Nine general-purpose digital computing systems are commercially available for the control of continuous and batch type industrial processes. For quick reference, these computers are compared in a single table. A general discussion of general-purpose digital computers and the characteristics of the nine control computer systems are included.

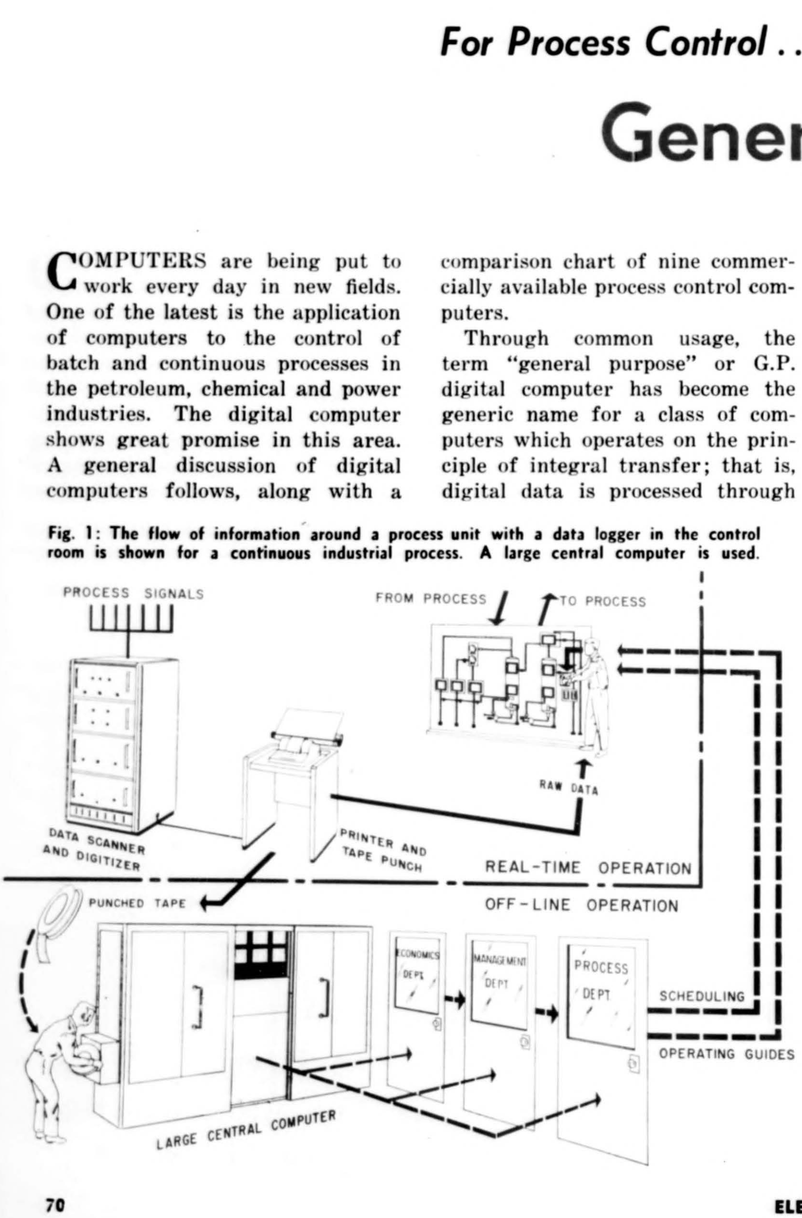
For Process Control . . .

General Purpose

COMPUTERS are being put to work every day in new fields. One of the latest is the application of computers to the control of batch and continuous processes in the petroleum, chemical and power industries. The digital computer shows great promise in this area. A general discussion of digital computers follows, along with a comparison chart of nine commercially available process control computers.

