CHAPTER III

ANALYSIS AND TRENDS

ANALYSIS AND TRENDS

INTRODUCTION

The information for each of the 103 systems described in Chapter II has been subdivided into eighteen topics, permitting the data to be presented in an organized manner and simplifying the comparison of features of the different systems. The following paragraphs, paralleling the subdivisions of the systems descriptions of Chapter II, present a quantitative analysis of the data and show recent trends in the field of computing machinery. It is emphasized again that the information given in Tables II through XV in this Chapter is to be used with caution. The tables have been constructed only to show trends, permit comparison of systems and show the present state of the art. Information pertaining to a specific system should be obtained from the system description in Chapter II.

DESIGNATION OF COMPUTING SYSTEMS

The names of various types of computing systems existing in the United States stem from different sources. It would have been convenient if some system of classification and standard nomenclature had been established many years ago. The nomenclature could have incorporated the name of the manufacturer and model number, the nature or application of the system, and the name or location of the operating agency. However, a system of nomenclature was not established, resulting in an odd mixture of names for computing systems. Many computing systems bear the name of the manufacturing organization, for example IBM 704, LITTON 20, NCR 304, and ILLIAC. The names of some machines indicate the nature or purpose of the system, for example DATATRON, DATAMATIC 1000, EDVAC, and LGP 30. Other machine titles indicate the name of the operating agency, such as DYSEAC, SEAC, NORC, OARAC, ORACLE and ORDVAC. Some titles are indicative of the location of the system, such as FLAC and LARC. The names of some machines are trade names like UNIVAC II and ELECOM 125. There are some machines named after specific persons, as are ALWAC 800 and JOHNNIAC. Arbitrary names, like GEORGE, also exist. Perhaps the only trend in computing machine nomenclature has been to develop names which were contractions or pronouncable abbreviations of significant titles. Examples of this are EDVAC, for Electronic Discrete Variable Automatic Computer; MANIAC, for Mathematical Analyzer And Numerical Integrator and Computer; and ORDVAC, for ORDnance Variable Automatic Computer. In connection with this, the suffix AC usually means Automatic Computer.

MANUFACTURERS OF COMPUTING SYSTEMS

In the interest of national defense, the development of electronic computing systems could not wait until normal economic laws brought about the supply of systems based solely upon commercial demand. The Department of Defense supported research and development in the field of electronic digital computers to be utilized for rapid scientific computation on defense projects.

The original electronic digital computer, the ENIAC, designed and developed by the Moore School of Electrical Engineering of the University of Pennsylvania, for the Ballistic Research Laboratories was placed in operation at the Aberdeen Proving Ground in January 1947. Many early electronic machines were manufactured at educational institutions such as the Institute for Advanced Study, MIT, Harvard and the Universities of Pennsylvania and California. Parallel research was performed by industry, and by 1950, large scale digital electronic computers were being delivered commercially. At the present time mass production of large scale systems is well underway. Several hundred large scale systems of various types have been mass produced, and thousands are on order. Table I shows the manufacturers of all the machines described in Chapter II and Table II shows the quantities of these systems which have been produced.

APPLICATIONS OF COMPUTING SYSTEMS

The installation of the ENIAC, at the Ballistic Research Laboratories of the U. S. Army Ordnance Corps marked the beginning of the widespread use of electronic computing machines. Since the advent of the ENIAC, a large expansion has taken place in the computer field. Investment rates in computing equipment in the United States have risen from ten million dollars per year in 1953 to one hundred million dollars per year in 1956. It is anticipated that expenditures for computing equipment will pass the one billion dollars per year mark within the next few years.

Almost every commodity industry such as oil, steel and rubber is utilizing computing equipment for both scientific and commercial applications. Service industries, such as banking, transportation, and insurance have applied large scale systems toward the solution of problems in the fields of accounting, reservations control, and bookkeeping. Manufacturers have used computing systems for design engineering and scientific research. Many systems are being utilized for inventory and stock control. The determination of manufacturing plant location and stock parts storage are being made by linear programming methods. Electronic computers are being utilized by the construction industry for design and location of structures and road nets.

