Honeywell

SERIES 16

MOVING-HEAD DISK OPTIONS 4623, 4651, AND 4720 PROGRAMMERS' REFERENCE MANUAL

SUBJECT:
Programming Considerations for Series 16 Moving-Head Disk Options 4623, 4651, and 4720.

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PREFACE

This manual describes programming considerations for three Honeywell options: the Type 4720 20-Surface Single Spindle Moving-Head Disk File, the Type 4651 2-Surface Dual Spindle Moving-Head Disk Store, and the Type 4623 10-Surface Single Spindle Moving-Head Disk File. These three devices are used with Series 16 General Purpose Computers. They share the same control unit design and are programmed in a similar manner.

All three of the options described in this manual support the Series 16 Operating Program (OP-16), the Batch Operating System (BOS), the On-Line Executive for Real Time (OLERT), and the Disk Operating System (DOP); M$FT fulfills general formatting requirements for user systems and supports the formatting of disk packs used with OLERT, OP-16, and DOP.

BOS interprets and executes directions for program management, i.e., control cards which specify loading, assembly, compilation, and execution-time information. DOP provides a method for accessing named files at run time; these files may be card images, print-line images, object text, or binary (core-images). DOP supports I/O supervisors for language processors, such as the DAP assembler and the Fortran compiler, and for the linking loader. OP-16 and OLERT generally are found in interrupt-driven real-time multitask operations. BOS and OLERT, like DOP, support a named file storage and access system.

This manual is divided into six sections: The first three sections describe the 20-Surface Disk, 2-Surface Disk, and 10-Surface Disk respectively. The fourth section provides example programs for the three options. The fifth section describes driver program M$IO and formatter program M$FT, used by the three options. The final section is on the use of these options in a Fortran environment.

Information contained in this manual enables the reader to write assembly language programs operating the options either directly or through the Honeywell-supplied I/O library, assuming the reader has a basic familiarity with Series 16 assembly language programming and the 316/516 Programmers' Reference Manual, Doc. No. 70130072156, Order No. BX47 (formerly M-490).

#CA38

REVISION HISTORY

New Revision Level of Manual	Change No.	Effective Date	Pages Affected by Revision
B	9731	October, 1971	Cover, Copyright, 1-5, 1-8, 1-11, 1-17, 1-18, 2-1, 2-5, 2-6, 2-7, 2-11, 2-17, 2-18, 3-1, 3-2, 4-1, 4-3 thru 4-11; Section III changed to IV, Section IV changed to V, new Sections III and VI added.

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TYPE 4720 20-SURFACE SINGLE SPINDLE MOVING-HEAD DISK FILE OPTION

DESCRIPTION

The 20-Surface Single Spindle Moving-Head Disk File Option, Type 4720, consists of a disk control unit and one to eight disk storage units. Each disk storage unit houses a disk drive and a disk pack, the recording medium. Figure 1-1 shows the Type 4720 20-Surface Single Spindle Disk Storage Unit, and Figure 1-2 shows the Type 4722 20-Surface Disk Pack. The disk control unit is referred to in this manual alternately as the DCU and the disk controller. Unit, when used alone, is synonymous with disk storage unit.

Notice in Figure 1-3, the system block diagram, that the disk control unit may be connected to the central processor through either a direct multiplex control (DMC) channel or a direct memory access (DMA) channel. The DMC transfers data between memory and the peripheral devices over the standard I/O bus. The DMA transfers data to and from memory at high speed over a special data bus. DMC also allows use of the I/O bus; DMA does not. Although this option can operate via the I/O bus, Honeywell neither supports nor recommends such operation.

The recording medium, known as the disk pack, is a stack of 11 aluminum plates coated with magnetic material. It is physically interchangeable with the IBM 15-megabyte disk pack. With required adjustments, the Honeywell drive can read from or write on an IBM disk. Figure 1-4 shows the physical organization of the Honeywell disk pack.

The Type 4720 option reads from and writes on number 203 cylinders*. The term "cylinder" refers to a set of 20 recording tracks which are at the same radial distance from the hub. The drive detects the beginning of all tracks by sensing one physical index mark on the disk pack hub. Each track is divided into records in a format defined by the user. The fields within a record are discussed under "Programming Information" in this section.

The controller is described in Doc. No. 70130072318; the drive is described in Doc. No. 60034962002, 172/273/274 Disk Pack Drives Operation Maintenance Manual.

*By convention, cylinders 200, 201, and 202 are used as spares.

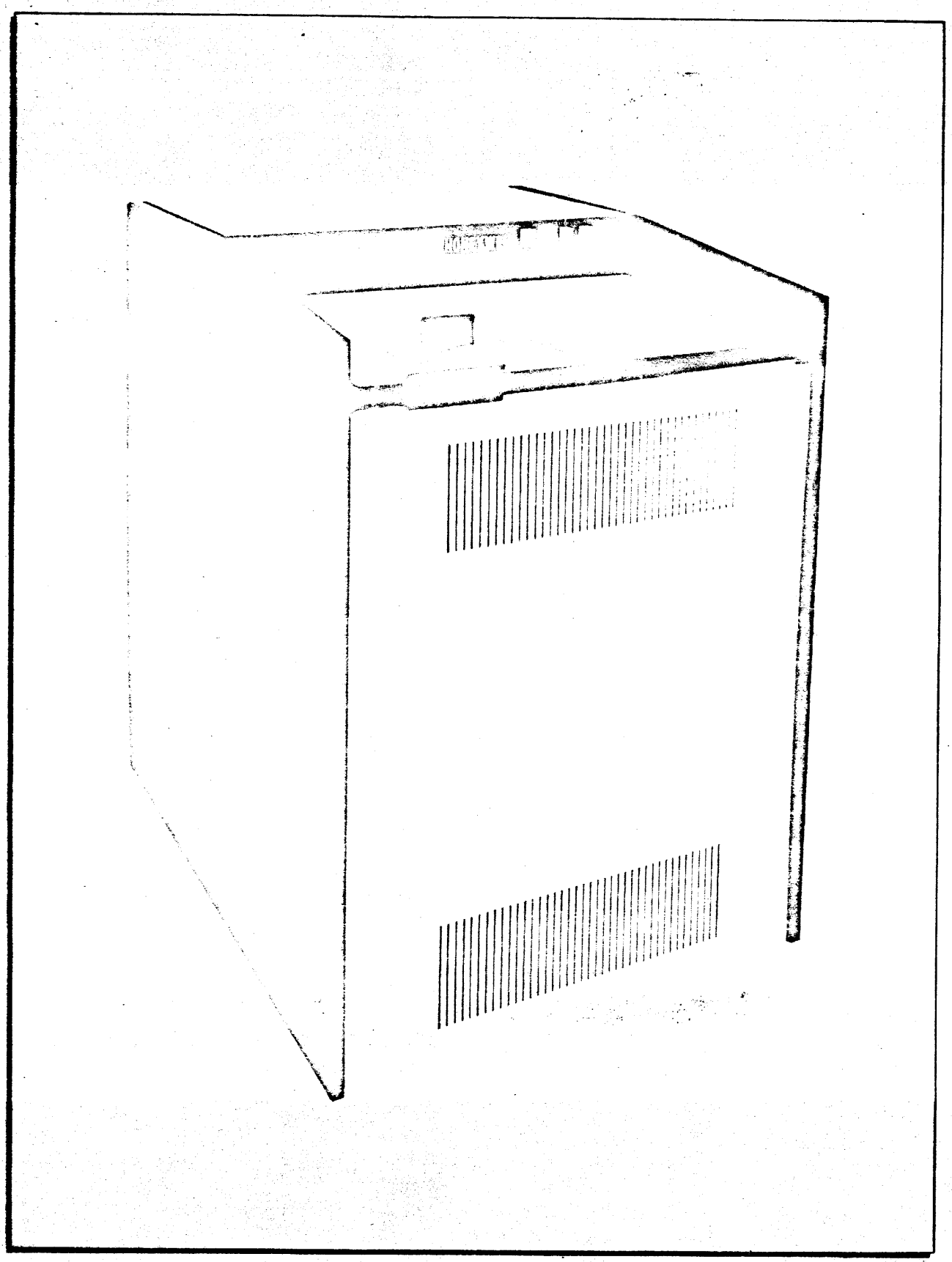


Figure 1-1. 20-Surface Single Spindle Disk Storage Unit, Type 4720

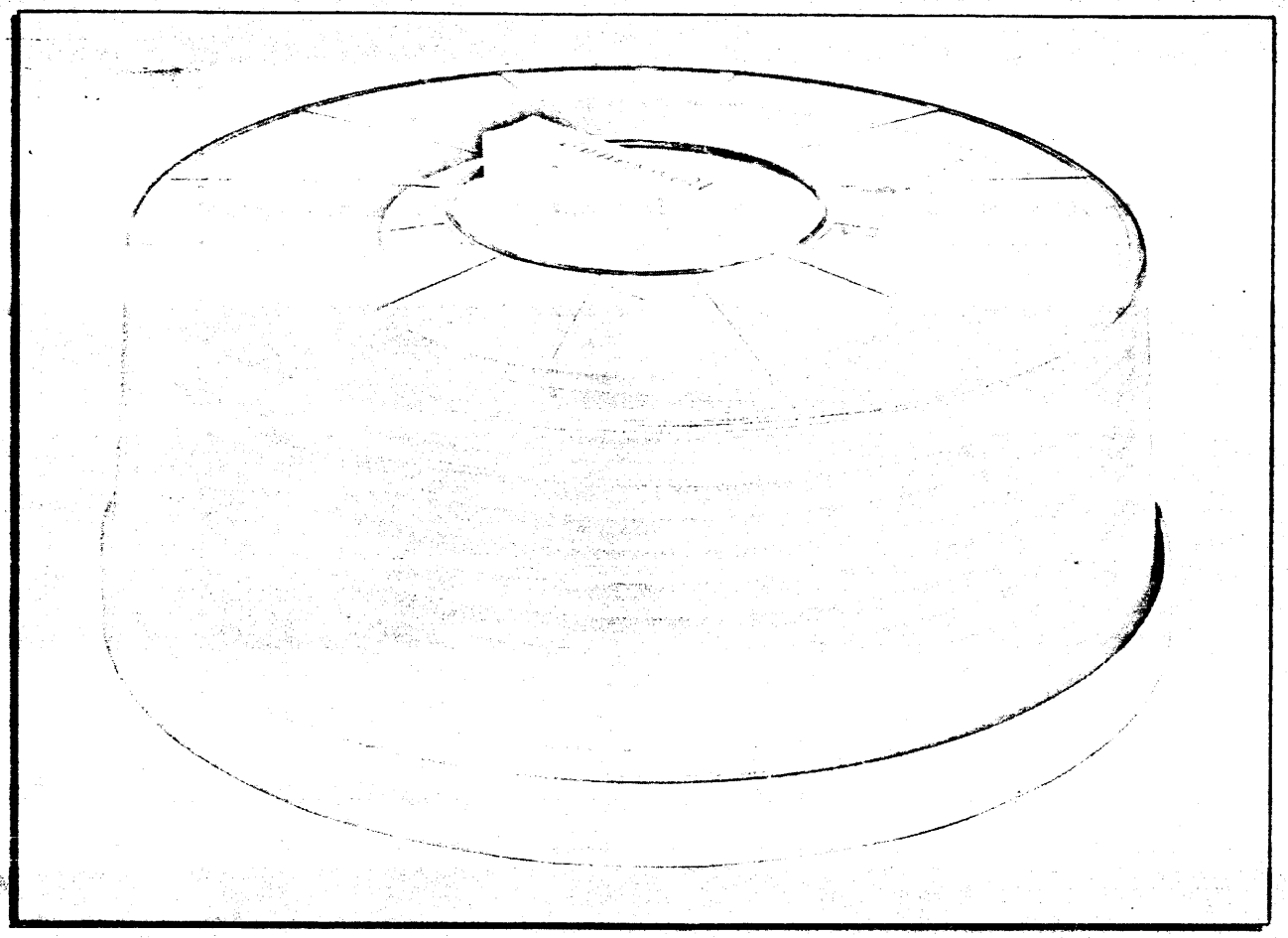


Figure 1-2. 20-Surface Disk Pack, Type 4722

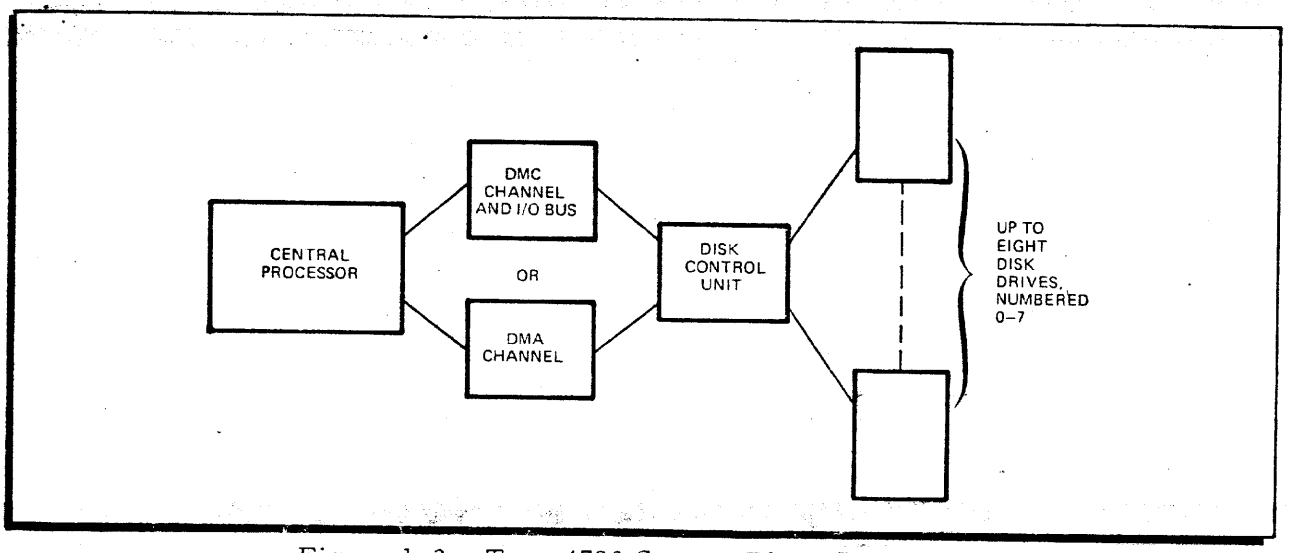


Figure 1-3. Type 4720 System Block Diagram

Type Number Information

To specify a 20-Surface Moving-Head Disk system, choose from the following types.

Type No.	
4720	Disk Control Unit with one Disk Storage Unit (each DCU is capable of controlling up to eight Disk Storage Units)
4721	Additional Disk Storage Unit (Disk Storage Drive and Disk Pack)
4722	Additional Disk Pack

Timing

The timing of disk rotation, bit transfer, and head travel is shown in Table 1-1. The timing of specific data input and output operations is discussed under "Programming Information."

Table 1-1. Timing for Basic Type 4720 Disk Functions

Rotational speed	2352-2448 rpm
Time for one revolution	25 ms (nominal)
Average rotational latency (Time lapse for required data to move under head)	12.5 ms
Word transfer time	12.8 µs
Word data aperture	12 µs
Maximum head travel time:	
1 cylinder	20 ms
200 cylinders	110 ms

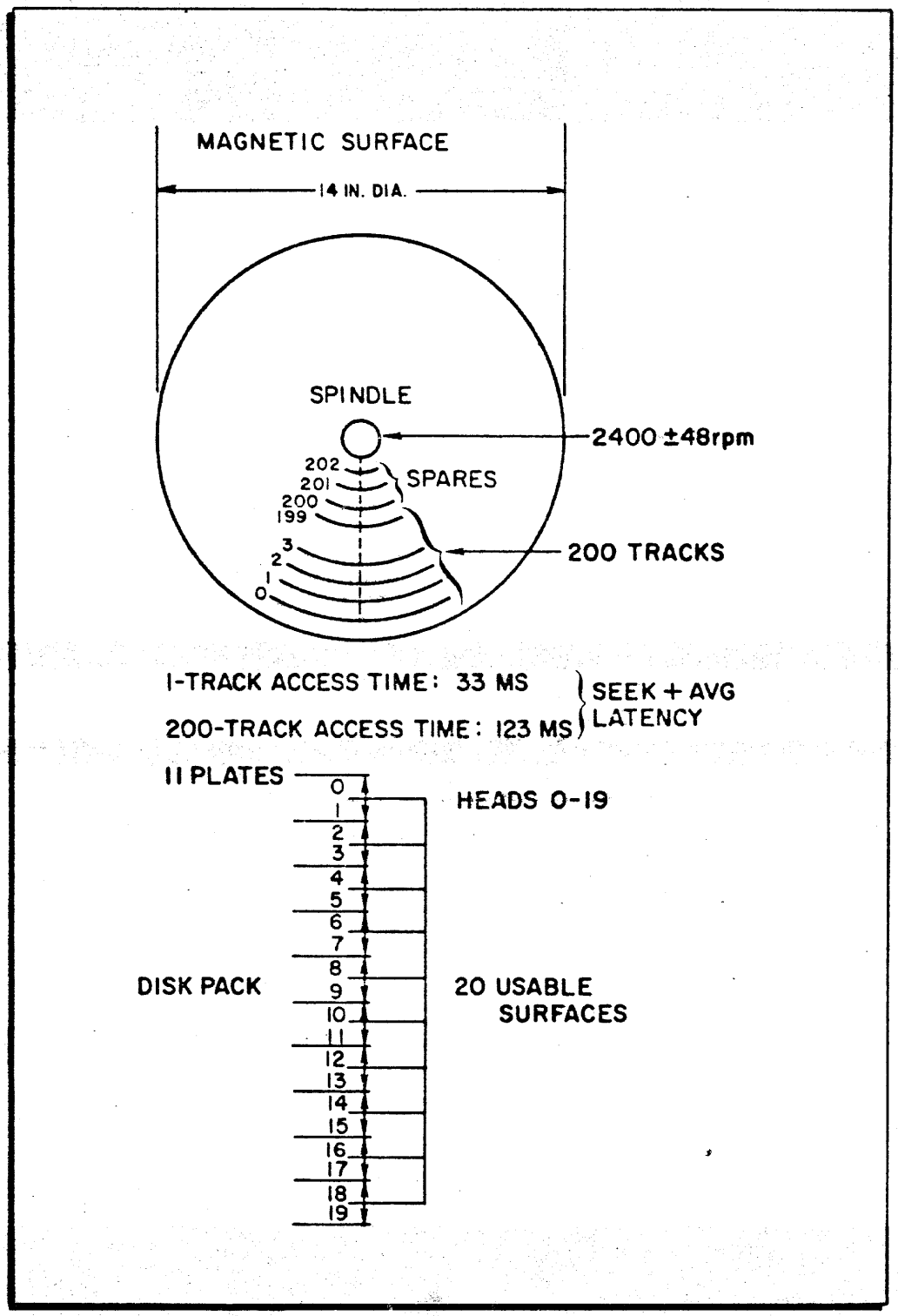


Figure 1-4. Physical Organization of Type 4722 Disk Pack

Storage Capacity

The storage capacity of a disk pack depends on the format chosen for the tracks. Each track may be formatted for 1 to 103 records. The maximum capacity of a track is 1,891 words in 1 record. The 16.5-word overhead and the timing tolerance (5 percent gap) associated with each record reduce the net storage capacity as more records are formatted.

Table 1-2 shows the gross storage capacity. Figure 1-5 shows the capacity of a track as a function of the number of records formatted on it. Table 1-3 shows record capacity as a function of the number of records per track for some commonly selected values.

Table 1-2. 20-Surface Moving-Head Disk Capacity*

	Maximum	Minimum
Words per track	1,891	103
Words per surface	378,200	20,600
Words per disk pack	7,564,000	412,000
Words per control unit (with 8 drives)	60,512,000	3,296,000

*Maximum capacity obtained with one 1,891-word record per track; minimum capacity obtained with 103 one-word records per track.

Table 1-3. Type 4722 Record Capacity as Function of Records/Track*

N	D'	N	D'	N	D'
1	1891	12	135	23	62
2	914	13	123	24	59
3	599	14	113	25	56
4	443	15	106	26	53
5	350	16	97	27	50
6	288	17	90	28	48
7	244	18	84	29	46
8	212	19	79	30	44
9	186	20	74	31	42
10	166	21	70	32	40
11	149	22	66	33	38

*N = no. of records/track.
D' = no. of 16-bit words/record for G = 5%
Data applicable for primary power frequencies of 60 ± 1/2 Hz. or 5- ± 1/2 Hz.
For tolerances greater than 1/2 Hz, see "Track Format and Gap" in this section.

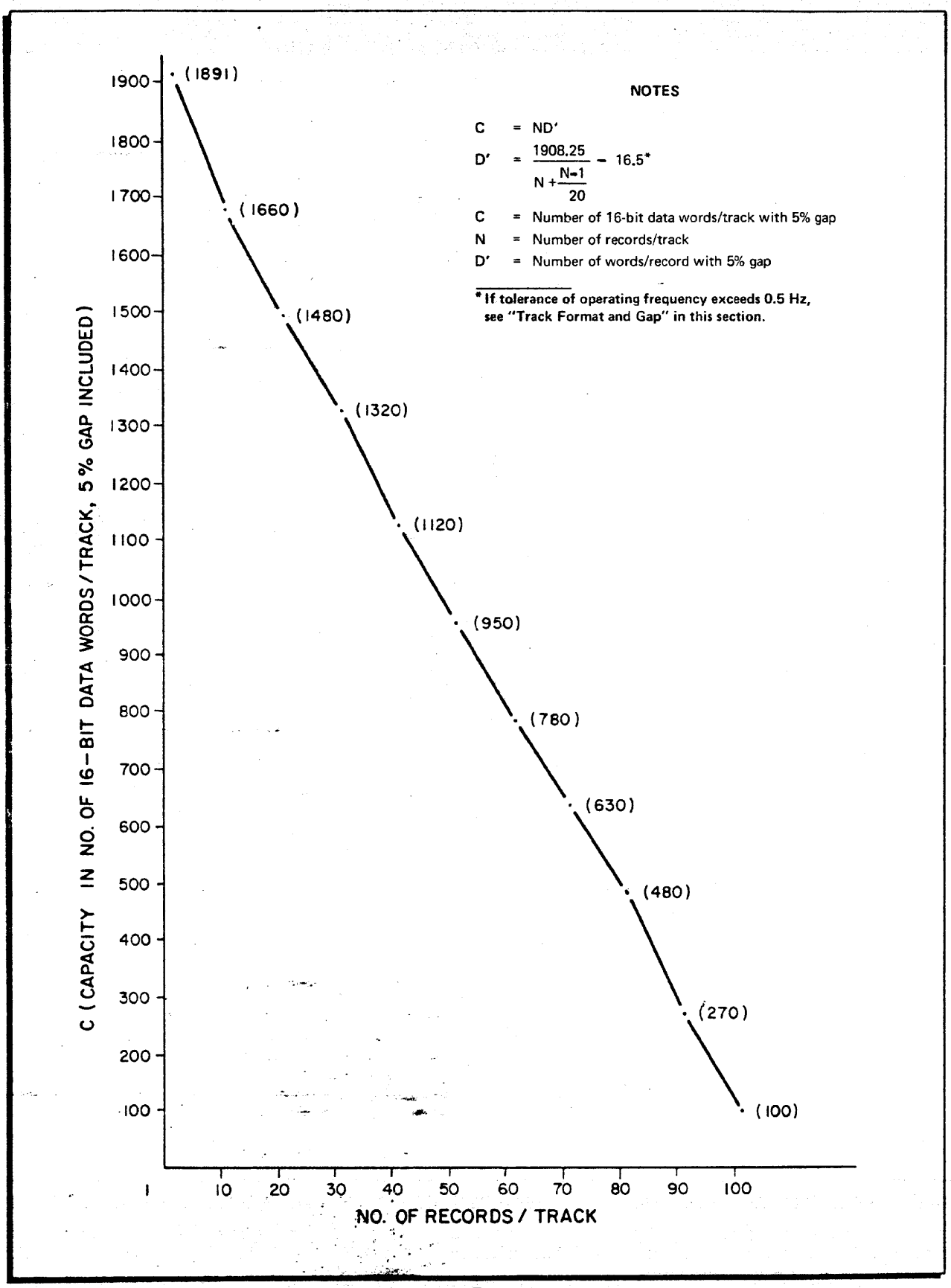


Figure 1-5. 20-Surface Disk Track Capacity vs Number of Records per Track

OPERATION

Controls and Indicators

Each disk drive contains four indicator/switches which function as follows.

START/READY

To start up the disk, apply power to the unit (if not on), load the disk pack, close the cover, and press START. The indicator will illuminate, the disk will rotate, and the heads will seek to track zero. In about 25 seconds the READY indicator will light. During this cycle-up sequence a set of brushes will wipe all recording surfaces and then retract.

STOP

Press STOP to remove power from the spindle drive motor and brake the spindle. The START light will go out, STOP will illuminate, and the heads will retract. In about 15 seconds the disk will stop rotating and will release the cover lock solenoid.

FAULT/CP FINISHED

The FAULT indicator lights upon detection of any of the following conditions.

a. Selection of more than one head

b. Improper combination of read, write, and erase heads or drivers (e.g., both read and erase)

c. Attempt to read, write, or erase with head not directly on track

d. Disk not rotating at proper speed

Depressing FAULT clears the indicator. If the condition reappears, the indicator lights again. Clearing a recurrent fault may be attempted by stopping the unit, then restarting it with the START switch.

OCP '0425 controls the CP FINISHED indicator. The programmer can program this indicator to flash as a signal to the operator that the program is finished with the current disk pack. The command also causes the unit to cycle down. Push CP FINISHED to turn off the indicator.

PERMIT/PROTECT

The permit state allows writing or formatting on a disk. Since the unit cycles up (i.e., starts) in the protect state, press PERMIT before attempting either of these operations.

Power

The main circuit breaker at the front of the disk drive controls power to the unit except for the main motor. Controller logic is powered from the computer. The main motor is controlled by the START pushbutton and interlocked with the plastic cover.

Changing Disk Packs

The disk pack should be changed with the main circuit breaker ON. This activates the spindle brake, making pack changing easier and safer.

To install a pack, hold it by its cover handle, and remove the bottom cover by unscrewing the knob at the bottom. Slide back the plastic cover on the disk drive and lower the pack over the matching spindle, being careful not to bump one against the other. Twist the disk pack handle clockwise until the pack is firmly seated on the spindle. Raise the disk pack cover and remove it. Close the plastic cover of the disk drive immediately to prevent the entry of dust.

To remove a pack, first make sure it is not rotating. Then slide back the plastic cover of the drive and place the disk pack cover over the disk pack, making sure it is seated. Twist the disk pack cover handle counterclockwise until the pack is free. Remove the disk pack and close the drive cover. Place the disk pack in position over the bottom cover and tighten it with the bottom knob.

Cleaning Disk Packs

Dust or dirt on the disc pack recording surfaces may cause read or write errors as well as permanent damage to the surfaces and the read/write heads. Honeywell disk pack drives are equipped with nylon cleaning brushes to ensure optimum performance. Manual cleaning on Honeywell drives equipped with brushes is not usually necessary; brushes clean the packs during each cycle-up.

If a specific pack continually causes read errors after write operations, however, cycle up the unit five times. The brushes will clean the error-causing disk pack during the cycle-up process. If read errors persist and the record or format was written on another drive, this may be the cause of the error. If errors persist and the drive used for writing and reading is the same and otherwise satisfactory, take the error-causing track out of service and assign one of the spare tracks. If spare tracks are not available, remove the pack from service, as the entire surface may be degraded.

Check the disk pack filter on the bottom of each pack and change it when necessary. Filters can be ordered through your local Honeywell Field Service Office.

Note that Honeywell disk packs are impervious to 91-percent isopropyl alcohol (2-propanol); however, other solvents may cause damage.