Through common usage, the term "general purpose" or G.P. digital computer has become the generic name for a class of computers which operates on the principle of integral transfer; that is, digital data is processed through the computer based upon the entire numerical value of the quantity. This distinguishes the general purpose computer from the incremental transfer computer (the digital differential analyzer or DDA is an example of an incremental machine). The general purpose computer is therefore defined in terms of its internal logic rather than its general applicability. Its logic permits it to perform all arithmetic functions such as addition, subtraction, multiplication, and division as well as non-arithmetic functions such as shifting numbers, etc. It can compare quantities, make logical decisions based on results of comparisons, vary its sequence of operation as a result of its own decisions, and detect its own failures plus those of other components in a system.

Fig. 1: The flow of information around a process unit with a data logger in the control room is shown for a continuous industrial process. A large central computer is used.



Process Control Computer Applications

In process control applications, the computer must be linked to the process variables such as temperatures, pressures, flows, tank levels, fluid compositions, etc. The process measuring elements or transducers are predominantly analog devices.

This article is based on an article by the **author** which appeared in the July 1959 **issue of the ISA** Journal (Instrument **Society** of America).

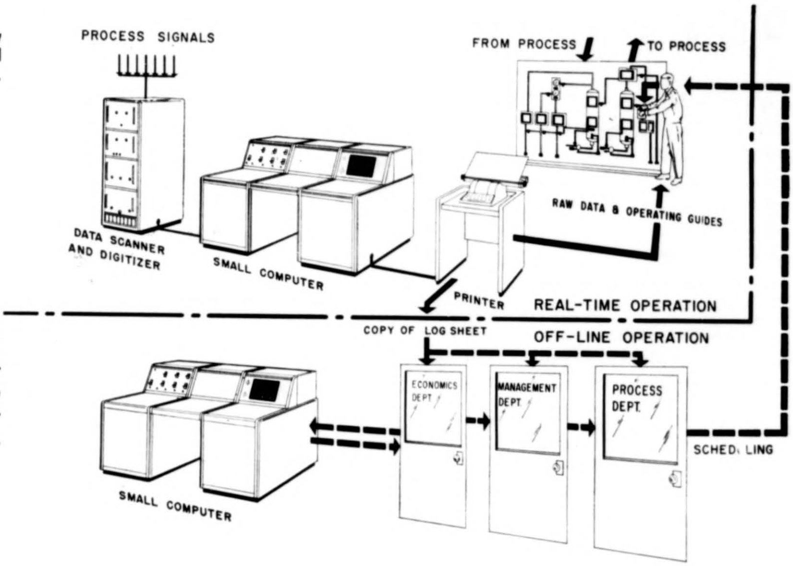


Fig. 2: The information flow when using a small digital computer is illustrated.

By ARTHUR H. FREILICH
Research Engineer
Burroughs Corporation
Research Center
Paoli, Penna.

Digital Computing Systems

To connect the digital computer to the transducers, it is necessary to provide an input switching system which will select the input to be read into the computer. It is also necessary to provide an analog-to-digital conversion system to convert the selected analog transducer signal into a digital value which can be entered into the computer. Therefore, a process control computer system requires input switching and A/D conversion units as well as the computer itself. Similarly, if the output of the computer is to be used to change the settings of the analog controllers which are responsible for holding a single variable, such as a temperature, at a constant value, it is necessary to provide a digital-to-analog converter and an output switching system at the computer output. With such an input and output system, the computer can then measure process conditions and change control setpoints. These setpoint changes would cause the process to operate in a more optimum manner. The particular optimum may vary from process to process or from day to day; it will always, however, involve not only process conditions but the all-important economic criteria of cost, demand, etc.

It is in the area of more optimum (hence more profitable) operation that computer control holds promise. Present analog controllers can maintain stable process operation today. But such operation may not be the most profitable. Seeking-out and maintaining the optimum process operating points is the job of the control computer.

Since the process is essentially an analog system, why use a digital computer at all? Certainly, linking an analog computer to the analog process is far simpler. The answer to this question lies in the scope of the problem to be solved by the computer.