Many problems require the processing of large quantities of data, such as is obtained from missile tracking, telemetering, mineral deposit prospecting and record keeping. The use of electronic computing equipment permits the processing of large quantities of such data over relatively short periods of time.

Many "on-line" applications of both general and special purpose computers are being made. These control applications include such examples as control of wind tunnel testing and continuous-flow manufacturing. Computers are being used for aircraft fire and flight control.

A discussion of applications of specific systems will be found under the sub-heading "APPLICATIONS" in the various computing systems descriptions given in Chapter II.

NUMERICAL SYSTEM

Internal Number System

Many types of number systems have been utilized for the development of logical designs of computing systems. Among these number systems are the straight binary, octal, binary coded decimal, straight decimal, sexadecimal, biquinary, binary coded alphanumeric, and binary coded decimal (excess three). Of 101 different relevant systems, 54 utilize a straight binary system internally, whereas 42 utilize the decimal system (primarily binary coded decimal) and 5 systems utilize a binary coded alphanumeric system of notation. Of course, in nearly every computing system, information is ultimately handled in binary form, particularly in storage and in arithmetic units. The primary method of storage exploits the inherent properties of material media, such as semiconductors, and ferroelectric and ferromagnetic materials. The state of conduction or the polarization of ferroelectric and ferromagnetic materials determine the nature of the information which is stored or being processed. Decimal digits are handled as groups of four bits, or tetrads. Alphanumeric data usually requires the use of six bits, permitting 64 different symbols. Some systems utilize seven bits for expressing a single character, permitting 128 different characters, or may utilize a single bit as an "odd-even" check bit. Programmers and coders preparing problems for solution by numerical methods may work with decimal or alphanumeric notation and need not be concerned with the binary coding performed automatically by the machine.

Word Length

The selection of word length for computing systems is based upon many considerations. For information words, the precision required for the solution of problems may be the major consideration. For instruction words, word space must be allocated to the address of the operand (or operands for multi-address codes), the command, and perhaps spares, tags, or check digits. For example, the ORDVAC utilizes 39 bits plus sign for an information word. One half of a word, or 20 bits, is subdivided into a 12 bit address portion (for 4,096 high speed storage locations) a 6 bit command portion for 64 commands, and a 2 bit spare digit portion for special applications and versatility. The variation of word length among existing systems is rather wide. Table III shows the word lengths of the 103 systems described in Chapter II, in descending order of magnitude. The average or nominal word length for fixed word length machines is approximately 40 binary or 12 decimal digits.

Number of Instructions Per Word

In many systems the machine word structure permits several instructions to be expressed by a single word. Of 68 systems, 43 were reported as operating on a one instruction per word basis and 22 were reported as operating on a two instructions per word basis. Several systems required two words to express a complete instruction and, in one system, 2, 3 or 4 instructions could be expressed by a single word, at the option of the programmer.

Arithmetic System

Most of the earlier machines operated on a fixed point arithmetic system. The binary or decimal point was arbitrarily fixed at either the right or left end of the number. For some systems a centered decimal point permitted the direct expression of whole and fractional parts of numbers. Scaling is required, for example, when a decimal or binary point is located at the left end of a number, in which case all quantities must be scaled between the values of minus one and plus one.

Many of the later machines were manufactured with built-in automatic floating point equipment, permitting numbers to be expressed as fractional parts and exponent parts. The exponent usually is a power of two or ten. Floating point circuitry was added to many of the older systems. A review of this sub-heading in the systems descriptions found in Chapter II and an examination of Table III will show the distribution of fixed and floating point equipment.

