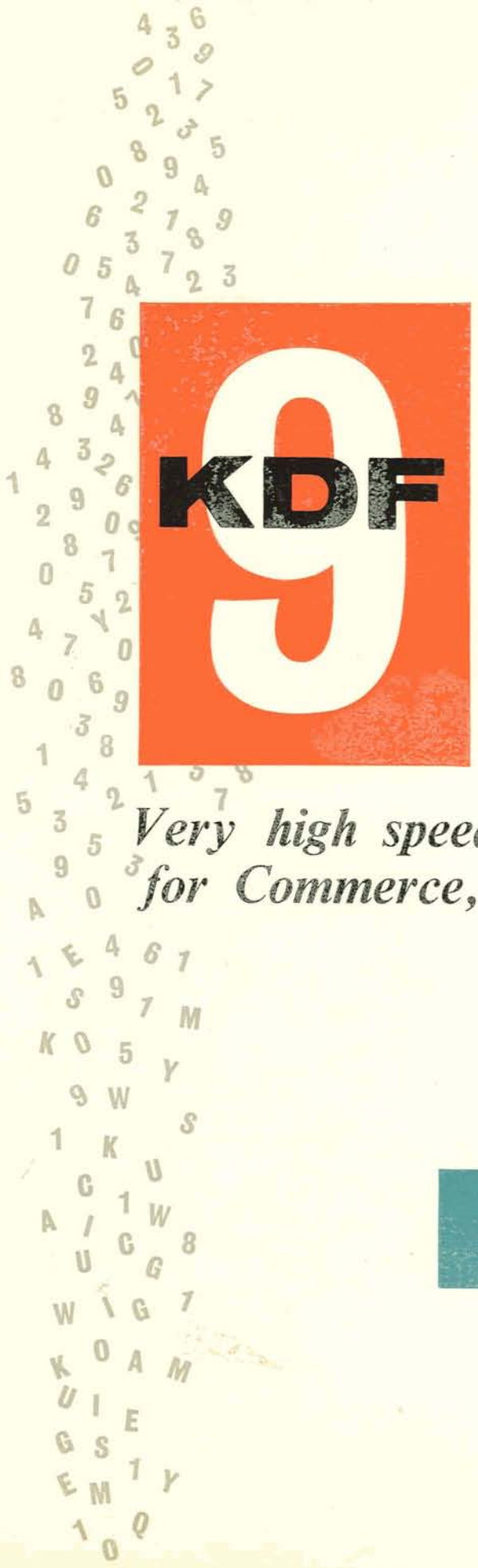
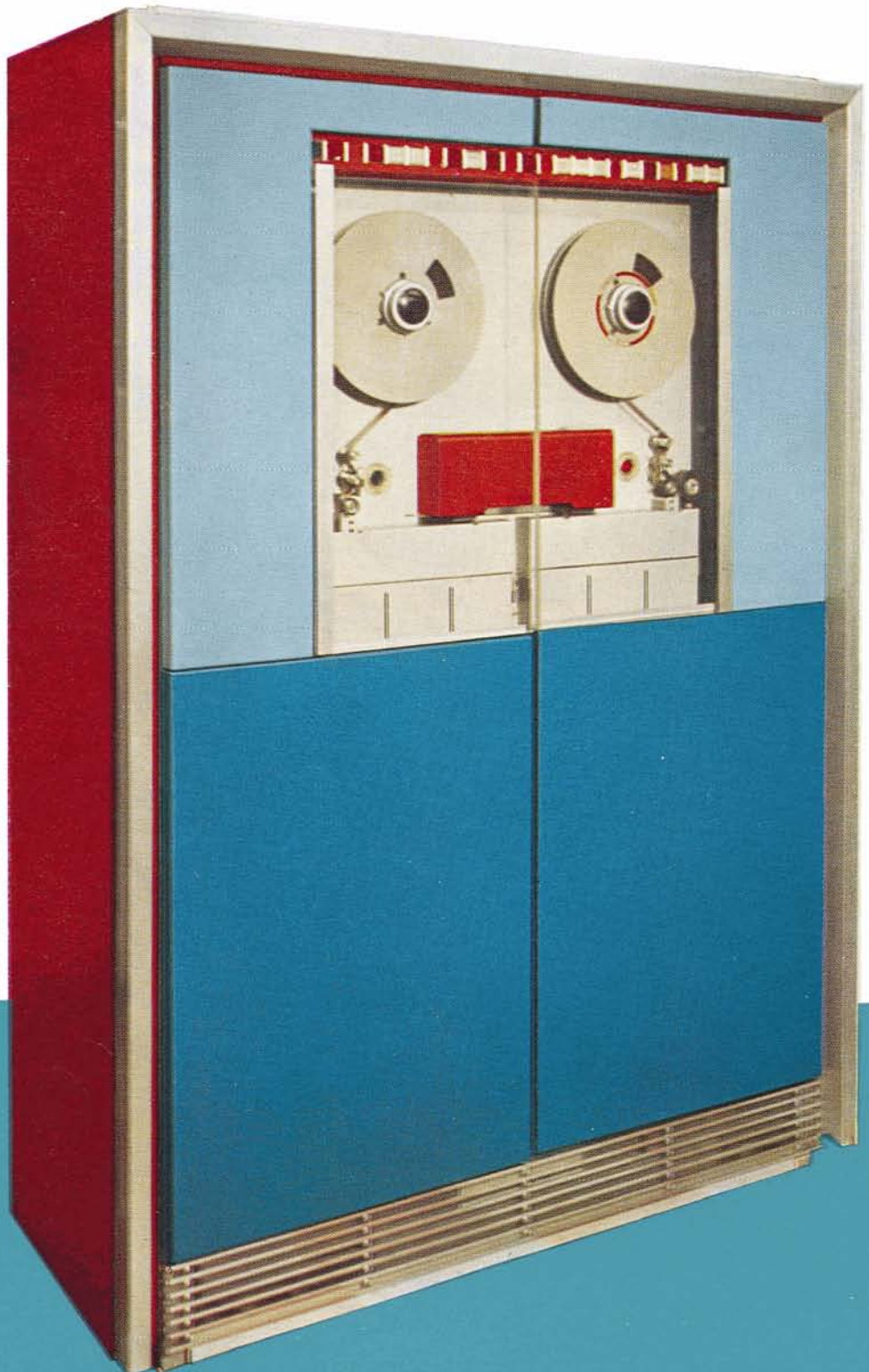


Very high speed data processing system for Commerce, Industry, Science

'ENGLISH ELECTRIC'



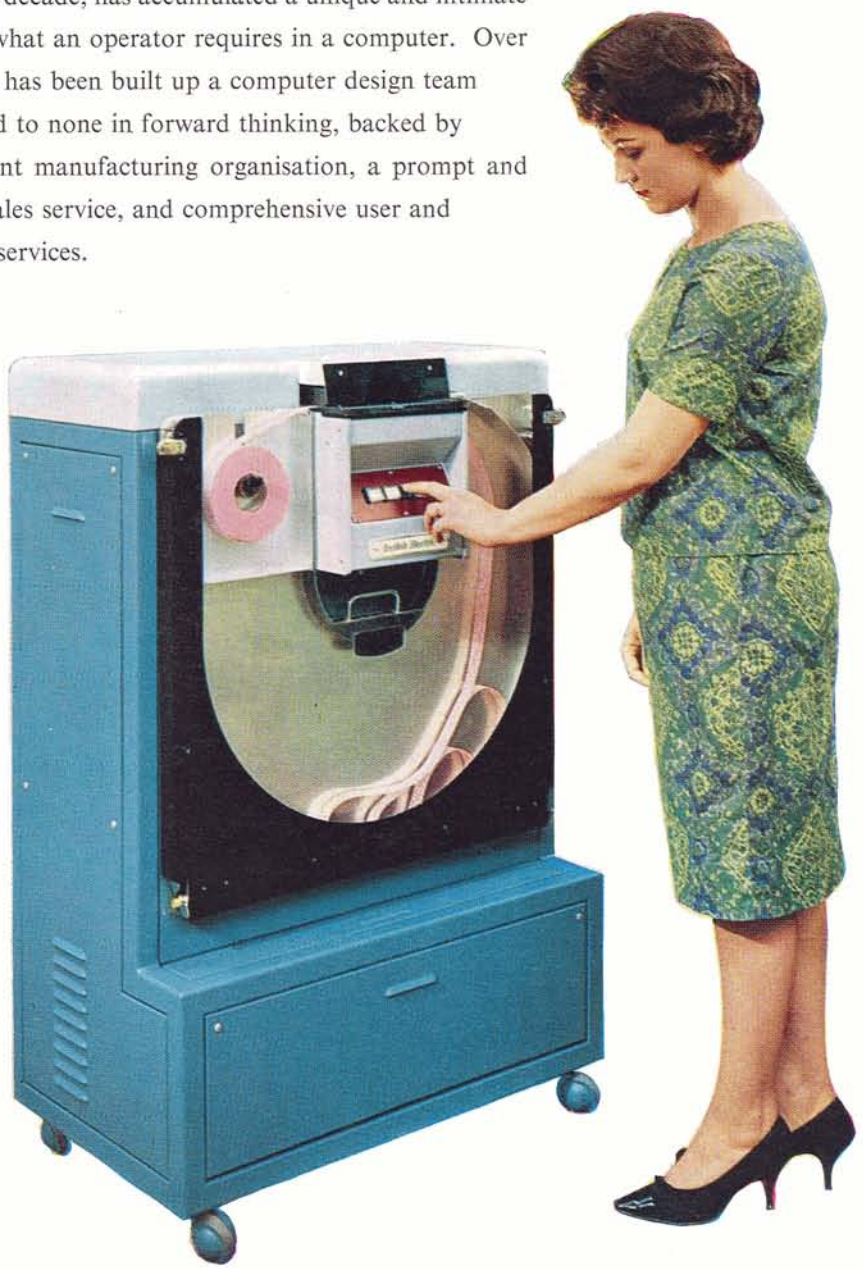
The KDF 9 *Lineage*

On the pages that follow is described the 'English Electric' KDF9 Data Processing system—one of the most advanced electronic digital systems yet devised.

