconds. Instructions may be obeyed directly from 8 of these lines.

There are four short lines to accommodate one word each, access time immediate; three short lines to accommodate 3 words each; average access time 48 microseconds. Thus the total high speed store comprises 402 words. This is considered to be a large high speed store for a machine of this class. This is borne out by the fact that the 'DEUCE' has the highest installed capacity in Europe in the Scientific field.

The magnetic drum storage is provided by magnetic recording on an addressable drum rotating at 6,510 r.p.m. The total drum storage capacity is 8,192 words, which is equivalent to 65,536 binary coded decimal digits or 40,960 6 digit characters There are 256 tracks of 32 words each, with an average access time of 20 milliseconds. The transfer time is 15 milliseconds within any block of 16 tracks; an additional period of 35 milliseconds is necessary for switching to a new block.

The average access times referred to above are based on the idea of random sampling of these stores. However, one of the strong points of 'DEUCE' is that the programmer is given the opportunity to reduce storage access time by careful arrangement of material within the store. It should also be noted that the arithmetic circuits may continue to operate during the delay times associated with transfers to and from the magnetic drum. In a similar manner facilities not associated with multiplier, divider or double length accumulator may be used while multiplication or division is in progress. Thus it is possible to have three operations going on in the computer at the same time apart from the additional possibility of input and output operations. These are a Write or Read operation on to the magnetic drum (or a switching operation between blocks), a Multiplication or Division and other Arithmetic operations. This facility gives a substantially effective increase to machine speed over and above that inherent in the basic pulse repetition frequency of 1 megacycle.

MAGNETIC TAPE

The magnetic tape facilities on 'DEUCE' are provided by twin transporter units, i.e., two tape transported mechanisms mounted in one console. Up to 8 tape decks can be provided on the standard equipment although more can be added by the provision of some extra equipment.

Most customers and prospective customers think in terms of 4 decks i.e., 2 twin deck transporters. The significant feature of the magnetic tape system on 'DEUCE' is the facility of varying the block length i.e., the amount of information written on to the tape at full speed without interrruption.

The shorter the block lengths the greater is the proportion of tape wasted, due to the gaps which must be left between blocks and the more the number of accelerations and decelerations of the tape required. The ability to choose the length of block means that the most appropriate unit of information can be associated with a block and compact storage thereby achieved without sacrificing the flexibility with which data may be handled.

The equipment supplied enables information to be written on and read from magnetic tape. No off-line equipment to prepare magnetic tape is supplied for use with the 'DEUCE'. This policy has been decided upon economic grounds. An equipment which would convert from punched cards or paper tape to magnetic tape costs about £35,000. Os. Od. and the alternative use of the Computer with high speed paper tape or punched card input at a rate approaching 1,000 characters per second, is a far better proposition. It has been estimated that the average saving in Computer time using magnetic tape input is only about 20% and since the cost of the ancillary high speed paper tape equipment is for example, only approximately £1,500. Os. Od. it is considered a far better proposition. Using the Computer as an input device allows initial processing of data to be conveniently carried out.

BALANCE OF STORAGE SYSTEM

It is not readily possible to enlarge the high speed store of 'DEUCE' without re-organisation of the order code, which means in fact, the design of new equipment.

Considerable advantage stems from the standardisation of a computer over a period of years in that production methods and maintenance procedures are fully "proven" and that an extensive organisation can be built up by mutual effort with consequent enormous savings in programming effort.

Most computer problems can be solved more expeditiously given a larger high speed store, but the consequent saving of machine time and programming effort does not always justify the additional capital outlay, extra maintenance and running costs that are required. 'DEUCE' represents an effective compromise on both economic and utilitarian grounds, when the whole range of problems to be tackled by the computer is taken into consideration in a large range of applications. The 'DEUCE' High Speed

Store, supported by the Magnetic Drum backing store and the facilities for interchange of information between these stores, provides an efficient arena for the programme to carry out the necessary manipultations and calculations.

It is possible to fit a second Magnetic Drum and associated electronic circuitry, thus doubling the capacity of the backing store. In these circumstances the machine would remain compatible with existing machines so that all existing programmes could still be used.

FACILITIES PROVIDED

In addition to the arithmetic facilities already described the 'DEUCE' has facilities for logical operations including automatic shifting, up or down. Also 8 instruction modifying accumulators are provided, the modification being limited to those digits in the instruction word which normally require modification. Facility for automatic counting and exit from loops is included.