Instruction Type

Internally programmed automatic computers require that part of the instruction word be devoted to the address (or addresses) of the operand (or operands). The question of how many addresses are to be incorporated into a single word has been answered in many ways. In single address machines, the address of one operand is given in the address portion of the instruction word. In two address machines, the address of two operands are given, for instance the addresses of the minuend and subtrahend are given for a subtract instruction. For three address machines, the address for storing the result, e. g., the sum, difference, product, quotient or square-root, is given. The three address machines usually refer automatically to the next storage location, in sequence, for the next three-address instruction word. Machines using the four-address instruction will express the location of two operands, the location for storing the results of the operation, and the location of the next instruction, all in one four-address word. Coding for four-address machines is somewhat simplified, however, a complex machine structure is necessary. The following table shows the quantity of different systems utilizing the various instruction types:

One-address	46
Two-address	13
Three-address	15
Four-address	7
Variable address	9
Not Applicable	13
Total	103

ARITHMETIC UNITS

Operation Time

Since the primary function of an arithmetic unit in any computer is to perform repetitive arithmetic operations rapidly, the time required to carry out an add instruction is extremely important when selecting a computing system for a specific application. Tables IV and V were prepared to show at a glance the general state of the art with respect to arithmetic speeds. It must be emphasized that the values stated in the table are on an "as reported basis".

Table IV shows the approximate relative order of add time when including the storage access time. In many systems, it is not possible to determine the time required for one addition without considering storage access. This may be due to the fact that in many types of operation, sums may form in an accumulator as the addend is brought from storage, hence access time may be inseparable from add time.

Construction of Arithmetic Units

Most of the computing systems described in this report utilize tubes as the basic driving element in the arithmetic unit. Exceptions include recent transistorized models such as those shown in Table XII. Approximately 23 of a total of 85 systems utilize diode logic (gating) in some form in the arithmetic unit. Several systems utilize magnetic cores in the arithmetic unit.

Basic Pulse Repetition Rate

One may consider that there are three regions of the frequency spectrum in which the synchronous computing systems operate. These may be termed the low frequency band, less than 100 kilocycles per second, the intermediate frequency band from 100 kilocycles to less than one megacycle, and the high frequency band or the one megacycle and above band. Of 75 systems on which the information was obtained, approximately 20 systems operate at less than 100 kilocycles per second, 35 systems operate in the 100 kilocycle and less than one megacycle range and 20 systems operate in the high frequency band.

Arithmetic Mode

The question of serial versus parallel operation of arithmetic units is rapidly being resolved as the number of faster parallel operating units increases. Of a total of 101 systems in which this feature was reported, 46 operated purely on a serial basis and 34 performed arithmetic operations on a parallel basis. However, the majority of the parallel operating systems were of a later design. Arithmetically, the parallel system computes results much more rapidly than the serial system. Eleven systems operate in a serio-parallel manner, usually parallel when considering a single character made up of a binary configuration of pulses, but serial when considering a word as being made up of a series of characters. The speed of a computer, however, is based on its ability to read, write, and transfer information rapidly as well as its ability to do arithmetic rapidly.

STORAGE

An extremely diverse and dynamic field of interest in the study of computing systems is the subject concerning storage devices. Many ingenious devices, utilizing the ability of various material media to store or record energy transformations, have been devised. Early forms of storage involved mechanical deformation of material media. These are exemplified by cams, springs, gears, music box cylinders, perforated player piano rolls, code wheels and perforated paper tape. All these storage devices required the movement of large masses of material and consequently long access time was inherent. The capacity, in terms of stored information per unit volume of material, was very low.

During World War II, the search for more rapid access storage devices led to the use of the vacuum tube. The two states, that of conduction and that of cut-off, permit information storage. This system, as was used on the ENIAC, proved effective from an access time consideration, however, the system was extremely bulky and required thousands of electronic vacuum tubes for a storage unit consisting of 20 words of 10 decimal digits each.

Chronologically, the next development was the use of acoustic delay lines of mercury and quartz. A transducer at each end of a length of these materials permits energy conversions and allows the storage of information in the form of high frequency (e. g. 8 megacycles/sec) pulse packets. The information is continuously recirculated. Information is inserted or read out through the use of standard gating techniques. Among the computers utilizing acoustic mercury delay lines are the DYSEAC, EDVAC, ELECOM 125, FLAC, MIDAC, RAYDAC, SEAC and UNIVAC. The TECHNITROL-180 computer utilizes an acoustic quartz delay line. Other types of delay lines used for storage of information are the magnetostrictive, as used in the FERRANTI PEGASUS and the electromagnetic or distributed L-C network. See Tables VI, VII and VIII, which list the computing systems utilizing delay line storage units. Although in operating principle there is no difference, it is necessary to make a distinction between a delay line used in a storage loop in which information is continuously circulated, and a delay line used only for purposes of timing the arrival of information at selected points for performing various logical operations. In the latter, the function is delay, or temporary storage, rather than permanent storage. Since delay lines store information serially as a train of electrical or sonic pulses, average random access time is limited to half of the time length of the delay line plus the time equivalent to one word length. Because of the serial nature of the system, delay line storage units are limited in speed.