PROGRAMMING INFORMATION

Relevant Hardware Information

UNIT NUMBER ASSIGNMENT

Each disk drive is assigned a number from 0 to 7 at its installation, and each drive should be labelled with its appropriate number.

TRACK FORMAT AND GAP

Figure 1-6 shows the track format. Information is recorded on the disk in a serial bit stream.

Field A is a 64-bit field which allows for jitter in detection of the index mark. This field is recorded only before the first record of the track. Fields B, E, and K are 64-bit fields which allow for the distance between the erase head and the read/write head. Fields C, F, and J are special fields also used internally. Field D is the address, which is a 24-bit field with the first 8 bits ignored. The remaining 16 bits contain a program-assigned address for each record. Field G contains the data of the record. Field H is a 16-bit record checksum for field G. Field L is a gap field which must be at least 5 percent of the total length of fields B through K:

$$L = 16(0.05(G + 16.5)) = 0.80G + 13.2$$

where L is the length of field L in bits, G is the length of field G in words, and 16.5 is the length in words of fields B through K except G. If the frequency tolerance exceeds 0.5 Hz, increase the gap proportionally. For example, with a tolerance of 1.0 Hz, increase the gap to 10 percent:

$$\frac{5\%}{0.5\ \text{Hz}} = \frac{\text{Gap}}{1.0\ \text{Hz}}$$

To access sequential records within the same rotation, take into account time T between the end-of-busy for the first record (which allows the next OCP to be sent) and the output of the second setup word as follows.

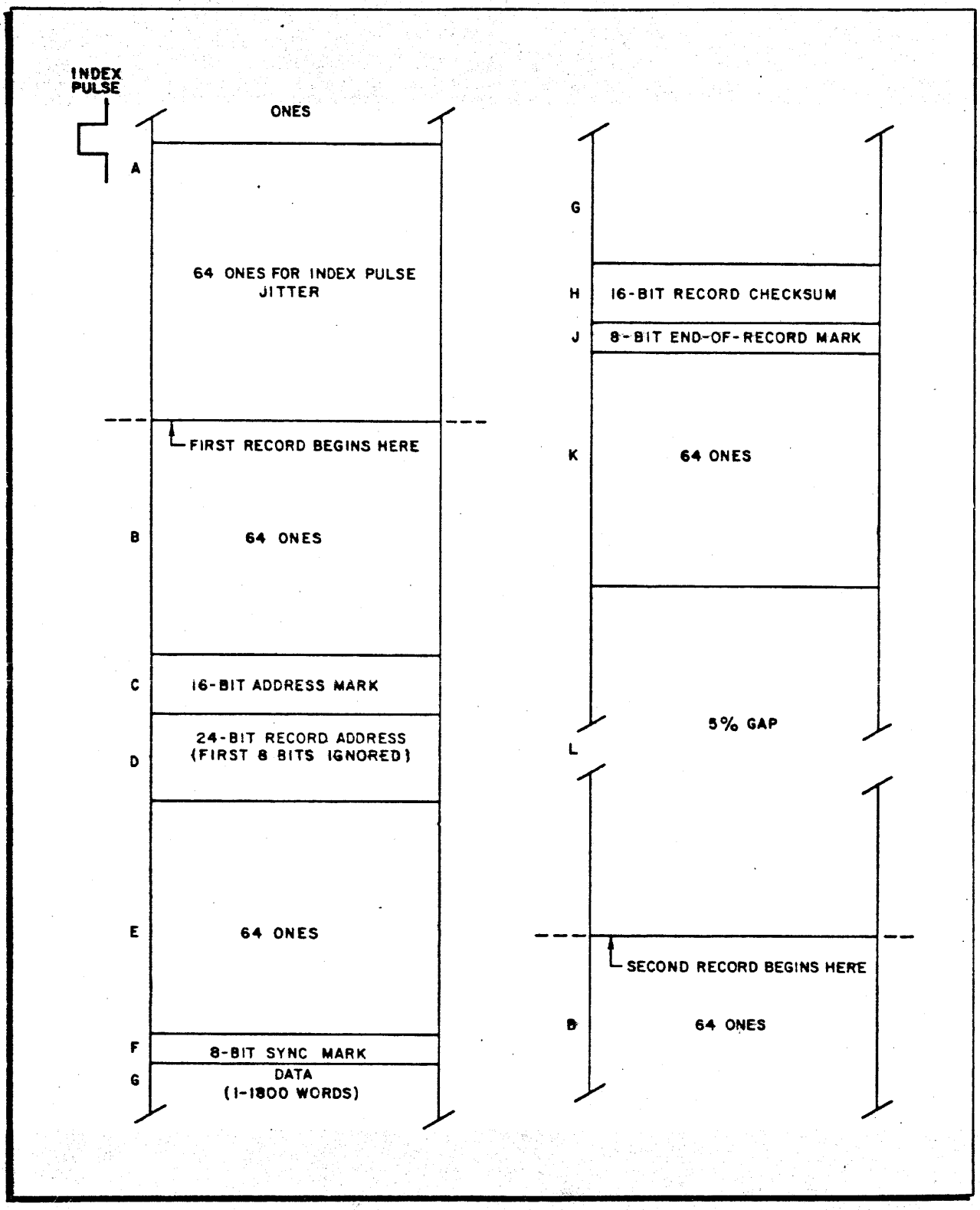


Figure 1-6. 20-Surface Disk Track Format

$$L = 16(0.05(G + 16.5) + 0.078T + 1.75)$$
$$= 0.80G + 41.2 + 1.25T$$

where T is in μs. The minimum time T between the initiating OCP and output of the second setup word is 55 μs.

STATUS WORD

The programmer can obtain detailed information about the state of important elements within the controller by requesting a status word transfer. In particular, the contents of the status word help him to determine if recovery from an error state is possible. Figure 1-7 shows the format of the status word with the significance of each bit (when set) called out.

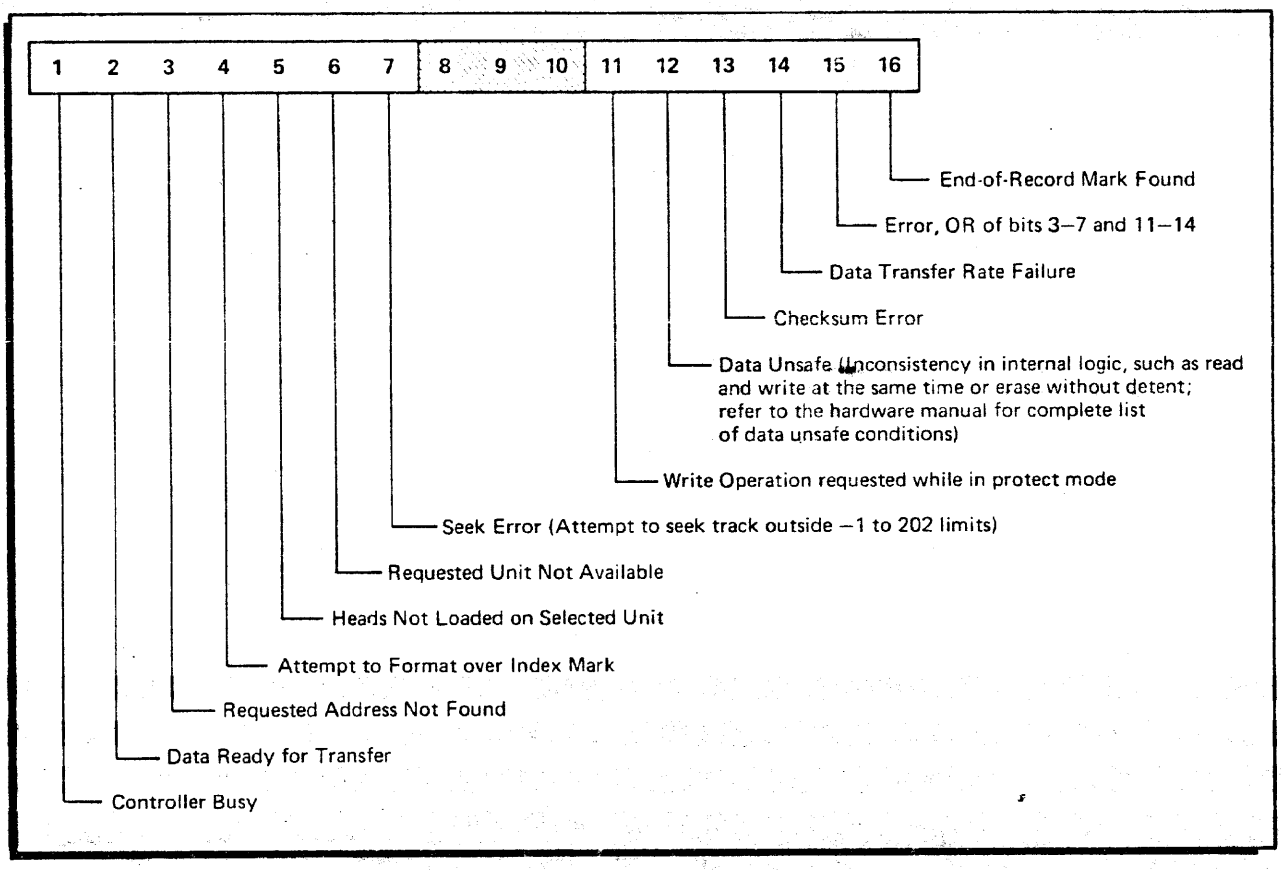


Figure 1-7. 20-Surface Disk Status Word Format

SETUP WORDS

Six of the OCP instructions require one or two setup words which transfer information necessary for the particular operation. Figure 1-8 contains these six OCPs and the formats of the corresponding setup words.

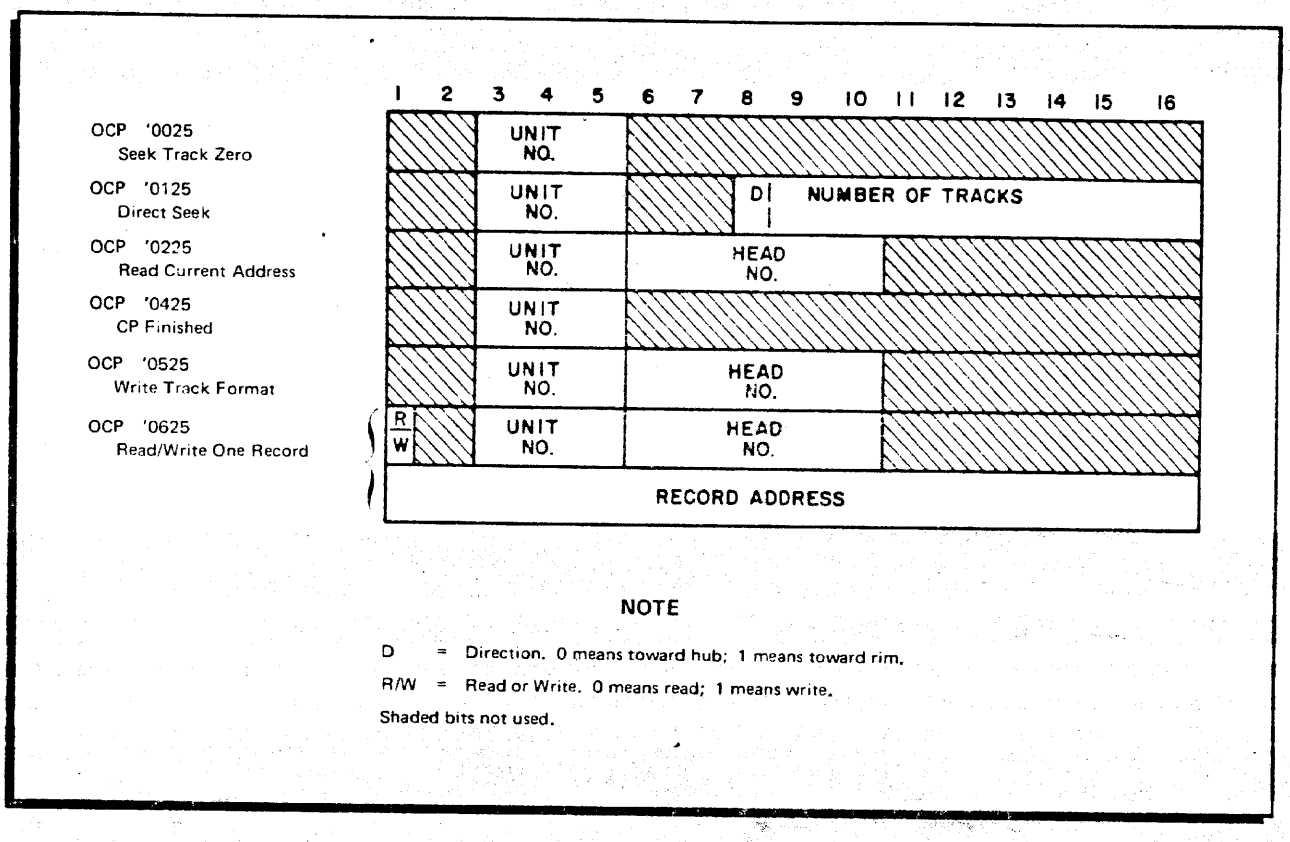


Figure 1-8. 20-Surface Disk Instructions with Required Setup Words

CHECKSUM

As data is written onto the disk the controller accumulates a checkword. The checkword is formed by exclusively ORing all data words into a register. At the end of an n-word transfer, the checkword is a 16-bit even-parity checksum which is written onto the disk as word n+1.

When data is read from the disk and passes back through the controller, the hardware recomputes the checksum. Word n+1 is included in the computation. If the result is nonzero, the checksum error bit in the status word is set. A programmer may examine the checkword by requesting an n+1 word read operation.

INTERRUPT REQUESTS

Certain conditions cause hardware interrupt requests. These conditions are listed under "Acknowledge Interrupt, OCP '1425" in this section.

ACCESS TO DMC DEDICATED LOCATIONS

On a Model 316 with high-speed DMC the programmer is guaranteed access to DMC dedicated locations only when the disk controller is not busy. More information on this

subject is presented in the 316/516 Programmers' Reference Manual (Doc. No. 701300-72156) under "316 High-Speed DMC Dedicated Locations."

General Instruction Sequences

The instruction complement for the Type 4720 is given in Table 1-4. Tables 1-5 through 1-9 give appropriate instruction sequences for common operations.

SEEK, SEEK TRACK ZERO

Before information can be transferred to or from a record, the head must be positioned on the proper track. Two instructions perform this function: One is an absolute seek to cylinder 000; the other moves the head a specified number of cylinders in either direction from the current position. The programmer is expected to keep track of the current head position within his program. Table 1-5 shows the sequence of operations required for the seek operations.

Table 1-4. 20-Surface Moving-Head Disk Instructions*

Instruction	Function
OCP '0025	Seek track zero
OCP '0125	Direct seek
OCP '0225	Read current address
OCP '0425	CP finished
OCP '0525	Write track format
OCP '0625	Read or write one record
OCP '1025	Stop transfer
OCP '1125	Read status word
OCP '1325	Enable DMC/DMA mode
OCP '1425	Acknowledge interrupt
OCP '1725	Enable I/O bus mode
INA 'X025	Input from disk to A-register if ready
OTA '0025	Output contents of A-register to disk if ready
SKS '0025	Skip if ready
SKS '0125	Skip if disk not requesting interrupt
SKS '0225	Skip if operational
SKS '0325	Skip if not busy
SKS '0425	Skip; if no error
SKS '0725	Skip if unit 7 not seeking
SKS '1125	Skip if unit 0 not seeking
SKS '1225	Skip if unit 1 not seeking
SKS '1325	Skip if unit 2 not seeking
SKS '1425	Skip if unit 3 not seeking
SKS '1525	Skip if unit 4 not seeking
SKS '1625	Skip if unit 5 not seeking
SKS '1725	Skip if unit 6 not seeking
SMK '0020	Set interrupt mask (bit 4)

*Address of moving-head disk control unit is 25. X in INA 'X025 may be either 1 or 0; 1 means clear A-register before input; 0 means input without first clearing.

Table 1-5. 20-Surface Disk Seek and Seek Track Zero Instruction Sequence

Step	I/O Bus & DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	Test if drive seeking	Test if drive seeking
3	—	Set up DMA for one-word transfer
4	Execute seek instruction	Execute seek instruction
5	Output setup word	(Enter DMA)
6	—	(End-of-range)
7	Handle seek complete interrupt request	Handle seek complete interrupt request

CP FINISHED

Execution of the CP finished instruction causes the selected unit to seek track zero, power down, and flash the CP FINISHED indicator. The flashing continues until the operator presses CP FINISHED. The sequence of operations required for a CP finished instruction is shown in Table 1-6.

Table 1-6. 20-Surface Disk CP Finished Instruction Sequence

Step	I/O Bus and DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	—	Set up DMA for one-word transfer
3	Execute CP Finished instruction	Execute CP Finished instruction
4	Output setup word	(Enter DMA)
5	—	(End-of-range)

READ CURRENT ADDRESS

Disks often are formatted so that the address of each record identifies the track, head, and unit. By reading the address of the next record formatted under such a system, a programmer can determine the track location and relative rotational position of the heads on the disk. Table 1-7 shows the sequence of operations required for reading the current address. When the DMA is used, the address is returned as the second word of the two-word buffer.

Table 1-7. 20-Surface Disk Read Current Address Instruction Sequence

Step	I/O Bus	DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator	Test control unit busy indicator
2	—	Set up DMC for one-word input transfer	Set up DMA for one-word output transfer
3	Enable transfer via I/O bus	Enable transfer via DMC/DMA	Enable transfer via DMC/DMA
4	Execute read current address instruction	Execute read current address instruction	Execute read current address instruction
5	Output setup word	Output setup word	(Enter DMA)
6	INA current address	(Enter DMC)	(Disk control unit switches DMA to input)
7	Return to DMC/DMA mode	(End-of-range)	(End-of-range)

WRITE TRACK FORMAT

Table 1-8 shows the sequence of operations required for writing a track format. Formatting takes place in the following order (after the setup word).

a. Record address

b. Data for every word in the record (may be blank or filler)

c. End-of-range

d. Five-percent gap word (whose value is the number of bit cells in the gap field)

e. Repetition of steps a. through d. for each record

f. End-of-range, acknowledge interrupt, and stop transfer after the last record (which writes gap to the track origin)

The 5-percent gap word related to the previous record must be output as the first word of the block being output for the present record.

Because of timing constraints the CPU must be dedicated exclusively to formatting. Time-sharing or multiprogramming is not possible, because time is not available to handle interrupts.

Table 1-8. 20-Surface Disk Write Track Format Instruction Sequence

Step	DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	Set up DMC for n+1-word output[a]	Set up DMA for n+2-output[b]
3	Enable transfer via DMC/DMA	Enable transfer via DMC/DMA
4	Execute write track format instruction	Execute write track format instruction
5	Output setup word	(Enter DMA)
6	(Enter DMC)	—
7	(End-of-range)	(End-of-range)
8	Reinitialize DMC for n+2-word output[c]	Reinitialize DMA for n+2-word output[c]
9	(Enter DMC)	(Enter DMA)
10	Repeat steps 6 through 9 for each record	Repeat steps 6 through 9 for each record
11	Reinitialize DMC for 1-word output[d]	Reinitialize DMA for 1-word output[d]

[a] For first DMC transfer, word 1 should be record address and the remaining n words should be data.

[b] For first DMA transfer, word 1 should be setup word, word 2 should be record address, and the remaining n words should be data.

[c] For subsequent DMC or DMA transfers, word 1 should be the 5-percent gap word for the preceding record, word 2 should be the record address, and the remaining n words should be data.

[d] Last DMC or DMA transfer should be 5-percent gap word for the previous record. Set-up must be accomplished within 60 μs and subsequent interrupt request must be followed by stop transfer and acknowledge (clear) interrupts commands. The drive will write gap until it detects track origin.

If the programmer has ensured that enough space remains on disk for gap for the final record (he may include the 64-bit field A), he need not transfer the 5-percent gap for the final record. If the last gap word is not transmitted or timing requirements are not satisfied, the drive writes gap to track origin and sets the data-transfer rate-failure bit in the status word.

READ OR WRITE ONE RECORD

The sequence of instructions for these two operations is almost identical. The data words, preceded by two setup words, are transferred between the computer and the disk. The address is read but not modified. The record checksum is written or read and compared but is not transferred to the computer unless a read has been specified for more words than the record contains. Table 1-9 shows the sequence of operations required for reading or writing one record.

Table 1-9. 20-Surface Disk Read or Write One Record Instruction Sequence

Step	DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	Set up DMC for n-word input or output	Set up DMA for N+2-word output[a]
3	Enable transfer via DMC/DMA	Enable transfer via DMC/DMA
4	Execute read/write one record instruction	Execute read/write one record instruction
5	Output first setup word	(Enter DMA)
6	Output second setup word[b]	—
7	(Enter DMC)	(Disk control unit switches DMA to input when reading)
8	(End-of-range)	(End-of-range)

[a] For DMA transfers, words 1 and 2 must be setup words; the remaining n words are data storage locations.

[b] The time of second setup word is critical only if sequential access within the same rotation is desired (see "Track Format and Gap", a preceding paragraph).

In an under-range read the controller transfers the specified number of words to memory and discards the remainder of the record. The controller becomes not busy shortly after the end-of-record mark is detected. The checksum is handled as in a normal read.

An over-range read, which inputs the checksum word (often useful for error recovery), terminates at the end-of-record mark. The checksum error bit (bit 13 in the status word) is valid as in a normal read. An under-range write causes no problems.

An over-range write reduces the gap field correspondingly for up to four words over the original format. If more than four words are written beyond the format, the next record (and format) is destroyed. The current record is readable under most circumstances.

READ STATUS WORD

The sequence in Table 1-10 shows the order of instructions to read the contents of the status register. With DMC it is easiest to code this operation using the I/O bus as shown below, although DMC is perfectly acceptable.

Table 1-10. 20-Surface Disk Read Status Word Instruction Sequence

Step	I/O Bus	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	Enable I/O bus	Set up DMA for one-word input transfer
3	Execute read status word instruction	Execute read status word instruction
4	Input status word	(Enter DMA)
5	Enable DMC/DMA	(End-of-range)

Instruction Descriptions

SEEK TRACK ZERO, OCP '0025

This instruction and its associated setup word cause the heads on the selected unit to move to track 000. The disk control unit busy indicator is set for 50 μs after the setup word is output; the seeking indicator of the selected unit is set for 20 to 110 ms after the setup word is output (see Table 1-1).

More than one disk drive may be seeking at a time. When the heads reach track zero, the controller generates an interrupt request (which may be delayed until the controller becomes not busy). This instruction is ignored if issued while the disk control unit busy indicator is set. A seek-track-zero instruction executed with the heads already on track zero is processed the same as a seek-track-zero from any other position.

DIRECT SEEK, OCP '0125

This instruction and its associated setup word cause the heads on the selected unit to move the number of tracks specified by bits 9 through 16 of the setup word and in the direction specified by bit 8 of the setup word, where 0 means toward the center of the disk (higher track numbers) and 1 means toward the outside of the disk (lower track numbers). If the disk control unit detects a 0 in the difference field (bits 9 through 16), it sends no orders to the disk drive, sets the seek error bit in the status word, and generates an interrupt request. The disk control unit busy indicator is set for 50 μs after the setup word is output; the selected unit seeking indicator is set for 20 to 110 ms after the setup word is output. This instruction is ignored if issued while the disk control unit busy indicator is set.

The programmer can code several units to seek concurrently with successive OCP seeks and setup words. He must test for controller busy between OCP's. If several units

are seeking, the programmer can either acknowledge interrupts as they occur or wait until all units have finished seeking, and then clear all interrupt requests with one acknowledge interrupt. An interrupt request will be delayed until the controller becomes not busy (e.g., a data transfer follows a seek). A seek directed to a nonexistent track results in a seek to zero and a seek error in the status word.

READ CURRENT ADDRESS, OCP '0225

This instruction and its associated setup word cause the next address encountered on the selected track by the selected head to become available on the input bus. The disk control unit busy indicator is set from the time the setup word is output until the address becomes available to the central processor. Then the ready indicator is set, the busy indicator is reset, and an interrupt request is generated. This OCP has no effect if issued while the DCU is busy.

CP FINISHED, OCP '0425

Execution of this instruction and its associated setup word cycles down the unit, starts the CP FINISHED indicator flashing, and illuminates STOP. A programmer may code this operation to signal the operator that a certain disk is no longer needed by the executing program. The DCU busy indicator remains set for 50 μs after the setup word OTA. No interrupt request is generated.

WRITE TRACK FORMAT, OCP '0525

This instruction and its associated setup word cause the selected head on the selected unit to detect the track origin and write a new format on the track. In addition, data may be written in the newly formatted records. The address, the data, and the gap size are under program control. If the output transfer rate is not maintained by the computer, the disk control unit aborts the operation, writes gap to the track origin, and sets the data-transfer rate-failure bit in the status word. The DCU is busy from the time of the order-initiation OCP until formatting terminates at track origin. Refer to "Track Format and Gap" earlier in this section for information on how to format to access sequential records on a track.

READ OR WRITE ONE RECORD, OCP '0625

This instruction and its two associated setup words cause the selected head on the selected disk drive to read or write one record at the specified record address on the current cylinder. Bit 1 of the first setup word must be 0 for read and 1 for write.

Read

The unit reads until one of the following conditions occurs.

a. End-of-record is sensed.

b. The computer fails to maintain the necessary input transfer rate.

c. Two index pulses are tallied

d. The stop transfer instruction (OCP '1025) is executed or DMC/DMA end-of-range occurs. Data transfer will cease, but the disk control unit continues reading to the end of the record. When a stop transfer instruction is executed during a read operation, the last data word transferred before the instruction takes effect is interpreted as a checksum. The checksum error bit in the status word may be set. This feature is useful in test programs.

The control unit busy indicator is set from the time the OCP is issued until the read is completed in one of the four ways listed above.

If the program specifies a larger number of words (range) to be read than the record contains, the record checksum is transferred to the central processor as if it were data, and the end-of-record is sensed before the next word is transferred. If, at the end of the read operation, the checking logic indicates an error, the checksum error bit in the status word is set.

Write

Data is written into the addressed record until one of the following conditions occurs.

a. The stop transfer instruction (OCP '1025) is executed or DMC/DMA end-of-range occurs.

b. The computer fails to maintain the necessary output transfer rate.

c. Two index pulses are tallied.

When condition a. or b. is encountered, the word being written is finished, and the checksum record is written along with the end-of-record mark and the field of ones (fields H, J, and K of Figure 1-6). When condition c. occurs, the operation is terminated immediately.

The programmer should make sure that the record written is no larger than allowed by the record format. If it is too long by four words or less, the 5-percent gap is diminished but the following record will not be affected. If it is more than four words too long, the following records are destroyed.

The controller is busy from the time the OCP is issued until a., b., or c. above terminates the operation. The read/write operation may be requested when one or more units are seeking and will be executed either immediately or when the appropriate seek is complete. Any pending interrupt request is delayed until the operation is complete, i.e., until the controller becomes not busy.

STOP TRANSFER, OCP '1025

This instruction, which does not require a setup word, stops track formatting if issued immediately after the DCU has received the last data word. If this OCP is not issued within 50 μs of end-of-range for the last record formatted, the data-transfer rate-failure bit in the status word is set. Execution of a stop transfer instruction forces the controller to not busy. In this way, a programmer can clear a busy hangup which may result from an OCP with no setup word transfer or a hardware fault. If issued during a read operation, this instruction forces a diagnostic checksum (see "Read", preceding).

READ STATUS WORD, OCP '1125

This instruction causes the status word to be the next data-like word transferred via I/O bus, DMC, or DMA (whichever is enabled). Code INA '0025 or '1025 after the OCP to make the transfer via I/O bus. For DMC or DMA transfers, initialize the channel before issuing the OCP. Before issuing OCP '1125 while the DCU is busy, delay 50 ms (two revolutions) to allow completion of any transfer in progress. Reading the status word does not alter the state of the controller other than to clear the status request. See Figure 1-7 for the status word format.

