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ADDITIONAL OPERATIONAL SPECIFICATIONS FOR VARIABLE BLOCK ROTATING MASS STORAGE DEVICES

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A Supplement to FIPS PUB 63-1

Additional Operational Specifications for Variable Block Rotating Mass Storage Devices

Abstract

This report is a supplement to Federal Information Processing Standards Publication (FIPS PUB) 63.* FIPS 63 specifies the command set and track formats of Variable Block Rotating Mass Storage (VBRMS) Devices. The VBRMS devices specified in FIPS 63 are frequently called Count, Key, and Data devices because each data recorder includes a separate count field, an optional key field, and a variable length data field. A number of distinct classes of VBRMS devices exist in common use, some of which are obsolete and therefore of little present interest. This report covers recent VBRMS devices which are widely available. It specifies details of capacities and sense information pertinent to each class. Only sense information which is useful to error recovery software is specified. Sense information which is used to diagnose internal subsystem faults is not specified.

*FIPS PUB 63 refers to the most recent revision of that publication designated as FIPS 63-1, 63-2, etc.

Foreword

This report incorporates, with minor revisions, material extracted from the earlier version of FIPS PUB 63, dated 1979 August 27 that described supplemental device specifications for VBRMS Classes A, B, and C.

In addition, two new sections, similar in form to those extracted from FIPS 63, have been added for two new classes, D and E. It is anticipated that this specification will be revised to incorporate additional classes as new VBRMS devices become commercially available.

The Federal Information Processing Standard I/O Channel Interface, FIPS 60,* provides specifications for the functional, electrical, and mechanical characteristics of the I/O Channel Interface. This includes the general specification of address, command, status, and data information flow over the I/O Channel Interface.

The Federal Information Processing Standard entitled Operational Specifications for Variable Block Rotating Mass Storage Subsystems, FIPS 63, specifies the logical interface between peripheral subsystems of the variable block rotating mass storage generic category and the Standard I/O Channel, including:

(1) Addressing formats for rotating mass storage control units and devices.

(2) Command formats for the control of rotating mass storage control units and devices.

(3) Data formats for transfer of data to and from rotating mass storage subsystems.

(4) Record formats for the rotating mass storage media.

(5) Programming considerations for rotating mass storage subsystems.

Most commercially available disk subsystems which conform to FIPS 60 and FIPS 63 employ devices which conform to one of the VBRMS classes, specified herein. The specifications which follow may be used to procure devices of a specific class for reasons of compatibility or interchangeability.

*FIPS 60 refers to the most recent revision of that publication designated as FIPS 60-1, 60-2, etc.

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Introduction — Terminology

Each of the specifications which follow defines the characteristics of a particular class of Variable Block Rotating Mass Storage (VBRMS) device as viewed from the I/O channel looking through a control unit. The following definitions are used in this introduction and in the class specifications:

Access Mechanism - An assembly, containing read/write heads and a mechanism for positioning them to the desired cylinder. In some cases, a single access mechanism is used to implement more than one device. In other cases, a single drive may have two access mechanisms, each implementing a separate device.

Control Unit - Control units attach to the I/O channel and connect it to disk drives. Control units for magnetic disks usually contain a programmable unit which converts the relatively high level commands of FIPS 63 to the lower level commands required by the disk drives. Control units also generate and check the error correcting codes used to protect the separate ID, Key, and Data fields which are recorded.

Device - For the purpose of this document, a device is whatever can be uniquely addressed as a device over the I/O channel. The class specifications which follow specify the characteristics of devices. A device is a logical concept which may not map one-to-one into drives. A single drive may contain one or more devices. In principle, a device could span several drives; in practice, this does not occur.

Drive - A drive is a single rotating assembly, usually with several recording surfaces and one or more access mechanisms. A single drive may contain one or more devices.

Subsystem - The combination of a control unit attached to one or more devices.

Unit - The term unit is not used in the class specifications which follow. However, it is used commercially to indicate a single physical assembly which may contain one, two, or more drives and devices. The introduction briefly describes the common commercial packaging of devices and drives into units. Note also that manufacturers frequently offer the same device in two kinds of units; one, often called an "A" unit, connects directly to the control unit, and the other, often called a "B" unit, connects to an A unit or another B unit, forming a "string" of units.

VBRMS Classes

Variable Block Rotating Mass Storage (VBRMS) subsystems utilizing the I/O Channel Interface of FIPS 60 and the command set of FIPS 63 were first available in 1965. Since that time, compatible magnetic disks have been very widely used and have dominated the commercial marketplace for large "mainframe" computers. The command set and storage format specified in FIPS 63 employs records with separate Count (sometimes called ID), optional Key, and variable length Data fields, and devices which employ it are frequently called the Count, Key, and Data devices. These FIPS 63 conforming devices are also referred to here as Variable Block Rotating Mass Storage (VBRMS) devices to distinguish them from the type of RMS devices that only record in fixed block format and which have been designated

FBRMS devices. While a number of classes of VBRMS devices have been built, several are obsolete and little used today. The VBRMS classes defined herein encompass virtually all FIPS 60 compatible magnetic disk devices in use today. Those classes are:

Class A: This VBRMS device class was introduced in 1971 with a capacity of roughly 100 Mbytes of storage per device. In 1973, an improved version was introduced with double the track density of the original Class A devices, and twice the original capacity (200 Mbytes/s). Devices of this class typically use a block multiplexor channel with the High Speed Transfer feature (see FIPS 60, I/O Channel Interface) and have a typical data transfer rate of 806 kbytes/s. Although some commercial fixed medium devices which operate in "native mode" as Class B devices are capable of emulating Class A devices, most Class A drives employ a removable disk pack, with 19 data surfaces and 1 servo surface. Since future I/O channel compatible removable pack drives are not expected, Class A drives should remain in wide use for some time. Although standards do not exist to provide for the use of disk packs from Class A devices as a medium of data exchange, such packs are often used for that purpose.

Class B: This class was introduced in 1976 with a capacity of roughly 317.5 Mbytes of storage per device. Since its original introduction, several manufacturers have offered "double density" drives with twice the original capacity. Such double density drives typically are made to appear to the I/O channel as two logically separate 317.5 Mbyte devices. All Class B devices use fixed, sealed (Winchester) media. Most Class B drives employ 15 data surfaces, with 2 read/write heads per surface, yielding a cylinder of 30 tracks. A separate servo surface is also used. At least one manufacturer makes a Class B drive with 20 surfaces and electronically remaps addresses in the control unit so as to appear as two logical devices with a 30 track cylinder. Devices of this class typically use a block-multiplexor channel with the High Speed Transfer feature and have a typical data transfer rate of 1198 kbytes/s. Class B devices are typically packaged two drives to a "unit," so a single density Class B unit typically contains two logical devices, while a double density unit contains four logical devices. Many drives which normally operate as Class B devices are capable of operating as (i.e., emulating) Class A devices.