KDF9 is the outcome of many years' experience accumulated by 'English Electric' as designers, manufacturers, and users of computers, the Company being one of the pioneers in the field in Britain. In the early post-war years 'English Electric' co-operated with the National Physical Laboratory in the development of the " ACE " Pilot Model, one of the first electronic digital computers made in the United Kingdom. The Company then proceeded with the development and production of a fully engineered computer which was to set new standards of speed and capacity. Great interest was shown in this undertaking and, literally at the drawing board stage, the Company was asked to build one each for the National Physical Laboratory and the Royal Aircraft Establishment, Farnborough. The new machine, which was named " DEUCE," was an immediate success and soon became widely known as the most powerful and advanced computer of its type. Successive marks were developed to meet the demand for increased speed and storage, all of which give the utmost satisfaction to their users.

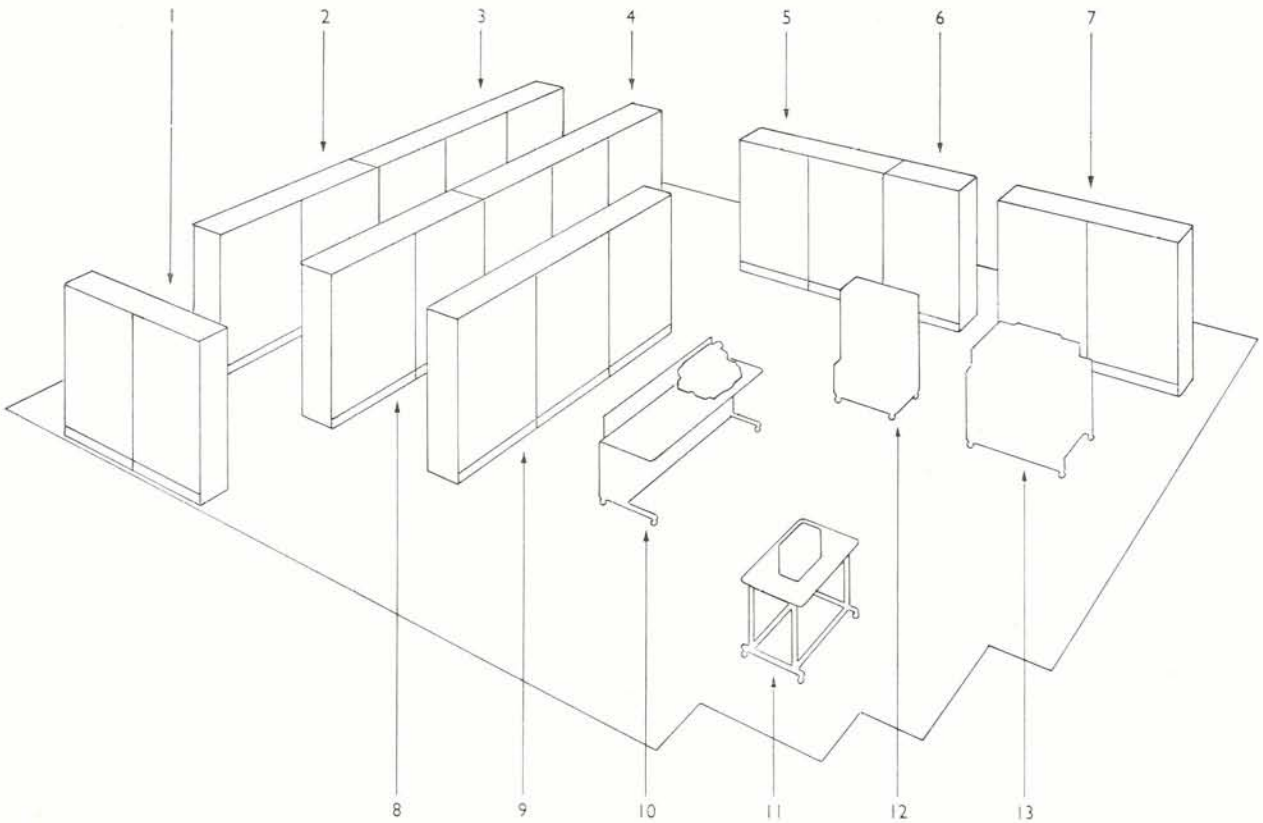
As the use of computers became more widely known and appreciated there came increased demands for computers of much greater speed and capacity, and 'English Electric' addressed themselves to the task of meeting these demands. A computer manufacturing division was established at Kidsgrove, North Staffordshire, and is now known as the Data Processing and Control Systems Division. From its inception the division has continuously expanded and produces a wide variety of analogue and digital computers and ancillary equipment. These include the " LACE " series of analogue computers, multi-point scanners. " DATAPAC " systems of logical elements for process control and data handling, the KDP10 large-scale commercial data processing system, and now : the KDF9 general purpose computer for commerce, industry, and science.

The success of 'English Electric' computers is in no small measure due to the fact that the Company is one of the largest USERS of analogue and digital computers and, during the past decade, has accumulated a unique and intimate knowledge of what an operator requires in a computer. Over the years there has been built up a computer design team which is second to none in forward thinking, backed by a highly efficient manufacturing organisation, a prompt and reliable after-sales service, and comprehensive user and programming services.



Contents

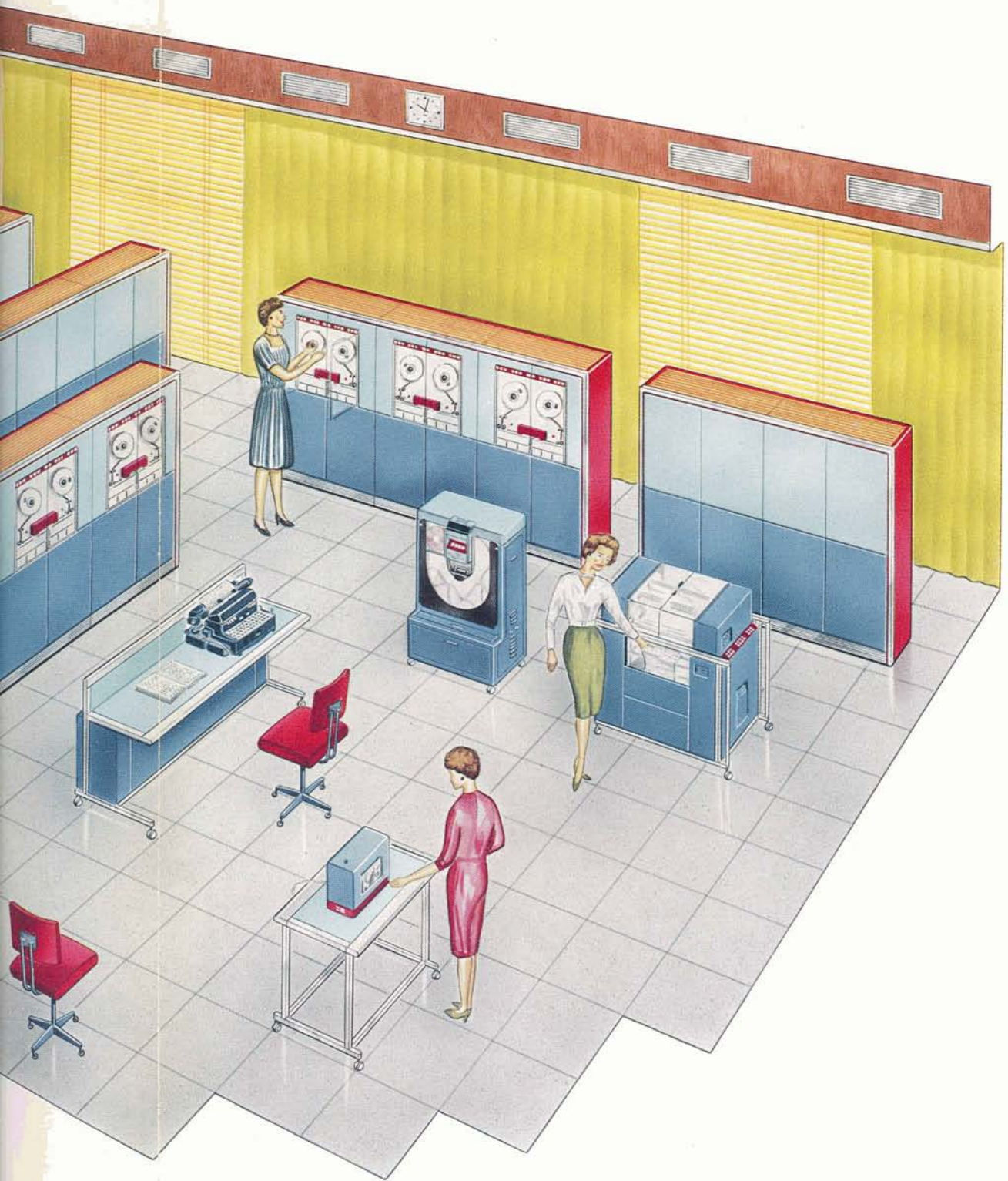
Key to System Illustration opposite



1. Power Supply Units (2)
2. Input/Output Units (2)
3. Main Store Units (3)
4. Main Control Units (3)
5. On-Line Magnetic Tape Units (2)
6. Off-Line Magnetic Tape Unit (1)
7. Printer Control Units (2)
8. Arithmetic Units (2)
9. On-Line Magnetic Tape Units (3)
10. Control Desk and Monitor Printer
11. Paper Tape Punch
12. Paper Tape Reader
13. Off-Line Printer

KDF 9

Impression of complete installation



The KDF 9 *System*

Designed and manufactured by the Data Processing and Control Systems Division of 'ENGLISH ELECTRIC' the KDF9 all-British computing system embodies the wealth of experience of the Company as designers, manufacturers, and users of computer systems for commercial, industrial, and scientific data processing applications. It is a general purpose system intended for general data processing applications and exceptionally fast large scale computation.

