INDUSTRIAL DATA PROCESSING APPLICATIONS

A loose-leaf service of Information Handling applications for Industry.

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PREFACE

The purpose of the INDUSTRIAL DATA PROCESSING APPLICATIONS handbook is to provide within one volume detailed, in-depth reports of the efforts of today's industrial firms to improve their operating efficiency and competitive standing through better handling of business and technical information. These up-to-date reports which use only the latest information are designed for the use of business executives, production specialists, systems managers and others concerned with the improvement of their organizations' data processing operations. The reports are equally useful to readers from companies which are just starting to investigate the use of EDP as to those who now maintain highly sophisticated installations.

Through the IDPA case studies, readers can see how other companies are developing new applications to take full advantage of their hardware capabilities. The readers can thus determine how applicable these new ideas for more efficient operation are for their own firms. By benefiting from the experience of other companies, they can also save their organizations possible "trial and error" development costs.

The IDPA handbook's coverage extends over all manufacturing industries and over all industrial data processing activities from plant floor process control and data collection through to front office order-handling and procurement control. Similarly, applications described involve the use of all types and/or combinations of information-handling equipment now on the market. Particular emphasis is also placed on the development of new procedures which, while based on the original equipment, make more economical and effective use of existing capabilities and, while providing management with fuller, more up-to-date information, heighten an organization's operating efficiency.

The handbook's loose-leaf format makes it possible for readers to keep up-to-date with the latest developments in the fast-moving information processing field. The binder, in effect, provides convenient, portable housing for what amounts to an active information file. There will never be a time at which the handbook can be said to be completed since new products, new ideas, new methods are constantly being developed.

For this reason, INDUSTRIAL DATA PROCESSING APPLICATIONS is strictly a subscription service designed to help those involved in data processing to look ahead. Users of this service can measure their own needs and their own budgets to the current trends in equipment and procedures. Whether they are designing a new system or improving one now in operation, the following pages will give them the information needed for comparison of capabilities, effectiveness and applicability.

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Industrial Data Processing Applications handbook is intended to be a source of up-to-date information for people who are directly concerned with electronic data processing. However, a brief sketch of historical background lends depth to the subject and shows there is nothing new about automation except the word itself.

Generally these accounts of historical progress begin with the origin of the 10 digits, based on finger count, a subject everybody learns in their earliest arithmetic lessons. Much has been written about notched sticks, counting stones, Napier's rods and the persistence of the abacus with its centuries-long record of efficiency. The chronological progress carries through the 1600s and the efforts of Pascal, Grillet, Leibnitz, and others; then to Jacquard of the late 1700s and his punched cards, the nature and purpose of which are generally misinterpreted.

Jacquard's achievement was a step toward industrial automation, not data processing, although it was a form of mechanical programming. The holes, being a literal translation of the treadling draft, controlled the cyclic rise and fall of the loom harness which, in turn, produced the pattern in the fabric. The cards, therefore, contained a stored program which repeated over and over.

Possibly Charles Babbage, a generation or so after Jacquard, may have been influenced by the mechanics of the loom. His cards did not constitute a program but did carry a punched code to represent numbers. These holes were intended to activate the mechanism of his "difference engine" and can be said to have constituted the memory of the machine. Babbage obtained a grant from the British government about 1830, but the engine was a failure largely because steam, unreliable, and unwieldy, was the only power available.

These early efforts to remove drudgery from accounting operations can be said to be automation if, in its connection with data processing, automation can be taken to mean the mechanization of arithmetic processes. Pascal, Grillet, et al, produced the earliest calculators and adding machines, manually operated, and the basic principles of these can be found in today's office machines.

On The American Scene

Americans appeared on the inventive scene of data processing in the mid-1800s. J. P. Smith is credited with producing the first keyboard-operated adding machine. During the next two or three decades the pace of invention was greatly accelerated so that by the time Dr. Herman Hollerith appeared on the scene in the 1880s the office equipment industry was fairly well-established with typewriters and adding machines. Office automation, however, was trailing behind industrial automation. The tabulators with which Dr. Hollerith produced the 1890 census statistics were not considered originally for office purposes but this probably is the most accurate area in which to establish the beginning of history in the automation of data processing just as Jacquard is regarded as the progenitor of industrial automation.

Dr. Hollerith's first efforts came only about 50 years after Babbage's but during that time electricity had been brought under control. The Hollerith punched card code consisted of only a single hole which permitted the flow of electricity. Babbage's code consisted of a row of holes equivalent to the number they represented (six holes for number six; seven holes for number seven; etc.) intended for mechanical action. These two factors of power (steam vs. electricity) and principle (action vs. exception) made the difference between Babbage's failure and Hollerith's success.

James E. Powers, an English engineer who succeeded Hollerith in the Bureau of the Census in 1908, established a punched-card code based on mechanical sensing which might have been suggested by the Babbage system. However, as in the Hollerith code, the original Powers system used only one hole to represent a number (the "no-hole" positions prevent mechanical action). A later refinement, to double the capacity of the original 45-column card, introduced a control hole to establish an even number as against a single hole to indicate an odd number.

Both the Hollerith and the Powers systems are still in use in tabulating equipment and as input to computers. The Hollerith patents became the property of International Business Machines Corp. while the Powers patents became Remington Rand property (more recently designated as part of the Sperry Rand Univac line). Powers' name is still in the industry, however, on the line of Powers-Samas equipment which is produced in England.

From Card to Electron

Punched cards provide the only means for automating data processing until developments in electronics which were accelerated during World War II. Strictly speaking, the history of EDP properly begins in the 1930s — preceding developments like punched cards and punched tape belong to the history of integrated data processing. Electronic data processing makes use of punched cards and tape as input but its own history, which involves magnetic tape as input, began with the machines made by Dr. Howard H. Aiken, of Harvard University and the inventors of ENIAC, Dr. John W. Mauchly and Prof. J. Prosper Eckert of the University of Pennsylvania.

An even earlier contribution to EDP development came in 1919 when a paper describing an electronic "trigger circuit" was published by W. H. Eccles and F. W. Jordan in the first volume of "Radio Review." The trigger circuit could be used for counting and was regarded as a mere curiosity at the time, as was Babbage's engine, but it was a hint that the new science of electronics could be used as a computational aid.

Dr. Aiken and Dr. Mauchly advanced their first suggestions and ideas for electronic computation during the 1930s but it wasn't until the pressure of the war effort that they were able to put these ideas into action. These projects fulfilled the plans originated by Babbage and others, using some of the techniques devised by Hollerith and Powers and developing further a technology directly traceable to Eccles and Jordan.

In the spring of 1943, Dr. Mauchly, then an associate professor of electronics at the Moore School of Electrical Engineering, University of Pennsylvania, submitted a memorandum to the Army Ordnance Department outlining a plan for a general-purpose digital computer using electronic counting circuits to speed their work. The ultimate result of this was ENIAC, the first all-electronic digital computer, which was completed in the fall of 1945.

Dr. Aiken, working with the United States Navy Ordnance Department and IBM at Harvard University, completed Mark I, the first large-scale general-purpose digital computer, in 1944 after five years of work. However, it was constructed entirely of mechanical parts and had its limitations although it was 20 times as fast as a desk calculator and could perform better than three additions a second.

ENIAC represented the first major break with the past since it was entirely electronic except for the punched card input machinery which had been modified to work with the electronic circuitry. Modern computing systems seem to have evolved from a wedding of the techniques of ENIAC and Mark I. Three more computers for the Navy's Bureau of Ordnance followed Mark I. These were the Aiken Relay Calculator, Mark II (completed in 1947); Harvard Mark III (completed in 1949) and the Harvard Magnetic Drum Calculator, Mark IV (completed in 1951).

There is a profusion of "firsts" in the development of electronic computers and every one of them can be justified on one basis or another. For example, Dr. Vannevar Bush, then professor of electrical engineering at Massachusetts Institute of Technology, developed the first large-scale computing machine in 1925. He developed a more comprehensive analyzer in 1930 and another in 1942.

An Industry Is Started

Many other "firsts" are claimed and substantiated in the various universities which were working on computer projects. The record of commercial "firsts" is much more distinct. Eckert and Mauchly formed a business partnership in 1946 to promote the use of electronic computers for commercial use and started business as the Electronic Control Co. This was later incorporated as the Eckert-Mauchly Computer Corp. which, in 1950, completed a BINAC computer for Northrop Aircraft, Inc. Like all others of its predecessors, BINAC was a scientific computer and the first to use the principle of complete internal self-checking. It was really two computing systems, each operating independently, with the results being checked constantly to ensure complete agreement.

Before BINAC was completed, the company had completed Univac, the first computer ever to be planned and produced to handle both numbers and descriptive information. It was also the first to separate input and output from the actual computation facility. Both these characteristics made the commercial use of computers economically attractive.

About the same time Eckert and Mauchly formed their first partnership, in 1946, a group called Engineering Research Associates, Inc. was formed in Minneapolis to build computers for the government, commerce and industry. This group produced the ERA 1101 which was put to work in Washington in 1950. This was about the time Remington Rand Inc. abruptly entered the computer business by purchasing the Eckert and Mauchly enterprise and ERA to combine them with their own laboratory operation which had produced the 409 series of punched card electronic calculators.

The ERA 1101 then became Univac 1101 and the Remington Rand punched card calculators became the Univac 60 and 120. In 1951 a Univac went to work for the Bureau of the Census and in 1952 a Univac I computer in Remington Rand headquarters in New York went on television to forecast the Eisenhower landslide. Much to the chagrin of public relations personnel and programmers alike, Univac I accurately forecast the results of the election on the first print-out but the people involved had little confidence in the new so-called "giant brain" and, accordingly, reprogrammed it to come up with results which they felt were more realistic. They later found the computer's first forecast was the best, thereby learning a valuable lesson about the capability of the new equipment.

Although IBM had been active in the electronic computer field since 1939 when they began working with Dr. Aiken, the company did not become commercially active until 1953 when the IBM 650 was planned. This preceded their 700-series of which 701 represented the first clean break away from punched-card equipment. A previous large scale computer was completed in 1947 and filled a large room in the World Headquarters building at Madison Ave. and 57th St. in New York City. It was, at the time, a major effort in the field.

The Industry Expands

Since 1950 the growth of the EDP industry has been nothing less than explosive. Old, established business equipment manufacturers swung quickly into line to produce their own computers — Burroughs, National Cash Register, Monroe, Addressograph and others. The Office Equipment Manufacturers Institute became revitalized and reorganized as the Business Equipment Manufacturers Assn. and staffed its office to handle the problems of standards within the industry.

Electronics firms like RCA, Minneapolis-Honeywell and Collins Radio moved into the computer area. Other large firms like Bendix tried to reap some of the attractive profits and failed while other, entirely new organizations like Control Data Corp. went into business and prospered. Corporations went through a period of almost frenzied maneuvering to establish strong beach-heads on the sales front.

By 1965, approximately 15 years after the industry began, most manufacturers were established in their relative positions and settled into a reasonably stable pattern of competition.

Computers, once regarded as suitable only for government office and big business purposes, began to appear in modular units with sales to the smaller business firms in mind. Honeywell's 200, the Univac's 1050, IBM's System 360, RCA's Spectra 70 and General Electric's Compatibles were some of the first to be engineered to lure the profit dollars from the big market of small users.

Production lines also found uses for the computer almost from the time they were first put to use for scientific research. Process industries, notably in chemical and petroleum products, were quick to begin working out plans for computer control of plants and refineries. Tool and machine manufacturers put the computer to work, through numerical control, to produce intricately designed parts in metal and plastic. Operations Research, a new science which became known publicly during World War II, was sired by computers which made it practical to solve complex equations and problems.

Critical path scheduling, which once depended largely upon human intuition and experience, became one of the basic applications for computers in most industries.

Data processing in industrial plants was almost entirely separate from that which took place in the office until the advent of computers. The foreman's office generally was the common meeting ground for the record keeping tasks of the office and those performed by department heads in the plant. Computers in both the plant and the office united these functions through data collection, process control and office automation.

International Marketing Begins

International marketing of computers and components began even before the appearance of the Harvard-IBM Mark I collaboration of 1944 and Univac I which is regarded as the first digital computer offered for business purposes in this country. The British, in the late 1940s, produced EDSAC at Cambridge University which later led to the development of LEO I by the Lyons Catering Co. LEO I was built primarily for the use of the catering firm but a company called Leo Computers Ltd. was formed and several more computers were built before they merged with English Electric Co. Ltd., another of the early contenders for computer profits.

International interchange of products and systems began in earnest in the early 1950s. International Business Machines Co. in the United States and the Hollerith Co. in England (now International Computers and Tabulators Ltd.) quickly gained prominence domestically and internationally. The MADAM Mark I, installed in Coventry in 1951, was the first digital computer to be installed in England. It was built at Manchester University in conjunction with Ferranti Ltd. and was quickly followed by Mark II of which seven were built, the first being installed in 1953. These are now credited to ICT although that organization was not formed until completion of a merger, in 1958, which brought together the formerly competitive tabulating systems of Dr. Hollerith and Mr. Powers (The Hollerith Co. and Powers-Samas).

In this country the ENIAC, developed by Eckert and Mauchly, came into being in 1948 soon after the appearance of the EDSAC. These two digital computers, probably more than any other single development in scientific and analog computers, contributed much to the beginnings of the industry.

New ideas for computer uses in data processing developed quickly and by 1950 a Univac 1101 (then known as the ERA 1101 for its builder, Electronic Research Associates) had been installed for the Bureau of the Census in Suitland, Md., and Burroughs had introduced its 204 to the American market.

During the Fifties, while corporations and companies were merging, forming, merging again and, for some, looking down the long row of red figures, the pioneers in the development of computers were jealously guarding - or trying to guard - every new idea. Univac and IBM were squared off on the domestic scene and both were field testing new ideas abroad. As a result, one of the earliest indications of the birth of a new generation in computer art came from West Germany where Univac was trying out a transistorized unit which was to become known as the Solid-State 90 in December 1958. This was a revolutionary system for its time since it occupied far less space than its predecessors, Univac I and II which were vacuum tube computers. Until it was formally introduced, the Solid-State, which originally had only a punched card input, was known as the Universal Computing Tabulator. IBM's initial offer of second generation computers was the 7070 which was announced in September 1958. The first installation was in 1960.

It was about this period in the industry's history when General Electric appeared in the market with a process control computer dubbed the GE 312. The GE 210, a general purpose, digital computer, also appeared at this time, 1959, and was immediately followed by the GE 225 - both of them of the second generation. In Europe, Elliott was moving ahead in England. Their first offering was the 401 in 1954. The 402 and 403 (WREDAC) appeared in 1955 and later versions of the 402 were introduced in 1958.

In France, La Compagnie des Machines Bull was preparing to enter the field with its Gamma 30, introduced in 1961. This system was the RCA 301 computer built in France for European installation. By this time other American manufacturers were engaged in overseas production for overseas sales.

Italy and Japan also appeared in the lists in the latter half of the 1950 decade. Ing. C. Olivetti SpA in 1957 installed its ELEA 2001, intended primarily for teleprocessing purposes. The forerunner of their 9000 series, the 9001, appeared the same year. This was a vacuum tube computer but was followed by a tube and transistor system, the 9002, in 1958. The Japanese OKI, built by OKI Electric Industry Co. Ltd., was installed in 1958. Their 5090D came out in 1961. Japan's Fuji Manufacturing Co. was first heard from with computers in 1958 when they introduced the FACOM 201. Other early Japanese equipments were the MADIC I, introduced in 1959 by the Matsushita Co.; the MELCOM 1101, built by Mitsubishi Electric Co. and the NEAC 2203, built by Nippon Electric Co. and installed in 1959.

Sweden and the Ukraine were both in the field early, although neither has made any impact of importance on the international market. Facit Electronics AB, best known of the Swedish computer makers, installed their first system in 1957. The Mathematical Institute of the Ukrainian Academy of Sciences in Kiev was one of the first to build a computer, the

MESM, which was installed in 1950. The Computing Center of the Academy of Science of the Ukrainian Soviet Socialist Republic installed a computer known as the Kiev in 1959.

These rapid fire developments on the international front spurred the growth of the International Standards Organization to give increased attention to the many aspects of the industry which require international standardization. Matters such as machine and program languages which are standardized on a local basis in various countries had to be surveyed from a standpoint of interchange since computers could not be utilized to their fullest capacity by large corporations unless an international form of language could be devised.

What of the Future?

Some of the more idealistic among computer philosophers forecast a day when language barriers will no longer exist, at least among the members of the computer fraternity. This, they feel, will go a long way toward ironing out the world's misunderstandings and difficulties.

Not quite so optimistic are some of the other forecasts (and these are being argued pro and con in every language) which foresee the computer and machines running society.

Still another phase of life among the computers to come is presented by those who contend that the systems will need more and more people to manage them. These particular prophets began to appear through the aegis of the Bureau of Labor Statistics in the Department of Labor, the agency which earlier in the development of computers was inclined to "view with alarm."

This particular volume - INDUSTRIAL DATA PROCESSING APPLICATIONS - is entirely noncommittal on the subject of future developments except to regard the computer as a permanent fixture in the world economy — and a definite contributor to the betterment of industrial processes and methods.

This section provides a general analysis of the structural elements in computer data processing, and of the arithmetic systems used by general-purpose computers.

There are five integral functions involved in the utilization of an electronic digital computer: input or reading, storage or memory, computing or arithmetic, control, and output.

Input or Reading

The problem to be solved or the job to be processed is basically entered into the computer in two parts: The instructions, and the data to be acted upon. As a rule, the instructions or the program is entered into the internal memory of the computer via punched cards or magnetic tape. In many business applications the data to be acted upon includes certain established information, or a master file, which already has been recorded on external storage devices.

The input that involves data to be acted upon may be considered in two phases: preparation and recording of the original data in a medium through which the computer can accept the data, and the entering of the data into the computer. The media most commonly used for input are:

a. Punched cards
b. Punched or printed paper tape
c. Magnetic tape
d. Magnetic cards
e. Magnetic ink character recognition (MICR), or magnetic ink characters imprinted on paper documents.
f. Optical character reading, or documents imprinted with characters which can be scanned and recognized by optical reading devices, with the information transmitted to the computer.
g. Direct keyboard or other input.

Storage or Memory

Storage media may be considered either internal or external. Internal storage is generally characterized by relatively limited capacity but fast access time. External storage media accommodate large quantities of data but the access time is slower. The main types of storage media used with electronic computers include: thin-film, magnetic cores, magnetic drums, magnetic discs, magnetic cards, or magnetic tapes. The order is approximately one of increasing capacity and slower access time. With magnetic drums, the distinction between internal and external storage becomes somewhat nebulous.

All these devices are permanently magnetized in the sense that should the electricity supply be shut off, the data would remain recorded. Earlier computer storage devices such as the cathode-ray tube and the sonic delay line had the disadvantage of needing constant regeneration, and the discontinuance of the electricity supply could result in the loss of the stored data.

Computing or Arithmetic

This stage does the adding and subtracting, multiplication, division, and other arithmetic and comparing functions. Computing operations can be either on a parallel or a sequential basis. On a parallel basis, all the digits of a factor are operated on simultaneously as in a desk adding machine. On a sequential basis, the digits are operated on one at a time in series, similar to the way one would solve a numerical problem with pencil and paper.

Control

This area of the system's makeup tells the computing unit exactly what to do and when and where to do it. Instructions in the necessary detail come from memory storage and are originally programmed into the machine via the input. The control not only tells the computer the address from which it must secure the data to be processed but also where to store the information for the next operation. Also, overall functioning of the computer system is supervised by the control section.

Output

When the computation or processing phase has been completed in a business computer system, the results are generally printed out in alphanumeric characters. Output devices most commonly used for this function are high speed line printers, accounting machines and automatic electric typewriters. A high speed printer may be equipped with an optical type font to facilitate further processing of the printed output. The output can also be in the form of an intermediate storage medium such as punched cards, punched tape, magnetic tape or magnetic cards.

NUMBERING SYSTEMS

General-purpose electronic computers use the binary system of arithmetic. One of the most commonly used codes to represent characters within the computer is called binary coded decimal (BCD) notation. Some other computer codes in use are the two-out-of-five fixed count, the biquinary, and the excess three notation codes. (Refer to Table 6.)

The development of numbering systems, and pure binary, modified binary, and other systems used in computing devices are described here.

Mayan Arithmetic

One of the original numbering systems used in America, the system of the ancient Mayas of Central America, utilized the scale of 20. It may be thought of as based on counting the fingers and toes, one by one, in lots of five. This system also may be called the four fives, or tetraquinary, or vigesimal. (Refer to Table 1.)

Vestiges of counting in the scale of 20 appear in the Norse, Celtic, French, English and other languages, as in phrases like "four score" in English and "quatrevingt" (80) in French. The 20 shillings in the British pound is another example.

Table 1. Mayan vs. Decimal Arithmetic

Mayan	Decimal	Mayan	Decimal	Mayan	Decimal	Mayan	Decimal
	1	• —	6	• — —	11	• — — —	16
••	2	•• —	7	•• — —	12	•• — — —	17
•••	3	••• —	8	••• — —	13	••• — — —	18
∘•••	4	•••• —	9	•••• — —	14	•••• — — —	19
—	5	— —	10	— — —	15	— — — —	20

Roman Arithmetic

A considerably older system than the Mayan is the method of counting and arithmetic used in ancient Rome. The modern Roman notation still finds application in English today. Basically, the Roman is a "biquinary" or "two fives" system; however, it departs from being a true biquinary system because it uses different symbols as each new power of 10 is attained. Thus, I and V apply to the units; X and L to the 10s; C and D apply to the hundreds; and M applies to the thousands. In the true biquinary system, each decimal digit is replaced by two digits: the first in this pair is either 0 (or 0 understood) or 1; the second is either 0, 1, 2, 3 or 4. (Refer to Table 2.)

The biquinary system actually has been used more than once in automatic digital computers. One example: the relay computers of Bell Laboratories. The system is sometimes particularly useful in computers when circuits are installed to ensure that one, and only one, of the units 0 to 4 is recorded; and one, and only one, of the units 0 and 5 is recorded.

Table 2. Roman Arithmetic

Ancient Roman	Modern Roman	Decimal	True Biquinary	Ancient Roman	Modern Roman	Decimal	True Biquinary
I	I	1	1	VIII	VIII	8	13
II	II	2	2	VIIII	IX	9	14
III	III	3	3	X	X	10	100
IIII	IV	4	4	XI	XI	11	101
V	V	5	10	L	L	50	1000
VI	VI	6	11	LXXXX	LXL	90	1400
VII	VII	7	12	C	C	100	10000

The biquinary is used in the Chinese abacus, which is supposedly derived from the Roman abacus. Each bead above the horizontal strut is worth five times as much as each bead below the strut. The convention is that any bead moved toward the strut counts; moved away, it does not count. In the Japanese abacus, there are only single beads above the strut. These are in units of 10 instead of five.

With the Chinese abacus, addition is performed using 17 rules; the same is true for subtraction. However, additional rules must be mastered to learn multiplication and division tables. In some Oriental schools, courses are given in the use of the abacus. Advanced courses teach shortcuts in abacus arithmetic.

Binary Arithmetic or the Scale of Two

A numbering system that has been known for years, but has only recently become markedly useful, is the system of counting called the binary scale or binary notation. It uses just two digits, 0 and 1, and is based on position, just as the decimal notation uses 10 digits (0, 1, 2, up to 9) and is also based on position. In the binary scale, the position of a digit tells the power of 2. For example, in decimal figures 10,000 represents one 10-thousand or 10 to the fourth power (10^4), whereas in binary the same characters (10000) represent 16 or two to the fourth power (2^4). Similarly, 100 which is one hundred or 10 squared (10^2) in decimal, but in binary it is four or two squared (2^2). (Refer to Table 3.)

The two digits, 0 and 1, often stand for two opposite conditions or states in certain elements of computer hardware. For example, 1 and 0 may mean current or no current at a certain time, pulse or no pulse at a certain time, presence or absence of a magnetic recording in a certain position on magnetic tape, positive or negative polarization of a spot on a magnetic drum surface, on or off of a flip-flop transistorized circuit, truth or falsehood of a statement, open or closed in a computer gate circuit, and so forth.

Each mark in the binary columns above is either a zero (0) or one (1). These are binary digits or bits. The term "bit" by extension is used to designate the minute magnetized portion on tape and other media which serves as the basic unit of information.

Table 3. Binary Code

Decimal	Binary	Decimal	Binary	Decimal	Binary	Decimal	Binary
0	0	5	101	9	1001	14	1110
1	1	6	110	10	1010	15	1111
2	10	7	111	11	1011	16	10000
3	11	8	1000	12	1100	17	10001
4	100			13	1101		

Aside from zero and one in both scales, the binary number requires more digits to be expressed than the equivalent decimal number. For example, each binary number between decimal 64 and decimal 127 has seven binary digits. On the average, a binary number will have about 3-1/3 times the digits of the equivalent decimal number. Because of this, binary arithmetic is inconvenient for pencil and paper calculation. The binary numbers may be written in the scale of eight or octal notation: each triplet of binary digits is recorded as one digit in the scale of eight, as shown in Table 4:

Table 4. Octal Notation

Binary Triplet	Octal Digit	Binary Triplet	Octal Digit
000	0	100	4
001	1	101	5
010	2	110	6
011	3	111	7

In this way, the binary number 111, 110 (in decimal 62) may be written in the scale of eight as 76 (i.e., seven times eight, plus six).

Most general-purpose computers accept decimal input and produce decimal output, with internal operations done in pure binary. Translation of decimal to binary and binary to decimal is automatic.

Table 5 lists several binary numbers and their decimal equivalents in powers of two.

Table 5. Binaries and Their Decimal Equivalents

Binary Number	Decimal Equivalent
1	2^0 or 1
10	2^1 or 2
100	2^2 or 4
1000	2^3 or 8
10000	2^4 or 16

Binary Coded Decimal Notation

One of the disadvantages of the binary notation is that the larger the numbers the more difficult it is to convert from decimal to binary or from binary to decimal. Even if this were alleviated, another serious limitation in using this notation for commercial purposes is that the arithmetic may produce different results, because of rounding off here and there through a calculation. If performed in binary, a calculation involving prices might be a cent or two different from the result of a calculation performed in decimal.

Accordingly, a method called binary coded decimal notation often is used to translate decimal digits individually into a binary code, keeping the decimal position or column unchanged. Thus, 57 would be translated as 0101, 0111 in binary coded decimal notation.

Computers such as the IBM 1401 utilize binary coded decimal notation in the form of a seven-bit alphanumeric code. Numeric, alphabetic and special characters are represented using seven positions in binary notation. Each set of positions is divided into three groups: one check position, two zone positions, and four numeric positions. The numeric digits zero though nine are represented in binary coded decimal form by the four numeric positions, which are assigned the decimal values of eight, four, two and one. Zero is represented as 1010, which is actually the binary number for ten. This eliminates the situation of no pulse pattern for zero. The two zone positions, B and A, are used in conjunction with the numeric bits for representing alphabetic and special characters. The B and A bits provide three possible bit combinations: 10, 01 and 11. These zone bits are not present (00) when the numeric digits zero through nine are represented. The C position, a check bit, is used for code checking only.

Table 6 illustrates the more commonly used codes.

Some Other Codes Used

Modifications of binary or binary coded decimal notation can be used to advantage in computer systems. One of the codes used is the two-out-of-five fixed count code. Five positions of binary notation are assigned the values of zero, one, two, three and six. Decimal values in the basic code are represented by bits present in only two of the five positions. Total number of possible combinations is 10, or one for each decimal digit. To avoid the situation of no pulse pattern for a character, zero is represented by the 1-2 bit combination. Alphabetic and special characters are represented as two digit numbers. One of the main advantages of this system is that each digit transferred in data processing operations can be tested to assure that it has exactly two bits.

Another binary method used by International Business Machines Corp. is the six-bit numeric code. Six positions of binary notation are divided into three groups: one check bit, one flag bit, and four numeric bits with the assigned values eight, four, two and one. The 10 decimal digits are represented in binary coded decimal form using the four numeric bit positions. The F (flag) bit is used to indicate special conditions, such as the sign of a numeric data field, and the C bit is used for parity checking.

Among the other coding systems used, the Excess Three Notation (XS-3) is advantageous because it facilitates the subtraction operation within the computer. In this system, each decimal digit is coded as that decimal digit plus three. The code for nine minus any digit is that digit with the ones replacing zeros and the zeros replacing ones. Thus, zero is 0011 and nine is 1100; two is 0101 and seven is 1010. The ease with which the computer can get these complements tends to simplify subtraction.

Table 6. Numeric and Alphabetic Use of Codes

A. Numeric

Decimal	Pure Binary	IBM Seven-Bit Binary Coded Decimal	Two-out-of-Five Fixed Count Code	Biquinary	Univac XS-3 Notation
	Place Value 8 4 2 1	Place Value 8 4 2 1	Place Value 0 1 2 3 6	Place Value Bin. Pos. Quin. Pos. 0 5 0 1 2 3 4	Place Value 8 4 2 1
0	0	1 0 1 0	0 1 1 0 0	1 0 1 0 0 0 0	0 0 1 1
1	1	0 0 0 1	1 1 0 0 0	1 0 0 1 0 0 0	0 1 0 0
2	1 0	0 0 1 0	1 0 1 0 0	1 0 0 0 1 0 0	0 1 0 1
3	1 1	0 0 1 1	1 0 0 1 0	1 0 0 0 0 1 0	0 1 1 0
4	1 0 0	0 1 0 0	0 1 0 1 0	1 0 0 0 0 0 1	0 1 1 1
5	1 0 1	0 1 0 1	0 0 1 1 0	0 1 1 0 0 0 0	1 0 0 0
6	1 1 0	0 1 1 0	1 0 0 0 1	0 1 0 1 0 0 0	1 0 0 1
7	1 1 1	0 1 1 1	0 1 0 0 1	0 1 0 0 1 0 0	1 0 1 0
8	1 0 0 0	1 0 0 0	0 0 1 0 1	0 1 0 0 0 1 0	1 0 1 1
9	1 0 0 1	1 0 0 1	0 0 0 1 1	0 1 0 0 0 0 1	1 1 0 0

B. Alphabetic

Check Bit	Zone Bits		Numeric Bits			
C	B	A	8	4	2	1

Bit Positions, IBM Seven-Bit Alphanumeric Code

One Digit					One Digit				
0	1	2	3	6	0	1	2	3	6
1	0	0	0	1	1	1	0	0	0

Letter A in Two-out-of-Five Code

One Digit							One Digit						
0	5	0	1	2	3	4	0	5	0	1	2	3	4
0	1	0	1	0	0	0	1	0	0	1	0	0	0

Letter A in Biquinary Code

WORD FORMAT IN COMPUTERS

Use of a digital data word format in which characters can be represented in binary or binary coded decimal form is illustrated below. A word in this format consists of 27 bits: 24 for data, one for sign, and two parity bit positions. Each word can store either six 4-bit numeric digits and a sign; four 6-bit alphanumeric digits (the sign is not used); or a 24-bit binary number with a sign.

Table 7. Word Formats

DIGITAL DATA WORD FORMAT

Six 4-bit numeric digits along with sign constitute a digital word.

DIGITAL WORD*	S	DIGIT 6	DIGIT 5	DIGIT 4	DIGIT 3	DIGIT 2	DIGIT 1
	25	24 20	19 17	16 13	12 9	8 5	4 1

S — Bit 25 indicates the sign.
Digits — 6, 5, 4, 3, 2, 1 — Each digit is expressed in XS-3 Form.

ALPHA-NUMERIC DATA WORD FORMAT

Four 6-bit alpha-numeric digits constitute an alpha-numeric word.

ALPHA-NUMERIC*	S	DIGIT 4	DIGIT 3	DIGIT 2	DIGIT 1
	25	24 19	18 13	12 7	6 1

S — Not used.
Digits—4, 3, 2, 1—Each digit is represented by 6 bits.

BINARY DATA WORD FORMAT

The entire 24-bit data portion of any memory location can be used to represent a binary value ranging from 0 through plus or minus 16, 777, 215.

BINARY WORD*	S	24 - BIT BINARY NUMBER
	25	24 1

S — Bit indicates the sign, 1 for minus and 0 for plus.

Two parity-bit positions are omitted for illustrative purposes.

COMPUTER ARITHMETIC

Binary Arithmetic

The value of zero in binary is always zero in decimal. The value of one in binary, however, doubles as it is shifted to the left. In the same way the value of a digit in the decimal system is multiplied by 10 if it is shifted one column to the left. Examples of binary arithmetic are shown in Table 8.

Table 8. Binary Arithmetic

Binary addition is as follows:

0 plus 0 = 0

0 plus 1 = 1

1 plus 0 = 1

1 plus 1 = 10 (that is, 0 and 1 to carry)

Other examples:

1 plus 1 plus 1 = 11

11 plus 1 = 100, etc.

Binary subtraction is as follows:

1 minus 1 = 0

11 minus 1 = 10

10 minus 1 = 1

Binary multiplication is as follows:

0 times 0 = 0

1 times 0 = 0

0 times 1 = 0

1 times 1 = 1

More examples of binary multiplication:

10 times 10 = 0100

11 times 11 = 1001

Binary division is performed like decimal division, using subtraction and quotients. An example is:

$$
\begin{array}{r@{\,}r}
 & 11 \\
1011 \,\big)\!\!\! & \overline{100001} \\
 & \underline{1011} \\
 & 1011 \\
 & \underline{1011}
\end{array}
$$

Floating Point Arithmetic

Most general-purpose computers are designed to incorporate a floating decimal point feature for scientific and engineering calculations. The principle of this arithmetic shortcut applies in both longhand and computer calculation. To the mathematician, a number with many places, such as one billion, is easier expressed as 10^9 rather than 1,000,000,000. The following is an example of a multiplication problem in decimal notation, done first in longhand and then with the floating decimal principle:

Longhand	Floating Decimal
25,000,000	2.5×10^7
x 2,500	x 2.5×10^3
12,500,000,000	6.25×10^{10}
50,000,000	or
62,500,000,000	62,500,000,000

The floating point method is much simpler. Numbers other than 10 are multiplied, but the exponents of 10 are added. No carrying of zeros is necessary. The mathematician thinks of one million as 10^6, and not 1,000,000.

Language In Data Processing

In any data processing system, a unit performing one operation must be able to accept, act upon and pass along information which was previously produced and processed by another unit. Again, at a given point in the system this information must be made intelligible to the people using the system. The means by which information is passed from one machine to another or to a human being is called language.

Communication between machines of varying language, as between people of differing nationality, is possible through a form of translation called conversion of code. Punched cards can be converted to magnetic tape, paper tape to magnetic tape, and so on. These steps cut down efficiency and increase costs. It is self-evident that a common language is of prime importance.

Common language is the standard language used by nearly every piece of equipment and is, therefore, understood without need of conversion. One example is the five-level code punched paper tape. Another is the banking industry's MICR (magnetic ink character recognition). COBOL (Common Business Oriented Language) is a programming common language. Magnetic tape is still another form.

Common Language In Punched Cards

Punched cards are considered to be common language since all equipment is now designed to read both 80 and 90 column cards. Until a few years ago the difference in coding by square and round holes created a language barrier between the equipment of IBM and Univac which could be overcome only by translation.

The IBM code, originated by Dr. Herman Hollerith in the late 1800s, uses 80 vertical columns, each containing 12 positions. The Univac code, designed by James E. Powers in 1908, has two horizontal tiers, called upper and lower registers, in each of which there are 45 columns, (90 in all) each column containing six positions. The original Powers tabulating card carried only one register of 45 columns of 12 positions each or only slightly more than half the capacity of the Hollerith card. The innovation of two registers gave the Power Accounting Machine Co. a competitive advantage at the time it was introduced since it gave them 10 columns more than their competitor. (See Fig. 1)

Common Language in Paper Tape - Five-Level Code

Five-level punched tape is a paper strip 11/16ths of an inch wide with a series of perforations in five rows or tracks along the length of the tape. If the rows are visualized as horizontal and the columns as vertical, each column will contain a combination of holes and no-holes which will designate a letter, a number or a symbol.

Origin of the 5-Level Code Punched Paper Tape

The 5-level code has been in use since it was introduced in 1870 by Jean Maurice Emile Baudot (1845-1903) of the French Ministry of Posts and Telegraphs. The code has become the common language used by record communication companies all over the world. Printing telegraph machines have been able to understand each other ever since it was

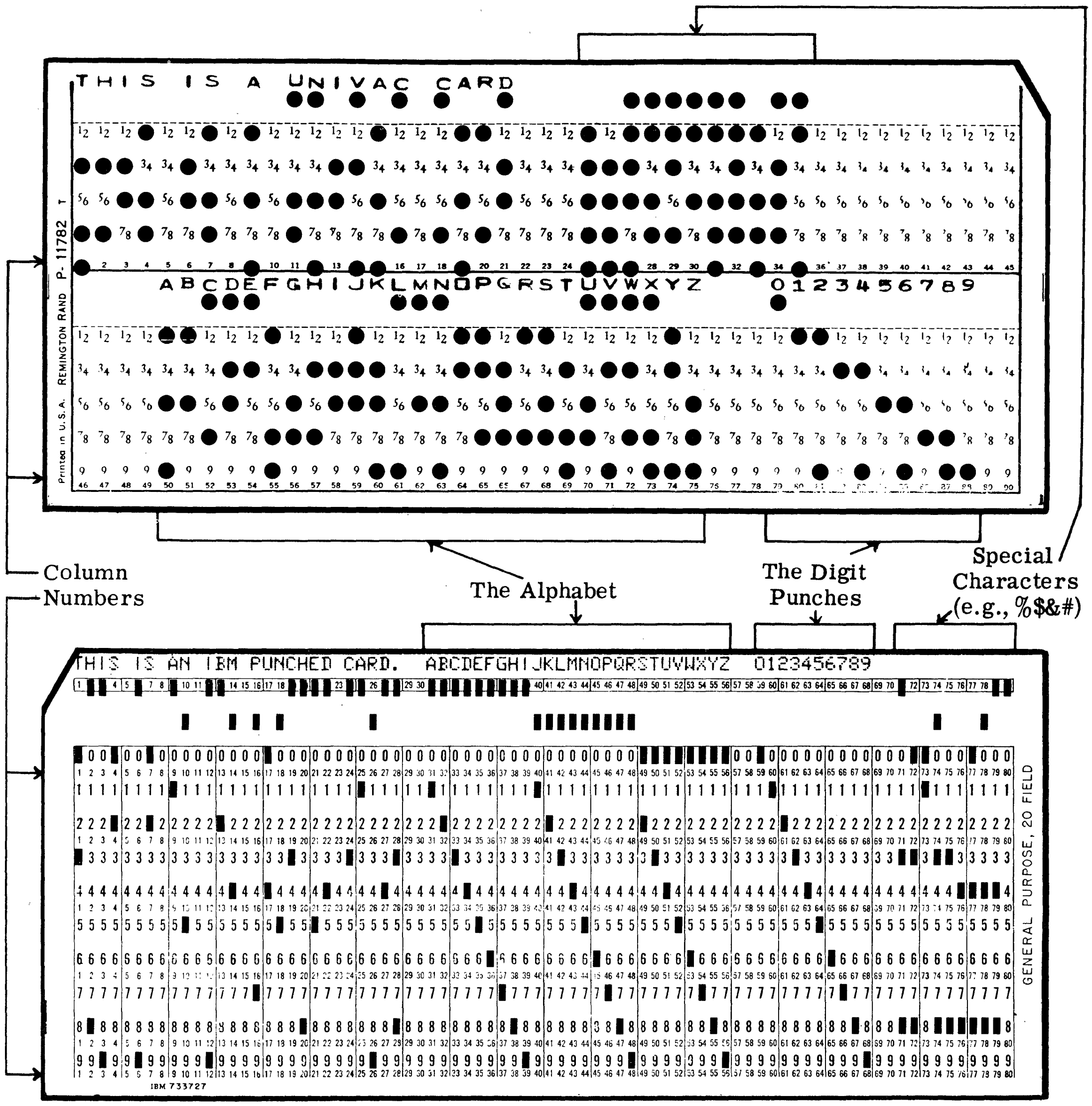


Fig. 1. This illustration shows the two tabulating card codes which are in general use as input for computers and tabulating equipment. Similar codes appear in smaller cards which have fewer columns but which use the same codes illustrated here.

introduced. They all use the same 5-level code and the same style of paper tape. This applies to such domestic equipment as the Teletypewriter of Teletype Corp. and the teleprinter of Kleinschmidt Div., SCM; also to the Creed teleprinter made in England; the Olivetti machine of Italy; and the Lorenz and Siemens Halske printers of Germany.