In small processes or small control systems, the analog computer is the better answer. But where the control system requires logical decisions, data reduction, complex calculations and modifications of the computations dependent upon process conditions, then the logical ability of the digital computer becomes important.

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The general purpose digital computer is more accurate and more flexible than analog computers but requires a larger outlay of initial capital. Therefore, the analog computer holds an advantage in the smaller installation; the general-purpose digital machine is more powerful and more economical in larger systems.

In terms of control speed, most serial general-purpose digital computers are relatively slow, with a frequency response of less than 5 to 10 cycles per second. However, since it operates on the entire numerical value and can have a completely different program for different inputs, the general-purpose digital computer is well-suited to multiplexed systems in process control where the computer is time-shared among many inputs. Present investigations into sophisticated routines for control may increase the frequency response of G.P. digital computers by a considerable factor.

Table I is a comparison of nine digital computers for on-line computing and process control applications. All these computers are of the general purpose digital type with the exception of the Genesys machine which is a hybrid computer (G.P. logic and incremental

Digital Computers *(Continued)*

logic combined). All of the machines are of the internally stored program type except the Ferranti ARGUS computer. It uses pegboards for the storage of program steps and constants. (Only limited data are available at present on the Ferranti ARGUS.)

In addition to the nine computers in Table 1, there are several other general purpose digital computers being developed for process control:

A. A computing system is being developed jointly by Leeds & Northrup Co. and Philco Corporation, called the LN-3000.

B. Minneapolis - Honeywell, through the Industrial Products Group and the Datamatic Div., is developing the D-290 Computer for process control. The first unit is scheduled for installation at Philadelphia Electric Co. in 1960.

C. RCA and Foxboro are jointly furnishing computer control systems.

About Table 1 . . .

The following discussion clarifies the points of comparison in Table I:

1. Internal Number Base — All the computers listed use the binary system as their internal number system.

2. Operating Mode — A serial computer operates on each digit of a number in sequence, processing the digits in time sequence through the same hardware components. A parallel computer operates on all digits in parallel at the same time, through parallel channels of hardware. A serial computer is slower than the equivalent parallel unit, but is generally smaller and less expensive.

3. Bulk Memory Type — Three types of bulk memory (drum memories, disc memories and core storage) are used for storage of instructions and data in the machines listed. A drum memory consists of a rotating drum with magnetic tracks upon which the data are recorded by means of reading and writing heads. In one drum revolution, all data pass beneath both a read and write head and can be either read or recorded. However, it is necessary to wait until the exact data desired is under the proper head. Up to one complete drum revolution may be required before the desired data can be obtained. The average waiting time, known as average access time, generally runs about 7 milliseconds on the listed computers, assuming one-half drum revolution as average. Access time can represent an appreciable amount of computing time. The computer program should be written to minimize access time as much as possible. Circulating registers can be provided in drum memories for faster access to limited amounts of data which are transferred from main storage to the fast access circulating registers. Drum memories are relatively inexpensive storage media at the present time, compared to core memories. Disc memories are similar to drums but use a flat mag-