Class C: This VBRMS device class was introduced in 1973. Class C drives employ a removable data module which combined the recording medium and heads in a single sealed unit. Both 35 and 70 Mbyte capacity data modules exist. These data modules proved quite expensive, however, and Class C devices are rapidly diminishing in importance. Class C devices were the first disk drives to employ a closed filtered environment, low mass heads and a lubricated surface for the heads to rest upon when the drive is not rotating. This is frequently called "Winchester" technology and it is now widely used in drives with fixed, non-removable media. Although the Class C sealed removable data module drives had limited commercial success, the technology they introduced has been very successful in non-removable media drives. Class C devices typically use a block multiplexor channel with the High Speed Data Transfer feature and have a typical data transfer rate of 885 kbytes/s.

Class D: This VBRMS device class was introduced in 1981. Devices of this class have a logical structure permitting a nominal maximum capacity of 409.8 Mbytes. Typically, two access mechanisms, each with two heads per surface, are used per drive, forming two logical devices in a single physical unit with a total nominal capacity of 819.7 Mbytes. Thin film recording heads and run length limited

recording codes typically provide high recording densities. While most magnetic disks spin at 3600 rpm, Class D disks typically spin at 2964 rpm, which reduces the data transfer rate somewhat, and increases access latencies. Even with the slower rotation, Class D devices transfer at a nominal rate of 1859 kbytes/s, and many older I/O channels may be too slow for Class D devices. A block multiplexor channel with the High Speed Data Transfer feature is needed (see FIPS 60, I/O Channel Interface).

Class E: At the present time, Class E VBRMS devices are the highest technology commercially available magnetic disks. Devices of this class were first delivered to customers late in 1981. Each unit typically consists of two drives, each with two access mechanisms. Each access mechanism is a logical device with its own address and can access about 630 Mbytes of data. A Class E unit with four logical devices then has a nominal capacity of 2.52 Gbytes. Thin film recording heads and run length limited recording codes combine to permit very high recording densities and data transfer rates. The usual data transfer rate for Class E devices is 3 Mbytes/s, which requires an I/O channel with the Data Streaming feature (see FIPS 60, I/O Channel Interface). Some control units, however, contain a special "speed matching buffer" which allows Class E devices to be used with I/O channels which would otherwise be too slow.

CLASS A VARIABLE BLOCK ROTATING MASS STORAGE DEVICE SPECIFICATION

1. INTRODUCTION. This specification is one of a series that supplement FIPS PUB 63, Operational Specifications for Variable Block Rotating Mass Storage (VBRMS) Subsystems. Each specification in this series specifies the track format and sense information content for a particular class of variable block rotating mass storage device. The intent of this specification is to specify those characteristics of VBRMS subsystems which must be preserved to ensure interchangeability in normal operation, but not those characteristics needed to diagnose internal subsystem faults. Commercially available disk drives of this class usually employ a removable storage medium.

1.1 Scope. This specification prescribes the format and content of the 24 bytes of sense information generated by Class A rotating mass storage devices. The first eight sense bytes (bytes 0-7) are defined to contain high-level information reporting on the general state of the device resulting from the immediately preceding operation. The eighth byte identifies which of seven specified formats are employed in presenting the detailed sense information contained in the remaining 16 bytes.

1.2 Classification of Applicable Devices. Subsystems containing Class A VBRMS devices for which this specification is applicable are those that attach to the I/O Channel Interface specified in FIPS 60 and meet the following device level requirements:

Maximum Storage Capacity	=	100 or 200 megabytes per logical device address.
Cylinders/Address	=	404 or 808 logical user cylinders plus 7 alternate cylinders per logical device address.
Tracks/Cylinder	=	19 logical tracks per logical cylinder.
Maximum Track Capacity	=	13,030 bytes per logical track.

2. TRACK FORMAT. Track format is as defined in FIPS PUB 63. The optional extended home address information defined in Figure 2 of FIPS 63 is not provided in Class A devices.

3. SENSE INFORMATION. As described in FIPS PUB 60, sense bytes are used to supplement information contained in the status byte (see section 2.7 of FIPS 60). In general, sense information is fundamentally related to the design, operating features, and performance characteristics associated with a particular class of I/O device. Since FIPS 60 is applicable to a variety of peripheral subsystems, covering a wide range of performance characteristics and capabilities, it addresses only those items of sense information common to applicable equipment. Further details on the interpretation of information contained in the sense bytes pertaining to Class A devices are prescribed herein.

3.1 Generation and Processing. The rotating mass storage devices for which this specification is applicable provide for the generation of 24 bytes of sense information that describe any unusual conditions detected during the last operation of the subsystem as well as the actual state of the I/O device involved. The sense information is stored in the device and control unit and is transmitted to the channel in response to any of the sense commands. The sense information is cleared from the device upon acceptance of any command other than Test I/O or No-Op and by a

system reset of the control unit. Note that sense bits should be set to zero when their definitions are incompatible or inconsistent with choice of design. Unused sense bits should also be set to zero. If a device has the capability to recover from a particular error condition without software intervention, it is not necessary to generate sense information.

3.2 Summary of Format. The first eight bytes (0-7) of sense information provide high level information concerning general device status and condition. Sense byte 7 also identifies one of seven different formats, numbered 0-6, by which the remaining bytes 8-23 are to be interpreted. Three of these formats, numbered 1, 2, and 3 are employed for reporting manufacturer-related maintenance and diagnostic information. Two of the formats (formats 4 and 5) are used to report on device data errors. One format (format 0) is used to report on programming and system checks. Format 6 is used to report device usage/error statistics. Further details regarding the definition of these seven formats as well as the specifications for their contents are provided in sections 4 through 12 that follow for Class A VBRMS devices.

4. High-Level Sense Bytes 0-7. The first eight sense bytes contain high level information for Class A devices, as defined in section 1.2.

4.1 Byte 0: Common.

Bit	Designation	Interpretation
0	Command Reject	Indicates: (1) Invalid command code. (2) Invalid command sequence. (3) Invalid or incomplete argument transferred by a control command. (4) Track formatted without home address. (5) Write portion of file mask violated. (6) Write command issued when write protection mechanisms enabled. Bit 6, byte 1, will also be set. (7) Format write attempted on defective track. (8) A record zero count field of a defective track that points to itself instead of an alternate track.
1	Intervention Required	Indicates: (1) Addressed device not attached to system. (2) Addressed device not ready. (3) Addressed device in maintenance mode and unavailable for use. (4) Diagnostic Write or Load command issued and diagnostic is resident in control storage.
2	Bus Out Check	Indicates the control unit has detected a parity error in the data transferred from the channel.