In the early days of telegraphy, from 1837 (date of Samuel F. B. Morse's invention) to 1870, all transmission and reception of signals took place over open-wire land circuits with the hand key sender and sounder. This crude but inexpensive apparatus was still in limited use in remote rural areas until a few years ago. There were two disadvantages to manual sending and receiving: first, the telegraph operator had to know Morse or some other code to translate the dots and dashes being transmitted; and secondly, telegraph lines were too expensive to justify the slow speed of manual sending.

Baudot's solution was to prepare a punched paper tape on a machine equipped with a keyboard. This was done independently of the transmitting operation. Later, the 5-level tape could be fed into a transmitter connected directly to the line. The transmitter automatically converted the punched holes into familiar telegraph signals. This operation ("off-line" as opposed to "on-line") allowed faster transmission and hence more economical use of the valuable telegraph line. At the other end of the line, a machine similar to an electric typewriter received the signals, translated them, and printed out the results.

This was a big step forward in telegraph practice. In addition to the data transmission speed being increased, operators no longer needed training in Morse or any other code.

The same principles of operation are still in use throughout the world, both for land and radio telegraph circuits. Improvements in equipment and circuits have, of course, increased speed and reliability.

The tape itself has been improved to make it serve also as a printed document when necessary. Clear printing over the punched holes is impossible, but by adding 5/16ths of an inch to the width of the tape, a printing surface devoid of holes is made available. Another kind of tape has holes that are not punched all the way through the tape, so that no chad or confetti is produced. This chadless tape can be imprinted directly in the code areas.

From the telegraph point of view, the 5-level code is the shortest possible. It gives the utmost feasible use of telegraph line time. It is well adapted to the principle known as "multiplexing" or the sending of more than one message over the same line at the same time, using different non-conflicting electrical properties of the line.

The word "channel" in communications terminology means one of a number of simultaneous message paths over one circuit or one carrier frequency. For this reason the terms "5-unit code" or "5-level code" are less confusing than "5-channel code," although the last description is commonly used.

The following illustrations show a sample 5-level code punched paper tape, two methods of printing on the tape, and a chart of the complete code:

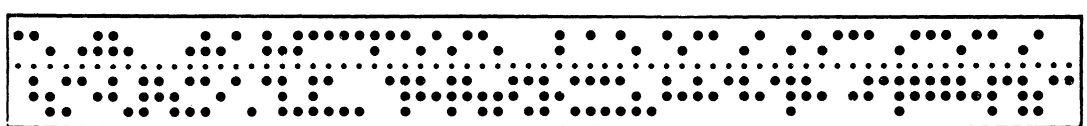


Fig. 2. This fully perforated five-level code tape is in the same code used by Baudot in the late 1800s. The smaller holes, not part of the code, fit onto the teeth of a small sprocket which advances the tape through the recorder and transmitter.

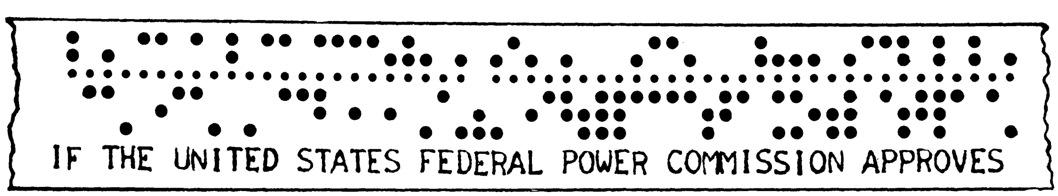


Fig. 3. The full-inch perforated tape, which provides an additional 5/16 of an inch for imprinting, makes it possible to combine complete perforation with straight line printing.

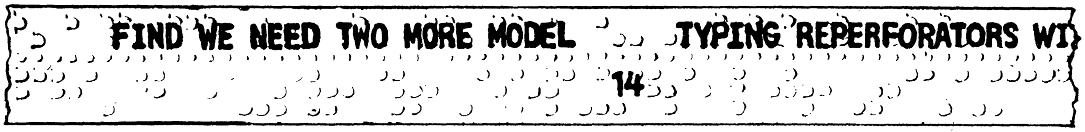


Fig. 4. Imprinting in the coded area of a chadless tape is shown here. Notice that numeric characters appear on a lower register. This is due to the shift arrangement of the code itself. Also note that all alphabetic characters are in capitals.

FIGURES	-	?	:	$	3	!	&	£	8	'	(	)	.	,	9	0
LETTERS	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
	1	1		1	1	1				1	1					
NUMBERS	2		2				2		2	2	2	2				2
INDICATE	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
MARKING			3			3		3	3		3		3	3		3
IMPULSES		4	4	4		4	4			4	4		4	4	4	
		5					5	5				5	5		5	5

FIGURES	1	4	BELL	5	7	;	2	/	6	"	BLANK	LETTERS	FIGURES	SPACE	C.R.	L.F.
LETTERS	Q	R	S	T	U	V	W	X	Y	Z						
	1		1		1		1	1	1	1		1	1			
NUMBERS	2	2			2	2	2					2	2			2
INDICATE	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
MARKING	3		3		3	3		3	3			3		3		
IMPULSES		4				4		4				4	4		4	
	5			5		5	5	5	5	5		5	5			

Fig. 5. This chart indicates the codes used in the five-level format for each letter, number and symbol. The two shift codes are in the fourth and fifth columns from the right and are marked "letters" and "figures." These are used to shift to printing numeric characters and punctuation marks, and to shift back to alphabetic characters. There are 32 possible combinations of holes and no-holes in the five-level code. The letter A or hypen is expressed by a punch in track one and track two, for example. The letter B or a question mark is coded by punched holes in tracks one, four and five and so on. Since there are 32 possible combinations and 26 letters of the alphabet, six combinations can be used for instructions.

Codes Using Six, Seven and Eight-Level

Other codes with six, seven or eight levels are less widely used in telegraph transmission but have come into prominence for data transmission, automated typesetting and numercial control. (See Fig. 5).

One of the main advantages is in the control of errors that may arise in transmission. For example, the seventh position can be used for checking if the convention is adopted that the total number of holes in each column shall always be odd. The seventh position will therefore contain a hole if the number of holes in the remaining six positions is even, but will contain no hole if the number is odd. In the transmission of data to electronic data processing systems, where the information cannot be checked by the human eye, as with a telegram, self-checking codes are of prime importance.

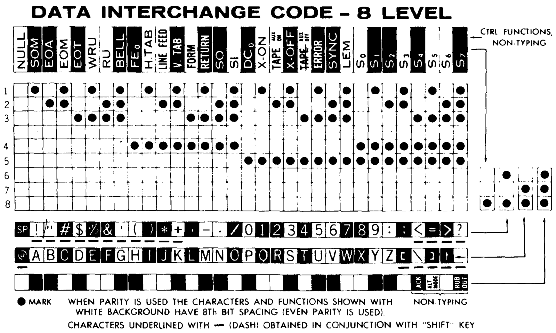


Fig. 6. This chart illustrates the 8-level code used for data interchange. Note that the code used in the upper five levels differs from that used in the Baudot code. The code indicated at the right in the above chart is used in conjunction with the basic code to produce characters or for checking purposes as indicated.

Common Language in Magnetic Tape

Metal or plastic tapes, on which magnetized bits have been recorded in code, were once used only in computer equipment. They are now used for data transmission over telephone or telegraph lines directly to other magnetic tapes or to a converter which produces paper tape. Computer generated magnetic tapes are used in numerical control systems for programming purposes. Magnetic tapes can be used interchangeably from one computer system to another when the programming is acceptable to the receiving system or can go directly to a memory system.

Most codes by which the magnetized bits form the numbers and letters are based on the binary counting system which is described in the chapter on Computers and Arithmetic Systems. As in the Baudot and other punched paper tape codes, the combinations of bits and no-bits in any given column determine the character represented by the code. Presence of a bit activates a switch to permit passage of current --- absence of the bit, of course, leaves the switch open.

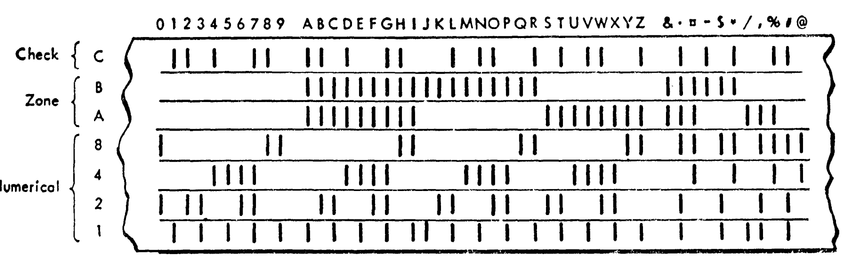


Fig. 7. Here is a 7-level code used for magnetic tape. The dashes indicate the presence of a magnetized bit which is not discernable to the naked eye unless the tape is dipped into a solution containing powdered metal. This leaves a deposit on the magnetized areas which reveals the coded characters as indicated in this diagram.

Common magnetic tape recording densities are 200, 556, 800 and 1,000 characters per inch. Advances in self-clocking magnetic tape properties have enabled the pulse-packing density to go as high as 2,000 and 3,000 characters per inch.

Magnetic tape data transfer speeds range up to 500,000 characters per second although the speeds generally used in business applications are much lower.

MICR (Magnetic Ink Character Recognition)

Two codes, known as E 13B and CMC 7, are in use for sorting documents. The first of these, a code consisting of bars and spots, was developed under the aegis of the American Banking Assn. in the early 1950s and is in common use throughout the United States. The other system (CMC 7) is a European development consisting of vertical bars spaced to produce a code in numerical formats which more closely represent the usual Arabic numbers than the E 13B. The International Standards Organization's attempts to standardize on one or the other code produced documented arguments on both sides of the Atlantic, each extolling the virtures of the native system.

All codes used in electronic data processing are under continuous study of the American Standards Assn. and the International Standards Organization in their efforts to establish more efficient world wide communications. For example, in 1964 standards were recommended to the ISO for MICR character sizes and shapes and for six-bit and seven-bit character codes. Recommendations of this sort are subjected to painstaking scrutiny by the several national committees involved. When finally accepted by ISO these standards speed up international interchange of information.

Operations Research, born of military necessity prior to World War II, has moved into industry to such an extent that large corporations now recognize it as a separate department, responsible, to a greater or lesser degree, for solving entirely new types of problems brought about through electronic data processing. It was another application of electronics --- the radar system --- which spawned the new science. Human and technological problems which arose during early investigations into the use of radar, gave the philosophy its name because research was necessary to devise operational use of the systems.

British armed services, under whose aegis Operational Research began, soon established O/R sections in all three branches. United States, in 1942, decided to introduce the science to its own military services.

From this point onward, progress of O/R as a science has been almost phenomenal, largely because the advent of office computers and automation brought so many problems which were beyond the knowledge and experience of the business and industrial community.

The subject is complex --- so much so that executives frequently have avoided it because their busy schedules allow little time for the hours of study required to get even a superficial understanding. The result of this has been the publication of numerous tracts and books prepared either by authors interested in mathematics or mathematicians who sought to be authors. Some of these have been successful in a degree relative to the time and talent the reader could bring to the subject.

Perhaps the best of them is a small booklet published by Honeywell Electronic Data Processing Div., Wellesley Hills, Mass., called Operations Research For The Executive. With minor editing for style conformity the booklet, through the courtesy of the Honeywell organization, forms the basis of this chapter in INDUSTRIAL DATA PROCESSING APPLICATIONS. The revised text follows:

Operations Research Made Simple

Simply, Operations Research is the application of mathematical techniques of operational problems, providing management with factual, quantitative reports on the relative merits of all potential courses of action.

That's O/R - simply - and the purpose of this chapter is to give some ideas or general concepts of O/R by treating it as basically as possible. A fundamental treatment of a subject as complex as O/R naturally sacrifices some detail and, therefore, definition. However, this chapter should give a "general" concept of O/R to dispel any confused, inaccurate impression which may now prevail.

Consistent with this goal, basic definitions and basic examples are used with the hope that you'll profit by this reading.

Operations Research For The Executive

We make decisions every day. Facts are gathered, identified, arranged and assigned relative weights. But even after long and careful evaluation, the decision is often a gamble carrying Russian Roulette odds - and consequences. Speaking of the hit-or-miss nature of decision-making today, one executive recently said: "I get Lilliput under my thumb, make a decision, then Gulliver stands up." Another said that he slept well at night if he got more than 55% of his decisions right the first time.

These and similar comments chorus the same theme: decisions are tougher today than ever. Not only are the factors involved in a decision increasing in number but they're more complicated in nature, thanks to the very same highly efficient, interrelated industrial organizations we ourselves have created. After the decision has been made, it generates countless ripples. This means that the effects of incomplete, off-center or wrong decisions can be expensive. Operations Research is a tool for aiding the process of decision-making.

What is Operations Research?

Operations Research involves the application of mathematical techniques to the front-line, nuts-and-bolts problems of commerce and industry, operational problems as diverse as, but not restricted to, labor distribution, profitable inventory levels, price quotations, production planning and securities purchasing. It consists of collating all available data on a problem and providing management will factual, quantitative reports on the relative merits of all potential courses of action. The final decision can then be made by management in the knowledge that due weight has been given to all relevant facts.

More specifically, Operations Research involves:

(1) Statement of the problem involved.

(2) Collection of relevant data.

(3) Analysis of data to provide a model of the real-life situation, and checking the validity of the model.

(4) Manipulation of the model to estimate what will happen under varying circumstances.

(5) Selection of the optimum course of action.

(6) Continuing check on the validity of the model in the light of fresh data.

Let's apply this O/R methodology to an actual problem taken from our section on Queuing Theory. The problem (1) is to reduce the productive time lost by workers while waiting in line for parts. The information (2) we need consists of the average number of men arriving at the line (per hour), and the time required to service them. This information is the basis of our model (3) which, by use of a queuing formula, provides us with the average line length per hour, the average waiting time per man, and the average total manhours lost per hour. By (4) further calculations, we find the loss reduction to be gained by adding one and two (or more) men. We then select the best course (5). If, some time later, a production increase brings longer lines, we'll want to (6) check the model to make sure that our choice is still the most profitable.

Computerized Operations Research

Operations Research takes on a new dimension with the computer because it can now be applied to an extent previously prohibitive in time and costs. For one thing, all the data you need for problem-solving may be quickly accessible and computer-ready as a by-product of such routine computer operations as billing, inventory or accounts receivable. Capability is another factor. The worth of any O/R solution is directly related to the percentage of factors taken into consideration. As a problem becomes more complex, the problem-solving procedure grows more lengthy and costly using human effort, so we often economize by oversimplifying the problem and excluding all but the most important factors. In so doing, we may arrive at solutions that are far less than optimal. Using a computer, however, a great number of factors can be handled, and manipulated at electronic speeds.

OPERATIONS RESEARCH TECHNIQUES

There are many different types of operational problems, the nature of any one of which lends itself more (if not exclusively) to one particular problem-solving technique rather than another. On the following pages, you will find a basic description of six of these techniques (Linear Programming, Queuing Theory, Theory of Games, Dynamic Programming, Statistical Analysis and Simulation) and the problems to which they apply.

Linear Programming

Linear Programming (LP) is a mathematical technique whereby the best allocation of limited resources may be determined by manipulation of a series of linear equations. Each factor in the problem is evaluated against all other factors and in relation to the long range goals, yielding optimum paths of action for management consideration.

All of us use informal linear equations to solve even our simplest personnal allocations, whether planning our day (time) or our household budget (money). As O/R specialists, we would construct our problem in terms of a "criterion function", an algebraic linear equation which is to be maximized or minimized, and a set of constraints - linear equations representing factors which act upon the criterion function. In terms of planning our day, our criterion might be happiness, which would be a function of leisure time and earned income. Two constraints are involved: the amount of time available (24 hours) and the minimum amount of money we can afford to earn. We assign values to money and leisure time and, by running through a series of linear equations, arrive at the combination of both that will bring us the most happiness. This is often a fast, unconscious procedure. It is also relatively simple, unlike the operational problems to which LP is applied. Take the following steel-slitting problem for an example.

The problem is to slit standard-sized rolls of steel into various widths and quantities for delivery to customers. The objective is to minimize trimming waste; or, putting it in terms of our previous definition, find the most economic allocation (slitting arrangement) of a limited resource (steel rolls) to competing demands (different widths).

Naturally, as the variety of desired widths becomes greater, the number of possible slitting combinations increases, and the problem becomes more complex.

In determining these combinations, we have to consider the width of the original roll, the maximum number of slit widths in one roll, the specific widths on order, and the maximum allowable trim loss. These combinations can easily run into the hundreds. Then, once they are determined, the combinations that will best satisfy the quantities ordered and minimum trim loss must be established.

Generating all possible combinations, and then proceeding to find the best, could require several manhours or even days; or, all of these factors can be reduced to a mathematical equation, incorporated into an LP program, and run off on a computer in a matter of minutes. The result is vital information for management decisions; significant reductions in trim loss, inventory and lead time - greater profit margin.

Following are just a few more problems to which linear programming has been successfully applied:

Transportation -

Given a large number of warehouses with limited capacities and a large number of distributors with known demands, linear programming enables the design of a shipping schedule that will minimize total costs.

Product Mix -

Given a set of raw materials with given characteristics and given a set of market prices for finished products, linear programming will indicate how these raw materials should be combined to produce the highest possible profits for the company. Blending of gasoline is an example of this type of application.

Advertising Budgets -

Given a restricted advertising budget and estimates about the effectiveness of an advertising dollar when applied to a particular medium, linear programming aids in the design of a total advertising program that will maximize advertising effectiveness.

Queuing Theory

When a flow of goods (or customers) is bottlenecked at a particular servicing point, losses accumulate in the form of lost business, idle equipment, and unused labor. Minimizing such costs involved in waiting lines, or queues, is the object of Queuing Theory, an O/R technique for the most efficient handling of a line at a particular point of service.

For example, what is the expected length of a line when 29 workmen arrive randomly each hour at a toolstore where the storeman takes an average of 2 minutes to serve each man? Queuing Theory predicts that the line will settle down to an average length of 28 men and an average wait of 58 minutes. In each hour, then, there will be 28 manhours lost in waiting. Further calculations show that one extra storeman will reduce the average line to 0.28 men, releasing 27.3 men for productive work. Adding a third man, however, would only cut the average length to 0.04, and might not be justified when weighing the third man's salary against the production time gained.

You can find inumerable other queuing problems. For instance, buffer stocks are a queue of components waiting for machining. Warehouse stocks are a queue of finished goods waiting for customers. Aircraft stacked above an airport waiting for landing directions form another queue.

Many queues can be handled by computerized mathematical analysis. In other cases, they are better handled by simulation techniques which effectively recreate the queuing situation on a computer to show what happens. Simulation is particularly useful where the queue is not steady, as in a canteen faced with the need to serve lunch to a large number of workers in the shortest possible time. Simulation might also be applied to such difficult queuing situations as public transport and refuse removal, cyclic systems where the output from one queue forms the input to the next, and impatient customers who refuse to queue.

Game Theory

Game Theory is a mathematical theory dealing with decision-making in a competitive situation and therefore has definite possibilities in the business area. The theory assumes a competitive situation in which both parties are active and have an effect on the final outcome. The object is to arrive at an optimal course of action by consideration of all possible moves and chance happenings.

For example, Games Theory provides a guide to the price level at which a bid for a contract should be submitted to achieve the maximum probable profit. If accepted, a high bid yields a high profit, but the chance of acceptance is low, so that a very high bit offers little hope of profit. Similarly, a very low bid ensures a high probability of securing the contract - and of taking a loss. Somewhere between these extremes lies the optimum bit as predicted by the theory of games. Knowledge of your competition, his resources, and his bidding pattern is extremely helpful.

It should be noted that game theory is, as yet, a new and comparatively academic technique that serves primarily as a guide in thinking about competitive situations rather than as a tool for arriving at specific courses of action.

Statistical Analysis

Statistical Analysis can be described as the technique of using statistical methods to squeeze the maximum information from available data. Expressed in another way, statistical analysis is a method of obtaining the same information from less data. Where data are costly to obtain, important economies may result. The computer's ability to extract the maximum information from data means that small and inexpensive trials can often provide all the answers required by management. Pilot trials can be run to determine the effect of a particular change before that change is applied throughout the organization.

The best known application of Statistical Analysis is quality control. Statistical Quality Control is based on techniques for determining precisely when manufacturing tolerances start to drift out of control so that corrective action can be taken. Since the cost of inspecting a mass-produced finished item often approaches or exceeds the cost of manufacturing, sample inspection offers the most economical solution. Statistical theory provides the information for designing the sample, that is, its size and the manner in which it should be taken. It furthermore aids in the analysis of the sample and indicates the size of the risk that is associated with the acceptance or rejection of the lot on basis of sample information. An operation analyst when designing a quality control system of this type would take into consideration such factors as the cost of inspection, the cost of sampling, and the cost associated with the shipment of a defective item. He would, in short, not just limit himself to the statistical aspect of the inspection problem, but would consider the whole cost structure that would be influenced by his particular plan.

A few other uses of statistics in operations research are the design of inventroy systems and the planning of production and employment. An essential component of these activities is the capability of forecasting future demand, for which statistical theory provides some techniques. A manufacturer of thermostats may have a hunch that his sales are lagging behind the issuance of building permits by about six months. Statistical theory can assist in testing his hunch and, furthermore, will indicate how much his sales variations are likely to be, given the variations in the issuance of building permits.

The application of statistical techniques frequently require a considerable amount of computations especially when the problem under consideration is complex. For instance, in our sales forecasting example, computations would be increased significantly if the manufacturer wanted to refine his forecast by basing it not only on building permits but also on lumber and brick sales in his area or on aggregate income statistics. While very simple problems can be handled by desk calculators within a reasonable time period, more complicated problems require the services of a computer.

Dynamic Programming

The essence of Dynamic Programming is that an optimum decision must be made at every stage of a multi-stage problem. When considering only a single stage, there may appear to be a number of different decisions of equal merit. Only when the effect of each decision at every stage on the overall goal is determined can the final choice be made. This integration of the cumulative effect of the path of decisions through each stage of the network is the real essence of DP.

DP can be simply illustrated by the problem of finding the best route between two points. A motorist normally solves this problem in stages. First he decides that there are, in this instance, four possible intermediate places at which he may lunch. He determines the optimum routes from his starting point to each intermediate place. He next establishes the optimum route from each possible lunch stop of his destination. The shortest total length (or time) for a journey then determines which is the best intermediate point to choose.

Many problems encountered in business life are of the multi-stage type for which DP and the computer are finding ever-increasing application. One such is the problem of investment, replacement and maintenance of equipment, where decisions of capital equipment must be made at regular (often annual) intervals.

The general problem of investment is to decide whether or not it is economical to expend capital on carrying out a process cheaper and/or better. The general approach is to compare savings in running cost given by a new machine against the amortization cost of the necessary capital expenditure. As a machine wears out and decreases in efficiency, its running costs go up and the advantages of replacement increase. In general, a new machine should be purchased when current maintenance and depreciation costs for the old machine exceed the minimum annual cost for the new machine (taking into account production savings where appropriate). All these things and sundry others must be considered in your decision.

The very fact that you're large enough for a computer implies that you're also large enough to have complex multi-stage problems requiring computerized Dynamic Programming.

Simulation

It has been said by one statistician that if you cannot calculate, then simulate. This seems to relegate simulation to an underserved place as second-best. It's true that the sheer complexity of many problems makes mathematical formulation prohibitive (if not impossible) and simulation necessary. Still, even where a problem can be solved, mathematical analysis sets out to provide a general solution to all problems of the type being considered. Simulation manipulates only the data relevant to the problem in question and thus often offers a simpler and cheaper, though less general, solution.

Using this technique, a computer is programmed to simulate the behavior of the situation being studied. A typical example is the simulation of stock behavior to establish the optimum rules for inventory control. The computer is supplied with demands for a particular part or parts during successive periods, together with details of variations in lead-times, etc. Possible inventory control policies are fed into the computer which prints out the resultant response expressed in terms of average inventory level, stockouts, number of orders placed, etc. From this printout, it is possible to select the policy likely to give the best results under a given set of circumstances.

Realism demands that as many details in the problem as possible be considered. While this may be a major task, the advantages of accurately evaluating a policy in advance often overcomes the cost.

Data Transmission and the EDP System

Elements involved in data transmission may be divided into three general areas: circuits and networks; modulating-demodulating equipment for converting recorded digital or analog information to tones suitable for transmission over telephone lines; and the business machine terminal equipment.

Companies providing private line circuits or data communication service through a public network were once divided into two distinct categories -- voice communication telephone and record telegraph transmission. In the United States, the American Telephone and Telegraph Co. (the Bell System) and telephone companies such as General Telephone and Electronics, Inc., were in the first category. International communication firms like Western Union Telegraph Co., RCA Communications Inc. and International Telephone and Telegraph Co. were in the second group. The distinctions of service which once characterized these companies have practically disappeared. All of them now offer both voice and record transmission.

Most recent among communications firms is Comsat (Communications Satellite Corp.) which was formed under auspices of the Federal government to direct developments of Telstar, Relay and other satellites. The corporation, publicly-owned, has proven itself as an investment but full, commercial use of the orbiting relay stations is still in the future. There have been successful demonstrations and experiments in which the satellites have transmitted data and facsimile but, by early 1965, no regular pattern of utilization had been established.

Circuits and equipment from these carriers of telephone and telegraph messages are available to business or data, facsimile and voice transmission. The circuits may be classified according to frequency bandwidth. In general, the wider the band width the more expensive the rental. Narrowest band widths are used by telegraph circuits. These accommodate telegraph printers and other machines, such as the Friden Flexowriter, which use the 5-level code. Voice-grade circuits are needed for transmission of data in 5 to 8-level paper tape and punched cards. Facsimile transmission and rapid sending of data from such media as magnetic tape or computer core memories would require a wider voice-grade band width. Closed-circuit television would require an even wider band width.

In addition to providing circuits, the message carriers also lease modulating-demodulating units necessary for data/voice tranmission over voice-grade circuits. The most widely used of these is the Bell System Data-Phone data set. Terminal equipments manufactured by business machine companies utilize different models of these data sets.

The serial mode of transmission is basically the Baudot code which has been used in practically all data transmission equipment. In this system, the tape code is transmitted as a series of impulses; a high frequency is used for a blank and a low frequency for the bit. The code is read and stored in a buffer before being transmitted, then at the receiving terminal the bits are assembled in a buffer and fed to the tape punch.

The parallel mode of transmission uses two frequencies for each bit position in the tape code; one to represent a bit, and one to represent a blank. All code levels are transmitted simultaneously, eliminating the need for serializing and reassembly buffers. Since the parallel mode transmits each bit for number of cycles it is less susceptible to the noise hazards of the telephone line.

The various types of terminal equipment available allow transmission of information from punched cards, punched paper tape, magnetic tape, core memories of computers, keyboards and magnetic disks, as well as from handwritten messages and maps, charts and other image data suitable for facsimile transmission. Information can be received in the above media or as printed copy. Manufacturers such as IBM have devised configurations of terminal equipment in which the data received does not have to be in the same media as the data transmitted (e.g., data sent in punched card form can be received on magnetic tape).

Telegraph transmission, which has been around for a long time, provides printed output with which errors can be easily and visually detected. This is not true with data received in coded media. Without error control, a transmission error due to such conditions as a "knock in the line" could not be detected until it had caused trouble in the records. High speed and accuracy are of paramount necessity.

Most terminal equipment using voice grade circuits has some form of error control. Most common types are vertical and horizontal (or longitudinal) block parity. Detection is for the most part automatic, with correction both automatic and manual. Incorporation of these techniques has played a large part in the growing application of an established concept to the needs of modern business.

Introduction To Process Computers

Industrial processes fall into two broad categories -- discrete or continuous. Many manufacturing operations are discrete in that the manufacturing steps can be separated in time. For example, automobile production is a discrete process. The assembly of the engine need not follow the construction of the chassis or vice-versa. Although automobile production could be controlled by a computer it does not necessarily lend itself to control by a process computer.

In continuous processes such as petroleum refining, steel production, or the making of paper, process computers are used to control and regulate the variables inherent in the process. These variables may be temperature, pressure, voltages, etc. The process computer also has to compensate for outside disturbances such as ambient temperature.

In order to perform these functions the process computer has to take hundreds of readings concurrently, evaluate them instantly, and adjust controls as the process requires.

A process computer system as considered here is a combination of computer, associated hardware and real-time software. It is capable of receiving analog and digital input signals from the process, computing results concerning the process, and providing outputs to the process for controlling the operation. As a secondary function the process computer may also be used for certain business functions related to the process, such as inventory control, scheduling, dispatching, and preparation of invoices. The need for precise signal measurement in the presence of electrical noise, severe environment, 24-hour-per-day reliable operation, and unique programing considerations require a computer designed specifically for industrial process automation -- the process computer. It is a highly integrated hardware/software system, specifically for real-time on-line control situations.

Real-Time On-Line Control

Real-time for a process computer is typically seconds and milliseconds with occasional excursions into the microseconds region at one end and minutes and hours at the other end. The process computer system must be capable of responding to situations generated by the process or by the computer, and satisfy the demand without interjecting time lags or instability.

On-line implies that the process computer is intimately associated and connected with the particular process in obtaining and operating on information originated by the process or by the operator.

Control obviously applies to the manipulation of controllable elements in the process to produce the desired results. Reports to management and the operator on the process operation are implicit in any computer system.

Some of the important considerations in process computer design are reliability/availability, maintenance, process relationships, environment, process sensitivity, hardware/software relationships, speed, memory and programing. Some of these factors are considered in the design of all computers; however, the emphasis and objectives differ depending upon the particular application -- process, business, scientific.

Downtime Considerations

Availability is one of the most important characteristics of a process computer because downtime means so much more than just the cost of computer time. Process computers have a design objective for availability of at least 99.5 percent and are moving toward 99.9 percent. Achieving this kind of performance requires that both the number of failures and the average time to repair them must be held to an absolute minimum. Process computers use highly reliable components that have been proved in many years of stringent military applications. The number of components should be kept to a minimum by the organization of the computer. An efficient modular packaging system permits rapid restoration of service to minimize downtime.

Environmental Capability

As well as high availability, the need for continuous operation requires the process computer to withstand adverse physical environments and electrical stresses. In spite of the care normally used in providing well-regulated power and an acceptable atmosphere for the computer, abnormal operating occurrences can impose severe hardships for the computer. For example, the power system may suffer partial outgages or other problems causing poor frequency and voltage deviations, or the building air conditioning may fail. Design considerations in process computers must include such factors.

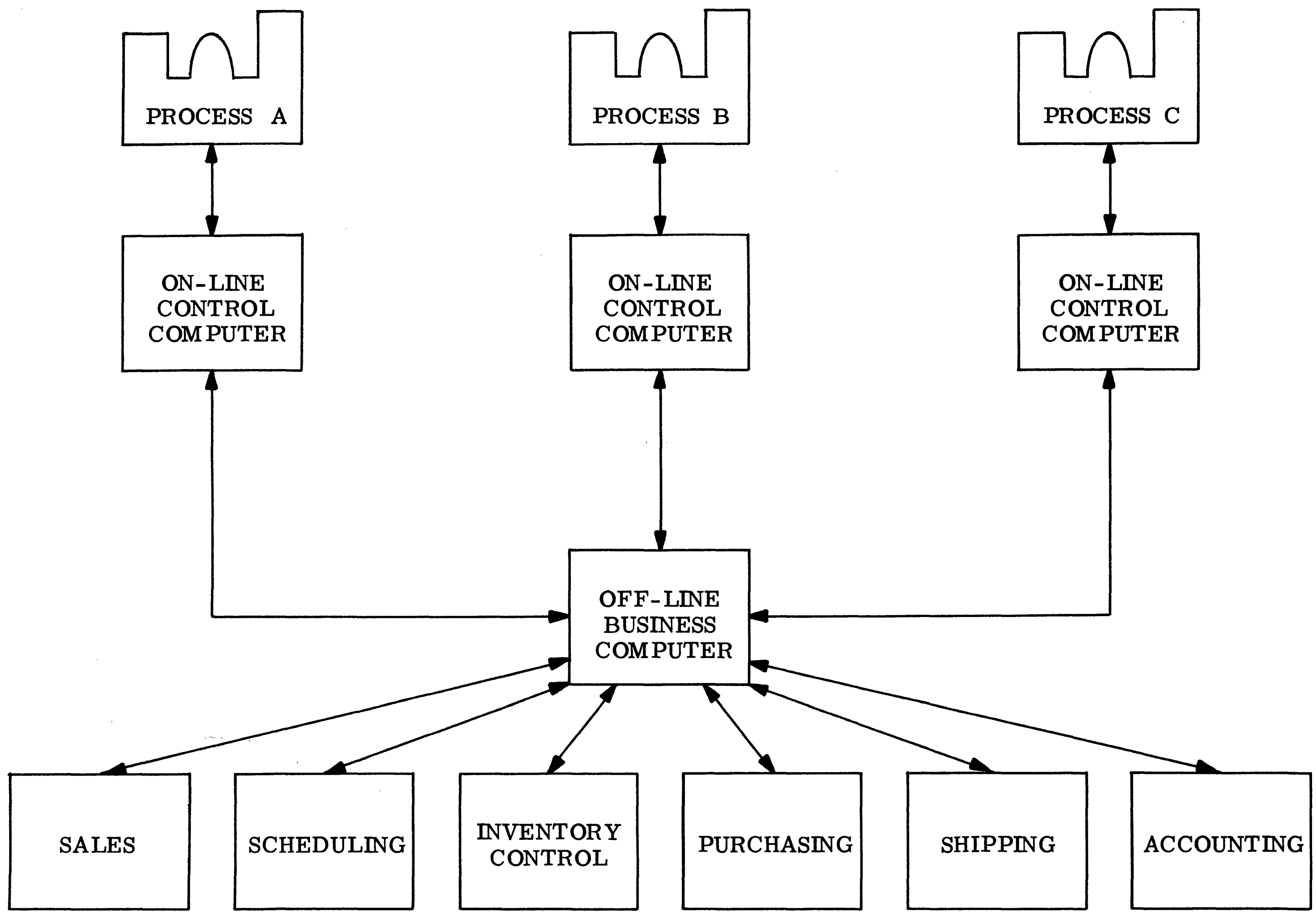
A significant consideration in overcoming these problems is the use of simultaneous "worst case" design criteria for the circuitry. Basically, this means that the circuitry will perform according to specification when all of the parameters (temperatures, voltages, etc.) are simultaneously at their worst conditions in relation to all other parameters. For example, process computers should be able to operate over a wide temperature range without air conditioning. With the wide ambient conditions and electrical stresses to which a process computer can be subjected, this provides an extra margin of safety on normal applications.

Maintenance

Since the majority of process computers are sold rather than rented or leased, they are exposed to widely differing maintenance requirements. Therefore, ease of servicing is an important factor and can be carried out by modular packaging. This approach puts the electronics in a single, easy-to-reach position and minimizes the amount of physical movement necessary to trace signals or to check various functional modules. The electronics are organized into functional groupings such as arithmetic unit, priority interrupt module, peripheral buffer, etc., with each functional module identified as to its use. Therefore, with the compact functional organization, relative ease of access, and high reliability, the maintenance time required is small.

Proximity to Process

Proximity to the process is important in a process computer because of the problems which arise with distance. If the computer system were remotely located, the long runs of leads from sensors to an analog scanner would introduce significant sources of measurement problems due to increased exposure to noise, ground loops, ambient temperature effects on cabling impedance, etc. While these factors can be overcome, they add significantly to the cost of the computing system and should be kept at a minimum. Using special equipment, it is possible to locate the analog scanner and computer output controller remotely from the central processor and communicate digitally between them. In this case the analog transmission problem is no greater, but new problems are created using digital transmission techniques in the form of additional equipment required to transmit and receive information.



PROCESS COMPUTER CONFIGURATION

In addition, the people who use process computers are operators and normally are located close to the process. With information input/output to the process and operator being the heart of a process computer, it would seem to defeat the purpose to do anything in this information flow to make it less reliable.

Major Functions of Process Computer Applications and Design

Sensitivity to the process in terms of ability to measure and monitor all of the significant characteristics, initiate control action and report on process operations are usually the major functions in process computer applications. Both analog and digital information must be brought into the system with high speed and accuracy. Similarly, the computer must output its commands to the process to improve stability, efficiency, quality, throughput, etc. Off-normal process conditions must be recognized and alarmed as they occur with corrective action taken in proper sequence within the process time constant. All of these areas dictate a system design which is oriented specifically to be "process sensitive." These areas, while mentioned individually, must also be considered in the design of the system and its components. New functions such as direct digital control impose changing philosophies on the designer.

Combining Hardware and Software

Both hardware and software are intimately involved in providing good sensitivity to the process. Hardware must accept many types of process and human inputs -- high and low level a-c or d-c signals, contacts, pulses, and output information in a variety of forms -- analog, momentary or time contact closures, pulses, hard copy, etc. The program must also be flexible enough to handle the variety of random occurrences in real-time without losing track of the process.

A process computer should integrate the design of hardware and software which includes analog scanning, digital scanning, automatic interrupts and digital or analog outputs. All of these functions generally operate in a buffer form to maximize the availability of the central processor. A program will do the organizing of all computer tasks and assure that all work gets done within the realm of real-time. This program should be sensitive to both real-time and process-time. Under either normal or emergency process conditions the program should perform its operations within the real-time of the process. When process conditions change, the program will change its priority assignments to meet the immediate process requirements in the order of their urgency without losing track of lower order requirements.

The nature of processes is such that they require emphasis on logical and arithmetic capability in a computer. Word rather than character organization, different commands and software packages facilitate programing. Logical operations are important in start-ups, batch operations, and other situations where action depends upon the on-off relationship of many parameters.

Flexibility

Equally important is the need for a process computer to communicate with business computers. Flexible input/output interfaces to other computers and peripheral equipment give this capability. To meet the needs of widely varying applications, flexibility of hardware is required and software must be available to operate in every different system organization. Functional modularity also increases flexibility. Independent building blocks designed as a family permit system to match system requirements. Modular compatible software is also used to facilitate system programing for various configurations.

In addition, features of a computer system are based on the needs of process computers. For example, circular list processing, which is implemented by hardware on some computers and by software on others, is included in the design because of the way process computer input/output programs are organized and executed -- to a large degree from lists.