TABLE 1

Manufacturer	Thompson-Ramo-Wooldridge Prod., Inc. Los Angeles, Calif.	General Elec. Co. Phoenix, Arizona	G.P.E. Controls Chicago, Illinois	Daystrom Systems La Jolla, Calif.	Panellit, Inc. Skokie, Illinois	Genesys Corp. Los Angeles, Calif. (11)	Autonetics Downey, Calif.	Bendix Corp. Los Angeles, Calif.	Ferranti Electric, Inc. Hempstead, N. Y.
Computer	RW-300	GE-312	Libratrol—500	Complete Daystrom Computer System	Panellit 609	Unit Memory Processor	RECOMP II	G-15	ARGUS
Internal Number Base	Binary	Binary	Binary	Binary	Binary	Binary	Binary	Binary	Binary
Operating Mode	Serial	Serial	Serial	Serial	Serial	Serial in G.P. mode Parallel in incremental	Serial	Serial	—
Bulk Memory Type	Drum	Drum	Drum	Magnetic Core	Magnetic Core	Magnetic Disc	Magnetic Disc	Drum	Cores (15)
Bulk Memory Capacity Minimum	7,936	2,048	4,096	1,024	4,096 (7)	10,000	4,080	2,176	256 (15)
Maximum	7,936	16,384	4,096	16,384	4,096 (7)	30,000	4,080	2,176	256 (15)
Word Length	17 bits + sign	20 bits + sign	30 bits + sign	20 bits + sign	38 bits + sign	19 bits + sign	39 bits + sign	28 bits + sign	9 bits + sign
Logic	Diode	Transistor	Diode	Diode-Transistor	Core-Transistor	Hybrid logic	Diode gating	Diode	—
Active Components Cores (in logic)	None	None	None	None	800	157 to 350	None	None	—
vacuum tubes	13	None	171	None	None	None	None	450	—
transistors	approx. 580	approx. 1,600	approx. 250 (4)	approx. 1,800	2,400	212 to 280	1,137	None	—
diodes	approx. 4,000	approx. 2,000	1,850	approx. 5,000	1,000	85 to 125	10,628	3,000	—
Instruction Type	Double address (1+1)	Single or double address (1+1)	Single address	Single address	Single address	Single address (12)	Single address	Modified (1+1) (12)	Single address
Words/Instruction	Two	—	One	One	One	One	—	One	One
No. of Different Inst. Normal	20	>60	16	46	—	20	49	56	—
Maximum	>34	very high	—	85	64	Up to 500	—	1300 W/micro-coding	—
Clock Frequency	153.6 Kc.	250 Kc.	136 Kc.	50 Kc.	167 Kc.	50 to 500 Kc.	151 Kc.	100 Kc.	—
Add Time w/o access	0.78 ms.	0.096 ms.	0.25 ms.	0.44 ms.	0.720 ms. (8)	—	0.54 ms.	0.27 ms	—
Mult. Time w/o access	2.99 ms.	0.29 to 2.02 ms.	15.0 ms.	9.24 ms.	2.80 ms. (8)	—	10.8 ms.	15.12 ms.	—
Time to Perform Calc. in Fig. 3	42 ms. (1)	30 ms (1) (17)	900 ms. (5)	75 ms.	31.7 ms.	50 ms. (13)	98 ms.	216 ms.	—
Max. Input Switching Speed	3,840 pts./sec. (1,000 pts./sec. typical)	300 pts./sec.	200 pts./sec.	284 pts./sec.	350 pts./sec. (9) 5-10 pts./sec. (10)	300 pts./sec.	Can be tied to commercially available A/D input and D/A output systems.	Can be tied to commercially available A/D input and D/A output systems.	A/D input and D/A output conversion equipment are included in system.
A/D Conversion Input Range	0-10.23 V. (2)	0-10 mv.	0-10V. std.	0-50 mv.	0-60 mv.	0-8V.			
D/A Conversion Output Range	0-15 V. or 0-5 ma.	0-20 V.	as required	as required	as required	as required			
Time to Perform Calc. in Fig. 3a	42 ms. (16)	63 ms. (3)	915 ms. (5)	79.2 ms. (6)	39.7 ms. (19)	100 ms.	105 ms. (typical)	Varies for application.	—
Weight	600 lbs.	3,000 lbs.	1,000 lbs.	2,000 lbs.	2 cabinets	200 lbs.	197 lbs. (computer only)	800 lbs.	—
Size	36" x 56" x 29"	76" x 108" x 24"	30" x 42" x 60"	4 std. racks	66" x 56" x 16"	desk size	23" x 21" x 16.5"	60" x 27" x 32"	48" x 48" x 24"
Power Requirement	500W, 120V, 60 cy.	4KW, 120V, 60 cy.	1500W, 117V, 60 cy.	less than 2KW.	1 KVA.	350 watts	500W, 115V, 60 cy. (14)	3.5 KW, 110V, 60 cy.	—
Price	$98,000 with basic input-output.	Varies depending on application.	$85,000 with A/D input & output logic.	$135,000 and up for complete sys.	$125,000 for complete control sys.	Varies depending on application.	$86,000 for computer only.	$49,500 for (18) computer only.	—

