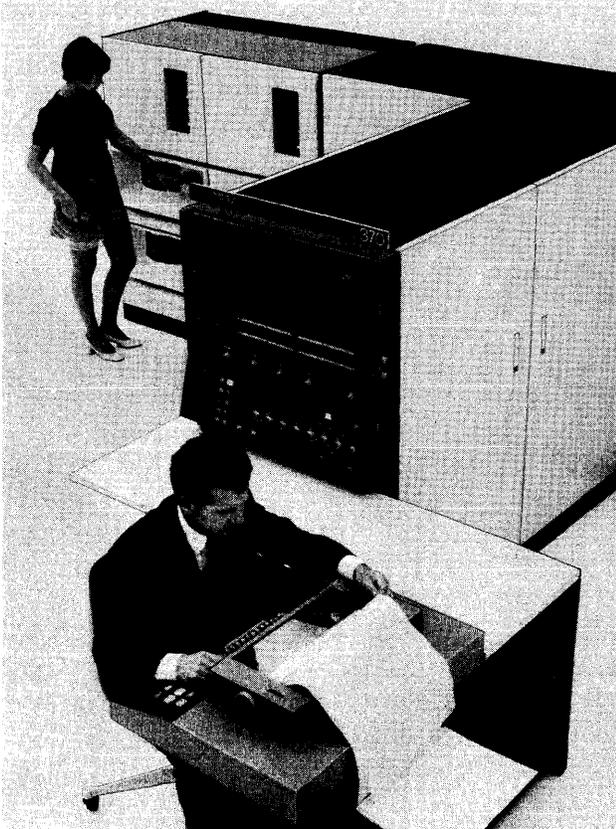


IBM System/370 Model 145



This view of the Model 145 Processor and console also shows the new, low-cost 2319 Disk Storage Facility.

MANAGEMENT SUMMARY

The third member of IBM's new System/370 product line is, surprisingly, one of the most technologically exciting computers ever to reach the market. The Model 145, introduced on September 23, 1970, is the first commercial computer from a major manufacturer to use an all-semiconductor main memory. What's more, the Model 145 extends the concept of microprogrammed control to a new high in flexibility, while its integrated disk control logic permits the use of 2314-style disk pack storage at an unprecedentedly low price.

As expected, the Model 145 is designed to serve as an effective upgrade machine for current users of the System/360 Models 30 and 40. It offers these users greatly increased internal speed, memory capacity, and input/output capabilities with little or no reprogramming.

Initial customer deliveries of the Model 145 are scheduled for August 1971. It will be manufactured at IBM's >

The Model 145 offers dramatic performance improvements over the medium-scale System/360 Model 40 at a modest increase in price. It features an all-semiconductor main memory, flexible microprogrammed control, low-cost disk storage, and System/360 compatibility.

CHARACTERISTICS

MANUFACTURER: International Business Machines Corporation, 112 East Post Road, White Plains, New York 10601.

MODELS: System/370 Model 145.

DATA FORMATS

BASIC UNIT: 8-bit byte. Each byte can represent 1 alphanumeric character, 2 BCD digits, or 8 binary bits. Two consecutive bytes form a "halfword" of 16 bits, while 4 consecutive bytes form a 32-bit "word."

FIXED-POINT OPERANDS: Can range from 1 to 16 bytes (1 to 31 digits plus sign) in decimal mode; 1 halfword (16 bits) or 1 word (32 bits) in binary mode.

FLOATING-POINT OPERANDS: 1 word, consisting of 24-bit fraction and 7-bit hexadecimal exponent, in "short" format; 2 words, consisting of 56-bit fraction and 7-bit hexadecimal exponent, in "long" format; or 4 words in "extended precision" format.

INSTRUCTIONS: 2, 4, or 6 bytes in length, specifying 0, 1, or 2 memory addresses, respectively.

INTERNAL CODE: EBCDIC (Extended Binary-Coded Decimal Interchange Code).

MAIN STORAGE

TYPE: Monolithic integrated circuits (bipolar LSI).

CAPACITY: Four models of the 3145 Processing Unit are available:

Model FED—114,688 bytes
Model GE—163,840 bytes
Model GFD—212,992 bytes
Model H—262,144 bytes

The capacity of a Model H system can be increased to 393,316 or 524,288 bytes by adding a 3345 or 3346 Main Storage Frame, respectively, plus a 3046 Power Unit.

If necessary, the Reloadable Control Storage can be expanded from its standard 32,768 bytes to a maximum of 65,536 bytes, in 2048-byte increments, at the expense of main storage capacity (e.g., if the full 65,536 bytes of RCS is required, the main storage capacity will be reduced by 32,768 bytes).

CYCLE TIME: 540 nanoseconds for reading and 607.5 nanoseconds for writing. The central processor fetches instructions a doubleword (8 bytes) at a time, while data accesses (both fetches and stores) are made on a word (4-byte) basis. Thus, 8 instruction bytes or 4 data bytes are fetched during a single 540-nanosecond read cycle, >

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▷ facilities in Endicott, New York, where it was developed, and at the IBM World Trade Corporation plant in Mainz, Germany. The first Model 145 system is scheduled to go into operation early in 1971 at Endicott, and by July twelve systems will be available for customer testing throughout the country.

Monthly rentals for typical Model 145 configurations will range from about \$14,700 to \$45,000, with purchase prices ranging from about \$690,000 to \$2,150,000. Thus, the Model 145 is priced between System/360 Models 40 and 50, while its performance substantially exceeds that of the Model 50.

MONOLITHIC STORAGE

By far the most newsworthy feature of the Model 145 is its "monolithic main memory," which makes use of bipolar LSI (large-scale integration) technology in place of conventional magnetic cores. A Model 145 system can have from 114K to 524K bytes of main storage plus 32K bytes of Reloadable Control Storage (RCS), all consisting of LSI chips. Cycle times are 540 nanoseconds per 4-byte or 8-byte fetch and 607.5 nanoseconds per 4-byte store.

A Model 145 storage array chip is about one-eighth of an inch square and contains 1434 microscopic circuit elements forming 174 interconnected circuits. Each chip holds 128 storage bits and the associated decoding, addressing, and sensing circuitry. Two storage array chips are mounted on a half-inch-square substrate, and two of the substrates are packaged into a 512-bit storage array module. Twenty-four of the modules are then mounted on a storage array card, which is about 3.50 by 4.75 inches in size and holds 12,288 storage bits. Finally, the cards are placed in Basic Storage Modules. Each module is about 13.25 inches long, 5.5 inches deep, and 9 inches wide and contains 48K bytes of storage plus its associated circuitry.