3	Equipment Check	Indicates an unusual hardware condition somewhere in the device or control unit. The condition may be further defined in bytes 7 through 23.
4	Data Check	Indicates: (1) A correctable data error detected in information received from a device. The correctable bit 1, byte 2 will be set, and correction data will be in bytes 15 through 23. (2) An uncorrectable data error detected in information from a device. The condition is defined in byte 7.
5	Overrun	Indicates insufficient channel transfer rate to keep up with device transfer rate, on either a read or a write operation. When writing, the remaining portion of the record area is padded with a replicated data byte. Overruns may be retried by the control unit and if the retry eliminates the overrun the overrun condition is not posted.
6-7	Not Used	Set to zero for Class A devices.

4.2 Byte 1: Control Unit/Device State.

Bit	Designation	Interpretation
0	Permanent Error	Indicates an error not able to be recovered: (1) Control unit retry has been attempted and was unsuccessful. (2) No system error recovery procedure required or desirable. (3) A drive in unsafe condition has been detected and retry should not be attempted. This bit overrides any other sense bit settings and indicates that system error recovery procedures are not required.
1	Invalid Track Format	Indicates: (1) An attempt made to write data exceeding track capacity. (2) Index encountered at unexpected point during a read or search operation. (3) A previous operation attempted to write data exceeding the track capacity; this operation resulted in a record written into index.

2	End of Cylinder	Indicates: (1) A multitrack read or search attempted to go beyond the cylinder boundary. (2) An overflow operation attempted to go past the cylinder boundary. Byte 1, bit 7 will be set to indicate this condition.
3	Message to Operator	May be optionally used with format 3 to report permanent failures in alternate control units or paths.
4	No Record Found	Indicates a programming error due to two index points being sensed in command chain with no intervening Read in home address or data area, or without an intervening Write, Sense, or Control command.
5	File Protected	Indicates the file mask has been violated by: (1) Seek command. (2) Multitrack read or search. (3) An overflow operation violates the seek portion of the file mask. Byte 1, bit 7 (operation incomplete) is also set.
6	Write Inhibited	Indicates a write command issued when write protection mechanism is enabled. Byte 0, bit 0 will also be set.
7	Operation Incomplete	Indicates one of the following conditions occurred when processing an overflow record. For any of these conditions, byte 3 contains restart command information: (1) Overflow to a file protected boundary. Byte 1, bit 5 also set. (2) Overflow beyond cylinder boundary. Byte 1, bit 2 also set. (3) Correctable data error found in data area--not last segment. Byte 2, bit 1 and byte 0, bit 4 also set. (4) Correctable data error found in home address or count area--not first segment. (5) Uncorrectable data error found in any area--not first segment. (6) Defective or alternate track found after start of data transfer. (7) Seek error found in second or later segment.

4.3 Byte 2: Device/Media State.

Bit	Designation	Interpretation
0	Not Used	Set to zero for Class A devices.
1	Correctable	Indicates that the data error indicated by bit 4, byte 0 is correctable. Bytes 15 through 22 contain error recovery information.
2	Redundant Path	May be optionally used to indicate that the connection between control unit and device is via a redundant path. Redundant paths are used to achieve higher availability.
3	Environmental Data Present	Indicates that bytes 8 through 23 contain either usage/error statistics (format 6) or error logging information. Byte 7 indicates the format for bytes 8 through 23.
4	Emulation Mode	Optionally indicates that Class A RMS device characteristics are being emulated by a device that does not have Class A characteristics as its native mode.
5-7	Not Used	Set to zero for Class A devices.

4.4 Byte 3: Restart Command.

Bit	Designation	Interpretation
0-7	Restart Command	When bit 7, byte 1 is set, byte 3 indicates the command in process at the time of the interruption of the incomplete operation. 06 hexadecimal for the Read command and 05 hexadecimal for the Write command.

4.5 Byte 4: Physical Device Identification.

Bit	Designation	Interpretation
0-7	Model Dependent Address	This byte, if used, indicates the complete physical address of the device identified with the sense information. Since there is considerable variation in the precise interpretation of this byte in different Class A subsystems, the vendor's documentation should be used to determine its precise format and interpretation.

4.6 Byte 5: Cylinder Address.

Bit	Designation	Interpretation
0-7	Cylinder Low Address	For formats 0, 1, 2, 4, and 5, identifies the low-order cylinder address of the latest seek argument from channel. The meaning of this byte is model dependent for formats 3 and 6.

4.7 Byte 6: Cylinder High and Head Address.

Bit	Designation	Interpretation
0	Diagnostic Cylinder	This bit may be optionally used to indicate that a diagnostic cylinder is selected. Unspecified for formats 3 and 6.
1	Cylinder High Address-1	For 100 Mbyte devices, indicates the high order bit (value: 256) of the low-order cylinder address in byte 5. Unspecified for formats 3 and 6. For 200 Mbyte devices, indicates the high order bit (value: 512) of the low-order cylinder address in byte 5. Unspecified for formats 3 and 6.
2	Cylinder High Address-2	For 100 Mbyte devices, this bit is not used and is set to zero. Unspecified for formats 3 and 6. For 200 Mbyte devices, this bit indicates the high order bit (value: 256) of the low-order cylinder address in byte 5. Unspecified for formats 3 and 6.
3-7	Head Address	For formats 0, 1, 2, 4, and 5, identifies the head address of the last seek. Bit 3=16, bit 4=8, bit 5=4, bit 6=2, and bit 7=1. The use of this field is unspecified for formats 3 and 6. If an alternate track condition is detected and operation incompleted is posted during an overflow operation, byte 6 is set to the head address of the defective track plus 1.

4.8 Byte 7: Format/Message Designation.

Bit	Designation	Interpretation
0-3	Format	Indicates the format of bytes 8 through 23 as follows, in hexadecimal: 0 programming or system check 1 device equipment check 2 control unit equipment check 3 control unit control check 4 uncorrectable data check 5 correctable data check or data check with displacement information 6 usage/error statistics 7-F Not used for Class A devices.
4-7	Message	Indicates the specific nature of the error conditions for each of the above formats. The messages for Class A devices are shown below under the description for each of these formats.

5. FORMAT 0: Control Unit Program/System Check. If format bits 0-3 in byte 7 are all zero, then the sense format indicates programming or system check information associated with the control unit.

5.1 Format 0 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the programming or system check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class A devices.

5.2 Format 0, Bytes 8 Through 20. Sense bytes 8 through 20, for format 0, are not used and are set to zero for Class A devices.