NOTES

(1) Time shown is based on use of optimum coding. Computer routines are available to automatically code programs for minimum access.
(2) Complete input system including amplifiers, filters, electronic switches, etc. can handle input ranges as low as 0-10 mv., floating input for thermocouples.
(3) Assumes settling time of 20 ms. for low level differential amplifier and a 5 ms. settling time for the scanner.
(4) This figure includes transistorized A/D and D/A conversion units.
(5) Based on accuracy of nine decimal digits in square root calculation. Faster on special order.
(6) Assumes 20 ms. stabilization time, concurrent with computation.
(7) Magnetic film back-up storage available as required.
(8) Includes random access time.
(9) Clean, high-level signals.
(10) Process signals, low-level with noise.
(11) The Genesys machine is a hybrid computer, combining the logic of the G. P. computer and the incremental computer.
(12) Microprograming available.
(13) In hybrid mode. Calculation time is 150 ms. in G. P. mode.
(14) Includes power for paper-tape reader, paper-tape punch typewriter and console.
(15) Core storage is for data only. Program steps and constants are stored on pegboards (128 constants and up to 4,096 program steps.)
(16) Input switching and conversion system is independent of the arithmetic computer which has immediate access to most recent data.
(17) Based on square root calculation accuracy of 10 bits; for 19 bit square rooting accuracy, time is 34 ms.
(18) $1,485 per month lease including maintenance.
(19) Does not include settling time.

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netic disc as the storage medium.

Core memories consist of a matrix of magnetic cores, wired so that each core can be driven to one of two states of magnetism. One core is used to store each binary bit. Reading and writing with cores are accomplished by various schemes which, for reading, sense the state of the magnetism of the core and for writing, drive the core to the desired state of magnetism. Cores are addressed by energizing wires representing the X, Y and Z coordinates of the core in the matrix. Thus, data can be read out of any core, regardless of location, in the same period of time. The access cycle time (write, read, write) is negligible compared to a drum, being only a few microseconds. This speed of access represents a tremendous saving in computer calculating time. However, core memories are expensive and require fairly large amounts of peripheral read-write equipment.

4. Word Length—The size of the word (one unit of stored digital data) in the computer and memory is not too critical in process control applications since all machines provide between 9 and 39 binary bits. This is equivalent to a precision of 1 part in 500 to approximately 1 part in 10^{11}. Most of the machines can operate with either single or double precision arithmetic, so that even greater accuracy is available.

5. Instruction Type — A digital computer performs its computations in accordance with its program. The program is a series of instructions which tell the computer what it is to do.

For the instruction ADD, for example, it is necessary to tell the computer what numbers to add and what to do with the results. Some of the required logic is built into the computer and some is dependent on the program. In a typical computer, the ADD instruction may sequence the computer through the following sub-steps: (1) obtain one number from a location in memory specified in the instruction. (2) add this number to the number already in the accumulator (The accumulator is a register in the arithmetic section of the computer). (3) put the result of the addition in the accumulator. The programmer must insure that one of the two numbers to be added is already in the accumulator prior to this instruction. He then specifies the memory location for the second number. The result of the addition is in the accumulator at the end of this program step and the programmer must then take this into account in writing the next step of the program.