The Model 145 memory circuits were developed by the IBM Components Division and are in production at the division's plant in Burlington, Vermont.

IBM claims three important advantages for its monolithic storage:

- Higher storage speeds can be obtained because of (1) the shorter physical distances between the memory components, and (2) the nondestructive readout capability of the monolithic storage, which eliminates the need for a regeneration cycle after each read operation.
- Storage serviceability is improved because each 12,288-bit storage array card is a complete functional component that can be replaced within a few minutes.

▶ and 4 data bytes are stored during a 607.5-nanosecond write cycle.

CHECKING: All data paths between the central processor and main storage are parity-checked by byte. When data is stored, an error-correcting code is substituted for the parity bits. (An 8-bit modified Hamming code is appended to each 8-byte "doubleword" of data.) When the data is retrieved, single-bit errors are detected and corrected automatically, and most multiple-bit errors are detected and signalled so that appropriate program action can be taken.

STORAGE PROTECTION: The Store and Fetch Protection features, which guard against inadvertent overwriting and/or unauthorized reading of data in specified 2048-byte blocks of storage, are standard in Model 145.

CENTRAL PROCESSORS

INDEX REGISTERS: Sixteen 32-bit general registers, used for indexing, base addressing, and as accumulators, plus four 64-bit floating-point registers.

INDIRECT ADDRESSING: None.

INSTRUCTION REPERTOIRE: Consists of all of the instructions that comprise the System/360 "commercial instruction set" (i.e., the standard System/360 set plus the decimal arithmetic instructions), together with 13 new "enhancement" instructions. Floating-point arithmetic is an optional feature.

The basic Model 145 instruction set includes complete arithmetic facilities for processing variable-length decimal and fixed-point binary operands, as well as instructions which handle loading, storing, comparing, branching, shifting, editing, radix conversion, code translation, logical operations, packing, and unpacking. In addition, a group of "privileged instructions," usable only by the operating system, handle input/output and various hardware control functions.

The 13 new instructions are:

- Compare Logical Characters Under Mask (CLM)
- Compare Logical Long (CLCL)
- Halt Device*
- Insert Characters under Mask (ICM)
- Load Control (LCTL)*
- Move Long (MVCL)
- Set Clock (SCK)*
- Shift and Round Decimal (SRP)
- Store Channel ID (STIDC)*
- Store Characters under Mask (STCM)
- Store Clock (STCK)
- Store CPU ID (STIDP)*
- Store Control (STCTL)*

*Privileged instruction.

These new instructions facilitate programming and reduce execution times for record blocking and unblocking, long move and compare operations, decimal arithmetic, and various hardware control functions.

INSTRUCTION TIMES: Average execution times, in microseconds, for some representative instructions are as follows:

| | |
|-----------------------------------|------|
| Add (32-bit binary): | 2.14 |
| Multiply (32-bit binary): | 20.1 |
| Divide (32-bit binary): | 34.8 |
| Load (32-bit binary): | 1.69 |
| Store (32-bit binary): | 1.50 |
| Add (5-digit packed decimal): | 11.9 |
| Compare (5-digit packed decimal): | 10.6 |

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- ▷ ● Storage space requirements are reduced to about half the space required for equivalent amounts of core storage in the System/360 Model 40.

On the negative side, the volatility and newness of the monolithic storage may cause some concern among prospective users.

Monolithic storage requires power to maintain either a zero or one state. Thus, the stored data is lost whenever the power is turned off (whereas core storage maintains its magnetized state when the power is removed). This storage volatility is not likely to create serious problems for Model 145 users—but it should spur them to review their operating and checkpoint/restart procedures to make sure that processing can be resumed after unexpected power failures without undue loss of time.

The newness of the monolithic storage technology naturally makes it less of a “sure thing” than core memory, which has been refined to a high level of reliability through more than 15 years of widespread use. On the other hand, the very fact that IBM has taken on the role of technological leader by announcing this long-awaited advance indicates that the company is quite certain that its monolithic storage is now ready to pass the critical tests of economy and high reliability in mass production. IBM has already had extensive experience in producing fairly large semiconductor memories for use as buffer stores in its large-scale computers, beginning with the 80-nanosecond, 16K to 32K buffer memory for the System/360 Model 85, introduced in January 1968. Though the component density of the Model 145 main storage is considerably higher than in the previously announced IBM buffer memories, it represents only a reasonable evolutionary step forward in integrated-circuit technology rather than a revolutionary one.

RELOADABLE CONTROL STORAGE

The microprograms which control all the internal operations of the Model 145 Processor reside in an extension of the monolithic main memory called Reloadable Control Storage (RCS). The microprograms are loaded into RCS by means of a small read-only disk unit called the Console File. Located beneath the operator's console table, the Console File reads single-disk cartridges at the rate of 33,300 bits per second. Each cartridge holds up to 65,280 bytes, and the basic 32K bytes of RCS can be fully loaded in about 45 seconds. IBM will supply prewritten disk cartridges containing all the control microprograms required for a specific Model 145 installation.

The basic 32K bytes of RCS can be extended to a maximum of 65K bytes at the expense of a corresponding reduction in main storage capacity. This can be done at any time, in 2048-byte increments, by simply changing

| | |
|----------------------------------|-------|
| ▶ Add (short floating-point): | 5.85* |
| Multiply (short floating-point): | 16.8* |
| Divide (short floating-point): | 28.7* |
| Add (long floating-point): | 7.52* |
| Multiply (long floating-point): | 45.7* |
| Divide (long floating-point): | 89.6* |

*With optional Floating-Point Instructions.

OPTIONAL FEATURES: The Floating-Point Instructions Feature, a no-cost option, provides instructions to perform floating-point arithmetic operations in three different modes: short (1-word), long (2-word), and extended precision (4-word). The Floating-Point Instructions require 2240 bytes of Reloadable Control Storage.

The Direct Control Feature provides six external interrupt lines which are independent of the normal data channels, plus two instructions which provide for single-byte data transfers between an external device and main storage.

The Channel-to-Channel Adapter permits direct communication between two System/370 processors via their standard I/O channels. The adapter occupies one control unit position on each of the two channels it interconnects.