ENABLE DATA TRANSFER VIA DMC/DMA, OCP '1325;
ENABLE DATA TRANSFER VIA I/O BUS, OCP '1725

OCP '1325 (or '1725), which does not require a setup word, enables the disk control unit to use the DMC/DMA (or I/O bus) exclusively. It does not initiate an order to any of the disk drives.

Pressing MSTR CLEAR initializes the system for DMC or DMA transfers. To initialize the system for I/O bus transfers, execute OCP '1725 before executing the OCP which implies the data transfer (e.g., OCP '0625, Read One Record). Transfers are enabled via the I/O bus until OCP '1325 is executed or the computer is MSTR CLEARed.

ACKNOWLEDGE INTERRUPT, OCP '1425

This instruction, which does not require a setup word, does not initiate any orders to the disk drives but does reset (clear) an interrupt request if one is present. The following situations cause interrupts if allowed.

a. The disk control unit goes from busy to not busy, except for the 50-μs busy at the beginning of a seek, CP-finished, or read-status-word instruction. Any OCP, except read-status-word, addressed to the disk control unit resets this interrupt request.

b. A seek operation is completed. If this happens when the disk control unit is busy, the interrupt is delayed until the control unit goes to not busy. If a direct seek is requested and its setup word specifies a difference of zero tracks, this interrupt request is generated immediately. Only OCP '1425 resets this interrupt request.

c. A disk drive error (bits 5, 6, 7, 11, or 12 in the status word) is detected. The operation is terminated, and an interrupt request is generated at the end of the 50-μs order process interval.

d. End-of-range is reached in write-track-format operations with DMC/DMA mode set. The interrupt signals the program to reinitialize the DMC/DMA within the time constraints. It may be cleared by OCP 1425 during the format operation, or by OCP '1425 or OCP '1025 at the end of the format operation.

INPUT FROM DISK TO A-REGISTER IF READY, INA '0025

If the disk control unit has a data word ready for transfer, this instruction ORs the word from the DCU into the A-register and skips the next instruction. At the completion of the instruction, data-ready and status-request are reset. If data is not ready, INA '0025 is treated as a NOP. To maintain the data transfer rate, INA must be executed within 12 μs of the time data becomes ready (time constraints do not apply for status and address transfers). INA '0025 is not applicable to a DMA configuration.

CLEAR A-REGISTER AND INPUT FROM DISK TO A-REGISTER IF READY, INA '0025

This instruction performs a function similar to that above, except the A-register is cleared before the data is ORed in.

OUTPUT TO MOVING-HEAD DISK IF READY, OTA '0025

If the data ready indicator is set, this instruction outputs data (usually a setup word) to the moving-head disk, resets data ready, and skips the next instruction. If data ready is reset, the instruction is treated as a NOP. The timing requirements for disk data are the same as for INA '0025 and '1025. Timing of setup words is noncritical. OTA '0025 is not applicable to a DMA configuration.

SET INTERRUPT MASK (BIT 4), SMK '0020

The state of the standard interrupt mask for the moving-head disk is made equal to bit 4 of the A-register (which must contain the entire mask word) by executing SMK '0020.

SKIP IF READY, SKS '0025

The data ready indicator is used on both read and write operations to signal that another word may be transferred to or from the disk control unit. SKS '0025 tests this indicator. This instruction generally is not useful.

SKIP IF NOT INTERRUPTING, SKS '0125

This instruction skips if the disk control is not generating an interrupt request. Interrupt conditions are listed under OCP '1425.

SKIP IF OPERATIONAL, SKS '0025

This instruction skips if the DCU is not busy and if no error bits in the status word are set. It skips if the previous data transfer was completed satisfactorily or a seek operation started without error.

SKIP IF NO ERROR, SKS '0325

This instruction skips if no error bit is set in the status word (bits 3 through 7 and 11 through 14).

SKIP IF NOT BUSY, SKS '0425

This instruction tests the disk control unit busy indicator and skips if the controller is not busy. The control unit is busy for the duration of a read, write, or write format operation, and for 50 μs after the beginning of a seek. See the relevant OCP descriptions for specific information about busy conditions.

SKIP IF UNIT NOT SEEKING, SKS 'XX25

These instructions (Table 1-4) test the seek indicator of each disk drive. Since the indicator is set near the end of the 50-μs seek cycle, a valid indication of unit seeking can be obtained only after the DCU has gone not busy.

SECTION II

TYPE 4651 2-SURFACE DUAL SPINDLE MOVING-HEAD DISK STORE OPTION

DESCRIPTION

The 2-Surface Dual Spindle Moving-Head Disk Store Option, Type 4651, consists of a disk control unit and one or two disk storage units. Each disk storage unit houses two disk drives and two disk packs, the recording media. The device is also available with only one spindle (Type 4650). Figures 2-1 and 2-2 show a 2-Surface Dual Spindle Unit and a 2-Surface Disk Pack, respectively. The disk control unit is referred to in this manual alternately as the DCU and as the disk controller. Unit, when used alone, is synonymous with disk storage unit.

Notice in Figure 2-3, the system block diagram, that the disk control unit may be connected to the central processor via either a direct multiplex control (DMC) channel or a direct memory access (DMA) channel. The DMC transfers data between memory and the peripherial devices over the standard I/O bus. The DMA transfers data to and from memory at high speed over a spacial data bus. DMC also allows use of the I/O bus; DMA does not. Although the option can operate via the I/O bus, Honeywell neither supports nor recommends such operation.

The recording medium, known as a disk pack, is an aluminum plate coated with magnetic material. A nonremovable, opaque plastic cassette protects the disk. The pack is physically interchangeable with the IBM Model 2315 disk pack. With required adjustments, the Honeywell drive can read from or write on an IBM disk. Figure 2-2 shows the disk pack with the cover elevated as when the heads are in position on the disk. The molded handle is on the far side of the disk as shown in the figure. Figure 2-4 shows the physical organization of the pack.

The Type 4651 reads from and writes on number 203 cylinders.* The term "cylinder" refers to a pair of recording tracks which are at the same radial distance from the hub. The drive detects the beginning of all tracks by sensing one physical index mark on the disk pack hub. Each track is divided into records in a format defined by the user. The fields within a record are discussed under "Programming Information" in this section.

*By convention, cylinders 200, 201, and 202 are used as spares.

The controller is described in Doc. No. 70130072318; the drive is described in Doc. No. 60036601002, 155 Disk Pack Drive Operation Maintenance Manual.

Type Number Information

To specify a 2-Surface Moving-Head Disk system, choose from the following types:

Type No.	
4651	Disk Control Unit with one Dual Spindle Disk Storage Unit (each DCU is capable of controlling up to four spindles)
4652	Additional Dual Spindle Disk Storage Unit (two Disk Storage Drives and two Disk Packs)
4650	Disk Control Unit with one Single Spindle Disk Storage Unit
4653	Additional Disk Pack

Timing

The timing of disk rotation, bit transfer, and head travel is shown in Table 2-1. The timing of specific data input and output operations will be discussed under "Programming Information" in this section.

Storage Capacity

The storage capacity of a disk pack depends on the format chosen for the tracks. Each track may be formatted for 1 to 103 records. The maximum capacity of a track is 1,891 words in one record. The 16.5-word overhead and the timing tolerance (5-percent gap) associated with each record reduce the net storage capacity as more records are formatted. Table 2-2 shows the gross storage capacity. Figure 2-5 shows the capacity of a track as a function of the number of records formatted on it. Table 2-3 shows record capacity as a function of the number of records per track for some commonly selected values.

OPERATION

Controls and Indicators

Each disk drive contains six indicator/switches which function as follows.

POWER ON (GREEN)

Press this switch to power up the unit and release the cover lock. POWER ON, LOAD, STOP, and PERMIT or PROTECT (depending on the state of the switch) will be illuminated.

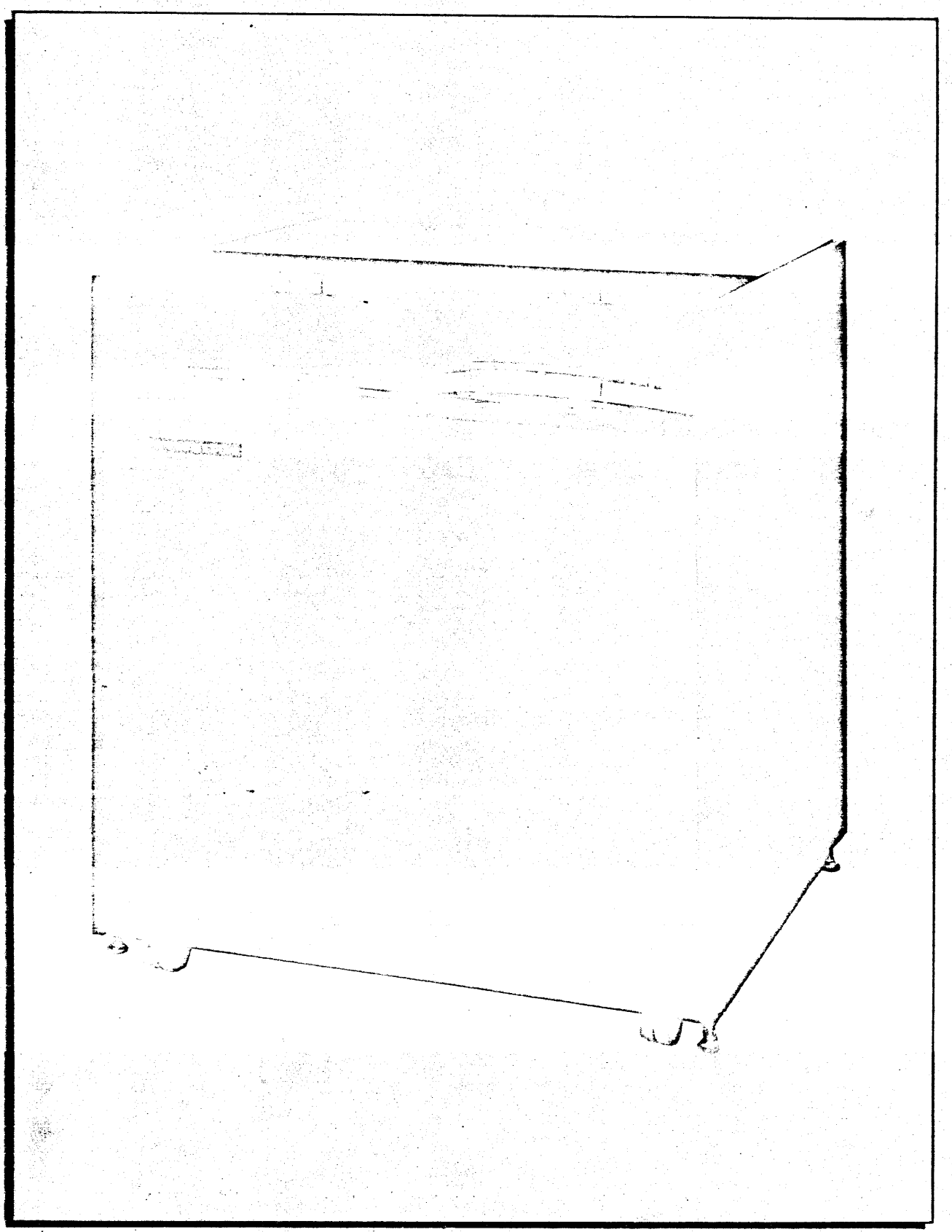


Figure 2-1. 2-Surface Dual Spindle Disk Storage Unit, Type 4651

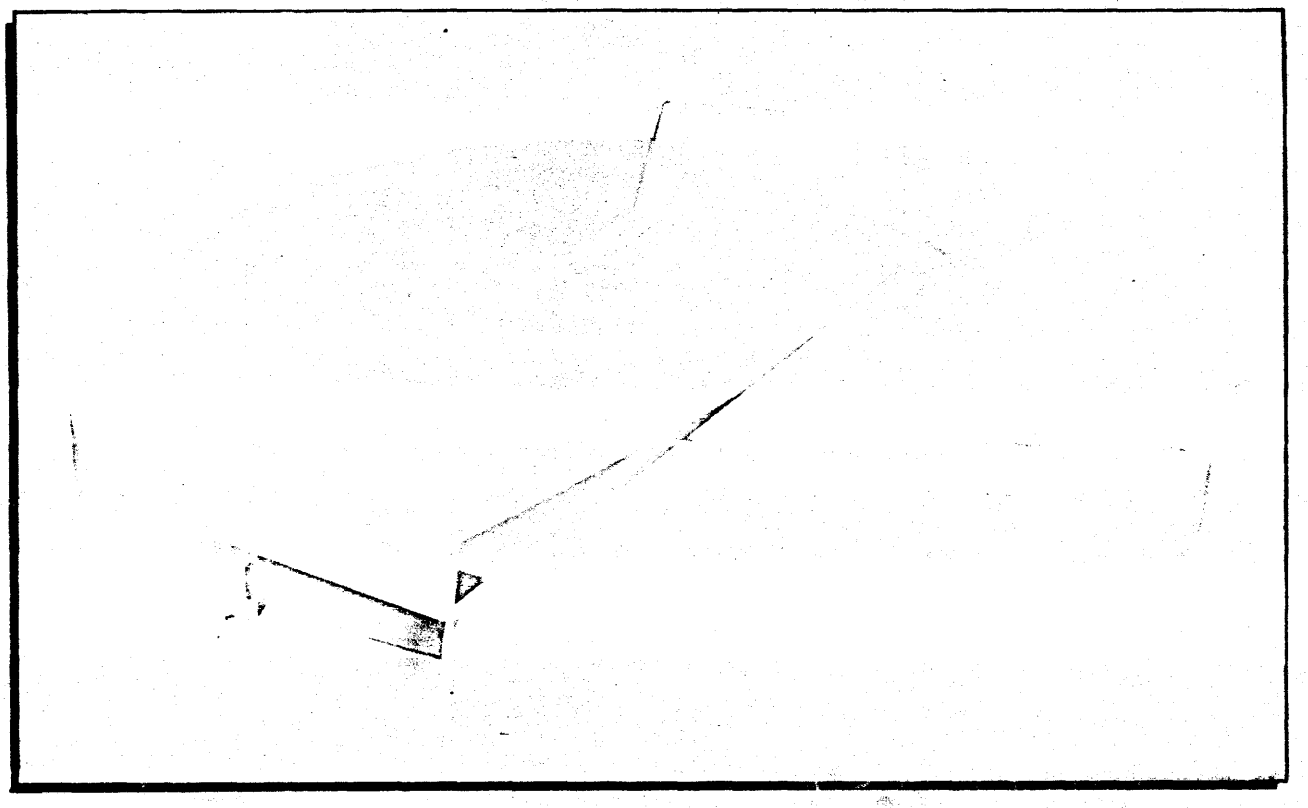


Figure 2-2. 2-Surface Disk Pack, Type 4653

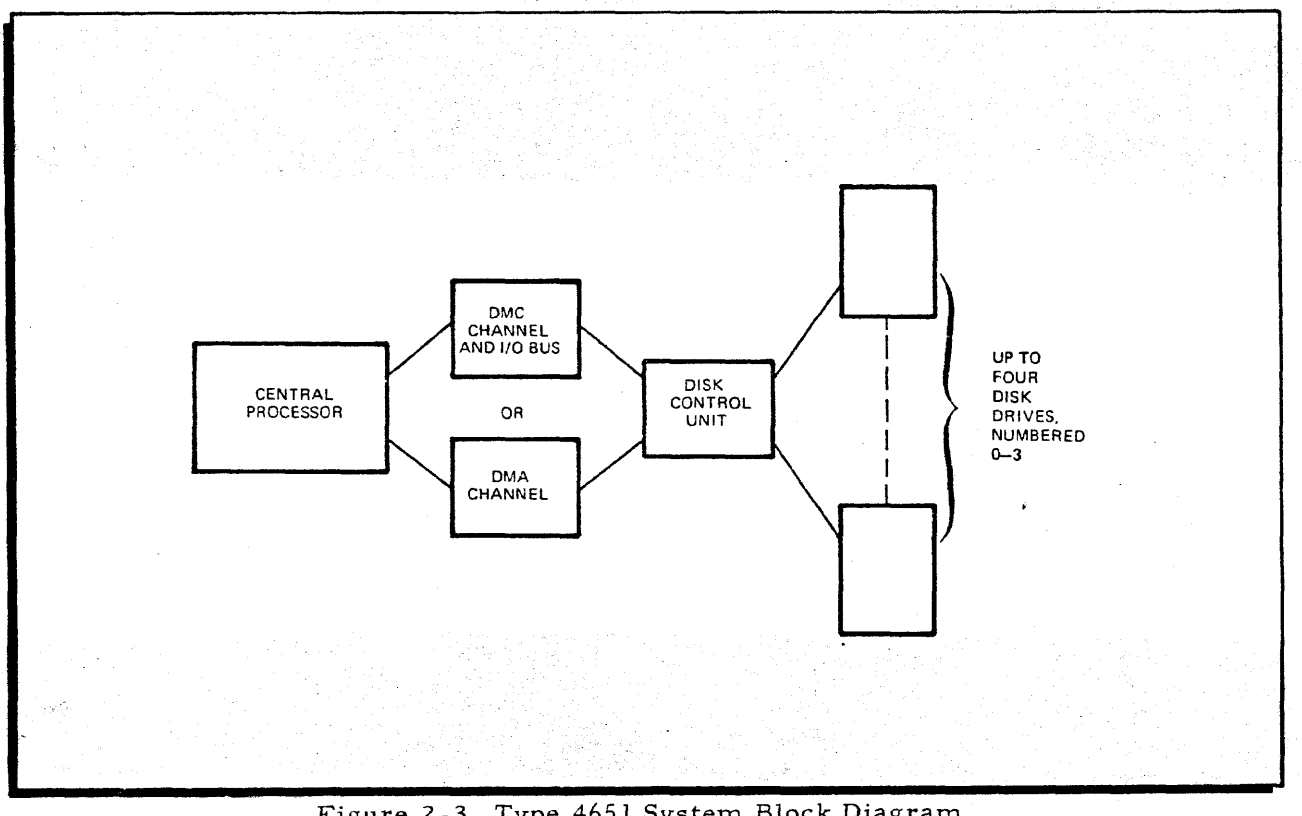


Figure 2-3. Type 4651 System Block Diagram

Table 2-1. Timing For Basic Type 4651 Disk Functions

Rotational speed	1683-1717 rpm
Time for one revolution	35.3 ms (nominal)
Average rotational latency (Time lapse for required data to move under head)	17.65 ms
Word transfer time	18.1μs
Word data aperture	17 μs
Maximum head travel time:	
1 cylinder	20 ms
200 cylinders	200 ms

Table 2-2. 2-Surface Dual Spindle Moving-Head Disk Capacity*

	Maximum	Minimum
Words per track	1,891	103
Words per surface	378,200	20,600
Words per disk pack	756,400	41,200
Words per control unit (with 4 drives)	3,025,600	164,000

*Maximum capacity is obtained with one 1,891-word record per track. Minimum capacity is obtained with 1-3 one-word records per track.

POWER OFF (RED)

Press this switch to remove power from the unit. POWER OFF will be illuminated; all other indicators are extinguished.

START/STOP

To start up the disk once power is on, load the disk packs, close the cover, and press START. Pressing START locks the cover, starts the spindle and disk rotating, loads the heads (positions them the correct distance above the surface of the disk), extinguishes STOP and LOAD, and illuminates START and READY. READY is illuminated approximately 45 seconds after START is illuminated.

To stop spindle rotation and unload the heads, press STOP. The cover lock is released, STOP and LOAD are illuminated, and START and READY are extinguished. LOAD is illuminated approximately 15 seconds after STOP is illuminated.

READY/LOAD

READY is illuminated when the heads are loaded on the associated drive. LOAD is illuminated when the heads are unloaded, and the disk cassette may be changed.

CHECK

CHECK is illuminated upon detection by the hardware of an improper combination of read, write, and erase heads or drivers (e.g., both read and erase). It also is illuminated when the head has been positioned outside its limits while the unit was being selected.

Press CHECK to clear the former conditions, then retry the operation. If this procedure fails, the error is not recoverable under software control. The latter condition, however, can be corrected by issuing a Seek Track Zero instruction to the controller.

PERMIT/PROTECT

The permit state allows writing or formatting on a disk. Since the unit cycles up (i.e., starts) in the protect state, press PERMIT before attempting either writing or formatting. With power on and the computer started, one of these indicators should illuminate.

Table 2-3. Type 4653 Record Capacity As Function of Records/Track

N'	D'	N'	D'	N'	D'	N'	D'
1	1891	9	186	17	90	25	56
2	914	10	166	18	84	26	53
3	599	11	149	19	79	27	50
4	443	12	135	20	74	28	48
5	350	13	123	21	70	29	46
6	288	14	113	22	66	30	44
7	244	15	106	23	62	31	42
8	212	16	97	24	59	32	40

N = No. of records/track.
D = No. of 16 bit words/record for G = 5%
Data applicable for primary power frequencies of 60 ±1/2 Hz or 50 ±1/2 Hz. For tolerances greater than 1/2 Hz, see "Track Format and Gap" later in this section.

Power

The main circuit breaker at the front of the disk drive controls power to the unit except for the main motor. Controller logic is powered from the computer. The main motor is controlled by the START switch and interlocked with the plastic cover.

Changing Disk Packs

Make certain the main circuit breaker is on before loading a disk pack. Open the plastic cover on the disk drive. Holding the pack by its molded handle on the front of the cassette, slide it back into the unit until it seats securely. Close the plastic cover of the disk drive immediately to keep out dust.

To remove a disk pack, push STOP and wait for LOAD to light. Then open the cover, remove the cassette, and close the cover.

PROGRAMMING INFORMATION

Relevant Hardware Information

INDEX MARK

Two slits on the hub of each disk pack, when sensed by a photoelectric device on the drive spindle, signal beginning-of-track to the controller.

UNIT NUMBER ASSIGNMENT

Each disk drive is assigned a number from 0 to 3 at installation time. Each drive should be labelled with the appropriate number.

TRACK FORMAT and GAP

Figure 2-6 shows the track format. Field A is a 16-bit field which allows for jitter in detection of the index mark. This field is recorded only before the first record of the track. Fields B, E, and K are 64-bit fields which allow for the distance between the erase head and the read/write head. Fields C, F, and J are special fields also used internally. Field D is the address which is a 24-bit field with the first 8 bits ignored. The remaining 16 bits contain a program-assigned address for each record. Field G contains the data of the record. Field H is a 16-bit record checksum for field G. Field L is a gap field which must be at least 5 percent of the total length of fields B through K:

$$L = 16(0.05(G + 16.5)) = 0.80G + 13.2$$

where L is the length of field L in bits, G is the length of field G in words, and 16.5 is the length in words of fields B through K except G. If the frequency tolerance exceeds 0.5 Hz, increase the gap proportionally. For example, with a tolerance of 1.0 Hz, increase the gap to 10 percent:

$$\frac{5\%}{0.5\ \text{Hz}} = \frac{\text{Gap}}{1.0\ \text{Hz}}$$

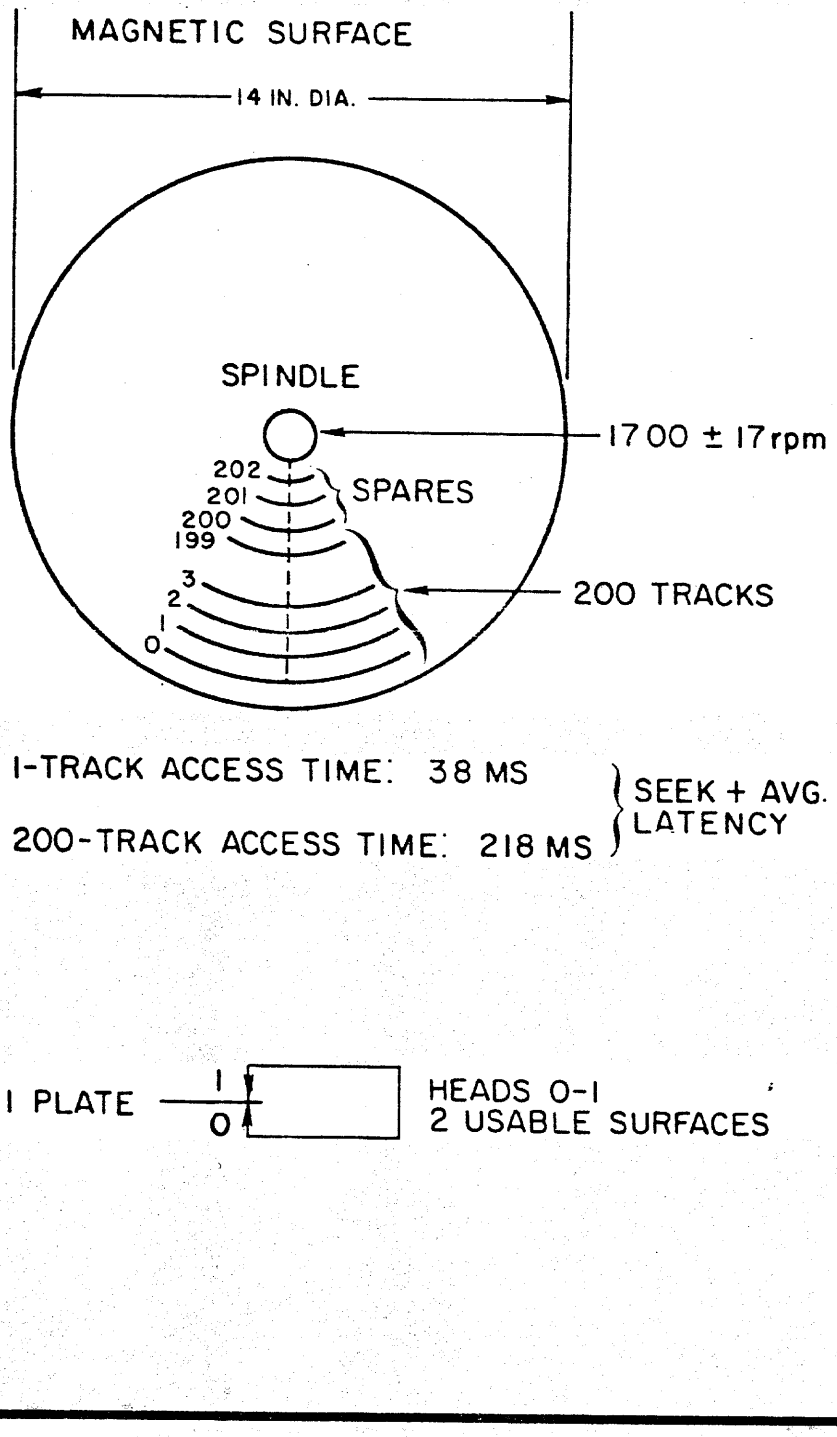


Figure 2-4. Physical Organization of Type 4653 Disk Pack

To access sequential records within the same rotation, take into account the time T between the end of busy for the first record (which will allow the next OCP to be sent) and output of the second setup word, as follows.

$$L = 16(0.05(G + 16.5) + 0.078T + 1.75)$$
$$= 0.08G + 41.2 + 1.25T$$

where T is in μs. The minimum time T between the initiating OCP and output of the second setup word is 55 μs.

STATUS WORD

The programmer can obtain detailed information about the state of important elements within the controller by requesting a status word transfer. In particular, the contents of the status word help him to determine if recovery from an error state is possible. Figure 2-7 shows the format of the status word with the significance of each bit (when set) called out.

SETUP WORDS

Six of the OCP instructions require one or two setup words which transfer information necessary for the particular operation. Figure 2-8 contains these six OCP's and the formats of the corresponding setup words.

CHECKSUM

As data is written onto the disk the controller accumulates a checkword. The word is formed by exclusively ORing all data words into a register. At the end of an n-word transfer, the checkword is a 16-bit even parity checksum which is written onto the disk as word n+1.

When data is read from the disk and passes back through the controller, the hardware recomputes the checksum. Word n+1 is included in the computation. If the result is non-zero the checksum error bit in the status word is set. A programmer may examine the checkword by requesting an n+1-word read operation.