Process Computer Programs

Process computer programs are characterized by the high degree of program regimentation and provision for accepting interrupts frequently. Real-time process computer programing requires a high level of program organization to insure that all of the work is accomplished and proper priorities are assigned to the tasks with changing conditions on the process. Inter-communication between programs is significant and time consuming. Information is constantly being stored and retrieved from small tables. Table storage and retrieval rates are asynchronous. When bulk storage is used, such as drums or discs, transfer between core and bulk can be a significant problem because of the completely random nature of many occurrences.

Programing Aids

Special programing aids are required for process computer work. Additionally, consideration must be given to aids which ease programing, simplify training, use existing programs, and aids which often must operate on-line. One of the languages used throughout industry for simplifying programs is FORTRAN. This allows a program to be written for real-time operation with provision for segmenting programs where necessary because of time or memory limitations. For control jobs requiring sequential operation such as turbine start-up there are other special program languages. These permit a programer to write control statements in a straightforward manner. This software is specifically designed for process control.

Process Computer Evaluation

Evaluating a process computer is obviously complex and has criteria which vary in weight from one application to another. The parameters defining a successful computer application cannot be as specifically delineated and quantitized as can a power transformer or even a business computer. Much emphasis must be placed upon the supplier, his experience and process knowledge, his breadth and depth of resources as well as on the specific hardware/software offering.

In this latter area, the evaluation should be on the specific application and probable future uses rather than on the broad features and performance specifications. These factors are of primary importance, although not necessarily in the order stated. In addition, factors such as expandability, total performance per dollar, system accuracy (including input, calculation, and output), training programs, and software support (i.e., debugging aids, library sub-routines) are also important when related to the application. Total performance embraces such factors as word length, memory utilization, instrument complement, and speeds, as they influence the tasks which a process computer must perform. One useful technique is to design a test problem embodying the key factors in the application and obtaining a figure of merit based on total performance per dollar.

In summary, these key items should be referred to in evaluation of a computer for use in an industrial process:

1. Supplier's know-how and dependability.
2. Cost/performance on applicable benchmark problem.
3. Software aids and their benefit in process work.
4. Industrial design.
5. Reliability accuracy.
6. Ease of maintenance.
7. Expandability.

This chapter on process control computers is based mainly on information derived from the booklet, What's a Process Computer, published by the General Electric Co., Process Computer Section, Phoenix, Arizona.

ACCESS TIME
The time interval between the instant at which information is: (a) called for from storage and the instant at which delivery is completed, i. e., the read time; or (b) ready for storage and the instant at which storage is completed, i. e., the write time.

ACCUMULATOR
A storage register which receives the sum from the adder. The actual electronic arithmetic operations are performed in the adder.

ACTION
A control action. That which is done to regulate the controlling element in a process or operation. The action ranges from "on" and "off" to derivative and rate types of action.

ADDRESS
A number which designates a register, a memory location or a device.

ADDRESS, ABSOLUTE
An operand address which: 1) is independent of the instruction address, and 2) specifies an operand whose memory address is also independent of the instruction address.

ADDRESS, EFFECTIVE (OPERAND)
The true operand (or memory address of the operand) of an instruction. See address modification.

ADDRESS, INDIRECT
An address of a location that contains the address of the operand rather than the operand itself.

ADDRESS, INSTRUCTION
An instruction's memory address. The symbol * is frequently used to designate this address.

ADDRESS, MEMORY
The address in memory of the location containing an instruction or operand.

ADDRESS, OPERAND
The contents of the instruction's address field.

ADDRESS, RELATIVE
An operand address which: 1) is independent of the instruction address, and 2) specifies an operand whose memory address is dependent upon the instruction address. The difference between the operand's memory address and the instruction address is a constant.

ADDRESS, TRUNCATED
An operand address whose address field is shorter than the programable memory's Memory Address Register. The remaining fields in the instruction determine the algorithm for computing an effective address from the truncated address.

ADDRESS FIELD
That part of an instruction or word containing an address or operand.

ADDRESS MODIFICATION
The hardware action of computing an instruction's effective operand address from its operand address by some sequence of the following operations as prescribed within the instructions:

1. Indexing:
   Adding an index to the address.
2. Derelativization:
   Adding a base address to the address.
3. Indirect addressing:
   Using the intermediate computed address to obtain another address from memory.

ADDRESSABILITY, MEMORY
A measure of capability and ease of programing used in evaluating computers. The maximum number of locations specifiable by a non-indexed instruction using the instruction's minimum execution time.

ALARM
An audible or visible signal that indicates an abnormal or out-of-limits condition in the plant or control system.

ALGOL
Algebraic Oriented Language -
An international algebraic procedural language for a computer programing system.

ALGORITHM
A fixed step-by-step procedure for accomplishing a given result.

ALPHANUMERIC
Characters which are either letters of the alphabet, numerals, or special symbols.

ANALOG COMPUTER
A computer which represents numerical quantities as electrical and physical variables. Solutions to mathematical problems are accomplished by manipulating these variables.

This glossary was based mainly on information extracted from Glossary of Process Computer Terms, published by the General Electric Process Computer Section, Phoenix, Ariz. In addition, excerpts are reprinted by permission from IBM General Information Manual -- Introduction to Control Systems.

ANALOG-TO-DIGITAL CONVERTER
The analog-to-digital converter changes analog signals to digital values for computer use.

ASCII
A contraction for "American Standard Code for Information Interchange". This proposed standard defines the graphics and codes for a character set to be used for information interchange between equipments of different manufacturers.

ASSEMBLE
To transform assembly language into absolute coding.

ASSEMBLY PROGRAM
The processor portion of an assembly system.

ASSERTION BOX
A block or figure on a flow chart which explains the action or contents of some other portion of the flow chart.

ATTENUATE
To obtain a fractional part, or reduction in amplitude, of an action or signal.

BAND
Gamut or range of frequency spectrum between two defined limits.

BANDPASS FILTER
A filter which allows free passage to frequencies within its designed range and which effectively bars passage to all outside that range. A filter having a single transmission band.

BANDWIDTH
Bandwidth is the difference between the limiting frequencies of a continuous frequency band. The bandwidth of a device is the difference between the limiting frequencies within which performance in respect to some characteristic falls within specified limits.

BASE
A number base; a quantity used implicitly to define some system of representing numbers by positional notation; radix.

BAUD
Bits per second. A contraction of the name Baudot who was an early pioneer in data communications and the originator of the Baudot Code. Baud is normally used as the unit for bandwidth in data communications. For instance, 180 baud line is a transmission line capable of handling 180 bits per second.

BAUDOT CODE
The system for encoding symbols in printing telegraphy. Also referred to as "5-Bit Code" and "5-Channel Code" and "5-Unit Code"; "Teletype Code".

BINARY
Pertaining to numbers expressed in the Base 2 number system.

BINARY CODED DECIMAL (BCD)
A term commonly given the codes of a character set.

BINARY SEARCH
An algorighm for searching an ordered table to find a particular item. The procedure involves selecting the upper or lower half of the table based upon an examination of its midpoint item. It then selects the upper or lower portion of the previously selected portion.

BIT
A contraction of binary digit. See Digit.

BLANK
The character which results in memory when an input record such as a card column which contains no punches is read; the character-code which will result in the printing of nothing in a given position. When associated with paper tape, blank refers to a section of tape which has only the sprocket hole punched.

BLOCK
A group of words or characters considered or transported as a unit, particularly with reference to input and output. The term is used sometimes in connection with magnetic tape as a synonym for record, or to refer to grouped records on tape.

BLOCK
To fill the unused remaining words in a block with a prescribed constant.

BOOLEAN ALGEBRA
An algebra named for George Boole. This algebra is similar in form to ordinary algebra, but with classes, propositions, yes/no criteria, and so forth, for variables rather than numeric quantities. It includes the operators AND, OR, NOT, EXCEPT, IF, THEN.

BOOLEAN EXPRESSION
In FORTRAN, a quantity expressed as the result of Boolean operations AND, OR, and NOT upon Boolean variables.

BOOTSTRAP
A short sequence of instructions, which when entered into the computer's programable memory will operate a bulk storage memory device to load the programable memory with a larger more sophisticated program — usually a loader program.

BRANCH
An instruction which when executed may cause the arithmetic and control unit to obtain the next instruction from some location other than the next sequential location. A branch is one of two types: Conditional, Unconditional.

BREAK
To break, in a communication circuit, is for the receiving operator or listening subscriber to interrupt the sending operator or talking subscriber and take control of the circuit. The term is used especially in connection with half-duplex telegraph circuits and two-way telephone circuits equipped with voice-operated devices.

BREAKPOINT
A point of special interest in a routine requiring man communication prior to continuance.

BUFFER
A device which stores information temporarily during data transfers.

BYTE
The smallest number of bits that can be read from a memory into the computer's arithmetic and control unit by a single instruction.

CABLE
A cable is an assembly of one or more conductors, usually within an enveloping protective sheath, in such structural arrangement of the individual conductors as will permit of their use separately or in groups.

CALLING SEQUENCE
A sequence of instructions, parameters and parameter addresses. The calling sequence specifies the entry to the subroutine and uniquely determines by its parameters the action to be performed. A minimum calling sequence consists of an entry specification only.

CARD IMAGE
The arrangement of information in memory resulting from a computer read of a punched card. The information arrangement required for a computer output of a card. A card image is hardware dependent, varying from computer to computer.

CARRIER
1. High-frequency current on which voice or signaling channels can be modulated.
2. Wave suitable for modulating by the intelligence to be transmitted over a communication system. The component of a transmitted wave upon which an audio signal or other form of intelligence can be impressed. The carrier can be a high frequency current superimposed on a voice circuit, on which can be modulated additional voice or signaling channels.

CARRIER FREQUENCY
The carrier frequency is the frequency of the unmodulated carrier wave, if sinusoidal, or the center frequency of the unmodulated carrier when a recurring series of pulses are used.

CARRY
1. A condition occurring during addition when the sum of two digits in the same column equal or exceeds the number base.
2. The digit to be added to the next higher column.
3. The process of forwarding the carry digit.

CASCADE CONTROL
Interlocking of two or more controllers to relate two or more variables. The set point of the secondary controller is regulated by the output of the first controller to maintain the primary variable at the set point.

CENTRAL PROCESSOR
The portion of any computer that consists of the Arithmetic Unit, the Control Unit, and the Storage Unit.

CHANNEL
A means of one way transmission. Several channels may share a common path as in carrier systems; in this case each channel is allotted a particular frequency band which is reserved to it.

CHARACTER
One of a set of elements which may be arranged in ordered groups to express information. Each character has two forms: 1) a man intelligible form, the graphic, including the decimal digits 0-9, the letters A-Z, punctuation marks, and other formating and control symbols; and 2) its computer intelligible form, the code, consisting of a group of binary bits. Codes have been defined using 5, 6, 7 and 8 bit groups.

CLEAR
To replace information in a storage device by zero (or blank, in some machines).

CLOSED LOOP
A family of automatic control units linked together with a process to form an endless chain. The effects of control action are constantly measured so that if the process goes off the beam, the control units pitch in to bring it back into line.

CODE
To prepare coding.

CODING
The ordered set of computer instructions required to perform a given action or solve a given problem.

CODING, ABSOLUTE
Coding in the numeric language form acceptable to the computer arithmetic and control unit.

CODING, DERELATIVIZED
Absolute coding with all relative addresses modified by addition of their instruction's Base Addresses.

CODING, DYNAMICALLY RELOCATABLE
Relocatable coding for a computer which has special hardware to perform the derelativization.

CODING, RELOCATABLE
Absolute Coding containing relative addresses, which when derelativized, may be loaded into any portion of a computer's programable memory and will execute the given action properly. The loader program normally performs the derelativization.

CODING, SYMBOLIC
The language for an Assembly Programing System. In general, each symbolic language statement corresponds to one computer instruction.

COMMAND
A pulse, signal, or set of signals initiating one step in the performance of a computer operation. See Instruction.

COMMON LANGUAGE
A language having national or international usage, for which processor programs are available to translate it into the absolute coding required for many different computers.

COMPARATOR
A device for comparing two different transcriptions of the same information to verify the accuracy of transcription, storage, arithmetic operation or other process, in which a signal is given dependent upon the relative state of two items, i.e., larger, smaller, equal, difference, etc.

COMPARE
To examine the representation of a quantity relative to a reference quantity for purposes of discovering one of the following relationships: equality; greater than; less than. The discovered relationship is used to select one of several hardware or program actions.

COMPILER
A processor program for a Procedure Oriented Programing System.

COMPILER LANGUAGE
The source language for a Procedure Oriented Programing System, e.g., FORTRAN language.

COMPUTER
Any device capable of accepting information, applying prescribed processes to the information, and supplying the results of these processes; sometimes, more specifically, a device for performing sequences of arithmetic and logical operations; sometimes, still more specifically, a stored-program digital computer capable of performing sequences of internally-stored instructions, as opposed to calculators on which the sequence is impressed manually (desk calculator) or from tape or cards (card programed calculator).

COMPUTER, OFF-LINE
The computer is not actively monitoring or controlling a process.

COMPUTER, ON-LINE
Computer is actively monitoring or controlling a process.

COMPUTER, LIMITED
A program which time shares computation with Input/Output but is unable to fully utilize the I/O equipment because the computation time exceeds the I/O time. See I/O Limited.

CONDITIONAL JUMP
A conditional branch instruction which implicitly specifies the branch address to be one of the next two or three sequential addresses.

CONNECTOR
In flow charting, a symbol used to indicate the interconnection of two points in the flow chart.

CONSTRAINTS
Limits on process variables set by equipment or product specifications for reasons of safety, acceptability, etc.

CONTACT OPERATE
Contact operate instructions cause process voltages to be connected to process indicators, pumps, motors, or other devices by means of computer-operated relay points.

CONTACT SENSE
Contact sense instructions determine the status, open or closed, of electrical contacts. A closed contact, for example, may represent the status of a process device such as a pump running, a tank overflowing, or a closed valve.

CONTENTS
The information stored in any stored medium.

CONTROL
The ability to bring a plant or process to any desired state and maintain it there.

CONTROL, OPEN-LOOP
An operation when computer-evaluated control action is applied by an operator.

CONTROL SIGNAL
The signal which energizes the valve or other actuator to take corrective action.

CONTROL SYSTEM, ON-LINE, CLOSED-LOOP
In which the Control System is connected directly to the instrumentation through an analog-to-digital converter to complete the feedback loop. The computer optimizes, then applies control action directly to the process by actuating the valves, setting the controllers, etc. via analog output devices, and thus produces results in real-time as changes occur.

CONTROL UNIT
That portion of a computer which directs the automatic operation of the computer, interprets computer instructions, and initiates the proper signals to the other computer circuits to execute instructions.

CONTROLLABLE VARIABLES
The independent variables such as temperatures, pressures, air and liquid flow rates, etc., that can be manipulated.

CONVERSION
1. Changing the form of representation of information, such as from the language of one type of magnetic tape to that of another.
2. The process of changing the information and (sometimes) methods of a data processing operating to a different method. For instance, we speak of conversion from tabulating equipment to computer processing.

CORE MEMORY
A programable random access memory consisting of many ferromagnetic toroids strung on wires in matrix arrays. Each toroid acts as an electromagnet to store a binary digit. A core memory has zero latency time.

CONTROL VALUE
Digital representation of an analog value.

COUNTER
A device or location which can be set to an initial number and increased or decreased by an arbitrary number by stimuli applied one at a time.

CROSSTALK
The unwanted transfer of energy from one circuit, called the "disturbing" circuit, to another circuit, called the "disturbed" circuit; e.g., voice communication heard in a given circuit originating in an adjacent circuit.

CYCLE
A set of operations repeated as a unit; a non-arithmetic shift in which the digits dropped off at one end of a word are returned at the other end in circular fashion; cycle right and cycle left. To repeat a set of operations a prescribed number of times including, when required, supplying necessary address changes by arithmetic processes or by means of a hardware device such as a B-box or cycle-counter.

DATA
A collection of facts, numeric and alphabetical characters, etc., which is processed or produced by a computer. Data is properly plural, the singular form being datum but, in common computer usage "data" is taken as plural or singular.

DATA LINK
Equipment which permits the transmission of information in data format.

DATA PROCESSING
A generic term for all the operations carried out on data according to precise rules of procedures; a generic term for computing in general as applied to business situations.

DATA TRANSMISSION
This term has been all inclusive to describe the transfer of business data, destined generally to machines.

In a strict sense, data transmission means the transmission of data-comprising digital information which is intelligible to both humans and machines.

DEBUGGING
The process of determining the correctness of a computer routine, locating any errors in it, and correcting them. Also the detection and correction of malfunctions in the computer itself.

DEBUGGED PROGRAM
A program that will perform actions in the logical sequence expected and produce accurate answers to one or more test problems which have been specifically designed to execute all foreseeable paths through the program.

DEBUGGING, ON-LINE
The act of debugging a program while time sharing its execution with an on-line process program. On-line debugging is accomplished in such a way that any any attempt by the "slave" program undergoing debugging to interfere with the operation of the process program will be detected and inhibited.

DECODER
A device which accepts a code and transforms it into one of several predefined actions.

DECODING
1. Internal hardware operations by which the computer determines the meaning of the operation code of an instruction. Also sometimes applied to addresses.
2. In interpretive routines, some subroutines and elsewhere, an operation by which a routine determines the meaning of parameters.

DEMODULATOR
In a broad sense, a demodulator is a device which so operates on a carrier wave as to receive the wave with which the carrier was originally modulated.

DEPENDENT VARIABLES
Temperatures, pressures, concentrations, etc., resulting within the process. Effects of the inputs. They cannot be directly controlled.

DERIVATIVE ACTION
Also called rate action. Control action that furnishes a correction proportional to the rate of change of the deviation.

DIAGNOSTIC ROUTINE
A test program used to detect and identify hardware malfunctions in the computer and its associated I/O equipment.

DIGITAL DATA
Pertaining to physical quantities; where a physical quantity is expressed as a set of ordered digits enclosed in powers of a number base.

DIGITAL-TO-ANALOG (D/A) CONVERTER
A device which transforms digital data into analog data.

DISC MEMORY
A non-programable bulk-storage, random access memory consisting of a magnetizable coating on one or both sides of a rotating thin circular plate. Memory latency time is of the order of hundreds of milliseconds.

DISTURBANCES
Effects of uncontrollable variables on process, e.g., composition of oil, which must be compensated for by manipulation of independent variables.

DOUBLE PRECISION
Data requiring two computer words to contain it. Often called Double Length.

DRIVER
Small programs that control external devices or execute other programs.

DRUM MEMORY
A memory consisting of a magnetizable coating on outer surface of a rotating cylinder. Drum memories are typically used in present day computers as non-programable, bulk-storage random-access memories. Memory latency time is of the order of milliseconds.

DUMP
A small program that outputs the contents of memory onto hard copy which may be listings, tape or punched cards.

DUPLEX CIRCUIT
A telegraph circuit permitting simultaneous two-way operation.

DUPLEX, FULL
Method of operation of a communication circuit where each end can simultaneously transmit and receive.

DUPLEX, HALF
Permits one direction, electrical communications between stations. Technical arrangements may permit operation in either direction but not simultaneously. Therefore, this term is qualified by one of the following suffixes: S/O for send only; R/O for receive only; S/R for send or receive.

DYNAMIC PROGRAMING
A mathematical theory of multi-stage decision processes.

DYNAMIC STATE
A process is in the dynamic state or transient condition when the process variables are changing with time.

ENCODER
A device which will accept one of several discrete input signals and transform it into a predefined code.

ENGINEERING UNITS
Units of measure as applied to a process variable, e.g., PSI, Degrees F., etc.

EXCHANGE
One or more central offices with associated plant and stations in a specified area, usually with a single rate of charges.

EXECUTIVE CONTROL PROGRAM
A main system program designed to establish priorities and to process and control other routines.

FACSIMILE
Transmission of pictures, maps, diagrams, etc., by wire. The image is scanned at the transmitter and reconstructed at the receiving station.

FEEDBACK
Applied to a system which is continually comparing its output with its input and making corrections. If closed-loop, the feedback system is self-correcting.

FIELD
A set of one or more adjacent columns on a punched card(s) or one or more bit positions in a complete word(s) consistently used to record similar information.

FILE MAINTENANCE
The processing of a master file required to handle the non-periodic changes in it. Examples: Changes in number of dependents in a payroll file, the addition of new checking accounts in a bank.

FILTER
1. Device used in a frequency transmission circuit to exclude unwanted frequencies and to keep the channels separate.
2. Device to suppress interference which would appear as noise.

FINAL CONTROL ELEMENT
Valve or other device which is changed by the controller to correct the value of the variable being manipulated.

FIX
To convert data from floating point number representation to fixed point representation.

FIXED POINT
A notation or system of arithmetic in which all numeric quantities are expressed by a predetermined number of digits with the point implicitly located at some predetermined position; contrasted with floating point.

FLAG
A bit (or bits) used to store one bit of information. A flag has two stable states and is the software analogy of a flip-flop.

FLIP-FLOP
A bi-stable device; a device capable of assuming two stable states; a bi-stable device which may assume a given stable state depending upon the pulse history of one or more input points and having one or more output points. The device is capable of storing a bit of information; controlling gates, etc.; a toggle.

FLOAT
To convert data from fixed-point number representation to floating-point representation.

FLOATING CONTROL
Control in which the final control element moves at a constant rate in response to a signal that the variable has deviated.

FLOATING POINT
A form of number representation in which quantities are represented by a bounded number (mantissa) and a scale factor (Characteristic or Exponent) consisting of a power of the number base, e.g., $127.6 = 0.1276 \times 10^3$ where the bounds are 0 and 1.

FLOW CHART
A graphical representation of a sequence of operations, using symbols to represent the operations such as compute, substitute, compare, GO TO, IF, read, write, etc. Flow Charts of different levels of generality can be drawn for a given problem solution. Terms used are: System flow chart, program flow chart, coding level flow chart, etc.

FORMAT
The predetermined arrangement of characters, fields, lines, page numbers, punctuation marks, etc. Refers to input, output and files.

FORTRAN
Formula Translator -- the language for a scientific procedural programing system.

FORTRAN COMPILER
A processor program for FORTRAN.

FREQUENCY, VOICE
A voice frequency is a frequency lying within that part of the audio range which is employed for the transmission of speech.

Note: Voice frequencies used for commercial transmission of speech usually lie within the range 200 to 3500 cycles per second.

FULL-DUPLEX OPERATION
Full-duplex, or duplex, operation refers to communication between two points in both directions simultaneously.

FUNCTION TABLE
Two or more sets of information so arranged that an entry in one set selects one or more entries in the remaining sets; a dictionary; a device constructed of hardware, or a sub-routine, which can either (a) decode multiple input into a single output or (b) encode a single input into multiple outputs; a tabulation of the values of a function for a set of values of the variable.

GARBAGE
Unwanted and meaningless information in memory.

GENERATOR
A program designed to create specific routines from specific input parameters and skeletal coding.

HALF-DUPLEX SERVICE
In which the data communication channel is capable of transmitting and receiving signals, but is not equipped for simultaneous and independent transmission and reception.

HARD COPY
Any form of computer produced printed document.

HARDWARE
The mechanical, magnetic, electrical and electronic devices of which a computer is built.

HOLLERITH
A 12-bit code used for recording characters in punched-card memories.

HOUSEKEEPING
Operations in a routine which do not directly contribute to the solution of the problem at hand, but which are made necessary by the method of operation of the computer. Examples: Loop testing, tape sentinels, record grouping. Also called red tape operations.

IDENTIFIER
A symbol whose purpose is to identify, indicate or name a body of data.

INDEX
An integer used to specify the location of information within a table or program.

INDEX REGISTER
A memory device containing an index.

INFORMATION CHANNEL
The transmission and intervening equipment involved in the transfer of information in a given direction between two terminals.

An information channel includes the modulator and demodulator, and any error-control equipment irrespective of its location, as well as the backward channel when provided.

INITIALIZE
A program or hardware circuit which will return a program, a system or a hardware device to an original state.

I/O LIMITED
A program which time shares computation with Input/Output but is unable to fully utilize the central processor because the I/O equipment is unable to keep up with the program's demands for data input and output.

INSTRUCTION
A set of bits which will cause a computer to perform certain prescribed operations. A computer instruction consists of:

1. An operation code which specifies the operation(s) to be performed.
2. One or more operands (or addresses of operands in memory).
3. One or more modifiers (or addresses of modifiers) used to modify the operand or its address.

INSTRUMENTATION
The application of devices for the measuring, recording and/or controlling of physical properties and movements.

ITEM
A set of one or more fields containing related information; a unit of correlated information relating to a single person or object; the contents of a single message.

INTERFACE
A concept involving the specification of the interconnection between two equipments having different functions.

INTERLACED MEMORY
A memory with sequentially addressed locations occupying physically separated positions in the storage media.

INTERNAL STORAGE
See Memory, on-line.

INTERPRETIVE ROUTINE
A routine which carries out problem solution by process of: (1) decoding instructions written in a pseudo-code, and selecting and executing an appropriate sub-routine to carry out the functions called for by the pseudo-code. (2) Proceeding to the next pseudo-instruction. It should be noted that an interpretive routine carries out its functions as it decodes the pseudo-code, as contrasted to a compiler, which only prepares a machine-language routine which will be executed later.

INTERRUPT
A break in the normal flow of a system or program occurring in such a way that the flow can be resumed from that point at a later time. Interrupts are initiated by signals of two types:

1. Signals originating within the computer system to synchronize the operation of various components.
2. Signals originating exterior to the computer system to synchronize the operation of the computer system with the outside world (e.g., an operator or a physical process).

KEY
The field or fields of information by which a record in a file is identified, and/or controlled.

KEYBOARD LOCKOUT
An interlock feature which prevents sending from the keyboard while the tape transmitter or another station is sending on the same circuit, to avoid breaking up the transmission by simultaneous sending.

LABEL (PROGRAM)
An ordered set of characters used to symbolically identify an instruction, a program, a quantity, or a data area. The label also symbolically designates the memory location which is to contain the instruction, etc. The label is, therefore, the symbolic analog of an address. A label may be absolute, relative, direct, or indirect.

LABEL (TAPE)
1. A paper label attached to a tape reel to identify its contents.
2. The first record on a tape. The label identifies the contents of the tape.

LEFT JUSTIFIED
A field of numbers (decimal, binary, etc.) which exists in a memory cell, location or register, possessing no zeros to its left.

3	9	2	7	6	4	0	0	5	0

LIBRARY PROGRAMS
A software collection of standard and proved routines and sub-routines by which problems and parts of problems may be solved on a given computer.

LINKAGE
A means of communicating information from one routine to another.

LINEAR PROGRAMING
A form of Mathematical Programing in which each variable is expressed as a linear function of the parameters.

LIST
An ordered set of items contained within a memory in such a way that only two items are readily program addressable. These items are the earliest appended (beginning item) and the most recently appended (ending item). Items stored into the list are "appended" following the ending item. Items read from the list are "removed".

LIST, PUSH-DOWN
A list frequently used in data processing. Both appends and removals are made at its end.

LIST, QUEUING
A list frequently used for scheduling actions in real time on a time-priority basis. Appends are made following the ending item. The beginning item is always the removed item.

LOAD
The demand for the controlled variable, heat, pressure, etc., required by the process as input.

LOADER
A program that operates on input devices to transfer information from off-line memory to on-line memory.

LOCATION
The contiguous set of bit positions in a memory uniquely specified by an address.

See Address; Word.

LOGGER
A device which automatically records physical processes and events, usually with respect to time.

LOOP
A coding technique whereby a group of instructions is repeated a specified number of times, usually with some modification to certain instructions in the group.

LOOP, CLOSED
A family of automatic control units, one of which may be a computer, linked together with a process to form an endless chain.

LOOP, OPEN
A family of automatic control units, one of which may be a computer, linked together manually by operator action.

MACRO INSTRUCTIONS
A symbolic language statement for a Macro-Assembly Programing System. A statement can correspond to several computer instructions. See Coding, Symbolic.

MASK
A machine word that specifies which parts of another machine word are to be operated on.

MATHEMATICAL MODEL
A collection of equations that represents mathematically all that goes on in the process, i.e., a mathematical description of the process.

MATHEMATICAL PROGRAMING
A mathematical theory for optimizing a set of variables controlling a process for a given set of parameters.

MEMORY
A device or media used to store information in a form that can be understood by the computer hardware.

MEMORY, BULK STORAGE
Any non-programable large memory.

MEMORY, CARD
An off-line Bulk Storage memory. Memory media is a rectangular array of 960 bit positions on the card. Bits are specified by holes in these positions.

MEMORY CYCLE TIME
The minimum time between two successive data accesses from a memory.

MEMORY LATENCY TIME
The time required for the memory's control hardware to physically move the memory media containing the desired data to a position where it can be electrically read. Alternately the reading device may be moved to the desired data. Latency is associated with serial memories and certain random-access memories.

MEMORY, OFF-LINE
Any memory media, capable of being stored remotely from the computer, which can be read by the computer when placed into a suitable reading device.

MEMORY, ON-LINE
A memory media used as a non-removable part of a computer system.

MEMORY, PROGRAMABLE
A memory whose locations are addressable by the computer's program counter, i.e., a program within this memory may directly control the operation of the Arithmetic and Control Unit.

MEMORY, RANDOM ACCESS
A memory whose information media is organized into discrete locations, sectors, etc., each uniquely identified by an address. Data may be obtained from such a memory by specifying the data address(es) to the memory, e.g., core, drum, disc, cards.

MEMORY, SERIAL
A memory whose information media is continuous. Data is identified in its content or form. Data may be obtained only by performing a serial search through the contents of the memory.

MEMORY, TAPE
A serial, bulk-storage, off-line memory. Two forms are common: Paper Tape; Magnetic Tape.

MERGE
To produce a single sequence of items, ordered according to some rule (i.e., arranged in some orderly sequence), from two or more sequences previously ordered according to the same rule, without changing the items in size, structure, or total number. Merging is a special case of collation.

MESSAGE
A group of words, variable in length, transported item of information.

MESSAGE
A communication of information or advice from a source to one or more destinations in suitable language or code. In telegraphic and data communications a message is composed of three parts as follows:

1. A heading containing a suitable indicator of the beginning of the specific message together with information on any or all of the following: the source and destination, data and time of filing, and routing or other transmission information;

2. A body containing the information or advice to be communicated;

3. An ending containing a suitable indicator of the conclusion of the specific message, either explicit or implicit.

MNEMONIC
Assisting or intended to assist, memory; of or pertaining to memory; mnemonics is the art of improving the efficiency of the memory (in computer storage). See also Label.

MODEM
A contraction of "modulator-demodulator". The term may be used with two different meanings:

1. the modulator and the demodulator of a modem are associated at the same end of a circuit;

2. the modulator and the demodulator of a modem are associated at the opposite ends to form a channel.

MODIFIER
A quantity used to alter the address of an operand, e.g., the cycle index. See Address Modification.

MODULATION
Process by which certain characteristics of a wave are modified in accordance with a characteristic of another wave or a signal.

MONITOR
An operating programing system which provides a uniform method for handling the real-time aspects of program timing, such as scheduling and basic input/output functions.

MULTI-PROGRAMING
A technique for handling numerous routines or programs seemingly simultaneously by overlapping or interleaving their execution, that is, by permitting more than one program to time-share machine components.

NETWORK-TELEPHONE
Describes a system of points inter-connected by private voice-grade telephone wire whereby direct point-to-point telephone communications are provided. This traffic usually by-passes commercial telephone switching facilities; the customer provides his own operating personnel for leased lines and facilities. Service is available from local common carriers.

NETWORK-TELETYPE
Describes a system of points, interconnected by private telegraph channels, which provide hard copy and/or telegraphic coded (5-channel) punched paper tape, as required, at both sending and receiving points. Typically, up to 20 way-stations share send-receive time on a single circuit, and can exchange information without requiring action at a switching center. If two or more circuits are provided, a switching center is required to permit cross-circuit transmission.

NEUTRAL ZONE (DEAD ZONE)
A range on either side of the set point in which no control action takes place.

NOISE
An extraneous signal in an electrical circuit capable of interfering with the desired signal. Loosely, any disturbance tending to interfere with the normal operation of a device or system.

NUMBER
1. A mathematical entity that may indicate quantity or amount of units.
2. Loosely, a numeral.

NUMERICAL CONTROL
Pertaining to the automatic control of Processes by the proper machine interpretation of numerical data.

OBJECT MACHINE
The computer on which the object program is to be executed.

OBJECT PROGRAM
The absolute coding output by a Processor Program. See Source Program.

OFFSET
The count value output from an A/D converter resulting from a zero input analog voltage. Used to convert subsequent non-zero measurements.

OPERAND
Any quantities entering or arising in an operation. An operand may be an argument, a result, a parameter, or an indication of the location of the next instruction.

OPERATING SYSTEM
A group of programing systems operating under control of a data processing monitor program.

OPERATION (ØP) CODE
That part of an instruction designating the operation to be performed.

OPERATION, PARALLEL
Operates on all bits of a word simultaneously.

OPERATION, SERIAL
The flow of information through a computer in time sequence, usually by bit but sometimes by character.

OPERATIONAL
The status of a computer or program when it has been running correctly, using line data, for some-time.

ORIGIN
In coding, the absolute memory address of the first location of a program or program segment.

OUTPUT
Information transferred from the internal storage of a computer to output devices or external storage.

OVERFLOW
In an arithmetic operation, the generation of a quantity beyond the capacity of the register or location which is to receive the result; over-capacity; the information contained in an item of information which is in excess of a given amount.

OVERLAY
A technique for bringing routines into high-speed memory from some other form of storage during processing, so that several routines will occupy the same storage locations at different times; used when the total memory requirements for instructions exceed the available high-speed memory. Also see: Segment.

PACK
To insert data into one or more fields of a multi-field memory locations.

PARAMETER
In a sub-routine, a quantity which may be given different values when the sub-routine is used in different main routines or in different parts of one main routine, but which usually remains unchanged throughout any one such use; in a generator, a quantity used to specify input/output devices, to designate sub-routines to be included, or otherwise to describe the desired routine to be generated.

PARITY BIT
A binary digit appended to an array of bits to make the sum of all the bits always odd or always even.

PARITY CHECK
A check that tests whether the number of ones (or zeros) in an array of binary digits is odd or even.

PATCH
Section of coding inserted into a routine to correct a mistake or alter the routine; explicitly transferring control from a routine to a section of coding and back again.

PERIPHERAL
Input/output equipment used to make hard copies or to read in data from hard copies (typer, punch, tape reader, line printer, etc.). Paper tape is considered hard copy for this definition.

PILOT
In a transmission system, a pilot is a signal wave, usually a single frequency, transmitted over the system to indicate or control its characteristics.

PRECISION
The degree of discrimination with which a quantity is stated, e.g., a three-digit numeral discriminates among 1,000 possibilities. Precision is contrasted with accuracy, e.g., a quantity expressed with 10 decimal digits of precision may only have one digit of accuracy. See Accurate.

PROBLEM ORIENTED LANGUAGE
A source language oriented to the description of a particular class of problems.

PROCEDURAL ORIENTED LANGUAGE
A source language oriented to the description of procedural steps in machine computing, e.g., FORTRAN.

PROCESSOR
The translating routine of a programing system.

PROGRAM
A plan for the solution of a problem. A complete program includes plans for the transcription of data, coding for the computer and plans for the absorption of the results into the system. The list of coded instructions is called a routine; to plan a computation or process from the asking of a question to the delivery of the results, including the integration of the operation into an existing system. This programing consists of planning and coding, including numerical analysis, systems analysis, specification of printing formats, and any other functions necessary to the integration of a computer in a system.

PROGRAMING SYSTEM
A system consisting of a programing language and a computer program, the Processor, to convert the language into absolute coding.

PROPAGATION
Traveling of a wave along a transmission path.

PROPORTIONAL CONTROL
The final control element is opened or closed in proportion to the amount the controlled variable deviates from the set point.

PROPORTIONAL PLUS RESET CONTROL
Control action which corrects in proportion to the deviation of a controlled variable from its set point and the time integral of the deviation. Often referred to as two-mode control.

PSEUDO (ØP) INSTRUCTION
A symbolic representation of information to a compiler or interpreter; a group of characters having the same general form as a computer instruction, but never executed by the computer as an actual instruction.

PULSE
A change in the intensity or level of some medium, usually over a relatively short period of time, e.g., a shift in electric potential of a point for a short period of time compared to the time period, i.e., if the voltage level of a point shifts from -10 to +20 volts with respect to ground for a period of 2 microseconds, one says that the point received a 30 volt 2 microsecond pulse.

PULSE
A signal characterized by the rise and decay in time of a quantity whose value is normally constant.

PUNCHED CARD
A piece of lightweight cardboard on which information is represented by holes punched in specific positions.

PUNCHED PAPER TAPE
A strip of paper on which characters are represented by combinations of holes.

QUEUE
Waiting lines resulting from temporary delays in providing service.

QUOTIENT
The quantity resulting from the division of a dividend by a divisor. If the dividend is not an even multiple of the divisor, the quantity left over is the remainder.

RANGE
A characterization of a variable or function. All the values which a function may have.

RATIO, SIGNAL-TO-NOISE
(Signal-Noise Ratio)
The signal-to-noise ratio is the ratio of the magnitude of the signal to that of the noise. This ratio is often expressed decibels.

RATIO CONTROL
Maintains fixed ratio between input (primary) variable and controlled (secondary) variable.

RAW DATA
Data which has not been processed; may or may not be in machine-sensible form.

READ
To copy, usually from one form of storage to another, particularly from external or secondary storage to internal storage; to sense the meaning of arrangements of hardware; to sense the presence of information on a recording medium.

READER
A device capable of sensing information stored in an off-line memory media (cards, paper tape, magnetic tape) and generating equivalent information in an on-line memory device (register, memory locations).

REAL-TIME
1. Pertaining to the actual time during which a physical process transpires.
2. Pertaining to the performance of a computation during the actual time that the related physical process transpires in order that results of the computation can be used in guiding the physical process.

RECEIVER
A device which transforms a varying electrical signal into sound waves or other usable form.

RECORD
A collection of fields; the information relating to one area of activity in a data processing activity, i.e., all information on one inventory item. Sometimes called item.

RECURSION
The continued repetition of the same operation or group of operations.

REGISTER
A memory device capable of containing one or more computer bits or words. A register has zero memory latency time and negligible memory access time.

REPEATER
A device whereby currents received over one circuit are automatically repeated in another circuit or circuits, generally in an amplified form.

RESET
To return a register or storage location to zero or to a specified initial condition.

RIGHT JUSTIFIED
A field of numbers (decimal, binary, etc.) which exists in a memory cell, location, or register possessing no significant zeros to its right is considered to be right justified.

0	0	0	1	2	0	0	0	0	0

is considered to be a seven-digit field right justified.

0	0	0	0	0	0	1	2	0	0

is a two-digit field not right justified.

ROUNDOFF
To delete the least significant digit(s) of a numeral and to adjust the past retained in accordance with some rule.

ROUTINE
A series of computer instructions which performs a specific, limited task.

ROUTINE, INTERPRETIVE
A routine which carries out problem solution by process of:

1. Decoding instructions written in a pseudo-code, and selecting and executing an appropriate subroutine to carry out the functions called for by the pseudo-code.
2. Proceeding to the next pseudo-instruction. It should be noted that an interpretive routine carries out its function as it decodes the pseudo-code, as contrasted to a compiler, which prepares a machine-language routine which will be executed later.

ROUTINE, SERVICE
A routine designed to assist in the actual operation of the computer. Tape comparison, block location, certain post mortems, and corrections routines fall into this class.

RUN
One performance of a program on a computer; performance of one routine, or several routines automatically linked so that they form an operating unit, during which manual manipulations are not required of the computer operator.