Other processor options are described in the sections on Compatibility Features and Input/Output Control, which follow.

COMPATIBILITY FEATURES: The Model 145 Processing Unit can be equipped with compatibility features and associated emulator routines that enable them to execute programs written for the earlier IBM 1400 Series and 7010 computers. These “integrated emulators” permit emulated programs to be processed along with native-mode System/370 programs in a multiprogramming mix under either DOS or OS control. In general, their use requires a Model 145 system with I/O devices equivalent to those of the system to be emulated (plus the devices required by the operating system), and with more core storage capacity and processing power. Only the more common peripheral devices (card readers, punches, printers, magnetic tape units, disk drives, and consoles) can be emulated, and certain special and custom features are not supported.

The 1401/1440/1460 Compatibility Feature (# 4457) is a no-charge, field-installable option which, in combination with special software, enables a Model 145 to execute IBM 1401, 1440, or 1460 instructions. Internal speed in the emulation mode is approximately 4.9 times that of the 1401—and about 10% faster than 1401 emulation under CS40 on an IBM 360/40. The compatibility feature occupies 4800 bytes of Reloadable Control Storage, and the associated emulator routines require a minimum of 17K bytes of main storage under DOS and 20K bytes under OS.

The 1401/1440/1460, 1410/7010 Compatibility Feature (# 4458) is a no-charge, field-installable option that provides the capability to emulate IBM 1410 and 7010 programs in addition to all the facilities of the 1401/1440/1460 Compatibility Feature described above. Internal speed in the emulation mode is about twice that of the 1410 and two-thirds that of the 7010. The compatibility feature occupies 6000 bytes of Reloadable Control Storage, and the associated emulator routines require a minimum of 28K bytes of main storage under DOS and 22.5K bytes under OS.

OS/DOS Compatibility is a standard feature of the Model 145 Processing Unit. Used in combination with the DOS Emulator Program, it facilitates DOS-to-OS conversions by making it possible to run a DOS Supervisor and DOS programs under control of the Operating System/360

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▷ the value in an address boundary register. In fact, most Model 145 installations will probably find it necessary to extend the RCS capacity well beyond the basic 32K bytes. Here, for example, are the RCS requirements for a fairly typical configuration:

| | |
|---|--------------|
| Basic System Microcode | 24,600 bytes |
| Floating-Point Instructions | 2,240 bytes |
| Unit control words for 64 multiplexer subchannels | 1,024 bytes |
| Integrated File Adapter (for 2319) | 8,800 bytes |
| 3210 Console Printer-Keyboard, Model 1 | 3,040 bytes |
| 1401/1440/1460 Compatibility Feature | 4,800 bytes |
| Total: 44,504 bytes | |

Thus, a 12K extension of RCS (from 32,768 to 45,056 bytes) would be necessary, reducing the effective main storage capacity to 12K bytes below its rated size. Use of additional multiplexer subchannels, the Block Multiplexer Channel Feature, and other options can further increase the RCS requirements.

Reloadable Control Storage, as implemented in the Model 145, has several significant advantages:

- Different versions of the system microcode, supporting different features and options, can be readily interchanged. In fact, at some appropriate future date, the Model 145 could conceivably assume a radically different instruction repertoire and functional characteristics. Many of the functions now performed by software could be "built into the hardware" through the development of suitable control microprograms (the much-discussed "firmware" concept).
- Many of the capabilities which formerly required specialized hardware (floating-point arithmetic, emulators, block multiplexing, etc.) can now be implemented through microprogramming, at no extra cost to the user except for the RCS required to hold the microcode.
- Serviceability is enhanced because the basic system microcode can quickly be replaced by suitable diagnostic microprograms whenever maintenance is required. The use of a single level of storage for both microcode and users' programs also helps to simplify servicing.

It can be argued that higher system throughput could be achieved if two separate storage units were used to hold the control microcode and the users' programs—but IBM maintains that the use of a single writable storage unit is a key factor in achieving its price/performance goal for the Model 145.

▶ (MFT or MVT). The DOS Emulator runs as a problem program under OS control. It can be multiprogrammed with other OS jobs, and it in turn can use the multiprogramming options of DOS. The DOS Emulator Program, the DOS Supervisor, and up to three DOS processing-program partitions are all executed in a single MFT partition or MVT region of at least 38K bytes; the DOS Emulator Program alone requires 22K to 26K bytes of main storage. IBM states that the internal speed of executing DOS job streams in OS/DOS Compatibility mode on a Model 145 varies from approximately 1.0 to 4.3 times faster than execution of the same job streams under DOS control on a 360/40.

CONSOLE INPUT/OUTPUT: Model 145 offers a choice of two Console Printer-Keyboards. The 3215 uses a matrix printing unit that operates at 85 characters per second. The 3210 is a newly designed unit that prints at 15 characters per second. An additional 3210 Console Printer-Keyboard can be installed in a remote area (such as the installation's tape library or scheduling room). The console I/O units require from 3040 to 4180 bytes of Reloadable Control Storage.

INPUT/OUTPUT CONTROL

I/O CHANNELS: One Byte Multiplexer Channel and one Selector Channel are standard in the Model 145 Processing Unit. Up to three additional Selector Channels can be added, and any or all of the Selector Channels can be equipped to operate as Block Multiplexer Channels. (If the Integrated File Adapter is installed, only one additional Selector Channel can be used.)