INTERRUPT REQUESTS

Certain conditions cause hardware interrupt requests. These conditions are listed under "Acknowledge Interrupt, OCP '1425" in this section.

ACCESS TO DMC DEDICATED LOCATIONS

On a Model 316 with high-speed DMC the programmer is guaranteed access to DMC dedicated locations only when the disk controller is not busy. Mor information on this subject is presented in the 316/516 Programmers' Reference Manual (Doc. No. 70130072156) under "316 High-Speed DMC Dedicated Locations."

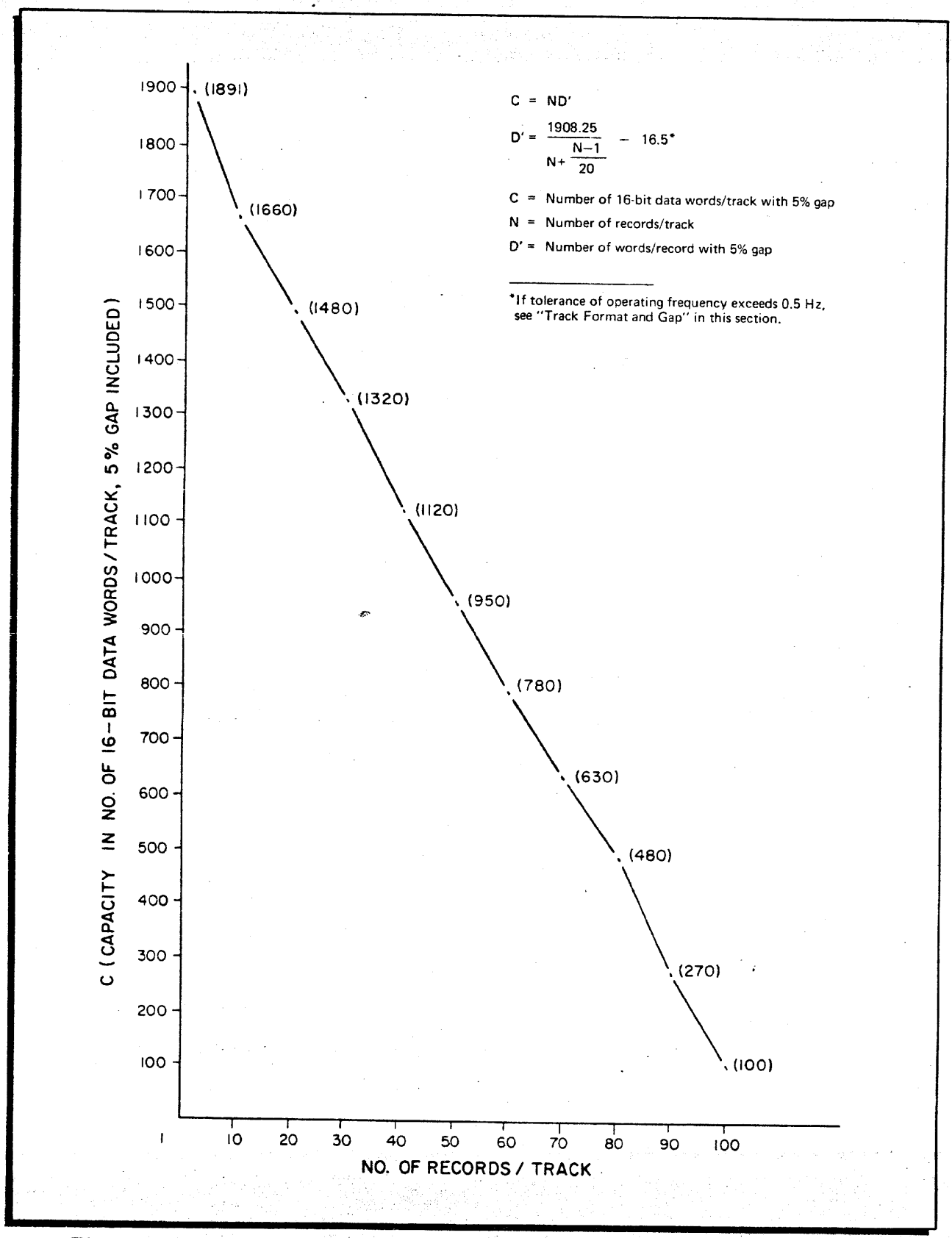


Figure 2-5. 2-Surface Disk Track Capacity vs Number of Records per Track

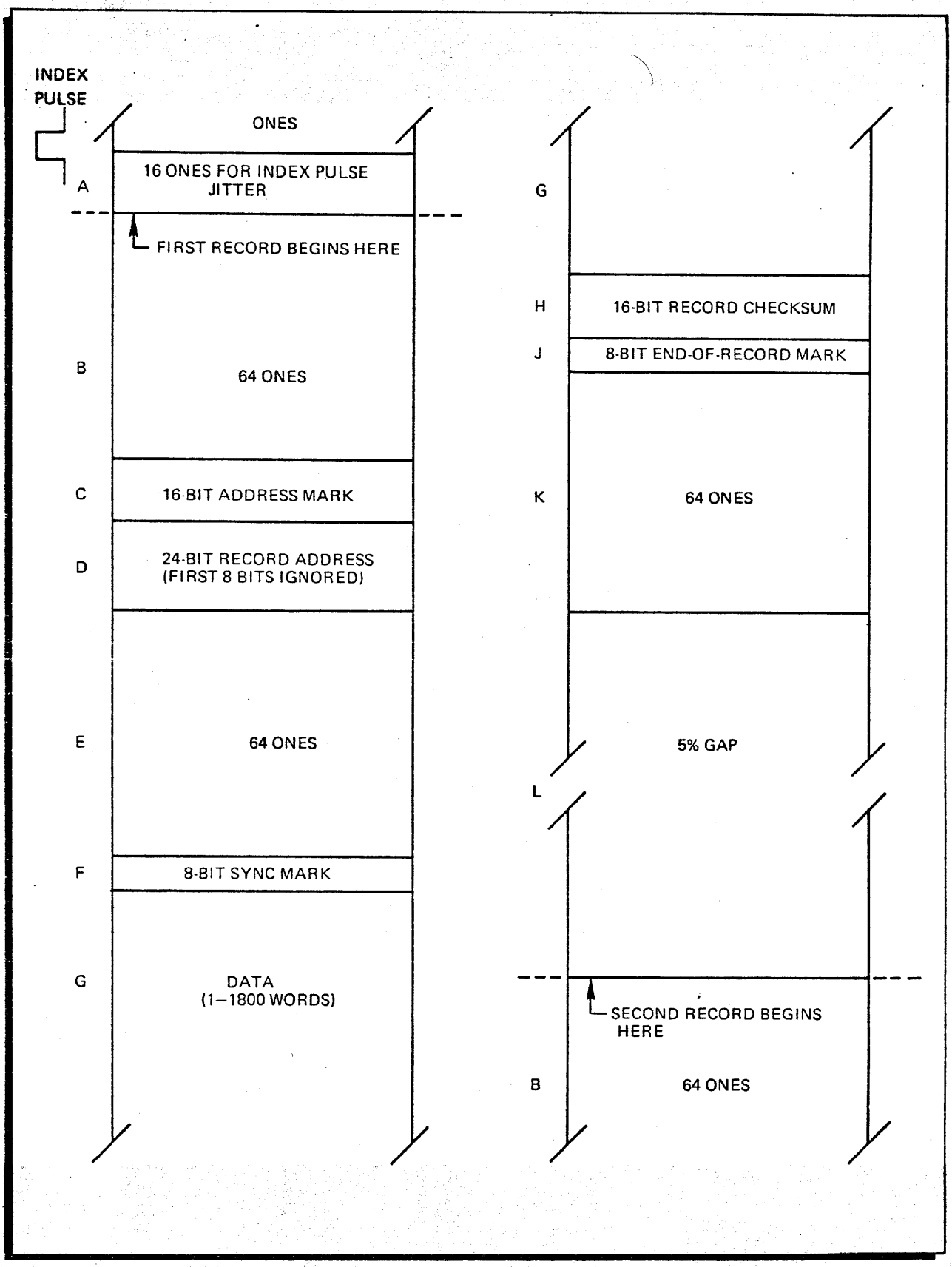


Figure 2-6. 2-Surface Disk Track Format

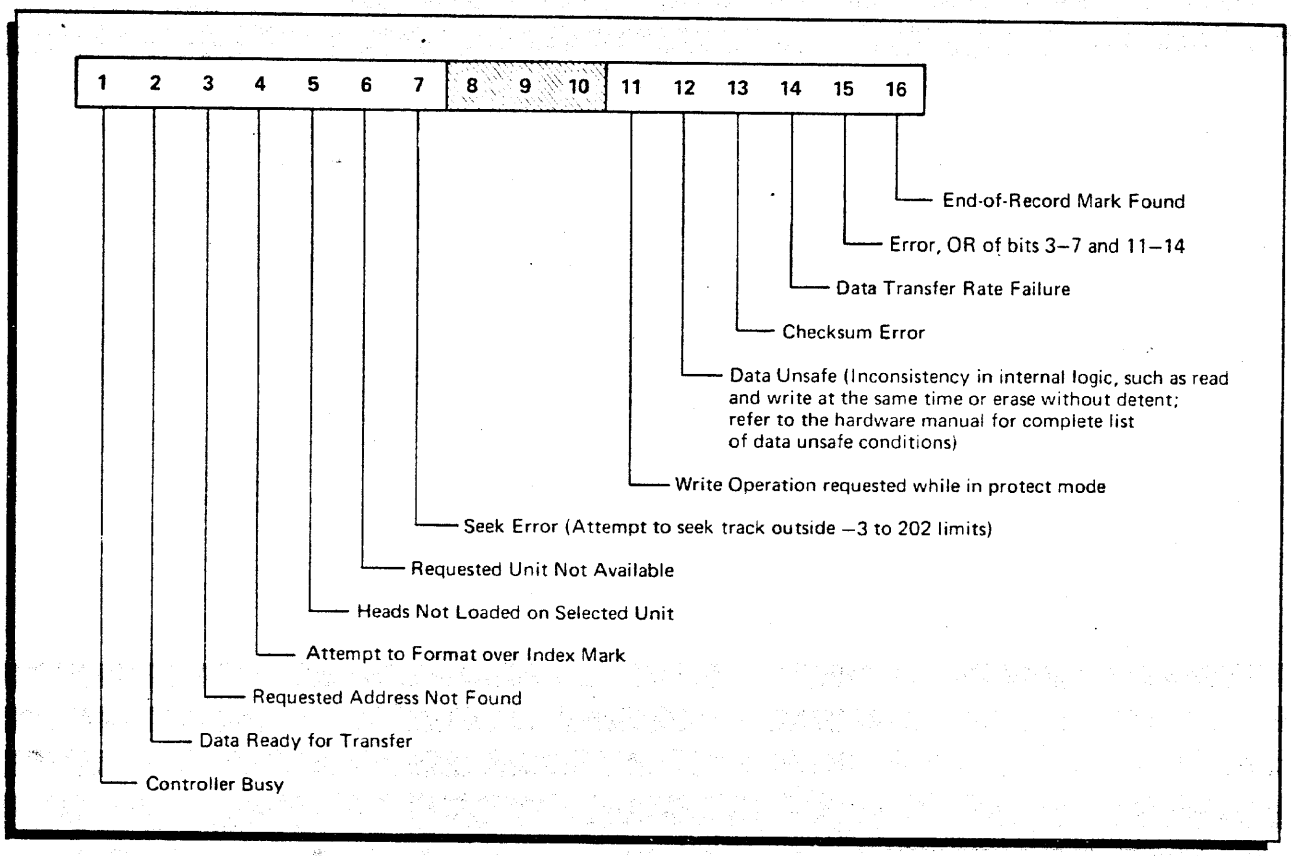
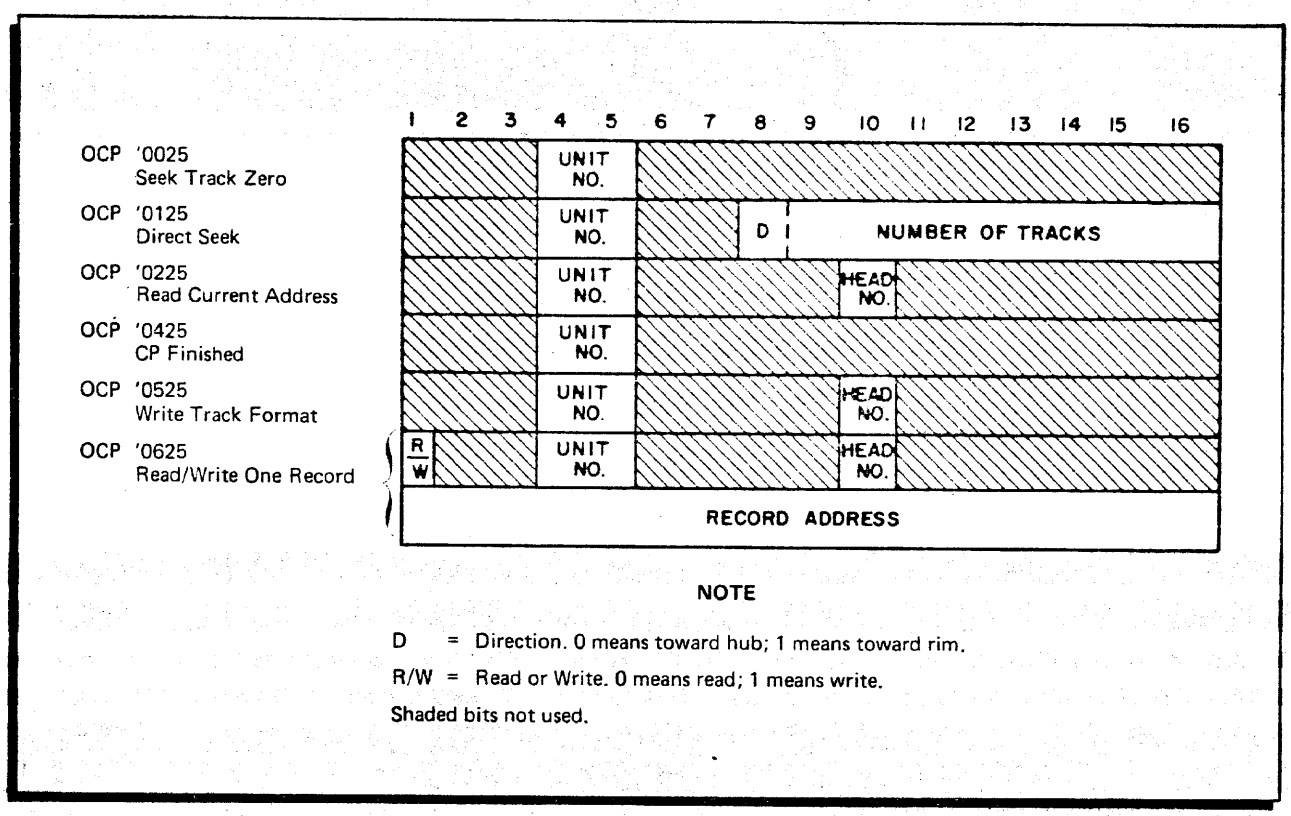


Figure 2-7. 2-Surface Disk Status Word Format



NOTE

D = Direction. 0 means toward hub; 1 means toward rim.

R/W = Read or Write. 0 means read; 1 means write.

Shaded bits not used.

Figure 2-8. 2-Surface Disk Instructions with Required Setup Words

General Instruction Sequences

The instruction complement for the Type 4651 is given in Table 2-4. Tables 2-5 through 2-8 give appropriate instruction sequences for common operations.

Table 2-4. 2-Surface Moving-Head Disk Instructions*

OCP '0025	Seek track zero
OCP '0125	Direct seek
OCP '0225	Read current address
OCP '0425	CP finished
OCP '0525	Write track format
OCP '0625	Read or write one record
OCP '1025	Stop transfer
OCP '1125	Read status word
OCP '1325	Enable DMC/DMA mode
OCP '1425	Acknowledge interrupt
OCP '1725	Enable I/O bus mode
INA 'X025	Input from disk to A-register if ready
OTA '0025	Output contents of A-register to disk if ready
SKS '0025	Skip if ready
SKS '0125	Skip if disk not requesting interrupt
SKS '0225	Skip if operational
SKS '0325	Skip if no error
SKS '0425	Skip if not busy
SKS '1125	Skip if unit 0 not seeking
SKS '1225	Skip if unit 1 not seeking
SKS '1325	Skip if unit 2 not seeking
SKS '1425	Skip if unit 3 not seeking
SMK '0020	Set interrupt mask (bit 4)

*The address of the moving head disk control unit is 25. X in INA 'X025 may be either 1 or 0: 1 m ans clear the A-register before input; 0 means input without first clearing.

SEEK, SEEK TRACK ZERO

Before information can be transferred to or from a record, the head must be positioned on the proper track. Two instructions perform this function. One is an absolute seek to cylinder 000. The other moves the head a specified number of cylinders in either direction from the current position. The programmer is expected to keep track of the current head position within his program. Table 2-5 shows the sequence of operations required for the seek operations.

Table 2-5. 2-Surface Disk Seek and Seek Track Zero Instruction Sequence

Step	I/O Bus & DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	Test if drive seeking	Test if drive seeking
3	-	Set up DMA for one-word transfer
4	Execute seek instruction	Execute seek instruction
5	Output setup word	(Enter DMA)
6	-	(End-of-range)
7	Handle seek complete interrupt request	Handle seek complete interrupt request

CP FINISHED

Execution of the CP finished instruction causes the selected unit to seek track zero and power down. The sequence of operations required for a CP finished instruction is shown in Table 2-6.

Table 2-6. 2-Surface Disk CP Finished Instruction Sequence

Step	I/O Bus and DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	-	Set up DMA for one-word transfer
3	Execute CP finished instruction	Execute CP finished instruction
4	Output setup word	(Enter DMA)
5	-	(End-of-range)

READ CURRENT ADDRESS

Disks are often formatted so that the address of each record identifies the track, head, and unit. By reading the address of the next record formatted under such a system, a programmer can determine the track location and relative rotational position of the heads on the disk.

Table 2-7 shows the sequence of operations required for reading the current address. When the DMA is used, the address is returned as the second word of the two-word buffer.

Table 2-7. 2-Surface Disk Read Current Address Instruction Sequence

Step	I/O Bus	DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator	Test control unit busy indicator
2	-	Set up DMC for one-word input transfer	Set up DMA for two-word output transfer
3	Eanble transfer via I/O bus	Enable transfer via DMC/DMA	Enable transfer via DMC/DMA
4	Execute, read current address instruction	Execute read current address instruction	Execute read current address instruction
5	Output setup word	Output setup word	(Enter DMA)
6	INA current address	(Enter DMC)	(Disc control unit switches DMA to input)
7	Return to DMC/DMA mode	(End-of-range)	(End-of-range)

WRITE TRACK FORMAT

Table 2-8 shows the sequence of operations required for writing a track format. Formatting takes place in the following order (after the setup word)

a. Record address

b. Data for every word in the record (may be blank or filler)

c. End-of-range

d. Five-percent gap word (whose value is the number of bit cells in the gap field)

e. Repetition of steps a. through d. for each record

f. End-of-range, adknowledge interrupt, and stop transfer after the last record (which will write gap to the track origin)

The 5-percent gap word related to the previous record must be output as the first word of the block being output for the present record

Because of timing constraints, the CPU must be dedicated exclusively to formatting. Time-sharing or multiprogramming is not possible, because time is not available to handle interrupts.

Table 2-8. 2-Surface Disk Write Track Format Instruction Sequence

Step	DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	Set up DMC for n+1-word output[a]	Set up DMA for n+2 output[b]
3	Enable transfer via DMC/DMA	Enable transfer via DMC/DMA
4	Execute write track format instruction	Execute write track format instruction
5	Output setup word	(Enter DMA)
6	(Enter DMC)	
7	(End of range)	(End of range)
8	Reinitialize DMC for n+2-word output[c]	Reinitialize DMA for n+2-word output[c]
9	(Enter DMC)	(Enter DMA)
10	Repeat steps 6 through 9 for each record	Repeat steps 6 through 9 for each record
11	Reinitialize DMC for 1-word output[d]	Reinitialize DMA for 1-word output[d]

[a] For the first DMC transfer, word 1 should be the record address and the remaining n words should be data.

[b] For the first DMA transfer, word 1 should be the setup word, word 2 should be the record address, and the remaining n words should be data.

[c] For subsequent DMC or DMA transfers, word 1 should be the 5%-gap word for the preceding record, word 2 should be the record address, and the remaining n words should be data.

[d] The last DMC or DMA transfer should be the 5%-gap word for the previous record. The setup must be accomplished within 60 μs and the subsequent interrupt request followed by stop transfer and acknowledge (clear) interrupts commands. The drive will write gap until it detects track origin.

If the programmer has ensured that enough space remains on the disk for gap for the final record (he may include the 64-bit field A), he need not transfer the 5% gap for the final record. If the last gap word is not transmitted or timing requirements are not satisfied, the drive writes gap to track origin and sets the data-transfer rate-failure bit in the status word.

READ OR WRITE ONE RECORD

The sequence of instructions for these two operations is almost identical. The data words, preceded by two setup words, are transferred between the computer and the disk. The address is read but not modified. The record checksum is written or read and compared but is not transferred to the computer unless a read has been specified for more words than the record contains. Table 2-9 shows the sequence of operations required for reading or writing one record.

Table 2-9. 2-Surface Disk Read or Write One Record Instruction Sequence

	DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	Set up DMC for n-word input or output	Set up DMA for N+2-word output[a]
3	Enable transfer via DMC/DMA	Enable transfer via DMC/DMA
4	Execute read/write one record instruction	Execute read/write one record instruction
5	Output first setup word	(Enter DMA)
6	Output second setup word[b]	—
7	(Enter DMC)	(Disk control unit switches DMA to input when reading)
8	(End-of-range)	(End-of-range)

[a] For DMA transfers, words 1 and 2 must be the setup words; the remaining n words are data storage locations.

[b] The time of the second setup word is critical only if sequential access within the same rotation is desired (see "Track Format and Gap", a preceding paragraph).

In an under-range read, the controller transfers the specified number of words to memory and discards the remainder of the record. The controller becomes not busy shortly after the end-of-record mark is detected. The checksum is handled as in a normal read. An over-range read, which inputs the checksum word (often useful for error recovery), terminates at the end-of-record mark. The checksum error bit (bit 13 in the status word) is valid as in a normal read. An under-range write causes no problems.

An over-range write will reduce the gap field correspondingly for up to four words over the original format. If more than four words are written beyond the format, the next record (and format) is destroyed. The record is readable under most circumstances.

READ STATUS WORD

The sequence in Table 2-10 shows the order of instructions to read the contents of the status register. With DMC it is easiest to code this operation using the I/O bus as shown below, although DMC is perfectly acceptable.

Table 2-10. 2-Surface Disk Read Status Word Instruction Sequence

Step	I/O Bus	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	Enable I/O bus	Set up DMA for one-word input transfer
3	Execute read status word instruction	Execute read status word instruction
4	Input status word	(Enter DMA)
5	Enable DMC/DMA	(End-of-range)

Instruction Descriptions

SEEK TRACK ZERO, OCP '0025

This instruction and its associated setup word cause the heads on the selected unit to move to track 000. The disk control unit busy indicator is set for 70 μs after the set-up word is output; the seeking indicator of the selected unit is set for 20 to 200 ms after the setup word is output (see Table 2-1). More than one disk drive may be seeking at a time. When the heads reach track zero, the controller generates an interrupt request (which may be delayed until the controller becomes not busy). This instruction will be ignored if issued while the disk control unit busy indicator is set. A seek-track-zero instruction executed with the heads already on track zero is processed the same as a seek-track-zero from any other position.

DIRECT SEEK, OCP '0125

This instruction and its associated setup word cause the heads on the selected unit to move the number of tracks specified by bits 9 through 16 of the setup word and in the direction specified by bit 8 of the setup word, where 0 means toward the center of the disk (higher track numbers) and 1 means toward the outside of the disk (lower track numbers). If the disk control unit detects a 0 in the difference field (bits 9 through 16), it sends no orders to the disk drive, sets the seek error bit in the status word, and generates an interrupt request. The disk control unit busy indicator is set for 70 μs after the setup word is output; the seeking indicator of the selected unit is set for 20 to 200 ms after the setup word is output. This instruction is ignored if issued while the disk control unit busy indicator is set.

The programmer can code several units to seek concurrently with successive OCP seeks and setup words. He must test for controller busy between OCP's. If several units are seeking, the programmer can either acknowledge interrupts as they occur or wait until all units have finished seeking, and then clear all interrupt requests with one

acknowledge interrupt. An interrupt request will be delayed until the controller becomes not busy (e.g., a data transfer immediately follows a seek). A seek directed to a non-existent track will result in a seek to zero and a seek error in the status word.

READ CURRENT ADDRESS, OCP '0225

This instruction and its associated setup word cause the next address encountered on the selected track by the selected track by the selected head to become available on the input bus. The disk control unit busy indicator is set from the time the setup word is ouput until the address becomes available to the central processor. The ready indicator is then set, the busy indicator is reset, and an interrupt request is generated. This OCP has no effect if issued while the DCU is busy.

CP FINISHED, OCP '0425

Execution of this instruction and its associated setup word cycles down the unit and illuminates both the STOP and LOAD indicators. A programmer may code this operation to signal the operator that a certain disk is no longer needed by the execution program. The DCU busy indicator remains set for 70 ms after the setup word OTA. No interrupt request is generated.

WRITE TRACK FORMAT, OCP '0525

This instruction and its associated setup word cause the selected head on the selected head on the selected unit to detect the track origin and write a new format on the track. In addition, data may be written in the newly formatted records. The address, the data, and the gap size are under program control.

If the output transfer rate is not maintained by the computer, the disk control unit aborts the operation, writes gap to the track origin, and sets the data-transfer rate-failure bit in the status word. The DCU is busy from the time of the order initiation OCP until formatting terminates at track origin a maximum of 70 μs later. Refer to "Track Format and Gap" earlier in this section for information on how to format to access sequential records on a track.

READ OR WRITE ONE RECORD, OCP '0625

This instruction and its two associated setup words cause the selected head on the selected disk drive to read or write one record at the specified record address on the current cylinder. Bit 1 of the first setup word must be 0 for read and 1 for write.

Read

The unit reads until one of the following conditions occurs.

a. End-of-record is sensed.

b. The computer fails to maintain the necessary input transfer rate.

c. Two index pulses are tallied.

d. The stop transfer instruction (OCP '1025) is executed or DMC/DMA end-of-range occurs. Data transfer will cease, but the disk control unit continues reading to the end of the record. When a stop transfer instruction is executed during a read operation, the last data word transferred (before the instruction takes effect) will be interpreted as a checksum. The checksum error bit in the status word may be set. This feature is useful in test programs.

The control unit busy indicator is set from the time the OCP is issued until the read is completed in one of the four ways listed above.

If the program specifies a larger number of words (range) to be read than the record contains, the record checksum is transferred to the central processor as if it were data, and the end-of-record is sensed before the next word is transferred. If, at the end of the read operation, the checking logic indicates an error, the checksum error bit in the status word is set.

Write

Data is written into the addressed record until one of the following conditions occurs.

a. The stop transfer instruction (OCP '1025) is executed or DMC/DMA end-of-range occurs.

b. The computer fails to maintain the necessary output transfer rate.

c. Two index pulses are tallied.

When condition a. or b. is encountered, the word being written is finished, and the checksum record is written along with the end-of-record mark and the field of ones (fields H, J, and K of Figure 2-6). When condition c. occurs, the operation is terminated immediately.

The programmer should make sure that the record written is no larger than allowed by the record format. If it is too long by four words or less, the 5% gap will be diminished, but the following record will not be affected. If it is more than four words too long, the following records are destroyed.

The controller is busy from the time the OCP is issued until a. b. or c. above terminates the operation. The read/write operation may be requested when one or more units are seeking and will be executed either immediately or when the appropriate seek is complete. Any pending interrupt request is delayed until the operation is complete, i.e., the controller becomes not busy.