The keynote of the KDF9 design is USER CONVENIENCE and the utmost attention has been paid to the economics of its operation. An entirely new modular instruction code provides extreme simplicity of programming, and new standards of economy in the number of instructions and program storage space. In addition, the code facilitates translation from any problem language to an efficient machine program. The computing facilities include fixed or floating-point half-length working to increase effective storage and double-length working for problems demanding high precision.

KDF9 can be equipped with a very wide range of peripheral devices—including those associated with the complementary KDP10 system. There is no practical limit to the total number of devices which can be connected to the system, and any number can operate simultaneously, subject to a maximum theoretical instantaneous transfer rate of 1·33 million alphanumeric characters per second.

Transfers of blocks of data to or from peripheral units operate simultaneously with each other and with operations of the central computer. Up to four independent programs may operate concurrently by sharing the time of the control and arithmetic circuits. A time-smoothing advance control levels out peak demands on the main store and increases the already high speed of the computer by a factor of up to 35%.

The use of solid-state devices and printed circuits ensures maximum reliability, ease of maintenance has received careful attention, and all components are readily accessible. The external appearance, styling, and layout of KDF9 closely follow that of KDP10, and the durable and colourful finish of the cubicles continues the elegant standard established
by the latter equipment.

A printed circuit "flip-flop" board

KDF 9 *Storage Systems*

MAIN INTERNAL STORE.

KDF9 uses a ferrite matrix main store, transistor driven, with a complete cycle time of 6 microseconds. One module of core store contains 4,096 words of 48 binary digits. These may be treated as 4,096 full-length words, 8,192 separately addressable half-length words, 32,768 6-bit alphanumeric characters, or from 8,192 to 24,576 KDF9 instructions.

The store is expansible and up to eight modules may be fitted to the computer, giving a total random access store capacity of 32,768 words. Provision is made in the instruction code for addressing even larger random access stores should this become necessary.

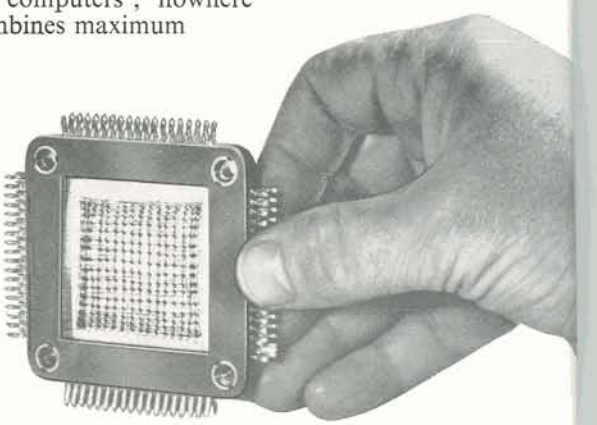
For scientific purposes any one word may be treated as a signed fixed-point number, or a floating-point number with 8-bit characteristic and 40-bit fraction. It may also be treated as a double-length or half-length fixed or floating-point number.

The diagram on page 10 clearly shows the various ways in which the KDF9 word may be used.

NESTING STORES.

KDF9 is the acme of advanced thought and design in electronic computers ; nowhere is this more true than in the design of the nesting store which combines maximum ecomony in programming with maximum operating speed.

A nesting store is, in effect, a series of sixteen registers holding a column of items of data, with the rule that an incoming item joins the column at the top and causes all the items already present to move down one place. Similarly, an item can be transferred out of the column only from the top, and when this happens all the remaining items move up one place.



16-bit Q-store core plane

Nesting Store core plane (24-bits)

Current Operation Nesting Store Most arithmetic and other operations in the KDF9 take place in the current operation nesting store, the operands and the result being stored in the top few locations. The exact number of locations actively concerned varies from one to four depending on the operation being performed.

An important feature of the store is that arithmetic operations and certain functions such as duplication of an operand, reversing the relative position of operands, and erasure, do not require reference to the main store. This feature increases the speed of computation and effects a considerable economy in program instructions. Furthermore, by use of the modular instruction code, instructions can be shorter than hitherto.

NESTING STORES PERMIT EASIER PROGRAMMING, FASTER COMPUTING, AND SHORTER INSTRUCTIONS

Subroutine Jump Nesting Store In addition to the current operation nesting store, there is a nesting store of sixteen 18-bit registers used in entering and leaving subroutines. On entering a subroutine the next instruction location is stored in the top register, the previous contents moving down. On leaving the subroutine, control is transferred to the instruction whose address is in the top location, and the other contents move up. In this way closed subroutines of up to sixteenth order can be handled very simply and subroutines of even higher orders can be conveniently accommodated.

ADDRESS MODIFICATION AND COUNTING (Q-STORES)

There are 15 high-speed addressable registers called Q-stores which may be used for address modifications and counting, in which case they hold three separate 16-bit numbers : a counter, an increment, and a modifier. Each main store transfer instruction specifies a Q-store, the modifier part of which is added to the main address before execution ; the instruction may also specify that after the transfer the increment is added to the modifier and the counter is decreased by one. The three parts of a Q-store are separately addressable and may be used as temporary stores or as accumulators ; thus the assembly of Q-stores may be looked upon as 15 48-bit high-speed stores or accumulators, or as 45 16-bit high-speed stores or accumulators. Data are transferred into a Q-store from the top cell of the nesting store and vice versa.

Q-STORES PERMIT EASIER PROGRAMMING, FASTER COMPUTING, AND SHORTER INSTRUCTIONS

Q-STORE: STORAGE OF 48-BITS

(TOTAL NUMBER OF Q-STORES : 15)

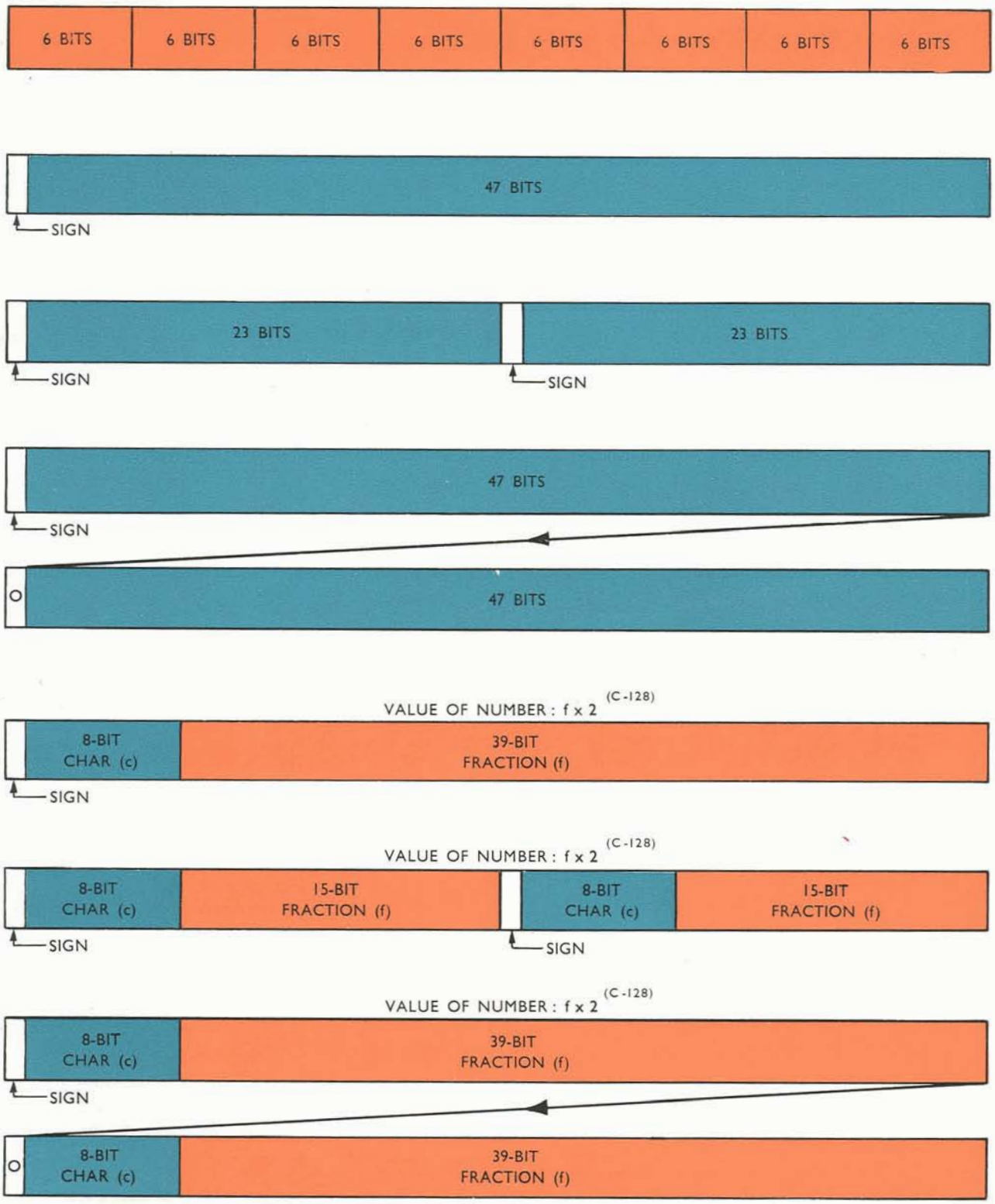
The breakdown of the

THE KDF 9 WORD HAS 48 BITS

IT MAY BE USED AS

- EIGHT 6-BIT ALPHA- NUMERIC CHARACTERS
- ONE 48-BIT FIXED-POINT NUMBER
- TWO HALF-LENGTH FIXED-POINT NUMBERS
- HALF DOUBLE-LENGTH FIXED-POINT NUMBER
- ONE 48-BIT FLOATING-POINT NUMBER
- TWO HALF-LENGTH FLOATING-POINT NUMBERS
- *HALF DOUBLE-LENGTH FLOATING-POINT NUMBER

KDF9 computer word



* CHARACTERISTIC OF LEAST SIGNIFICANT HALF IS 39 LESS THAN THAT OF MOST SIGNIFICANT HALF.