'DEUCE' has a particularly good range of programming testing aids. The whole of the high speed store can be displayed on two cathode ray tubes and all 32 words of a long delay line may be inspected simultaneously. This is of great advantage when used judiciously during programming testing and operation, but also proves extremely useful to engineers in diagnosis of faults. An automatic Programme-Display facility is provided by which the Computer is made to proceed through the programme, one instruction at a time, punching the full details of that instruction on the next row of a card. This facilitity is particularly useful in checking the sequence of instructions generated by instruction modification. A system is available for modifying any part of the high speed store by manual operation of keys on the operating desk without affecting the programme.

No 'post mortem' facility is built in, but auxiliary programmes are available for punching out the whole or part of the Computer store as desired. The great advantage in speed of binary output on cards should be noted in this respect.

Other useful devices include 'Request Stop' by which the Computer can be instructed to proceed at full speed until an instruction of a specified form is reached. A series of lights on the control panel indicate the instruction currently in the control circuits. These assist programme testing, Operator warning and failure indication under static conditions and at full speed convey a reassuring impression of the rhythm associated with the programme.

A feature of 'DEUCE' coding not always appreciated is the ease with which extra instructions may be inserted into the existing sequence. A system of interlocks minimises the chance of a mistake being made by the Operator.

CHECKING

No form of built-in checking is provided except on the magnetic tape store. It is felt that a simple parity check would not offer an acceptable degree of certainty, and, compared with the alternative of extensive automatic checking equipment, the provision of consistency checks in the programme is deemed more economic. 'DEUCE' has a facility which proves very useful in the construction of checking procedures. This is the ability to effect up to 32 individual operations with one instruction. Thus, for instance 32 numbers can be summed in the space of 1 millisecond and at the expense of only one extra instruction.

The main advantage of a parity check system lies in the immediate detection of faults, thus minimising wastage of computer time. The reliability of the 'DEUCE' store has proved such that this consideration has no significance. However, with magnetic tape storage it is felt that occasional drop outs may occur due to dust particles and therefore immediate detection of an error would in fact save valuable time. A two way parity check i.e., lateral and longitudinal for each block, is considered necessary.

FLOATING POINT WORK

With regard to the use of floating point arithmetic on 'DEUCE' the following notes are of interest.

Considering a number in floating point notation of the form $a.2^b$ then the standard single-length floating point sub-routines allow 'b' to vary thus -

$$-2^{31} \leqslant b < 2^{31}, \quad \text{occupying one word.}$$

'a' is such that $-\frac{1}{2} \geqslant a > 1$ or $\frac{1}{2} \leqslant a < 1$ and 30 digits plus a sign digit are used to represent 'a' in the second word. However, double length and triple length floating point sub-routines are available. In both cases 'a' and 'b' have the same ranges as before, but in the first case 62 digits and in the second 94 digits (both plus sign digits) are allocated to 'a'. Single length double length and triple length sub-routines therefore require two, three and four words per number respectively.

Routines for semi-floating arithmetic are available using one word per number. In these, 9 digits are allocated to 'b' and 20 to 'a' (plus signs) so that whereas $-2^9 \quad b \quad 2^9$. Automatic check for overflow of 'b' is available at the cost of an extra 9 words of storage.

Finally routines exist for operations on floating point complex numbers (single length) requiring four words for each complete number.

In connection with the space occupied by these sub-routines for addition, subtraction etc., in the high speed store, this information is given in the following table.

Storage required by Sub-routines for $\pm$, x, $\div$

Single length	64 words
Double length	108 words
Triple length	230 words
Semi-Floating (without check)	87 words
Complex Floating (including "modulus"	134 words

Storage required by Sub-routines for

Log $_e$x (floating)	38 extra words	single length
exp (x) (")	63 extra words	single length
arc tg. x (fixed point)	87 words	single length

All these routines also use some or all of the 18 words of temporary storage provided on 'DEUCE'. It should be noted that a considerable amount of overlapping occurs between these routines since the higher functions use the basic operations of addition, subtraction etc., in the standard sub-routine form. For an accurate estimate of the solution of any given problem it is necessary to study the detailed properties of the sub-routines carefully.

The above figures give a rough guide when it is remembered that the 'DEUCE' high speed store normally holds 256 instruction words and 128 words for data and constants (32 of which form the buffer store for Magnetic transfers) in addition to the 18 words of temporary storage mentioned above.