SCALE
To alter the units in which all variables are expressed, to bring all magnitudes within bounds dictated by need, register size, or other arbitrary limits.

SCALE FACTOR
One or more coefficients used to multiply or divide quantities in a problem in order to convert them to a given magnitude, e.g., plus one to minus one.

Actual Number	Number in Storage	Scale Factor
9.0	0.0009	+ 4
0.0009	9.0	- 4

SCANNER ANALOG INPUT
A device which will, upon command, connect a specified sensor to measuring equipment and cause the generation of a digit count value which can be read by the computer.

SECTOR
A set of bits comprising the smallest addressable unit of information in a drum or disk memory.

SEGMENT
Part of a Segmented Program.

SEGMENTED PROGRAM
A program that has been divided into parts (segments) in such a manner that:

1. Each segment is self contained. Only one segment must be in the computer's programable memory at any given time. The remaining segments may reside in Bulk Storage Memory.
2. Interchange of information between segments is by means of data tables in known memory locations.
3. Each segment contains instructions to cause (or request a Monitor to cause) the transfer of the next segment into programable memory. Segments need not overlay each other. See Overlay.

SENSOR
A transducer or other device whose input is a quantitative measure of some external physical phenomenon and whose output can be read by a computer.

SERIAL TRANSFER
A system of data transfer in which elements of information are transferred sequentially.

SERIAL TRANSMISSION
A system of transmitting bits of character in line sequence. Generally used in telegraphic operation.

SERVOMECHANISM
A closed loop system in which the error or deviation from a desired or preset norm is reduced to zero; An electromechanical device that orients itself to a master device by sensing and reducing its deviation signal, from the master, to zero.

SHIFT
To move information serially right or left in a register(s) of a computer. Information shifted out of a register may be lost, or it may be re-entered at the other end of the register.

SHIFT, ARITHMETIC
To shift a number in a register in order to scale the number. See Scale.

SIGNAL, START
(In a start-stop system)
Signal serving to prepare the receiving mechanism for the reception and registration of a character, or for the control of a function.

SIGNAL, STOP
(In a start-stop system)
Signal serving to bring the receiving mechanism to rest in preparation for the reception of the next telegraph signal.

SIGNAL, TELEGRAPH
The set of conventional elements established by the code to enable the transmission of a written character (letter, figure, punctuation sign, arithmetical sign, etc.) or the control of a particular function (spacing, shift, line-feed, carriage return, phase correction, etc.); this set of elements being characterized by the variety, the duration and the relative position of the component elements (or by some of these features).

SIGNIFICANT DIGIT
A digit that contributes to the precision of a numeral. The number of significant digits is counted beginning with the digit contributing the most value, called the most significant digit, and ending with the one contributing the least value, called the least significant digit.

SIMPLEX
Applied to a circuit that provides a one-way path for telegraph-type signals.

SIMULATOR
A device or computer program that performs simulation.

SOFTWARE
The collection of all programs for a computer.

SORT
To arrange items of information according to rules dependent upon a key or field contained in the items.

SOURCE PROGRAM
Program statements in the language of a Programing System.

STATEMENT
In computer programing, a meaningful expression or generalized instruction in a source language.

STEADY STATE
A process is said to be in steady state when none of the variables are changing with time.

STORE-AND-FORWARD SWITCHING CENTER
A message switching center in which the message is accepted from the sender whenever he offers it, held in a physical store, and forwarded to the receiver whenever he is able to accept it.

SUBROUTINE
A subroutine is a series of computer instructions to perform a specific task for many other routines. It is distinguishable from a main routine in that it requires as one of its parameters, a location specifying where to return to the main program after its function has been accomplished.

SUPPORT SYSTEM
A programing system used to support the normal translating functions of machine oriented, procedural oriented, and problem oriented language Processors.

SWITCH
An interpretation of a location which will contain a variable unconditional branch or transfer instruction.

SWITCHING
Operations involved in interconnecting circuits in order to establish a temporary communication between two or more stations.

SWITCHING CENTER
An installation in a communication system in which switching equipment is used to interconnect communication circuits.

SYMBOL TABLE
A table of Labels and their corresponding numeric values.

SYMBOLIC CODING
Broadly, any coding system in which symbols other than actual machine operations and addresses are used.

SYSTEM
An assembly of components united by some form of regulated interaction to form an organized whole. A collection of procedures, men and machines, by which industrial or business activity is carried on.

TABLE LOOK-UP
A procedure for obtaining the function value corresponding to an argument from a talbe of function values.

TABULAR LANGUAGE
The language for a problem oriented programing system. The language format is tabular in nature.

TELECOMMUNICATION
Any process that enables a correspondent to pass to one or more given correspondents (telegraphy or telephony), or possible correspondents (broadcasting), information of any nature delivered in any usable form (written or printed matter, fixed or moving, pictures, words, music, visible or audible signals, signals controlling the functioning of mechanisms, etc.) by means of any electromagnetic system (electrical transmission by wire, radio transmission, optical transmission, etc., or a combination of such systems).

TELEGRAPH CHANNEL
The transmission media and intervening apparatus involved in the transmission of telegraph signals in a given direction, between two terminal sets, or more generally, between two intermediate telegraph installations.

A means of one-way transmission of telegraph signals.

A telegraph channel is characterized by the number of significant conditions and by the modulation rate; it is designed to transmit.
For example: A 50-band channel for two-condition modulation.

TIME-SHARE
To use a device for two or more interleaved purposes.

TORN TAPE SWITCHING
A manual switching system for teletype systems. Messages are received from one circuit in the form of punched paper tape which is then "torn" off and carried to a tape sender for retransmission to the destination. Normally, the incoming console, with tape punches, is placed opposite the outgoing console, with tape readers -- with attendants operating between the two.

TRACING ROUTINE
A routine that provides a historical record of specified events in the execution of a program.

TRACK
The portion of a moving storage medium, such as a drum, tape, or disc, that is accessible to a given head position.

TRANSDUCER
A device for converting energy from one form to another.

TRANSFER VECTOR
A transfer table used to communicate between two or more programs. The table is fixed in relationship with the program for which it is the transfer vector. The transfer vector provides communication linkage between that program and any remaining sub-programs.

TRANSIENT
A phenomenon experiencing a change as a function of time; something which is temporary; a buildup or breakdown in the intensity of a phenomenon until a steady-state condition is reached; an aperiodic phenomenon. The time rate of change of energy is finite and some form of energy storage is usually involved.

TRAP
An unprogramed conditional jump to a known location, automatically activated by hardware, with the location from which the jump occurred.

TRUNCATE
To terminate a computational process in accordance with some rule, e.g., to end the evaluation of a power series at a specified term.

TRUNK
A trunk is a telephone line or channel between two central offices or switching devices, which is used in providing telephone connections between subscribers.

TRUTH TABLE
A table that describes a logic function by listing all possible combinations of input values and indicating, for each combination, the true output values.

UNDERFLOW
Pertaining to the condition that arises when a machine computation yields a non-zero result that is smaller than the smallest non-zero quantity that the intended unit of storage is capable of storing.

UNPACK
To separate various sections of packed data.

VARIABLE
A quantity that can assume any of a given set of values.

VOICE-FREQUENCY (VF);
TELEPHONE FREQUENCY
Any frequency within that part of the audio-frequency range essential for the transmission of speech of commercial quality, i.e., 300-3400 c/s.

WAY-OPERATED CIRCUIT
A circuit shared by three or more stations on a "party line" basis. One of the stations may be a switching center. May be single or duplex circuit.

WORD
A set of bits comprising the smallest addressable unit of information in a programable memory.

WORD LENGTH
The number of bits in a word.

WORD, TELEGRAPH (CONVENTIONAL)
A word comprising five letters together with one letter-space, used in computing telegraph speed in words/minute or traffic capacity.

WORKING STORAGE
Programable memory locations reserved for intermediate and partial results.

WRITE
To deliver data to a medium such as storage.

ZERO-SUPPRESSION
The elimination of nonsignificant zeros in a numeral.

This glossary was based mainly on information extracted from Glossary of Process Computer Terms, published by the General Electric Process Computer Section, Phoenix, Ariz. In addition, excerpts are reprinted by permission from IBM General Information Manual -- Introduction to Control Systems. © 1961 by International Business Machines Corp.

The role of a business information system is to collect information about what is happening in the organization as it goes about its business, and to disseminate responses to this information. In most cases the business system is computer-based, but in all cases the system also includes non-computer functions. Customarily, the latter are decision functions or data preparation and dissemination functions. In no case can a permanent distinction be made between what is a computer-based type of function and what is a non-computer-based type of function. The roles of the machinery and of operating and supervisory personnel are complementary. The boundary between them shifts with technical evolution.

A process control system can be described in essentially the same terms--with the difference that the system relates to a physical process rather than a business process. Process control (using computers) is a technology which has been described in the trade journals of the computer industry and even in those of the user industries for many years. It comes as something of a surprise, therefore, to find that the number of process control computers currently installed is still under 1, 500. Several reasons can be advanced for this.

In the first place much of the early work with computers was devoted exclusively to the task of "data-logging." Industrial processes, contrary to what might be expected of engineering disciplines, have been governed as much by art and experience as by science. The acceptable values of the controlling parameters of a process have been judged by the quality of the product and the interdependence of the parameters has been codified in rules of thumb based on years of experience and frequently undocumented.

The computer, regarded as a data recorder and data reduction device, offered an escape from the operating rigidity enforced by these rules of thumb. It permitted fundamental research into the characteristics of the process. Accordingly, the early years of process control were devoted to the essential tasks of coupling a computer to the places in the process where the crucial parameters could be measured, of recording the data from these places, and of analyzing their interdependence and the dependence on them of the quality and quantity of the output.

Awesome Spectres

The use of the computer to compute "set points" and, hence, to control the action of conventional process controllers is a development of more recent vintage. The year 1959 has been cited as the availability date of the first control computer--the TRW 300. The first "closed loop," as opposed to data-logging, application was reported in November 1960 in connection with an ammonia plant.

Secondly, although the justification for using control computers was established and accepted during the early years of development, there has been little retroactive fitting of computer control to existing plants. This reluctance stems in part from the design of conventional controllers which makes adaptation to computer control difficult, and in part from the fact that the plants in question are used almost continuously and have a 10-15 year working life.

A third factor of some importance is that a control computer which is an essential part of the operating of a plant raises the spectre of what happens if the computer is "down," and the equally awesome spectre of what happens if the unions don't like it. Either contingency may result in the plant being closed down and production terminated.

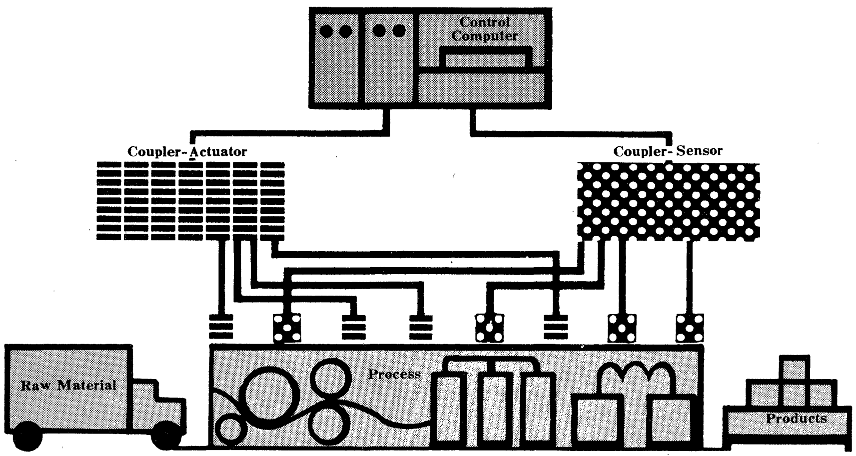


EXHIBIT 1. PROCESS CONTROL SYSTEM, SHOWING PHYSICAL PROCESS FOR CONVERTING RAW MATERIAL INTO FINISHED PRODUCT. MEASUREMENTS ARE TAKEN BY SENSORS AND CONTROL APPLIED TO THE PROCESS THROUGH ACTUATORS, ALL UNDER DIRECTION OF COMPUTER WHICH STORES MATHEMATICAL MODEL OF ENTIRE PROCESS.

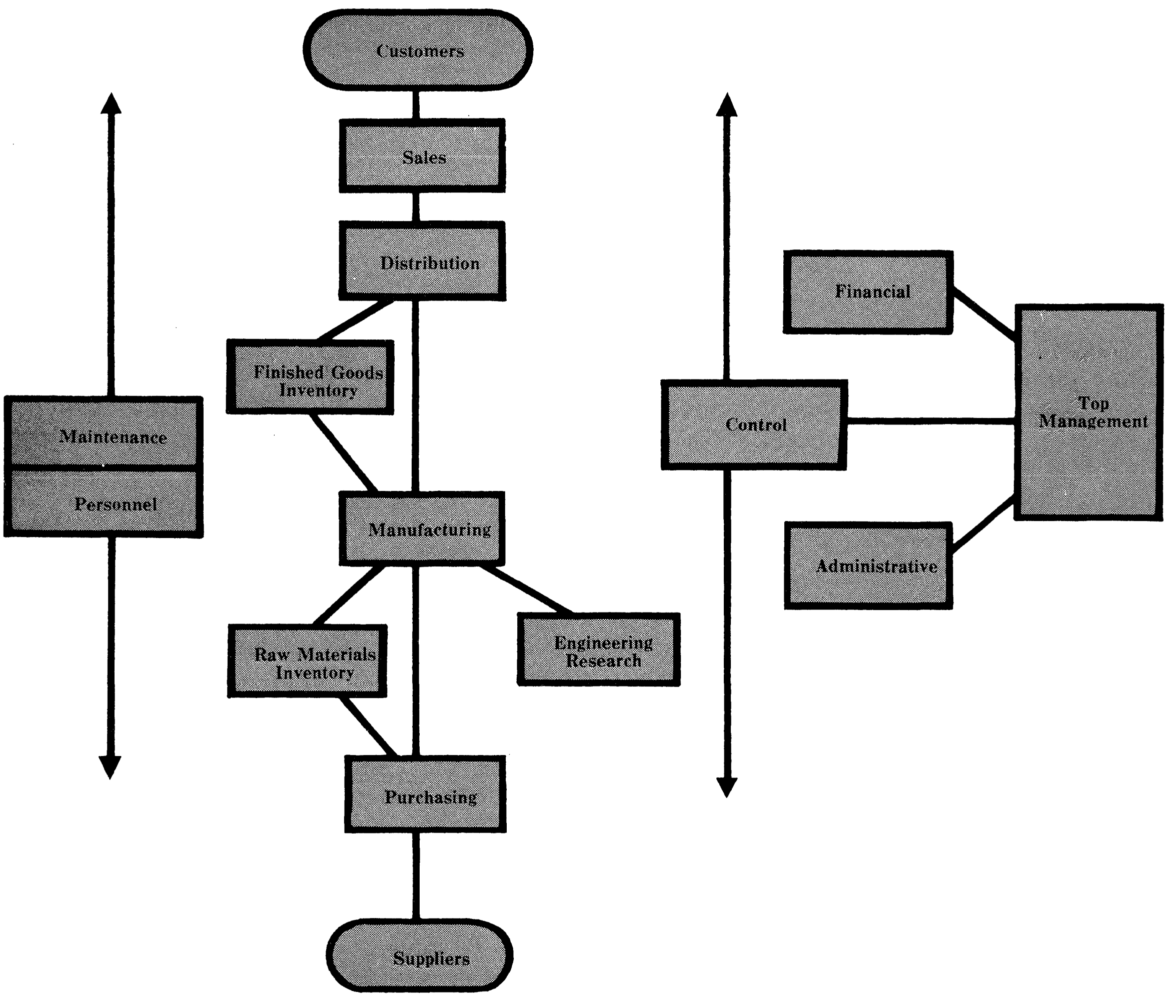


EXHIBIT 2. FUNCTIONAL AREAS OF BUSINESS, AS THEY EFFECT FLOW OF MATERIAL FROM SUPPLIERS TO CUSTOMERS. BUSINESS ADDS VALUE TO MATERIAL BY TRANSFORMING IT IN SOME WAY. FLOW REQUIRES PURCHASING AND MARKETING FUNCTION. RAW MATERIAL INVENTORIES REDUCE DEPENDENCE ON SUPPLIERS. FINISHED GOODS INVENTORIES RECONCILE ORDER IRREGULARITIES WITH REQUIREMENTS FOR CONTINUOUS PRODUCTION. CONTROL FLOW IS EXERCISED BY MIDDLE AND LOWER MANAGEMENT. LONGER TERM HEALTH OF THE ENTERPRISE IS PRINCIPAL CONCERN OF TOP MANAGEMENT.

There exists, in addition, a statistical difficulty as to what is to be counted as a process control computer, and a disclosure difficulty resulting from the secrecy with which much of the relevant activity is shrouded.

Within this environment the process control computer industry is now developing into an integral part of the "plant and equipment" industry. One source estimates a threefold increase in industry usage of control computers depending on the classification adopted; i.e., depending on what is counted as a process computer, the predicted 1970 total is between 2,400 and 3,600.

'Dial-up' Telephone Line

The principal characteristics of the projected systems can be enumerated. Obviously, the specific characteristics of control systems vary with the requirements of the particular industrial process since the making of, say, cement has little in common with refining petroleum. Following is the type of system (illustrated in Exhibit 1) toward which all industries are trending:

1. The computer is in the "control loops" so that individual set-point controllers have been eliminated and the entire production process is dependent on the computer remaining operable.

2. The sensors and actuators are designed for compatibility with digital control rather than for incorporation into conventional analog instrumentation.

3. The computer is programed with a mathematical model of the process being controlled. This model relates the "dependent" process variables (quantity of output, percentage composition of output) to the "input" variables (compositions of raw materials, furnace temperature) which are either controllable or non-controllable. The model is an equation or a series of equations which states the interdependence of all the variables. It determines the set-points of the controllable variables given the values of the uncontrollable variables.

4. The interrelationships of the variables are expressed by linear coefficients and by special functions. These are determined by analysis of data gathered from the process. Since data gathering is a continuous process, the model is reoptimized from time to time in the light of the current additional data.

These characteristics imply a need for the following computer capability:

1. Ability to sense a number of measuring devices (sensors) and to control the positioning of a number of control devices (actuators) with a frequency consonant with the dynamic responses of the process.

2. Continuous data input, continuous calculation of the conditions of the process using the input data and continuous data output.

3. Absolute reliability.

4. Periodic analysis of the available data to adjust the model so that it better represents the process.

The first two capabilities are met by a computer which is designed to multiplex inputs and outputs, and to manipulate and process data. This is the computer commonly referred to as a "direct digital control computer." The requirement for high reliability usually dictates the use of more than one control computer so that the control of the critical "loops" is not dependent on one piece of equipment.

The periodic revision of the model requires the use of a computer with a large and versatile computational ability. However, in view of the periodic nature of this requirement, one such computer can service a number of direct digital control computers. With this arrangement, the control computers store operating data and transfer them to the analytical computer, for example, by "dial-up" telephone line. If analysis of this data indicates the desirability of modification to the mathematical model of the process which is stored in the direct digital control computer, the modification can be conveyed to the DDC computers through the same dial-up communication channel. Because of the periodic nature of its communication with the controlled process, the computer used for the analytical function is usually described as the "supervisory computer."

Less Chance of Total Failure

Some difficulty attaches to the delineation of the major markets of the process control technology described above. All processes require control, and all sizable ones are a market for some kind of control equipment which is justifiable because machinery can do the job more accurately, with less chance of total failure, and possibly cheaper than a human being.

However, common usage, as exemplified by one report, identifies major process control markets in the following industries: cement; chemicals; electric power generation and transmission; petroleum refining; pulp and paper; and steel. Some markets which currently are marginal are in food and beverages; gas production and transmission; metal working; nonferrous metals; oil producti and transmission; rubber; stone, clay and glass; and water and sewage treatment.

The common characteristics of major market industries are difficult to determine. Continuit of production is a characteristic of some of them; e.g., cement, where batched processing is norma

Motivation is equally diverse. Production difficulties with conventional production methods have spurred interest in process control technology in the pulp and paper industry and the steel industry. By contrast, the principal motiviation in the electric power industry has been the protection of expensive generating equipment during run-up and run-down.

The use of a "production recipe" is a crucial factor in many processes; e.g., ammonia production, but not in others; e.g., electric power. On the other hand, the start-up of a turbine require the use of a control algorithm which describes the interrelationships of variables, just as the production of ammonia requires the use of a mathematical model.

Expanding Boundaries

However, dependence on a mathematical model or control algorithm is not a feature unique to the major market industries listed above. Modern production techniques for discrete products are dependent on systems of control which embody production and scheduling algorithms similar in concept those used in the continuous flow process industries. The regulation of a modern high volume production line depends on adjusting the rates of flow of parts and sub-assemblies to key assembly points the sensing of obstructions, the circumvention of breakdowns, and so on. Although the outputs of these production lines consist of discrete units (cars, bottles of beer), the manufacturing process has a large measure of continuity--much more so than the production of steel, for example, which is essentially a "batched" process.

Hence, it is not possible to define the major market industries for process control technology with respect to continuity of process, common motivation, or the use of a sophisticated control algorithm.

In practice, it seems likely that developments in the next 10 years will unify process control technology as it is currently known and will expand its boundaries until they join with and overlap thos of the production technology of manufacturing discrete product units.

Staying within the context of the major market industries listed above, what is the nature of th business of which the physical production facility and its process control equipment are a part? In general terms, the related business is the generation of orders and the distribution of products. Exhibit 2 illustrates the functional areas of the business at a level of abstraction which makes the exhibit pertinent to most businesses and certainly to all manufacturing concerns.

/lade-to-Order Plant

There is a flow of material from suppliers to customers. The business in question adds 'alue to the material by transforming it in some way. The flow requires a purchasing function and ι marketing (sales and distribution) function. Raw material inventories reduce the day-to-day de-›endence on suppliers. Finished goods inventories reconcile the irregularities of customers' orders vith the requirements for continuous production. The plant is kept in productive condition through a naintenance function and a conceptually similar function is performed for employes by the personnel lepartment.

Control over the flow is exercised by middle and lower management. The longer term health ›f the enterprise is the principal concern of the top management.

Once the level of abstraction represented in Exhibit 2 is left, there is a need to reference the lescription of the business to the specifics of the industry of which the business is a unit. An attempt o diagram the manufacturing function, for example, has only limited usefulness unless the special :haracteristics of a particular industry are reflected in it. A chemical plant which is operated con-inuously for long periods normally receives production requirements based on economic forecasts rom elsewhere in the company rather than receiving individual customers' orders directly from 'egional sales offices. In contrast to this, a chemical plant producing a wide range of insulating naterials for electrical and electronic companies operates as a job shop, and orders and changes o orders are processed directly by the plant. For a plant of this type the "production requirements" ıre inappropriate and are replaced by "customer order processing."

Similarly, a made-to-order plant has direct control over its suppliers, whereas a petroleum 'efinery has little or none--deliveries of "crude" being determined elsewhere in the company. Direct :ontrol over suppliers implies support of the purchasing function by a requisitioning function.

In the case of hydroelectric generating plants and of plants manufacturing oxygen from the air, he supply of raw materials is not a matter requiring routine attention. In these cases the requisi-ioning, receiving, and inspection functions for raw materials lose their significance.

For these reasons any generalized description of the business environment within which process ontrol technology is applied and, hence, of the information needs of the business must be lacking in ›recision. It may, however, be helpful to visualize the possible information needs of a business without lefining the business.

The in-plant control group accounts for the flow of material through the plant: from raw material hrough the various stages of work-in-process to shipment either to finished goods inventory or to the ustomer. The utilization of the factors of production (raw materials, labor, capital equipment) is an ›utput of accounting for the flow of material. If this information is gathered within a system of standard osts, variances can be reported on efficiency of utilization of anticipated factor prices (wage rate, 'aw material costs).

›ufficiently Accurate Picture

The various accounting and control functions are presumed responsible for performing non-lant functions such as payment of supplier, customer billing, salesmen's compensations, and for leveloping control reports for corporate management. The purpose of the latter is to provide cor-orate management with an intelligible and sufficiently accurate picture of the company's operations. 'his picture is filled in by whatever informal methods of communication the top executive officers hoose to employ. However, the basic picture is important and to the degree that bigness of diver-ification has caused the picture to become unintelligible and insufficiently accurate, corporate ıanagement loses effectiveness in grappling with its short and long term planning functions. Inten-ification of informal communication, for example by more traveling or by relocating divisional ıanagement in a corporate headquarters building, may succeed in making good some of the infor-ıation which formal reporting fails to supply. However, there is recognition of the need to make he formal reporting more adequate.

Good Reports Out of Poor Reports

Two fundamental problems exist at the outset of any project aimed at improving a company's formal reporting system. In the first place, information from the separate plants will be aggregated in some way before it reappears in corporate reports. Hence, there must exist a basic level of compatability between the information reported by the separate plants. Secondly, and perhaps more fundamentally, the information reported and the aggregation to which it is subjected form a management information system, the usefulness of which is directly dependent on the quality of the systems design. Managerial accounting systems have been characterized by liability to misinterpretation usually due to problems of cost allocation. However, even with increased emphasis on direct costing, there remain areas of managerial concern such as product line and product mix analysis in which allocation of costs is unavoidable. To say that management must understand its reporting system does not thereby make good reports out of poor reports. If the effort required to interpret a report's contents is too great, the report becomes more trouble than it is worth.

The point of identification here is that standardization of charts of accounts, though necessary, is neither sufficient nor primary. The more fundamental task is the design of an integrated reporting system capable of giving corporate management the aggregated information it needs in the form of variances, trends, and so on. According to some of the more able practitioners in this field, such a system is compatible with the needs of plant management and of corporate custodial reporting providing the system is designed on a modular or "building block" basis. This enables costs to be assembled in different ways to meet the needs of different groups inside and outside the organization.

With this explanation of the information requirements of a business, it is now possible to explore the interaction of these needs with the information generated by process control systems.

The foregoing has described two functions of a business which are commonly regarded as essentially separate. These functions are process control, which implies control over a physical production system, and management control, which implies control over an information, decision and action system.

An elementary example, which favors simplicity at some cost to realism, helps to bring the area of interaction into focus. Exhibit 3 illustrates the control of a number of oil wells in one or more oil fields. The production process is the pumping of oil into storage tanks which hold the "finished goods" inventory. Monitoring consists of measuring the rates of flow from the wells and analyzing the percentages of oil, water, and gas in the total flow. Control is exercised through pumps and valves at the well heads. Pumping is coordinated with storage by measuring the depth of liquid in the storage tanks.

Control of the production of the wells requires measurement of rate of flow, of water content, and of quantity of oil in storage.

In order to operate and manage the business, the following information is needed: inventory on hand; well production data; analysis of output of wells; and dollar amounts owing to owners of the wells.

The latter arises in the cases of independently owned wells. The owners are recompensed on the basis of quantity of oil pumped excluding, of course, any water that is pumped out with the oil.

A Stream of Data

Evident in this simple example is a close interaction between the information required for control of the process and that required for control of the business. The simplified example identifies the major areas of interaction between the physical processes and the business of which they are a part. These areas are:

1. Information about the factors of production; i. e., about the labor employed, and the physical assets used in converting the raw material (quantity employed, time occupied, downtime).

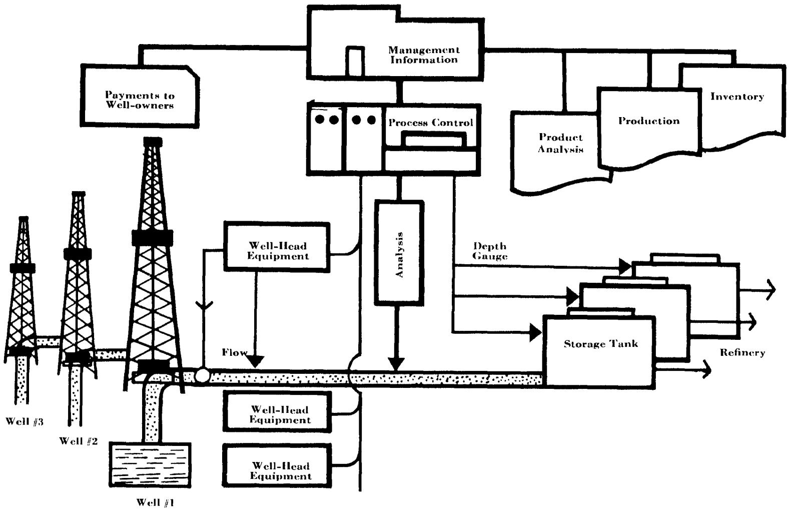


EXHIBIT 3. INTERACTION BETWEEN INFORMATION REQUIRED FOR CONTROL OF PROCESS AND BUSINESS. CONTROL OF WELL PRODUCTION REQUIRES MEASUREMENT OF RATE OF FLOW, WATER CONTENT AND QUANTITY OF OIL IN STORAGE. BUSINESS CONTROL REQUIRES INVENTORY ON HAND, WELL PRODUCTION DATA, ANALYSIS OF WELL OUTPUT AND DOLLAR AMOUNTS OWING TO WELL OWNERS.

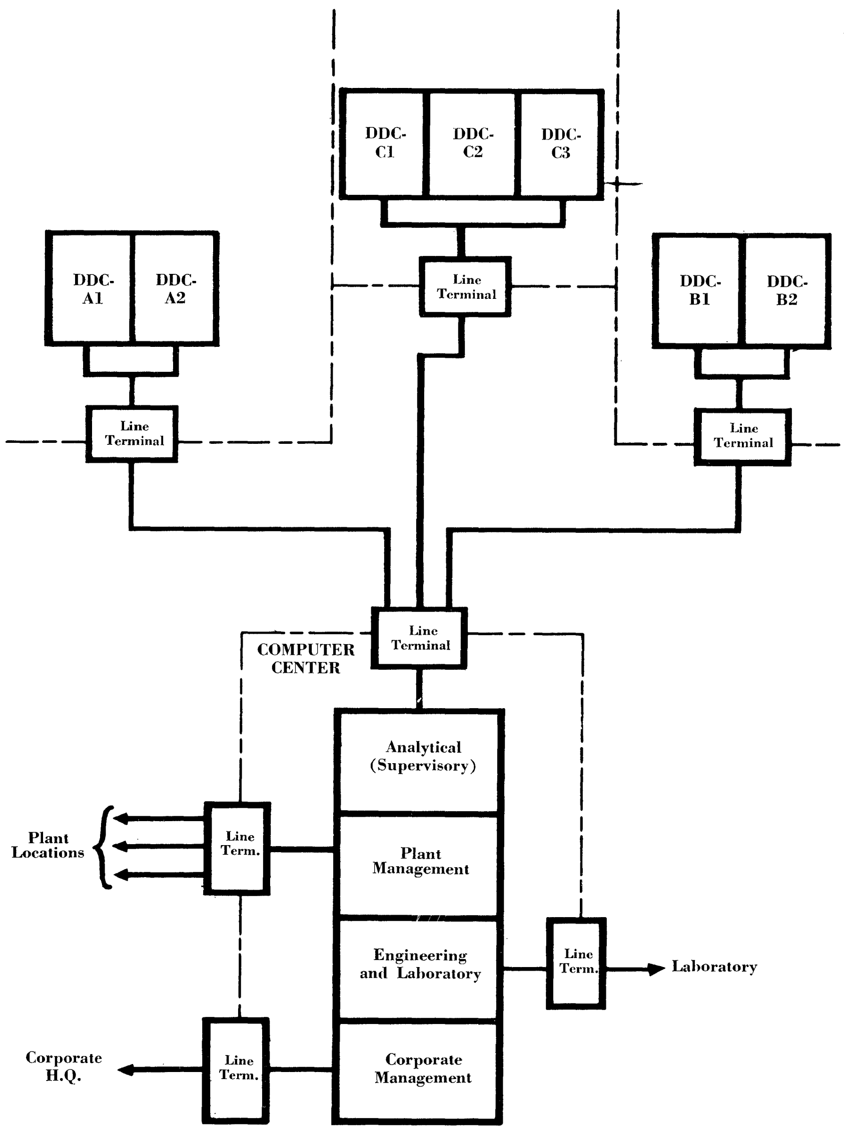


EXHIBIT 4. CONFIGURATION OF PROCESS-BUSINESS CONTROL OF THE FUTURE.

2. Information about the raw material (its use, replenishment, quality, and cost).

3. Information about the yield from the process (the quantity, shipment, and quality).

4. Information about the work-in-process (degree of completion, holdups).

The key issue is not the extent of interaction but the justification for automatically capturing data at its sources rather than at some later time through human intervention. All of the data available to the process control system through instrumentation of the physical process can, of course, be made available to the business system through an output/input operation requiring the intervention of a human operator. In practice, the process control systems instrumentation produces a large quantity of data--of which only a small percentage is useful to the business system. For example, a stream of data from a sensor in the output of a process might contain a flow reading many times a minute. In contrast to this, a half-hourly accumulated output reading is adequate for monitoring yields. Consequently, it is usually feasible to obtain this information with operator intervention by designing a report and calling for its periodic completion.

Massaging It as Necessary

However, automatic reporting can be justified for the following reasons:

1. Although the "business" data required is a small fraction of the process data, collecting and recording the information still imposes a burden on the operating staff. Hence, a constraint to minimize the reporting requirements is always present. Automation permits more freedom in specifying requirements and, hence, the reporting is more comprehensive.

2. The staff is likely to classify the reporting procedures as "red tape" and the recorded data may lack accuracy and completeness for this reason, if for no other.

3. "Tampering" with the operating data is less possible when the data is reported automatically. Employes at all levels who understand the criteria used in evaluating their performance may be tempted to "shade" the reported data in their own favor.

4. Delays in forwarding operating reports are virtually eliminated.

5. The automatic reporting can be used around-the-clock, whereas conventional reporting by a human being introduces difficulties of shift work (scheduling of personnel, premium payments, and so on).

6. Communication collection costs are competitive in those cases where the sources of data are widely dispersed.

The costs associated with automatic collection of data for the business system are influenced by a number of important considerations. In the first place the data in question is derivable in general from that used to control the physical process. Hence, costs of collection are only those incurred in extracting the business data from the process data, "massaging" it as necessary and forwarding it to the site of the "business" computer. These costs are offset by the collection costs associated with any less automatic reporting system--the tangible costs of the forms and input equipment required and the intangible costs associated with burdening the operating staff.

Secondly, the communication costs are trivial in a modern process control configuration. Currently, the analytical (supervisory) computer is a free-standing unit independent both physically and functionally of the computer or computers used to implement the company's information systems. This independence is due in part to the traditional separation of business and process control systems, in part to the relative novelty of communication-oriented data processing, and in part to the computer industry's practice of distinguishing between scientific and business computers.

The latter tendency persists to some extent despite the advent of IBM's System/360, the design objectives of which included abolition of the separation. However, it is now possible to select from a number of sources computers equipped with characteristics which enable them to do a satisfactory job of both the analysis of operating data for control of the physical process and the reporting of data for control of the business. This being so, it seems likely that the typical configuration of the near future will be similar to the hierarchy discussed in a pioneer article by James Madigan of B. F. Goodrich Chemical Co. and illustrated in Exhibit 4.

This configuration has two important effects on costs attributable to the collection of data for management and control of the business. Firstly, the communication links are justified and established primarily to forward operating data on the physical process to the supervisory processor periodically. The additional volume of data needed for business functions in addition to that required for analysis and resetting of the control model of the process is insignificant. Hence, the added communication costs are negligible.

Lack of Understanding

Secondly, processing costs of the business system must be borne no matter how the basic business operating data is collected. In the configuration of Exhibit 4, economies of scale accrue because the processing of data from a number of production units has been centralized in a large installation.

The only important area of cost is, therefore, that associated with the capturing of the operating data formerly collected by human intervention (meter reading, operator entries in machine logs) and the tying in of these data sources to the direct digital computer. As one example of this, the measurement of storage tank contents in Exhibit 3 can be cited. This information can be obtained by a person. However, installation of unattended depth gauges has the advantages listed above with respect to dispersion of data sources, round-the-clock availability, and so on.

To the extent that the business information can be derived from operating data used for control of the physical process, the costs of origination are minor or nonexistent.

So far the control needs of the physical processes and those of the business system have been discussed and the nature, extent, and justification of the interaction of these needs have been explored. With this understanding of the area of interest it is possible to ask what progress has been made toward integration of the two sets of control needs.

At this time the only possible answer to this question is "Not much!" Although, according to Dr. Hodge of IBM, "many companies have five to 10-year long range plans" in the area of integrating their physical and business systems, the achievement to date has been very limited.

The pertinent literature of the last five years is impressive for the extent and depth of its coverage of the technical aspects of process control, and for the apparent lack of concern with the related business aspects. An article by Hodge published in Chemical Engineering Magazine, June 1965, addresses the area of interaction and its effect on corporate control directly. But for the most part the literature surveyed contains only side references to the subject.

One of the major problems is the lack of understanding of costs and benefits of closer integration, a condition which seems to stem mainly from lack of appropriately competent personnel and, hence, from a lack of investigation.

Shortage of personnel is undoubtedly a major problem in the process control industry. Lee Meadows, Jr., formerly of Union Carbide, expressed the problem as being that "there are too few competent people working in both process control and business information systems" and that "those who are available have too much to do to worry about the integration of the two types of systems."

This absorption with the engineering aspects of the physical system is understandable in what is still an infant technology. Nevertheless, there is an obvious danger that preoccupation with control problems of the physical process and with optimization of the output of the process may result in neglect of areas of equal opportunity for improvement.

It is unlikely that industries which have been labeled as marginal markets for process control have reached this stage of "over-preoccupation" with the physical process. Even among major markets the production processes of the pulp, paper, cement, and steel industries still have areas of special difficulty which are absorbing the efforts of the professional staff. Consequently, integration with business systems is still regarded as a future development. With respect to the steel industry, for example, one reference concludes an examination of process control problems by saying that "The use of computers in data processing, production planning, and decision making is quite common. The industry can look forward to the day when these functions will be combined with the process control functions."

By contrast, in petroleum refining and the chemical industry where process control has been a force for a decade, the exploitation of opportunities for improvement through increased integration might reasonably be anticipated. A "limited survey" indicates that an appreciation of these opportunities is readily discernible but that such activity as exists is confined to the planning groups.

Madigan (of B. F. Goodrich) believes that development of integration will be slow because of the necessary decentralization of modern industry. While plant management is constrained by many policy guidelines established by corporate management, the productivity of the physical manufacturing facility remains the responsibility of plant management. In Madigan's view it will be some years before corporate management will seek to influence any aspect of the physical facilities by any method except the gentlest of persuasion. This imposes a barrier of sorts which might well lead to neglect of an important area for improved efficiency. However, this may be regarded as one of the costs of securing the operating advantages of decentralized responsibility.

Unexplored Territory

Fred Lambrou (formerly of Mobil Oil Co.--now with Allis-Chalmers) believes that the international operations of a company have a similar barrier since their overseas operations are operated under a local affiliate's responsibility. Furthermore, the legal status of the affiliates requires a separateness from the parent company and this adds to the height of the barrier.

Despite these factors, however, the continuing development of corporate organization points to the evolution of compromises in which the corporate influence can be effective without inhibiting the drive and freedom of divisional and affiliated managements. Lambrou, for one, feels "that in a worldwide international decentralized operation it is imperative that, although the local affiliate has full responsibility, the corporation nevertheless can suggest certain practices to be followed."

Presumably, these organizational needs and compromises will eventually be translated into such practices and in time they will include greater interaction between process systems and business systems of a manufacturing organization.