KDF 9

Programming

The KDF9 instruction code achieves remarkable economy in program storage space and clearly reflects the wealth of ' English Electric ' experience in computer programming and automatic programming schemes. Programming is exceptionally easy and the code facilitates translation of programs written in any new or existing psuedocode into an efficient machine program. This is a valuable feature of considerable importance to potential users who have large capital assets in existing programs compiled for earlier and slower machines.

MODULAR INSTRUCTION CODE.

The instruction format is based on the novel concept of a modular or variable-length instruction word, each instruction occupying only sufficient digits to specify the operation concerned. To achieve this the word is divided into six " syllables " of eight bits each, and an instruction may occupy one, two, or three syllables.

Instructions to fetch or store numbers in the main store use three syllables and this is sufficient to specify the address of any location, and how the address is to be modified. In addition to main store transfers the instructions cover conditional or unconditional jump operations.

The majority of instructions, however, need only one syllable and cover the operations in the nesting store. They include all arithmetic and logical operations and also certain special operations for manipulating and rearranging the top four items of data in the nesting store. *This results in striking economy of storage space for a given program.*

The two-syllable instructions specify various ranges of operations including peripheral transfers, transfers to or from Q-stores, shifting and manipulating data stored more than one item to a word, and indirect addressing of the main store (including half-length transfers).

RANGE OF INSTRUCTIONS

Main Store Transfers Transfers between the main store and nesting store may be on full-length or half-length words. In half-length working every half-word of the main store is separately addressable. Half-length working is particularly valuable when low precision working is acceptable as it doubles the effective size of the main store.

Arithmetic Operations A comprehensive list of arithmetic operations is available ; these include a variety of single, double, and mixed-length operations on both fixed and floating-point numbers, and a generous supply of manipulative and discrimination instructions. There are facilities for conversion between binary and any single-word mixed-radix representation in 6-bit characters that are particularly valuable for data processing work.

Peripheral Transfers A transfer of data between the main store and a peripheral device is initiated by an instruction which merely specifies the main store location, the identity of the peripheral unit, the number of words to be transferred, and the operation to be performed. The transfer then takes place autonomously and proceeds in parallel with internal or other external operations.

INTERLOCKS

There are full interlocks on the instructions which transfer data so that the programmer has no problem in timing such transfers. The appropriate area of the main store remains inaccessible to any other operation until completion of the transfer and all automatic checks within a block. On a computer not equipped with time-sharing facilities the user may have several peripheral devices working simultaneously, each with its own area of core store securely interlocked. The interlocks allow all other operations in the computer to proceed, provided only that they do not make reference to the interlocked area. If so, then a hold-up occurs until the peripheral transfer is cleared.

If the computer is equipped with time-sharing facilities (described in next section), instead of a hold-up occurring an alternative lower priority program will be entered and obeyed while data transfers are taking place. Thus time is utilised which, on a conventional machine, would be lost during interlock periods.

KDF 9

Control Systems

The KDF9 system provides for a combination of units which will meet the widest possible range of requirements. In consequence, alternative main control units are available : Conventional, in which operations proceed in normal sequence (apart from the autonomous operation of peripheral transfers already described), Time-Sharing, and Time-Smoothing Advance Control.

TIME-SHARING

The system can handle up to four completely independent programs at one time, each program being given a priority rating by the operator. Each program is allocated its own *required* area of the main store and set of peripheral devices, the program designated as the highest priority proceeding uninterrupted until some delaying condition arises. For example, data may be required from a magnetic tape unit and no further work can be carried out until the required block has been read into the main store. In these circumstances interruption takes place and work on this program lapses. A second-priority program is then started and continues until it, too, is delayed or the first-priority program is ready to continue.

Comprehensive automatic interlocks are provided to prevent any possibility of inadvertent interference between programs, and both commercial and scientific programs can be performed concurrently if desired. If a program attempts to use equipment not allocated to it, it is interrupted, a failure message printed, and control is transferred to another program.

The allocation of equipment to programs, program interruptions, and failure indications, is handled by a stored supervisory routine.

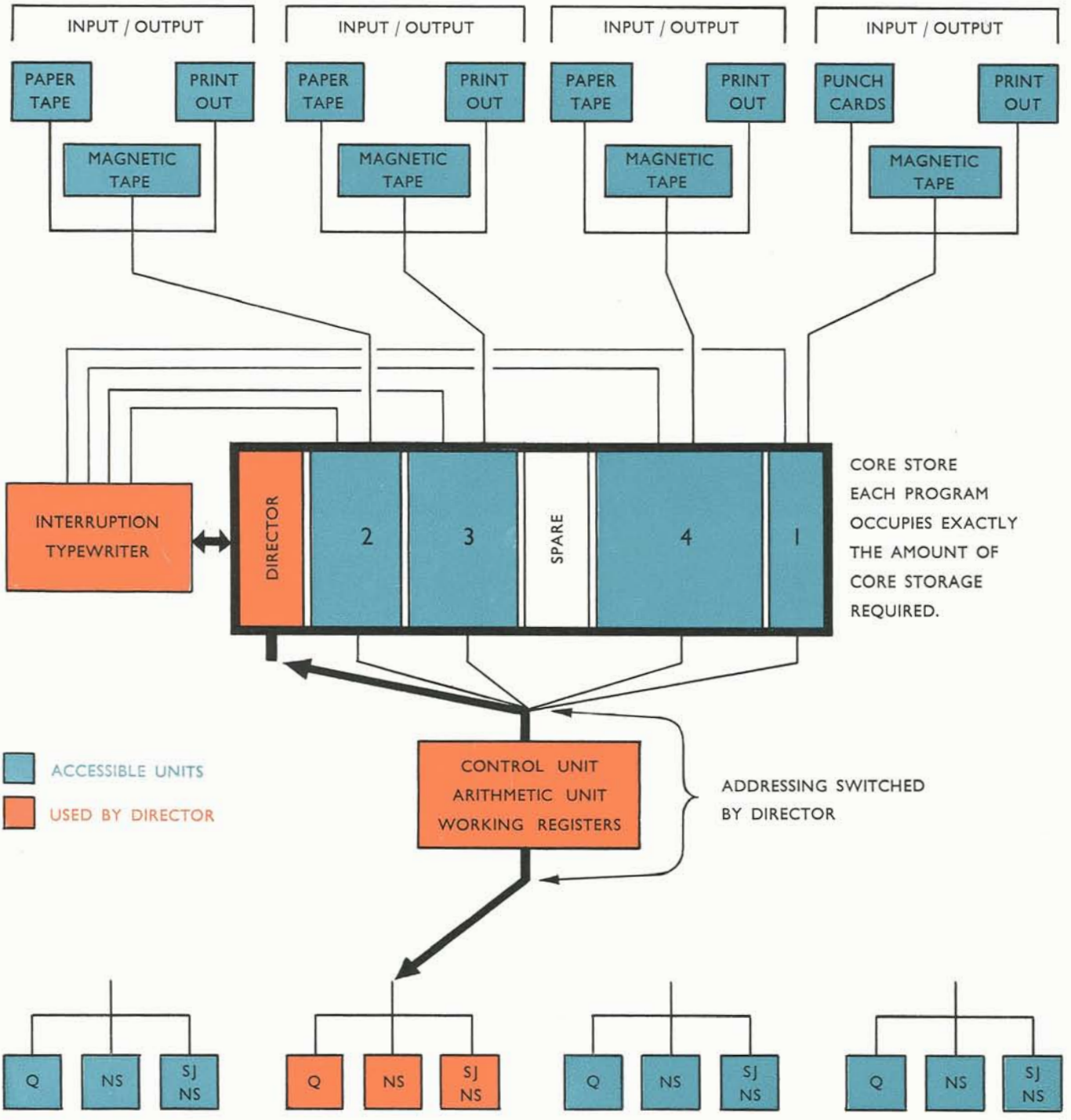
The diagram opposite depicts a typical time-sharing system, but showing only a " token " set of peripheral devices per program. It also indicates that the four areas of core storage are varied in size to suit the actual program length, thus allowing considerable flexibility in the storage of programs.

TIME-SMOOTHING ADVANCE CONTROL

A further available feature is the time-smoothing advance control, the function of which is to level out peak demands on the main storage and on arithmetic operations. By anticipating future requirements for data from the main store, and by allowing other operations to proceed during the transfer of data into the main store, the already high speed of the computer may be increased by a factor of up to 35%. No additional programming is required ; programs written for any alternative control unit can be used without alteration.