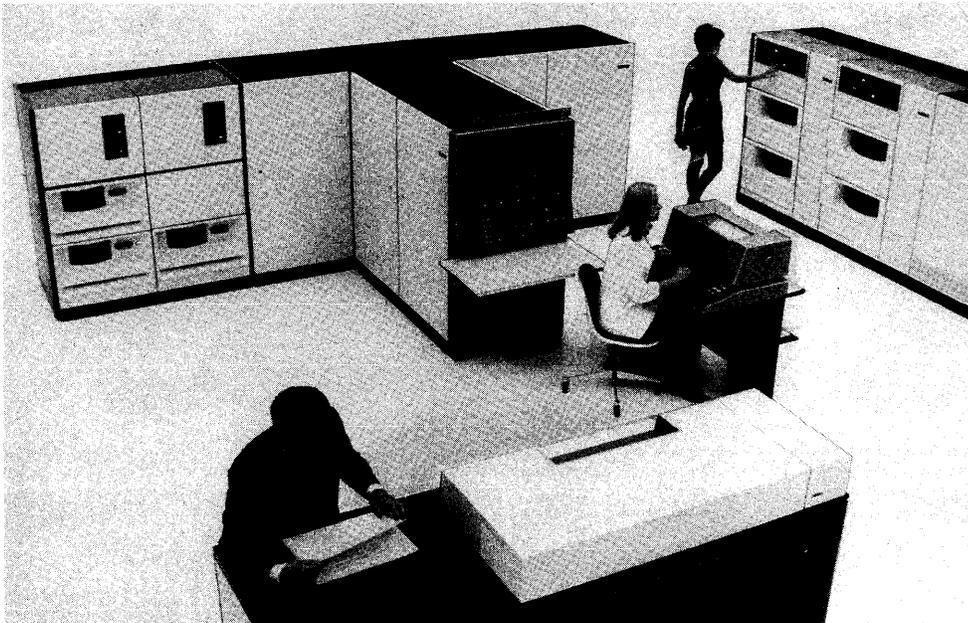
The Byte Multiplexer Channel is functionally compatible with the System/360 Multiplexer Channel. It has a single data path that can be shared by a number of simultaneously operating low-to-medium-speed I/O devices (in "multiplex mode") or monopolized by a single faster device (in "burst mode"). In either case, one byte of data at a time is transferred between main storage and an I/O device. Eight control unit positions and 16 subchannels are standard. No-charge options permit the number of subchannels to be expanded to 32, 64, 128, or 256. The unit control words for each subchannel require 16 bytes of Reloadable Control Storage.

Each Selector Channel permits a high-speed data transfer operation by one peripheral device at a time. The channel remains busy throughout the time a channel program is in operation, even when no data is being transferred. Data is transferred to and from main storage on a one-byte-at-a-time basis unless the optional Word Buffer feature is installed; the buffer provides four-byte data transfers on all Selector Channels and permits higher data rates. The maximum Selector Channel data rate is 1.85 million bytes/second with the Word Buffer and 820,000 bytes/second without it.

The Block Multiplexer Channel Feature, a no-charge option, permits any or all of the installed Selector Channels to operate as Block Multiplexer Channels. Each Block Multiplexer provides a single data path that can be shared by a number of high-speed peripheral devices which transfer data alternately in burst-mode fashion. While the channel is interleaving blocks of data to and from various devices, it can also control non-data-transfer functions on other devices. The basic microcode for the Block Multiplexer Channel Feature occupies 2100 bytes of Reloadable Control Storage, and each group of 8 unit control words requires 64 additional bytes.

CONFIGURATION RULES: In general, each Model 145 channel can accommodate up to 8 peripheral control units and address as many as 256 devices. Most System/370 peripheral devices can be connected to any of the three types of channels. High-speed tape, disk, and drum ▶

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The 3-drive 2319 Disk Storage Facility (at left) attaches directly to the Model 145 Processor. A 4-drive 3330 Disk Storage Facility is at right, and a 2000-lpm 3211 Printer is in the foreground.

▷ PROCESSOR CHARACTERISTICS

As an upgrade machine for System/360 Model 30 and 40 users, the Model 145 offers the following major advantages:

- Internal processing speeds 3 to 5 times as fast as the Model 40 and 5 to 11 times as fast as the Model 30.
- Main storage capacities of up to 524,288 bytes—twice the maximum capacity of the Model 40 and eight times that of the Model 30.
- Greatly increased I/O capabilities—a standard Byte Multiplexer Channel and up to four Selector Channels, with a maximum system I/O data rate of 5.3 million bytes per second.
- Numerous improvements in the processor facilities, as described below.

The model 145 Processor shares many significant characteristics with the System/360 processors (Model 25 and above) and with the previously announced System/370 Models 155 and 165. Reflecting its “all-purpose” design philosophy, the Model 145 has a large, complex instruction repertoire. Like Models 155 and 165, it adds 13 new instructions to the System/360 instruction set. The new instructions will help reduce execution time and program storage requirements by enhancing decimal arithmetic performance, eliminating the need for multiple “move” instructions, and facilitating the blocking and unblocking of records.

▶ units require either a Block Multiplexer or Selector Channel, and card readers, printers, and other low-speed devices will normally be connected to the Byte Multiplexer Channel.

SIMULTANEOUS OPERATIONS: Concurrently with computing, a Model 145 can control a maximum of one high-speed I/O data transfer operation per Selector or Block Multiplexer Channel and one low-speed I/O operation on each subchannel of the Byte Multiplexer Channel. Alternatively, the Byte Multiplexer Channel can operate in burst mode and handle a single higher-speed I/O operation. The maximum total I/O data rate for all channels (with the Word Buffer installed) is 5.3 million bytes/second.

I/O INTERFERENCE: All Model 145 I/O channels are “integrated,” which means they share the use of the control storage and arithmetic/logic unit with the Processing Unit. Thus, the channels interfere with one another and with the Processing Unit whenever they initiate or complete an I/O operation, as well as whenever they require access to control storage or main storage.

Selector Channels require one main storage cycle for each byte of data transferred to or from storage, or one cycle per four-byte transfer if the Word Buffer is installed. Other Selector Channel operations (Start I/O, Test I/O, etc.) require from 2.2 to 37.9 microseconds each.

For the Byte Multiplexer Channel, the maximum service-request times are 14.3 microseconds per byte in multiplex mode and 5.3 microseconds per byte in burst mode. Other Byte Multiplexer Channel operations require from 2.0 to 31.0 microseconds each.

MASS STORAGE

2319 DISK STORAGE FACILITY: Provides fairly rapid access to moderately large quantities of data stored in interchangeable 2316 Disk Packs. Consists of three IBM 2314-style disk drives and an integrated control unit. Each drive stores up to 29.17 million bytes of data, for a total storage capacity of over 87 million bytes per 2319 ▶

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▷ The Byte-Oriented Operand Feature, standard in the Model 145, allows users to ignore, in part, the restriction that non-decimal operands must be stored in core locations whose addresses are integral multiples of the operand length. It is important to note, however, that significant performance degradation is likely to occur if programmers are allowed to take advantage of this feature and ignore the usual boundary constraints on operand placement.