The conclusion to be drawn from this review is that the area of interaction of business systems and process control systems is largely an unexplored territory. As with any unexplored region, the richness of the deposits is difficult to predict without some exploratory mining operations. However, evaluations of the few competent "geologists" (Hodge, for example), based on their knowledge of the surrounding terrain, are enticingly high.

The financing of exploratory operations is less of a problem than finding the right personnel to form the survey team. Above all, there is a reluctance to embark on exploratory operations which stems from the structure of the modern corporations.

'Flesh and Blood'

At this juncture, exploratory operations are unlikely to be initiated by plant management. On the other hand, corporate management is accustomed to weighing carefully any intrusion on the responsibilities of plant management. This caution suggests that the interconnection of the physical process with the plant's business system may be viewed as a first step toward the imposition of tighter corporate control.

Despite this, the planning and design of new facilities is becoming increasingly a nonplant function if only because of the size of the investment. Consequently, the design of a new plant appears to be an opportunity to explore the interaction of business systems and process control system.

The prognostications are that exploiting this opportunity whenever it presents itself will lead to important economic benefits and that development of the area of interaction will lay the groundwork for a "flesh and blood" corporate information system in process and manufacturing industries.

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Tenth annual salary survey, covering over 37,000 data processing workers in 35 metropolitan centers, shows normal 'up' trend in wages

EDP Salary Study—1968

THE top jobs in data processing averaged about a 5 percent increase in income over last year, according to BUSINESS AUTOMATION's 10th annual survey of salaries in the data processing profession. The 1968 report showed that the manager of all data processing had an annual income of $14,612, up 4.8 percent over the 1967 average. For the manager of systems analysis, the survey reported an average annual salary of $13,156, an increase of 3.7 percent over the prior year. The manager of programing averaged $11,752, according to the poll, a 5.6 percent jump over 1967 figures. The average advance for all 22 EDP positions surveyed was 6.4 percent.

This year, as a further aid to salary comparisons, a regional report has been added (see p42). Survey participants were distributed among the nine-region breakdown as follows: New England, 10.1 percent; Middle Atlantic, 16.3; South Atlantic, 11.3; East North Central, 24.8; West North Central, 12.4; East South Central, 3.1; West South Central, 4.9; Mountain, 4.7; and Pacific, 12.4.

Also, a table showing median number of EDP employes, by size of installation, has been added to this year's report (see p42). The median number of data processing people for all participating installations was 17. Among the total employes reported by the larger installations were such figures as 823, 760, 650, 524, 475, 442 and 366—an indication of the manpower requirements for the big users of EDP.

A downward shift in the number of firms renting computers from manufacturers was indicated by the 1968 survey—76 percent as opposed to 84 percent last year. The number of firms purchasing equipment rose from 22 to 23.3 percent, while those leasing equipment from leasing companies increased to 9.7 percent from the 5 percent figure of a year ago.

A significant increase in the number of EDP installations reporting to top management was shown by this year's report. Over 37 percent of the data processing managers reported to the presidential and vice presidential level versus 19.6 percent in 1967.

The survey shed some new light on the thorny problem of overtime for systems analysts and programers. Nearly half of the participants indicated that no overtime was paid to the analyst/programer group. The chief reason given was the group's classification as "professional" employes. Where salary level was presented as the basis for determining overtime, $170 was the average weekly rate above which overtime was not paid. A large percentage of participants indicated that other forms of compensation for overtime was involved, mainly time off and expense allowances, the latter mostly involving meal expenses and, when necessary, lodging.

No. 1 need: systems analysts

Regarding positions most difficult to fill, systems analysis personnel took over the number one need spot, with programers dropping to second place, the reverse of last year's findings. Keypunch and computer operators continued as the third and fourth items on the "hard to get" list, with virtually the same percentage ranking as in 1967. Slightly over 1 percent of the participants indicated that EDP positions were not difficult to fill.

In the July issue of BUSINESS AUTOMATION, an addendum to the 1968 survey report, covering all 22 EDP jobs by an industry breakdown, will be published. The complete salary survey was compiled again this year by Market Facts, Inc., headquartered in Chicago, one of the nation's largest marketing firms.

Job Descriptions

Manager of All Data Processing

Plans, organizes and controls the overall activities of electronic data processing including systems analysis, programing, and computer operation activities through managing subordinates or by direct supervision. Personally handles major personnel, administrative and data processing problems.

Assistant Manager of Data Processing

Under general direction, assists the manager in planning, organizing and controlling the various sections of the department. Usually has departmental line responsibility but in certain instances may only have departmental staff responsibility. Consults with and advises other departments with regard to feasibility, systems and procedures, and records control studies and problems. May act for the manager in his absence.

Manager or Supervisor of Systems Analysis

Plans, organizes and controls the activities of the Systems Analysis Section in the establishment and implementation of new or revised systems and procedures concerned with electronic data processing. Usually considered as being in full charge of all systems analysis activities. Responsible for feasibility studies and systems design involving electronic data processing and makes recommendations on the action to be taken. Assigns personnel to the various projects and directs their activities. Consults with and advises other departments on systems and procedures.

Lead Systems Analyst

Usually considered as the assistant manager of systems analysis. Has full technical knowledge of the activity and also has supervisory duties of instructing, directing and checking the work of the other systems analysts. Assists in planning, organizing and controlling the activities of the section. Assists in the scheduling of the work of the section and the assigning of personnel to the various projects being studied or processed. May act for the manager in his absence.

Senior Systems Analyst

Under general direction, formulates logical statements of business problems and devises procedures for solutions of the problems. Usually competent to work at the highest level of all technical phases of systems analysis while working on his own most of the time. May give some direction and guidance to lower level classifications. Confers with management to define the data processing problem. Analyzes existing system logic difficulties and revises the logic and procedures involved as necessary. Develops logic and procedures to provide more efficient machine operations.

Junior Systems Analyst

Under direct supervision, assists higher level classifications in devising computer system specifications and record layouts. Usually fairly competent to work on several phases of systems analysis with only general direction but still needs some instruction and guidance for the other phases. Studies and analyzes existing office procedures as assigned. Prepares systems flow charts to describe existing and proposed operations. Prepares comprehensive computer block diagrams in accordance with instructions from higher level classifications.

Manager or Supervisor of Programing

Plans, organizes and controls the preparation of computer programs for the solution of business problems. Usually considered as being in full charge of all programing activities. Assigns, outlines and coordinates the work of programers engaged in writing computer programs and routines. Establishes standards for block diagraming, machine flow charting and programing procedures. May write and debug complex programs. Reviews and evaluates the work of the staff and prepares periodic performance reports. Collaborates with systems analysts and other technical personnel in scheduling equipment analysis, feasibility studies and systems planning.

Lead Programer

Usually considered as the assistant manager of programing. Has a full technical knowledge of programing. Also has supervisory duties of instructing, assigning, directing and checking the work of the other programers. Assists in scheduling programing projects and in the assignment of personnel to the various projects. Coordinates the activities of the programing section with the other sections in the overall computer department. May act for the manager in his absence.

Senior Programer

Under general supervision, develops and prepares machine logic flow charts for the solution of business problems. Usually competent to work at the highest level of all technical phases of programing while working on his own most of the time. May give some direction and guidance to lower level classifications. Analyzes problems outlined by systems analysts in terms of detailed equipment requirements and capabilities. Designs detailed machine logic flow charting. Verifies program logic by preparing test data for trial runs. Tests and debugs programs. Prepares instruction sheets to guide computer operators during production runs. Evaluates and modifies existing programs to take into account changes in systems requirements or equipment configurations. May translate detailed machine logic flow charts into coded machine instructions. May assist in determining the causes of computer operation malfunctions. May confer with technical personnel in systems analysis and application planning.

Junior Programer

Under direct supervision, assists in the review and analysis of detailed systems specifications and the preparation of the program instructions. Usually fairly competent to work on several phases of programing with only general direction but still needs some instruction and guidance for the other phases. Assists in the preparation of all levels of block diagrams and machine logic flow charts. Codes program instructions. Assists in preparing test data and testing and debugging programs. Assists in the documentation of all procedures used throughout the system.

Manager or Supervisor of Computer Operations

Plans, organizes and controls the operation of the computer and peripheral data processing equipment. Usually considered as being in full charge of all activities of equipment operations. Establishes detailed schedules for the utilization of all equipment to obtain maximum usage. Assigns personnel to the various operations and instructs them where necessary so they are trained to perform assigned duties in accordance with established methods and procedures. Reviews equipment logs and reports to the manager of data processing on equipment operation efficiency for the section.

Lead Computer Operator

Usually considered the assistant manager of computer operations. Has supervisory duties of instruction, assigning, directing and checking the work of the other computer operators, including seniors. Assists in the scheduling of the operations and the assigning of personnel to the various items of equipment required for the computer functions. Coordinates activities of the section with other sections of the overall data processing department. May act as shift supervisor. May act for the manager in his absence.

Senior Computer Operator

Under general supervision, monitors and controls computer by operating the central console. Usually competent to work at the highest level of all computer operation phases. May give some direction and guidance to lower level classifications. Studies program operating instruction sheets to determine equipment setup and run operation. Switches auxiliary equipment into circuit. Confers with technical personnel in the event errors require a change in instructions or sequence of operations. Maintains operating records such as machine performance and production reports.

Junior Computer Operator

Under direct supervision, assists higher level classifications in monitoring and controlling computer. Usually fairly competent to work on several phases of computer operations with only general direction but still needs some instruction and guidance for the other phases. Assists higher level classifications in carrying out the various duties associated with operating a computer or the auxiliary equipment directly associated with the computer. May keep records regarding output units and maintain records for stores and supplies.

Manager or Supervisor of Unit Record Equipment

Under supervision of the data processing manager, directs the personnel of the unit record department and manages the preparation of various reports and data. In non-computer installations may be considered manager of data processing with similar responsibility.

Lead Operator, Unit Record Equipment

Usually considered as assistant to manager or supervisor of unit record department. Has technical responsibility for report preparation. In charge of scheduling and machine usage. Directs training of personnel.

Senior Operator, Unit Record Equipment

Under supervision, operates all unit record equipment and assists in technical responsibility.

Junior Operator, Unit Record Equipment

Under direct supervision, operates a variety of equipment.

Keypunch Supervisor

Under supervision of the data processing or unit record manager, plans, schedules, supervises and directs keypunching and verifying activities; maintains the corresponding files; supervises assigned personnel to carry out the above activities.

Lead Keypunch Operator

Under direct supervision, assists in supervising the group engaged in operating keypunch and verifier machines; assists in the scheduling of keypunch functions; instructs workers on procedures used to perform routine assignments; trains new employes.

Senior Keypunch Operator

Under direct supervision, operates keypunch and verifier machines; instructs workers on procedures used to perform routine assignments; assists in training new employes.

Junior Keypunch Operator

Under direct supervision, operates keypunch machines and verifier machines; performs related clerical duties. ■

Weekly Salaries For All EDP Jobs by Regions

Job Description and Code ▶ Low, Average and High represent actual weekly salaries paid ▼		Manager of all Data Processing (01)	Ass't. Mgr. of Data Processing (02)	Manager of Systems Analysis (10)	Lead Systems Analyst (11)	Senior Systems Analyst (12)	Junior Systems Analyst (13)	Manager of Programing (20)	Lead Programer (21)	Senior Programer (22)	Junior Programer (23)
New England	L	110	135	125	135	115	90	153	125	115	80
	A	270	247	252	219	203	162	206	191	166	137
	H	481	400	350	300	262	243	314	287	233	188
Middle Atlantic	L	155	100	130	167	149	92	150	120	96	75
	A	303	260	260	243	230	168	246	217	194	165
	H	600	440	440	300	320	221	350	300	300	211
South Atlantic	L	145	150	150	135	135	100	138	130	115	70
	A	270	264	266	225	207	175	224	200	176	146
	H	450	461	387	296	293	249	327	269	302	212
East North Central	L	154	140	136	159	110	105	125	135	100	90
	A	279	240	248	231	207	180	219	203	174	147
	H	500	346	432	350	320	250	333	288	252	230
East South Central	L	173	156	200	169	140	90	210	105	120	72
	A	261	206	229	209	196	132	250	150	156	117
	H	352	250	260	312	269	194	328	257	256	160
West North Central	L	100	150	145	95	129	115	128	102	120	70
	A	286	228	247	218	215	171	226	195	182	148
	H	461	336	350	300	320	245	410	335	290	290
West South Central	L	150	166	194	180	156	129	135	150	96	80
	A	258	224	237	206	194	156	228	209	173	138
	H	450	288	345	275	238	205	415	315	250	205
Mountain	L	175	160	157	194	148	102	138	135	105	80
	A	250	248	229	217	193	152	202	181	167	140
	H	423	300	316	260	271	190	287	275	257	200
Pacific	L	180	179	165	190	142	110	130	135	133	104
	A	296	264	272	245	221	198	235	212	188	159
	H	577	374	420	350	310	289	310	271	260	200

Regional breakdown by states New England—*Maine, Vt., N.H., Mass., Conn., R.I.*
Middle Atlantic—*N.Y., Pa., N.J.*
South Atlantic—*W. Va., Md., Del., Va., N.C., S.C., Ga., Fla., District of Columbia*

Number of computers and peripheral devices installed per installation

Number	Computers	Tape Drives	Disc Drives	Disc Pack Drives	Printers	Displays	Optical Scanning
None	.0%	28.0%	73.4%	55.6%	1.4%	87.3%	88.0%
1	67.4	1.4	4.5	3.4	65.4	4.4	7.4
2	18.8	9.5	5.2	10.1	17.2	1.3	.9
3	5.7	3.5	3.9	10.1	5.7	.3	-
4	2.5	18.4	3.5	5.9	2.4	.7	-
5	.8	8.0	1.5	2.0	1.3	.2	-
6	1.6	7.2	1.0	2.0	.6	.2	-
7	.8	1.9	.1	.6	.7	.1	.1
8	.3	4.5	.7	1.4	.3	.2	-
9	.5	1.3	.6	.5	.2	.1	-
10 or more	.3	12.9	4.2	4.2	1.0	1.6	-
No Answer	1.0	3.7	4.1	4.5	3.8	3.6	3.6
Mean Average	1.66	3.90	.84	1.68	1.63	.34	.10

Median number of EDP employes by size of installation

Size by monthly rental	Median No. of employes
Under $3,000	6
$3,000-$6,000	10
$6,000-$9,000	15
$9,000-$12,000	22
$12,000-$18,000	26
$18,000-$25,000	41
$25,000-$50,000	55
Over $50,000	148
All installations	17

Basic Computer Input

Punched Cards	84.7%
Paper Tape	9.5%
Optical Scanners	3.9%
Magnetic Tape	27.9%
Others	10.4%
No Answer	.3%

Manager of Computer Operations (30)	Lead Computer Operator (31)	Senior Computer Operator (32)	Junior Computer Operator (33)	Manager of Unit Record Equipment (40)	Lead Opr. Unit Record Equipment (41)	Senior Opr. Unit Record Equipment (42)	Junior Opr. Unit Record Equipment (43)	Keypunch Supervisor (50)	Lead Keypunch Operator (51)	Senior Keypunch Operator (52)	Junior Keypunch Operator (53)
110	90	84	69	100	80	81	64	90	77	56	60
190	139	125	109	164	131	111	92	118	102	91	85
350	225	175	160	267	176	160	135	202	153	123	108
110	100	80	65	90	92	73	64	85	70	60	60
202	169	135	124	166	124	119	93	129	104	95	82
317	288	240	194	356	179	181	131	229	157	140	128
92	95	80	68	100	98	69	67	80	75	65	64
196	148	128	116	157	126	109	92	122	100	91	83
330	230	200	165	195	150	169	127	275	166	128	115
125	100	84	64	70	72	66	65	75	70	65	59
199	155	133	114	165	140	117	95	130	108	98	83
360	264	210	178	250	202	158	125	258	190	155	123
130	100	82	70	112	75	79	69	80	87	64	58
166	132	104	87	154	110	97	83	112	95	77	72
238	161	129	106	180	135	116	90	144	120	110	100
98	75	75	70	108	75	70	65	80	71	64	60
191	143	124	111	167	126	107	90	121	96	86	79
336	200	170	174	237	182	145	115	194	138	125	110
107	100	75	60	90	125	92	40	80	64	62	60
193	137	116	97	158	139	112	80	110	97	89	77
340	173	160	120	260	158	133	108	151	120	120	100
100	94	84	75	114	100	83	73	90	75	69	62
185	141	120	110	131	121	107	92	114	99	92	81
275	173	146	135	145	133	133	120	145	122	118	114
120	120	100	80	115	96	86	86	90	81	75	70
212	172	149	125	180	172	147	124	135	121	108	99
308	250	196	166	256	240	188	160	189	170	144	148

East North Central—*Wis., Mich., Ill., Ind., Ohio*
East South Central—*Ky., Tenn., Miss., Ala.*
West North Central—*N.D., Minn., S.D., Neb., Iowa, Kans., Mo.*

West South Central—*Tex., Okla., Ark., La.*
Mountain—*Mont., Idaho, Nev., Wyo., Colo., Ariz., N.M., Utah*
Pacific—*Wash., Ore., Calif.*

On overtime compensation for systems analysis and programing personnel:

All receive overtime pay	16.4%
Some do and some do not	36.1%
None receive overtime pay	44.8%
No answer	2.7%

Basis for not compensating for overtime:

Classified as "professional" employe	51.1%
Salary level *	39.6%
Misc. reasons	3.2%
No answer	6.1%

*Where salary level was determining factor, the survey indicated that $170 was the average weekly salary above which overtime was not compensated. The average number of weekly overtime hours for those compensated in overtime pay was 5.2 hours.

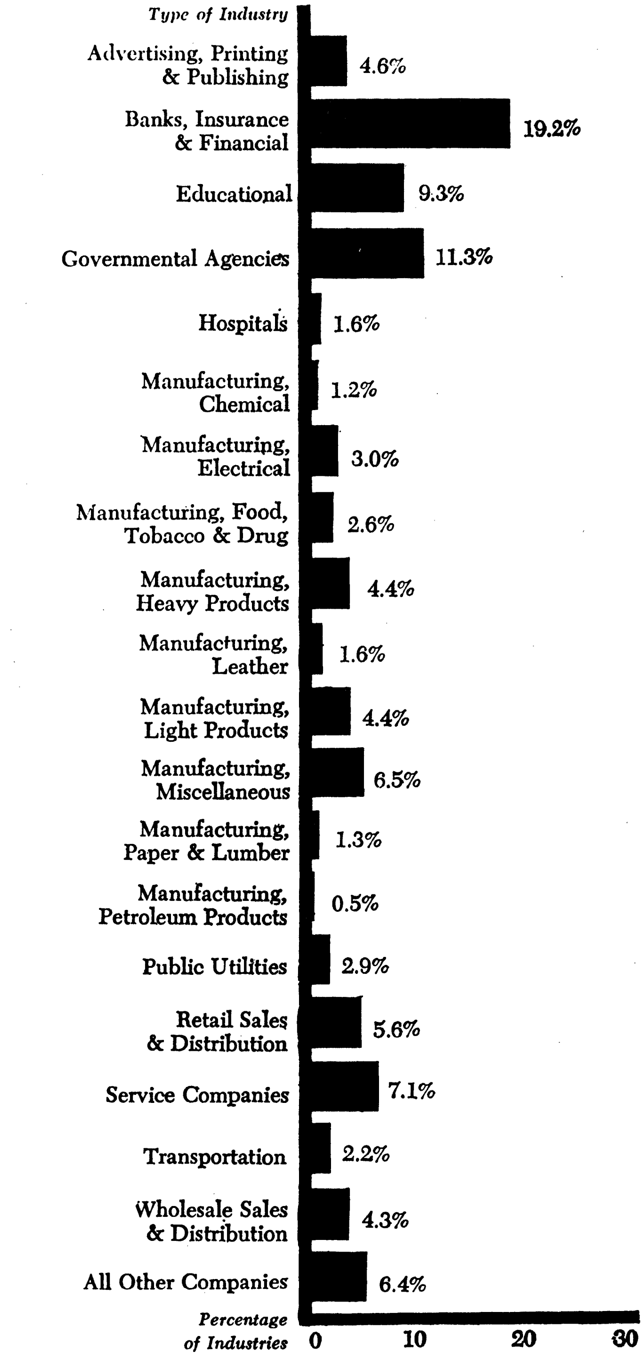
Other forms of compensation for overtime worked:

Yes	65.9%
No	32.0%
No answer	2.1%

Other forms of compensation:

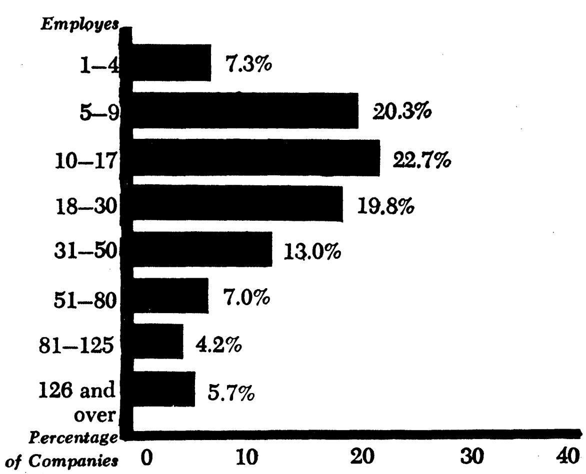
Expense allowance	38.1%
Time off	49.3%
Bonus	3.4%
Profit Sharing	1.3%
Stock Options	.5%
Extra Vacation	.5%
Misc.	3.4%
No Answer	3.5%

Industries Surveyed

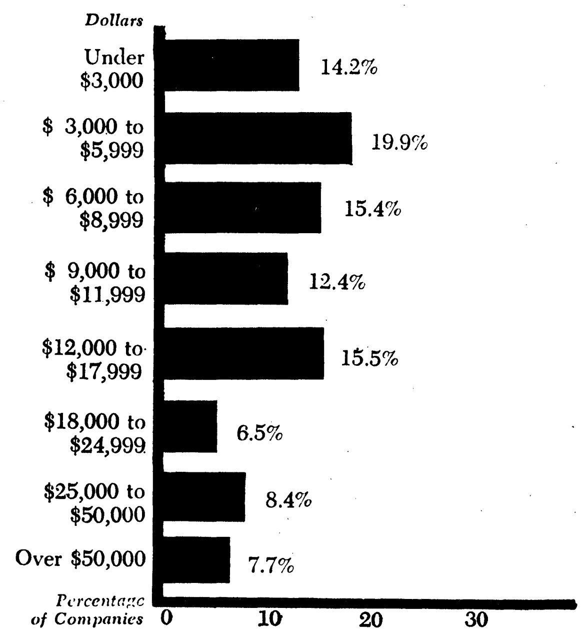


Monthly Dollar Rental ▶		Under $3,000		
Actual Salaries Paid ▶		**Low**	**Av.**	**High**
Job Description	**Job Code**			
Manager of All Data Processing	01	110	221	325
Ass't Manager of Data Processing	02	150	179	245
Manager of Systems Analysis	10	136	217	309
Lead Systems Analyst	11	150	200	250
Senior Systems Analyst	12	110	198	250
Junior Systems Analyst	13	102	144	200
Manager of Programing	20	130	168	200
Lead Programer	21	105	160	230
Senior Programer	22	110	155	230
Junior Programer	23	92	133	211
Manager of Computer Operations	30	110	161	260
Lead Computer Operator	31	100	127	154
Senior Computer Operator	32	88	118	147
Junior Computer Operator	33	75	106	150
Manager of Unit Record Equip.	40	100	164	240
Lead Operator, Unit Record Equip.	41	72	111	165
Senior Operator, Unit Record Equip.	42	66	109	140
Junior Operator, Unit Record Equip.	43	65	88	110
Keypunch Supervisor	50	85	113	170
Lead Keypunch Operator	51	70	97	134
Senior Keypunch Operator	52	70	92	125
Junior Keypunch Operator	53	59	83	121

Employes in Data Processing



Monthly Rental for DP Equipment



Weekly Salary Data for EDP Jobs by Installation Size

$3,001–$6,000			$6,001–$9,000			$9,001–$12,000			$12,001–$18,000			$18,001–$25,000			$25,001–$50,000			Over $50,000		
Low	Av.	High	Low	Av.	High	Low	Av.	High	Low	Av.	High	Low	Av.	High	Low	Av.	High	Low	Av.	High
100	250	600	170	269	435	190	292	460	188	296	500	212	310	433	190	315	500	221	361	577
150	188	250	150	224	288	135	236	325	140	246	440	190	243	327	160	279	374	195	296	461
150	231	350	162	225	280	125	245	387	170	242	440	145	243	350	130	278	432	160	276	420
95	210	300	172	209	260	165	222	312	135	216	300	157	223	269	177	243	305	159	241	350
142	191	320	140	198	300	110	211	310	115	202	306	129	203	271	146	216	298	130	220	320
98	143	192	100	149	188	90	168	249	90	160	214	125	171	216	102	181	289	125	183	256
125	199	350	134	204	280	160	222	328	125	221	300	167	223	306	144	236	350	160	245	415
102	172	265	127	178	232	155	192	288	115	190	275	135	191	287	147	203	300	138	218	315
106	162	300	98	164	224	100	177	256	105	175	302	96	170	260	104	180	250	107	195	275
70	131	255	70	134	183	85	143	207	88	143	230	78	138	199	90	147	200	80	167	214
92	167	235	100	179	275	130	187	275	98	189	308	126	207	312	110	224	360	125	227	340
75	133	220	94	138	185	90	142	188	100	145	260	113	162	225	105	163	264	100	165	288
75	118	185	80	122	186	80	127	174	82	129	210	75	129	188	84	138	201	86	138	240
60	100	150	68	108	150	64	109	148	70	109	178	71	108	160	65	114	166	70	127	194
70	136	209	90	147	250	130	148	187	100	168	215	90	148	186	90	161	237	100	184	356
80	129	200	75	126	160	92	127	168	90	136	196	90	139	210	96	140	179	85	139	240
75	117	150	79	108	150	78	111	170	73	112	155	75	122	188	69	118	164	79	122	185
40	84	131	70	103	140	67	95	150	73	97	127	64	102	160	65	100	136	64	101	160
80	112	175	90	118	200	86	124	177	75	123	275	90	127	165	90	134	258	87	136	229
64	97	190	72	98	127	70	104	135	75	105	170	71	107	175	85	112	157	77	110	166
65	90	130	56	93	144	65	94	135	64	93	135	70	98	155	68	100	140	64	96	140
64	81	148	64	80	109	63	85	116	60	84	123	60	87	125	58	88	128	60	86	130

Systems analysts and programers considered

as one group	69.8%
as separate groups	30.2%

As one group, the systems analysis and programing function reports to:

Data Processing Manager	80.8%
Higher level than DP Manager	14.2%
Lower level than DP Manager	5.0%

Weekly Average Salary Comparison	DP Mgr.	Reports to Higher	Lower
Manager, Systems Analysis	242	253	273
Lead Systems Analyst	221	231	230
Senior Systems Analyst	201	212	206
Junior Systems Analyst	167	196	171
Manager, Programing	218	252	216
Lead Programer	185	207	204
Senior Programer	176	163	176
Junior Programer	143	141	148

As separate group, the systems analysis function reports to:

Data Processing Manager	54.7%
Higher level than DP Manager	32.9%
Lower level than DP Manager	12.4%

Weekly Average Salary Comparison	DP Mgr.	Reports to Higher	Lower
Manager, Systems Analysis	258	275	258
Lead Systems Analyst	230	252	237
Senior Systems Analyst	218	218	216
Junior Systems Analyst	171	182	176

As separate group, the programing function reports to:

Data Processing Manager	72.9%
Higher level than DP Manager	10.9%
Lower level than DP Manager	16.2%

Weekly Average Salary Comparison	DP Mgr.	Reports to Higher	Lower
Manager, Programing	232	238	213
Lead Programer	210	219	212
Senior Programer	188	176	180
Junior Programer	166	144	144

Salaries of Selected EDP Positions by Metropolitan Areas

Job Description and Code ▶ Low, Average and High represented actual weekly salaries paid ▼		Manager of all Data Processing (01)	Ass't. Mgr. of Data Processing (02)	Manager of Systems Analysis (10)	Lead Systems Analyst (11)	Senior Systems Analyst (12)	Junior Systems Analyst (13)	Manager of Programing (20)	Lead Programer (21)	Senior Programer (22)	Junior Programer (23)
Atlanta, Ga.	L	200	197	230	180	174	*	138	150	124	70
	A	263	216	260	199	199	*	194	182	166	138
	H	332	245	308	217	210	*	250	224	207	189
Baltimore, Md.	L	190	*	202	231	185	150	200	130	129	100
	A	284	*	267	250	203	174	236	200	183	150
	H	350	*	294	277	250	190	260	254	200	190
Bloomington, Ill.	L	200	*	190	184	182	142	173	150	132	104
	A	265	*	222	215	198	165	227	190	177	145
	H	332	*	254	240	242	202	295	245	240	190
Boston, Mass.	L	180	175	170	135	115	90	160	150	135	80
	A	280	245	253	222	201	149	202	199	166	135
	H	450	400	340	300	250	197	254	287	212	173
Buffalo, N.Y.	L	210	205	205	*	169	98	190	*	135	100
	A	269	255	241	*	206	126	211	*	169	128
	H	335	305	262	*	239	156	231	*	237	167
Charlotte, N.C.	L	150	*	150	135	160	144	150	180	115	110
	A	266	*	267	212	201	174	205	199	170	130
	H	380	*	365	248	260	220	280	232	200	160
Chicago, Ill.	L	179	175	175	190	138	140	150	144	107	92
	A	280	231	254	239	212	190	220	196	163	148
	H	500	306	400	350	300	250	300	288	250	207
Cincinnati, Ohio	L	200	*	184	159	146	124	170	160	110	92
	A	270	*	252	196	186	149	205	183	142	120
	H	450	*	312	250	230	178	240	225	160	153
Cleveland, Ohio	L	187	140	136	175	110	105	175	150	100	92
	A	294	203	262	228	206	177	206	204	177	150
	H	462	346	404	327	273	230	245	250	240	194
Columbus, Ohio	L	221	192	192	220	148	132	156	135	108	120
	A	302	252	239	233	209	161	203	184	173	151
	H	400	300	282	240	275	197	254	225	225	208
Dallas, Texas	L	150	200	194	210	161	129	174	160	96	85
	A	265	240	253	228	195	154	234	188	169	138
	H	385	279	345	275	230	184	282	207	200	178
Denver, Colo.	L	175	160	157	194	148	102	138	140	118	92
	A	250	248	229	217	192	151	209	185	175	146
	H	356	300	316	260	271	190	287	275	257	200
Des Moines, Iowa	L	100	196	220	95	144	115	176	138	120	98
	A	274	244	255	221	201	152	208	166	154	141
	H	461	325	300	285	306	192	239	225	190	197
Detroit, Mich.	L	154	165	180	200	180	115	165	175	116	100
	A	280	257	264	255	226	208	248	239	187	157
	H	500	346	335	325	260	230	333	270	234	194
Harrisburg, Pa.	L	185	*	240	195	180	92	173	150	96	75
	A	257	*	258	215	188	150	211	193	162	116
	H	375	*	275	240	225	180	250	250	190	140
Hartford, Conn.	L	205	135	125	165	160	138	178	125	115	95
	A	281	223	257	219	207	167	231	197	177	142
	H	481	358	350	260	254	230	314	247	221	188
Houston, Texas	L	165	170	214	181	171	140	138	180	109	103
	A	260	238	244	202	196	147	210	206	171	148
	H	365	288	298	205	238	168	238	209	230	166
Indianapolis, Ind.	L	170	*	*	*	175	*	125	155	170	100
	A	257	*	*	*	186	*	232	213	205	162
	H	325	*	*	*	200	*	282	252	252	230
Los Angeles, Calif.	L	180	179	179	190	175	110	130	135	138	105
	A	315	271	286	257	236	217	236	214	196	165
	H	577	374	420	350	310	289	306	271	260	200
Miami, Fla.	L	173	156	169	208	152	138	167	135	120	110
	A	280	258	251	270	219	173	241	217	182	154
	H	370	461	367	296	277	222	327	269	226	186
Milwaukee, Wis.	L	180	195	173	165	110	120	125	145	115	90
	A	275	252	243	218	200	163	201	190	169	138
	H	360	288	432	305	320	227	253	231	226	189

Manager of Computer Operations (30)	Lead Computer Operator (31)	Senior Computer Operator (32)	Junior Computer Operator (33)	Manager of Unit Record Equipment (40)	Lead Opr. Unit Record Equipment (41)	Senior Opr. Unit Record Equipment (42)	Junior Opr. Unit Record Equipment (43)	Keypunch Supervisor (50)	Lead Keypunch Operator (51)	Senior Keypunch Operator (52)	Junior Keypunch Operator (53)
92	95	99	80	150	112	*	80	80	75	70	65
169	134	122	109	158	114	*	93	124	102	91	83
242	165	160	125	174	115	*	114	200	120	125	100
120	124	100	68	*	*	100	90	96	80	74	64
211	154	135	120	*	*	105	98	116	99	92	76
275	170	150	145	*	*	110	100	140	125	120	90
160	111	100	80	136	111	82	83	97	90	75	67
199	160	130	113	158	126	114	95	118	113	95	76
275	220	180	145	180	140	155	110	138	120	115	89
125	100	84	69	100	85	81	64	90	77	56	60
181	133	122	101	162	124	107	84	118	99	91	77
254	206	175	142	209	166	140	112	156	117	119	106
150	*	85	72	149	*	85	90	90	70	80	70
175	*	113	94	173	*	109	93	103	92	90	88
211	*	149	110	190	*	130	100	116	105	120	107
125	122	95	82	100	*	79	67	86	80	73	66
166	161	135	125	146	*	103	84	111	94	84	75
253	219	174	150	187	*	169	88	155	127	100	90
125	100	95	85	130	100	85	81	100	90	80	70
199	150	135	110	183	156	121	102	132	115	101	88
312	260	210	178	239	202	158	112	192	190	135	109
171	107	84	77	112	*	73	70	90	80	68	65
223	129	112	98	129	*	89	77	119	97	83	74
300	150	140	125	145	*	105	92	155	110	109	85
135	110	88	64	135	90	104	80	100	70	79	59
190	148	135	117	194	139	121	106	125	101	98	81
275	213	193	162	250	169	140	125	225	126	119	101
150	130	98	71	133	110	83	69	112	83	71	65
190	149	127	101	142	118	88	80	136	91	86	73
288	184	168	132	150	126	92	105	173	100	109	87
150	100	75	80	126	128	100	40	90	77	69	65
195	140	130	104	152	138	114	78	116	106	93	78
230	173	160	120	196	158	130	108	151	120	120	92
100	94	84	81	114	100	83	73	94	75	69	64
189	141	122	112	131	122	106	91	120	100	94	83
275	173	145	135	145	133	124	105	145	122	118	114
98	75	92	80	*	112	70	65	80	76	64	60
176	128	111	97	*	127	92	84	116	94	85	78
305	200	150	135	*	154	125	102	158	125	114	110
150	125	98	80	130	100	85	68	97	85	80	64
214	174	145	131	159	130	121	91	136	127	106	87
278	230	191	155	203	145	134	122	180	175	155	123
134	135	87	65	*	95	*	75	96	76	60	60
184	155	116	112	*	125	*	80	107	92	80	70
250	165	145	130	*	115	*	90	115	105	100	90
154	90	95	93	140	113	88	76	90	85	80	72
207	155	132	116	182	143	118	110	129	105	96	90
350	225	165	160	267	173	160	135	202	153	123	108
107	102	95	72	140	*	*	*	96	75	68	64
180	132	122	94	168	*	*	*	112	99	89	77
209	170	160	110	177	*	*	*	123	109	112	90
160	115	87	102	190	*	98	85	95	92	70	65
195	130	128	113	*	*	117	98	148	103	95	85
221	137	158	122	*	*	124	105	224	119	117	114
150	128	110	80	115	110	110	87	100	98	85	70
133	183	156	130	178	178	151	131	142	125	110	104
308	250	196	166	256	240	188	160	189	160	140	148
138	100	80	70	*	*	103	79	90	75	72	65
181	144	121	114	*	*	111	79	122	108	89	89
265	225	162	151	*	*	134	80	213	166	128	104
125	124	100	75	70	72	66	65	75	75	65	60
193	166	130	112	136	126	119	96	123	100	91	81
360	264	184	150	190	154	157	115	258	127	135	103

Salaries of Selected EDP Positions by Metropolitan Areas *(continued)*

Job Description and Code ▶ Low, Average and High represented actual weekly salaries paid ▼		Manager of all Data Processing (01)	Ass't. Mgr. of Data Processing (02)	Manager of Systems Analysis (10)	Lead Systems Analyst (11)	Senior Systems Analyst (12)	Junior Systems Analyst (13)	Manager of Programing (20)	Lead Programer (21)	Senior Programer (22)	Junior Programer (23)
Newark, N.J.	L	220	210	182	178	177	140	187	165	155	113
	A	284	245	279	243	242	175	259	205	195	133
	H	400	270	385	290	320	221	300	265	300	160
New York, N.Y.	L	210	158	200	172	150	100	187	175	120	100
	A	301	275	290	248	217	178	251	220	187	153
	H	600	440	440	300	260	213	350	300	269	200
Oklahoma City, Okla.	L	200	198	196	181	161	150	200	150	104	80
	A	264	247	214	187	185	167	219	167	150	121
	H	350	285	230	192	214	184	230	192	192	155
Philadelphia, Pa.	L	155	200	160	167	152	125	150	120	98	85
	A	293	282	263	252	243	163	259	229	215	180
	H	400	330	325	290	275	220	310	290	275	211
Phoenix, Ariz.	L	190	160	130	170	149	138	160	146	136	90
	A	300	180	214	211	193	193	187	167	166	136
	H	369	200	250	230	265	215	226	198	193	180
Pittsburgh, Pa.	L	224	*	260	204	167	146	173	155	121	80
	A	293	*	288	243	202	168	208	170	155	115
	H	423	*	303	269	227	196	242	180	189	135
Portland, Oregon	L	110	190	185	175	150	125	153	150	126	98
	A	254	217	247	215	198	177	192	172	156	133
	H	436	253	332	236	262	243	250	245	233	167
Richmond, Va.	L	145	195	193	185	182	125	196	166	125	100
	A	264	260	250	220	188	172	202	181	162	129
	H	425	325	317	288	190	202	208	201	190	168
St. Louis, Mo.	L	170	150	190	150	154	150	160	130	140	120
	A	285	222	268	261	232	189	232	214	211	165
	H	401	336	350	295	310	245	336	286	242	204
St. Paul/Minneapolis	L	165	150	145	158	129	138	144	141	120	70
	A	291	224	235	210	209	163	236	194	171	143
	H	458	288	290	300	320	196	410	335	290	290
San Francisco, Calif.	L	192	184	208	195	142	147	180	160	133	115
	A	294	272	281	230	209	174	241	211	186	153
	H	450	330	355	300	300	230	310	267	225	180
Seattle, Wash.	L	205	196	165	202	170	138	184	170	148	104
	A	268	231	230	204	184	160	217	204	165	138
	H	400	250	295	206	202	200	225	225	231	160
Syracuse, N.Y.	L	200	150	205	*	155	150	*	150	114	90
	A	260	193	216	*	210	180	*	197	161	122
	H	324	230	220	*	260	214	*	221	186	160
Washington, D.C.	L	173	150	200	173	135	140	150	138	115	96
	A	281	247	271	214	216	188	237	185	170	153
	H	450	350	387	267	293	249	314	242	302	212

Survey Profile of the Data Processing Manager

To whom does the data processing manager report?