The **KDF9** *Time-sharing system*

(DIRECTOR IN CONTROL - SWITCHING BETWEEN PRIORITIES)



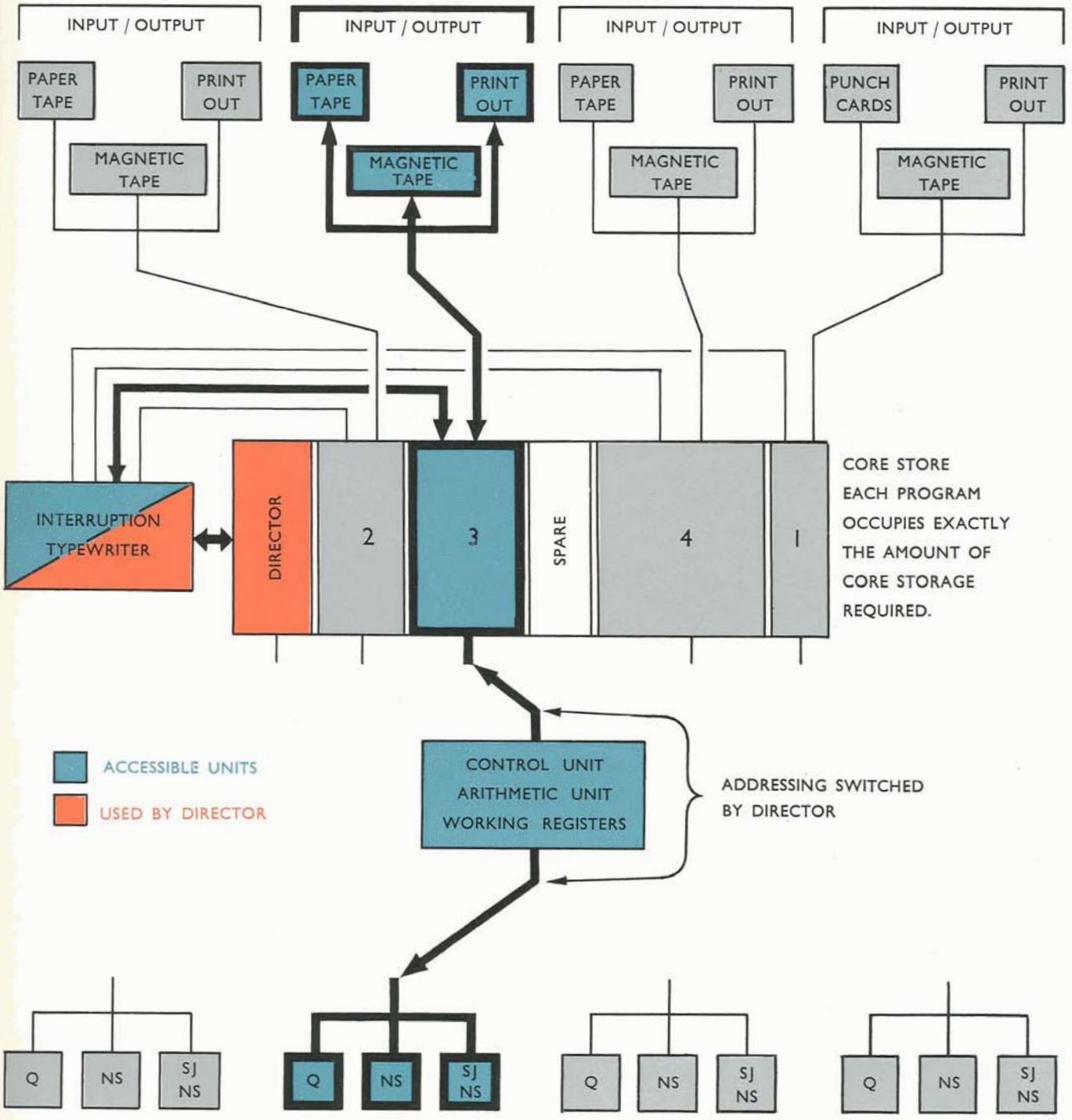
Q = Q-STORE (ADDRESS MODIFICATION AND COUNTING)

NS = CURRENT OPERATIONS NESTING STORE

SJNS = SUBROUTINE JUMP NESTING STORE

The **KDF9** *Time-sharing system*

(PROGRAM OPERATING)



Q = Q-STORE (ADDRESS MODIFICATION AND COUNTING)

NS = CURRENT OPERATIONS NESTING STORE

SJNS = SUBROUTINE JUMP NESTING STORE

KDF 9

Operating Speed

The design philosophy of KDF9 calls for an extremely high operating speed and typical speeds of arithmetic operations are :

Addition or Subtraction (fixed-point)	1 microsecond
(floating-point)	6 to 10 microseconds
Multiplication (fixed-point or floating-point)	14 to 18 microseconds
Division (fixed-point or floating-point)	30 to 35 microseconds
Mixed Radix Conversion (to or from binary) (dependent on word make-up)	50 to 150 microseconds
Shifts (up to 48 binary places)	1 to 4 microseconds

The computer is even faster than these times indicate because :

(*a*) Facilities for instruction modification and counting are particularly good.

(*b*) The time-smoothing advance control saves considerable time in most programs by anticipating " fetch " instructions.

(*c*) The programs are so compact that considerable time is saved in fetching instructions to be obeyed.

(*d*) The nesting store greatly reduces the frequency of access to the main store.

Thus the inner loop of matrix multiplication, which calls for access to two (modified) addresses in the main store, the multiplication of two floating-point numbers to give a double-length floating-point result, the accumulation of the result in a double-length floating point accumulator, and testing for the end of the row, takes less than 50 microseconds. Using the time-smoothing advance control this time is further reduced without the need for any alterations to the program.

COMMERCIAL OPERATIONS.

A sorting program that occupies only 35 words has been made for KDF9. In an example with 2,000 items of variable length, whose average length is four words per item, the time taken to sort into numerical sequence from random order by the standard two-way merge process is less than three seconds.

KDF9 is very suitable for production and stock control problems, and its high operating speed enables management in large and complex organisations to exercise the same tight control that hitherto was possible only in the " one man " business.

In stock control problems a forecast* for next week's usage of a particular item may be made from smoothed historical data of actual usage and its trend, by application of the formula :

$$f_{t+1} = \alpha Y_t + (1 - \alpha)\left[f_t \frac{b_{t-1}}{\alpha}\right] + \frac{b_t}{\alpha}$$

where :

f = week's forecast usage.
Y = last week's actual usage.
b = trend of usage.
t = subscript representing applicable week number.
α = smoothing constant.

The evaluation is done by a KDF9 routine which uses only six words of storage space and takes only 155 microseconds.

TYPICAL COMPUTATION TIMES

The calculation of the expression :

$$\frac{a\,(a^3\,b^2 + 1)}{b + 2c^2\,d^2}$$

where a, b, c, and d are fixed or floating-point numbers stored in successive store locations, takes less than 180 microseconds by a program occupying only five words (including fetches). This time is reduced if the time-smoothing advance control is used.

The diagram on page 18 shows the step-by-step nesting store functions and locations occupied during the calculation of the above expression. The variable-length instruction code is also depicted, from which it will be noted that the fourth three-syllable " fetch " actually runs from one word to the next.

A simultaneous linear equations routine occupies only 36 words of instructions and, using the method of successive elimination with interchanges, solves 100 equations in 15 seconds without advance control. With advance control this speed may be increased by a factor of up to 35%.

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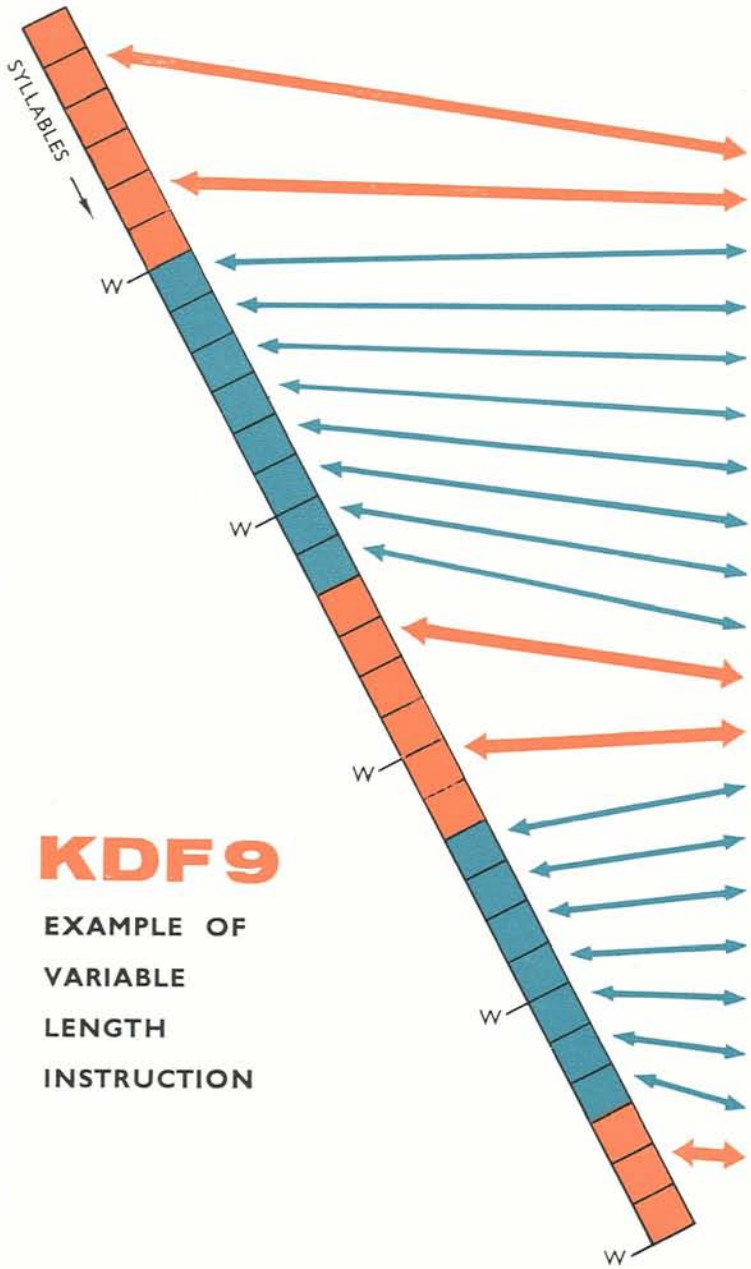
* Ref: "Statistical Forecasting for Inventory Control" — R. G. Brown