5.3 Format 0, Byte 21. Sense byte 21, for format 0, optionally may contain the ID of the control unit.

5.4 Format 0, Bytes 22 Through 23. Sense bytes 22 through 23, for format 0, may optionally contain an unspecified model dependent symptom code, or they may be zero.

6. FORMAT 1: Device Equipment Check. If format bits 0-3 in byte 7 contain a hexadecimal 1, then the sense format indicates equipment check diagnostic information associated with the device.

6.1 Format 1 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the device equipment check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class A devices.

6.2 Format 1, Bytes 8 Through 23. Sense bytes 8 through 23, for format 1, contain information relating to device equipment checks that is manufacturer-dependent and is not specified.

7. FORMAT 2: Control Unit Equipment Check. If format bits 0-3 in byte 7 contain a 2, then the sense format indicates equipment check diagnostic information associated with the control unit.

7.1 Format 2 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the control unit equipment check. Message number meanings for Class A devices are:

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class A devices.

7.2 Format 2: Bytes 8 Through 23. Sense bytes 8 through 23, for format 2, contain diagnostic manufacturer-dependent information relating to control unit equipment checks. This information is not specified for Class A devices.

8. FORMAT 3: Control Unit Control Check. If format bits 0-3 in byte 7 contain a 3, then the sense format indicates control unit control check diagnostic information associated with the control unit.

8.1 Format 3 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the control unit control check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class A devices.

8.2 Format 3, Bytes 8 Through 23. Sense bytes 8 through 23, for format 3, contain diagnostic information relating to control unit control checks. This information is not specified for Class A devices.

9. FORMAT 4: Data Check. If format bits 0-3 in byte 7 contain a 4, then the sense format indicates uncorrectable data check information associated with the device.

9.1 Format 4 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the uncorrectable data check.

Hexadecimal Number	Meaning
0	Home Address (HA) area Error Correcting Code (ECC) uncorrectable.
1	Count area ECC uncorrectable.
2	Key area ECC uncorrectable.
3	Data area ECC uncorrectable.
4	Data synchronization in HA area unsuccessful.
5	Data synchronization in count area unsuccessful.
6	Data synchronization in key area unsuccessful.
7	Data synchronization in data area unsuccessful.
8	Unspecified.
9	No address mark detection on retry.
A-F	Unspecified.

9.2 Format 4, Bytes 8 Through 23. Sense bytes 8 through 23, for format 4, contain uncorrectable data check information, as shown below for Class A devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Number of the record in last count field read.

Note: Contents of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 or 4 (error occurred in HA), 1 or 5 (error occurred in count area), or 9 (no Address Mark detection on retry).

Byte 13	Sector number of the record in error.
Byte 14	Amount of offset used to recover from the error.
Byte 15	Number of retries used to recover from the error.
Byte 16	Identification of physical device that wrote record in error.

Byte 17-21	Unspecified.
Bytes 22-23	Fault symptom code, interpretation of codes not specified.

10. FORMAT 5: Correctable Data Check. If format bits 0-3 in byte 7 contain a 5, then the sense format indicates correctable data check information.

10.1 Format 5 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the correctable data check. Message number meanings for Class A devices follow:

Hexadecimal Number	Meaning
0	Correctable home address data check.
1	Correctable count area data check.
2	Correctable key area data check.
3	Correctable data area data check.
4-F	Unspecified.

10.2 Format 5, Bytes 8 Through 23. Sense bytes 8 through 23, for format 5, contain correctable data check information as shown below for Class A devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Record number of the record in last count field read. This byte is unreliable after a Space Count command.

Note: Counts of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 (error occurred in HA), or 1 (error occurred in count area).

Byte 13	Sector number of the record in error.
Byte 14	Amount of offset used to recover from the error.
Bytes 15-17	Specifies the number of bytes processed by the control unit to the end of the data area in error.

Bytes 18-19	Error displacement location of first byte in error within the data area measured from the end of area.
Bytes 20-22	Error pattern used for error correction function.
Byte 23	Bits 0-6 not used, bit 7 indicates that the channel truncated data transfer.

11. FORMAT 6: Usage/Error Statistics. If format bits 0-3 in byte 7 contain a 6, then the sense format indicates usage/error statistics information.

11.1 Format 6 Message Numbers. The message bits 4-7 in byte 7 optionally contain numbers further identifying the usage/error statistics for Class A devices.

Hexadecimal Number	Meaning
0-F	Not specified for Class A devices.

11.2 Format 6, Bytes 8 Through 23. Sense bytes 8 through 23, for format 6, contain usage/error statistics information as shown below for Class A devices.

Byte Number	Usage
8-11	Accumulated count of the number of bytes processed by the control unit in read or search operations. Retry operations are not included in count. Only key and data area counts are included.
12-13	Contains count of the number of correctable data errors processed by the control unit.
14-15	Contains a count of the number of uncorrectable data errors retried and successfully processed by the control unit.
16-17	Count of the number of seek commands processed by the control unit.
18	Not specified.
19	Count of number of seek errors retried by the control unit.
20-23	Not specified; these bytes typically contain error statistics for command and data overruns. Consult the vendor's documentation for the appropriate format.

12. FORMATS 7 Through F. If format bits 0-3 in byte 7 contain hexadecimal 7 through F, the sense format is unspecified for Class A devices.

CLASS B VARIABLE BLOCK ROTATING MASS STORAGE DEVICE SPECIFICATION

1. INTRODUCTION. This specification is one of a series that supplement FIPS PUB 63, Operational Specifications for Variable Block Rotating Mass Storage (VBRMS) Subsystems. Each specification in this series specifies the track format and sense information content for a particular class of rotating mass storage device. The intent of this specification is to specify those characteristics of VBRMS subsystems which must be preserved to ensure interchangeability in normal operation, but not those characteristics needed to diagnose internal subsystem faults. Commercially available disk drives of this class usually employ a non-removable storage medium. A number of Class B devices are available with "double density" recording, which appear to be two separate Class B devices, but are packaged in a single physical unit.

1.1 Scope. This specification prescribes the format and content of the 24 bytes of sense information generated by Class B rotating mass storage devices. The first eight sense bytes (bytes 0-7) are defined to contain high-level information reporting on the general state of the device resulting from the immediately preceding operation. The eighth byte identifies which of seven specified formats are employed in presenting the detailed sense information contained in the remaining 16 bytes.

1.2 Classification of Applicable Devices. Subsystems containing Class B VBRMS devices for which this specification is applicable are those that attach to the I/O Channel Interface specified in FIPS 60 and meet the following device level requirements:

Maximum Storage Capacity	=	317.5 megabytes per logical device address.
Cylinders/Address	=	555 logical user cylinders plus 5 alternate cylinders per logical device address.
Tracks/Cylinder	=	30 logical tracks per logical cylinder.
Maximum Track Capacity	=	19,069 bytes per logical track.