President	11.3%
Vice President	25.8%
Controller, Assistant Controller	25.4%
Secretary-Treasurer	7.9%
Director of Management Services	4.9%
Director, Systems & Data Processing	6.6%
Director of Information	1.4%
Other Administrative Titles	15.3%
No Answer	1.4%

Data processing manager promoted to position from within company: 51.4%

Hired for position from outside company: 46.8%

No answer: 1.8%

Manager of Computer Operations (30)	Lead Computer Operator (31)	Senior Computer Operator (32)	Junior Computer Operator (33)	Manager of Unit Record Equipment (40)	Lead Opr. Unit Record Equipment (41)	Senior Opr. Unit Record Equipment (42)	Junior Opr. Unit Record Equipment (43)	Keypunch Supervisor (50)	Lead Keypunch Operator (51)	Senior Keypunch Operator (52)	Junior Keypunch Operator (53)
170	120	105	79	135	92	78	74	95	90	80	70
195	145	126	103	159	116	103	90	120	102	93	81
216	177	160	130	188	135	150	110	140	118	128	104
136	125	90	70	140	92	73	75	95	90	73	65
200	170	144	124	201	126	131	95	145	119	101	89
317	288	240	194	356	179	181	130	229	153	130	120
150	110	84	60	*	*	92	70	80	64	62	60
169	134	109	98	*	*	103	77	105	81	79	73
202	154	146	115	*	*	133	83	115	106	100	86
140	104	85	70	90	95	80	64	85	75	70	62
208	176	138	132	162	126	118	93	123	99	95	78
300	240	210	170	240	168	150	131	165	127	119	95
110	164	100	65	*	*	*	*	95	92	78	70
219	185	127	108	*	*	*	*	120	110	94	93
310	208	171	146	*	*	*	*	172	157	140	128
170	129	90	90	140	*	92	82	103	82	65	61
220	160	138	106	163	*	108	97	136	101	93	77
288	190	165	138	186	*	140	115	168	115	108	90
110	121	101	85	105	80	89	83	92	84	70	67
187	136	122	116	152	138	116	107	113	103	90	88
240	175	165	148	215	176	149	128	162	123	117	108
142	110	90	70	162	98	69	72	85	78	65	65
191	149	112	94	174	111	92	89	106	94	87	83
246	180	149	120	187	142	125	127	129	117	119	100
145	105	96	85	125	100	90	70	90	85	75	70
209	148	131	122	165	116	97	84	115	101	92	85
336	198	170	174	201	144	110	100	147	121	125	100
127	90	75	75	108	75	90	75	87	71	64	64
192	146	124	110	167	133	115	92	127	95	85	77
269	192	160	155	237	182	145	115	194	138	124	94
120	127	100	81	160	96	86	86	90	93	80	73
214	168	143	122	197	129	122	107	128	115	108	93
307	220	186	148	227	146	170	150	177	170	144	123
150	120	109	80	125	*	115	104	90	81	75	70
169	148	137	113	145	*	132	113	116	114	101	84
225	192	160	150	161	*	140	126	142	140	122	104
136	100	80	70	*	*	105	71	94	98	73	60
172	125	117	95	*	*	112	75	105	100	85	73
220	138	148	121	*	*	126	82	105	104	98	88
140	118	99	80	120	110	97	88	100	92	80	78
233	148	142	117	153	140	126	98	136	108	102	90
330	230	200	165	195	150	140	105	275	125	125	115

**indicates insufficient information available*

Number of years dp manager has had position:

Less than one year	6.4%
One year	17.2%
Two years	20.4%
Three years	13.2%
Four years	9.4%
Five years	6.4%
Six years	5.6%
Seven years	3.2%
Eight years	2.9%
Nine years or more	12.6%
No answer	2.7%

Age of data processing managers:

Under 24	0.9%
25-29	10.6%
30-34	20.0%
35-39	26.6%
40-44	18.4%
45-49	11.0%
50-54	5.5%
55-59	3.1%
60 and over	1.2%
No answer	2.7%

Weekly Salaries for All EDP Jobs by Industry

Job Description and Code ▶ Low, Average and High represent actual weekly salaries paid ▼		Manager of all Data Processing (01)	Ass't. Mgr. of Data Processing (02)	Manager of Systems Analysis (10)	Lead Systems Analyst (11)	Senior Systems Analyst (12)	Junior Systems Analyst (13)	Manager of Programing (20)	Lead Programer (21)	Senior Programer (22)	Junior Programer (23)
Advertising, Printing & Publishing	L	165	200	184	165	110	118	130	160	130	80
	A	**267**	**236**	**238**	**225**	**200**	**158**	**206**	**206**	**180**	**141**
	H	450	298	308	300	264	194	288	250	224	174
Bank, Insurance and Financial	L	100	135	125	95	110	100	128	102	98	70
	A	**287**	**238**	**252**	**217**	**194**	**160**	**225**	**191**	**167**	**139**
	H	577	365	365	277	320	248	410	288	302	212
Educational	L	145	150	150	135	150	125	135	105	115	80
	A	**261**	**226**	**224**	**209**	**200**	**164**	**217**	**189**	**176**	**137**
	H	454	374	260	284	254	200	300	257	241	183
Governmental Agencies	L	156	100	136	165	149	90	150	138	96	75
	A	**299**	**261**	**255**	**244**	**223**	**189**	**233**	**214**	**194**	**169**
	H	500	350	420	350	310	256	336	300	275	215
Hospitals	L	200	110	170	135	115	90	150	125	118	100
	A	**267**	**210**	**204**	**172**	**164**	**140**	**237**	**193**	**177**	**153**
	H	316	261	248	231	207	164	250	240	260	188
Manufacturing (Electrical)	L	185	175	212	263	173	138	173	150	133	85
	A	**283**	**231**	**293**	**289**	**234**	**199**	**239**	**227**	**187**	**146**
	H	443	257	385	300	298	289	306	267	242	187
Manufacturing (Food, Tobacco & Drugs)	L	182	170	165	185	185	170	227	141	148	102
	A	**290**	**233**	**255**	**253**	**214**	**186**	**275**	**200**	**195**	**151**
	H	500	270	350	300	240	196	350	300	252	230
Manufacturing (Heavy Products)	L	150	173	190	184	165	146	210	135	129	88
	A	**276**	**230**	**245**	**251**	**212**	**176**	**247**	**181**	**175**	**145**
	H	433	245	350	312	310	245	328	193	256	188
Manufacturing (Light Products)	L	195	175	170	173	149	120	125	145	106	96
	A	**271**	**205**	**251**	**245**	**205**	**172**	**194**	**191**	**179**	**143**
	H	385	250	320	285	260	236	259	230	219	197
Manufacturing (Miscellaneous)	L	154	184	175	175	145	98	150	130	110	80
	A	**272**	**250**	**248**	**228**	**211**	**173**	**218**	**186**	**181**	**150**
	H	462	346	404	327	300	215	310	250	240	214
Public Utilities	L	218	198	185	181	152	129	156	150	96	80
	A	**312**	**308**	**267**	**249**	**215**	**166**	**200**	**192**	**168**	**147**
	H	558	400	432	305	280	243	314	245	269	200
Retail Sales & Distribution	L	175	156	190	155	135	110	150	150	120	104
	A	**275**	**232**	**237**	**221**	**212**	**170**	**224**	**198**	**175**	**147**
	H	420	346	350	270	275	218	318	290	231	185
Service Companies	L	110	150	145	192	129	100	138	127	100	70
	A	**290**	**241**	**270**	**213**	**217**	**148**	**237**	**224**	**172**	**134**
	H	600	440	440	250	320	205	415	315	300	205
Transportation Companies	L	200	210	190	159	155	125	200	185	140	120
	A	**291**	**236**	**273**	**215**	**185**	**170**	**246**	**234**	**195**	**160**
	H	458	461	387	325	257	250	314	269	257	188
Wholesale Sales & Distribution	L	160	150	212	210	150	125	200	135	115	99
	A	**275**	**203**	**245**	**244**	**209**	**181**	**228**	**190**	**175**	**138**
	H	462	306	350	300	260	230	250	271	242	255
Miscellaneous Industries	L	185	155	200	190	148	125	220	155	115	78
	A	**283**	**234**	**267**	**259**	**229**	**181**	**254**	**211**	**177**	**153**
	H	423	345	400	350	320	222	327	335	290	290

Manager of Computer Operations (30)	Lead Computer Operator (31)	Senior Computer Operator (32)	Junior Computer Operator (33)	Manager of Unit Record Equipment (40)	Lead Opr. Unit Record Equipment (41)	Senior Opr. Unit Record Equipment (42)	Junior Opr. Unit Record Equipment (43)	Keypunch Supervisor (50)	Lead Keypunch Operator (51)	Senior Keypunch Operator (52)	Junior Keypunch Operator (53)
120	100	90	62	70	70	66	65	90	80	69	62
178	**144**	**131**	**98**	**143**	**120**	**109**	**99**	**127**	**98**	**91**	**77**
275	206	201	127	173	182	170	150	173	127	115	115
100	75	82	64	90	75	70	65	80	70	64	60
193	**142**	**120**	**101**	**147**	**120**	**101**	**87**	**119**	**99**	**91**	**79**
310	225	180	160	210	179	140	140	202	145	125	113
125	100	80	70	100	75	73	70	75	72	62	58
176	**143**	**122**	**106**	**147**	**122**	**96**	**93**	**116**	**98**	**91**	**78**
284	219	172	149	209	135	164	128	170	134	120	122
130	105	80	65	125	96	85	73	86	86	60	59
223	**176**	**146**	**134**	**171**	**145**	**121**	**103**	**131**	**114**	**99**	**93**
336	250	215	185	256	240	185	160	275	190	144	130
135	115	95	87	112	96	87	80	96	80	75	62
185	**152**	**128**	**113**	**160**	**145**	**120**	**105**	**117**	**116**	**101**	**97**
277	222	188	156	205	210	188	160	156	144	132	125
155	112	90	82	110	102	88	75	115	85	77	66
214	**156**	**138**	**118**	**177**	**125**	**113**	**102**	**130**	**107**	**100**	**86**
300	185	163	155	240	140	140	110	160	130	122	108
150	129	106	75	77	100	90	85	95	85	76	70
201	**153**	**139**	**110**	**140**	**124**	**113**	**100**	**123**	**104**	**96**	**89**
242	180	160	150	215	145	140	115	160	117	123	114
140	100	75	87	120	115	114	85	100	80	65	64
207	**161**	**127**	**114**	**186**	**124**	**120**	**99**	**122**	**106**	**96**	**84**
312	190	186	150	220	125	140	115	150	175	155	123
130	115	88	74	84	74	72	70	90	75	72	64
189	**142**	**128**	**107**	**160**	**118**	**104**	**98**	**122**	**104**	**98**	**83**
282	167	162	127	175	154	115	115	169	132	135	120
120	100	80	60	135	92	78	40	90	64	68	64
195	**145**	**128**	**112**	**185**	**136**	**118**	**90**	**129**	**104**	**97**	**85**
290	213	193	162	250	202	158	131	225	160	140	148
125	100	91	75	100	85	79	64	90	77	67	60
213	**165**	**145**	**130**	**207**	**131**	**129**	**101**	**152**	**117**	**100**	**82**
360	288	240	194	356	176	181	136	258	156	131	115
140	105	90	80	115	110	85	72	90	77	68	64
192	**144**	**125**	**109**	**149**	**124**	**108**	**98**	**123**	**99**	**92**	**81**
278	204	191	150	175	165	134	115	200	145	130	105
92	100	85	70	90	98	69	64	80	75	64	64
181	**142**	**118**	**97**	**169**	**131**	**109**	**91**	**120**	**109**	**93**	**82**
340	250	185	140	260	155	145	110	175	145	122	109
145	125	108	93	162	123	103	75	111	90	78	70
206	**162**	**141**	**126**	**206**	**142**	**116**	**96**	**140**	**119**	**103**	**95**
269	225	174	151	231	160	145	110	213	166	140	114
129	90	84	71	105	90	85	68	80	81	56	64
188	**154**	**125**	**110**	**124**	**102**	**111**	**80**	**118**	**104**	**90**	**83**
350	260	210	178	160	125	126	100	177	133	110	109
120	100	75	75	114	72	66	81	85	71	65	64
203	**154**	**125**	**109**	**162**	**145**	**112**	**103**	**114**	**97**	**95**	**78**
308	220	173	145	190	200	135	130	150	144	139	112

Nation-Wide Weekly Salary Data for All EDP Jobs

Job Description	Job Code	Established Ranges Average Low	Established Ranges Average High	Actual Salaries Paid Low	Actual Salaries Paid Average	Actual Salaries Paid High
Manager of All Data Processing	01	249	349	100	281	600
Ass't. Manager of Data Processing	02	223	304	100	247	461
Manager of Systems Analysis	10	222	309	125	253	440
Lead Systems Analyst	11	201	273	95	232	350
Senior Systems Analyst	12	180	249	110	212	320
Junior Systems Analyst	13	149	207	90	175	289
Manager of Programing	20	203	280	125	226	415
Lead Programer	21	176	242	102	203	335
Senior Programer	22	154	210	96	180	302
Junior Programer	23	126	173	70	151	290
Manager of Computer Operations	30	178	248	92	197	360
Lead Computer Operator	31	138	186	75	154	288
Senior Computer Operator	32	117	156	75	131	240
Junior Computer Operator	33	100	134	60	116	194
Manager of Unit Record Equipment	40	144	194	70	164	356
Lead Operator, Unit Record Equipment	41	114	150	72	134	240
Senior Operator, Unit Record Equipment	42	99	131	66	118	188
Junior Operator, Unit Record Equipment	43	89	116	40	99	160
Keypunch Supervisor	50	110	148	75	125	275
Lead Keypunch Operator	51	95	124	64	105	190
Senior Keypunch Operator	52	85	111	56	95	155
Junior Keypunch Operator	53	77	99	58	85	148

Average number of years' experience for key EDP personnel:

	DP Managers	Systems Analysts	Programers
Less than year	.4%	.6%	.6%
1 to 2 yrs.	1.5%	2.6%	4.9%
2 to 3 "	5.7%	5.8%	16.1%
3 to 4 "	9.9%	10.5%	17.0%
4 to 5 "	9.0%	10.0%	12.8%
5 to 6 "	12.7%	14.3%	13.3%
6 to 7 "	8.2%	7.8%	5.9%
7 to 8 "	6.7%	5.7%	2.7%
8 to 9 "	8.2%	6.9%	4.1%
9 or more	31.4%	20.0%	11.3%
No Answer	6.3%	15.8%	11.3%

Educational level of management and supervisory personnel:

	Data Processing	Systems Analysis	Programing
College Degree	49.1%	50.7%	34.8%
Some College	38.2%	38.6%	47.6%
High School Graduate	11.5%	9.6%	16.3%
None of the above	.4%	.1%	.2%
No Answer	.8%	1.0%	1.1%

Positions most difficult to fill

Systems analysts	47.1%
Programers	45.2%
Keypunch Operators	14.6%
Computer Operators	11.0%
Unit Record Operators	4.5%
Others	2.3%
None	1.2%
No Answer	3.6%

Average starting weekly salary reported for beginning trainee in systems analysis and programing, $123.

If 45 units must be out today at point 36 and 15 a month are built, then one month out in time 15 more must be coming through the pipeline; two months out another 15; three months out, another 15. Three months out on the chart from today, there must be a total of 90 purchase orders placed for the part at point 13 for a total of 90 of these parts going through the manufacturing process. Seventy-five of them should have gotten to point 22; 45 should have gotten to point 36. If they haven't, the sales schedule can't possible be met. The solution is to set up a very simple graph of these event numbers and say at point 36 the activity level should have been 45 units, at points 31 to 35, a half-month out, the activity level should be 52; at point 27, a month out, the activity level should be 60, at point 21 to 23, two months out, the activity level should be 75 and so on. The dotted line which connects these points then represents a "line of balance" of demand to which one can compare the actual level of action or inventory. If there is less than this line, we have shortages. If there are more than this line, resources have been used poorly.

Chart H shows an actual line of balance for an actual product A. It consists of 36 control lines. The long dashed lines show the purchasing points. The solid lines are the receiving points. The short dashed lines are the manufacturing points, the cross matches the assembly points and the dotted, the final assembly. What this indicates is that as of today, at point 1 and 2, there should be purchase orders placed for 170 of parts 1 and 2. At points 3 and 4, 130 of these items should have been received from the vendor, and so on. Then at point 36, in order to meet our schedule, 45 should have been shipped. The horizontal dotted line is the activity level which should have existed. The height of the lines shows that, based on the shipping documents, the receiving reports, the purchase order information, the manufacturing reports, what level of activity has actually taken place. Comparing the actual level to the recorded level is all that's needed to measure controls. If someone says: what is management by exception? this is it.

LINE OF BALANCE

MATERIALS MANAGEMENT

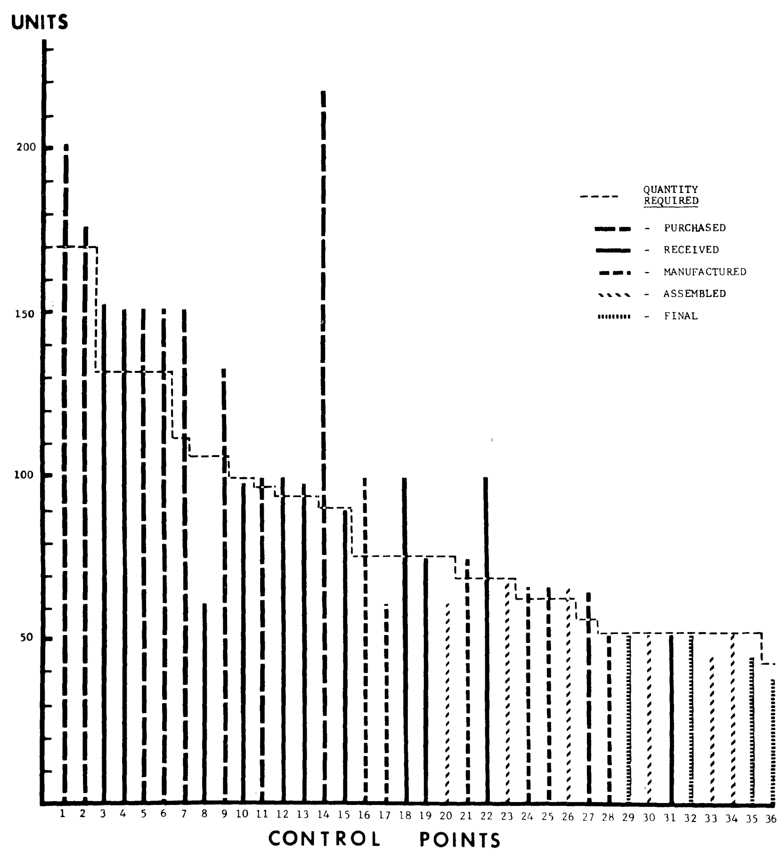


CHART H

Many companies try and establish controls, line of balance or a computer program or any kind of production control technique on all parts, at all levels. They try and control everything and in trying to control everything, nothing is controlled. Line of balance is a very effective tool--it is done in a way that can actually be seen, comprehended so that action may be taken. This tool is the only one that allows a comparison of what should be, to what is. If 15 a month of product A are shipped according to the schedule, then the horizontal dotted line goes up to 15 a month, or 3 a week. The moment that horizontal line rises above the vertical line at any point, a central control group has the ability to interrogate and determine why action wasn't taken. The prize is the ability to expedite only where it is needed, not everywhere.

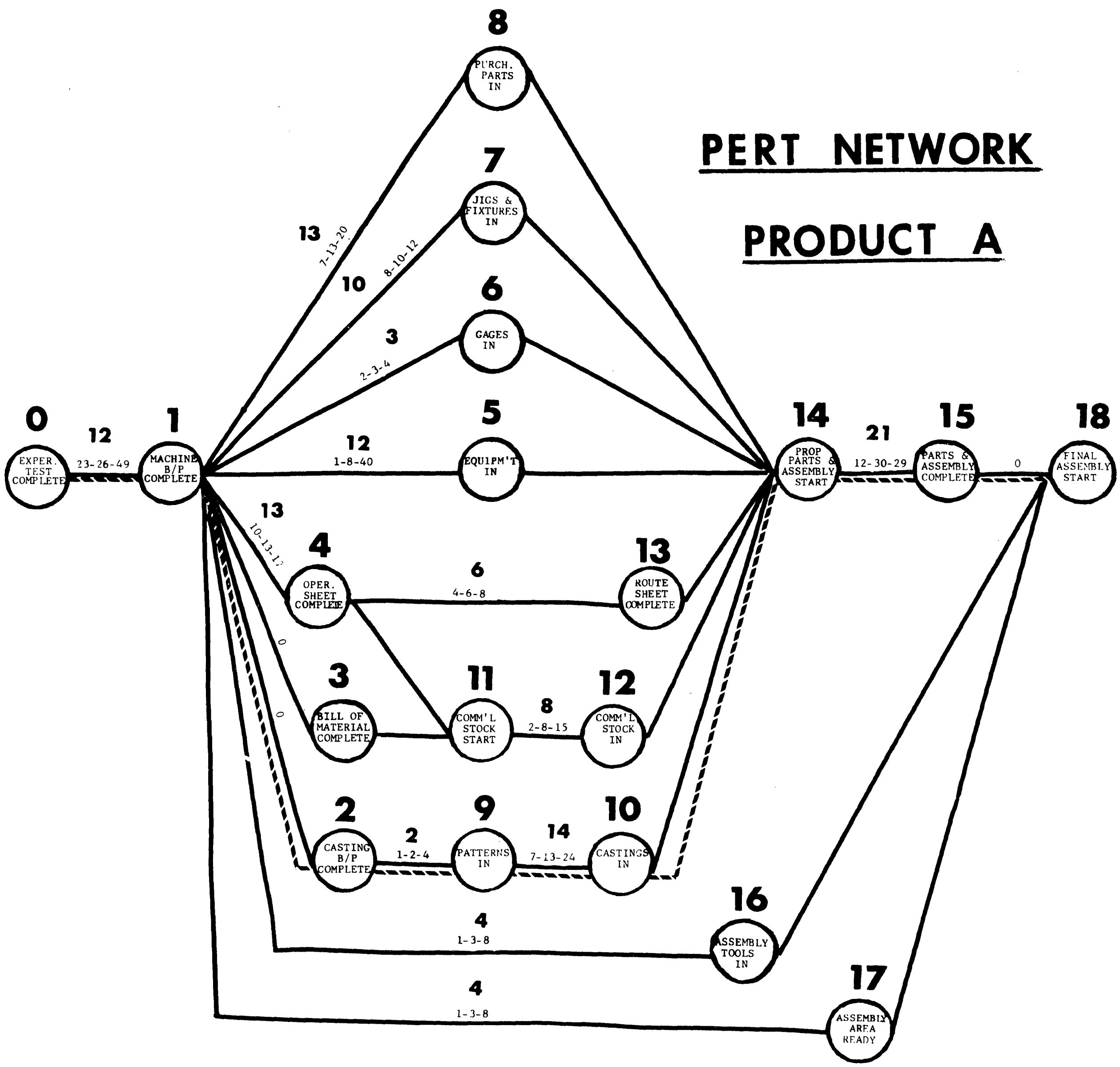


CHART I

A PERT network is shown on Chart I. PERT is a network technique in which all of the activities that should take place are set down and their relationship is determined. The PERT network for product A consists of 18 events. It shows that in order to start final assembly of product A at point 18, the assembly area must be ready, the assembly tools must be in, and the parts and assemblies complete. Before the parts assembly is complete, they must be made. Before production parts are made and assembled, purchased parts must be in, fixtures must be in, gauges and equipment in, route sheets complete, commercial stock in and casting in. Before the castings are in, patterns must be available. Before any of this can begin, machine blueprints must be finished. All this is what the PERT network shows.

Essentially, a PERT network is a visual presentation of the activities that need to be done. It shows which activities can be done in parallel, and which must be done in series. By interviewing people and looking at records and determining which sequence of activities, to be done in a series, takes the longest time, a critical path is determined. This means if production can't be started until all of the parallel activities are finished which precede it... if these are the ground rules...and if the longest activity (casting) in these preceding items (2, 9, 10) takes 16 weeks, then that determines time. If the purchased parts (item 8) can be obtained in 13 weeks, then they will wait 3 weeks until the castings are complete. If purchasing is expedited and parts arrive in 10 weeks, they will wait 6 weeks. Unless the time on the critical path is reduced, no other management action on parallel paths has significance.

Consider this example. Product A was developed as a prototype machine. It had new features never before contained on such machines. When it was shown in operation, the sales department was highly enthusiastic about the effect on sales. The production lead time for similar products had been a year. The sales department exerted pressure and received a management commitment for 6-month delivery. Promotion was begun and orders accepted on this basis.

PERT was suggested to management as a means for planning and control, and an engineer was assigned to chart product A as a test. When he had interviewed all major department heads, he had the 18-event network shown. The total time was 72 weeks. Management's reaction was predictable; they reinvestigated. In engineering the time estimated was 36 weeks. Where questioned, the manager discussed his staff capability, and the other products which were being designed and drawn. These too were essential. He then realized he had not allowed for vacation or illness in his estimates; but management had heard enough. They determined that the time was 72 weeks, not the promised 26 weeks. The value here is that this was determined now, when action could be taken. Management was able to take action, to determine what could be done to shorten this critical path. They subcontracted the drawing. They did a number of other things, and reduced time on the critical path down to 48 weeks.

PERT is frequently not used because people talk about 10,000 events and solving it on a computer and so on. Frequently, PERT networks that are developed are not used because the sheer maintenance of them becomes too great. But, if one considers the A items, the key tasks, a manageable PERT network may be desired which anybody can solve just by looking at it. One doesn't need a computer to solve an 18-event or even a 200-event network.

The profit picture in any company in the future will be to a significant extent a result of the intelligent gathering and use of good information. Each company should be concerned that it is providing its managers with the kind and quality of information they need to do their job best.

Bertram A. Colbert, of Price Waterhouse & Co. in Chicago, author of this article, is a financial analyst. He is a regular lecturer on logistics and other aspects of management activities.

Those businesses involved in choosing a complete EDP system often discover that the procedure generates difficult questions.

The U.S. Air Force's methods for choosing and buying computers could well be studied by businesses interested in acquiring a system but uncertain how to evaluate usefulness and equipment prices.

In many cases, concepts pioneered by the military have been taken over later by the business community, which has been able to refine the original concepts and apply them to civilian marketing-management uses. An IDPA editor interviewed Col. Sylvester P. Steffes, chief of the Electronic Data Processing Office, Electronic System Div., L. G. Hanscom Field in Bedford, Mass., for particulars in the complicated producure of computer choice employed by the Air Force in asking for bids for the Phase II Base Level Data Automation Standardization program. Under this program, third generation machines would provide data processing support for functions except supply and military pay at Air Force bases around the world.

Question: Many users evidently still employ haphazard methods in trying to decide which EDP systems to buy or rent. Some industry experts have suggested that the Air Force evaluation of its Phase II Base Level Data Automation Standardization Program could conceivably become a model for commercial enterprises. Would you describe the system analysis that went into the formulation of the bid package?

Col. Steffes: The analysis which went into the development of the bid package, or the Request For Proposal (RFP) as we call it, was essentially the same as is accomplished on all programs. Naturally, because of the size and scope of the Phase II project, development of the RFP required considerably more effort. The first step was to analyze all newly developed management systems and to identify those current systems which would be replaced. The second step was to analyze all currently operating systems on the multitude of equipment in operation at bases worldwide so as to obtain workload statistics. When this had been accomplished, analyses were made of the workload statistics at the various bases and these revealed that, for selection purposes, the bases could be placed into four workload levels: these were identified as workload levels A through D, with A being the smallest and D the largest.

Next, more than 1,000 applications were defined and simulated to gather data on the capability of currently announced equipment to perform the processing tasks. Like processing functions were then consolidated for presentation in the RFP; the workload expressed in the RFP reflected approximately 250 applications for each workload level.

In gathering the work statistics, it was then possible to develop some of the minimum mandatory requirements for printing, card reading and punching, etc., for each workload level expressed in the RFP.

Such an analysis must be made in every program. The amount of effort will depend on the size and scope of the program and the type of selection being accomplished -- i.e., a capacity replacement action where all workload is known and programs developed, a new acquisition involving only applications under development, or a combination of these two. In any case, the method of expressing the workload to vendors should be modified to fit the particular situation...

We use a carefully thought out technical approach which is continually improved as experience and requirements dictate. With the rapid changes and advances in computer technology, our evaluation procedures and techniques must be kept up-to-date.

The Air Force computer evaluation process is a rigorous and demanding approach. Basically, we validate and evaluate vendors proposals in five major areas. These areas are systems performance, technical characteristics, software, vendor support and costs. To ensure utmost objectivity, separate teams of our technical experts are established to independently evaluate these areas, using criteria which were pre-established before release of the RFP. This procedure ensures that "we don't change horses in the middle of the stream." Cost data, of course, is withheld from other evaluation teams to ensure that results are not colored by dollar factors. You may be aware that our procedures also include the use of benchmarks (test standards) and simulation techniques. These tools aid considerably in validating the performance characteristics of competing vendors' proposed computer systems, and they provide a high degree of confidence in our evaluation results.

The combined findings of the independent evaluation teams are documented and presented to a board of senior military and civilian personnel. The board weighs the technical findings and applies senior judgment in arriving at its source selection recommendation which must be approved at the headquarters and Secretary of the Air Force levels. It is interesting to note that none of the participating vendors is identified by name to the various reviewing officials in order that their judgments may be completely objective. While this is somewhat of a thumbnail description of our evaluation and selection process, it does point out some of the technical aspects of our approach as well as the inherent objectivity and self-discipline necessary in computer source selections.

It may be of interest also that our professional staff here at the EDP Equipment Office is assisted by a full time MITRE Corp. group in keeping our evaluation tools sharp and consistent with the latest state-of-the-art technology. I wish to add, however, that MITRE does not participate in evaluation of proposals. We use only organic capability for that. (Ed. Note: MITRE is a systems engineering company--private, not for profit--organizationally structured similar to The RAND Corp. It provides systems engineering and technical support to U.S. Government agencies.)

Question: What are plans for the future in incorporating new procedures and steps?

Col. Steffes: As I indicated previously, we are continually searching for improved evaluation techniques. In reality, this search is a never ending process. We must continually update the means for validating and evaluating technical improvements both in the hardware and software computer areas.

During the past year-and-a-half, for example, we have been confronted with a host of new technology such as multiprograming, multiprocessing, real time environment, etc. If you are in the computer evaluation business, you must continually review your procedures and develop new techniques to meet evolving technology.

I am sure if anyone has studied the RFPs issued by this office since its inception, he will find that the specifications and evaluation questionnaires have been refined, standardized in format, and the contents updated as the computer technology progressed. What was an excellent evaluation approach for first and second generation equipment is no longer applicable to third generation computer technology, and we must continually fill the void. Our work with MITRE is dedicated completely to this very necessary function.

Question: What specifications were asked for in bidding the system?

Col. Steffes: The RFP package defined a workload that had to be accomplished in 200 hours of operational use time a month. In general, the system characteristics required high speed central processing, immediate access storage, remote stations, magnetic tapes, and so forth. For this particular project, there were quite a number of items which we call mandatory requirements -- which vendors had to meet or comply with. Some of them are as follows:

— The workload as defined in the RFP had to be accomplished in the 200 hours just mentioned.

—Specific software capabilities were required for the Executive Control System, Cobol and Fortran compilers.
—Specified processing capabilities in terms of remote device speeds, printing, card reading and punching speeds were stated.
—A required capability was that of running the object programs on all configurations compiled from the same source programs, subject only to capacity limitations and the number of I/O components available for use.
—Modularity of equipment and software to permit complete interchangeability of CPUs, I/O components, Immediate Access Storage (IAS) devices and other data communication devices were specified.
—It was necessary to perform a live test demonstration of the equipment proposed for the "D" level workload.

Ground Rules

Question: What recommendations do you have for commercial users in evaluating EDP systems? What should and what shouldn't they do?

Col. Steffes: First of all let me say that there is no one set technique for evaluating EDP systems. In my reply to a previous question, I mentioned the areas which the Air Force evaluates in selecting computers. These basic areas are essential in any computer evaluation, but we find that even after we have gone through more than 30 separate selection actions we still can improve on our technique. The answer is to strive for professionalism which best can be developed by a repetitive process with highly qualified technicians. Since, however, most users select computers with ad hoc committees, I will address myself to that situation.

The most important ingredient to an evaluation project is the system specifications. Every user, commercial or otherwise, must recognize that the computer selection can be only as effective as the system specifications will allow it to be. The specifications, with the proper requirements and constraints, are the sole basis for vendors to determine the optimum EDP system to meet the user's needs, and they establish the ground rules to be followed by the vendors. Before preparing the specifications for the vendors, the user should perform a detailed analysis of his requirements in order to clearly define his system. In this manner, the user accomplishes a two-fold objective. First of all, he will be able to present a well thought out and defined set of system specifications. Secondly, the user benefits since he becomes intimately aware of the myriad of processes necessary to successfully implement a computer system.

In general, I would suggest that the user consider the following actions preparatory to soliciting vendors for computer proposals:
—Expend as much effort and time as possible in analyzing and developing specifications.
—Develop evaluation criteria based upon the specifications released to industry prior to the issuance of the RFP.
—Determine the techniques to be used for validating vendors' proposals; e.g., benchmarks, simulation, etc.
—Establish firm dates for accomplishing all defined tasks; e.g., proposal submission, benchmark, equipment installation, etc.

In conducting the actual evaluation, I would state that there is no substitute for thoughtful hard-dollar analysis, based upon the preestablished criteria. The users must satisfy themselves that the vendors have proven conclusively their ability to provide what they claim.

In summary, the user must define the system specifications clearly and precisely. He must know the method of evaluation of the vendors' proposals before the bid package is released. It is essential to remember that the computer selected will be only as good as the data provided to the vendor and the evaluation creteria used.

Question: What suggestions do you have in setting up a bid?

Col. Steffes: A bid package should contain at least four parts.

--One part should be the administrative ground rules of the project, including such items as purpose of the solicitation, closing date for vendors' proposals, dates of conferences or presentations, etc.

--Another part should cover the description or parameters of the system to be automated; that is, the system specifications. This would include mandatory requirements determined necessary by the user.

--The live test demonstration requirements, if any, should be included as another part. This would include instructions and procedures for the demonstration, the type of programs, test data to be used, etc.

--Another element of the bid package should be a format for the response to be submitted by the vendors. This part would consist of the general format of the proposals including forms to be completed on performance data, technical characteristics, cost, etc.

FORMAT OF VENDORS' PROPOSALS

Part I System Proposal
Executive summary
Mandatory requirements
Systems concept and description
Workload processing capabilities
Timing tables
Alternative system proposals
System responsiveness data

Part II Technical Data
Technical literature
Equipment characteristics
Schematic diagram
Software
Vendor support
Technical data details

Part III Cost
Cost tables
Cost questionnaire
Special cost elements
Certificate of cost
Procurement plans
Proposed conditions

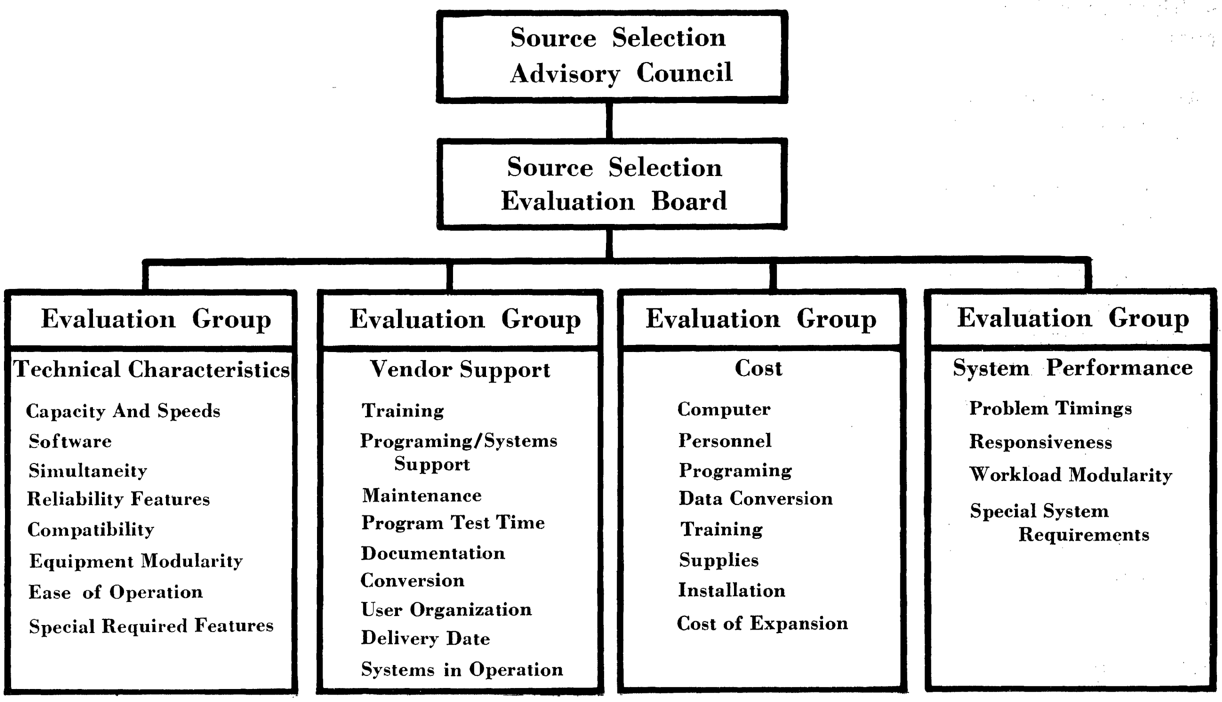
Question: What should users look for and look out for?

Col. Steffes: The user should validate the vendors' proposals to ensure that they meet his requirements. If vendors' statements or claims are not clear, the user should formally request written clarification from the vendors.