Two standard hardware features help to make the Model 145 a more "time-conscious" system. An improved interval timer with a resolution of 3.3 milliseconds facilitates the timing of short-duration tasks, while a new time-of-day clock with a 1-microsecond resolution provides a consistent measure of elapsed time for job accounting, communications, and real-time functions.

The Model 145 does not utilize the buffer memory concept which is the principal architectural feature of the larger Models 155 and 165. Cost/performance considerations apparently dictated the use of a single level of high-speed monolithic main storage instead of the more complex two-level memories employed in the larger System/370 processors.

For its logic circuits (as distinguished from its memory circuits), the Model 145 employs IBM's Monolithic Systems Technology (MST). Each MST logic chip is slightly over one-sixteenth of an inch square and contains more than 100 components forming up to 8 interconnected circuits. Thus, the circuit density is considerably lower than in the storage array chips, though the concepts employed are quite similar.

IBM is placing a strong emphasis on increased reliability and serviceability in the Model 145, as in the larger System/370 models. An automatic retry capability for central processor operations and error-correcting circuits for main and control storage will often make it possible to continue processing despite hardware faults. Expanded machine-check interrupt facilities will aid in error recording and recovery. And a variety of new software facilities, together with centrally located maintenance data banks, will facilitate equipment servicing.

PERIPHERAL EQUIPMENT

The Model 145 can use most of the same peripheral devices as the System/360. The System/360 peripherals that will *not* be supported for use in a Model 145 configuration (mainly because of obsolescence or very limited user interest) are as follows:

1052 Printer-Keyboard
1231 Optical Mark Page Reader
1285 Optical Reader

▶ facility. Up to five additional disk drives can be connected, using any combination of the single-drive 2312 Disk Storage Module, the two-drive 2318, and the four-drive 2313. Total on-line storage capacity with the maximum complement of eight drives is 233 million bytes.

Each 11-disk 2316 Disk Pack has 200 data tracks on each of the 20 data recording surfaces. Each track can hold up to 7,294 bytes of data in variable-length records. Each disk has a comb-type access mechanism that can read or write up to 145,880 bytes (20 tracks) in each of its 200 positions. Average head movement time is 60 milliseconds, average rotational delay is 12.5 milliseconds, and data transfer rate is 312,000 bytes per second.

The 2319 connects to a Model 145 via the Integrated File Adapter (IFA) rather than a standard I/O channel. The IFA requires 8800 bytes of Reloadable Control Storage and precludes the use of two of the three optional Selector Channels; it is programmed as if a standard Selector Channel and disk control unit were present. The Record Overflow and File Scan features are standard on the IFA, but the Word Buffer, Block Multiplexing Feature, Channel-to-Channel Adapter, Two-Channel Switch, and Auxiliary Storage Control cannot be used with the IFA.

2305 FIXED-HEAD STORAGE, MODEL 2: Provides fast access to medium-sized quantities of information. Each drive unit contains 6 nonremovable disks with 12 recording surfaces and can store up to 11.2 million bytes of data. Each of the 768 addressable tracks can hold up to 14,660 bytes. A fixed read/write head serves each track. Average access time is 5.0 milliseconds, and data transfer rate is 1.5 million bytes per second. A 2835 Model 2 Storage Control connects up to two 2305 Model 2 drive units to a Model 145 Selector Channel operating in the Block Multiplexer Channel mode; the Word Buffer feature is also required. The optional Two-Channel Switch permits the 2835 to be connected to two channels.

Two standard features help the 2305 take advantage of the capabilities of the System/370 Block Multiplexer Channel mode. Rotational Position Sensing lets the drive unit disconnect from the channel during most of the rotational delay period, leaving the channel free for other operations. Multiple Requesting permits queuing of multiple requests for access to data stored on a 2305 drive; after each request is logged, the channel disconnects until the desired record position is reached and the channel is free.

3330 DISK STORAGE: Provides fairly rapid access to extremely large quantities of data stored in interchangeable 3336 Disk Packs. Each 3330 Disk Storage Module contains two independent disk drives, each mounted in a powered drawer for operating convenience. Up to four 3330 modules (eight drives) can be connected to a 3830 Storage Control, which occupies one control unit position on a Model 145 Selector Channel operating in the Block Multiplexer Channel Mode. Rotational Position Sensing and Multiple Requesting, as described under the 2305 above, are standard features. A Command Retry facility enables the 3330 subsystem to recover from many errors without the use of time-consuming error recovery programs. Error correction coding circuitry in the control unit permits detection and correction of bursts of errors up to 11 bits in length on a single track.

Each 3336 Disk Pack contains 12 disks. Nineteen disk surfaces are used for data recording, and a 20th surface holds prerecorded data that controls seeking, position sensing, and clocking. Each disk pack holds up to 100,018,000 bytes of data, so an 8-drive 3330 subsystem can store over 800 million bytes on-line. Each data track has a capacity of 13,030 bytes, and each of the 404 data cylinders holds up to 247,570 bytes (19 tracks). Head ▶

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- ▷ 1404 Printer
- 1412 Magnetic Character Reader
- 1418 Optical Character Reader
- 1428 Alphameric Optical Reader
- 1445 Printer
- 1827 Data Control Unit
- 2150 Console
- 2301 Drum Storage
- 2302 Disk Storage
- 2361 Large-Capacity Core Storage
- 7340 Hypertape Drive
- 7772 Audio Response Unit

Model 145 systems can also make use of the 2000-lpm 3211 Printer and the high-performance 3330 Disk Storage Facility, which were announced along with Models 155 and 165 in June 1970. Also usable is the super-fast 2305 Model 2 Fixed-Head Storage Facility, introduced in February 1970 for System/360 Models 85 and 195. The Block Multiplexer Channel feature, a no-charge option, enables the Model 145 to take full advantage of the Rotational Position Sensing and Multiple Requesting capabilities which add to the power of the 2305 and 3330. Neither the 2305 nor the 3330, however, will be supported under DOS for the Model 145.

The only new peripheral unit announced with the Model 145 is a highly significant one—the 2319 Disk Storage Facility. The basic 2319 provides three 2314-style disk pack drives and can be expanded to a maximum of eight drives. Each drive stores up to 29 million bytes of data in an interchangeable 11-disk pack.