2. TRACK FORMAT. Track format is as defined in FIPS PUB 63. For Class B devices, there are 6 bytes of optional extended home adress information defining the presence and location of media defects. From zero to three defects may be defined.

3. SENSE INFORMATION. As described in FIPS PUB 60, sense bytes are used to supplement information contained in the status byte (see section 2.7 of FIPS 60). In general, sense information is fundamentally related to the design, operating features, and performance characteristics associated with a particular class of I/O device. Since FIPS 60 is applicable to a variety of peripheral subsystems, covering a wide range of performance characteristics and capabilities, it addresses only those items of sense information common to applicable equipment. Further details on the interpretation of information contained in the sense bytes pertaining to Class B devices are prescribed herein.

3.1 Generation and Processing. The rotating mass storage devices for which this specification is applicable provide for the generation of 24 bytes of sense information that describe any unusual conditions detected during the last operation of the subsystem as well as the actual state of the I/O device involved. The sense information is stored in the device and control unit and is transmitted to the channel in response to any of the sense commands. The sense information is cleared from

the device upon acceptance of any command other than Test I/O or No-Op and by a system reset of the control unit. Note that sense bits should be set to zero when their definitions are incompatible or inconsistent with choice of design. Unused sense bits should also be set to zero. If a device has the capability to recover from a particular error condition without software intervention, it is not necessary to generate sense information.

3.2 Summary of Format. The first eight bytes (0-7) of sense information provide high level information concerning general device status and condition. Sense byte 7 also identifies one of seven different formats, numbered 0-6, by which the remaining bytes 8-23 are to be interpreted. Three of these formats, numbered 1, 2, and 3 are employed for reporting manufacturer-related maintenance and diagnostic information. Two of the formats (formats 4 and 5) are used to report on device data errors. One format (format 0) is used to report on programming and system checks. Format 6 is used to report device usage/error statistics. Further details regarding the definition of these seven formats as well as the specifications for their contents are provided in sections 4 through 12 that follow for Class B VBRMS devices.

4. High-Level Sense Bytes 0-7. The first eight sense bytes contain high level information for Class B devices, as defined in section 1.2.

4.1 Byte 0: Common.

Bit	Designation	Interpretation
0	Command Reject	Indicates: (1) Invalid command code. (2) Invalid command sequence. (3) Invalid or incomplete argument transferred by a control command. (4) Track formatted without home address. (5) Write portion of file mask violated. (6) Write command issued when write protection mechanisms enabled. Bit 6, byte 1, will also be set. (7) Format write attempted on defective track. (8) A record zero count field of a defective track that points to itself instead of an alternate track.
1	Intervention Required	Indicates: (1) Addressed device not attached to system. (2) Addressed device not ready. (3) Addressed device in maintenance mode and unavailable for use. (4) Diagnostic Write or Load command issued and diagnostic is resident in control storage.
2	Bus Out Check	Indicates the control unit has detected a parity error in the data transferred from the channel.

3	Equipment Check	Indicates an unusual hardware condition somewhere in the device or control unit. The condition may be further defined in bytes 7 through 23.
4	Data Check	Indicates: (1) A correctable data error detected in information received from a device. The correctable bit 1, byte 2 will be set, and correction data will be in bytes 15 through 23. (2) An uncorrectable data error detected in information from a device. The condition is defined in byte 7.
5	Overrun	Indicates insufficient channel transfer rate to keep up with device transfer rate, on either a read or a write operation. When writing, the remaining portion of the record area is padded with a replicated data byte. Overruns may be retried by the control unit and, if the retry eliminates the overrun, the overrun condition is not posted.
6-7	Not Used	Set to zero for Class B devices.

4.2 Byte 1: Control Unit/Device State.

Bit	Designation	Interpretation
0	Permanent Error	Indicates an error not able to be recovered: (1) Control unit retry has been attempted and was unsuccessful. (2) No system error recovery procedure required or desirable. This bit overrides any other sense bit settings and indicates that system error recovery procedures are not required.
1	Invalid Track Format	Indicates: (1) An attempt made to write data exceeding track capacity. (2) Index encountered at unexpected point during a read or search operation. (3) A previous operation attempted to write data exceeding the track capacity; this operation resulted in a record written into index.
2	End of Cylinder	Indicates: (1) A multitrack read or search attempted to go beyond the cylinder boundary.

		(2) An overflow operation attempted to go past the cylinder boundary. Byte 1, bit 7 will be set to indicate this condition.
3	Message to Operator	May be optionally used with format 3 to report permanent failures in alternate control units or paths.
4	No Record Found	Indicates a programming error due to two index points being sensed in command chain with no intervening Read in home address or data area, or without an intervening Write, Sense, or Control command.
5	File Protected	Indicates the file mask has been violated by: (1) Seek command. (2) Multitrack read or search. (3) An overflow operation violates the seek portion of the file mask. Byte 1, bit 7 (operation incomplete) is also set.
6	Write Inhibited	Indicates a write command issued when write protection mechanism is enabled. Byte 0, bit 0 will also be set.
7	Operation Incomplete	Indicates one of the following conditions occurred when processing an overflow record. For any of these conditions, byte 3 contains restart command information: (1) Overflow to a file protected boundary. Byte 1, bit 5 also set. (2) Overflow beyond cylinder boundary. Byte 1, bit 2 also set. (3) Correctable data error found in data area--not last segment. Byte 2, bit 1 and byte 0, bit 4 also set. (4) Uncorrectable data error found in any area--not first segment. (5) Defective or alternate track found after start of data transfer. (6) Seek error found in second or later segment.

4.3 Byte 2: Device/Media State.

Bit	Designation	Interpretation
0	Not Used	Set to zero for Class B devices.
1	Correctable	Indicates that the data error indicated by bit 4, byte 0 is correctable. Bytes 15 through 23 contain error recovery information.

2	Redundant Path	May be optionally used to indicate that the connection between control unit and device is via a redundant path. Redundant paths are used to provide higher availability.
3	Environmental Data Present	Indicates that bytes 8 through 23 contain either usage/error statistics (format 6) or error logging information. Byte 7 indicates the format for bytes 8 through 23.
4-7	Not Used	Set to zero for Class B devices.

4.4 Byte 3: Restart Command.

Bit	Designation	Interpretation
0-7	Restart Command	When bit 7, byte 1 is set, byte 3 indicates the command in process at the time of the interruption of the incomplete operation. 06 hexadecimal for the Read command and 05 hexadecimal for the Write command.