Use of **KDF 9** *instruction code to evaluate* $\frac{a(a^3b^2+1)}{b+2c^2d^2}$



KDF 9

EXAMPLE OF VARIABLE LENGTH INSTRUCTION

OPERATION	N1	N2	N3	N4	N5
FETCH ..	b	—	—	—	—
FETCH ..	a	b	—	—	—
DOUBLE DUP.	a	b	a	b	—
DUPLICATE ..	a	a	b	a	b
MULTIPLY ..	a^2	b	a	b	—
MULTIPLY ..	a^2 b	a	b	—	—
DUPLICATE ..	a^2 b	a^2 b	a	b	—
MULTIPLY ..	a^4 b^2	a	b	—	—
ADD ..	a^4 b^2+a	b	—	—	—
REVERSE ..	b	NUM	—	—	—
FETCH d ..	d	b	NUM	—	—
FETCH c ..	c	d	b	NUM	—
MULTIPLY ..	cd	b	NUM	—	—
DUPLICATE ..	cd	cd	b	NUM	—
MULTIPLY ..	c^2 d^2	b	NUM	—	—
DUPLICATE ..	c^2 d^2	c^2 d^2	b	NUM	—
ADD ..	$2c^2$ d^2	b	NUM	—	—
ADD ..	DENOM	NUM	—	—	—
DIVIDE ..	$\frac{\text{NUM}}{\text{DENOM}}$	—	—	—	—
STORE ..	—	—	—	—	—

TOTAL WORDS (W): 5

Main Store Instruction

TOTAL SYLLABLES : 30

Nesting Store Instruction

KDF 9

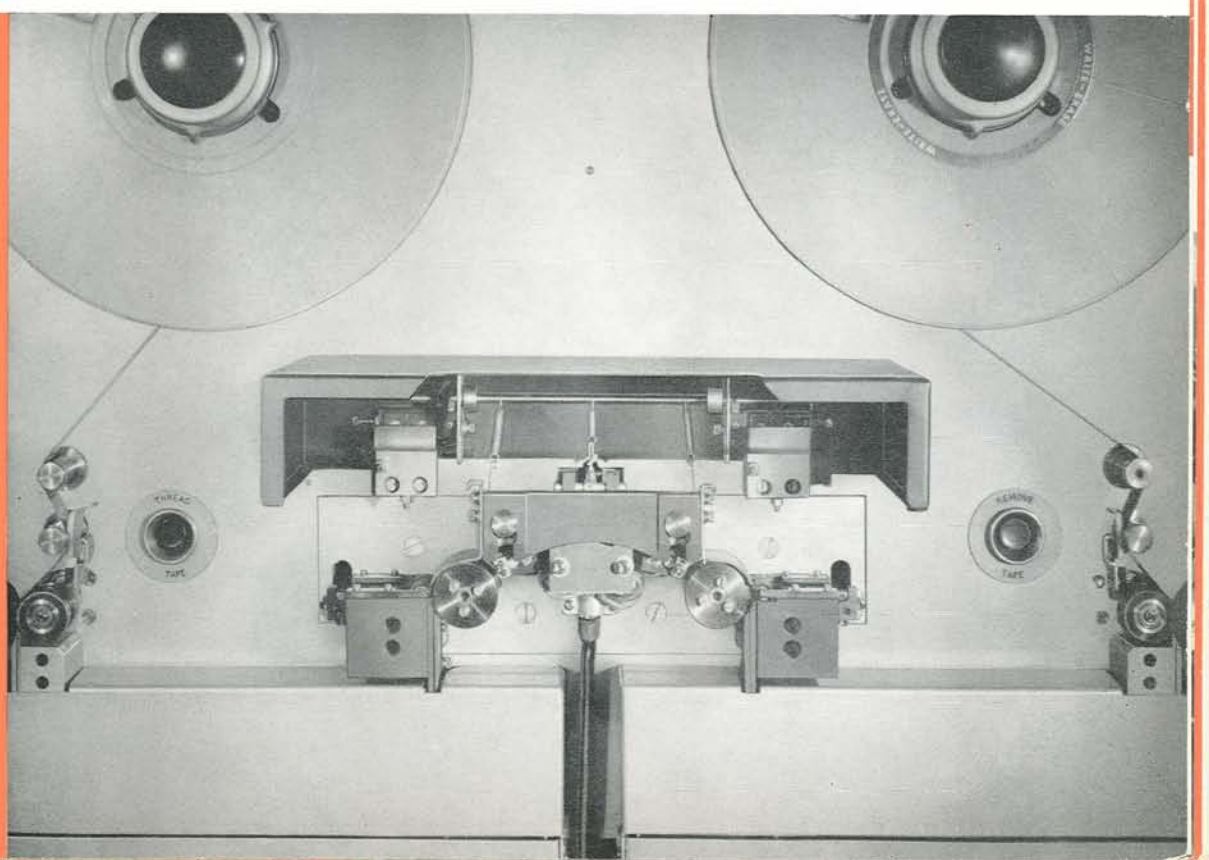
Peripheral Devices

A very comprehensive range of peripheral devices is available for use with KDF9. In addition to the 'English Electric' high speed paper tape reader, the devices include the high performance magnetic tape units, high speed line printers, and card readers and card punches of the 'English Electric' KDP10 Data Processing System. The KDP10 range of off-line transcribers may also be used with KDF9.

ALL THESE DEVICES HAVE BEEN TESTED AND PROVEN IN SERVICE

There is no practical limit to the total number of peripheral devices which can be connected into the system, and any number can operate simultaneously, subject to a maximum theoretical total instantaneous transfer rate of 1·33 million characters per second.

The channels of communication with the peripheral equipment have been designed to allow easy addition of existing devices or any further devices which may be developed in the future.



The Reading and Recording Head of the Magnetic Tape Unit.

MAGNETIC TAPE UNITS

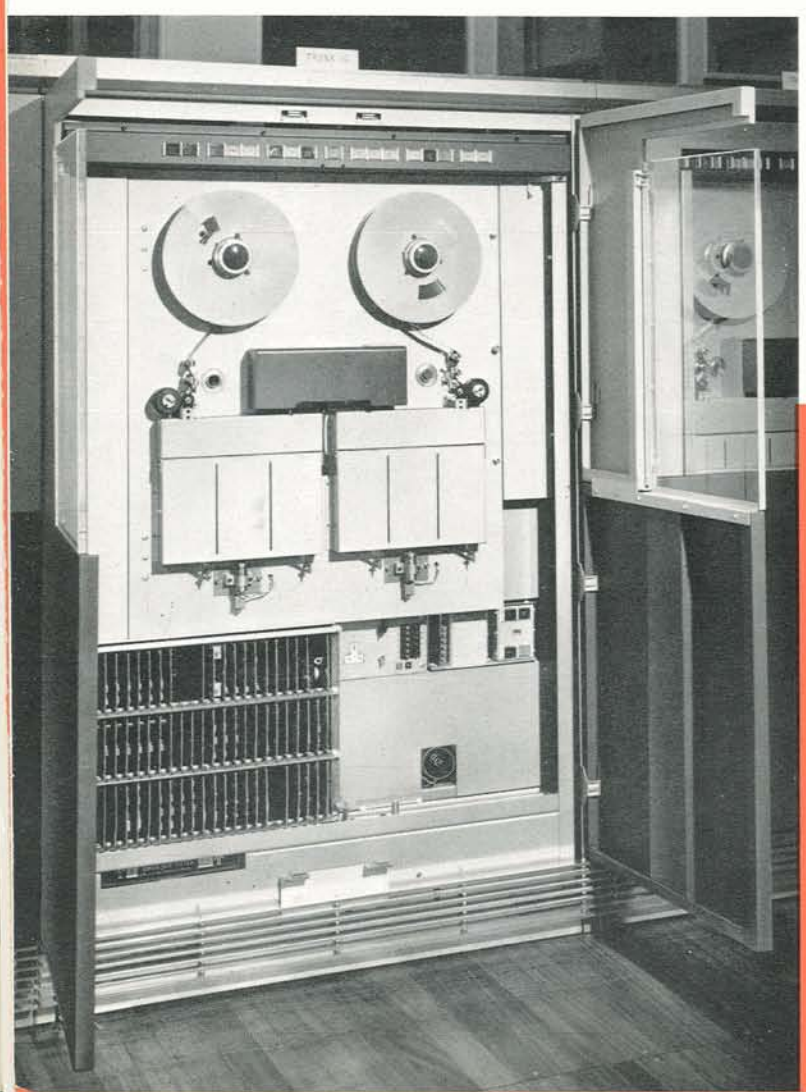
The magnetic tape units—already fully proven in the KDP10 system—are designed to provide the maximum accuracy and reliability in operation, and special attention has been given to safeguards against flaws or errors. Each unit is fully transistorised and is used for reading, writing, and erasing characters on magnetic tape in response to applied control signals. Reading is possible in the forward or reverse direction ; writing and erasing are possible only in the forward direction.

The magnetic tape is $\frac{3}{4}$ in. wide and contains 16 recording channels. Information is recorded simultaneously across eight channels and duplicated on the other eight channels. In each group six channels are for information, one for parity, and one for timing.

When data are read from one set of channels the signal received is merged with the signal from the adjacent set and a correct output is obtained even if a bit from one channel is completely missing. This ensures protection against " drop-outs " due to dust particles or small local imperfections in the tape. The accuracy of information read from the tape is further ensured by means of a parity check.

The high performance of the tape unit is founded upon a recording density of 333·3 characters per inch, a start/stop time of 2·5 milliseconds, and very short inter-block gaps of 0·5 in average.

The magnetic tape units have a reading or writing rate of 33,333 characters per second. Tape units of similar characteristics but operating at the rate of 66,666 characters per second will shortly be available. The increase in transfer rate is achieved without sacrifice of start/stop time or interblock gap length.



A magnetic tape unit showing tape-feed and plug-in control circuits

PAPER TAPE PUNCH

KDF9 is equipped with a medium-speed paper tape punch which normally perforates one-inch tape in an eight-channel even-parity binary code. In response to multiwire electrical impulses the punch fully perforates paper tape at the rate of 110 characters per second. An eight-inch diameter reel holds 1,000 feet of tape. By suitable output subroutine, tape may be punched in any code on any of the standard widths of tape.