SAMPLE CALCULATION (1)

(1) READ IN NEW INPUT X (exclusive of input switching time or A/D conversion)

(2) CALCULATE $AX + B = Y$

(3) COMPARE Y TO C TO INSURE THAT $Y < C$

(4) COMPARE Y TO D TO INSURE THAT $Y > D$

(5) CALCULATE $Z = \sqrt{EY}$

(6) CALCULATE $J = \frac{[ZF - G] K}{H + L}$

(7) STORE J IN BULK MEMORY (use average access time)

(8) STORE Z IN BULK MEMORY (use average access time)

SAMPLE CALCULATION (2)

Same as above except:

(1) Assume input X must be selected by computer, switched into A/D converter and read into computer from converter.

Fig. 3 (top) 3a: Calculations supplied to manufacturers to determine computer speeds.

Various types of instructions are used. The simplest type is the single address instruction where the programmer specifies the function to be performed and a single memory address. Each function (add, divide, shift left, compare, etc.) is assigned a numerical designation which the control section of the computer interprets prior to sequencing the computer through the required steps. A counter in the control unit keeps track of the instructions and supplies the computer with the address of the next instruction. The instructions are normally taken in numerical sequence, based on the memory address in which the instruction is stored.

In a double address machine, the instruction generally specifies the operation, the location in memory of the data to be operated upon and the location of the next instruction. This particular double address instruction format is known as (1+1) and permits locating the next instruction on a drum or disc memory so that access or waiting time between instructions is reduced to a minimum (optimum coding or minimum access program).

6. Number of Different Instructions—The normal number of instructions shown is the number which is available as standard in the machine. The maximum number represents the largest number of instructions which the logic of the machine can handle in terms of available digits in the instruction code, etc. In some machines, computer operations on a level of detail lower than a normal instruction are available to the programmer to permit so-called micro-programming or micro-coding in which the programmer constructs his own instructions from detailed steps.

7. Clock Frequency, Add Time, Multiply Time — These classifications are all related to the arithmetic speed of the computer, as is the memory access time. However, no one of these factors is a suitable index for determining machine speed. The structure and flexibility of the instruction code, the memory access time, the arithmetic speed, and the input-output capabilities all play a part in determining the speed of a computer in a given problem.

8. Time to Perform Calculation in Fig. 3—The calculation shown in Fig. 3 was programmed by the manufacturers of eight of the computers in the table. The results are listed to indicate relative computational speeds of the machines. Note that no input switching, analog-to-digital conversion or readout times are included in this calculation. The sample problem involves memory access, add times, multiply times, etc. It represents typical calculations encountered in scaling a process input, comparing it to high and low limits for determining abnormal conditions, calculating a flow from a differential pressure reading and calculating a process control guide involving several variables.

Where fast access memories such as circulating registers are available in a drum or disc computer, the calculation time is based on use of the fast access memory. Drum computers which permit optimum coding list the calculation time with an optimum coded program.

9. Input Switching Speed and A/D Conversion Ranges—The maximum input switching speeds shown in Table I are not necessarily attainable with typical low level process inputs. An individual amplifier on each low level input (or an amplifier shared among a few inputs) would be required along with a filter for each input, in order to attain the switching speeds shown as maximum. In most process applications at present, such switching speeds are not required and slower speeds result in less costly input systems. In all cases, amplifiers can be used on low level inputs to make them compatible with A/D converter input ranges.

In the case of the RECOMP-II and G-15, these computers are not normally furnished with integral A/D and D/A input-output converters but are generally tied to commercially available A/D and D/A systems.

10. Time to Perform Calculation in Fig. 3A—The calculation previously shown in Fig. 3 is used, with the added requirement that the computer select an input, convert it from analog form to digital form and read it into the computer prior to computation.

Because of variations in the methods of handling input signals, the calculation times for Fig. 3A should be used only as a general guide. Exact input speeds will generally depend on the type of input signal, the input equipment used in the particular installation and the requirements of the application.

11. Price — Since all computer control systems are tailored to the application, the prices shown are only general figures. In some cases, prices are for basic systems, with a minimum of input-output equipment. In other cases, typical complete process control computer systems are included in the price. In the case of the RECOMP-II and the G-15, the prices shown cover only the computer. In considering pricing for a computer control system, one should also bear in mind the cost of transducers, measuring devices and control elements which might not otherwise be required in the installation. Such additional costs, plus engineering and systems analysis costs, can easily equal the cost of the computer system itself.