4.5 Byte 4: Physical Device Identification.

Bit	Designation	Interpretation
0-7	Physical Device	This byte indicates the complete physical address of the device identified with the sense information. The active bit indicates the physical address of the drive as follows:

bit 0 = drive 0	bit 4 = drive 4
bit 1 = drive 1	bit 5 = drive 5
bit 2 = drive 2	bit 6 = drive 6
bit 3 = drive 3	bit 7 = drive 7

4.6 Byte 5: Cylinder Address.

Bit	Designation	Interpretation
0-7	Cylinder Low Address	For formats 0, 1, 2, 4, and 5, identifies the low-order cylinder address of the latest seek argument from channel. The meaning of this byte is model dependent for formats 3 and 6.

4.7 Byte 6: Cylinder High and Head Address.

Bit	Designation	Interpretation
0	Diagnostic Cylinder	Indicates that a diagnostic cylinder has been selected.

1-2	Cylinder High Address	For formats 0, 1, 2, 4, and 5, identifies the high-order cylinder address of the last seek. Bit 1 has a weight of 512 and bit 2 has a weight of 256.
3-7	Head Address	For formats 0, 1, 2, 4, and 5, identifies the head address of the last seek. Bit 3=16, bit 4=8, bit 5=4, bit 6=2, and bit 7=1. If an alternate track condition is detected and operation incomplete is posted during an overflow operation, byte 6 is set to the head address of the defective track plus 1. The use of this byte is model dependent for formats 3 and 6.

4.8 Byte 7: Format/Message Designation.

Bit	Designation	Interpretation
0-3	Format	Indicates the format of bytes 8 through 23 as follows, in hexadecimal: 0 programming or system check 1 device equipment check 2 control unit equipment check 3 control unit control check 4 uncorrectable data check 5 correctable data check or data check with displacement information 6 usage/error statistics 7-F Not used for Class B devices.
4-7	Message	Indicates the specific nature of the error conditions for each of the above formats. The messages for Class B devices are shown below under the description for each of these formats.

5. FORMAT 0: Control Unit Program/System Check. If format bits 0-3 in byte 7 are all zero, then the sense format indicates programming or system check information associated with the control unit.

5.1 Format 0 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the programming or system check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class B devices.

5.2 Format 0, Bytes 8 Through 23. Sense bytes 8 through 23, for format 0, are not specified for Class B devices.

6. FORMAT 1: Device Equipment Check. If format bits 0-3 in byte 7 contain a hexadecimal 1, then the sense format indicates equipment check diagnostic information associated with the device.

6.1 Format 1 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the device equipment check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class B devices.

6.2 Format 1, Bytes 8 Through 23. Sense bytes 8 through 23, for format 1, contain information relating to device equipment checks that is manufacturer-dependent and is not specified.

7. FORMAT 2: Control Unit Equipment Check. If format bits 0-3 in byte 7 contain a 2, then the sense format indicates equipment check diagnostic information associated with the control unit.

7.1 Format 2 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the control unit equipment check. Message number meanings for Class B devices are:

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class B devices.

7.2 Format 2: Bytes 8 Through 23. Sense bytes 8 through 23, for format 2, contain diagnostic manufacturer-dependent information relating to control unit equipment checks. This information is not specified for Class B devices.

8. FORMAT 3: Control Unit Control Check. If format bits 0-3 in byte 7 contain a 3, then the sense format indicates control unit control check diagnostic information associated with the control unit.

8.1 Format 3 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the control unit control check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class B devices.

8.2 Format 3, Bytes 8 Through 23. Sense bytes 8 through 23, for format 3, contain diagnostic information relating to control unit control checks. This information is not specified for Class B devices.

9. FORMAT 4: Data Check. If format bits 0-3 in byte 7 contain a 4, then the sense format indicates uncorrectable data check information associated with the device.

9.1 Format 4 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the uncorrectable data check.

Hexadecimal Number	Meaning
0	Home Address (HA) area Error Correcting Code (ECC) uncorrectable.
1	Count area ECC uncorrectable.
2	Key area ECC uncorrectable.
3	Data area ECC uncorrectable.
4	Data synchronization in HA area unsuccessful.
5	Data synchronization in count area unsuccessful.
6	Data synchronization in key area unsuccessful.
7	Data synchronization in data area unsuccessful.
8	Unspecified.
9	No address mark detection on retry.
A-F	Unspecified.

9.2 Format 4, Bytes 8 Through 23. Sense bytes 8 through 23, for format 4, contain uncorrectable data check information, as shown below for Class B devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Number of the record in last count field read.

Note: Contents of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 or 4 (error occurred in HA), 1 or 5 (error occurred in count area), or 9 (no Address Mark detection on retry).

Byte 13	Sector number of the record in error.
Byte 14-21	Unspecified.

Bytes 22-23	Fault symptom code, interpretation of codes not specified.

10. FORMAT 5: Correctable Data Check. If format bits 0-3 in byte 7 contain a 5, then the sense format indicates correctable data check information.

10.1 Format 5 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the correctable data check. Message number meanings for Class B devices follow:

Hexadecimal Number	Meaning
0-2	Unspecified.
3	Correctable data area data check.
4-F	Unspecified.

10.2 Format 5, Bytes 8 Through 23. Sense bytes 8 through 23, for format 5, contain correctable data check information as shown below for Class B devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Record number of the record in last count field read.

Note: Counts of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 or 1.

Byte 13	Sector number of the record in error.
Byte 14	Unspecified.
Bytes 15-17	Specifies the number of bytes processed by the control unit to the end of the data area in error.
Bytes 18-19	Error displacement location of first byte in error within the data area measured from the end of area.
Bytes 20-22	Error pattern used for error correction function.

Byte 23	Not used.

11. FORMAT 6: Usage/Error Statistics. If format bits 0-3 in byte 7 contain a 6, then the sense format indicates usage/error statistics information.

11.1 Format 6 Message Numbers. The message bits 4-7 in byte 7 optionally contain numbers further identifying the usage/error statistics.

Hexadecimal Number	Meaning
0-F	Not specified for Class B devices.

11.2 Format 6, Bytes 8 Through 23. Sense bytes 8 through 23, for format 6, contain usage/error statistics information as shown below for Class B devices.

Byte Number	Usage
8-11	Accumulated count of the number of bytes processed by the control unit in read or search operations. Retry operations are not included in count. Only key and data area counts are included.
12-13	Not used. Set to zero for Class B devices.
14-15	Contains a count of the number of initially uncorrectable data errors retried by the control unit.
16-17	Count of the number of seek commands processed by the control unit.
18-23	Not specified; these bytes typically contain error statistics for command and data overruns. Consult the vendor's documentation for the appropriate format.

12. FORMATS 7 Through F. If format bits 0-3 in byte 7 contain hexadecimal 7 through F, the sense format is unspecified for Class B devices.