An alternative punch operating at 300 characters per second will shortly be available.

HIGH-SPEED PAPER TAPE READER

The paper tape reader used with KDF9 is a standard 'English Electric' model which has been completely proved in service in numerous installations. Tape can be read continuously at the rate of 1,000 characters per second. An outstanding feature of the tape reader is its ability to stop from full speed in 0·5 millisecond, thus allowing the tape to stop *without overrunning the next character*. The reader can be started and stopped up to 50 times per second.

In KDF9 the tape reader normally accepts one-inch eight-channel even-parity tape. A signal is also provided from the feed hole of the tape for clocking purposes. The photo-transistors sensing the paper tape are temperature-compensated by means of thermistors to ensure trouble-free operation.

The reader is equipped with a magazine which will hold up to 300 feet of paper tape or alternatively handle a closed loop of tape up to 100 feet in length. Reels holding up to 1,000 feet of tape can be used on the unit, the tape feeding into any suitable container. The tape magazine is detachable and extra magazines can be used to facilitate rapid changeover of tapes.

The reader can be instantaneously adjusted to handle all other standard tape widths and suitable input routines allow any code to be handled.

The illustration shows the location of the tape-reel and containment of the tape in the magazine.

HIGH SPEED ON-LINE PRINTER

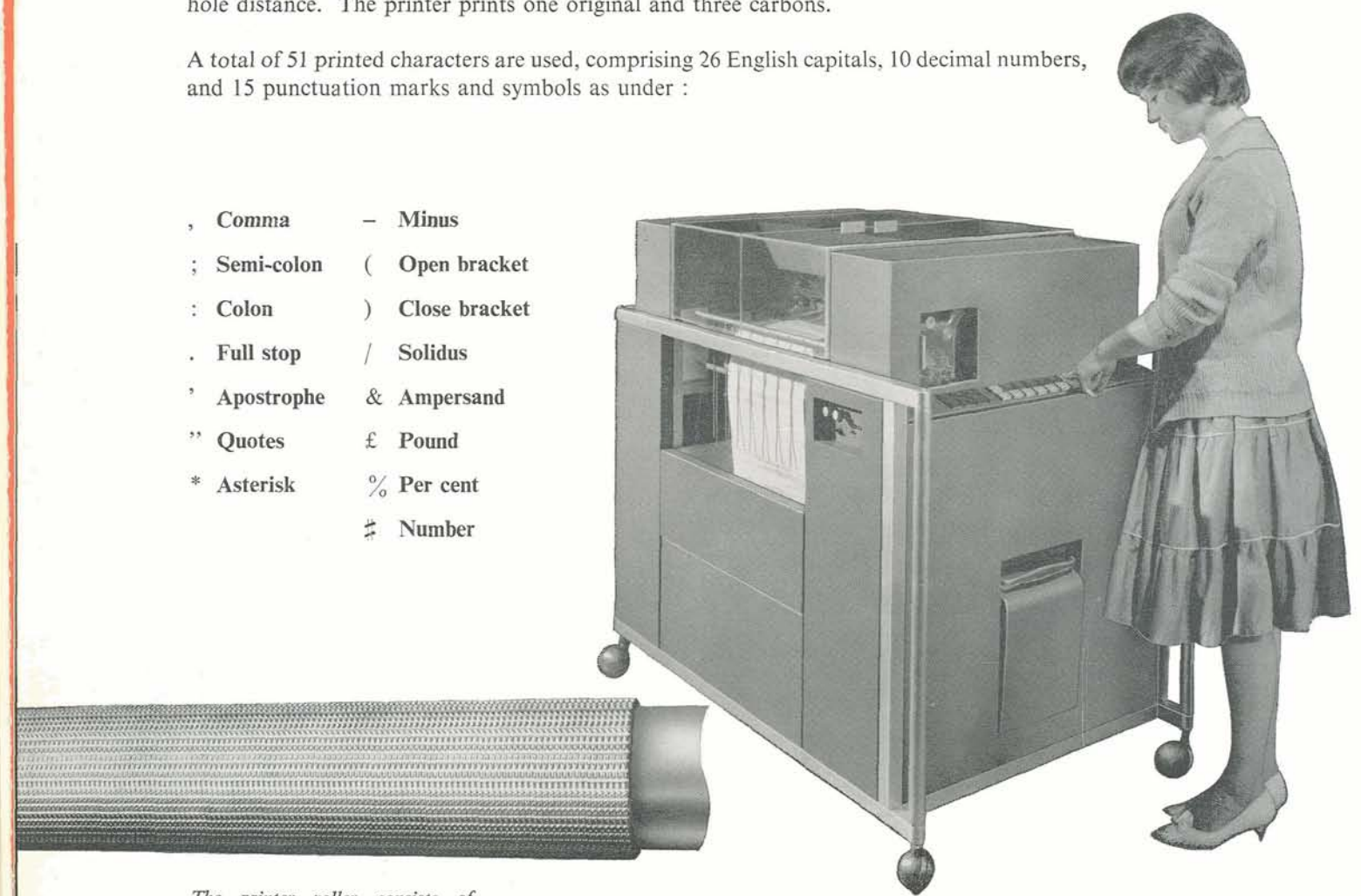
The on-line printer is electrically connected to the computer and prepares output documents at high speed. The printing format is controlled by the computer, either directly or through a punched tape loop in the printer unit. The printer is fully transistorised.

The input rate and the line printing rate are determined by the computer. The printer output is 600 lines per minute, printing single-spaced copy on continuous edge-perforated blank or pre-printed forms with a maximum of 120 characters per line. The vertical alignment within a horizontal line is better than plus or minus ·008 in. per single copy.

The paper stock is single or multiple sheet fanfold and may be from 3 in. to 22 in. wide and up to 17 in. sheet length, providing the length is a multiple of the standard $\frac{1}{2}$ in. sprocket-hole distance. The printer prints one original and three carbons.

A total of 51 printed characters are used, comprising 26 English capitals, 10 decimal numbers, and 15 punctuation marks and symbols as under :

,	**Comma**	–	**Minus**
;	**Semi-colon**	(	**Open bracket**
:	**Colon**	)	**Close bracket**
.	**Full stop**	/	**Solidus**
'	**Apostrophe**	&	**Ampersand**
"	**Quotes**	£	**Pound**
*	**Asterisk**	%	**Per cent**
		#	**Number**



The printer roller consists of 120 axially mounted rings each having 51 printed characters around its periphery.

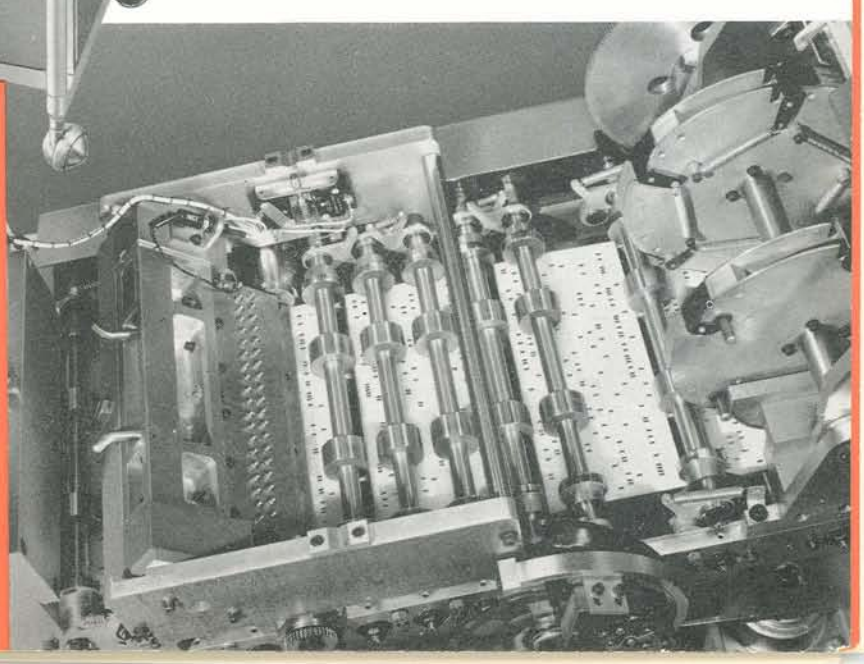
INTERRUPTION TYPEWRITER

The interruption typewriter is an on-line device, similar to an electric typewriter, which prints on paper from data received directly from the computer store. It is mainly used for two-way communication between the computer and the operator. The interruption typewriter can be used as a monitor printer printing at a rate of ten characters per second, and as a keyboard input in conjunction with an attached edge-punched card reader for controlling the course of a computation. An integral punch produces seven-hole punched paper tape simultaneously with the printed output.

PUNCHED CARD EQUIPMENT

Card readers and punches are available, operating at 400 and 150 cards per minute respectively. The equipments incorporate comprehensive checking arrangements. In reading, each row of a card is read twice and the readings compared ; in punching, each row is read immediately after punching and compared with the data intended to be punched.

(above) Inserting cards in the delivery chute of the card reader.



(right) The feed mechanism of the card reader.

Off-line Operations

As the main computer represents a substantial part of the capital cost of an installation, the use of off-line equipment can be of great economic importance. The transfer of input and output operations to off-line working using magnetic tape releases the computer from major time-consuming operations, and ensures that the fullest economic use of high operating speed is obtained. This is particularly important if time-sharing facilities are not available.

If desired, printing may be carried out at a distance from the main computer. For example, printing equipment may be installed at a centre many miles from the computer and the magnetic tape reels containing the output sent by post from the computing centre to the printing centre. One reel of magnetic tape is capable of producing up to six hours' continuous printed output, representing 220,000 to 320,000 lines of print.

The tried and tested off-line transcribers developed for KDP10 may be used with KDF9 ; these include transcription from punched cards to magnetic tape and vice versa, and from magnetic tape to the printers described in the following paragraphs. All transcribers have comprehensive editing facilities.