General Computer Descriptions

Autonetics RECOMP-II—This is a general purpose digital computer, all transistorized, single address, disc memory machine. It has floating point arithmetic and automatic decimal conversion. It is utilized ordinarily for engineering and scientific calculations. However, with appropriate input-output units, it can be used for process control installations. It has 4,080 word storage capacity, each word containing 39 bits plus sign.

Bendix G-15—A general purpose digital computer with drum memory, modified double address for optimum coding and micro-coding which permits programmer to construct his own commands. A 16-word fast access memory is provided on the drum. The G-15 is a commercial computer, widely used for engineering, business, and scientific data processing. It has also been used in a variety of on-line applications including wind tunnels, navigation, tracking, and processing plants. This computer does not include A/D and D/A input-output units, but most such commercial units may be used under control of the computer for complete on-line computing systems. Beckman Systems is now using a G-15 with their equipment for a computer control package.

Daystrom Computer—This computer is the heart of the Daystrom Operational Information System. It is a solid state digital system using magnetic core memory with single address instructions. Although a relatively slow clock speed (50 kc) is used, the random access core memory permits relatively fast computation speeds without need for optimum programming. The Daystrom A/D input system normally integrates each sampled input for 100 ms. to obtain a high noise rejection rate without use of filters. Where it is practical to filter each input or where no noise is present, input sampling can be performed at 284 points per second. It was specifically designed for process monitoring and control.

Ferranti Argus — The Ferranti Argus is a transistorized process control computer manufactured in England and marketed in the U. S. by Ferranti Electric in Hempstead, N. Y. It is unique among the available computers because it does not have an internal stored program. At 256 word core memory is provided for storage, but program steps and constants are manually stored in pegboards, contained in trays in the computer. In this manner, 512 program steps and 128 constants can be stored in the computer. A unit is available for expansion to 4096 steps. Input A/D and output D/A conversion equipment is an integral part of the Argus system. The computer is designed for closed-loop control.

General Electric GE-312—It is an all solid-state digital computer, using magnetic drum storage for both data and program, specifically designed for process monitoring and control. Computer is available in an upright air conditioned cabinet and uses removable printed circuit cards. Instructions can be either single address or double address (1 + 1) for optimum coding. Computer itself can be used to code program for minimum access. In addition, routines are available for simulating the 312 on an IBM 704 to assist in programming. An optional feature is circulating registers on the drum to provide 4 to 16 words of fast access memory. Includes A/D and D/A conversion units and input-output switching. The application determines scanning and input-output requirements.

GPE Controls Libratral - 500—Manufactured by Librascope and marketed by GPE Controls (both subsidiaries of GPE). This computer is an adaptation of LGP-30, a commercial digital computer widely used for many engineering, scientific, business, and accounting applications. Over 250 LPG-30 computers are now in use. Libratral-500 uses drum memory with 3 single-word fast access circulating registers for instructions. Specifically designed for process monitoring and control. Basic unit includes scanner, voltage-to-digital converter, and output logic. Computer operation is serial, fixed binary point, with internally stored program using single address instructions. A transistorized model will be released shortly.

Genesys Unit Memory Processor—This is a hybrid unit, combining both general purpose digital and incremental logic. It operates as either or both. It is housed in a desk type enclosure. All functions of the computer are achieved with a magnetic disc memory (10,000 to 30,000 words capacity) and a small magnetic core-transistor sequential network. The general purpose logic is used for decision making, arithmetic, etc. and the incremental logic for integration, etc. This combination uses a minimum of active components, relying heavily on the reliable passive storage elements of the magnetic disc memory. A/D conversion is by an all-electronic feedback encoder. The system is built according to individual applications. Process operation is optimized through adaptive control methods.