The 2319 interfaces with the Model 145 Processor through the optional Integrated File Adapter (IFA) rather than a standard I/O channel. The IFA microcode occupies 8800 bytes of RCS and performs most of the disk control functions that normally require expensive specialized circuitry. As a result, IBM is offering the 2319 facility at a surprisingly low price—so low that the independent peripheral manufacturers have already raised howls of protest. The 3-drive 2319 and the IFA rent for a total of just \$1,550 per month, whereas a 3-drive 2314-A Direct Access Storage Facility with the same functional specifications rents for \$2,935 per month, or nearly twice as much. At this price, it will be difficult for most Model 145 buyers to justify *not* including a 2319 in their configurations.

Communications control functions in the System/370 will be handled, as in the System/360, by the 2701 Data Adapter Unit and the 2703 Transmission Control, which place the communications processing burden squarely upon the associated central processor. Though numerous companies are now supplying “front-end” communications processors for use with the System/360, IBM has to date failed to endorse the concept by introducing a similar unit for either the System/360 or 370. ▷

- ▶ movement time ranges from 10 to 55 milliseconds and averages 30 for random accesses. Average rotational delay is 8.4 milliseconds and data transfer rate is 806,000 bytes per second. Deliveries are scheduled to begin in August 1971.

OTHER MASS STORAGE DEVICES: In addition to the new units described above, the System/360 mass storage units listed below can also be used with the System/370 Model 145. Please refer to the IBM System/360 report (70C-491-03) for descriptions of these units.

- 2303 Drum Storage
- 2311 Disk Storage Drive
- 2314 Direct Access Storage Facility
- 2321 Data Cell Drive

INPUT/OUTPUT UNITS

3211 PRINTER: Provides high-speed printed output by means of an endless “train” of 432 type characters that move horizontally in front of the print hammers. The standard character set, consisting of 48 graphic characters in 9 identical arrays, yields a single-spaced printing speed of 2000 lines per minute. Speeds of up to 2500 lpm can be obtained with smaller character sets, and a 120-character Text Printing set yields an expected printing speed of 906 lpm. The Universal Character Set feature is standard, permitting the use of character arrangements which are optimized for specific applications. Up to 254 different graphic characters can be used on a print train, and the train cartridges can be interchanged by an operator.

The 3211 Printer has a standard 132-character line that can be expanded to 150 print positions. Horizontal spacing is 10 characters/inch, and vertical spacing is 6 or 8 lines/inch. A 180-position forms control buffer, loadable from main storage, defines vertical format control operations, eliminating the need for a carriage control tape. Skipping speed is at least 30 inches per second, with acceleration to a maximum speed of 90 inches per second after 7 lines have passed. Forms ranging from 3.5 to 18.75 inches in width and from 3 to 24 inches in length can be handled. A powered forms stacker automatically compensates for the height of the paper stack, and a self-positioning platen adjusts itself to the thickness of the forms being used.

The 3211 Printer can be connected to a Model 145 Byte Multiplexer, Block Multiplexer, or Selector Channel via a 3811 Printer Control Unit. Deliveries are scheduled to begin in December 1971.

OTHER INPUT/OUTPUT UNITS: In addition to the 3211 Printer, the System/360 I/O units listed below can also be used with the System/370 Model 145. Please refer to the IBM System/360 report (70C-491-03) for descriptions of these units.

- 1017 Paper Tape Reader, Models 1 and 2
- 1018 Paper Tape Punch
- 1259 Magnetic Character Reader, Model 2
- 1287 Optical Reader, Models 1-4
- 1288 Optical Page Reader
- 1403 Printer, Models 2, 3, 7, N1
- 1419 Magnetic Character Reader
- 1442 Card Read Punch, Model N1
- 1442 Card Punch, Model N2
- 1443 Printer, Model N1
- 2250 Display Unit, Models 1 and 3
- 2260 Display Station, Models 1 and 2
- 2285 Display Copier
- 2401 Magnetic Tape Unit, Models 1-6
- 2415 Magnetic Tape Unit and Control, Models 1-6
- 2420 Magnetic Tape Unit, Models 5 and 7
- 2495 Tape Cartridge Reader
- 2501 Card Reader, Models B1 and B2
- 2520 Card Read Punch, Model B1
- 2520 Card Punch, Models B2 and B3
- 2540 Card Read Punch
- 2671 Paper Tape Reader

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▷ SOFTWARE

IBM has insured against a repetition of the software development crisis that plagued the industry during the mid-sixties by enabling the System/370 computers to use most of the software that is already in use with the System/360. Model 145 users can choose to operate under either the sophisticated and complex Operating System/360 (OS) or the simpler but less powerful Disk Operating System (DOS). Associated with each of these operating systems is a broad range of compilers, utility routines, and application programs. After years of agonizing development work, the System/360 software has now reached a point where it can perform virtually all of the advertised functions—though its efficiency in many areas still leaves ample room for improvement.

Model 145 users can also make use of all the new and enhanced software products that were announced along with Models 155 and 165 in June 1970.

COMPATIBILITY

As expected, the Model 145 will offer a high degree of program and data compatibility with the System/360 and with the previously announced System/370 models. Current System/360 users will be able to run their application programs on a System/370 with little or no modification. Two minor changes to the System/360 architecture may be of significance to certain users: (1) the ASCII mode hardware facility is not implemented in the System/370, and (2) the handling of invalid signs on decimal operands is different.

Otherwise, virtually all of the new hardware features of the System/370 represent extensions, rather than modifications, of the System/360 architecture. As a result, it should be fairly easy to execute existing System/360 programs on a System/370—usually with no need for reassembly or recompilation. Conversely, it will *not* be possible to directly execute System/370 programs on a System/360 if they make use of the System/370's new instructions or other new hardware features—but this type of downward compatibility is of far less importance to most users.

Integrated emulation is an important Model 145 option—offered, for the first time, at no extra cost—that will enable users to run most IBM 1400 Series and 7010 programs on a Model 145 without change. The emulator microprograms occupy 4800 to 6000 bytes of RCS. The Model 145 emulators run under control of the regular operating system, enabling emulator jobs to be processed as part of a multiprogramming mix. Thus, IBM has granted another reprieve to the thousands of users who have not yet gotten around to converting their second-generation programs—and simultaneously ensured that a ▷

▶ COMMUNICATION CONTROL

System/370 data communications functions will be controlled by the IBM 2701 Data Adapter Unit, 2702 Transmission Control, 2703 Transmission Control, and/or 7770 Audio Response Unit. Please refer to the System/360 report (70C-491-03) for descriptions of these units.