HIGH SPEED OFF-LINE PRINTER.

A printer similar to the on-line printer may be used for simultaneous off-line operation, in which case it accepts coded data from magnetic tape on a separate magnetic tape unit. The printing format is controlled by a plug-board or by a punched tape loop in the printer unit. Operation in the " select mode " enables up to 15 different types of print format to be produced from the same reel of magnetic tape.

The input is accepted from the magnetic tape unit at the rate of 33,333 characters per second, in bursts of one line. The printing output rates and alignment are the same as for the on-line printer.

Because of the asynchronous nature of the operation, numeric data are printed at the rate of 900 lines per minute and the output speed will always lie between 600 and 900 l.p.m. depending upon the ratio of alphabetical to numerical content of the data.

The off-line printer uses the same 51 printed characters as the on-line printer and also the same paper stock.

XERONIC PRINTER.

An off-line Xeronic printer receiving its input from magnetic tape may also be used. The printer prints up to 3,000 lines per minute printing either two columns (128 characters per column line) or four columns (64 characters per column line), the line spacing being six lines per inch. A standard form layout, selected from up to 20 alternatives, can be printed on blank paper simultaneously with the data.

KDF 9

User Services

'English Electric', drawing on their vast experience of generating, maintaining, and publishing a comprehensive library of routines for DEUCE, has established a comprehensive user and programming service for KDF9. This is an essential adjunct to a machine of this speed and power.

All KDF9 users are entitled to the full facilities of the programming service, which is based on the highly successful Deuce Programming Service, probably the most comprehensive in the world, over 600 programs and 350 subroutines having been published. 'English Electric' will supply full details of a wide range of standard programs for KDF9, a comprehensive library of subroutines, news bulletins of progamming techniques, and a set of test routines. All KDF9 owners will be encouraged to share in this valuable work by providing as much programming information as possible for publication in the library. In addition, the use of KDF9 within the English Electric Group of Companies in the fields of electrical and mechanical engineering, will give rise to further extensions to the library. In order to gain the maximum advantage from the services, a user exchange and liaison system will be established on the general lines of the extremely successful Deuce Users' Association.

KDF9 is extremely easy to program, but nevertheless a wide range of automatic programming schemes is available. In particular, there are efficient versions of ALGOL and other scientific and commercial autocodes which will appeal to all who wish to use programs written and tested on other machines. Such programs may be accepted directly by KDF9. In addition, an extremely powerful matrix scheme is being prepared so that all problems which can be expressed in matrix notation can be programmed as easily as the matrix equations can be written.

The requirements of the small organisations have not been overlooked—they will be able to enjoy the full facilities of the 'English Electric' KDF9 Time-Hire Computing Service. The service includes a full system and program consultancy organisation and a speedy postal service (in most cases " by return ").

Technical Synopsis

GENERAL

Binary Parallel Computer—Transistor Circuits
Autonomous operation of peripheral transfers
Time-sharing between up to four independent programs
Time-smoothing advance control
Power supply : 200 to 250V 50 c/s single-phase

WORD SYSTEM

Word Length	48 Binary Digits
Capacity	8 6-bit alphanumeric characters
	1 Fixed-point 48-bit number
	2 Separately-addressable 24-bit numbers
	½ Double-length fixed-point number
	1 Floating-point number with 8-bit characteristic and 40-bit fraction
	½ Double-length floating-point number
Instruction (Modular)	One, two, or three 8-bit syllables (two to six instructions per word)

INTERNAL STORAGE

Ferrite matrix store module—Capacity 4,096 48-bit words. Up to eight modules—capacity 32,768 words—may be fitted.

Cycle time : 6 microseconds
Rapid access nesting store for arithmetic operations
Rapid access nesting store for subroutine control
Rapid access Q-store of 15 special 48-bit registers

OPERATING SPEEDS

Addition or Subtraction (fixed-point)	1 μS
(floating-point)	6 to 10 μS
Multiplication (fixed or floating-point)	14 to 18 μS
Division (fixed or floating-point)	30 to 35 μS
Mixed Radix Conversion (to or from binary) (dependent on word make-up)	50 to 150 μS
Shifts (up to 48 binary places)	1 to 4 μS
Maximum theoretical total transfer rate (to or from peripheral devices)	1·33 million char./sec.

INPUT/OUTPUT EQUIPMENT.

Magnetic Tape Units	33,333 char./sec.
	or 66,666 char./sec.
Paper Tape Reader (1 in. tape)	1,000 char./sec.
Medium speed on-line paper tape punch (1 in. tape)	110 char./sec.
	or 300 char./sec.
High speed Line Printers	600-900 lines/min. (120 char./line)
Xeronic Printer (off-line)	3,000 lines/min.
Interruption Typewriter	10 char./sec.
Card reader	400 cards/min.
Card punch	150 cards/min.

CONSTRUCTIONAL

Unit	*Height*	*Length*	*Depth*	*Weight*
Control desk with interruption typewriter	2 ft. 6 in. (*0·76 m.*)	6 ft. 0 in. (*1·83 m.*)	2 ft. 9 in. (*0·84 m.*)	300 lb. (*136 kg.*)
*Main store and input/output control unit	5 ft. 9 in. (*1·75 m.*)	18 ft. 4 in. (*5·59 m.*)	1 ft. 7 in. (*0·48 m.*)	3,500 lb. (*1,587 kg.*)
*Arithmetic and main control unit	5 ft. 9 in. (*1·75 m.*)	18 ft. 4 in. (*5·59 m.*)	1 ft. 7 in. (*0·48 m.*)	3,500 lb. (*1,587 kg.*)
Power supply unit	5 ft. 9 in. (*1·75 m.*)	7 ft. 4 in. (*2·24 m.*)	1 ft. 7 in. (*0·48 m.*)	3,000 lb. (*1,360 kg.*)
Paper tape reader	4 ft. 9 in. (*1·45 m.*)	2 ft. 7 in. (*0·79 m.*)	1 ft. 8 in. (*0·51 m.*)	280 lb. (*127 kg.*)
Paper tape punch	On control desk or separate table			27 lb. (*12 kg.*)
Card reader	3 ft. 9 in. (*1·14 m.*)	4 ft. 0 in. (*1·22 m.*)	2 ft. 6 in. (*0·76 m.*)	500 lb. (*227 kg.*)
Card punch	3 ft. 9 in. (*1·14 m.*)	4 ft. 0 in. (*1·22 m.*)	2 ft. 6 in. (*0·76 m.*)	400 lb. (*181 kg.*)
Line printer	3 ft. 9 in. (*1·14 m.*)	3 ft. 9 in. (*1·14 m.*)	2 ft. 6 in. (*0·76 m.*)	500 lb. (*227 kg.*)
Printer control	5 ft. 9 in. (*1·75 m.*)	7 ft. 4 in. (*2·24 m.*)	1 ft. 7 in. (*0·48 m.*)	600 lb. (*272 kg.*)
Magnetic Tape Unit	5 ft. 9 in. (*1·75 m.*)	3 ft. 8 in. (*1·12 m.*)	1 ft. 7 in. (*0·48 m.*)	900 lb. (*408 kg.*)

POWER REQUIREMENTS

All units	200 to 250V 50 c/s single-phase
Control desk with interruption typewriter	—
*Main stores with input/output control unit	2·4 kW
*Arithmetic and main control unit	1·7 kW
Power supply unit	1·6 kW
Magnetic Tape Unit	1·5 kW
Paper tape reader	0·5 kW
Paper tape punch	0·1 kW
Card reader	1·9 kW
Card punch	1·5 kW
Line printer	3·2 kW

* Figures relate to a typical installation having a 16,384 word main store, time-sharing control, and a total of eight input/output devices.

After Sales Service

'English Electric' were among the pioneers of computer maintenance service in this country, and are able to remove completely from the user the onus of responsibility for the maintenance of a system. Proposals can be put forward by our Service Department to cover combinations of the following features :

1. Comprehensive service by resident engineers covering one, two, or three shifts of operation for up to seven days per week, or non-standard timetable to cover specific demanded cases.
2. The provision of a backing service of skilled electronic and mechanical engineers to ensure, by regular inspection, the maintenance of the equipment to a highly efficient standard, particularly the mechanical parts of peripheral equipment.
3. The provision of reserve items of peripheral equipment, held at base, such as tape stations and line printers, thus covering cases of an accident or major breakdown at a Customer's site.
4. The provision of initial spares and test gear either as an initial capital investment, or as part of an annual service charge.
5. A comprehensive annual service charge or, alternatively an annual service charge based on replacement at the Customer's expense of certain parts subject to wear (magnetic tape unit recording heads, print rolls and hammers), should this be deemed necessary subsequent to the first three shift years of operation.
6. In circumstances in which the Customer desires to provide his own first line maintenance, the provision of services as detailed in (2) above.

The KDF9 Computer Service can be as comprehensive as you wish — and your expenditure can be accurately budgeted.

Note: The Company's policy is one of continuous development and improvement of its products and, therefore, the right is reserved to supply products which may differ slightly from those described and illustrated in this publication.

The 'ENGLISH ELECTRIC' *KDF9 Data Processing System*

The preceding pages will have shown that KDF9 is the most advanced digital computing system yet devised. Nevertheless, it is worthwhile repeating some of the more important features, and these are listed below :

- Extremely fast operating speed
- Simple and economical programming
- Ease of translation from any psuedocode to an efficient machine program
- Time-sharing between up to four independent programs
- Comprehensive range of fast and flexible peripheral devices
- Simultaneous operation of peripheral transfers up to a maximum theoretical total transfer rate of 1.33 million 6-bit characters per second
- Wide range of strictly designed arithmetic operations, single, double, and half-length, fixed and floating-point
- Main store size and number of peripheral units easily expansible to suit work load
- Design and construction techniques based on maximum reliability and ease of maintenance

For further information write to :

'ENGLISH ELECTRIC'

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