A technique used to great effect in 'DEUCE' interpretative schemes especially those connected with Matrix Manipulation, is 'block-floating' arithmetic, that is the association of one exponent (b) with several mantissae (a_1, a_2.....a_n) the whole block of a's

being 'normalized' to suit the common exponent. With reasonable number variation this technique is more than economical in time and storage than the "fully floating" approach and almost as accurate.

The floating point operation results are always normalized. All floating point sub-routines include a PREPARE section which normalizes any floating number so all results are produced in normal form.

Approximate average times	ADD/SUBTRACT	6	milliseconds
	MULTIPLY	$5\frac{1}{2}$	"
	DIVIDE	$4\frac{1}{2}$	"

It should be remembered that 'DEUCE' is basically a fixed point machine and that Addition and Subtraction times are largely dependent on the compatibility of the numbers.

ALTERNATIVE VERSIONS OF 'DEUCE'.

'DEUCE' is now being manufactured in two distinct forms referred to as 'DEUCE' Mark I and 'DEUCE' Mark II. 'DEUCE' Mark I is intended primarily as a scientific computer and is provided with input and output via 64 columns of punched cards. It may be fitted with Magnetic Tape auxiliary storage if desired and also high speed paper tape input and paper tape output if required.

'DEUCE' Mark II is primarily intended as a central unit of a data processing system but nevertheless retains all the advantages and power of the Mark I as a scientific machine. It is fitted with a combined input-output machine using 80 columns of punched cards and automatic conversion facilities are built in.

The Mark II is, of course, usually used with Magnetic Tape Storage and like the Mark I, paper tape input and output may be used if desired. Also a second 80 column card input/output can be fitted if necessary.

The basic 'DEUCE' Mark II is more expensive than the Mark I. It should be noted that conversion of a Mark I equipment to Mark II form on site costs considerably more than the difference in price between the two machines.

ANCILLARY EQUIPMENT.

Editing equipment both for punched cards and paper tape are not normally provided directly by this Company. However, satisfactory arrangements can be made with the manufacturers of these equipments.

In respect of Card equipment the purchase of several Key Punches and Verifiers is recommended and at least one Reproducer. The latter should be modified to reproduce individual rows. A card sorter, or access to such, proves useful if a great deal of data is being handled. Some form of card to print device is essential. A normal 100 lines a minute tabulator with arithmetic facilities is usually necessary for scientific work. A card operated typewriter is available to satisfy the demand for some means of producing a very neat print with great flexibility in layout. Details are given below.

A fast line-printer for output from Magnetic Tape is being developed. This will not be available for at least two years, and is likely to be an expensive piece of equipment. Different techniques are being explored for the solution of this problem, but a scientific installation is well advised to think in terms of punched card output devices.

CARD OPERATED TYPEWRITER.

The equipment uses -

An IBM 056 Verifier, a 14" Platen Typewriter type IBM 10 pitch Pica, and has a maximum overall operating speed of 10 characters per second.

It has two types of control,

a) A control Card (Standard 80 Column) on a rotating drum.

b) By indicative columns on the data cards.

The drum card gives column by column control of the card reader and of the information to be printed, this control being repeated for each input card. It gives 32 combinations of control of which the following are examples:-

Start and Stop skipping.

Tabulate and skip.

Carriage Return-Line feed and eject the card.

Stop printing after this column and then tabulate.

Calendar, etc., etc.

INPUT.

64 Column Card Input.

This will operate at 200 cards per minute. The 64 Columns

may be in decimal, alphabetic or binary, but it is necessary for the Computer to effect any conversion or translation concurrently, reference being made to the input for each row of a card. Normally time is available for computation between successive cards. All existing 32 column programmes may be used without alteration. This input can have plugboard facilities if necessary. The 64 column read and punch facility is explained further in our publication DP1/5a enclosed.

Fast Paper Tape Input.

The high speed paper tape input, fitted if required as an optional extra, will operate at approximately 850 characters per second. The device will read either 5 hole or 7 hole paper tape. 8 hole tape will be accepted though only 7 holes will be sensed. Of these 7, one digit will complete parity leaving a 6-bit character to be read into the main store. The use of the paper tape will be independent of the code punched on the tape, the computer being given the task of converting the code to a standard form.