The search for shorter access time brought about the development of the electrostatic storage unit, also called the cathode ray tube storage device. The material medium in motion was now limited to electrons, i.e., in beams and on charged areas on the screen of a cathode ray tube. These charged areas behaved somewhat like an array of charged capacitors. Selection of storage locations and the transfer of information was efficiently performed by an easily deflected pencil or beam of electrons which was used for both storage and interrogation. Parallel transfer, i.e. all digits of a given word are transferred simultaneously, became possible with this type of storage system.

The electrostatic storage system, with the inherent problems associated with high accelerating voltages, screen imperfections and other tube failures, is gradually yielding to the utilization of magnetic cores for the storage of information. A 32 x 32 array of ferrite cores, which might constitute a typical storage plane, may measure only a few inches on each side. The cores are placed at the intersection of the wires of a mesh, and a third winding may be threaded through all the cores for sensing stored data. The storage takes place in the form of magnetically oriented molecular or atomic dipoles which retain their orientation upon removal of the magnetizing force. Many manufacturers intend to provide computing systems with large capacity core storage units. Advances have been made in the use of perforated ferrite plates and magnetic films deposited on glass as a magnetic storage unit. The storage principle is the same as for magnetic cores. Table VI shows the access time of high speed storage units in their approximate relative order of magnitude for the storage units used in various computing systems. It must be emphasized that the question of precisely what constitutes access time cannot easily be resolved unless a common understanding as to the definition is reached. In the usual sense, one may consider access time as the elapsed time between the initiation of a command to transfer an item of information, usually one word, from one address in the storage to another designated register, and the complete arrival of the item at the designated location. In many systems, particularly serial storage units, access time depends upon the time location of the word in the serially circulating group of words at the instant the transfer command is initiated. For this and other reasons, much misunderstanding can arise in the consideration of access time. The data presented in Table VI should therefore be considered to be approximate.

The capacity of high speed storage units has risen during the past few years as rapidly as access time has diminished. Table VII shows the capacity of high speed storage units in terms of number of words and word length, arranged in relative order of magnitude of equivalent binary capacity.

Rapid access storage of limited capacity must be supported by a large capacity for a well balanced storage system. This permits the transfer of large blocks of information from the rapid access storage unit to the large capacity storage unit for use at another location or time in the computation process. The storage device must be far more rapid than punched cards or paper tape. The most prevalent device for auxiliary storage of this type is the magnetic drum. The access time for large blocks of information is of the order of tens of milliseconds for most magnetic drum units. Many computing systems utilize magnetic drums as the primary storage unit. Several systems utilize large capacity drum units for commercial applications such as payroll, stock inventory, and personnel records where access times of the order of microseconds are not required. Table IX shows the capacity of various drum storage systems currently in use.

The characteristics of a storage device, namely, capacity and access time are two aspects of a storage system which come under consideration when designing or using a machine. The user of a system, at times, can trade capacity for access in the sense that under certain conditions he can accomplish an equivalent amount of computation with a large capacity-long access time system as with a small capacity - short access time system. There are limits to this however, for when access time approaches the order of milliseconds, computation is seriously slowed down. Since large capacity and short access time are features to be desired, let us examine a quantity determined by the expression:

$$\log_{10} \text{(Capacity in Equivalent Binary Digits/Access Time in Seconds)}$$

In early storage devices, such as music boxes and signal coding equipment, this number is of the order of two to three. Relay storage units have a number of the order of four or five. Tube registers of the ENIAC vacuum tube accumulator storage type, enabled this figure to be as high as 6.32. Magnetic Drum storage units are in the region of 6 to 7. Acoustic delay line storage systems show that this figure is in the range 8.67 to 9.61. The cathode ray tube storage (electrostatic) raised the figure as high as 10.79. The magnetic core storage unit permitted an increase of this figure to over 12. The following table shows the growth, or increase of this number, as development of computing system components progressed:

Storage Device	Approx. Median $\log_{10}$ Capacity/Access	Approximate Year of Development
Early Mechanical	2 - 3	Prior to 1930
Electromechanical	4 - 5	1935
Vacuum Tube	5 - 6	1940
Magnetic Drum	6 - 7	1945
Electrostatic (CRT)	9 - 10	1950
Static Magnetic (Mag. Core)	9 - 12	1955

Table VIII is a tabulation of the $\log_{10}$ Capacity/Access figures for the high speed storage units of various computing systems in approximate relative order of magnitude.

INPUT-OUTPUT

Previous discussions on arithmetic units and storage devices have shown the great strides that have been made in these fields during the past several years. Arithmetic operation and storage access times have decreased and storage capacity increased. Yet, the communication link between the person and the machine still presents a major problem. Paper tape and cards, inherently bulky, are prevalent and relatively slow, particularly for scientific applications. The main convenience afforded by cards, particularly in commercial systems, is their capability of storing a complete item of information on one card, which may be handled separately or as part of a group, such as data on an insurance policy, a payroll line, a stock item, a set of corresponding test data, etc. There is no doubt that punching cards is a slow process. Paper tape perforators are also relatively slow in the sense that the data to be punched is usually available at a rate faster than paper may be mechanically perforated, although high speed perforators are being developed and are finding application. Keyboard input systems are useful primarily for the manual insertion of words for test or other special purposes.

In addition to paper tape and card readers and punches, many systems utilize high speed printers and magnetic tape units as a medium of input and output. Magnetic tape output still requires a conversion from magnetic tape to cards or printed page in order that the information be available to operating personnel. However, since human intervention is gradually being reduced, the use of magnetic tape for input, output and storage is increasing rapidly. The prevalence of various input-output media for the 103 computing systems described in this report may be determined by examining the data under the subheading "INPUT" and "OUTPUT" in the systems descriptions given in Chapter II.

One method for decreasing machine time spent waiting for reading and writing instructions to be carried out is to provide for concurrent operation. The later machines have built-in circuitry for permitting reading and writing to take place during computations. Apparently the only stipulation is that a given storage location does not become involved in reading, writing and computing at the same time. Many machines compute while punching and reading cards or while "looking-up" information on tape.

Another method for reducing reading and writing time and to avoid a large amount of lost time when a large amount of machine reading and writing is necessary is to provide for reading and writing on a high speed device such as a magnetic tape or wire unit and allow "conversion" to another medium to take place off the machine at "leisure". Magnetic tape-to-card converters and inverters are becoming available as well as magnetic tape-to-printed page converters. Paper tape and cards may sometimes be considered as forms of storage, since information recorded on these media may be returned to the machine. Some progress has been made in the field of printed page readers.

It is often necessary to have computing systems capable of communicating with one another directly. For this reason, input-output media conversion is becoming quite prevalent and large conversion equipment is rapidly becoming available. Input-output schemes are so many and varied, that a complete treatment of this subject is beyond the scope of this report.

CIRCUIT ELEMENTS ENTIRE SYSTEM

There are many impressions which come to mind when one examines such things as tube and crystal diode counts in a large scale computing system. There is a tendency to visualize a large, sprawling system when the tube count is high. There may be large tube-changing programs based on experience in effect on these large systems. Failure rates, preventive maintenance techniques, tube life problems, design limitations and tube specifications must all be considered on a regular systematic basis when the tube count is high. Tube count and a knowledge of tube operating characteristics may yield an approximate estimation of some.of the problems that may be encountered in the operation of the system. Table X shows the approximate number of tubes utilized in some of the computing systems described in this report.

The servicing of a large electronic computing system can be materially simplified by reducing the number of tube types in the system. Standards for tube testing need apply to fewer tube types and tube checking can be further systematized due to a reduced number of test variations. Of course, a test specification or test criterion must be established for the most severe application for which the particular tube type will be applied. A severe or special circuit requirement may be better served through the use of another tube type.