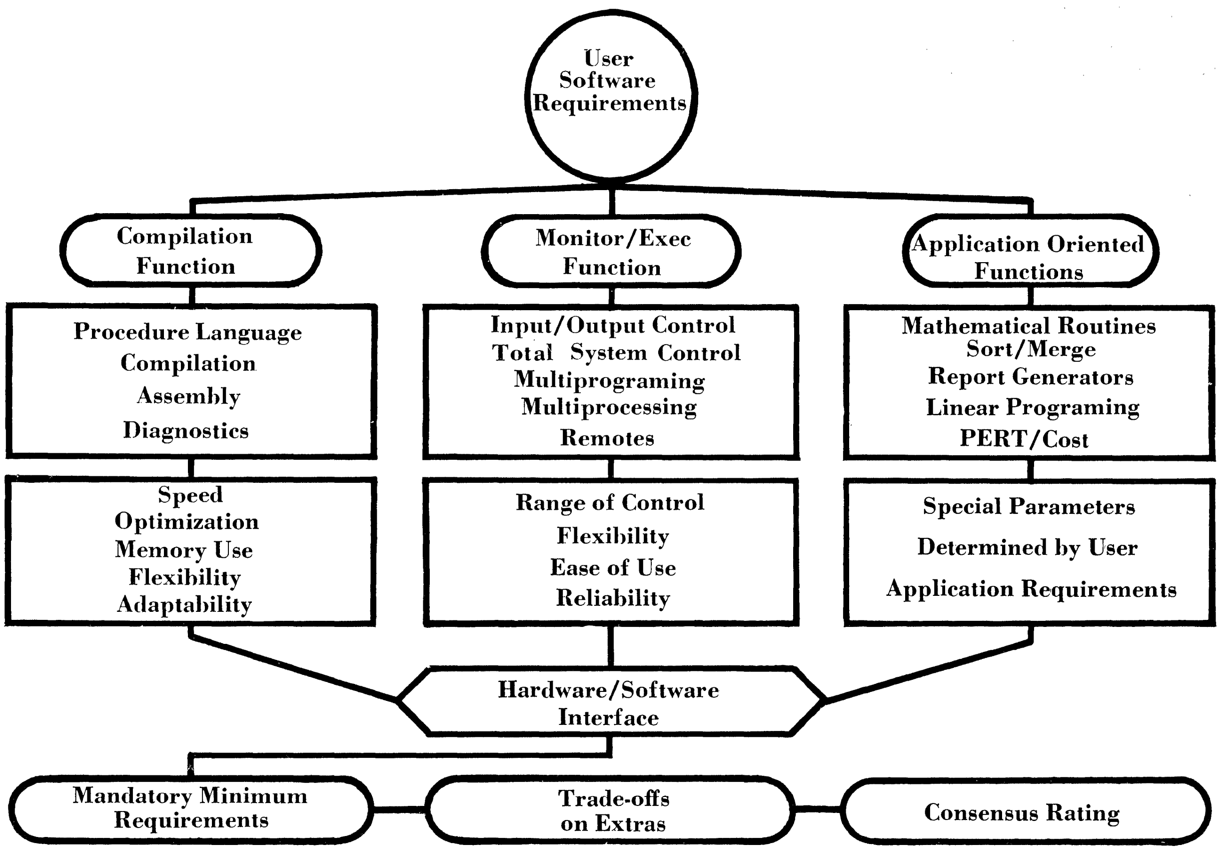
The validation of systems timing is probably one of the most critical factors in computer selection. The user should ensure that the vendors' approaches for processing the defined workload are valid and that the vendors have not used problem solving techniques or system processing short cuts to gain a throughput speed advantage, if these are not prescribed; e.g., combining master files to save storage space and processing time.

Another area that users should carefully analyze is the equipment system itself. Are the required hardware features or devices included in the equipment configuration proposed? Did the vendor demonstrate the exact EDP system proposed?

Organization For A Computer Selection Project



Software Evaluation



Users should look for straight answers in terms of capacities, performance, and costs. They should be wary of oral or even written promises, vague references and undefined terms such as "throughput" and such statements as "full compatibility " and "little reprograming effort required."

An orderly and logical evaluation and selection plan will assist the user in validating vendors' proposals and detect areas which are questionable or unclear.

Question: What steps should a user employ in selecting who should and who should not be invited to bid?

Col. Steffes: As you may know, within the Air Force we desire to obtain the maximum amount of competition possible. For this reason, we have developed what we call a master bidders' list. Normally, we send out a "Letterof Interest" to all vendors on our master list as well as a release which is published in the Department of Commerce Business Daily. In our Letter of Interest, we attempt to provide vendors with enough information on the project to help them determine their capability to participate. The RFPs developed are then sent to the vendors who have given us a positive response to our Letter of Interest.

As to advice to commercial users, my suggestion would be that they review selected vendors' capabilities to satisfy the particular requirement and, barring any other constraints, send out inquiries to several potential vendors. I believe they have more latitude than we do in the government.

Question: When selecting the winning bidder, what criteria should be used?

Col. Steffes: There is no "stock answer" which can be given to this question. The key here, I believe, is that the evaluation criteria should be preestablished prior to issuance of the bid specifications to the vendors. The emphasis of importance of one area over another will vary depending on the user's requirement. I feel the AF technique of establishing certain minimum requirements to be met for further consideration is very feasible. Vendors meeting these requirements are then further evaluated against the predetermined evaluation criteria.

PUTTING SYSTEMS

INTO MANAGEMENT

By Arnold E. Keller

Systems is a very busy word in today's business vocabulary. Management is deluged daily with books, magazine articles and seminars, all dealing with systems in one form or another. The spotlight moves from hardware systems to software systems, data systems, information systems, total systems, real time systems, on-line systems, on time systems, off-line systems, just to name a few. With all of this emphasis on systems, one might conclude that management has at last discovered the importance of systems and the systems man. Unfortunately, such a conclusion is not supported by the known facts.

For one thing, we still hear management refer to its particular system as a "punched card" system, or a "computer" system. And an even more common reference is to "our IBM" system.

There are many definitions of systems. One dictionary defines the word as "a due method or orderly manner of arrangement or procedure." There is general acceptance that a business system involves a planned arrangement of orderly events for meeting stated management objectives. If this is an acceptable definition, then it is obvious that a lot of management people who think they have a system have quite the opposite. For the most part, management has still to learn that machines do not a system make.

Getting the worst of it

A machine, be it adding machine, cash register, accounting machine or computer, can only add horsepower to a system. The machine is not a system. Unfortunately, many companies have bought the dream that all one had to do was plug in a computer and "presto"--before you could say "rerun," you had a management information system. These firms wanted a system in the worst way...and they got it.

It is no secret that a large number of business firms have, in the past 10 years, been on the greatest hardware binge in the history of the business equipment industry. It has cost a lot of money, and it has produced a colossal hangover. Were it of the alcoholic nature, it would task the resources of the aspirin industry to cure it.

We hasten to add that this is not necessarily criticism of the business equipment industry, for seller and buyer alike were captivated by this new-found electronic systems power, even though many sellers and buyers often didn't really understand the power. And, more often than not, the buyer didn't have the proper system current to handle the power. There were those who cautioned against putting the cart ahead of the horse, but nevertheless, there are quite a few high-powered carts out far ahead of the horses.

The problem centers on the fact that third generation systems power has arrived, with fourth generation power already looming on the horizon. But for the most part management has yet to grasp the significance of the first generation of systems power. In short, management, like the mythical Rip Van Winkle, has been asleep for 20 years as far as systems are concerned.

Now the significance of Rip Van Winkle's long sleep was not that he slept for 20 years. Figuratively speaking, we all know people who have done that. Some of them may even work for us. Some of them may even be our bosses. The important thing is that Rip slept through a revolution. He went to sleep with a picture of King George III hanging in the town square, and awoke with a picture of George Washington in its place.

And, like Rip, many business bosses have slept through a revolution: the information revolution. They went to sleep with accounting machines and punched card equipment clattering away in the corner of the office, and awakened--those who have awakened--with a million dollar computer system as the office centerpiece. It has been an expensive sleep. But there are some signs of an awakening.

And with this awakening has come the realization that when a properly designed business system is linked to capable computing power, management receives a powerful competitive weapon. But such a system does not come easily. In fact, it is an impossible attainment unless all echelons of management will make a total commitment to the program.

Which brings us face to face with the fact that a wide gap exists between the systems man and top management. Some say that the systems man has lost contact with top management. Some would question if the contact was ever established. Certainly the systems people must accept some of the responsibility for management's failure to understand the consequences of the information revolution. Others suggest that we have created too many "topless" systems: systems that perhaps meet various needs within the company, but seldom are used by senior management. And others have suggested that systems have become "the lost function." Whatever the reasons for the gap, it must be closed. And it is the job of the systems profession to see that it is closed.

As we have stated before, conviction and commitment are the management keys to systems success. More importantly, they may well be the keys to a firm's survival in the competitive battles that lie ahead. Conviction on the part of top management that an effective information system can contribute to the profitability of the enterprise. Commitment on the part of top management that responsibility for the systems operation will remain at the top corporate level and that the effort will receive the same degree of corporate attention as does any other critical area of the company.

Here, then, lies the challenge to the systems profession: to see that management has the conviction, and makes the commitment.

Never has top management been more in need of professional systems guidance. But for one reason or another the systems man has simply not been able to "turn on" top management, and more and more we find management going outside for guidance--usually to a consultant. Now there can be no argument about the value of a competent consultant and the genuine need for consulting services on various occasions, just as the need exists for internal auditing and the CPA. But there is something very much wrong when management continually ignores its in-house systems competence in favor of the outside consultant.

It has been said that the advantages of the consultant are: (1) independence and objectivity of outlook; (2) organizational mobility; (3) liberty to discuss a problem with anyone at any level in the organization; (4) diversity of experience; (5) freedom from routine duties and similar distractions; and (6) time.

These same advantages can and should apply to the systems professional. Why, then, the systems gap and the attempts by management to fill this gap with consultants? Perhaps the best answer is that the consultant has done a better job of "selling" management on his ability to solve management problems.

Viewing the total problem

And how do consultants solve management problems? According to the handbook of the Assn. of Consulting Management Engineers, Inc. they do it as follows:

The proper activity of management consultants is two-fold: analysis and synthesis, or discovery and understanding of management problems. These two processes go on continuously, and mutually complement each other during each client engagement. They point up the need to distinguish carefully all elements of a problem in order ultimately to unite them.

In the analytic process, the consultant seeks to discover the relevant facts about the management problem, to define and delimit it and determine its underlying causes. This is offset by the complementary process of synthesis in which the consultant fits all parts of the problem into a whole and views it in its totality in order to gain an understanding of its fundamental meaning.

Professional consultants have always found it helpful to have appropriate client personnel participate in the analysis and solution of management problems on most kinds of projects. This participation enables client employes to better understand the problem and its implications, helps to secure acceptance of the results of the study, makes it possible for the consulting staff to do a faster job on each project, and promotes better understanding and appreciation of the consultant's role throughout the organization.

In some situations the role of the consultant is to provide guidance to an internal task force of client personnel for the conduct of assigned projects. The essential function of a consultant in such situations is to provide guidance and to serve as planner and motivator to a client task force for the collection, analysis, coordination and synthesis of the required facts, and to supply leadership in the formulation of solutions to problems. He also retains accountability for results.

The procedure which management consultants ordinarily use in developing solutions to well-defined management problems usually involves four distinct phases; research, analysis, solution and installation.

The research phase includes two major activities: the planning of the survey or project and the gathering of facts bearing upon the problem. Typically, the planning of the study involves four main steps:

(1) The first step is to define its purpose. What, precisely, are we trying to gain from the work that is being done? The scope of the study must also be determined. How much ground is it to cover? What factors are we to consider? What are the boundaries of the area of fact-finding?

Great care must be taken to state the purpose and scope of a study clearly. It is very difficult to plan and conduct a project without establishing its boundaries, and a vaguely expressed objective can cause much misunderstanding among the persons concerned with the project.

Planning is done in stages. A broad outline is developed and then this outline is divided into successively finer divisions. The final detailed plan, moreover, is never regarded as finished. It is subject to continual review and revision as necessary to accommodate unpredicted or unusual situations that may arise.

(2) The second planning step is to determine the approach to the study. Having decided what the study is to be about, how should we proceed? How is the fact-finding team to be organized? What major steps must be taken?

(3) The third step is to determine the end product. This may seem premature while the study is still in the planning stages, but at least a tentative answer must be formulated in order to indicate how elaborate the fact-finding must be and what the consultant is expected to produce.

(4) The fourth step in planning is to estimate the amount of fact-finding that will be required. One way to do this is to review each of the organizational areas involved in the study, identifying its structure and functions and then estimating the number of interviews, write-ups of duties, analyses of documents and other work that will be necessary.

The second activity in the research phase is to gather the facts that seem to bear upon the problem. Fact-finding is the basis for both analysis of the status quo and the formulation of recommendations for its improvement. Therefore, fact-finding must be accurate, unbiased and comprehensive. Failure to be accurate in the collection and documentation of facts can have serious consequences, particularly when the time comes to present and obtain agreement on the recommendations.

Detailed diagnosis

When the initial planning has been completed and the facts bearing on the problem have been gathered, the next task is to analyze these facts and draw the right conclusions from them. This analysis phase usually involves four fairly distinct steps.

The first analytical step after the facts have been gathered is to define the problem, problem areas or opportunities for improvement in precise terms. In complex studies, the consultant may find it necessary to break this process down into the following steps: (1) systematically and thoroughly review the accumulated facts; (2) write a clear, well-organized summary of the existing situation; (3) summarize all the criticisms and complaints made by those interviewed; (4) test each situation to ensure that a problem does actually exist; (5) challenge every aspect of the situation to reveal weaknesses or opportunities for improvement; and (6) finally, summarize the major indicators of the problem.

When a precise understanding of the problem has been established, the next step in analysis is to determine the conditions that have created and are sustaining each problem. How long has each condition existed? When and where did it start? Is the situation growing better or worse? What are the basic causes both today and in the past? A detailed diagnosis of this kind is often the most important step in analysis. When the causes are known the proposals for correction may become obvious.

At this point the problem has been defined and diagnosed. But, before it can be solved, still another step is necessary: to determine the objectives which must be met by the solution. These objectives should establish concretely the end results to be achieved in higher profit, lower costs, increased sales, more production, fewer customer complaints and the like; the time and money required or allowable in achieving these end results; and any other limitations or goals necessary to achieve a solution that is workable, timely and acceptable to management.

The next step in the analysis is to develop alternative solutions which may provide answers to the problem. More often than not there are several ways of solving a problem. Rarely is there only one right answer; there may be a range of alternatives, each accompanied by risk and none a perfect solution to the problem. Alternative solutions do not guarantee the right decision. But they help prevent one from making the wrong decision by forcing him to think the problem through. The professional consultant always considers alternative solutions, even for familiar problems. To evaluate an alternative he tests it against the objectives which must be met by the solution of the problem.

At this point the task becomes one of selecting the solution which is the most workable, timely, practical and acceptable in terms of the client's needs.

In solving a client's problem the consultant must always be realistic. He must make certain that the solution makes sense to the client and that he will act upon the recommendations. Therefore, before working out the solution in detail, the consultant tries to reach an agreement with the client on the acceptability of the principles on which the solution is based. The presentation is usually made informally so that it can readily be modified to incorporate suggestions or ideas which the client may contribute.

The final step in the analysis of a management problem is to work out the details of the solution. This step requires extreme accuracy and careful attention to detail. It should, in effect, provide a blueprint of what needs to be done, by whom and in what sequence, so that the recommended solution will be understandable to all who must act upon it.

Once recommendations have been accepted they must be installed. The installation of approved recommendations is just as important as the effort spent in fact-finding, analysis and the development and presentation of recommendations. Installation must be carefully planned and supervised to ensure that the solutions which have been carefully designed are not jeopardized by inadvertent omissions or commissions caused by a lack of understanding on the part of client personnel who are to operate them.

There, in brief, is the consultant's approach to solving management's problems. If the systems professional assumes the consultant's role and substitutes his firm and its people where the "client" is referred to, the consultant's handbook offers an excellent guide for a step-by-step systems study. But none of this should be news to a systems professional. He, too, is a consultant to management. His whole reason for being is to help improve the operating effectiveness of his company. However, it is possible that the systems man has become so immersed in systems technology that he has lost the ability to communicate with management on levels that are meaningful and understandable.

Speaking at the 1968 Pittsburgh Systems Conference a few months ago, Willard F. Rockwell Jr., chairman, North American Rockwell Corp., stated that the most important step in the development of a sound management information system was the establishment of "a meaningful dialogue" between management and system people. "When we get right down to it," he said, "it's people that are going to make this thing go: managers with the ability and willingness to help determine the requirements; systems people with the ingenuity and resourcefulness to provide what is required economically. And," he added, "the key is the systems expert, the trained specialist who can systemize a fantastically increasing body of knowledge and focus it on the essential needs of society and business."

There can be no question but that the systems man has the key to success in the information revolution. But he must first shake his accounting room conservatism and put on a "hard sell" campaign to management. Systems power will eventually decide many of the competitive battles in the business community. Assuming that the systems professional understands this power better than anyone else--and he should--his task is to communicate this understanding to management. At the same time he must demonstrate the potential--and risks--of the powerful new systems tools available to management. If properly approached, management will listen. And if properly sold, management will buy. The consulting profession has already proved this.

If management refuses to listen, better to find new employment. But first be certain that the message has been communicated in a language that management understands. And management best understands "profits." If the systems man can demonstrate his ability to genuinely improve the profit picture, the gap between systems and management will quickly disappear.

NEW TOOLS FOR PLANNING, DECISION-MAKING AND CONTROL IN THE LOGISTICS FUNCTION

A manager must properly understand and evaluate a wide range of information about his operations to reach sound decisions. Often he has found himself overwhelmed with masses of data or long listings of historic information which has proved of little help in the decision-making process. Concise, complete and timely information is essential for effective planning, decision-making and control.

The concepts of systems design and development examined here are equally valid if a company is large or small, or if the data were obtained and processed through the most simple manual means or through the most sophisticated computer.

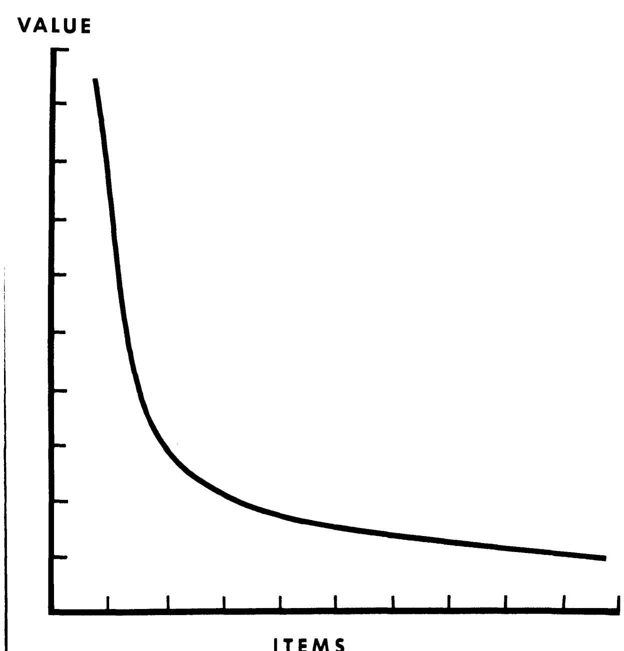
Of greatest importance is selecting for each level of management the small group of control data that is required and presenting this data in a manner which facilitates understanding, motivates action and provides a measure of effectiveness of the action which has been and is being taken.

The logistics function is the subject of this particular area of decision-making. As a result of sales; order entry, shipment of goods and billing are initiated. These in turn provide information for accounts receivable, sales analysis, inventory control, production scheduling, purchasing and all the interrelated parts of the system. These interrelationships must be considered in analysis of a system. (Chart A shows the flow of information which would be related to this function in a typical manufacturing company.)

In attempting to improve the effectiveness of planning and control, there is often a tendency to increase the level of activity or information in the belief that more activity will mean better control. If time, energy or effort were limitless, perhaps this might be so. However, there is only so much energy or effort which is available to be expended in the area of planning and control. The first determining factor is what is worth controlling and relating control to the return on the investment of effort. A principle which is fundamental to the program is called Pareto's curve.

Pareto was an Italian economist who lived and wrote at the turn of the century. Among other things, he studied the distribution of wealth in his country, Italy. He discovered that if he graphically portrayed the population of the country and the wealth of the country, that the distribution was not random or uniform, but that it followed a definite relationship represented by a curve. Essentially, 10 percent of the population controlled 90 percent of the wealth.

PARETO'S CURVE



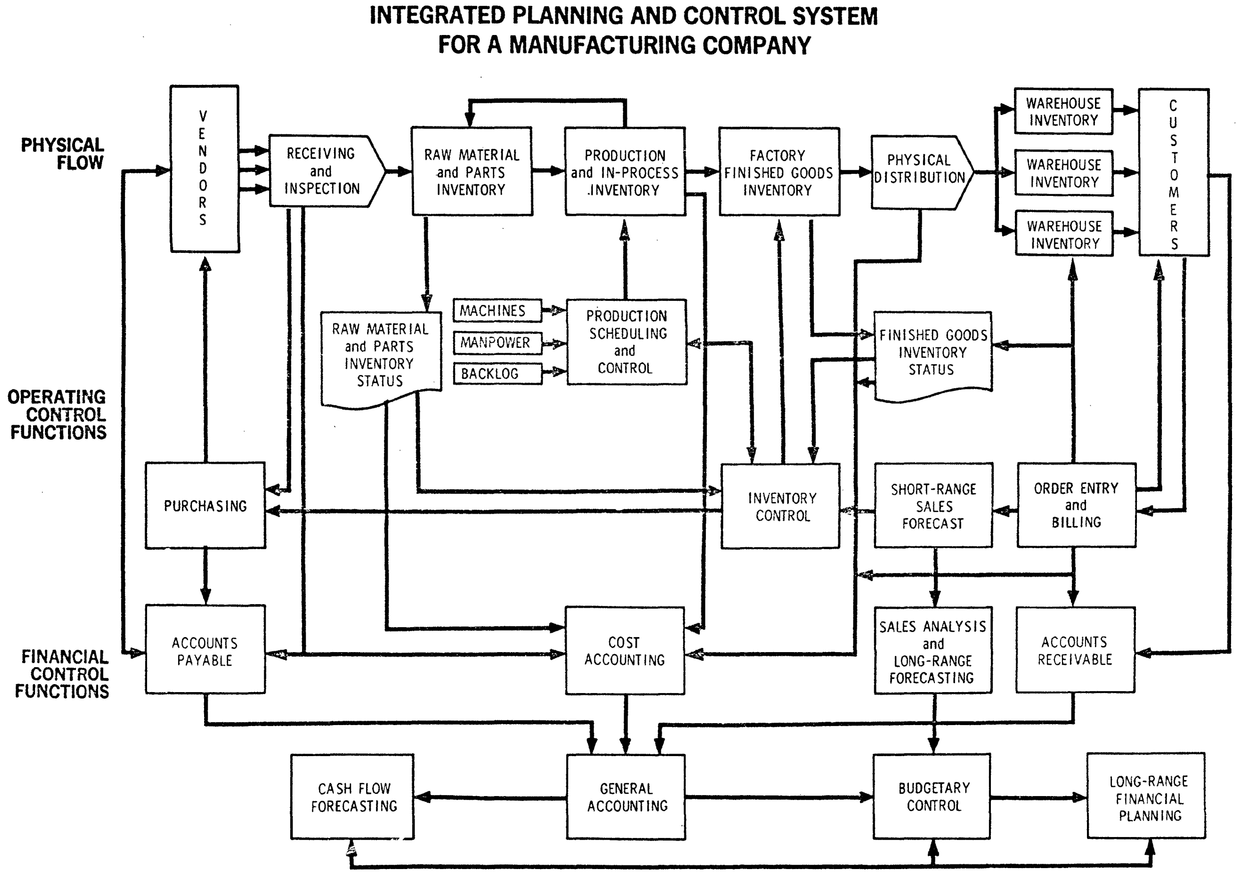


CHART A

In studying the distribution of wealth in several other European countries, he found it followed this same pattern. While it might vary--5, 10, or 15 percent controlling 70, 80 or 90 percent--essentially a small group influenced the major activity. He wrote this phenomena expressed in mathematical form in an economic treatise which was rediscovered about the time of World War II by people who were interested in inventory control. It was found that if all of the items in an inventory were grouped in a similar fashion, according to their value, the items in the inventory would follow this same pattern... 10 percent of the items in the inventory would account for perhaps 80 percent of the value. Typically, in an inventory, a grouping is as follows: 10 percent of the items account for 80 percent of the dollars; another 10 percent accounts for 10 percent of the dollars and the remaining percent of the items in inventory accounts for only 10 percent of the dollars in total.

A specific example is an inventory of 6,500 items in a company. Their total value is $3 million. Studying them, it is discovered that 450 of them, or only 7 percent of the total has a value of $2.2 million, 7 percent accounts for 73 percent of the total, another 900 items accounted for $500,000 and the remaining 5,200 items, almost 80 percent, accounted for $300,000 in value, or only 10 percent.

To restudy this inventory of 450 further, 65 items, or only one percent of the total of 6,500 accounted for $1.3 million in value, or 43 percent. In order to control inventory, one of the ways to control an inventory of $3 million value is to control all 6,500 items. However, by controlling 450, one controls $2.2 million; by controlling only 65 one controls $1.3 million. People who were studying this phenomenon began to find that it had application outside of only the dollar area. In working with this same inventory, it was seen that 10 percent of the items occupied 80 percent of the space or 10 percent of the vendors supplied 80 percent of the material or 10 percent of the vendors gave 80 percent of the lead-time problems. The phenomenon exists everywhere: 10 percent of the population reads 80 to 90 percent of the books, 10 percent of the engineers have 80 or 90 percent of the patents.

If the concept is universal, then it leads to some concepts that are important in terms of control.

In analyzing control methods, it is found that a uniform level of control effort is exerted. If there are standards on a labor force, there usually are standards on every task. If there is a forms control program, every form is controlled. If a Cardex inventory control system is set up, a Cardex record for every item in inventory is established. And, if the level of control is unsatisfactory, usually what happens is that it is raised. More detailed standards, more detailed records, more detailed accounts are put in.

But consider what happens if Pareto's Curve is true. It means that if a manager spends 100 hours a week in control, he only spends 10 percent of these hours where 90 percent of the value is. One of the first places people discover the impact of this is in a cost reduction program where somebody says: "Let's reduce inventory," and efforts are exerted to make a 10 percent savings. What happens is this: 80 percent of effort is exerted on low value items and 10 percent is saved. But is it 10 percent of the total expense? No; it is usually 10 percent of 10 percent or only 1 percent total savings result. There is a poor return on investment of time.

Now, if unlimited time, effort and energy were available, there wouldn't be a problem. However, this is unrealistic. In order to manage a logistics function, work must be planned, facilities and equipment must be arranged, a staff must be hired, people must be trained, forms must be ordered, vendors must be contacted and so on. All available time cannot be devoted to one activity. If there is only a 40- or 50- hour week to work, then the question must be considered: "Are we getting the most return from our time?"

Effective control takes place when the control effort is related to the item value. The object is to spend time controlling items in relationship to their worth. Following this plan theoretically, 80 percent of the time should be spent on items representing 80 percent of the value and 10 percent of the time should be spent on those that represent only 10 percent of the value. Instead of using a shotgun approach and treating everything the same way, different levels of efforts, different forms of control and different approaches to control, dependent on item value, would be attempted. The first approach of this type of control was "ABC control."

The types of control used are separated into three categories. Into the A classification go the items of high value, critical nature, long lead-time or high usage. In the C category are those of low value, short lead-time or where shortage control is relatively easy. And the B items are those somewhere in between; moderate value and moderate usage. Following Pareto's Curve definition, there would be 10 percent of the items in the A category, 10 percent in the B and 80 percent in the C.

Frequently, in considering ABC control, items are classified by dollar value only. That is, an item over $10 is an A item; between $1 and $10 is a B item; and under $1 is a C item. Suppose an item that costs $100 is part of a $3 million inventory. Would it automatically be an A item? If only one a year is used and it's carried in the store across the street as a shelf item, would it be an A item? No. Shortage control is relatively easy as very few are used. Assume a 30-cent item is in question. Is it a C item? Suppose a hundred thousand of them a year are used; they are made only by a vendor in Europe, and there is a three-month lead time. This is no longer a C item because it is 30 cents. It probably should be an A item in terms of its lead time, its importance. Classification should take into account a variety of weights and measures.

If one is considering processing inventory records on a computer, mechanizing inventory control, then classification becomes important, because it will determine how items are controlled. Again, there is no magic in ABC. One could have low value-high value classes; 10 percent of the items in the high value and 90 percent in the low. One could have five or ten levels. The important factor is that the use of different methods of control is considered. The object is getting the best return on the time invested. How?

Various controls can be used for this approach. First, the C items: since only 10 percent of our value is here, it is worth only 10 percent of available time. Normally, the first activity is purchasing. To save as much time as possible in handling this item, order yearly. If the item were ordered 30 times a year or 20 times a year or 5 times a year, purchasing activity could be minimized by ordering it once a year. That reduces not only the number of purchase orders to place with the vendor, but all of the associated activity besides.

Ordering once a year means the item is shipped once a year and that reduces, similarly, all of the related receiving, handling, receiving inspection, record posting, accounting and payment activity that would otherwise occur. Secondly, when the item has arrived, all of the clerical work normally associated with letting people know it's available must be minimized. To do this, the C item is put on a nonrecording issue basis. To over-simplify, the C items, when they come in, are checked for acceptability and put in big piles on the floor near where they're used, and people help themselves to them as needed. Only 10 percent of the inventory dollars are tied up in such piles, so there cannot be much value to worry about. So, acquisition should be easy: whenever anyone needs a C item, they would help themselves. No slips of paper or punched cards would be filled out; no receipts or disbursements to an inventory control record would be posted; no reference to receipts or individual disbursements on computer runs or daily stock status report would be made.

To minimize the effort of the accounting department, the item would be expensed on receipt. As soon as it arrived, it would be written off; the theory being, "we are using it up over this year on certain products; it is not necessary for control to cost out every disbursement of the product that we'd make during the year." However, C control is not no control. So, normally, this is what's done: as a year's supply is received, a three months' supply (sufficient to cover usage and lead time on normal replacement) of this C item and is taken and put in a controlled stockroom in a sealed container. The balance of the material is put in storage at the work area, and everyone gathers items as needed. When the workers run out of C items on the floor, the storekeeper pulls out the container to replace the floor supply. On top of the container is a traveling requisition which contains all the information related to this item. And the traveling requisition goes into the purchasing department for reorder.

The time of reorder is perhaps the most critical phase of the entire program...the review at the time of reorder. At this point, all of the questions that need to be asked must be asked. That is, a year's supply was ordered...has it been a year since the last ordered? Has usage gone up or gone down? Is more expected to be used this coming year? Less? Can the item be replaced by a plastic material at a lower cost? Can it be supplied by another vendor cheaper? Are people helping themselves to it? Should it be put in a controlled stockroom just to assure that there is no pilferage? When all of these questions have been answered, the reorder is instituted and the procedure is gone through again.

Also, the accounting department or internal auditing department is asked, on a sampling basis, to audit this approach. To test this system, 5, 10 or 20 items are examined during a week, month or year. Is there a sealed minimum stock? Is the traveling requisition used? Is this reviewed at the time of the order? Is there pilferage? When it seems that the system is working, then in effect, 80 percent of the items that are handled day-to-day are taken care of. Stock should not run out; on an average, there will be a six-month inventory; there should be no unexplained shortages. There should be sufficient inventory. Unexpected variations in demand, higher or lower should cause no problems and therefore, 80 percent of the expediting problems are removed.

To consider the B items: these are another 10 percent of the inventory items and represent another 10 percent of inventory dollars. The best way to capsulize a description of the control of these is to say that B items are controlled as effectively as most companies control all items. These are the items for which it is probably worthwhile to set up a Cardex or similar system, to keep track of receipts and disbursements. These items are probably important enough to keep track of the number received, the number issued, and the number left. They are probably items on which it would be necessary, based on forecasts or historic usage to set minimum or maximum quantities or reorder points and reorder quantities. And these items would probably be reviewed quarterly as a minimum, or at the time of reorder. At the quarterly review, the same questions should be asked as were about the other items. Another 10 percent of our clerical time will be spent here, if the approach has been followed properly.

Now the A items must be considered. These are only 10 percent of these items, but represent 90 percent of the money, and the lead-time problems, the storage problems, the problems with engineering changes and the problems with vendors. These are the goods that require time. All the time saved from control of C and B items will be poured back into control of A items. These are the items for which setting up special control reports is worthwhile. These deserve the most advanced, sophisticated methods of control--inventory models or formulas. These must be examined weekly or perhaps even daily for answers to these questions: How many? Where are they? Is anything unusual happening to affect them? The interesting that that occurs in real life, is that with this approach, two things occur that make it worthwhile.

Companies who have gone to this type of control find that 80 percent of the clerical time is saved on B and C items. When this time is poured back in control of A items, it is not necessary to put the whole 80 percent back. Usually what happens is that the control effort is doubled, tripled or quadrupled. Since A items are only 10 percent of the items to begin with, doubling, tripling and quadrupling control effort will only generate between a 20 and a 40 percent increase in time. Those who were controlling and spending a hundred hours uniform control find that, generally, only 50 to 60 hours need to be spent using ABC control for the same number of items. There is usually a net savings of something like 40 percent in the effort.

A second thing that happens is that because an increased amount of time is being spent where the dollars are, an inventory reduction takes place.

In order to operate a system effectively, some kind of a forecast is needed. Now, a forecast can be many things, and is perhaps the hardest item to get in a company. A forecast can be something as simple as "next year we're going to do about the same as last year." Or, a forecast can be a highly precise definition of what is scheduled. A specific example is demonstrated on Chart B. This forecast says that 215 of product A will be sold in the coming 15 months. It is helpful to know if (1) that will be all 215 the first month; (2) all 215 the last month (3) 15 a month straight through or (4)--as this forecast shows--a varying demand based on increased acceptance by the public of product A.

The more precisely this forecast is defined, the better the information provided. A principal reason for interest in the ABC approach is because not only is it a useful means for using the forecast, but is perhaps one of the most useful ways of getting the forecast.

A sale forecast (shown on Chart C) permits two actions. One, a manufacturing schedule may be made based on that forecast with an attempt to lead the forecast a little with the manufacturing schedule. The dotted line on the chart shows manufacturing will lead the sales forecast by about two to three weeks. Product A will be made about that much in advance so that shipments can be made from stock. Information on actual orders received is also necessary. Frequently, information like this is available, in detailed tabular form. An effective and helpful means for presenting information to management is by graphs. Following the ABC approach, one couldn't have a graph on every item or every product. But perhaps graphs might be constructed for the most important, the A items.

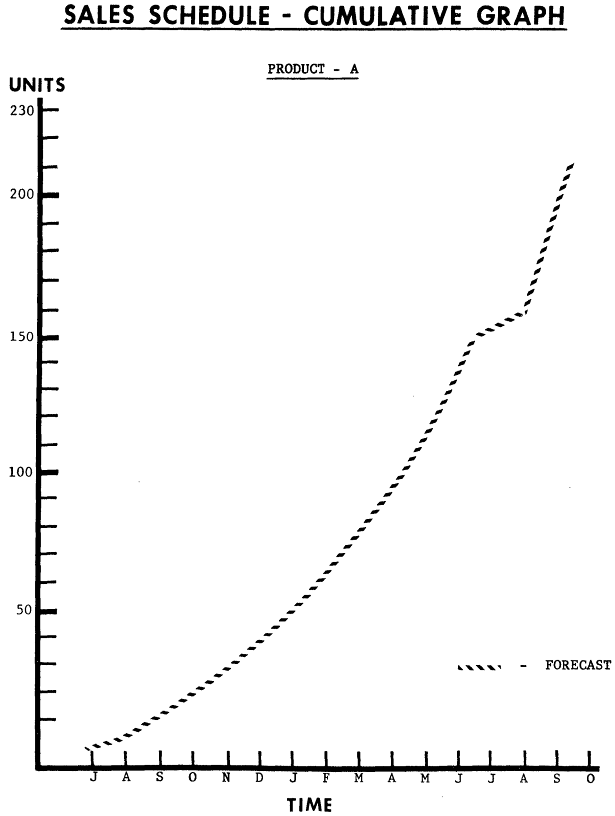


CHART B

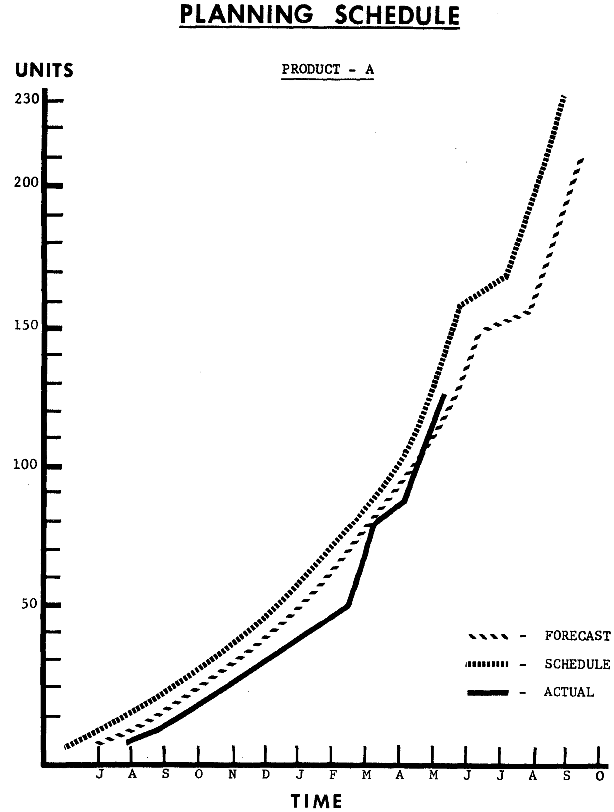


CHART C

The logistics manager can take the sales forecast for product A, which says 215 of product A will be sold in the coming period, and can calculate thusly: "The C items are 80 percent of activity, but only 10 percent of dollars. Therefore, C items will be ordered based on the sales forecast. The year's supply will be ordered immediately, only committing 10 percent of the inventory dollars." For the B items, an initial supply, perhaps three months' worth, is ordered to get going, and reorder points and reorder quantities will be set. If orders come in faster, the reorder point will be hit faster. If the orders don't come in as fast, only a small amount of the available dollars have been tied up and B orders will be adjusted as minimum quantities or reorder points are hit.

For the A items, the logistics manager will watch the actual orders received and their interrelationship with the sales forecast and manufacturing schedule. The A item orders will be adjusted to follow orders received as closely as possible. No more money will be committed than necessary. If these methods are used, good materials management develops and resources are used most effectively. Also, no one is sacrificing the sales department in terms of commitment to their forecast. And, having saved time from the B and C items, there is time to watch the A items.

An effective method of doing this is through the use of a management control report. An essential report can be prepared manually; it can be prepared on punched card equipment, it can be prepared on a computer. The most effective thing about good management control techniques is that while they are facilitated through the use of data processing equipment, they are also simple enough to be done manually. If one were trying to control all 6,500 items in the inventory described before, it could not be done. Many companies try.

It is not at all unusual to enter a company with data processing equipment and go into the materials management function to find a daily stock status report on 6,500 items. These companies state that by looking at this volume of paper, they can tell what the status is of any one of their 6,500 items at any point in time. There aren't that many hours in a day. But, of those 6,500 items, 65 items (1 percent) could be considered; close to 50 percent of the dollars could actually be controlled. Or 450 of them would equal control of close to 80 percent of the dollars. And if other information were available on purchase or manufacture, current cost, current lead time (either from the vendor or through manufacturing), current weekly usage, what safety stock is, how many weeks' supply in terms of finished goods, or how many are on hand or on order, then effective management control action can be taken.

Assume that there is an item that has a lead time from the vendor of six weeks and that 17 a week are used. Based on usage and lead time, there is a five-week safety stock. Chart D shows the number of weeks' supply on hand, on order and the safety stock. With this kind of information, weekly or even daily, immediate action can be taken. For example, a vendor calls and says "We've got new tooling, we've got new machines," or "Our new plant has just been completed." As a result of that, the lead time on this part is going to be three weeks instead of six, the safety stock could be cut from five down to three weeks or two weeks. If the vendor, on the other hand, says, "We're going into union negotiations now," or "our plant is going to be closed for a two-week shutdown," safety stock could be increased to cover for this, and higher protective inventories might be initiated.