Nearly all of the IBM communication terminal equipment covered in the Peripherals section of DATAPRO 70 can be used with the System/370. Examples are the 2740 and 2741 Communication Terminals, the 2260 and 2265 Display Stations, and the 2780 Data Transmission Terminal.

SOFTWARE

Software support for the System/370 is basically the same as that provided for the earlier IBM System/360. Support for the System/370 Model 145, however, is provided at only two basic levels: the Disk Operating System (DOS) and the Operating System/360 (OS). Two versions of OS support are provided: Multiprogramming with a Fixed Number of Tasks (MFT) and Multiprogramming with a Variable Number of Tasks (MVT). Both the DOS and OS support for the Model 145 are scheduled to become available in August 1971, concurrently with initial customer deliveries.

All of the following facilities will be supported under both DOS and OS for the Model 145: the new System/370 instructions, byte boundary alignment, extended precision floating-point, integrated emulation of the 1401/1440/1460 and 1410/7010, the 2319 Disk Storage Facility, the 3211 Printer, the 3210 Model 1 and 3215 Console Printer-Keyboards, processing of ASCII-mode tapes, Recovery Management Support (RMS), and the On-Line Test Executive Program (OLTEP).

The following facilities will be supported only under OS for the Model 145: the 2305 Fixed-Head Storage Unit, the 3330 Disk Storage Unit, the 3210 Model 2 Console Printer-Keyboard, Block Multiplexer Channels, the Time-of-Day Clock, the DOS Emulator Program, ASP, HASP, and CALL/360.

Since the System/370 is compatible with the System/360 and operates under control of essentially the same software, the great variety of System/360 DOS and OS compilers, assemblers, utilities, application packages, etc., will also be available, for the most part, for use with the System/370. Complete descriptions of the DOS and OS software facilities can be found in Report 70C-491-03.

Along with its introduction of the System/370 Models 155 and 165 in June 1970, IBM announced a number of new and enhanced software products, all of which are also usable on Model 145. These are described in Report 70C-491-04. Most of the new software products are offered for use under a licensing agreement at separate monthly charges ranging from \$40 to \$1,060.

PRICING

EQUIPMENT: The following systems illustrate typical Model 145 configurations. All necessary control units and adapters are included in the indicated prices, and the quoted rental prices include equipment maintenance.

SMALL DISK SYSTEM: Consists of 114K Model 145 Processor with Integrated File Adapter, 2319 Disk Storage Facility (3 drives, 87 million bytes total), 2540 Card Read Punch, 1403 Model 2 Printer, and 3210 Model 1 Console Printer-Keyboard. Monthly rental and purchase prices are approximately \$14,700 and \$693,000, respectively. ▶

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▷ high percentage of these users will stay "locked in" to IBM for several more years.

Another Model 145 compatibility feature facilitates conversions from DOS to OS by making it possible to run DOS jobs under OS control.

SUPPORT

The System/370 computers will receive essentially the same "unbundled" support as the System/360, which means that users must now pay separately for most of the educational courses and technical support that were formerly included in IBM's equipment prices.

Most of the existing System/360 software facilities were delivered prior to IBM's unbundling announcement in June 1969 and are therefore available to System/370 users at no additional cost. But most System/370 users will find it advantageous to use the improved assembler, compilers, sort routines, and other software products that were announced along with the System/370—and these new products are separately priced. Thus, it is becoming apparent that IBM computer users will henceforth be subjected to subtle pressures toward continual upgrading—to IBM's economic advantage—of their software as well as their hardware.

WHO'LL BUY THE MODEL 145?

Overall, the Model 145 shapes up as a highly suitable upgrade machine for Model 40 installations looking for dramatically improved performance at a modest increase in cost.

But for Model 25 and 30 users, the jump to a Model 145 is a large and expensive one—probably well beyond the economic means and performance needs of most current users of a Model 25 or 30. Thus, it is clear that at least one more key member of the System/370 line (Model 135?) remains to be announced. Until IBM chooses to unveil it, most Model 25 and 30 users will have to either make do with their present equipment or look to other sources of supply.

System/360 Model 50 users are certain to view the Model 145 with great interest. For them, the new model represents an opportunity to get significantly higher performance together with modest reductions in their equipment costs. IBM will naturally be anxious to prevent—or at least defer—this type of conversion, and it will be interesting to see what strategy and tactics it will employ. As a probable first step in this direction, IBM has already acknowledged that deliveries of Model 145 systems with more than 262K bytes of main storage will not begin until March 1972, seven months after the smaller sizes.

▶ **TAPE/DISK SYSTEM:** Consists of 262K Model 145 Processor with Integrated File Adapter and Two Selector Channels, 2319 Disk Storage Facility with one additional 2312 Disk Drive (4 drives, 116 million bytes total), eight 2401 Model 5 Magnetic Tape Units (120K) and dual-channel tape control, 2540 Card Read Punch, 1403 Model N1 Printer, and 3210 Model 1 Console Printer-Key-board. Monthly rental and purchase prices are approximately \$23,700 and \$1,113,000, respectively.

EXPANDED TAPE/DISK SYSTEM: Consists of 524K Processor with four Selector Channels, Block Multiplexer Channel and Word Buffer Features, 3346 Main Storage Frame, 3046 Power Unit, eight-drive 3330 Disk Storage Facility (800 million bytes), twelve 2420 Model 5 Magnetic Tape Units (160KB) and two tape controls, two 2540 Card Read Punches, two 3211 Printers, and 3215 Console Printer-Key-board. Monthly rental and purchase prices are approximately \$44,200 and \$2,117,000, respectively.

SOFTWARE: System/360 software which was being distributed by the IBM Program Library as of June 23, 1969, will be available to System/370 users at no additional charge. All subsequent IBM programming announcements (except for certain modifications and improvements of existing IBM programs) are designated as either System Control Programming or Program Products.

System Control Programming provides functions which are fundamental to the operation and maintenance of a system (e.g., loading, scheduling, supervising, and data management) and is available without charge.

Program Products are related to the application of a system to user tasks (e.g., compilers, utility programs, and application programs). These are offered on an individual-charge basis (see Report 70C-491-04).

SUPPORT: IBM Systems Engineering assistance is available to Model 145 users at a basic rate of \$28 per hour.