This, then increases the number of tube types. Normally, it is possible to select a type of tube for a group of duties. In a given system, for example, a certain type is selected for driving, for voltage amplification, for flip-flop circuits, normally "on" or "off" conditions, etc. This establishes a number of tube types for a given system and any modification of the system usually should include this "tube type" complement.

The question of crystal diode reliability, diode testing techniques, and diode logical network design, such as individual clamps versus wired plug-in units, become subjects of interest when diodes are utilized. The quantity of diodes in a given computing system may be indicative of the nature of the servicing problem, but only when the failure rates, life and circuit demands placed upon the diode are known. To some extent, malfunctions due to diodes can be aggravated by elevated temperatures. The extent of crystal diode use in the computing systems described in this report is shown in Table XI.

Many recently developed systems utilize transistors for driving, switching (gating) and other logical functions. Reduced power and reduced space requirements are advantages of these systems. The question of reliability is rapidly being resolved, as printed circuits and packaging techniques continue to be improved. Table XII shows the quantity of transistors utilized in the various computing systems described in Chapter II.

CHECKING FEATURES

The question of what type of checking features should be incorporated into a given general purpose computing system is still being tossed about by various manufacturers. The type of built-in check varies from manufacturer to manufacturer and from system to system.

It is usually possible to check all machine calculations by programming techniques. A well designed system can proceed for many hours without a malfunction. If this is the case, it is entirely possible that the installation of a checking system can do more harm than good since the checking features can malfunction and cause an alarm or stoppage when a machine malfunction has not occurred. For example, the second unit of twin arithmetic units can malfunction, the comparer of a redundancy checker can malfunction, or a forbidden pulse combination decoder can malfunction, all yielding false indications of a machine malfunction. Approximately 29 of the 103 computing systems described in this report do not have any kind of a built-in checking system. The only types of checks possible for the operators of these systems is a visual or test check on print-out, a complete or partial recalculation of the results, a programmed check or a marginal checking system to determine the reliability of the equipment.

The remaining 74 computing systems of the 103 reported utilize some form of built-in check. A redundancy or duplication check on storage and magnetic recording is used in about 10 systems. Twin arithmetic units, which perform calculations simultaneously, are utilized in 6 computing systems. Some type of overflow or exceed capacity is used on 12 of the 74 systems and an odd-even check is used on 20 systems. Various kinds of transfer checks are used on 6 systems. Approximately 11 systems established a checking system by detecting pulse combinations which are not supposed to occur in the process of computation. The various names that have been applied to this type of check are forbidden pulse combination, unused order (instruction), unallowable order digit, improper operation code, improper command, false code, forbidden digit, non-existent code, and unused code. There is a distinction to be made between the terms order, instruction, and command. The preferred definitions are given in the glossary of computer terminology. The following table shows the approximate distribution of checking methods in the systems described in this report. Only the primary checking system was selected from each machine. Many systems utilize more than one check technique.

Checking Method	Number of Systems
Redundancy	10
Twin Arithmetic Unit	6
Overflow or Exceed Capacity	12
Odd-Even-Parity	20
Forbidden Pulse Combination	11
Transfer	6
Miscellaneous	9
No built-in Check	29
Total	103

POWER, SPACE, AND WEIGHT

Important aspects of computing systems are the physical factors of power, space and weight.

Power requirements may very well dictate the physical location of a large computing system within a building, particularly when the power required is in excess of 50 KW. For most systems, however, the power is brought to the most favorable computer location from the point of view of personnel accessability for operation and servicing. Table XIII shows the power requirement of various domestic digital computing systems.

An interesting figure might be the relation between the number of tubes utilized in a computing system and the power requirement. In order to determine whether or not a consistent tube to power ratio could be established, the ratio was determined for the computing systems for which the data was available. Discounting a few systems in which the tube to power ratio exceeds 150 tubes/kilowatt and the few systems in which the ratio is less than 50 tubes/kilowatt, it may be said that for the vast majority of computing systems the tube-power ratio lies between 50 and 150 tubes per kilowatt. The average ratio of the systems reporting this data is 110 tubes per kilowatt.