STOP TRANSFER, OCP '1025

This instruction, which does not require a setup word, stops track formatting if issued immediately after the DCU has received the last data word. If OCP '1025 is not issued within 70 μs of end-of-range for the last record formatted, the data-transfer rate-failure bit in the status word is set. Execution of a stop transfer instruction forces the controller to not busy. In this way, a programmer can clear a busy hangup which may result from an OCP with no setup word transfer or a hardware fault. If issued during a read operation, this instruction forces a diagnostic checksum (see "Read," preceding).

READ STATUS WORD, OCP '1125

This instruction causes the status word to be the next data-like word transferred via I/O bus, DMC, or DMA (whichever is enabled). Code INA '0025 or '1025 after the OCP to make the transfer via I/O bus. For DMC or DMA transfers, initialize the channel before issuing the OCP. Before issuing OCP '1125 while the DCU is busy, delay 70 ms (two revolutions) to allow completion of any transfer in progress. Reading the status word does not alter the state of the controller other than to clear the status request. See Figure 2-7 for the status word format.

ENABLE DATA TRANSFER VIA DMC/DMA, OCP '1325
ENABLE DATA TRANSFER VIA I/O BUS, OCP '1725

OCP '1325 (or '1725), which does not require a setup word, enables the disk control unit to use the DMC/DMA (or I/O bus) exclusively. It does not initiate an order to any of the disk drives.

Pressing MSTR CLEAR initializes the system for DMC or DMA transfers. To initialize the system for I/O bus transfers, execute OCP '1725 before executing the OCP which implies the data transfer (e.g., OCP '0625, Read One Record). Transfers are enabled via the I/O bus until OCP '1325 is executed or the computer is MSTR CLEARed.

ACKNOWLEDGE INTERRUPT, OCP '1425

This instruction, which does not require a setup word, does not initiate any orders to the disk drives but does reset (clear) an interrupt request if one is present. The following situations cause interrupts if allowed.

a. The disk control unit goes from busy to not busy, except for the 70-μs busy at the beginning of a seek, CP-finished, or read status word instruction. Any OCP, except read status word, addressed to the disk control unit resets this interrupt request.

b. A seek operation is completed. If this happens when the disk control unit is busy, the interrupt is delayed until the control unit goes to not busy. If a direct seek is requested and its setup word specifies a difference of zero tracks, this interrupt request is generated immediately. Only OCP '1425 resets this interrupt request.

c. A disk drive error (bits 5, 6, 7, 11, or 12 in the status word) is detected. The operation is terminated, and an interrupt request is generated at the end of the 70-μs order process interval.

d. End-of-range is reached in write track format operations with DMC/DMA mode set. The interrupt signals the program to reinitialize the DMC/DMA within the time constraints. It may be cleared by OCP '1425 during the format operation or by OCP '1425 or OCP '1025 at the end of a format operation.

INPUT FROM DISK TO A-REGISTER IF READY, INA '0025

If the disk control unit has a data word ready for transfer, this instruction ORs the word from the DCU into the A-register and skips the next instruction. At the completion of the instruction, data ready and status request are reset. If data is not ready, INA '0025 is treated as a NOP. To maintain the data transfer rate, INA must be executed within 17 μs of the time data becomes ready (time constraints do not apply for status and address transfers). INA '0025 is not applicable to a DMA configuration.

CLEAR A-REGISTER AND INPUT FROM DISK TO A-REGISTER IF READY INA '1025

This instruction performs a function similar to that above, except the A-register is cleared before the data is ORed in.

OUTPUT TO MOVING-HEAD DISK IF READY, OTA '0025

If the data ready indicator is set, this instruction outputs data (usually a setup word) to the moving-head disk, resets data ready, and skips the next instruction. If data ready is reset, the instruction is treated as a NOP. The timing requirements for disk data are the same as for INA '0025 and '1025. Timing of setup words is noncritical. OTA '0025 is not applicable to a DMA configuration.

SET INTERRUPT MASK (BIT 4), SMK '0020

The state of the standard interrupt mask for the moving-head disk is made equal to bit 4 of the A-register (which must contain the entire mask word) by executing SMK '0020.

SKIP IF READY, SKS '0025

The data ready indicator is used on both read and write operations to signal that another word may be transferred to or from the disk control unit. SKS '0025 tests this indicator. This instruction generally is not useful.

SKIP IF NOT INTERRUPTING, SKS '0125

This instruction skips if the disk control is not generating an interrupt request. Interrupt conditions are listed under OCP '1425.

SKIP IF OPERATIONAL, SKS '0225

This instruction skips if the DCU is not busy and if no error bits in the status word are set. It skips if the previous data transfer was completed satisfactorily or a seek operation started without error.

SKIP IF NO ERROR, SKS '0325

This instruction skips if no error bit is set in the status word (bits 3 through 7 and 11 through 14).

SKIP IF NOT BUSY, SKS '0425

This instruction tests the disk control unit busy indicator and skips if the controller is not busy. The control unit is busy for the duration of a read, write, or write format operation, and for 70 μs after the beginning of a seek. See the relevant OCP descriptions for specific information about busy conditions.

SKIP IF UNIT NOT SEEKING, SKS 'XX25

These instructions (Table 2-4) test the seek indicator of each disk drive. Since the indicator is set near the end of the 70-μs seek cycle, a valid indication of unit seeking can be obtained only after the DCU has gone not busy.

SECTION III

TYPE 4623 10-SURFACE SINGLE SPINDLE MOVING-HEAD DISK FILE OPTION

DESCRIPTION

The 10-Surface Single Spindle Moving-Head Disk File Option, Type 4623, consists of a disk control unit and one to eight disk storage units. Each disk storage unit houses a disk drive and a disk pack, the recording medium. Figure 3-1 shows the 10-Surface Single Spindle Disk Storage Unit, and Figure 3-2 shows the 10-Surface Disk Pack. The disk control unit is referred to in this manual alternately as the DCU and disk controller. Unit, when used alone, is synonymous with the disk storage unit.

The system block diagram, presented in Figure 3-3, shows that the disk control unit may be connected to the central processor through either a direct multiplex control (DMC) channel or a direct memory access (DMA) channel. The DMC transfers data between memory and the peripheral devices over the standard I/O bus. The DMA transfers data to and from memory at high speed over a special data bus. DMC also allows use of the I/O bus; DMA does not. Although this option can operate via the I/O bus, Honeywell neither supports nor recommends such operation.

The recording medium, a Honeywell M-4005, is a stack of six magnetic oxide coated aluminum plates on a common shaft with a plastic handle and cover assembly. The pack is physically interchangeable with the IBM Model 1316 disk pack. With required adjustments, the Honeywell drive can read from or write on an IBM disk. Figure 3-4 shows the physical organization of the Honeywell disk pack.

The Type 4623 option reads from and writes on number 203 cylinders.* The term "cylinders" refers to a set of 10 recording tracks which are at the same radial distance from the hub. The drive detects the beginning of all tracks by sensing one physical index mark on the disk pack hub. Each track is divided into records in a format defined by the user. The fields within a record are discussed under "Programming Information" later in this section.

The disk controller is described in Doc. No. 70130072318; the drive is described in Doc. No. 60022580, 60022581, and 60022585, 259 Disk Pack Drive Operation-Maintenance Manual and Illustrated Parts Manual.

*By convention, cylinders 200, 201, and 202 are used as spares.

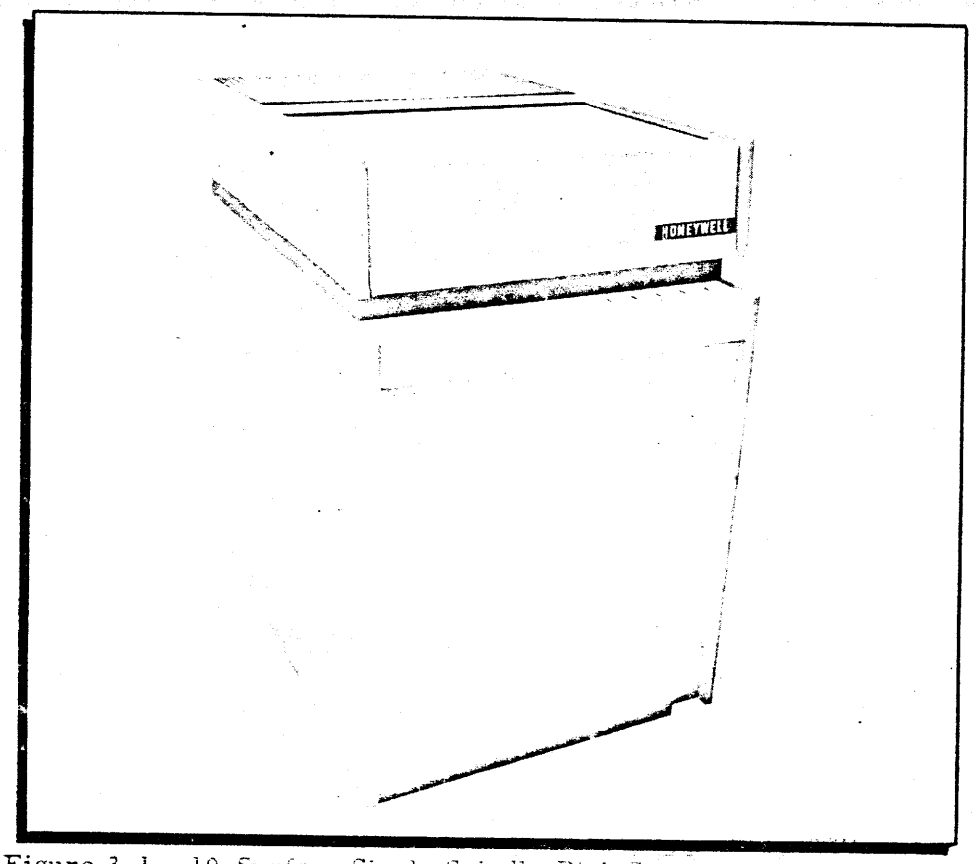


Figure 3-1. 10-Surface Single Spindle Disk Storage Unit, Type 4623

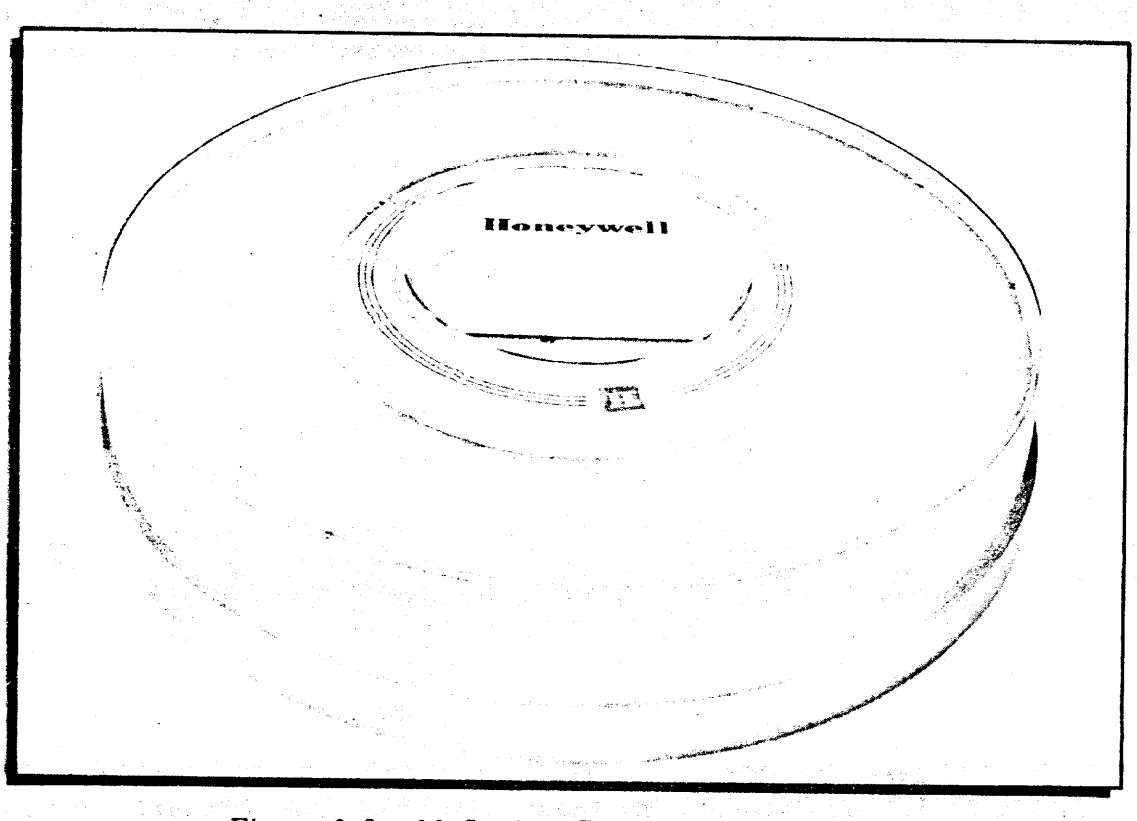


Figure 3-2. 10-Surface Disk Pack, Type 4622

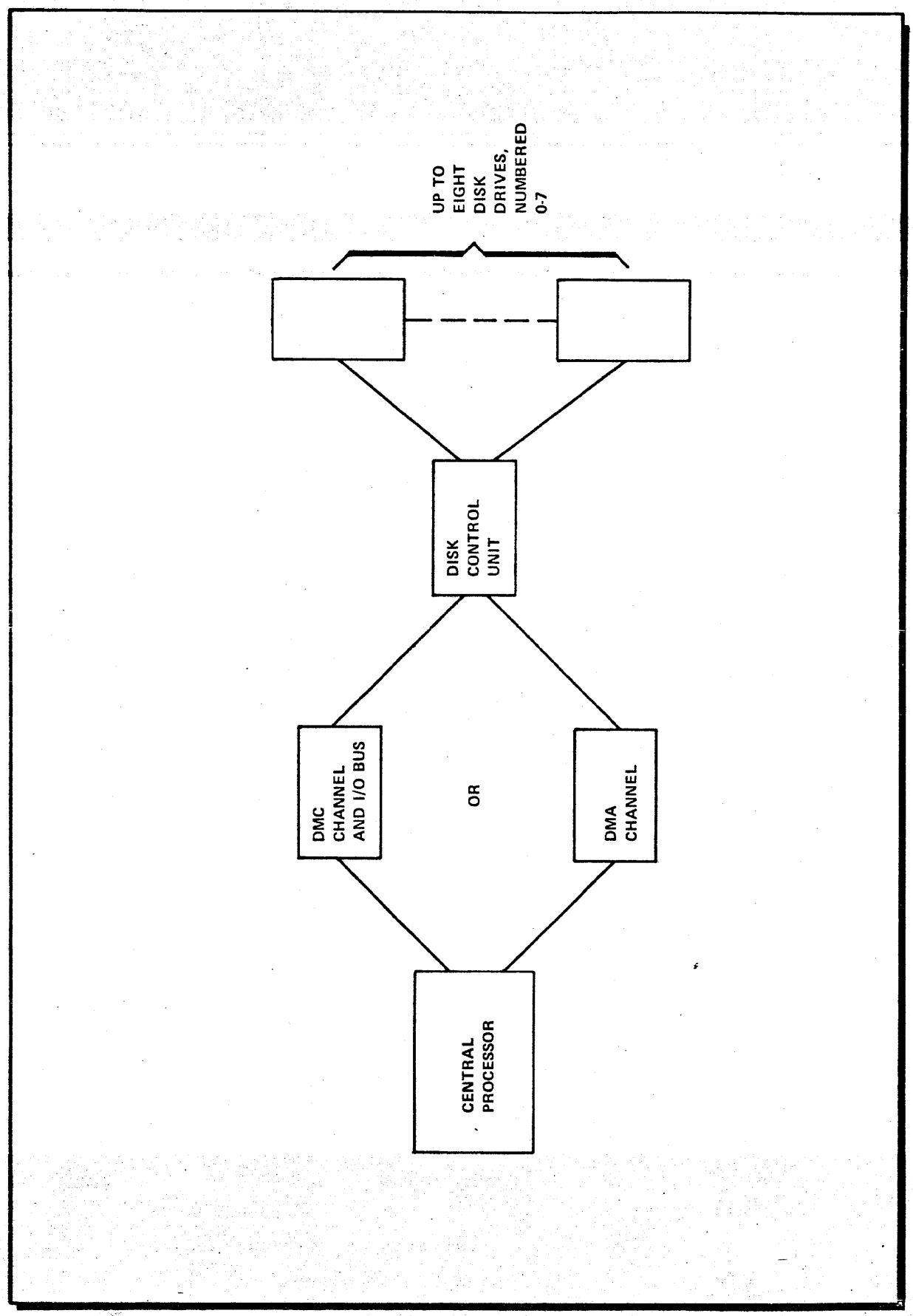


Figure 3-3. Type 4623 System Block Diagram

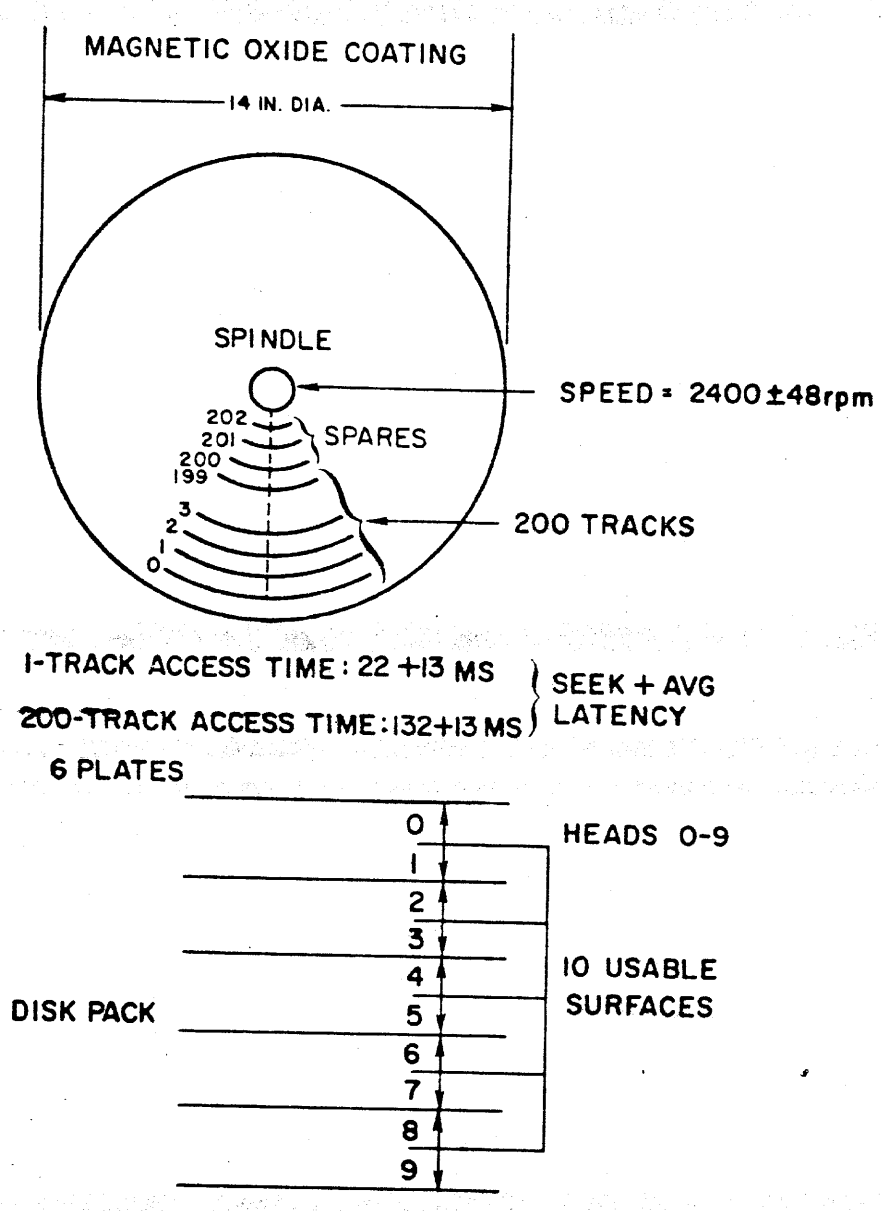


Figure 3-4. Physical Organization of Type 4622 Disk Pack

Type Number Information

To specify a 10-Surface Moving-Head Disk system, choose from the following types.

Type No.	
4622	Additional Disk Pack
4623	Disk Control Unit with one Disk Storage Unit (each DCU is capable of controlling up to eight Disk Storage Units)
4624	Additional Disk Storage Unit (Disk Storage Drive and Disk Pack)

Timing

The timing of disk rotation, bit transfer, and head travel is shown in Table 3-1. The timing of specific data input and output operations is discussed under "Programming Information" in this section.

Table 3-1. Timing for Basic Type 4623 Disk Functions

Rotational Speed	2352-2448 rpm
Timing for one revolution	25 ms (nominal)
Average rotational latency (Time lapse for required data to move under head)	12.5 ms
Word transfer time	12. μs
Word data aperture	12 μs
Maximum head travel time:	
1 cylinder	22 ms
200 cylinders	132 ms

Storage Capacity

The storage capacity of a disk pack depends on the selected track format. Each track may be formatted for 1 to 103 records. The maximum capacity of a track is 1,800 words in 1 record. The 16.5-word overhead and the timing tolerance (5-percent gap) associated with each record reduce the net storage capacity as more records are formatted.

Table 3-2 shows the gross storage capacity. Figure 3-5 shows the capacity of a track as a function of the number of records formatted on it. Table 3-3 shows record capacity as a function of the number of records per track for some commonly selected values.

Table 3-2. 10-Surface Moving-Head Disk Capacity*

	Maximum	Minimum
Words per track	1,800	103
Words per surface	360,000	20,600
Words per disk pack	3,600,000	206,000
Words per control unit (with 8 drives)	28,800,000	1,648,000

*Maximum capacity obtained with one 1,800-word record per track; minimum capacity obtained with 103 one-word records per track.

Table 3-3. Type 4622 Record Capacity as a Function of Records/Track*

N	D'	N	D'	N	D'
1	1800	12	128	23	58
2	869	13	117	24	55
3	569	14	107	25	52
4	421	15	99	26	50
5	332	16	91	27	47
6	274	17	85	28	45
7	232	18	79	29	43
8	200	19	74	30	41
9	186	20	70	31	39
10	157	21	66	32	37
11	141	22	62	33	36

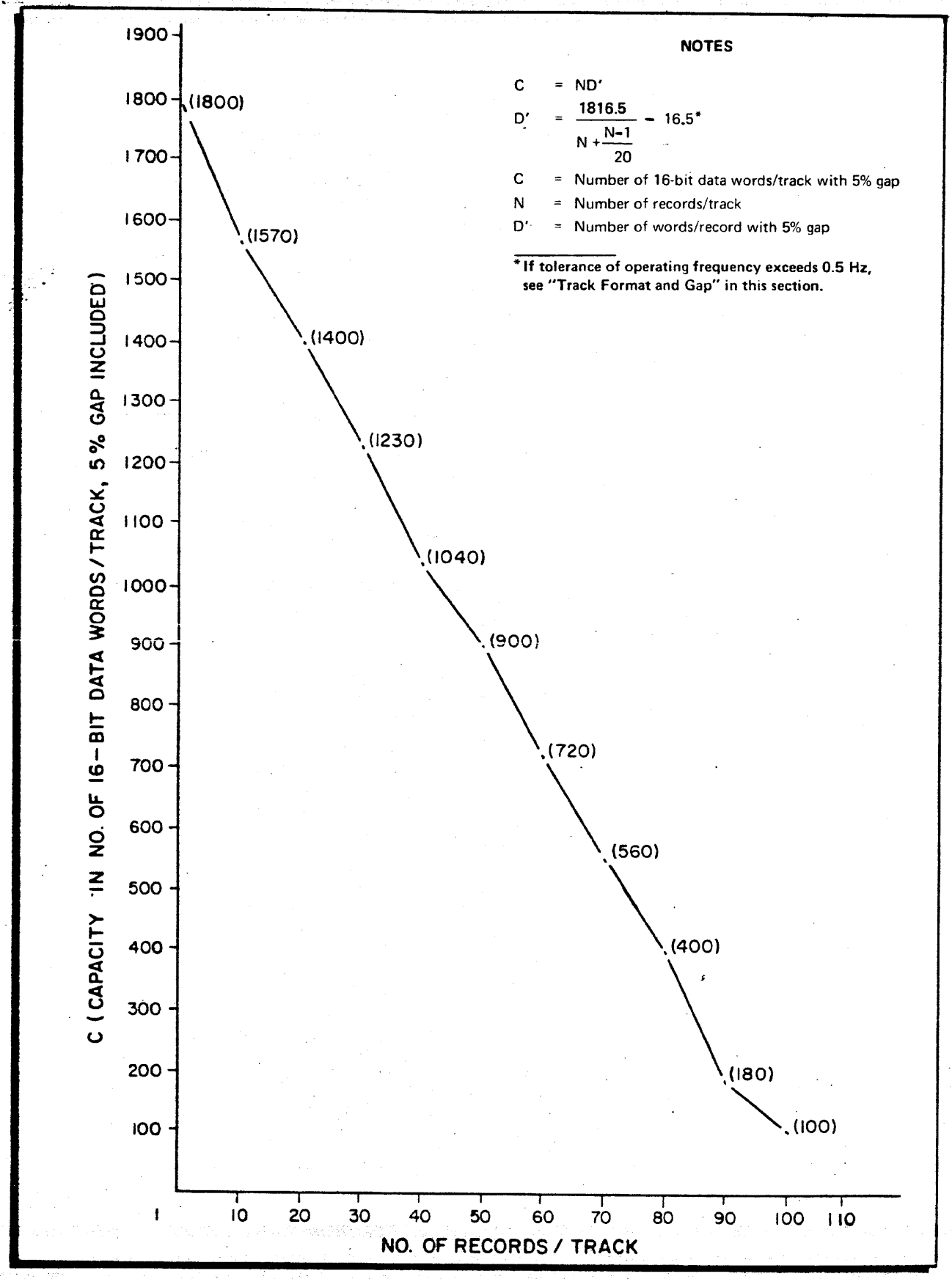


Figure 3-5. 10-Surface Disk Track Capacity vs Number of Records per Track

OPERATION

Controls and Indicators

Each disk storage unit has five indicator/switches located on the main control panel.

START INDICATOR/SWITCH

The START switch is used to start and stop the disk storage unit as follows.

Start

To start up the disk, apply power to the unit (if not on), load the disk pack, close the cover, and press START. The indicator will illuminate, the disk will rotate, and the heads will seek to track zero. In about 55 seconds the disk storage unit is ready for operation.

Stop

An individual disk storage unit may be turned off by pushing the illuminated START switch or by lifting the top cover. The heads will retract completely, and the spindle brake will be applied. About 20 seconds are required for this sequence.

UNIT NUMBER INDICATOR

This indicator is illuminated when the heads are loaded on the pack. It indicates the number assigned to the disk storage unit (0 through 7) in a multiple drive system.

FAULT INDICATOR/SWITCH

The FAULT indicator will illuminate upon detection of any of the following conditions.

a. Selection of more than one head.
b. Read and write modes selected at the same time.
c. Read and erase selected at the same time.
d. Erase mode selected without a write driver selected.
e. Erase mode selected and both write drivers selected.
f. Write drivers selected without erase mode selected.
g. Attempt to read, write, or erase with head not directly on the track.

The FAULT switch clears the indicator. If the fault condition reappears, the indicator is illuminated again. Clearing a recurrent fault may be attempted by stopping the unit, then restarting it with the START switch.

WRITE PERMIT INDICATOR/SWITCH

When this indicator is illuminated the unit is in the permit mode, and writing and formatting on the disk is allowed. Since the unit cycles up (i.e., starts) in the protect mode (indicator not illuminated), the WRITE PERMIT switch must be pressed before attempting the write or format operations.