MANAGEMENT CONTROL REPORT

INVENTORY STATUS - A ITEMS

P/M	Part number	Current cost	Current lead time	Current weekly usage	4-Week forecast usage	Current safety stock set	Inventory		Week's supply (finished / in work (order)) 0 1 2 3 4 5 6 7 8
							Finished	On order in work	
P	M-3107	28.90	6	17	17	5	20	120	1
P	M-7510	131.85	4	4	4	3	9	20	2
P	S-4601	8.64	8	60	60	7	420	500	7
M	L-2525	44.15	10	14	28	4	68	200	5
M	S-200	4.87	8	40	60	4	682	400	17
M	G-600	3.61	12	45	0	0	0	600	0

CHART D

One beginning could be to start manual intervention on any of the existing control techniques. It is one thing to run out of inventory inadvertantly, and it is another thing to run out of inventory deliberately--to run out on a Friday night when there is knowledge of a shipment on its way which will arrive Monday morning.

When it isn't necessary to depend on a clerk to notice, on a printed record, that a reorder point has been reached, but instead an inventory watch is constant, the situation is in a different kind of management area. When feedback is used, management is aware of the kind of control that is operating, and more effective action may be taken. It is this reduction of the inventory stock from the safety level that begins making a significant reduction in inventory dollars. If the inventory of major items can be deliberately cut back one week, two weeks' or three weeks' supply, significant reductions can be made because there are 80 percent of the inventory dollars tied up in these items. If a five-week safety stock is carried all the time, and that stock can be reduced by only one week (for an A item that costs $28 or $130), then significant savings can be realized.

One of the elements unrecognized by many firms who use either a machine method of controlling inventory or Cardex records, or operations research techniques, is that they can sometimes work too well. An example of that (shown on Chart E) is the typical EOQ control, where lead time and usage are determined within the current framework of operations and then, based on costs of ordering, costs of carrying, costs of shortage, how much to order and how much to have on hand is determined.

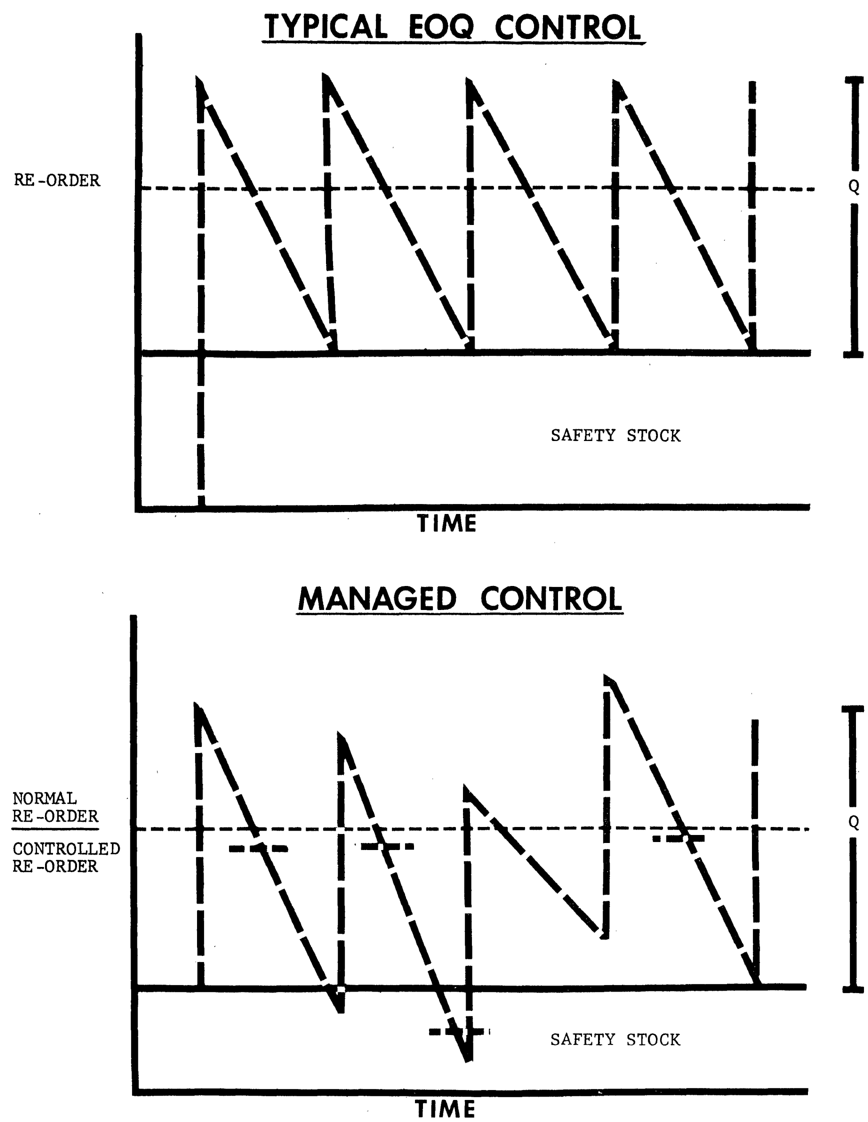


CHART E

Normally, then, an initial supply is received. The initial order has to cover the safety stock and the reorder period usage. Following the graph, at the initial stock level, the items following our forecast usage are beginning to be used. A reorder point is hit, and a reorder is submitted. Item use is continued, and if the forecasting is good, about the time the safety stock level is hit, the shipment from the vendor will arrive, and the original stock level is reestablished. The control technique is adjusted to be sure that usage and lead time is anticipated, so that about the time that the system is dipping into safety stock, the order will come in. In many instances it is considered detrimental to go into the safety stock, because the safety stock normally considers usage and replenishment and it considers paperwork time (the time that is involved between the time that the clerk in posting the records notices that the safety stock or the reorder point is hit), and the reorder is triggered.

If management control is exercised, essentially the same analysis would occur. More effort in the formula might be devoted to considering additional costs. As a result, the reorder quantity might be even more precisely determined. Normally what happens is first, safety stock is reduced somewhat because a reduction in clerical lead time is acknowledged.

Initial quantities are started in the same way. Replenishment quantities and safety stock are ordered and used. What would be the normal reorder point is reached. But management may decide to delay the reorder a week or two. Usage is continued, safety stock is dipped into before the item is received. Usage is again continued, the reorder point is hit. Again, management may say actual orders received are below the forecast; there will be no reorder yet. The item is reordered a week later and usage continues. Safety stock is dipped into. At this point, management learns that usage is going up for the item, they again reorder. About the time the item runs out, the first order comes in. As the reorder point is again reached, normal conditions have been established and so the reorder takes place at the normal time and as the safety stock is touched, the new material arrives. In a typical system, the average level of inventory is somewhere around the reorder point. It includes safety stock (which is never touched) and half of the remaining inventory. Consider the difference between the average level of inventory in a "typical" approach and the average inventory level with managed control. First there is a lower safety stock but secondly, by virtue of the fact that safety stock is dipped into deliberately, inventory is reduced. This is normally how the 20 or 30 percent inventory reduction which takes place as a result of the ABC control is obtained. Inventory is deliberately reduced. The computer or formal methods of control are not depended upon to do the job totally. Those controls work for the C items and the B items.

In a modern aircraft, an automatic pilot takes care of flight most of the trip. Probably eighty percent of a modern jet flight is flown on automatic pilot; but at the critical periods, to be sure that takeoff and landing are appropriate, or when traffic or some unexpected condition enters, the pilot steps in. What does he do? He overrides the automatic pilot, the computer. He enters into the activity and takes action. If the pilot had to control the aircraft all the time in a two-hour or five-hour jet flight, he'd be fatigued, and he would probably not be so effective as he can be when he lets the computer run the aircraft, and takes care of the little things. He has time, then, to look at the dials, to look at the condition around him, to notice that whatever the dials say, something different might be happening outside. There may be another unexpected aircraft in a hazardous position and he can take action to avoid a collision.

There are many who are lulled into a false sense of security by meaningless or erroneous computer reports. For instance, the report states that there is stock. A manager walks through the plant, never sees any of the stock, and says, "I don't understand. The computer tells me that I have it, I don't see it, but it must be there." Then one day he discovers, as the stock runs out, that there was a keypunching error. That may be all right for a C item, because the lead time is short, and it's not critical. And it may be all right for a B item. But it's not all right for an A item. By definition, it is important or critical and one can't afford to run out. No company can afford to have so dissipated its energies on meaningless or insignificant reports that there is no energy left for the control of really important items.

In order to control effectively, one has to know, in addition, how long it takes for something to get through the pipeline. Normally, in making product A, there are several documents involved. The first is a bill of materials. It calls out a certain number of parts in product A. It notes the arrangement, or the physical configuration of those parts, either by a listing or a print which supplies a picture of them. There are operation sheets, or route sheets that indicate that these parts go through different forms of manufacture. Some may be purchased and go into final assembly directly. Some may be purchased and go through manufacturing. From the manufacturing documents, the industrial engineering time studies and production control schedules, a good estimate of how long this process takes is available.

FLOW CHART

MANUFACTURED PRODUCT - A

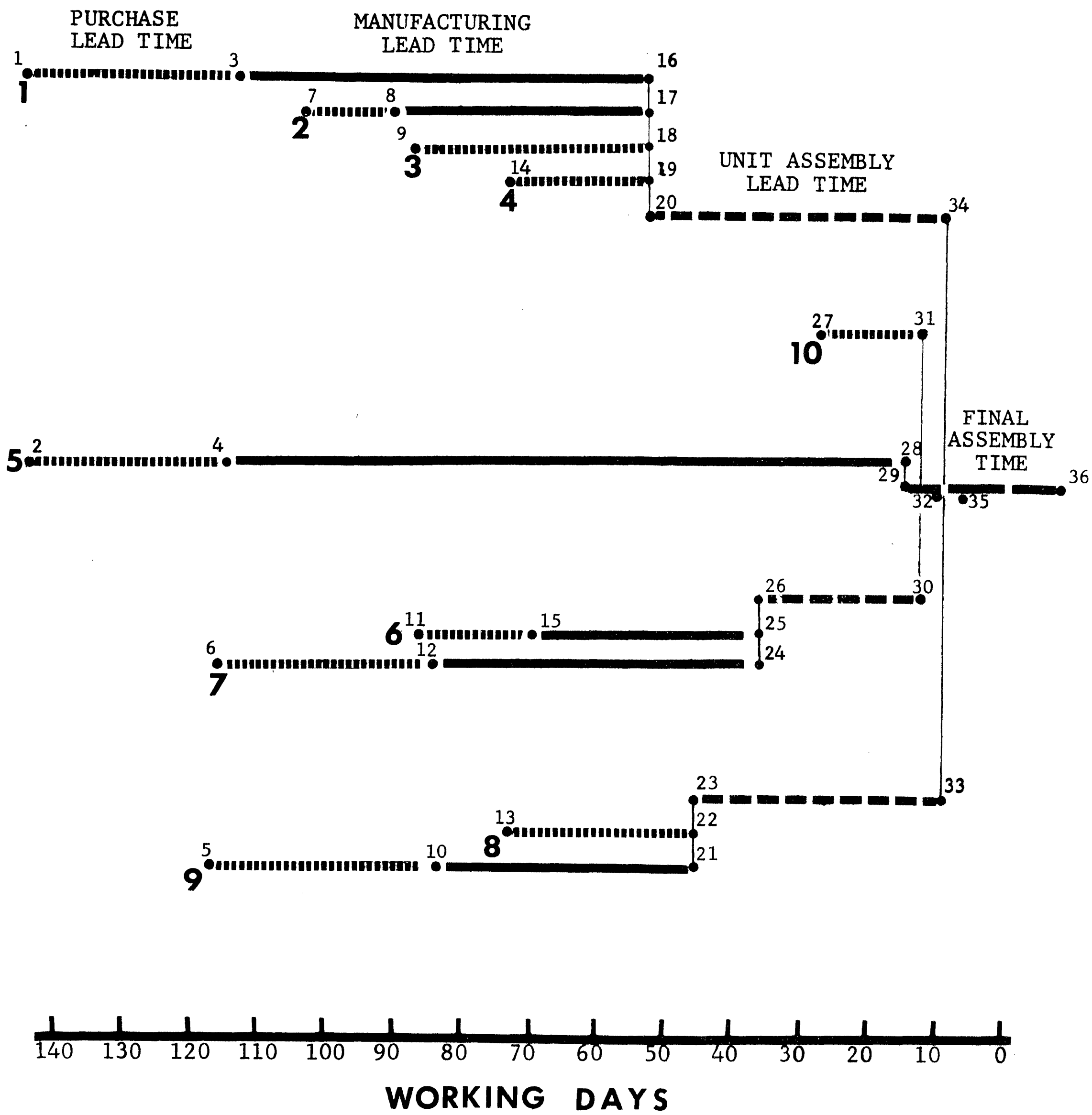


CHART F

This same information is shown on Chart F. Product A has ten major parts. The dotted lines show those items which are purchased; the solid, those which are manufactured; the dashed, those which go through assembly; the long dashes show the final assembly section. The groupings show the interrelationship of the parts which would be found on the route sheet and bill of materials, and on a time scale the time relationship that would be obtained. What this says is that the lead time for product A is 140 working days. There is about a six-week delivery from the vendors for certain purchased parts and a one- to two-week delivery on other parts. There is between six and twelve weeks' manufacturing lead time for certain items. In order to ship a finished product A, 140 days before product A moves off the dock, the purchase order for part 1 and part 5 must be placed because it takes that long to get them through. About 20 working days before product A is needed, the purchase order must be placed for part 10, because it has this lead time and it goes directly to final assembly If these relationships are true, that all these parts are needed to make product A, and they are needed in this relationship, then if something goes wrong and one of these parts is not available at the right time in relationship to this flow chart, product A isn't going to come off the line properly.

What's the best way of functioning according to this? If money and space were unlimited, everything could be ordered well in advance. If it takes 140 days to manufacture product A, then 180 days before everything would be ordered and in. That's a good approach, but money and space are limited and this cannot be done economically.

With ABC control, the C items are ordered well in advance. Thus 80 percent of the items will arrive long before needed. B items may be brought in 1 to 2 months before needed. A items are not ordered any sooner or later than necessary.

What might be involved in making product A is a shop scene like this: A worker on the line, building product A, helps himself from the piles of C items that are on racks near his place of work; all the resistors, condensors, valves, hardware items, all the low-cost non-critical items that he needs are right around him as he needs them. The B items to make several of product A have come to him in some kind of basket or cart or along the line and he uses these. As he puts the critical A item on product A, he realizes he's run out, and just as he takes the time to turn his head and say, 'I'm out,' a trucker arrives with his next item A to put in.

Now, that would give a maximum utilization of resources. It sounds almost theoretical, and yet in an automobile assembly plant, this is essentially what's done... if one considers a plant that is making a thousand automobiles a day. Most of the C items are in bins. Most of the B items go along conveyors. The A items are usually in railroad trains that are brought into the siding at the beginning of a shift, and the workers work out of them. At the coffee break, or lunch, the train is pulled out and a new train is brought into the siding. The turnover of C parts may be once every few months, once every year. The turnover of B's, several times a week. The turnover of A parts can be 400 times a year Some people say, "The automotive companies can do this because they're big," which is much like debating which came first, the chicken or the egg. Imagine what an automobile plant would be like if it tried to turn out a thousand cars a day and it had a once-a-year or three-times-a-year turnover of bodies. That many bodies couldn't be stored in the fields around the plant, much less inside the plant. It's big because it does these things.

It's not unusual to go into an ordinary company and find that its inventory turnover is three times a year, or four times a year or more. This takes a certain amount of storage space. One of the things that is not recognized is that just doubling the inventory turnover, in addition to giving better use of money, also reduces the space requirement in half. People who have warehouse problems can solve them by building another warehouse, it's true. But if inventory turnover is doubled, only half as much storage space is needed, so one of the ways to solve a warehousing problem is by concentrating attention on reducing the lead time on items.

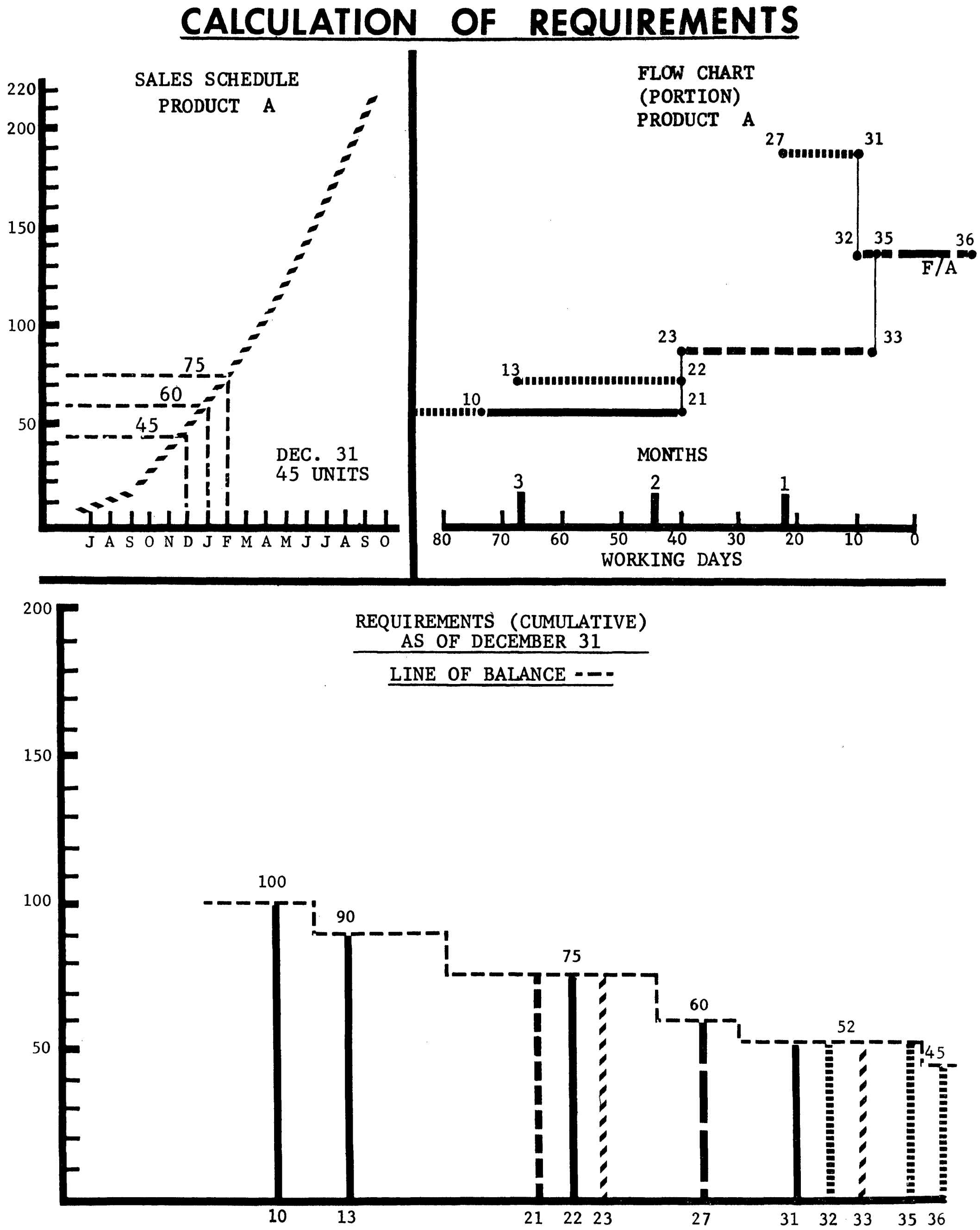


CHART G

An effective technique for control is detailed in chart G. It involves knowing the sales forecast or manufacturing schedule, indicating how many of product A will be needed at each point in time. This chart shows 215 over a given period, but as of 12/31, 45 will be needed in total. At the end of January, 60; at the end of February, 75; at the end of March, 90 in total. The portion of the flow chart shows that in order to meet the schedule, considering the interrelationship of lead time and usage, certain actions must be taken. One month before product A is needed, this part (shown at point 27) must be ordered; two months before the part is received from this vendor (shown at point 22); and the part from manufacturing (shown at point 21); three months out (the part shown at point 10) must be received.

PROCESS CONTROL COMPUTER COMPARISON CHART

MANUFACTURER TYPE MODEL		Purchase Price Range $1000	Rental ($1000 Month)	Storage Capacity (Wd-Words : Ch-Characters) (K=1000 : M=Million) Core (K)	Drum (K)	Disc (K)	Basic Word Length-Bits	Levels Program Interrupts	No. of I/O Channels	Core Memory Fence	Index Register Words	No. of Wired Instructions	Relative Addressing	ANALOG INPUT No. of Points	Scan Rate - Low Level	Scan Rate - High Level	DIGITAL INPUT No. of Points	Input Rate	ANALOG OUTPUT No. of Points	Output Rate	DIGITAL OUTPUT No. of Points	Output Rate	Digital Display	Analog Display	Input Console	Paper Tape I/O	Card I/O	Line Printer	Mag Tape	Remote Data Acquisition	I/O Typewriter	Simultaneous Operation of Peripheral Equipment	REMARKS
		CENTRAL PROCESSOR												PROCESS INPUT/OUTPUT									OPERATOR COMMUNICATION EQUIPMENT			PERIPHERAL EQUIPMENT							
BAILEY METER CO. Wickliffe, Ohio 44092	Bailey 750 (752)	50-150K			Wd - up to 45K		20	n/a		n/a	n/a	Macro-Inst. used throughout	n/a	Up to 1000	5 pps	5 pps	Up to 1000	5 pps			none	n/a	yes	yes	yes	Output	Output	yes	no	yes	Output	yes	750 (752) - Stored program, multi-channel information and monitoring system - no computing capability.
	Bailey 750 (754)	75-200K	n/a	n/a	Wd - up to 45K	n/a	25	1/function	1/ function	n/a	yes	Macro-Inst. used throughout	yes	Up to 2000	15 or 30 pps	15 or 30 pps	Up to 10K	3KC	Un-limited	1 pps	Up to 10K	Pro-gramable											750 (754) - Custom designed stored program multi-channel process information and monitoring system. Can have computer capability added to it. (Same as 756 except without computer.)
	Bailey 756	100-300K			Up to 45K		25	1/function		n/a	yes	Macro-Inst. used throughout	yes	Up to 2000	30 pps	30 pps	Up to 10K	3KC			Up to 10K	Pro-gramable				yes					yes		756 - Custom designed general purpose
	Bailey 756 A	250-400K		8K	Up to 45K		25	5		yes	yes	34 plus modifiers	yes	Up to 4000	100 pps	100 pps	Up to 4000	100KC	Up to 10K	100 pps	Up to 10K	100KC											
COMPUTER CONTROL CO., Inc. Old Connecticut Path Framingham, Mass. 01702	DDP-24	73	2.5	Wd 4-32K			24	1-32	64		1-3 hardware	59			250 cps.			525KC	Un-limited			525KC								no		yes	Paper tape I/O - DDP 116, 124, 224 - 300 cps. I/ - 110 cps./o - DDP 24 - 300 cps. I/ 60 cps./o
	DDP-116	28.5	.92	Wd 1-32K			16	1-64	18	Variable	1	61			100-250 cps.			580KC				580KC										I/O time-shared with LPV	Card I/O 100 cps. - DDP 116 - 124, 224 and 24 200/100 cps.
	DDP-124	65-130	2.05-4	Wd 32K	Wd 128K	Wd 2M		16				60	yes	2,048	250 cps.	20KC	Optional	577KC	128	50-100KC	Optional		yes	yes	yes	yes	yes	yes	yes	yes	yes	Time-shared I/O with central processor	Line Printer 116 300 lpm, 124 500 lpm, 224 and 24 300 lpm. Magnetic tape 116 25-60KC, 124, 200 & 556 bpi + 45 and 75 ips 224-200, 556 and 800 bpi - 45 and 75 ips 24, 25-41KC
	DDP-224	75-250	2.5-6	Wd 65K			24	128	64	n/a	3 hardware	80						525KC				525KC										Either full simultaneous or time-shared I/O with central processor	I/O Typewriter 116 10 cps. - 124, 224, 24 - 15 cps.
CONTROL DATA CORP. Control System Div. 4455 Miramar Rd. La Jolla, Calif.	Control Data 636	60-300	n/a	Wd 33K	Wd 262K	n/a	16	16	3	yes	n/a	n/a	n/a	2,046		50K pps	1,600	1mc	64	1/8ms	1,024	1/10ms	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	Card I/O and magnetic tape units are non-standard.
DIGITAL EQUIPMENT CORP. 146 Main Street Maynard, Mass.	PDP-6	350-1000		Wd 262,144	n/a	Un-limited	36	7	128	yes	15	363	yes	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional	Optional			Reader includes W/CP punch option	As option	Optional	Optional		Included W/CP up to 64 remote as options	System is asynchronous	
	PDP-7	45-350	n/a	Wd 4-32K	Wd 32-131K	n/a	18	16	64	no	8 (Auto)	13 Arith plus I/O	no	Un-limited	Up to 60KC	Up to 200KC	Un-limited	10M bits/sec.	Un-limited	200KC	Un-limited	10M bits/sec.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	
	PDP-8	18		Wd 4096	n/a		12	1				50			1KC	200KC		8M bits/sec.	Variable			8M bits/sec.											
ELLIOTT PROCESS AUTOMATION, LTD. Elstree Way Borehamwood, Herts. England	Elliott Arch 101	30		Wd 256	n/a		12	n/a	32		n/a	Variable	no	32	100/sec.		Manual		32	n/a			4 Digit										Type 1 ddc. Figures relate to basic machine without logging facilities.
	Elliott Arch 1000	45-180		Wd 8K	Wd 200K	n/a	18				1	20-32	Translation program	Typically 500	5/sec. nominal						n/a	n/a	no	no	no	no	no	no	no				Modular system with optional arithmetic facilities. 23 systems already installed.
	Elliott Arch 2000	120-450	n/a	Wd 32K	Wd 150K	Wd 200K/disc.	24	1	Variable —	no			yes		100/sec.	Variable	Variable	Variable	Variable	Variable										yes	yes	no	Uses Elliott 4100 series machine for central processor.
	Elliott Arch 2030	150-500		Wd 250K		Wd 200K/disc.	24				n/a	300	no	8X128	150/sec.						Variable	Variable	10 decades or Variable	Variable	yes	yes	yes	yes	yes				Uses Elliott 4130 processor.

(Continued)

S/7

PROCESS CONTROL COMPUTER COMPARISON CHART

	CENTRAL PROCESSOR												PROCESS INPUT/OUTPUT									OPERATOR COMMUNICATION EQUIPMENT			PERIPHERAL EQUIPMENT							
			Storage Capacity (Wd-Words : Ch-Characters) (K=1000 : M=Million)										ANALOG INPUT			DIGITAL INPUT		ANALOG OUTPUT		DIGITAL OUTPUT												
MANUFACTURER TYPE MODEL	Purchase Price Range $1000	Rental ($1000 Month)	Core (K)	Drum (K)	Disc (K)	Basic Word Length-Bits	Levels Program Interrupts	No. of I/O Channels	Core Memory Fence	Index Register Words	No. of Wired Instruc-tions	Relative Address-ing	No. of Points	Scan Rate - Low Level	Scan Rate - High Level	No. of Points	Input Rate	No. of Points	Output Rate	No. of Points	Output Rate	Digital Display	Analog Display	Input Console	Paper Tape I/O	Card I/O	Line Printer	Mag Tape	Remote Data Acquisi-tion	I/O Type-writer	Simultaneous Operation of Peripheral Equipment	REMARKS
ELLIOTT PROCESS (Continued) Elliott Arch 8000	90-450	n/a	Wd 8192	Wd 150K	n/a	39	1	Variable	no	8192	64	Trans-lation program	Typically 512	5/sec nominal	Variable	Variable	Variable	Variable	Variable	Variable	Variable	10 dec-ades or Variable	Variable	yes	yes	yes	yes	yes	yes	yes	One hard-ware inter-rupt level	Early versions originally marketed and supplied in USA under name of ISI 609 - Uses Elliott 803 as central processor.
Elliott Arch 9000	60-180		Wd 8X8192			18	4			n/a	32	Variable	Variable -8X128 manually	100/ sec.																		Uses Elliott 920 series as central processor.
ENGLISH ELECTRIC-LEO-MARCONI COMPUTERS, LTD. Kidsgrove, Stoke-on-Trent, England KDN2	* 23-100	n/a	Wd 4-16K	Wd 130K	no	18	8	4,096	no	4	64	no	** 10-1000	** 50 pps	** 50 pps	** 18-1000	** 20K/ sec.	** 1-100	** 50 pps	** 18-1000	** 20K/ sec.	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	* Central Processor with I/P and O/P equipment. ** These figures indicate typical ranges of process I/Os for balanced systems. They do not represent the maximum for any type. Data acquisition and process I/O modules are supplied in configurations to meet systems requirements.
KDF7	* 59-450	n/a	Wd 32K	Wd 256K		24	128	Un-limited	yes	4	64	yes	** 100-2000	** 150 pps	** 10K/ sec.	** 100-5000	** .5M/ sec.	** 10-1000	** 20K/ sec.	** 100-5000	** .5M/ sec.							no				
FERRANTI ELECTRONICS Industry Street Toronto 15, Ont. Canada Argus 100	70	n/a	Wd 4-12K		yes	24	1	Up to 12K	no	3	32	no	Up to 200 loops	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	All Argus series are fully program compatible. Memory Protection - time-sharing of off-line computing with control functions.
Argus 300	87		Wd 4-65K										Up to 1,000 loops																			
Argus 400	50		Wd 4-16K	Wd 512K			8		yes	24		yes	Modules 32	10KC/ sec.	10KC/ sec.	Un-limited		Variable	15 usec. convert.	Variable		Decimal Display modules			300 cps read 110 cps punch	yes		16KC/ sec. 30 ips digital				Argus 400 and 500 are micro-miniature.
Argus 500	75		Wd 4-16K	Wd 512K			8						Modules 32												300 cps read 110 cps punch			16 KC/ sec. 30 ips digital				
FOXBORO CO. 38 Neponset Avenue Foxboro, Mass. 02035 Foxboro 97600A	150-350	3.5-8	Wd 32K	Wd 131K	n/a	18	36	4 direct access, 256 pro-gram control'd	yes (8000 word banks)	8 (Auto)	63 arith. 100 I/O	no	1,024	40-100	5K/ pss	1,026	800K/ pps	39 d/a 256 DDC	256 pps (voltage or current)	324	1,500 pps	Binaview	Meters and Plotters	Consoles for Pro-gramer, Operator, Engineer	yes	yes	yes	yes	no	yes	yes	
PCP-88 System	200-400	4.5-8			Wd 200K/ disc. Fixed Heads	12	24	2 direct access, 128 pro-gram control'd	no		38 arith. 100 I/O					684				216												The PCP-88 includes two or more Model 97400A computers in a master-slave arrangement: The master computer acts as the supervisor while the slave computer regulates the process.
GENERAL ELECTRIC CO. PROCESS COMPUTER SECTION 13430 No. Black Canyon Hwy. Phoenix, Ariz. 85029 GE/PAC 4020	54-400	1.35-9.8	Wd 2-32K	Wd 16-256K	Wd 0.256-4M	24	8-128	Mem 1-3 Auto 1-5	yes	7	77	yes	16-2,048	50-200/ sec.	40KC	20-1,280+	500K/ sec.	1-128	250K/ sec.	16-1,000	4K/ sec.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	1.6 usec. core memory cycle. Programing compatible with GE/PAC 4050 and 4060.
GE/PAC 4040	41-300	1.1-7	Wd 2-16K					Mem 1-2 Auto 1-5			75		16-2,048				250K/ sec.															5 usec. core memory cycle. Programing compatible with GE/PAC 4050 and 4060.
GE/PAC 4050 I	66-500	1.7-15															500K/ sec.															5 usec. core memory cycle. Programing compatible with GE/PAC 4050 and 4060.
GE/PAC 4050 II	66-500	1.7-15	Wd 4-64K					Mem 1-3 Auto 1-6			112		16-4,096				500K/ sec.	1-512		16-2,000												3.2 usec. core memory cycle. Programing compatible with GE/PAC 4050 and 4060.
GE/PAC 4060	77-750	1.9-25															250K/ sec.															1.6 usec. core memory cycle.
HONEYWELL Industrial Projects Group Wayne & Windrim Aves. Philadelphia, Pa. 19144 H-20/21	55-175	1.83-5.83	Wd 2-16K	Wd 65-525K	n/a	20	8-16	520	yes	1	126	no	1,024	200/ sec.	5K/ sec.	1,440	330K/ sec.	120	13,900/ sec.	1,440	333/ sec.	yes	yes	yes	yes	no	no	yes	yes	yes	yes	Honeywell system with H-21 central processor. H-21 central processor has memory cycle time of six microseconds.
H-20/22 (Continued)	67-190	2.23-6.33	Wd 4-16K				8-32																									Honeywell system with H-22 central processor. H-22 central processor has memory cycle time of 1.75 microseconds.

PROCESS CONTROL COMPUTER COMPARISON CHART

CENTRAL PROCESSOR

MANUFACTURER	TYPE MODEL	Purchase Price Range $1000	Rental ($1000 Month)	Storage Capacity (Wd-Words : Ch-Characters) (K=1000 : M=Million) Core (K)	Drum (K)	Disc (K)	Basic Word Length-Bits	Levels Program Interrupts	No. of I/O Channels	Core Memory Fence	Index Register Words	No. of Wired Instruc-tions	Relative Address-ing
HONEYWELL (Continued)	Honeywell 21	18-45	.6-1.5	Wd 2-16K	Wd 65-525K	n/a	20	8-16	520	yes	1	126	
	Honeywell 610	100-300	3.33-10	Wd 4-16K	Wd 16-84K	Wd 525K	24	20-902				42	yes
IBM CORP. 112 East Post Rd. White Plains, N.Y. 10601	IBM 1800	47.3-129	1.16-3.23	Wd 4-32K		Wd 1.53M	18	12-24	9	yes	3	27	yes
LEEDS & NORTHRUP CO. 4970 Stenton Avenue Philadelphia, Pa. 19144	LN 4100	75-160	1.7-3.5	Wd 2-16K					2	no		48+	
	LN 4200	95-250	2.1-5.6	Wd 2-16K	Wd 40-320K	Wd 4M +	24	1,024	2	no	1	64+	yes
	LN 4300	120-600	2.7-13.0	Wd 4-32K					2-12	Optional		94+	
PHILCO CORP. 3900 Welsh Rd. Willow Grove, Pa. 19090	Philco 3100	40-200	n/a	Wd 4.8-16K	Wd 32-96K		24	24	16 periph. 28 wd. 2 hi-spd.		*	64	
SCIENTIFIC DATA SYSTEMS 1649 Seventeenth Street Santa Monica, California 90404	SDS 92	26.5 112.3	.8-3.4	Wd 2-32K			12	256	1 std. plus N optional channels			43	
	SDS 910	41-126.8	1.2-4.2	Wd 2-16K					2			42	
	SDS 920	61-131.8	1.8-4.8	Wd 4-16K		16M per I/O channel *			2		1	64	
	SDS 925	78.5-149.8	2.-4.	Wd 4-16K	n/a							70	no
	SDS 930	89-356	2.-8.	Wd 4-32K			24	1,024	8 std. plus N optional			94	
	SDS 940	560-1000	14.0-25.0	Wd 32-64K						Optional		96	
	SDS 9300	150-600	3.4-13.5	Wd 4-32K							3	115 §§	
WESTINGHOUSE ELECTRIC Research & Development Center Pittsburgh, Pa.	PRODAC 50	30-250	n/a	Wd 16K			14	64	64		yes	25	yes
	PRODAC 550	250-1000	n/a	Wd 32K	265K		18	209	8	yes	yes	92	yes

PROCESS INPUT/OUTPUT · OPERATOR COMMUNICATION EQUIPMENT · PERIPHERAL EQUIPMENT

TYPE MODEL	ANALOG INPUT No. of Points	ANALOG INPUT Scan Rate - Low Level	ANALOG INPUT Scan Rate - High Level	DIGITAL INPUT No. of Points	DIGITAL INPUT Input Rate	ANALOG OUTPUT No. of Points	ANALOG OUTPUT Output Rate	DIGITAL OUTPUT No. of Points	DIGITAL OUTPUT Output Rate	Digital Display	Analog Display	Input Console	Paper Tape I/O	Card I/O	Line Printer	Mag Tape	Remote Data Acquisi-tion	I/O Type-writer	Simultaneous Operation of Peripheral Equipment	REMARKS
Honeywell 21			5K/ sec.		330K/ sec.					no	no	no	yes	no	no	yes	yes	yes	yes	
Honeywell 610	4,095	200/ sec.	200/ sec.	49,140	187,500/ sec.	4,095	30K/ sec.	49,140	187,500/ sec.	yes	yes	yes	no	yes	yes					
IBM 1800	2,432	100 pps	20K/ sec.	1,024	.5M- 16 bit wd/sec.	128	10 usec. per conv.	2,048	5M- 16 bit wd/sec.			yes	yes	yes	yes	yes		yes	yes	Provisions available for direct attachment to System/360 Models 30, 40, 44 and 50. Two processes or models - 4 usec or 2 usec. Peripheral equipment includes IBM 1627 plotter which provides real-time graphic display.
LN 4100 / LN 4200 / LN 4300	2,048	120-200/ sec.	120-200/ sec.	2,496	180K/ sec.	256	60 steps/ sec.	2,048	100K/ sec.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	Complete family of analog recorders, manual backup stations and automatic backup stations are available with L&N systems.
Philco 3100	32-4,096	65-260/ sec.	65-260/ sec.	8-1,024	125K 24 bit wd/sec.	8-1,024	500-2,000/ sec.	8-1,024	125K 24 bit wd/sec.	yes	yes	yes	300/ 50 cps.	400/ 100 cps.	300/ lpm	25KC - IBM compatible	yes	yes	yes	* Index Register Words - Unlimited in memory - One outside memory.
SDS 92 – SDS 9300	**	**	**	**	**	**	**	**	**	yes	yes	yes	yes	yes	yes	yes	§	yes	yes	* Using Data Multiplexer or Direct Access System. ** Process input/output is via analog/digital instruments and modules that constitute a separate product line from the computer itself. Process I/O rates are a function of this equipment rather than the computer. § Data collection is system-engineered, not a standard item. §§ Memory overlap feature (standard equipment) reduces execution time by one cycle per instruction. SDS 940 is designed especially for time-sharing and includes the following special features: dynamic relocation, memory fragmentation, memory protection, monitor/user modes and privileged instructions.
PRODAC 50	0-50K *	160 pps	160 pps	0-50K *	1,400 p/chnl.	0-50K *	2,800 p/chnl.	0-50K *	2,800 p/chnl.	yes	yes	yes	yes	yes	no	no	yes	yes	yes	* Total I/O points cannot exceed 50,000. Additional core can be used as mass memory.
PRODAC 550	0-150K			0-150K		0-150K		0-150K							yes	yes				* Total I/O points cannot exceed 150,000.

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THE CONCEPT OF IDPA'S CASE HISTORIES

Each monthly supplement to INDUSTRIAL DATA PROCESSING APPLICATIONS contains one or more case studies of "at work" installations. These supplements are prepared in order to further the reader's understanding of the tasks modern data processing systems are performing in a variety of industries.

In many cases the specific application in one industry may not apply directly to an application in another. However, similar problems exist in all industries. For example, an airlines reservations system does not have a direct relation to an automobile production system but the basic design of the reservations system could be applicable to inventory control or order processing. It is the indirect relationship our case studies offer that we believe should be of greatest interest to our readers.

The synopsis, which appears at the beginning of each report, is a brief summary of our examination of the installation. Generally, it gives the reader, at a glance, an idea of the functions performed by the system and an outline of the equipment used.

Each report is based on on-site observations by our personnel, on material supplied by the system's user and on interviews with employes of the manufacturer and the user's organization.