The problem of space requirements has been solved in so many ways it is impossible to determine a consistent relation between space requirement and any other factor. Large computing complexes have been installed in areas ranging from a corner of a basement to an entire floor of a large building. The pictorial coverage of computing systems and the space requirements discussed under the subheading "POWER, SPACE and WEIGHT" in the systems descriptions of Chapter II give a rough approximation of the space requirements of the computing systems described in this report. The dimensions of various components of unitized systems are important when considering clearance in rooms, passages, doorways and elevators.

Air conditioning requirements vary considerably from system to system. Air conditioners for computing equipment may utilize water to absorb the heat from circulated air, use a secondary loop of air, force the heated air to the outside, or utilize an outdoor evaporator. The smaller systems circulate room air and depend on the ambient temperature to cool. Almost 100% of the power required by the system is dissipated in the form of heat and must be removed. The large systems usually require separate heat removal facilities. For many systems, humidity and dust control within the machine are required in order to maintain satisfactory operation.

The factor of weight can be important when the floor loading limits for distributed and concentrated loads are within the weight range of the computing equipment. Many systems may require reinforced or specially constructed buildings. Many items of peripheral equipment may cause concentrated loads in excess of maximum permissable concentrated loadings on some structures. Vibration and shock caused by some equipment such as tabulators and card punches can cause troubles in other components. Shock and vibration absorbing pads are required in such cases. When unitized construction is used, the weight of a single unit must also be considered when transporting and installing.

PRODUCTION RECORD

In almost any new and rapidly changing field there will be many instances in which, an experimental prototype of a large piece of equipment will be built. This is the result of the normal course of events, namely, a feasibility study, a research effort, a development effort and a prototype construction. Mass production then occurs when the demand for systems is sufficient to warrant production in quantity.

A review of the subheading "PRODUCTION RECORD" will give an indication of the production status of various computing systems. The quantity produced, the quantity in current production, in current operation, and on order are given. Delivery times quoted show that immediate delivery is now possible for many computing systems. Table II shows the quantities of the various systems that have been produced.

COST, PRICE AND RENTAL RATE

Perhaps the most elusive and intricate item considered in the systems descriptions of this report is the question of initial cost, blandly described as "approximate cost of basic system". Manufacturers are quite naturally quoting current prices for their respective systems. Research and development may be absorbed by the first few models or spread out over many. The "one of a kind" system usually includes all research, development, construction, overhead and sub-contracting costs. The question of what is included under "basic system" is immediately brought to mind. The "basic system" includes an input device, the controls, the storage system, the arithmetic unit, and the output device. All conversion equipment such as card-to-printed page (tabulators), card-to-tape, tape-to-card etc. are considered peripheral equipment, and both the quantity and type is dependent upon specific system application. These are not included in the cost or price of the basic system. In order to determine the cost of a given system, refer to the system description. Table XIV shows the approximate relative cost of various computing systems. For the systems reported, cost figures range from $16,800 to $4,200,000.

The methods of computing system or component acquisition include direct purchase at a fixed price, direct purchase on a cost plus fixed fee basis, continuous rental, and rental with all or part of the rental applicable toward purchase. Most forms of rental include servicing. Direct purchase can include a service contract.

Rental rates are of the order of 3 per cent of the direct purchase price per month. The sale and lease policy of various manufacturers is given under the sub-heading "COST, PRICE AND RENTAL RATE" in Chapter II.

Table XIV shows the nominal price one may expect to pay for a basic system. For many systems, one might add 20 or 30 per cent for required peripheral equipment. Most prices include installation but not shipping costs. Some of the figures reflect prices which are not current and have not taken into account general price rises during the past several years. Some figures include initial service or some type of warranty. The figures quoted in Table XIV are for general consideration only, and are not for purposes of acquisition. Indeed, many systems are not available, even at the price quoted, since the price stated is actually the construction "cost" to the owner.

An attempt was made to discover whether a "system cost per tube" figure could be established. For the larger systems, the figure is of the order of 200 dollars per tube installed and for the smaller systems approximately 100 dollars per tube. However, a glance at Tables X and XIV will show that such a figure cannot be calculated with reasonable accuracy. An attempt to determine a figure such as "cost per cubic foot" of electronic computing equipment would be equally fruitless.