EDUCATION: IBM "Professional Courses" are now individually priced. System Features Instruction is offered to users of IBM data processing equipment at no charge. Customer Executive Seminars, Industry Seminars, and promotional sessions are still offered at no charge by IBM invitation.

CONTRACT TERMS: The standard IBM rental contract includes equipment maintenance and entitles the customer to up to 176 hours of billable time per month. Time used in excess of that amount is charged for, on all machines equipped with meters, at an extra-use rate. This rate, for most System/370 components, is 10% of the basic hourly rate (i.e., 10% of 1/176 of the monthly rental for each hour of extra use). ■

The appeal of the Model 145 is by no means limited to current users of the System/360. The Model 145's advanced technology and cost-effectiveness, coupled with its proven peripheral equipment and software, make it one of the most attractive medium-scale computers currently on the market. This combination of virtues is likely to attract many shrewd computer buyers into the IBM tent for the first time. □

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EQUIPMENT PRICES

| | | <u>Purchase Price</u> | <u>Monthly Maint.</u> | <u>Rental (1-year lease)*</u> |
|--|---|-----------------------|-----------------------|-------------------------------|
| PROCESSORS AND MAIN STORAGE | | | | |
| 3145 | Processing Unit | | | |
| | Model FED; 114,688 bytes of program storage | 500,400 | 1,210 | 10,425 |
| | Model GE; 163,840 bytes of program storage | 543,600 | 1,250 | 11,325 |
| | Model GFD; 212,992 bytes of program storage | 586,800 | 1,290 | 12,225 |
| | Model H; 262,144 bytes of program storage | 630,000 | 1,330 | 13,125 |
| | NOTE: 393,216 bytes of program storage requires a 3145 Model H plus a 3345, 3046, and 4901; 524,288 bytes of program storage requires a 3145 Model H plus a 3346, 3046, 4901, and 4902. | | | |
| 3345 | Main Storage Frame; 131,072 bytes | 138,240 | 120 | 2,880 |
| 3346 | Main Storage Frame; 262,144 bytes | 252,480 | 220 | 5,260 |
| 3046 | Power Unit (required for 3345 or 3346) | 14,400 | 33 | 300 |
| 4901 | Main Storage Frame Adapter (required on 3145 for attachment of 3345 or 3346) | 960 | 2 | 20 |
| 4902 | Main Storage Frame Adapter Expansion (required on 3145 for attachment of 3346) | 960 | 1 | 20 |
| PROCESSING UNIT FEATURES AND CHANNELS | | | | |
| Block Multiplexer Channels: | | | | |
| 1421 | For standard Selector Channel | NC | NC | NC |
| 1422 | For 2nd Selector Channel | NC | NC | NC |
| 1423 | For 3rd Selector Channel | NC | NC | NC |
| 1424 | For 4th Selector Channel | NC | NC | NC |
| 1850 | Channel-to-Channel Adapter | 12,720 | 13 | 265 |
| 3274 | Direct Control | 5,760 | 4 | 120 |
| 3910 | Floating-Point Instructions | NC | NC | NC |
| 4457 | 1401/1440/1460 Compatibility | NC | NC | NC |
| 4458 | 1401/1440/1460, 1410/7010 Compatibility | NC | NC | NC |
| 4650 | Integrated File Adapter (required for 2319) | 26,400 | 49 | 550 |
| Additional Multiplexer Subchannels: | | | | |
| 4951 | 32 subchannels | NC | NC | NC |
| 4952 | 64 subchannels | NC | NC | NC |
| 4953 | 128 subchannels | NC | NC | NC |
| 4954 | 256 subchannels | NC | NC | NC |
| 6982 | Selector Channel—2nd | 10,800 | 17 | 225 |
| 6983 | Selector Channel—3rd | 10,800 | 17 | 225 |
| 6984 | Selector Channel—4th | 10,800 | 17 | 225 |
| 7844 | Console Printer Adapter for 3210 Model 1 | 6,000 | 4 | 125 |
| 7845 | Console Printer Adapter for 3210 Model 2 | 4,800 | 6 | 100 |
| 7855 | Console Printer Adapter for 3215 | 8,400 | 7 | 175 |
| 8810 | Word Buffer | 9,600 | 6 | 200 |
| 3210 | Console Printer-Keyboard; 15 char/sec | | | |
| | Model 1; for local use | 5,600 | 85 | 175 |
| | Model 2; for remote use | 5,760 | 90 | 180 |
| 3215 | Console Printer-Keyboard; 85 char/sec | 8,000 | 55 | 200 |
| MASS STORAGE | | | | |
| 2305 | Fixed Head Storage Facility, Model 2; 11.2 million bytes | 183,300 | 555 | 3,900 |
| 2835 | Storage Control, Model 2 (for 2305 Model 2) | 117,500 | 445 | 2,500 |
| 2319 | Disk Storage Facility; 87 million bytes (3 disk drives and control; Integrated File Adapter required on 3145 Processing Unit) | 45,000 | 210 | 1,000 |
| 3330 | Disk Storage; 2-drive module; 200 million bytes | 61,100 | 200 | 1,300 |
| 3830 | Storage Control (for up to four 3330 modules) | 112,800 | 170 | 2,400 |
| 8170 | Two-Channel Switch (for 3830) | 9,400 | 10 | 200 |
| 3336 | Disk Pack (for 3330) | 1,000 | Time & mat'ls. | Purchase only |
| | NOTE: Please refer to the IBM System/360 Equipment Prices (Report 70C-491-03) for prices of other mass storage equipment that can be used in a System/370. | | | |
| INPUT/OUTPUT UNITS | | | | |
| 3212 | Printer; 2000 lpm | 81,600 | 380 | 1,700 |
| 3216 | Interchangeable Train Cartridge (for 3211) | 11,550 | 170 | 350 |
| 5554 | 18 Additional Print Positions (for 3211) | 2,640 | 8 | 55 |
| 3811 | Control Unit (for 3211 Printer) | 36,000 | 120 | 750 |
| 5553 | 18 Additional Print Positions (for 3811) | 960 | 5 | 20 |
| 2821-6 | Control Unit (for single 2540 Card Read Punch) | 14,960 | 90 | 440 |
| | NOTE: Please refer to the IBM System/360 Equipment Prices (Report 70C-491-03) for prices of other input/output and communications equipment that can be used in a System/370. | | | |

* Rental prices include equipment maintenance.
NC: No Charge.