CLASS C VARIABLE BLOCK ROTATING MASS STORAGE DEVICE SPECIFICATION

1. INTRODUCTION. This specification is one of a series that supplement FIPS PUB 63, Operational Specifications for Variable Block Rotating Mass Storage (VBRMS) Subsystems. Each specification in this series specifies the track format and sense information content for a particular class of rotating mass storage device. The intent of this specification is to specify those characteristics of VBRMS subsystems which must be preserved to ensure interchangeability in normal operation, but not those characteristics needed to diagnose internal subsystem faults. Commercially available disk drives of this class usually employ a sealed storage cartridge which is removable.

1.1 Scope. This specification prescribes the format and content of the 24 bytes of sense information generated by Class C rotating mass storage devices. The first eight sense bytes (bytes 0-7) are defined to contain high-level information reporting on the general state of the device resulting from the immediately preceding operation. The eighth byte identifies which of seven specified formats are employed in presenting the detailed sense information contained in the remaining 16 bytes.

1.2 Classification of Applicable Devices. Subsystems containing Class C VBRMS devices for which this specification is applicable are those that attach to the I/O Channel Interface specified in FIPS 60 and meet the following device level requirements:

Maximum Storage Capacity	=	35 or 70 megabytes per logical device address.
Cylinders/Address	=	348 (696 for 70 megabyte devices) logical user cylinders plus 1 (2 for 70 Mbyte devices) alternate cylinders per logical device address.
Tracks/Cylinder	=	12 logical tracks per logical cylinder.
Maximum Track Capacity	=	8,368 bytes per logical track.

2. TRACK FORMAT. Track format is as defined in FIPS PUB 63. For Class C devices, there are 2 bytes of optional extended home address information defining the presence and location of media defects. For Class C devices, up to one defect per track is allowed.

3. SENSE INFORMATION. As described in FIPS PUB 60, sense bytes are used to supplement information contained in the status byte (see section 2.7 of FIPS 60). In general, sense information is fundamentally related to the design, operating features, and performance characteristics associated with a particular class of I/O device. Since FIPS 60 is applicable to a variety of peripheral subsystems, covering a wide range of performance characteristics and capabilities, it addresses only those items of sense information common to applicable equipment. Further details on the interpretation of information contained in the sense bytes pertaining to Class C devices are prescribed herein.

3.1 Generation and Processing. The rotating mass storage devices for which this specification is applicable provide for the generation of 24 bytes of sense information that describe any unusual conditions detected during the last operation of the subsystem as well as the actual state of the I/O device involved. The sense information is stored in the device and control unit and is transmitted to the channel

in response to any of the sense commands. The sense information is cleared from the device upon acceptance of any command other than Test I/O or No-Op and by a system reset of the control unit. Note that sense bits should be set to zero when their definitions are incompatible or inconsistent with choice of design. Unused sense bits should also be set to zero. If a device has the capability to recover from a particular error condition without software intervention, it is not necessary to generate sense information.

3.2 Summary of Format. The first eight bytes (0-7) of sense information provide high level information concerning general device status and condition. Sense byte 7 also identifies one of seven different formats, numbered 0-6, by which the remaining bytes 8-23 are to be interpreted. Three of these formats, numbered 1, 2, and 3 are employed for reporting manufacturer-related maintenance and diagnostic information. Two of the formats (formats 4 and 5) are used to report on device data errors. One format (format 0) is used to report on programming and system checks. Format 6 is used to report device usage/error statistics. Further details regarding the definition of these seven formats as well as the specifications for their contents are provided in sections 4 through 12 that follow for Class C VBRMS devices.

4. High-Level Sense Bytes 0-7. The first eight sense bytes contain high level information for Class C devices, as defined in section 1.2.

4.1 Byte 0: Common.

Bit	Designation	Interpretation
0	Command Reject	Indicates: (1) Invalid command code. (2) Invalid command sequence. (3) Invalid or incomplete argument transferred by a control command. (4) Track formatted without home address. (5) Write portion of file mask violated. (6) Write command issued when write protection mechanisms enabled. Bit 6, byte 1, will also be set. (7) Format write attempted on defective track. (8) A record zero count field of a defective track points to itself instead of an alternate track.
1	Intervention Required	Indicates: (1) Addressed device not attached to system. (2) Addressed device not ready. (3) Addressed device in maintenance mode and unavailable for use. (4) Diagnostic Write or Load command issued and diagnostic is resident in control storage.

2	Bus Out Check	Indicates the control unit has detected a parity error in the data transferred from the channel.
3	Equipment Check	Indicates an unusual hardware condition somewhere in the device or control unit. The condition may be further defined in bytes 7 through 23.
4	Data Check	Indicates: (1) A correctable data error detected in information received from a device. The correctable bit 1, byte 2 will be set, and correction data will be in bytes 15 through 23. (2) An uncorrectable data error detected in information from a device. The condition is defined in byte 7.
5	Overrun	Indicates insufficient channel transfer rate to keep up with device transfer rate, on either a read or a write operation. When writing, the remaining portion of the record area is padded with a replicated data byte. Overruns may be retried by the control unit and if the retry eliminates the overrun the overrun condition is not posted.
6	Track Condition Check	(1) A read or search command, other than Search HA, Read HA, or Read RO, was attempted on a defective track. (2) A multi-track command caused head switching from a defective or alternate track. When byte 1, bit 7 (operation incomplete) is set with this bit, it indicates a read, search, or update write on an overflow segment (other than the first segment).
7	Seek Check	Set when a seek operation is incomplete or when an incorrect physical address is encountered when reading a home address or count area.

4.2 Byte 1: Control Unit/Device State.

Bit	Designation	Interpretation
0	Permanent Error	This bit is set when external error recovery procedures have attempted retry actions and failed to clear the fault.

1	Invalid Track Format	Indicates: (1) An attempt made to write data exceeding track capacity. (2) Index encountered at unexpected point during a read or search operation.
2	End of Cylinder	Indicates: (1) A multitrack read or search attempted to go beyond the cylinder boundary. (2) An overflow operation attempted to go past the cylinder boundary. Byte 1, bit 7 will be set to indicate this condition.
3	Message to Operator	May be optionally used with format 3 to report permanent failures in alternate control units or paths.
4	No Record Found	Indicates a programming error due to two index points being sensed in command chain with no intervening Read in home address or data area, or without a Write, Sense, or Control command.
5	File Protected	Indicates the file mask has been violated by: (1) Seek command. (2) Multitrack read or search. (3) An overflow operation violates the seek portion of the file mask. Byte 1, bit 7 (operation incomplete) will also be set.
6	Write Inhibited	Indicates a write command issued when write protection mechanism is enabled. Byte 0, bit 0 will also be set.
7	Operation Incomplete	Indicates one of the following conditions occurred when processing an overflow record. For any of these conditions, byte 3 contains restart command information: (1) Overflow to a file protected boundary. Byte 1, bit 5 also set. (2) Overflow beyond cylinder boundary. Byte 1, bit 2 also set. (3) Correctable data error found in data area--not last segment. Byte 2, bit 1 and byte 0, bit 4 also set. (4) Uncorrectable data error found in any area--not first segment. (5) Defective or alternate track found after start of data transfer. (6) Seek error found in second or later segment.