It is possible to convert numbers from decimal to binary at this speed, though occasional stopping of the tape may be necessary in order to store away the converted numbers.

High Speed Card Reader.

An endwise-feeding card reader operating at approximately 600 cards per minute is to be developed in the near future. Access to the whole 80 columns will give this equipment an effective input speed equivalent to that of the fast paper tape.

COMBINED INPUT/OUTPUT 'DEUCE' MARK II.

This device giving access to all 80 columns may operate synchronously at 100 cards per minute, though the input can operate independently at 200 cards per minute. Automatic conversion of decimal and translation of alphabetical coding to 6-bit binary in a buffer store is provided so that the computer need only refer to the input once for each card and computation may proceed, concurrently. Similarly automatic conversion and translation from 6-bit binary is provided on punching so that the computer need only refer to the output once for each card and again computation may proceed concurrently.

Normal 64 column input-output is included, the choice (64/80) being under programme control. Practically all existing 32 column programmes may be used without alteration. For further details, see publication DP1/12.

OUTPUT.

64 Column Card Output.

This provides a high rate of output compared with paper tape, particularly for intermediate binary results. The relevant rates are 107 alpha-numeric characters per second and 1,280 bits per second compared with 25 characters per second and 125 bits per second in the case of reliable paper tape equipment which is currently available. The technique of intermediate binary output is used extensively in scientific work on 'DEUCE' especially for breaking down long computations into stages in order to minimise wastage of computer time in the event of breakdown. Identification numbers are automatically punched on all output cards.

Paper Tape Output.

This is fitted where required by customers, but is not recommended for general use, in view of the poor rate of output mentioned above. It is usually required in cases where paper tape must be produced for use in other equipment, e.g. wind tunnel and machine tool control. Price varies according to the system of control preferred.

PROGRAMME LIBRARY.

Mention has been made of the 'DEUCE' programme library and its facilities. The varied applications have been concerned with the widest possible spectrum in research and design, in statistics and in operational research. From this work a very extensive library of programmes and sub-routines has been accumulated. To Purchasers of the 'DEUCE' Computer, copies of all such programmes and sub-routines are available for immediate use complete with full instructions, description and coding details. Facilities exist for the exchange of information between the various users operating these computers and consequently the library will continue to expand and increase its already great usefulness.

COMPUTING SERVICES.

The English Electric Co. has two computing centres operating in England, one at Stafford with two 'DEUCE' installations, the other one at London with one 'DEUCE'. These two centres operate a full computing service for industry and are available for both Home and Overseas use on a time hire basis. The Norwegian Government have chosen 'DEUCE' for their time hire service which will be engaged in both Statistical and Scientific work.

PROGRAMMING SYSTEMS.

A wealth of interpretative procedures present the programmer with a wide selection of techniques for presenting a problem to the machine. These represent varying degrees of compromise between simplicity of coding and optimum use of the computer's speed. The degree of compromise can therefore be chosen to suit the particular application. The systems at present available for use are described separately below and in more detail in the documents "DEUCE NEWS", 10, 19 and 20 which can be supplied upon request.

They are - a) The General Interpretative Programme
b) The Alpha-Code Programme
c) The Tabular Interpretative Programme

a) provides a very efficient scheme for handling numbers with a very easy coding system which has proved of inestimable value in scientific work.

b) proves virtually another order-code which has been chosen to be as simple as a computer order code can possibly be. Naturally efficiency has been sacrificed to achieve this end.

c) provides a useful compromise between (a) and (b).

The General Interpretative Programme (GIP).

The GIP is designed to facilitate the 'manipulation of matrices'. This term however, is capable of a very wide interpretation since a matrix is merely an ordered array of numbers and the manipulation carried out need not necessarily be those commonly associated with the "Matrix Algebra" of Mathematics. The term should in fact be taken to mean the 'carrying out of a sequence of operations on a set of numbers in a systematic manner' which after all is the basic function of a computer.

Many sequences of operations - organisational perhaps even more than arithmetical - are of frequent occurrence and numerous programmes, termed 'bricks' have been written which are capable of operating on any sets of numbers arrayed in conventional manner. Bricks may be used independently or successively, as normal programmes, but are designed so that when stored on the Magnetic Drum their sequence of operation may be controlled by the GIP according to a sequence of simple code-words supplied on cards by the Programmer (or often by an experienced girl operator). Only those bricks relevant to the problem need be read to the Magnetic Drum and these are extracted directly from the library.