CP FINISHED INDICATOR/SWITCH

OCP '0425 controls the CP FINISHED indicator. The programmer can program this indicator to flash as a signal to the operator that the program is finished with the current disk pack. The command also causes the unit to cycle down. The CP FINISHED switch is pressed to restart the drive and turn the indicator off.

Power

The main circuit breaker at the rear of the disk drive controls power to the unit except for the main motor. Controller logic is powered from the computer. The main motor is controlled by the START pushbutton and interlocked with the plastic cover.

Changing Disk Packs

The disk pack should be changed with the main circuit breaker ON. This activates the spindle brake, making pack changing easier and safer.

To install a pack, hold it by its cover handle, and remove the bottom cover by unscrewing the knob at the bottom. Slide back the plastic cover on the disk drive, and lower the pack over the matching spindle, being careful not to bump one against the other. Twist the disk pack handle clockwise until the pack is firmly seated on the spindle. Raise the disk pack cover and remove it. Close the plastic cover of the disk drive immediately to prevent the entry of dust.

To remove a pack, first make sure it is not rotating. Then slide back the plastic cover of the drive, and place the disk pack cover over the disk pack, making sure it is seated. Twist the disk pack cover handle counterclockwise until the pack is free. Remove the disk pack, and close the drive cover. Place the disk pack in position over the bottom cover, and tighten it with the bottom knob.

Cleaning Disk Packs

Dust or dirt on the disk pack recording surfaces may cause read or write errors as well as permanent damage to the surfaces and the read/write heads. Honeywell disk

pack drives are equipped with nylon cleaning brushes to ensure optimum performance. Manual cleaning on Honeywell drives equipped with brushes usually is not necessary; brushes clean the packs during each cycle-up.

If a specific pack continually causes read errors after write operations, however, cycle up the unit five times. The brushes will clean the error-causing disk pack during the cycle-up process. If read errors persist and the record or format was written on another drive, this may be the cause of the error. If errors persist and the drive used for writing and reading is the same and otherwise satisfactory, take the error-causing track out of service and assign one of the spare tracks. If spare tracks are not available, remove the pack from service, as the entire surface may be degraded.

Check the disk pack filter on the bottom of each pack and change it when necessary. Filters can be ordered through your local Honeywell Field Service Office.

Note that Honeywell disk packs are impervious to 91-percent isopropyl alcohol (2-propanol); however, other solvents may cause damage.

PROGRAMMING INFORMATION

Relevant Hardware Information

UNIT NUMBER ASSIGNMENT

Each disk drive is assigned a number from 0 to 7 at its installation, and each drive should be labelled with its appropriate number.

TRACK FORMAT AND GAP

Figure 3-6 shows the track format. Information is recorded on the disk in a serial bit stream.

Field A is a 64-bit field which allows for jitter in detection of the index mark. This field is recorded only before the first record of the track. Fields B, E, and K are 64-bit fields which allow for the distance between the erase head and the read/write head. Fields C, F, and J are special fields also used internally. Field D is the address, which is a 24-bit field with the first 8 bits ignored. The remaining 16 bits contain a program-assigned address for each record. Field G contains the data of the record. Field H is a 16-bit record checksum for field G. Field L is a gap field which must be at least 5 percent of the total length of fields B through K:

$$L = 16(0.05(G + 16.5)) = 0.80G + 13.2$$

where L is the length of field L in bits, G is the length of field G in words, and 16.5 is the length in words of fields B through K except G. If the frequency tolerance exceeds 0.5 Hz, increase the gap proportionally. For example, with a tolerance of 1.0 Hz, increase the gap to 10 percent:

$$\frac{5\%}{0.5\ \text{Hz}} = \frac{\text{Gap}}{1.0\ \text{Hz}}$$

To access sequential records within the same rotation, take into account time T between the end-of-busy for the first record (which allows the next OCP to be sent) and the output of the second setup word as follows.

$$L = 16(0.05(G + 16.5) + 0.078T + 1.75)$$
$$= 0.80G + 41.2 + 1.25T$$

where T is in μs. The minimum time T between the initiating OCP and output of the second setup word is 55 μs.

STATUS WORD

The programmer can obtain detailed information about the state of important elements within the controller by requesting a status word transfer. In particular, the contents of the status word help him to determine if recovery from an error state is possible. Figure 3-7 shows the format of the status word with the significance of each bit (when set) called out.

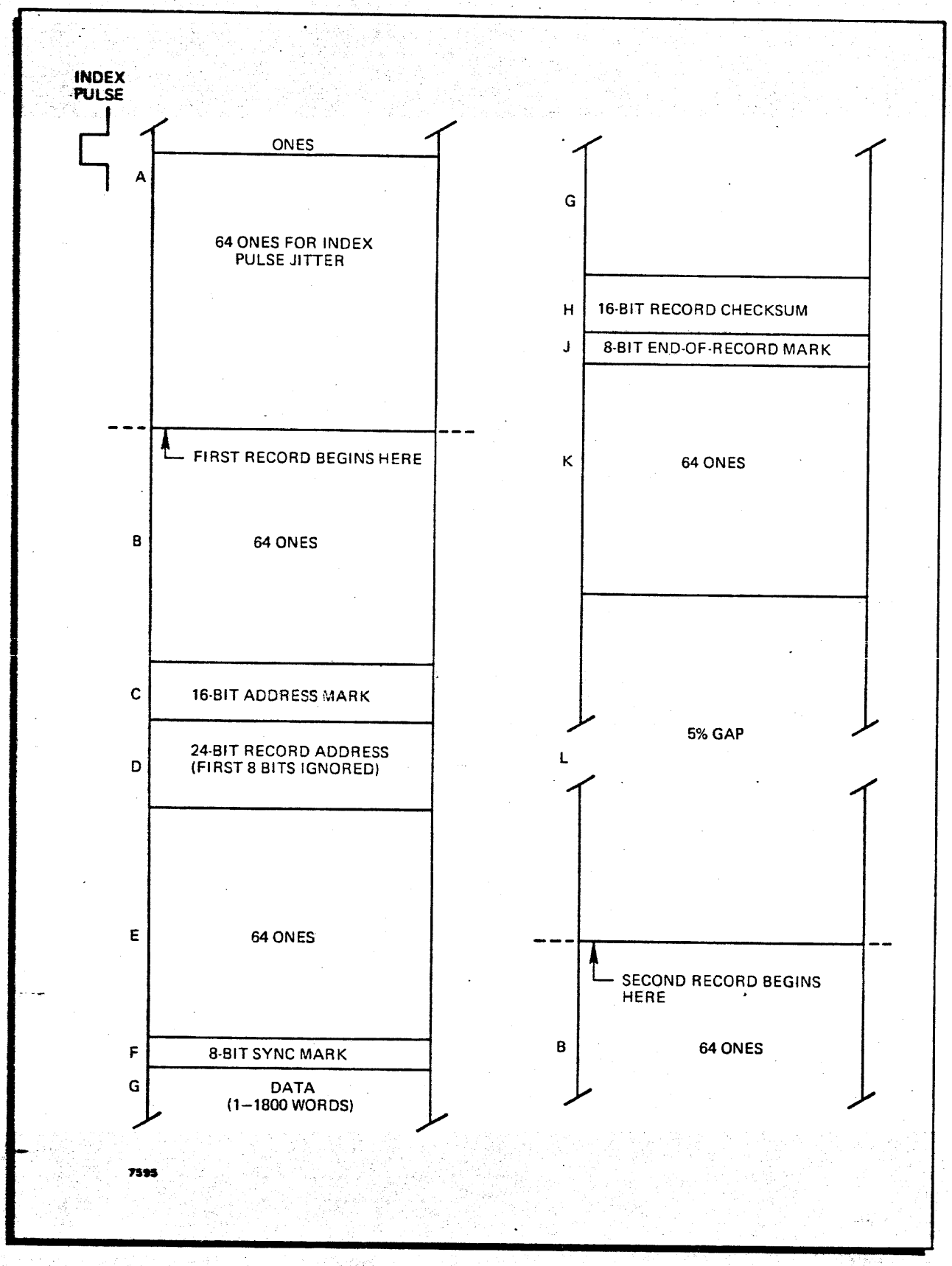


Figure 3-6. 10-Surface Disk Track Format

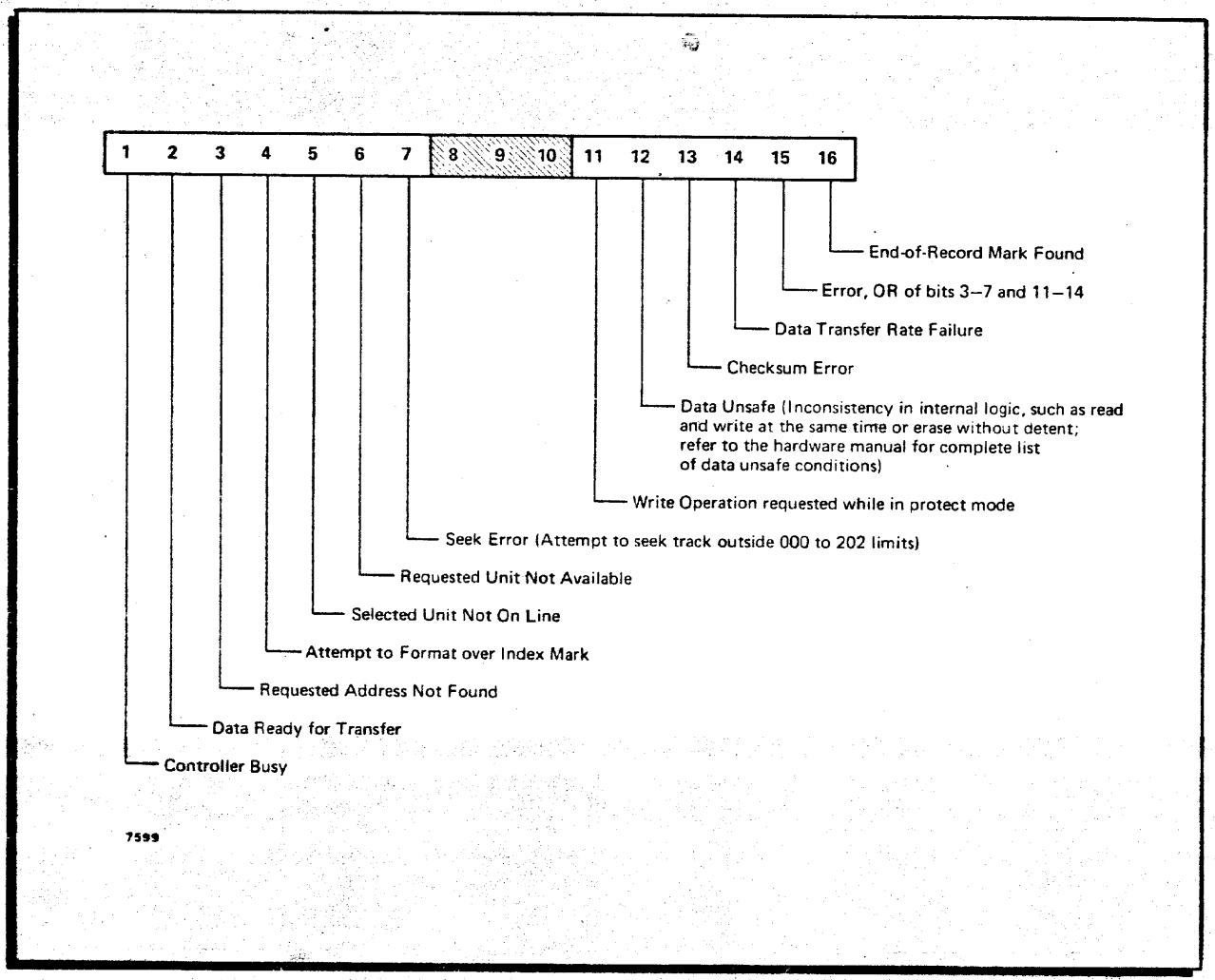


Figure 3-7. 10-Surface Disk Status Word Format

SETUP WORDS

Six of the OCP instructions require one or two setup words which transfer information necessary for the particular operation. Figure 3-8 contains these six OCP's and the formats of the corresponding setup words.

CHECKSUM

As data is written onto the disk the controller accumulates a checkword. The checkword is formed by exclusively ORing all data words into a register. At the end of an n-word transfer, the checkword is a 16-bit even-parity checksum which is written onto the disk as word n+1.

When data is read from the disk and passes back through the controller, the hardware recomputes the checksum. Word n+1 is included in the computation. If the result is nonzero, the checksum error bit in the status word is set. A programmer may examine the checkword by requesting an n+1 word read operation.

INTERRUPT REQUESTS

Certain conditions cause hardware interrupt requests. These conditions are listed under "Acknowledge Interrupt, Model OCP '1425," in this section.

ACCESS TO DMC DEDICATED LOCATIONS

On Model 316 with high-speed DMC the programmer is guaranteed access to DMC dedicated locations only when the disk controller is not busy. More information on this subject is presented in the 316/516 Programmers' Reference Manual (Doc. No. 70130072156) under "316 High-Speed DMC Dedicated Locations."

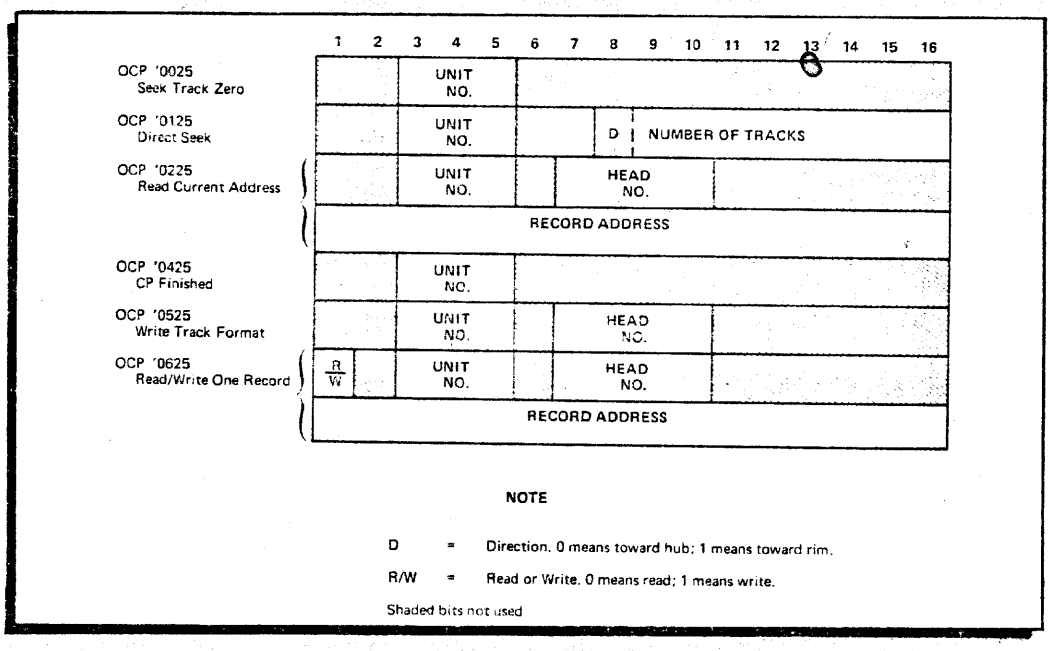


Figure 3-8. 10-Surface Disk Instructions with Required Setup Words

General Instruction Sequences

The instruction complement for the Type 4623 is given in Table 3-4. Tables 3-5 through 3-9 give appropriate instruction sequences for common operations.

SEEK, SEEK TRACK ZERO

Before information can be transferred to or from a record, the head must be positioned on the proper track. Two instructions perform this function: One is an absolute seek to cylinder 000; the other moves the head a specified number of cylinders in either direction from the current position. The programmer is expected to keep track of the current head position within his program. Table 3-5 shows the sequence of operations required for the seek operations.

Table 3-4. 10-Surface Moving-Head Disk Instructions*

Instruction	Function
OCP '0025	Seek track zero
OCP '0125	Direct seek
OCP '0225	Read current address
OCP '0425	CP finished
OCP '0525	Write track format
OCP '0625	Read or write one record
OCP '1025	Stop transfer
OCP '1125	Read status word
OCP '1325	Enable DMC/DMA mode
OCP '1425	Acknowledge interrupt
OCP '1725	Enable I/O bus mode
INA '0025	Input from disk to A-register if ready
OTA '0025	Output contents of A-register to disk if ready
SKS '0025	Skip if ready
SKS '0125	Skip if disk not requesting interrupt
SKS '0225	Skip if operational
SKS '0325	Skip if no error
SKS '0425	Skip if not busy
SKS '0725	Skip if unit 7 not seeking
SKS '1025	Skip if ready
SKS '1125	Skip if unit 0 not seeking
SKS '1225	Skip if unit 1 not seeking
SKS '1325	Skip if unit 2 not seeking
SKS '1425	Skip if unit 3 not seeking
SKS '1525	Skip if unit 4 not seeking
SKS '1625	Skip if unit 5 not seeking
SKS '1725	Skip if unit 6 not seeking
SMK '0020	Set interrupt mask (bit 4)

*Address of moving-head disk control unit is 25. X in INA 'X025 may be either 1 or 0: means clear A-register before input; 0 means input without first clearing.

Table 3-5. 10-Surface Disk Seek And Seek Track Zero Instruction Sequence

Step	I/O Bus & DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	Test if drive seeking	Test if drive seeking
3	—	Set up DMA for one-word transfer
4	Execute seek instruction	Execute seek instruction
5	Output setup word	(Enter DMA)
6	—	(End-of-range)
7	Handle seek complete interrupt request	Handle seek complete interrupt request

CP FINISHED

Execution of the CP finished instruction causes the selected unit to seek track zero, power down, and flash the CP FINISHED indicator. The flashing continues until the operator presses CP FINISHED. The sequence of operations required for a CP finished instruction is shown in Table 3-6.

Table 3-6. 10-Surface Disk CP Finished Instruction Sequence

Step	I/O Bus and DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	—	Set up DMA for one-word transfer
3	Execute CP finished instruction	Execute CP finished instruction
4	Output setup word	(Enter DMA)
5	—	(End-of-range)

READ CURRENT ADDRESS

Disks often are formatted so that the address of each record identifies the track, head, and unit. By reading the address of the next record formatted under such a system, a programmer can determine the track location and relative rotational position of the heads on the disk. Table 3-7 shows the sequence of operations required for reading the current address. When the DMA is used, the address is returned as the second word of the two-word buffer.

Table 3-7. 10-Surface Disk Read Current Address Instruction Sequence

Step	I/O Bus	DMC	DMA
1	Test control unit busy indicator .	Test control unit busy indicator	Test control unit busy indicator
2	—	Set up DMC for one-word input transfer	Set up DMA for two-word output transfer
3	Enable transfer via I/O bus	Enable transfer via DMC/DMA	Enable transfer via DMC/DMA
4	Execute read current address instruction	Execute read current address instruction	Execute read current address instruction
5	Output setup word	Output setup word	(Enter DMA)
6	INA current address	(Enter DMC)	(Disk control unit switches DMA to input)
7	Return to DMC/DMA mode	(End-of-range)	(End-of-range)

WRITE TRACK FORMAT

Table 3-8 shows the sequence of operations required for writing a track format. Formatting takes place in the following order (after the setup word).

a. Record address

b. Data for every word in the record (may be blank or filler)

c. End-of-range

d. Five-percent gap word (whose value is the number of bit cells in the gap field)

e. Repetition of steps a. through d. for each record

f. End-of-range, acknowledge interrupt, and stop transfer after the last record (which writes gap to the track origin)

The 5-percent gap word related to the previous record must be output as the first word of the block being output for the present record.

Because of timing constraints the CPU must be dedicated exclusively to formatting. Time-sharing or multiprogramming is not possible, because time is not available to handle interrupts.

Table 3-8. 10-Surface Disk Write Track Format Instruction Sequence

Step	DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	Set up DMC for n+1-word output[a]	Set up DMA for n+2 output[b]
3	Enable transfer via DMC/DMA	Enable transfer via DMC/DMA
4	Execute write track format instruction	Execute write track format instruction
5	Output setup word	(Enter DMA)
6	(Enter DMC)	—
7	(End-of-range)	(End-of-range)
8	Reinitialize DMC for n+2-word output[c]	Reinitialize DMA for n+2-word output[c]
9	(Enter DMC)	(Enter DMA)
10	Repeat steps 6 through 9 for each record	Repeat steps 6 through 9 for each record
11	Reinitialize DMC for 1-word output[d]	Reinitialize DMA for 1-word output[d]

[a] For first DMC transfer, word 1 should be record address and the remaining n words should be data.

[b] For first DMA transfer, word 1 should be setup word, word 2 should be record address, and the remaining n words should be data.

[c] For subsequent DMC or DMA transfers, word 1 should be the 5-percent gap word for the preceding record, word 2 should be the record address, and the remaining n words should be data.

[d] Last DMC or DMA transfer should be 5-percent gap word for the previous record. Setup must be accomplished within 60 μs and subsequent interrupt request must be followed by stop transfer and acknowledge (clear) interrupts commands. The drive will write gap until it detects track origin.

If the programmer has ensured that enough space remains on disk for gap for the final record (he may include the 64-bit field A), he need not transfer the 5-percent gap for the final record. If the last gap word is not transmitted or timing requirements are not satisfied, the drive writes gap to track origin and sets the data-transfer rate-failure bit in the status word.

READ OR WRITE ONE RECORD

The sequence of instructions for these two operations is almost identical. The data words, preceded by two setup words, are transferred between the computer and the disk. The address is read but not modified. The record checksum is written or read and compared but is not transferred to the computer unless a read has been specified for more words than the record contains. Table 3-9 shows the sequence of operations required for reading or writing one record.

Table 3-9. 10-Surface Disk Read or Write One Record Instruction Sequence

Step	DMC	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	Set up DMC for n-word input or output	Set up DMA for N+2-word output[a]
3	Enable transfer via DMC/DMA	Enable transfer via DMC/DMA
4	Execute read/write one record instruction	Execute read/write one record instruction
5	Output first setup word	(Enter DMA)
6	Output second setup word[b]	—
7	(Enter DMC)	(Disk control unit switches DMA to input when reading)
8	(End-of-range)	(End-of-range)

[a] For DMA transfers, words 1 and 2 must be setup words; the remaining n words are data storage locations.

[b] The time of second setup word is critical only if sequential access within the same rotation is desired (see "Track Format and Gap," a preceding paragraph).

In an under-range read the controller transfers the specified number of words to memory and discards the remainder of the record. The controller becomes not busy shortly after the end-of-record mark is detected. The checksum is handled as in a normal read.

An over-range read, which inputs the checksum word (often useful for error recovery), terminates at the end-of-record mark. The checksum error bit (bit 13 in the status word) is valid as in a normal read. An under-range write causes no problems.

An over-range write reduces the gap field correspondingly for up to four words over the original format. If more than four words are written beyond the format, the next record (and format) is destroyed. The current record is readable under most circumstances.

READ STATUS WORD

The sequence in Table 3-10 shows the order of instructions to read the contents of the status register. With DMC it is easiest to code this operation using the I/O bus as shown below, although DMC is perfectly acceptable.

Table 3-10. 10-Surface Disk Read Status Word Instruction Sequence

Step	I/O Bus	DMA
1	Test control unit busy indicator	Test control unit busy indicator
2	Enable I/O bus	Set up DMA for one-word input transfer
3	Execute read status word instruction	Execute read status word instruction
4	Input status word	(Enter DMA)
5	Enable DMC/DMA	(End-of-range)

Instruction Descriptions

SEEK TRACK ZERO, OCP '0025

This instruction and its associated setup word cause the heads on the selected unit to move to track 000. The disk control unit busy indicator is set for 50 μs after the setup word is output; the seeking indicator of the selected unit is set for 22 to 132 ms after the setup word is output (see Table 3-1).

More than one disk drive may be seeking at a time. When the heads reach track zero the controller generates an interrupt request (which may be delayed until the controller becomes not busy). This instruction is ignored if issued while the disk control unit busy indicator is set. A seek-track-zero instruction executed with the heads already on track zero is processed the same as a seek-track-zero from any other position.

DIRECT SEEK, OCP '0125

This instruction and its associated setup word cause the heads on the selected unit to move the number of tracks specified by bits 9 through 16 of the setup word and in the direction specified by bit 8 of the setup word, where 0 means toward the center of the disk (higher track numbers) and 1 means toward the outside of the disk (lower track numbers). If the disk control unit detects a 0 in the difference field (bits 9 through 16), it sends no orders to the disk drive, sets the seek error bit in the status word, and generates an interrupt request. The disk control unit busy indicator is set for 50 μs after the setup word is output; the selected unit seeking indicator is set for 22 to 132 ms after the setup word is output. This instruction is ignored if issued while the disk control unit busy indicator is set.

The programmer can code several units to seek concurrently with successive OCP seeks and setup words. He must test for controller busy between OCP's. If several units are seeking, the programmer can either acknowledge interrupts as they occur or wait

until all units have finished seeking, and then clear all interrupt requests with one acknowledge interrupt. An interrupt request will be delayed until the controller becomes not busy (e.g., if a data transfer follows a seek). A seek directed to a nonexistent track results in a seek to zero and a seek error in the status word.

READ CURRENT ADDRESS, OCP '0225

This instruction and its associated setup word cause the next address encountered on the selected track by the selected head to become available on the input bus. The disk control unit busy indicator is set from the time the setup word is output until the address becomes available to the central processor. Then the ready indicator is set, the busy indicator is reset, and an interrupt request is generated. This OCP has no effect if issued while the DCU is busy.

CP FINISHED, OCP '0425

Execution of this instruction and its associated setup word cycles down the unit, and illuminates the CP FINISHED indicator. A programmer may code this operation to signal the operator that a certain disk is no longer needed by the executing program. The DCU busy indicator remains set for 50μs after the setup word OTA. No interrupt request is generated.

WRITE TRACK FORMAT, OCP '0525

This instruction and its associated setup word cause the selected head on the selected unit to detect the track origin and write a new format on the track. In addition, data may be written in the newly formatted records. The address, the data, and the gap size are under program control. If the output transfer rate is not maintained by the computer, the disk control unit aborts the operation, writes gap to the track origin, and sets the data-transfer rate-failure bit in the status word. The DCU is busy from the time of the order-initiation OCP until formatting terminates at track origin. Refer to "Track Format and Gap," earlier in this section for information on how to format to access sequential records on a track.

READ OR WRITE ONE RECORD, OCP '0625

This instruction and its two associated setup words cause the selected head on the selected disk drive to read or write one record at the specified record address on the current cylinder. Bit 1 of the first setup word must be 0 for read and 1 for write.

Read

The unit reads until one of the following conditions occurs.

a. End-of-record is sensed.

b. The computer fails to maintain the necessary input transfer rate.

c. Two index pulses are tallied.

d. The stop transfer instruction (OCP '1025) is executed or DMC/DMA end-of-range occurs. Data transfer will cease, but the disk control unit continues reading to the end of the record. When a stop transfer instruction is executed during a read operation, the last data word transferred before the instruction takes effect is interpreted as a checksum. The checksum error bit in the status word may be set. This feature is useful in test programs.

The control unit busy indicator is set from the time the OCP is issued until the read is completed in one of the four ways listed above.

If the program specifies a larger number of words (range) to be read than the record contains, the record checksum is transferred to the central processor as if it were data, and the end-of-record is sensed before the next word is transferred. If, at the end of the read operation, the checking logic indicates an error, the checksum error bit in the status word is set.

Write

Data is written into the addressed record until one of the following conditions occurs.

a. The stop transfer instruction (OCP '1025) is executed or DMC/DMA end-of-range occurs.

b. The computer fails to maintain the necessary output transfer rate.

c. Two index pulses are tallied.

When condition a. or b. is encountered, the word being written is finished, and the checksum record is written along with the end-of-record mark and the field of ones (fields H, J, and K of Figure 3-6). When condition c. occurs, the operation is terminated immediately.