Panellit 609—This all purpose digital computer uses magnetic cores for both storage and logical operations in the computer. Transistor drivers operate the core logic circuits. It is housed in two upright cabinets. The core memory permits random access to any memory location with relatively high computing speed, and without need for optimum programming. The input-output system contains buffering and fast arithmetic units to permit processing inputs and outputs with a minimum of interference with main computer arithmetic units. The 609 uses one channel for computation and a second channel for on-line data logging. Attachments include a magnetic film memory for 250,000 words on a single reel. A/D and D/A conversion are available as required as a part of the system.

Thompson-Ramo-Wooldridge RW-300—A digital computer using diodes and transistors for logic and magnetic drum storage for both data and program. Available in desk size or upright model. It was specifically designed for on-line process control. Removable printed circuit cards used for internal circuitry and component mounting. Double address instructions (1+1) are used for optimum coding. Computer itself can be used to automatically code program for minimum access. A 16-word circulating register on the drum provides fast access during computation. The A/D conversion and input system operates independently of the arithmetic computer, so that inputs are sampled and converted to digital form and entered directly into the memory without interfering with computation. Thus, most recent input data is used in computation without waiting for selection of an input and receiving of data.

Westinghouse OPCON.—A fully transistorized logic control unit designed to automatically experiment with a process and optimize performance. It contains no numerical computation ability, depending on a small analog computer to calculate optimizing equations. Process equations are not necessary since the control unit uses the process itself as a model. Analog-to-digital conversion range is ±0.5 volts. Digital-to-analog conversion range is 0-5 ma. into 2000 ohm resistance (max.). Weight is 500 lbs.; size, 60 × 22 × 30 in.; power requirements are 260 w, 120 v, 60 cycles. Since OPCON is not a G. P. digital computer, but a special purpose logic device, it is not included in Fig. 3 comparison.

Installations

In the area of computer control of industrial processes such as found in the power, petroleum and chemical industries, there are quite a few general purpose digital computers either presently installed or on order. Among the present installations are those at:

1. Electricite de France, Chinon, France (T-R-W, RW-300).
2. Louisiana Power & Light Co., Sterlington, La. (Daystrom Computer).
3. Standard Oil (N. J.), Baton Rouge, La. (Librascope LGP-30 with Leeds & Northrup input system).
4. Texas Co., Port Arthur, Tex. (T-R-W, RW-300).
5. Universal Products Co., Des Plaines, Ill. (Daystrom Computer).
6. Dow Chemical Co., Midland, Mich. (Westinghouse OPCON Optimizing Logic System).

General-purpose digital computers are on order by the following companies for process control applications:

1. B. F. Goodrich Chemical Co., Calvert City, Md. (T-R-W, RW-300).
2. Carolina Power & Light Co., Darlington Station, (Daystrom Computer).
3. Gulf States Utilities, Louisiana (two units; one Panellit 609, one Daystrom Computer).
4. DuPont Co. (several Panellit 609 Computers).
5. Kansas Gas & Electric Co. (Daystrom Computer).
6. Louisiana Power & Light Co., Little Gypsy Station (Daystrom Computer).
7. Monsanto Chemica Co., St. Louis, Mo. (T-R-W, RW-300).
8. Philadelphia Electric Co., Phila., Pa. (Honeywell D-290).
9. Public Service Co. of Colorado (Libratrol 500).
10. Riverside Cement Co., Oro Grande, Calif. (T-R-W, RW-300).
11. Sun Oil Co., Marcus Hook, Pa. (Westinghouse OPCON Optimizing Logic System; also a Litton Model 80 Digital Differential Analyzer and a Genesys Machine).
12. Jones & Laughlin (G. E. 312).
13. Southern Calif. Edison (G.E. 312, two units).
14. Public Service of New Jersey (L N 3000, Philco-L & N).
15. Phillips Chemical Co. (Recomp II).
16. Standard Oil of Calif. (Recomp II).