PERSONNEL REQUIREMENTS

Personnel problems have confronted computing system operators and manufacturers from the very outset, in all phases of computer research, development, manufacture, installation, operation, improvement and servicing. Various grades of skills are required in the fields of engineering, physics and mathematics. Each large system has a crew of engineers and technicians for improving and servicing and a group of mathematicians and operators for problem analysis, coding and programming. In the very small systems, all of these functions may be performed by one or two persons. The systems descriptions in Chapter II show various estimates made by manufacturers and operators of what the personnel requirements are or should be for various systems. The estimates, in some cases do not show the personnel required for overtime, vacations, illness, and training purposes. Just as in any application of manpower to machines, it is necessary to provide sufficient manpower so as to maximize machine utilization whenever possible. Many installations consist of multimillion dollar computer complexes. Such large capital investments must be utilized at maximum efficiency in order to avoid severe losses. Twenty-four-hour operation increases the daily output and provides for more efficient utilization of capital equipment.

RELIABILITY AND OPERATING EXPERIENCE

The most discussed and most controversial issues in the field of computing machinery occur on the subjects of reliability, efficiency and system evaluation. The determination of the reliability of a system is difficult, primarily because of a lack of a common understanding or interpretation of the definitions of computer operating terms. What actually constitutes "good time" on a computing system? What is "down time", "scheduled engineering", "useful production and code checking"? An attempt has been made to provide working definitions of these and other terms in the Glossary of Computer Engineering and Programming Terminology given in Chapter V of this report. The very crude "Operating Ratio", as is used in the systems descriptions of Chapter II, is defined as the "Good Time" obtained on the machine divided by the time one actually "Attempted to Run" the system. The question arises as to where to put the time lost in scheduled engineering (preventive maintenance), since technically, one is not attempting to run the system during this period, yet the system is not actually "down". Many systems, are operated for 168 hours per week. The operating ratio for these systems would require that 168 be used as the denominator and the number of useful output hours as the numerator, yielding a much smaller (but perhaps truer) ratio than a system operated on an 8-hour 5-day week shift and using off-time for servicing. This latter type of operation may yield operating ratios of the order of .90 to 1.00 and give a false indication of reliability.

The question of how one determines the average error-free running period is also a difficult one. It may be estimated or calculated by actual counts of the periods of malfunction-free operation. It may be the period used as a guide by coders to prevent losses due to running for extended periods between obtaining output information, particularly where volatile storage media are being used. Many questions regarding the subject of "RELIABILITY AND OPERATING EXPERIENCE" are answered under this subheading in the computing systems descriptions given in Chapter II.

Many computing systems are approaching the age of retirement and replacement. Constant improvements have already replaced many of the original components of a system. The next few years will see the retirement of many of the older systems. Such retirement may take the form of salvage of parts, use for educational and training purposes, or scrap. Table XV shows how long some models of computing systems have been in existence.

FUTURE PLANS

The electronic digital computer field is a dynamic one. Plans for acquisition and improvement of systems and components are continually being made and modified. The plans of various operators and manufacturers are given under the subheading "FUTURE PLANS" in the systems descriptions of Chapter II.

INSTALLATIONS

A primary source of information concerning electronic digital computing systems is the operating organizations. The acquisitional and operational problems of one organization may have already been solved in one way or another by other organizations. Benefiting from the experiences of others can be profitable, if only to avoid mistakes. Under the subheading "INSTALLATIONS" in the systems descriptions of Chapter II, a list of the owners and operators of specific systems is given in order that contacts between owners and prospective owners may be established. Many co-operative "plans" have come into existence, under which owners or operators of specific systems have engaged in sharing computer experience.

ADDITIONAL FEATURES AND REMARKS

Under this subheading has been placed general information concerning specific computing systems which did not have a "place" in the previous sixteen subheadings. Included under this subheading are remarks concerning the pictures, information which arrived too late to be added to the system description under a proper heading, special features of the system and other miscellaneous items of information.