The programmer should make sure that the record written is no larger than allowed by the record format. If it is too long by four words or less, the 5-percent gap is diminished, but the following record will not be affected. If it is more than four words too long, the following records are destroyed.

The controller is busy from the time the OCP is issued until a., b., or c., above terminates the operation. The read/write operation may be requested when one or more

units are seeking and will be executed either immediately or when the appropriate seek is complete. Any pending interrupt request is delayed until the operation is complete, i.e., until the controller becomes not busy.

STOP TRANSFER, OCP '1025

This instruction, which does not require a setup word, stops track formatting if issued immediately after the DCU has received the last data word. If this OCP is not issued within 50 μs of end-of-range for the last record formatted, the data-transfer rate-failure bit in the status word is set. Execution of a stop transfer instruction forces the controller to not busy. In this way, a programmer can clear a busy hangup which may result from an OCP with no setup word transfer or a hardware fault. If issued during a read operation, this instruction forces a diagnostic checksum (see "Read", preceding).

READ STATUS WORD, OCP '1125

This instruction causes the status word to be the next data-like word transferred via I/O bus, DMC, or DMA (whichever is enabled). Code INA '0025 or '1025 after the OCP to make the transfer via I/O bus. For DMC or DMA transfers, initialize the channel before issuing the OCP. Before issuing OCP '1125 while the DCU is busy, delay 50 ms (two revolutions) to allow completion of any transfer in progress. Reading the status word does not alter the state of the controller other than to clear the status request. See Figure 3-7 for the status word format.

ENABLE DATA TRANSFER VIA DMC/DMA, OCP '1325;
ENABLE DATA TRANSFER VIA I/O BUS, OCP '1725

OCP '1325 (or '1725), which does not require a setup word, enables the disk control unit to use the DMC/DMA (or I/O bus) exclusively. It does not initiate an order to any of the disk drives.

Pressing MSTR CLEAR initializes the system for DMC or DMA transfers. To initialize the system for I/O bus transfers, execute OCP '1725 before executing the OCP which implies the data transfer (e.g., OCP '0625, Read One Record). Transfers are enabled via the I/O bus until OCP '1325 is executed or the computer is MSTR CLEARed.

ACKNOWLEDGE INTERRUPT, OCP '1425

This instruction, which does not require setup word, does not initiate any orders to the disk drives but does reset (clear) an interrupt request if one is present. The following situations cause interrupts if allowed.

a. The disk control unit goes from busy to not busy, except for the 50-μs busy at the beginning of a seek, CP-finished, or read-status-word instruction. Any OCP, except read-status-word, addressed to the disk control unit resets this interrupt request.

b. A seek operation is completed. If this happens when the disk control unit is busy, the interrupt is delayed until the control unit goes to not busy. If a direct seek is requested and its set-up word specifies a difference of zero tracks, this interrupt request is generated immediately. Only OCP '1425 resets this interrupt request.

c. A disk drive error (bits 5, 6, 7, 11, or 12 in the status word) is detected. The operation is terminated, and an interrupt request is generated at the end of the 50-μs order process interval.

d. End-of-range is reached in write-track-format operations with DMC/DMA mode set. The interrupt signals the program to reinitialize the DMC/DMA within the time constraints. It may be cleared by OCP '1425 during the format operation, or by OCP '1425 or OCP '1025 at the end of the format operation.

INPUT FROM DISK TO A-REGISTER IF READY, INA '0025

If the disk control unit has a data word ready for transfer, this instruction ORs the word from the DCU into the A-register and skips the next instruction. At the completion of the instruction, data-ready and status-request are reset. If data is not ready, INA '0025 is treated as a NOP. To maintain the data transfer rate, INA must be executed within 12 μs of the time data becomes ready (time constraints do not apply for status and address transfers). INA '0025 is not applicable to a DMA configuration.

CLEAR A-REGISTER AND INPUT FROM DISK TO A-REGISTER IF READY, INA '1025

This instruction performs a function similar to that above, except the A-register is cleared before the data is ORed in.

OUTPUT TO MOVING-HEAD DISK IF READY, OTA '0025

If the data ready indicator is set, this instruction outputs data (usually a setup word) to the moving-head disk, resets data ready, and skips the next instruction. If data ready is reset, the instruction is treated as a NOP. The timing requirements for disk data are the same as for INA '0025 and '1025. Timing of setup words is noncritical. OTA '0025 is not applicable to a DMA configuration.

SET INTERRUPT MASK (BIT 4), SMK '0020

The state of the standard interrupt mask for the moving-head disk is made equal to bit 4 of the A-register (which must contain the entire mask word) by executing SMK '0020.

SKIP IF READY, SKS '0025

The data ready indicator is used on both read and write operations to signal that another word may be transferred to or from the disk control unit. SKS '0025 tests this indicator. This instruction generally is not useful.

SKIP IF NOT INTERRUPTING, SKS '0125

This instruction skips if the disk control is not generating an interrupt request. Interrupt conditions are listed under OCP '1425.

SKIP IF OPERATIONAL, SKS '0025

This instruction skips if the DCU is not busy and if no error bits in the status word are set. It skips if the previous data transfer was completed satisfactorily or a seek operation started without error.

SKIP IF NO ERROR, SKS '0325

This instruction skips if no error bit is set in the status word (bits 3 through 7 and 11 through 14).

SKIP IF NOT BUSY, SKS '0425

This instruction tests the disk control unit busy indicator and skips if the controller is not busy. The control unit is busy for the duration of a read, write, or write format operation, and for 50 μs after the beginning of a seek. See the relevant OCP descriptions for specific information about busy conditions.

SKIP IF UNIT NOT SEEKING, SKS 'XX25

These instructions (Table 3-4) test the seek indicator of each disk drive. Since the indicator is set near the end of the 50-μs seek cycle, a valid indication of unit seeking can be obtained only after the DCU has gone not busy.

SECTION IV
EXAMPLES

Four examples are included in this section. Each assumes that a routine named ERR is available to handle errors which show up in the status word. This routine is not shown.

The techniques in the example programs apply to the 20-Surface Disk, 10-Surface Disk, and 2-Surface Disk, although the examples cite specific device characteristics of the 20-Surface Disk. To adapt these examples, address only surfaces 0 and 1 for the 2-Surface Disk and surfaces 0 through 9 for the 10-Surface Disk.

SEEK TRACK ZERO

Figure 4-1 is an example of a program for returning the heads of disk drive number 4 to track 000 on a DMC system. This program waits for the busy indicator to be reset before returning.

WRITE TRACK FORMAT

Figure 4-2 is an example of a program that formats track 3 (the fourth track) on the current cylinder into 25 records of 40 words each. Records in this example are assigned sequential numbers 1 through 25 decimal. The contents of buffer BUF are written as data in each record. Since BUF is not initialized, the programmer does not know in advance what data (or pseudo-data) will be written.

The program uses a DMC channel and formats on moving-head disk drive 1, head 3 (second drive, fourth head). The 5-percent gap is not long enough to allow immediate sequential access.

This example program does not allow interrupts but does mask on interrupt requests which can be tested with SKS '0125. The test determines when the DMC reaches end-of-range. The controller will cause an interrupt request regardless of error conditions within two revolutions.

READ ONE RECORD ON DMA/WRITE ONE RECORD ON DMC

Figures 4-3 and 4-4 are examples which illustrate differences between DMA and DMC operations. The first program reads a 40-word record from the current cylinder

of disk drive 1, head 3 (the track formatted in Figure 4-2). The second program writes a 4-word record on cylinder 139, surface 9, at address '26. Assume that the example M$FT program (Figure 5-4) has previously formatted the track.

One major difference between the two channel types is that DMA must start up in output mode for all operations, whereas with DMC read implies input mode and write implies output mode. With DMA, the controller automatically switches the channel to input mode after transfer of the setup words.

```
SEEK DAC    **          ENTRY POINT
     SKS    '0425       TEST BUSY INDICATOR
     JMP    *-1         DELAY UNTIL NOT BUSY
     SKS    '1425       IS UNIT 4 SEEKING?
     JMP    *-1         DELAY UNTIL NOT SEEKING
     OCP    '0025       RETURN TO TRACK ZERO
     LDA    ='20000     SETUP WORD FOR UNIT 4
     OTA    '0025       OUTPUT SETUP WORD
     JMP    *-1         DELAY IF NOT READY
     SKS    '0425       TEST BUSY INDICATOR
     JMP    *-1         DELAY UNTIL NOT BUSY
     SKS    '0325       ERROR?
     JMP    ERR         YES, PROCESS IT
     JMP*   SEEK        EXIT
```

Figure 4-1. Seek Track Zero Example

```
REC   OCP    '1425              MUST ACKNOWLEDGE INTERRUPT REQUEST
      SKS    '0125              IS DISC REQUESTING INTERRUPT?
      SKP                       YES, RESET DMC
      JMP    *-2                NO, DELAY UNTIL IT IS
*
      IRS    BUF                INCREMENT TRACK ADDRESS
      LDA    BFAD               DMC START IS 5% GAP WORD
      STA*   STRT               STORE IN DMC START LOCATION
*            DMC CAN BECOME ACTIVE AGAIN
      IRS    RCNT               UPDATE RECORD COUNT
      JMP    REC                NOT DONE, DO ANOTHER RECORD
*
      STA*   END                SET DMC FOR 1-WORD TRANSFER
      OCP    '1425              ACKNOWLEDGE INTERRUPT
      SKS    '0125              WAIT FOR INTERRUPT REQUEST
      SKP                       EXIT WHEN REQUEST ARRIVES
      JMP    *-2                LOOP WHILE WAITING
      SKS    '0425              TEST BUSY INDICATOR WHILE WRITING
*                                 GAP TO TRACK ORIGIN
      JST    TERR               ERROR TEST IF BUSY
      OCP    '1425              ACKNOWLEDGE INTERRUPT
      JMP*   FRMT               RETURN
*
TERR  DAC    *                  ENTRY TO ERROR TEST LOOP
      SKS    '0325              ERROR?

      JMP    ERR                YES, PROCESS IT
      STA    TEMP               NO, SAVE A AND
      LDA    TERR               LOAD RETURN POINTER
      SUB    =2                 DECREMENT RETURN POINTER
      STA    TERR               RESTORE POINTER
      LDA    TEMP               RESTORE A REGISTER
      JMP*   TERR               RETURN TO CALLING PROGRAM

*
GAP1  DEC    46                 NUMBER OF BITS IN 5% GAP
BUF   BSS    41                 STORAGE FOR ADDRESS FOLLOWED
*                                 BY 40 DATA WORDS
ADST  OCT    1                  ADDRESS OF FIRST RECORD
RCNT  OCT    0                  STORE RECORD COUNTER HERE
B1AD  DAC    BUF                FIRST DMC START
BFAD  DAC    GAP1               SUBSEQUENT DMC STARTS
BFND  DAC    ADST-1             DMC ENDING ADDRESS
STRT  OCT    20                 DMC CHANNEL 1 START ADDRESS
END   OCT    21                 DMC CHANNEL 1 END ADDRESS
TEMP  BSZ    1                  STORAGE FOR A REGISTER IN TERR
```

Figure 4-2. Write Track Format Example

```
READ DAC   **                  ENTRY POINT
     INH                       INTERRUPTS NOT WANTED
     SKS   '0425               TEST BUSY INDICATOR
     JMP   *-1                 DELAY UNTIL NOT BUSY
     LDA   BUFA                START ADDRESS
     SSP                       RESET FLAG FOR OUTPUT
     SMK   '0124               LOAD ADDRESS COUNTER
     LDA   =-42                2'S COMPLEMENT OF RANGE
     SMK   '1124               LOAD RANGE COUNTER
     OCP   '1325               ENABLE IN DMC/DMA MODE
     LDA   ='4300              FIRST SETUP WORD
     STA   BUF
     LDA   ='3                 SECOND SETUP WORD
     STA   BUF+1
     OCP   '0625               READ OR WRITE
*          DMA BEGINS READING
     LDA   ='10000             MASK BIT
     SMK   '0020               SET MASK BIT
     SKS   '0125               TEST FOR END-OF-RANGE INTERRUPT REQUEST
     SKP                       YES, SKIP TO EXIT ROUTINE
     JMP   *-2                 NO, DELAY UNTIL END-OF-RANGE OCCURS
     SKS   '0425               TEST BUSY INDICATOR
     JST   TERR                ERROR TEST IF BUSY
     OCP   '1425               ACKNOWLEDGE INTERRUPT
     JMP*  READ                NO, EXIT
*
TERR DAC   **                  ENTRY TO ERROR TEST LOOP
     SKS   '0325               TEST FOR ERROR
     JMP   ERR                 YES, PROCESS IT
     STA   TEMP                NO, SAVE A AND
     LDA   TERR                LOAD RETURN POINTER
     SUB   =2                  DECREMENT RETURN POINTER
     STA   TERR                RESTORE POINTER
     LDA   TEMP                RESTORE A REGISTER
     JMP*  TERR
BUFA DAC   BUF                 BUFFER ADDRESS
BUF  BSS   42                  DATA BUFFER
TEMP BSZ   1                   STORAGE FOR A REGISTER IN TERR
```

Figure 4-3. Read One Record on DMA Example

```
WRIT DAC   **                  ENTRY POINT
     INH                       INTERRUPTS NOT WANTED
     SKS   '0425               TEST CONTROLLER BUSY INDICATOR
     JMP   *-1                 DELAY UNTIL NOT BUSY
     LDA   BUFB                BUFFER ADDRESS
     SSP                       RESET FLAG FOR OUTPUT
     STA*  STRT                STORE IN DMC STARTING ADDRESS
     LDA   BFND                END-OF-BUFFER ADDRESS
     STA*  END                 STORE IN DMC ENDING ADDRESS
     OCP   '0625               READ OR WRITE
     LDA   ='1100              FIRST SETUP WORD
     SSM                       SET FLAG FOR OUTPUT
     OTA   '0025               OUTPUT FIRST SETUP WORD
     JMP   *-1                 DELAY UNTIL READY
     LDA   WADR                SECOND SETUP WORD
     OTA   '0025               OUTPUT SECOND SETUP WORD
     JMP   *-1                 DELAY UNTIL READY
*         DMC BEGINS WRITING
     LDA   ='10000             MASK BIT
     SMK   '0020               SET MASK BIT
     SKS   '0125               TEST FOR END-OF-RANGE INTERRUPT REQUEST
     SKP                       YES, SKIP TO EXIT ROUTINE
     JMP   *-2                 NO, DELAY UNTIL END-OF-RANGE OCCURS
     SKS   '0425               TEST BUSY INDICATOR
     JST   TERR                ERROR TEST IF BUSY
     OCP   '1425               ACKNOWLEDGE INTERRUPT
     HLT
*
TERR DAC   **                  ENTRY TO ERROR TEST LOOP
     SKS   '0325               TEST FOR ERROR
     HLT
     STA   TEMP                NO, SAVE A AND
     LDA   TERR                LOAD RETURN POINTER
     SUB   =2                  DECREMENT RETURN POINTER
     STA   TERR                RESTORE POINTER
     LDA   TEMP                RESTORE A REGISTER
     JMP*  TERR
*
BUFB DAC   BUF                 BUFFER ADDRESS
BFND DAC   BUF+3               END-OF-BUFFER ADDRESS
STRT OCT   20                  DMC STARTING ADDRESS
END  OCT   21                  DMC ENDING ADDRESS
WADR OCT   26                  WRITE ADDRESS
TEMP BSZ   1                   STORAGE FOR A REGISTER IN TERR
BUF  OCT   75                  DATA BUFFER
     OCT   100
     OCT   100
     OCT   150
```

Figure 4-4. Write One Record on DMC Example

A second important difference is that DMA requires a starting address and range to determine data boundaries, whereas DMC requires starting and ending addresses of the data area. Note in Figure 4-3 that DMA range must be coded in 2's complement form.

The means of outputting setup words for the two channel types also differ. DMA requires the setup word(s) in the first buffer location(s). DMC, on the other hand, must transfer the word(s) via the I/O bus (OTA '0025).

CAUTION

On DMA configurations that requirement for space for the setup word(s) has important implications. Either a two-word area for setup must be allocated in front of any area to be transferred, or the contents of one or two words must be saved and the words restored after use. For simultaneous compute/transfer operations the first method is recommended (with the second method the active program may inadvertently access the words used for setup).

SECTION V
DRIVER M$IO AND FORMATTER M$FT

DRIVER M$IO

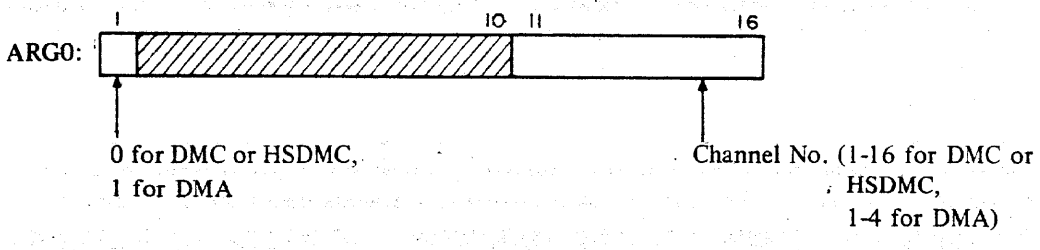
M$IO (Doc. No. 70181509000) is the standard Honeywell I/O Library driver program for the 20-Surface Moving-Head Disk File Option (Type 4720), the 10-Surface Moving-Head Disk File Option (Type 4623), and the 2-Surface Moving-Head Disk Store Option (Type 4651). This driver requires a DMC, high-speed DMC (HSDMC), or DMA channel, and supports up to eight disk drives. It occupies approximately 365_8 (245_{10}) words in memory.

Initialize Drive, M$IN

M$IN configures M$IO for channel type and number. If M$IN is not called, the driver assumes the default configuration of DMA channel 1. Since M$IN does not check whether the controller is busy before executing the instruction sequence, call it only at system initialization time.

The calling sequence and argument format for M$IN follow.

(L)	CALL	M$IN	DISK INITIALIZING ENTRY
(L+1)	OCT	ARG0	DMC/DMA, CHANNEL NUMBER
(L+2)			RETURN



Read Record, Write Record, or Read Current Record Address, M$IO

The arguments following the call to routine M$IO indicate the operation the driver is to perform — read a record, write a record, or read the address of the current record. If the current record address is requested, it is returned in the second word of the buffer.

After fetching its argument from the calling sequence, M$IO compares the current head position to that in ARG2; then seeks the track specified, if a seek is necessary.

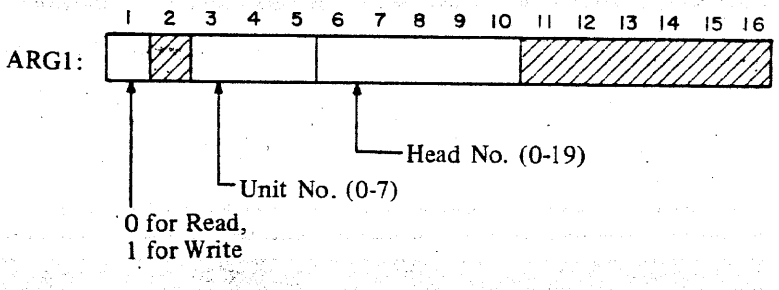
ARG2 is passed as an absolute cylinder number. Since each directed seek (i.e., not seek track zero) in the driver is followed immediately by a data transfer, only one unit can be seeking at a time.

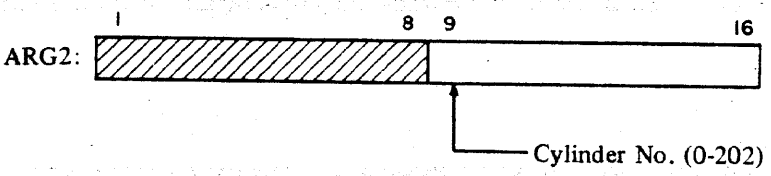
Bit 1 of ARG3 allows the programmer to control status checking. If the bit is zero, M$IO checks status before returning and puts the status word into the A-register (see Figure 1-7 for a description of the status word).

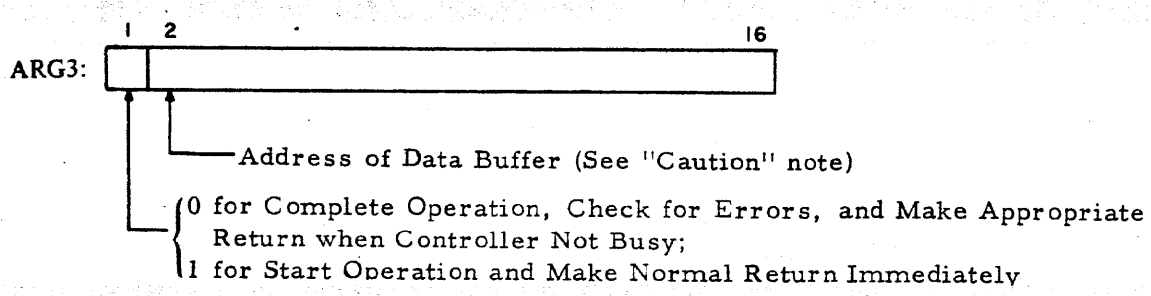
If a programmer wants to perform some computation while a data transfer is taking place, he can set bit 1 of ARG3. As soon as the data transfer begins (less than 400 µs after the call is made if the controller is not busy), control returns to the calling program. Then, by calling M$CK, the programmer can check status at a later time (after the data transfer is complete).

The sequence below calls M$IO; argument formats follow. Note that ARG4 is not meaningful for read-current-address.

(L)	CALL	M$IO	I/O ONE RECORD OR ADDRESS
(L+1)	OCT	ARG1	R/W, UNIT NUMBER, HEAD NUMBER
(L+2)	OCT	ARG2	CYLINDER NUMBER
(L+3)	OCT	ARG3	ERROR AND STATUS CHECK/RETURN, BUFFER ADDRESS
(L+4)	OCT	ARG4	RECORD ADDRESS
(L+5)	OCT	ARG5	TRANSFER DATA/READ CURRENT ADDRESS, NUMBER OF WORDS
(L+6)			ERROR RETURN
(L+7)			NORMAL RETURN







CAUTION

M$IO requires the first two words of addressed area for setup words; therefore, area two words longer than data block must be reserved for buffer (see "Caution" note under "Read One Record on DMA/Write One Record on DMC" in Section IV).

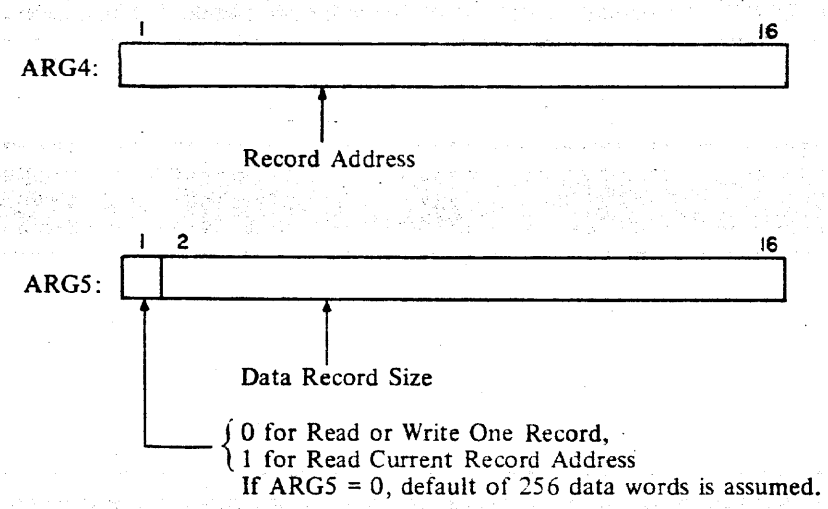


Figure 5-1 shows a sample calling sequence for M$IO. In this sequence M$IO reads record A7 of cylinder '133 with head 7 on drive 3. The record is 128 words long. The driver will return to the calling program immediately without checking status or data errors.

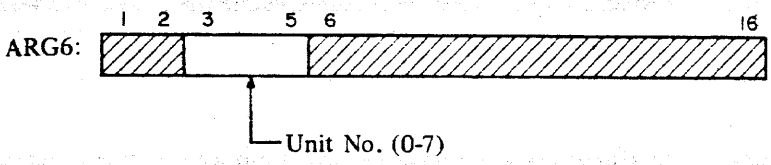
```
        CALL    M$IO
        OCT     014700      READ, UNIT 3, HEAD 7
        OCT     133         CYLINDER '133
        DAC*    BUF         BUFFER ADDRESS (Bit 1 set by * for no error or
                                                status checking)
        BCI     1,A7        RECORD ADDRESS
        DEC     128         NUMBER OF DATA WORDS TO BE READ
        JMP     ERR         ERROR RETURN
        JMP     CONT        NORMAL RETURN
BUF     BSS     130         SPACE FOR 2 SETUP WORDS AND 128 DATA WORDS
```

Figure 5-1. Driver M$IO Calling Sequence Example

Seek Track Zero, M$SZ

Entry M$SZ seeks track zero, allowing a calling program to recover control of the heads' position. It resets the current cylinder pointer for the selected unit to zero and also checks for errors. Call M$SZ as follows.

(L)	CALL	M$SZ	SEEK TRACK ZERO ON UNIT
(L+1)	OCT	ARG6	UNIT NUMBER
(L+2)			ERROR RETURN
(L+3)			NORMAL RETURN



The status word from the disk controller is returned in the A-register. The driver retains control until the seek has been completed.

Check Status, M$CK

Entries MSZ, MCF, and M$IO (unless ARG3, bit 1 is set) return the status word to the A-register using this routine. M$CK returns control to the calling program when the current operation is complete (DCU goes not busy).

Figure 1-7 shows the status word with an interpretation of its bits when set. When operating with the driver, status bits 1 and 2 are never set. The data-transfer rate-failure bit (bit 14) is set when a data transfer operation takes longer than 12 μs. DMC or real-time clock operations, memory increment breaks, and shifts may cause the 12-μs limit to be exceeded. Certain errors flagged in the status word are not uncommon and may be recoverable. In general, if a software function other than a data transfer rate failure produces an error, seek track zero and retry the operation.

The calling sequence for the routine is:

(L)	CALL	M$CK	INPUTS STATUS OF LAST OPERATION TO A-REGISTER
(L+1)			ERROR RETURN
(L+2)			NORMAL RETURN

Central Processor Finished With Unit, M$CF

A programmer can use the M$CF entry to signal an operator that his program no longer needs a specified disk drive. Before M$CF stops the disk, it waits for completion

of the current data transfer. It then cycles down the specified drive and, on Type 4720, starts the CP FINISHED indicator flashing. On Type 4623, the CP FINISHED indicator is illuminated when it cycles down.

M$CF returns the status word in the A-register and returns control when the current operation has been completed (DCU not busy). The following sequence calls M$CF; ARG6 is the same as in M$SZ above.

```
(L)      CALL    M$CF     CP FINISHED WITH UNIT
(L+1)    OCT     ARG6     UNIT NUMBER
(L+2)                     ERROR RETURN
(L+3)                     NORMAL RETURN
```

FORMATTER M$FT

Description

M$FT (Doc. No. 70181570000) provides the capability of formatting disk pack off-line on any of the following moving-head disk options: the 20-Surface Moving-Head Disk File Option (Type 4720), the 10-Surface Moving-Head Disk File Option (Type 4623), or the 2-Surface Moving-Head Disk Store Option (Type 4651). On systems with memory larger than 4K, the program can determine the format and addresses of a selected track and list (in octal) the contents of a selected record on the teletype. This formatter program also provides the capability of formatting disk packs used with OLERT.