All operations are fully self-checking and problems of

over-flow do not arise owing to the 'block-floating techniques adopted. Furthermore, the GIP, being merely a 'programme-control programme,' is often used in an unconventional manner to facilitate programme construction. In general the GIP allows a very efficient ulitization of the computer's power and speed especially when the programme changing time is small compared with the programme operation time. Punched cards form an ideal input-output medium owing to the high speed of binary input-output possible. Considerable use is made of intermediate binary-output in practical application of GIP.

The Alpha Code.

With this system the Programmer merely specifies his problem to the computer using an extremely simple and highly flexible order code. The instructions are actually supplied in alphabetical form.

An initial "compiling" run on the computer converts these into the binary form suitable for interpretation by the computer.

The programmer - who might well be an Engineer with one day's experience is absolved of the responsibility of studying scaling, the programme being in 'floating point' and input-output problems and results are automatically produced in a form suitable for tabulation. Single instructions can evaluate complicated functions such as 'exponentials' or 'solutions of differential equations' and "sub-routines" of alpha-instructions may be easily incorporated into a programme. Organisational, discriminatory a test facilitating instructions are provided in abundance and last minute corrections are particularly easy.

The obvious use of Alpha Code will be for personnel unfamiliar with 'DEUCE' order code who require a quick solution to a 'one-off' problem. However, skilled 'DEUCE' programmers will also find the Alpha Code of great value not only for 'one-off' problems, but for constructing major programmes by obtaining trial results for checking purposes and, perhaps more important for exploring the logical difficulties before the major programme is written.

The Tabular Interpretative Programme (TIP)

This is very similar to the GIP in operation, but can be said to 'manipulate vectors rather than matrices'. The motive for this approach is that many people used to carrying out calculations on desk machines, have formed the habit of organising their work 'by columns'. A typical code word might be a, b, c, d, meaning 'evaluate the function d (multiplication say) or corresponding elements of column a and column b storing the results away in column c.

The functions available are limited in number and for ease of handling the corresponding programmes are all stored each time the TIP is used. This scheme retains the efficiency of GIP while providing a coding scheme as easy, if not easier in many cases, than the ALPHA-CODE.

In addition, various systems exist for standardising and simplifying programming procedures.

POWER SUPPLIES.

The main power supply unit is designed to be fed direct from a 400 to 440 volt 50-60 c.p.s. 3 phase supply, and the total consumption of a 64 column machine without magnetic tape is approximately 9 KVA at a power factor better than 0.9.

The power consumption of an 80 column machine supplied with 4 tape decks is approximately 16 KVA. A voltage regulator is provided to cater for mains input variations of up to ± 10%.

The power supply unit is provided with additional interlock contactors for starting the fans of the ventilating system, but the power required by the fans is not included in the figure above. A further supply of about 300 watts (3 phase and neutral) is required to drive the heater and circulating fan of the delay line enclosure.

VENTILATION EQUIPMENT.

The installation of this equipment is usually carried out by a local contractor as it will be realised that local conditions make any other arrangmenet difficult.

The 'DEUCE' is provided with entries for 2 ducts into the roof from above, one for inlet air and the other for outlet. The pressure drop across the machine is approximately 0.5" s.w.g. at 2000 c.f.m. inlet. An axial flow should be provided in the inlet duct of sufficient capacity to deliver 2000 c.f.m. to the machine and this flow should be capable of being manually regulated to 1000 c.f.m. to take account of seasonal variations in ambient temperature. The outlet fan in the exhaust duct should be capable of handling approximately 1500 c.f.m. Full details of the system and recommended air filters and fans can be supplied on request.

INSTALLATION PROCEDURE.

During the last 3 years a generally agreed set of stringent Acceptance Tests have been devised. On standard machines the tests comprise, firstly, an input-output test which involves

the handling of 4 million binary digits through the input and output machines, allowing no errors or card jams. This is followed up by a general operational test comprising 16 separate runs each of half an hour's duration comprising a wide variety of different types of programme using all the machine facilities under a variety of working conditions. The machine is expected to pass this test in one 8 hour spell. Although it has not so far been specified it has been the general practice to do the first runs of each of the two above tests under marginal conditions, thus giving greater confidence in machine performance. These tests are normally repeated in full on site before the machine is handed over.

PREVENTATIVE MAINTENANCE.

Marginal Checking.