The formatter program requires approximately $3,593_{10}$ ($7,011_8$) core locations. It calls M$IO and several programs from V$LIB, the Verification Service Library. A self-loading system tape of M$FT must be generated on an 8K or larger system. Figure 5-2 presents the loader memory map when MFT, VLIB, and M$IN are loaded in that order.

```
*LOW    00211
*START  00211
*HIGH   10550
*NAMES  73603
*COMN   77700
*BASE   00174
V$IA    07012
V$IO    07060
V$TC    07162
V$QC    07177
V$Q     07210
V$T     07224
VSTR    07265
V$OA    07302
V$OZ    07313
V$OS    07402
V$OD    07460
V$AO    07630
V$FX    07760
V$FB    07775
V$SI    10040
V$SB    10065
M$IN    10162
M$IO    10205
M$CK    10375
M$CF    10401
M$SZ    10457
```

Figure 5-2. M$FT Memory Map

When M$FT is used on a 4K system the following dummy routine is required to dummy the indicated names on V$LIB. This limits M$FT to the format mode only.

```
      SUBR  V$IO,DUM
      SUBR  V$OA,DUM
      SUBR  V$OS,DUM
      SUBR  V$OZ,DUM
      SUBR  V$OD,DUM
      SUBR  V$FB,DUM
      SUBR  V$SB,DUM
      SUBR  V$AO,DUM1
      SUBR  V$FX,DUM1
      SUBR  V$SI,DUM1
        .
        .
        .
        .
      REL
DUM   DAC   **
      IRS   DUM
      JMP*  DUM
DUM1  DAC   **
      IRS   DUM1
      IRS   DUM1
      JMP*  DUM1
        .
        .
        .
      END
```

Use

To use M$FT, start the program at '1000. The program types out an identifying message and requests:

```
MODE ?:
```

The user responds with one of the following modes.

F to format

O to format OLERT disk pack

T to specify the track number

V to verify the format

R to read a record.

These five modes are explained in the following paragraphs.

FORMAT (F) MODE

One of four command types is input from either the teletype or the paper tape reader, or directly from the teletype keyboard after selecting the F mode. If the F mode is being selected for the first time, the heads should be positioned to cylinder zero before a formatting operation is initiated.

The following format is used for a keyboard entry.

Line feed

Command line (1 of the 4 types)

Carriage return

A paper tape entry must be in the following format.

Leader (optional)

Line feed ('212)

Command line (1 of the 4 types)

Carriage return ('215)

X-OFF ('223, or DC3 on some keyboards)

Command Types for F Mode

Four different command types are used with the F mode to perform various functions. The function of each command type is described below along with the specific format used for each type.

TYPE 1 COMMAND: This command provides formatting data, describes the channel configuration, and formats the specified parts of the disk. This command line has a maximum of 37 characters as shown in Table 5-1 where each ASR column is equal to one character.

The formatted record will contain in separate words the associated record address, unit number, cylinder number, head number, sequence of the record in the format, and a -1. The remaining data portion of the record will be filled with zeros.

A track can be formatted in 3 + n revolutions, where n is the number of records per track. Each revolution takes 25 or 35 ms depending on the type of unit. Formatting may be terminated by setting Sense Switch 1.

Table 5-1. Column Assignments for M$FT Type 1 Commands

ASR Column	Definition	Range and Base
1	Format command	Must be 1
2	Number of unit to be formatted	0-7
3-4	Number of starting surface	00-19
5-6	Number of surfaces to be formatted on current cylinder	$01\text{-}20_{10}$
7-9	Number of starting cylinder	$000\text{-}202_{10}$
10-12	Number of cylinders to be formatted	$001\text{-}203_{10}$
13-15	Number of records per track	$001\text{-}103_{10}$
16-19	Number of words per record	$0001\text{-}189_{10}$
20-25	Address of first record to be formatted	$000000\text{-}177777_8$
26-31	Increment to be added for address of each succeeding record	$000001\text{-}177777_8$
32-33	Additional gap over 5%[1] expressed in tenths of a percent (e.g., 7.3% gap would be specified by 23 in columns 32 and 33)	00-99
34	Channel type: 0 for DMA, 1 for DMC	0-1
35-36	Appropriate DMA or DMC channel number	$01\text{-}04_{10}$ for DMA $01\text{-}16_{10}$ for DMC
37	Interlace factor	0-7

[1] Additional gap over 5% is recommended if the prime power source is subject to frequency variations (as in standby supply) or if the disk packs are to transported to a different geographical area. Additional gap may also be used to gain interrecord programming time.

M$FT also contains an address interlace facility which allows the programmer to optimize access time and storage capacity. A 0 or 1 in column 37 of the command line indicates that records will be formatted sequentially (a 1:1 interlace factor); a 2 indicates that one nonsequential record will be formatted between sequentially numbered records (a 2:1 interlace factor); etc.

TYPE 2 COMMAND: This command returns all heads to cylinder zero. Column assignments for the command line are presented in Table 5-2. A type 1 command must be given before a type 2 command in order to provide I/O channel data. To provide channel data without actually formatting the disk, a type 1 command may be issued with one of the arguments intentionally specified out-of-range (e.g., an address of AAAAAA).

TYPE 3 COMMAND: To print the contents of the command buffer, a type 3 command is specified using the command line column assignments presented in Table 5-2. This command is of limited use.

TYPE 4 COMMAND: Command type 4 as presented in Table 5-2, is used to exit from the F mode.

Table 5-2. Column Assignments for M$FT Type 2, 3, and 4 Commands

Command Type	ASR Column	Definition	Range and Base
2	1	Seek track zero command	Must be 2
	2	Number of the unit commanded to seek	0-7
3	1	Command which prints command buffer	Must be 3
4	1	Command which exits to mode question	Must be 4

Keyboard Conventions for F Mode

In the F mode the following keyboard conventions apply.

Rubout (DEL) - Backspaces the line one column.

Left arrow - Erases the entire command line, issues line feed to start line again.

Space - Skips one line image column.

Backslash (shift L) or forward slash (/) - Skips six line image columns.

OLERT (O) MODE

This mode should be used instead of the F mode to format disk packs used with an OLERT system. When the O mode is selected, DMC channel 1 and unit 0 is assumed by M$FT. The gap size is fixed at 5%, and the interlace option is not available. Only one 20-surface unit may be formatted using this option, but up to two 10-surface units or four 2-surface units may be formatted. In a multiunit system formatting starts at unit 0, and M$FT automatically switches to the other unit as required.

After the O mode has been requested, the system requests the size of the program, table, and user areas, using the following format.

```
MODE ?: O
2, 10 OR 20 ?: 20        - Number of surfaces
IN CYLINDERS
      PGM SZ ?: 1        - Number of cylinders in program area
      TBL SZ ?: 1        - Number of cylinders in table area
      USE SZ ?: 1        - Number of cylinders in user area
```

The program area will have 512 words per record and three records per track. The addresses of the three records will be '0 + N, '1777 + N, and '3776 + N, where N is the relative track number in octal. Typical addresses for a 20-surface disk are presented in Table 5-3.

Table 5-3. Typical M$FT Program Area Addresses for 20-Surface Disk

Cylinder	Head	Record	N_{10}	Calculation	Address
1	8	3	28	'3776 + '34	'4032
0	8	2	8	'1777 + '10	'2007
2	13	1	53	'0000 + '65	'0065

The table area will have 104 words per record and 15 records per track. The addresses of the 15 records will be '0 + N, '313 + N, '626 + N, etc.

The user area will have 1,800 words per record and one record per track. The addresses of the records will be '0 + N.

Each area must be a minimum of one cylinder, but the total number of cylinders specified must not exceed 200 for a 20-surface unit, 400 for two 10-surface units, and 800 for four 2-surface units.

TRACK SPECIFICATION (T) MODE

Inputs in T mode serve as arguments for verify (V) and read (R) mode operations. The format of the T mode system/user interchange for a 20-surface disk is presented below. The range of arguments must be modified for the 2- or 10-surface disk.

UNIT ?:	0-7 (choose one)
CYL ?:	0-202 (choose one)
HEAD?:	0-19 (choose one)

See "Read One Record (R) Mode" below for keyboard conventions.

VERIFY FORMAT (V) MODE

In the V mode, M$FT reads addresses on the selected track until it finds a repeat. It then types out the octal addresses (in the order found) and associated decimal lengths of all the records on the track. Set Sense Switch 1 to suppress printout. See "Read One Record (R) Mode" below for keyboard conventions and information on the first use of the **V mode.**

READ ONE RECORD (R) MODE

In this mode, M$FT reads a record from the selected track and prints in octal the requested portion of the record. The following information is requested when the R mode is selected.

ADRS ?:	Octal record address
WORDS ?:	Decimal number of words to read ($\leq$ 1,892)
PRINT ?:	Decimal print limits, separated by a comma

The setting of Sense Switch 1 will suppress printing. With this switch set, M$FT will print out the first word specified in the response to the PRINT?: request.

KEYBOARD CONVENTIONS FOR T, V, AND R MODES

The following keyboard conventions apply in the T, V, and R modes.

Rubout (DEL)	- Returns to the first question with mode (e.g., UNIT?: in T mode).
Period or Carriage return	- Terminates an input field.
Comma	- Separates subfields (used only in R mode print limits).

CHANNEL DATA IN V OR R MODE

The first time V or R mode is requested, M$FT calls for channel data via the following questions.

C OR A ?: - Type C for DMC or A for DMA.

CHAN ?: - Type the channel number (1-16).

Error Messages

M$FT may output the diagnostic messages listed in Table 5-4 to indicate an error condition.

Table 5-4. M$FT Error Messages

WRONG CMND	Command type not within 1-4 range
WRONG CHAR	Input character neither number nor recognized control character
OVER 37 CHAR	37-character limit to command line exceeded
AA* OUT OF RANGE	Attempt to format more than 203 cylinders on one pack or Specified unit number > 7 or Decimal number greater than upper range limit
AA* NOT OCTAL	Nonoctal character where octal is required
AA* ZERO	Channel number, or number of surfaces, cylinders, records, or words/record to be formatted illegally specified as 0
ERR STATUS XX, XX	Error indication in status word (XX's are bit numbers set)

*AA is the number of the column which contains the error.

Formatting Examples

Figures 5-3 through 5-6 contain examples of M$FT formatting teletype outputs. In these examples the various modes and keyboard conventions are used to illustrate conventional and OLERT formatting. Input errors have been used to generate typical error messages.

CONVENTIONAL

Figure 5-3 illustrates conventional formatting. When M$FT is started an introductory line is typed and the mode is requested. When an invalid mode (1) is selected, M$FT ignores the entry and generates a second mode request. After selecting the F

mode, a command line of over 37 characters is entered causing M$FT to issue an error message and a mode request. Then, the F mode is selected again, and a valid command line is entered. This formats a single 1,800-word record at address '10000 on unit 0, head 0. DMC channel 1, a 5% gap, and a 1:1 interlace factor are used.

The next example in this illustration formats eight 800-word records on unit 0, cylinders 138 and 139, heads 8 and 9. The starting address is '17, the gap is 7%, and the interlace factor is 1:1. An error message is output, because column 25 of the command line contains an 8. A second format operation is attempted using the forward slash to tab across the line to the erroneous column. A backslash could have been used to perform the same function.

The second format operation is verified by checking the first and last records. The desired track is specified via the T mode, and then the V mode is selected. Each time M$FT is started at location '1000 it requests channel data the first time the V or R mode is specified. In this example the channel data is identified, and then the octal addresses and associated decimal lengths for all records on the track are printed. The last track is verified in a similar manner except the channel data is not requested a second time.

Next, the record at address '26 on cylinder 139, surface 9 is read. Although 1,000 words are specified, only the 800 words in the record plus the checksum are read, and the first 10 words are printed. Since this record was not the first record formatted on the track, three words of zero precede the address, unit, cylinder, head, and sequence numbers. The -1 word 9 is used to ensure that all bits are used at least once in checksum calculations.

In subsequent records in the format two words of zero precede the format program variables. The use of these variables and the -1 does not serve any specific function in M$FT, but they do provide the user with a means of tracing the format history of a disk pack and possibly a unit-to-unit compatibility problem.

FORMAT/WRITE

In Figure 5-4, 15 records of 100 words each are formatted on unit 0, surface 9, cylinder 139, with a starting address of '26 and a 2:1 interlace factor. The track is verified to check the formatting and record interlace. From the printout it can be seen that all records have 100 words and that the addresses have a 2:1 interlace.

```
DISC FORMAT  3 MAY 71 REV E
MODE ?: 1
MODE ?: F
1000001000001001180001000000000001010
OVER 37 CHAR
MODE ?: F
1000010000010011800010000000000001010


MODE ?: F
1008021380020020800000018000001201011
COLUMN 2500NOT OCTAL
MODE ?: F
////7
MODE ?: T
UNIT ?: 0
 CYL ?: 138
HEAD ?: 8
MODE ?: V
C OR A ?: C
  CHAN ?: 1
  000017   800
  000020   800


MODE ?: T
UNIT ?: 0
 CYL ?: 139
HEAD ?: 9
MODE ?: V
  000025   800
  000026   800


MODE ?: R
 ADRS ?: 26
WORDS ?: 1000
PRINT ?: 1,10
       1 000000
       2 000000
       3 000000
       4 000026
       5 000000
       6 000213
       7 000011
       8 000002
       9 177777
      10 000000
```

Figure 5-3. M$FT Conventional Formatting Example

```
MODE ?: F
1009011390010150100000026000001001012
MODE ?: T
UNIT ?: 0
 CYL ?: 139
HEAD ?: 9
MODE ?: V
  000034     100
  000044     100
  000035     100
  000026     100
  000036     100
  000027     100
  000037     100
  000030     100
  000040     100
  000031     100
  000041     100
  000032     100
  000042     100
  000033     100
  000043     100

MODE ?: T
UNIT ?: 0
 CYL ?: 139
HEAD ?: 9
MODE ?: V
  000041     100
  000032     100
  000042     100
  000033     100
  000043     100
  000034     100
  000044     100
  000035     100
  000026       4
  000036     100
  000027     100
  000037     100
  000030     100
  000040     100
  000031     100


MODE ?: R
 ADRS ?: 26
WORDS ?: 10
PRINT ?: 1,10
       1 000000
       2 000075
       3 000100
       4 000100
       5 000150
       6 000125
       7 000000
       8 000000
       9 000000
      10 000000
```

Figure 5-4. M$FT Format/Write Example

Then, an external routine (generated using the program in Figure 4-4) is loaded and run to write a 4-word record on the formatted track at address '26. The track is verified a second time to show that address '26 now contains a 4-word record. To verify that the data was written, a read operation is performed with an address of '26 specified. The four words that were written are printed along with the checksum.

INTERLACE

The example presented in Figure 5-4 illustrates the formatting of 15 records on a track with a 2:1 interlace factor. The verification of the track shows that records with sequential addresses have a single record formatted between them (i.e., record address '37 is between addresses '26 and '27).

It is not always possible to interlace records evenly for various interlace factors, but M$FT evaluates the records/track and interlace factor to determine the optimum formatting scheme. To illustrate this point, Figure 5-5 presents the results of a formatting operation where the 15 records have been formatted using a 3:1 interlace factor. The results of the verification indicate that all sequential records except address '32 and '37 are separated by two records. In the case of addresses '32 and '37, three records separate them and their next sequential address.

OLERT

Figure 5-6 illustrates the use of the OLERT (O) mode. In this example, the size of the three areas have been designated as one cylinder each.

Verification of unit 0, cylinder 0, head 0 indicates that the track has three 512-word records with addresses '0, '1777, and '3776 respectively. Then, verification is repeated for head 1 to illustrate the incrementing of the record addresses.

The table area is checked by verifying unit 0, cylinder 1, head 0, which has been formatted with 15 records of 104-words each. The first record address is '24, the second record address is '337 ('24 + '313), and so on until the fifteenth record address is '5456.

```
MODE ?: F
10090113900101501000000260000010010l3
MODE ?: T
UNIT ?: 0
 CYL ?: 139
HEAD ?: 9
MODE ?: V
  000036     100
  000043     100
  000032     100
  000037     100
  000044     100
  000026     100
  000033     100
  000040     100
  000027     100
  000034     100
  000041     100
  000030     100
  000035     100
  000042     100
  000031     100

MODE ?:
```

Figure 5-5. M$FT Interlace Example

```
MODE  ?: 0
2, 10 OR 20 ?: 20
IN CYLINDERS
   PGM SZ ?: 1
   TBL SZ ?: 1
   USE SZ ?: 1


MODE ?: T
UNIT ?: 0
 CYL ?: 0
HEAD ?: 0
MODE ?: V
   003776     512
   000000     512
   001777     512


MODE ?: T
UNIT ?: 0
 CYL ?: 0
HEAD ?: 1
MODE ?: V
   003777     512
   000001     512
   002000     512


MODE ?: T
UNIT ?: 0
 CYL ?: 1
HEAD ?: 0
MODE ?: V
   003467     104
   004002     104
   004315     104
   004630     104
   005143     104
   005456     104
   000024     104
   000337     104
   000652     104
   001165     104
   001500     104
   002013     104
   002326     104
   002641     104
   003154     104
```

Figure 5-6. M$FT OLERT Format Example

SECTION VI
FORTRAN ACCESS TO DISK STORAGE

Programmers writing in Fortran may use the disk in the same manner as an assembly language programmer. Data records will be unformatted (in the Fortran sense) and the programmer must supply the exact disk location to be used (unit, cylinder, head, and address). He must also provide for initializing the system, for operations corresponding to file opening and closing, and for transfer close-out (with error handling).

Honeywell does not provide object programs as part of the software package but suggests that the following examples be adapted to meet specific requirements. The code shown uses some non-ANSI features available in the one-pass Fortran Compiler (Doc. No. 70180463000), starting with revision H, and compiled on a computer with 8K or more of memory. If these conditions cannot be met, the same end result can be obtained by transferring more code to assembly language subroutines. The technique for doing this, using the argument transfer program F$AT, is detailed in the Assembly Language Manual (Doc. No. 70130072442).

ERROR PROCESSING

Disk data transfers are sensitive to the instructions being executed during the actual transfer period. If a DMC access cannot be made in the required time, then the data access error bit will be set in the status word and the transfer must be repeated. Some rate of access errors must be tolerated as a normal situation for simultaneous I/O transfer and computation if the disk is connected with a DMC (an access error is unlikely for connection to a DMA channel).

The propensity for access errors is greater in most respects for the Model 316 than for the Model 516, and greater still for a Model-20 DMC than for a Model-21 DMC. It is relatively high for a 10- or 20-surface option (12μs aperture) and low for a 2-surface option (17 μs aperture). The access error may result from other hardware activity (which generally is not under program control or from the time required for indirect addressing, long shifts, and the optional multiply, divide and normalize instructions.

The Model 516 Fortran programmer may reduce the access error rate by avoiding the use of relational operators in logical IF statements which compile a 15-bit shift instruction. Thus, during the transfer period, the code generated by IF (A.GT.B) GO TO 200 would be likely to cause an access error, while the code from IF (A-B) 100, 200, 200, would not. The access error rate usually cannot be reduced to zero, because most operations involving a multiply or divide (regardless of the hardware option) include a 15-bit shift. The presence of shifts (or multiply, divide, or indirect addressing) does not affect the Model 316 access error rate.

In the noninterrupt scheme suggested later the transfer is assumed "Closed-Out" just before the data is used (input) or just before the memory is re-used (output). If the transfer must be repeated, there is no advantage in attempting to perform useful computation, and the transfer will not be again subject to access errors caused by the program. It is possible to design a disk access method with several buffers before and after the data being acted upon, or a nonsequential or multitasking feature which will cause the above not to be applicable. It is also possible not to attempt simultaneous compute and seek plus transfer at all.

ASSEMBLY LANGUAGE INTERFACE

Figure 6-1 is a suggested interface to connect Fortran user programs to the driver program M$10. The corresponding names are identical except the dollar sign is replaced with the letter D. The arguments (which have labels related to the meaning) are known to Fortran programs if they are declared External. DMC channel 1 is assumed.

FORTRAN USING PROGRAM

Figure 6-2 is an example of a program that accesses the disk through M$IO. Before it becomes an operational program, it must be associated with a program requiring the access, either as a subroutine or by assigned or computed GO TO statements.

It is assumed that the correct values for the transfer desired have been computed and are in place:

UNIT	Unit 0 through 7
DCYL	Cylinder 1 through 203
DHEAD	Head 1 through 2, 10 or 20
RECAD	Address 32768 through 32767
WORDS	Word count 1 through 1800 or 1891

MODE	Read, write, read address (2HRD, WR or RA)
BUFA	BUFA1 or BUFA2

Two buffers of 62 words each have been declared as BUFR1 and BUFR2. Data areas DATA1 and DATA2 are 60 words each and are made equivalent two words into BUFR1 and BUFR2. This allows for the two words required by M$IO.

The arguments required by M$10 are declared as external:

STW	Setup word
CYL	Cylinder
BUF	Buffer address (in memory)
REC	Record address (on track)
WDS	Word count
CFUN	CP Finished unit
SZUN	Seek Zero unit

The initializing section is statements 90 through 92. The first part (which is executed only once) sets bit 1 in the two address constants BUFA1 and BUFA2. This will cause M$IO to return control as soon as a transfer or seek plus transfer is set up. The DO loop (executed each time the program is initialized) brings each unit (through UNMAX, assumed to be three in this example) to its reference position and aligns the pointer within M$IO. Note that the unit is shifted into position by multiplying by 2,048. An error during the seek zero operation (such as a unit not on line) would execute the statement GO TO 200 on return from MDSZ. A normal error-free seek will skip the instruction following the call.

Statement 100 is the start of the read-write-read address portion. The opening call to M$CK ensures that no operation is in process and the new arguments can be moved into place. The error path to statement 201 generally indicates that simultaneous calls are being made on the disk.

If the requested mode is found to be acceptable, the setup word is formed from the unit head and mode. Mode WR causes bit 1 of the setup word to be set. The cylinder, buffer and record address are moved forward verbatim. If the mode is RA, then bit 1 of the word count is set (the count must be positive), as it is forwarded. An error in the start of the requested operation (detected by M$IO via MDIO) will result in control going to statement 202.

A read or write operation is shown as going to statement 401 while the transfer or transfer plus seek is taking place. Eventually the transfer must be closed out by checking that it is complete and no errors were detected. This is done by a call to M$CK. An error will cause control to go to statement 204 as shown. No errors will result in control passing to statement 402 which is part of the user program.

If the mode was RA, then the call to M$CK. is made immediately. Upon return, the track record address that was just read will be found in the first word of the buffer area, and the rotational position of the disk may be determined.

No separate example is given for the central processor finished function, as it would be virtually identical to the seek zero example.

Except for statement 92, all continue statements must be replaced with code appropriate to the entire program. In the example they serve only to allow error-free compilation.

NON-ANSI FORTRAN FEATURES

The Fortran used in Figure 6-2 is non standard with respect to the use of the External declarations (which are used like the DAP assembly language pseudo operation EXT) and the Data statement (which corresponds to the DAP pseudo-operation DAC) to obtain the addresses of the buffers.

LOC and ISTORE are members of the Honeywell supplied library.

USE OF FORTRAN FORMAT STATEMENTS

A variable list may be processed against a format by use of the dummy device driver shown in Figure 6-3. During a write, data is gathered from the list elements and formatted into a 120-character buffer in F$IO. The unused portion of the buffer is filled with blanks. During a read, data is scattered from the 120-character buffer to become the new contents of the list. Of the two format lists, one is presumably an nA2 to effect an n-word buffer to buffer copy.

There can be no intervening Read or Write statements or the contents of F$IO will be disturbed. The choice of device 9 was arbitrary. Any device number that will not be required may be used; however, the dummy routine must be loaded before the run-time library is loaded.

Figure 6-4 shows an example of this scheme. The variables may be made equivalent to the desired points in the user buffer areas, or they may be scattered as in normal I/O lists.

```
        ENT   MDIN              DECLARE LABELS AS
        ENT   MDCF              ENTRY POINTS FOR
        ENT   MDSZ              CORRESPONDING FORTRAN
        ENT   MDIO              EXTERNAL DECLARATIONS
        ENT   STW
        ENT   CYL
        ENT   BUF
        ENT   REC
        ENT   WDS
        ENT   CFUN
        ENT   SZUN
*
        REL
*
MDIO    DAC   **                DATA READ OR WRITE ENTRY
        CALL  M$IO
STW     BSZ   1                 SETUP, WORD (UNIT AND HEAD)
CYL     BSZ   1                 CYLINDER
BUF     DAC   **                DATA ADDRESS IN MEMORY
REC     BSZ   1                 RECORD ADDRESS ON DISC
WDS     BSZ   1                 WORD COUNT
        SKP                     ERROR RETURN
        IRS   MDIO              NORMAL RETURN
        JMP*  MDIO
*
MDIN    DAC   **                INITIALIZE ENTRY
        CALL  M$IN
        DEC   1                 DMC CHANNEL ONE
        JMP*  MDIN
*
MDSZ    DAC   **                SEEK ZERO ENTRY
        CALL  M$SZ
SZUN    BSZ   1                 UNIT
        SKP                     ERROR RETURN
        IRS   MDSZ              NORMAL RETURN
        JMP*  MDSZ
*
MDCF    DAC   **                CPU FINISHED ENTRY
        CALL  M$EF
CFUN    BSZ   1                 UNIT
        SKP                     ERROR RETURN
        IRS   MDCF              NORMAL RETURN
        JMP*  MDCF
*
        END
```

Figure 6-1. Fortran-to-M$IO Interface

```
C
      INTEGER UNIT, DCYL, DHEAD, RECAD, WORDS, MODE,
     + BUFA, BUFA1, BUFA2, UNMAX,
     + BUFR1 (62), BUFR2 (62),
     + DATA1 (60), DATA2 (60),
     + STW, CYL, BUF, REC, WDS,  CFUN, SZUN
      EXTERNAL STW, CYL, BUF, REC, WDS, CFUN, SZUN
      EQUIVALENCE (BUFR1(3), DATA1(1)), (BUFR2(3),DATA2(1))
      LOGICAL INDONE
      DATA INDONE/.FALSE./,UNMAX/3/,
     + BUFA1/BUFR1/, BUFA2/BUFR2/
C
   90 IF (INDONE) GO TO 91
      INDONE = .TRUE.
      BUFA1 = BUFA1 + 32767 + 1
      BUFA2 = BUFA2 + 32767 + 1
      CALL MDIN
   91   DO 92 I = 1,UNMAX
        J = (I-1) * 2048
        CALL ISTORE (LOC(SZUN),J)
        CALL MDSZ
        GO TO 200
C
   92   CONTINUE
C
  100 CALL M$CK
      GO TO 201
C
  101 IF ((MODE.NE.2HRD).AND.(MODE.NE.2HWR).AND.(MODE.NE.2HRA))
     + GO TO 300
      J = (UNIT * 2048) + (DHEAD * 64)
      IF (MODE.EQ.2HWR) J = J+32767+1
      CALL ISTORE (LOC(STW),J)
      CALL ISTORE (LOC(CYL),DCYL)
      CALL ISTORE (LOC(BUF),BUFA)
      CALL ISTORE (LOC(REC),RECAD)
      J = WORDS
      IF (MODE.EQ.2HRA) J = J+32767+1
      CALL ISTORE (LOC(WDS),J)
      CALL MDIO
      GO TO 202
C
  102 IF (MODE.NE.2HRA) GO TO 401
      CALL M$CK
      GO TO 203
C
C
  400 CONTINUE
C
  401 CONTINUE
      CALL M$CK
      GO TO 204
C
  402 CONTINUE
C
  300 CONTINUE
C
  200 CONTINUE
  201 CONTINUE
  202 CONTINUE
  203 CONTINUE
  204 CONTINUE
C
      END
```

Figure 6-2. Fortran Code to Access Disk Through M$IO

```
*
      ENT   F$W9
      ENT   F$R9
*
      REL
*
F$W9  DAC   **
      CALL  F$IO
      DAC   **
      IRS   *-1
      JMP*  *-2
*
F$R9  DAC*  **
      CALL  F$IO
      DAC   **
      IRS   *-1
      JMP*  *-2
*
      END
```

Figure 6-3. Dummy Device Driver

```
C
      WRITE (9,900) IVAR1, IVAR2, IVAR3
      READ (9,901) DATA1
C
  900 FORMAT (1H ,7HFIG 6-4,4X,I3,4X,I5,4X,I5)
  901 FORMAT (60A2)
      END
```

Figure 6-4. Use of Dummy Device Driver