The 'DEUCE' has been so designed that built-in marginal checking facilities of the grid control type enable an extremely thorough system of preventative maintenance to be successfully carried out. This system which has been developed over the last 3 years depends on the complete checking and recording of performance figures on one or two units each day, so that the whole machine is checked in each two or three month period.

The design of the electronic circuitry makes it possible to inject marginal biasing voltages into approximately 95% of the valve stages in the machine, which are provided with suitable two pin sockets. The injection of this voltage enables a reliable assessment of the stages actual margin of safety to be measured and subsequently recorded. The correlation of these records over a period of time enables the engineer to obtain a reliable picture of how individual performance is deteriorating and advance warning of the great majority of non-catastrophic faults is obtained in this way.

A further facility is provided in that the machine is divided into 6 individual blocks of circuitry each made up of the stages referred to above, thus the safety of the whole of each block may be recorded week by week, and advance warning obtained of faster deterioration than normal.

In addition the 6 blocks are combined in one key on the front panel and the electronic balance of the machine offset towards both extremes of safety by the use of this key. Its average effect is to push the machine one third of the way to individual stage failure in either direction. The operation of the machine under the two extremes gives absolute confidence of its operation in the middle.

Daily Routine.

It is recommended that between 2 and 2½ hours each day are spent on preventative maintenance. This is mainly taken up by the routine checking described above and the running of 'DEUCE' programmes and confidence checks, which are contained in an extensive test programme library supplied with the machine. The English Electric Company as part of their maintenance service provide all the necessary forms for the recording of maintenance statistics including engineer's Log Books. Records show that no machine has been out of operation for a period exceeding 24 hours.

From the majority of machines at present in use weekly operational statistics are received. These are compiled into 4 weekly summaries which are circulated to all users to stimulate intersite competition.

It is essential to appreciate the definition of the statistics. The Scheduled Maintenance time which, as previously mentioned, should be of the order of 2 to 2½ hours daily, is not included in the final serviceability percentage, and it is also important to note that Scheduled Maintenance is not sacrificed to routine fault finding. In other words if a fault is present on the machine at the start of the morning's operations, Scheduled Maintenance will not commence until the fault is cleared and the clearance time will count against the machine under the heading of unusable time. The unusable time figures also include faulty running time on any one programme in the machine before a fault is discovered, as well as the time taken to clear it. Average serviceability is defined as

$$\frac{\text{Usable Time}}{\text{Unusable + Usable Time}} \times 100\%$$

It is notable that machine D which is owned by Short Brothers and Harland has averaged over 98% serviceability since its installation some 10 months ago.

Confirmation of these figures can be obtained from any 'DEUCE' users.

Maintenance Staff.

It is recommended that two site engineers be provided to maintain the Computer and its associated Electronic Equipments. A comprehensive 6 months training course at our Works for two of the purchasers' engineers is provided free of charge.

PROGRAMMER TRAINING AND ORGANISATION.

Training of programmers is also undertaken free of charge

at the Computing Centre at Stafford, the normal duration of a course being 3 weeks. An allocation of up to 30 hours of computer time is included for programming exercises and gaining experience of computer operation and programme testing. The trainees also acquire a knowledge of the organisation of the extensive subroutine and programme library.

A number of female operating staff are required not only for operation of the punched card equipment, but also for the operation of the computer itself which includes feeding the card input, dispersing the card output and interchanging magnetic tape reels where necessary. It has been found in practice that girls of higher school level are quite capable of carrying out this work efficiently. It is an advantage for at least one of these girls to be familiar with binary punching on a key punch and the coding of 'DEUCE' instructions in binary.

It is considered advisable that the administration of a computer installation should be in the hands of the Supervisor, preferably having a good knowledge of programming and an appreciation of the logical and engineering construction of computer and card machinery.

Prices and Delivery.

The cost of a MK. I 'DEUCE' is approximately (Sterling) £52,000. Os. Od. nett, F.O.B. U.K. Port. Deliveries of the order of 9 months can be offered. A MK. II 'DEUCE' costs approximately (Sterling) £60,000. Os. Od., F.O.B. U.K. Port with a delivery of approximately 12 months. These prices do not include for the preparation of the Computer Room or for any ventilation which is purchaser's responsibility, but on which advice is given in accordance with our normal practice. The prices do, however, include for supervision of unloading, the erection and commissioning of the equipment.