4.3 Byte 2: Device/Media State.

Bit	Designation	Interpretation
0	RPS Feature Present	Rotational Position Sensing (RPS) installed on selected device.
1	Correctable	Indicates that the data error indicated by bit 4, byte 0 is correctable. Bytes 15 through 23 contain error recovery information.
2	Not Used	Set to zero for Class C devices.
3	Environmental Data Present	Indicates that bytes 8 through 23 contain either usage/error statistics (format 6) or error logging information.
4	Emulation Mode	When on, indicates that Class C RMS device characteristics are being emulated by a device that does not have Class C characteristics in its native mode.
5-7	Capacity	Indicates capacity per logical device address as follows: 001 = 35 megabyte capacity 010 = 70 megabyte capacity 110 = 70 megabyte capacity with some part of the capacity implemented in zero seek time storage.

4.4 Byte 3: Restart Command.

Bit	Designation	Interpretation
0-7	Restart Command	When bit 7, byte 1 is set, byte 3 indicates the command in process at the time of the interruption of the incomplete operation. 06 hexadecimal for the Read command and 05 hexadecimal for the Write command.

4.5 Byte 4: Physical Device Identification.

Bit	Designation	Interpretation
0-7	Device Physical Address	Indicates the complete model dependent physical address of the device identified with the sense information. See vendor's documentation for the complete definition of this byte.

4.6 Byte 5: Cylinder Address.

Bit	Designation	Interpretation
0-7	Cylinder Low Address	For formats 0, 1, 2, 4, and 5, identifies the low-order cylinder address of the latest seek argument from channel. The meaning of this byte is model dependent for formats 3 and 6.

4.7 Byte 6: Cylinder High and Head Address.

Bit	Designation	Interpretation
0	Not Used	Set to zero for Class C devices.
1-2	High Cylinder Address	For formats 0, 1, 2, 4, and 5, identifies the high-order cylinder address. Bit 1 has a weight of 512 and bit 2 has a weight of 256.
3	Cylinder High Address, Continuation	Set to zero if emulation mode bit off (byte 2, bit 4). Has cylinder address weight 2048 if emulation mode bit on. When emulation mode is used (byte 2, bit 4 on), cylinders 2800 through 2804 are diagnostic cylinders.
4-7	Head Address	Indicates head address of the last seek, except retries. If an alternate track condition is detected and operation incomplete is posted during an overflow operation, byte 6 is set to the head address of the defective track plus 1. This information is used by the error recovery procedures to construct the seek argument to continue the operation. The remainder of the seek argument must be obtained from the user program.

4.8 Byte 7: Format/Message Designation.

Bit	Designation	Interpretation
0-3	Format	Indicates the format of bytes 8 through 23 as follows, in hexadecimal: 0 programming or system check 1 device equipment check 2 control unit equipment check 3 control unit control check 4 uncorrectable data check 5 correctable data check or data check with displacement information 6 usage/error statistics 7-F Not used for Class D devices.

4-7	Message	Indicates the specific nature of the error conditions for each of the above formats. The messages for Class C devices are shown below under the description for each of these formats.

5. FORMAT 0: Control Unit Program/System Check. If format bits 0-3 in byte 7 are all zero, then the sense format indicates programming or system check information associated with the control unit.

5.1 Format 0 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the programming or system check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class C devices.

5.2 Format 0, Bytes 8 Through 23. Sense bytes 8 through 23, for format 0, are not specified for Class C devices.

6. FORMAT 1: Device Equipment Check. If format bits 0-3 in byte 7 contain a hexadecimal 1, then the sense format indicates equipment check diagnostic information associated with the device.

6.1 Format 1 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the device equipment check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class C devices.

6.2 Format 1, Bytes 8 Through 23. Sense bytes 8 through 23, for format 1, contain information relating to device equipment checks that is manufacturer-dependent and is not specified.

7. FORMAT 2: Control Unit Equipment Check. If format bits 0-3 in byte 7 contain a 2, then the sense format indicates equipment check diagnostic information associated with the control unit.

7.1 Format 2 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the control unit equipment check. Message number meanings for Class C devices are:

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class C devices.

7.2 Format 2: Bytes 8 Through 23. Sense bytes 8 through 23, for format 2, contain diagnostic manufacturer-dependent information relating to control unit equipment checks. This information is not specified for Class C devices.

8. FORMAT 3: Control Unit Control Check. If format bits 0-3 in byte 7 contain a 3, then the sense format indicates control unit control check diagnostic information associated with the control unit.

8.1 Format 3 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the control unit control check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class C devices.

8.2 Format 3, Bytes 8 Through 23. Sense bytes 8 through 23, for format 3, contain diagnostic information relating to control unit control checks. This information is not specified for Class C devices.

9. FORMAT 4: Data Check. If format bits 0-3 in byte 7 contain a 4, then the sense format indicates uncorrectable data check information associated with the device.

9.1 Format 4 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the uncorrectable data check.

Hexadecimal Number	Meaning
0	Home Address (HA) area Error Correcting Code (ECC) uncorrectable.
1	Count area ECC uncorrectable.
2	Key area ECC uncorrectable.
3	Data area ECC uncorrectable.
4	Data synchronization in HA area unsuccessful.
5	Data synchronization in count area unsuccessful.
6	Data synchronization in key area unsuccessful.
7	Data synchronization in data area unsuccessful.
8	Unspecified.
9	No address mark detection on retry.
A-F	Unspecified.

9.2 Format 4, Bytes 8 Through 23. Sense bytes 8 through 23, for format 4, contain uncorrectable data check information, as shown below for Class C devices:

Byte 8	High-order cylinder byte of the last count field read.

Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Number of the record in last count field read.

Note: Contents of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 or 4 (error occurred in HA), 1 or 5 (error occurred in count area), or 9 (no Address Mark detection on retry).

Byte 13	Sector number of the record in error.
Byte 14-21	Unspecified.
Bytes 22-23	Fault symptom code, interpretation of codes not specified.

10. FORMAT 5: Correctable Data Check. If format bits 0-3 in byte 7 contain a 5, then the sense format indicates correctable data check information.

10.1 Format 5 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the correctable data check. Message number meanings for Class C devices follow:

Hexadecimal Number	Meaning
0-2	Unspecified.
3	Correctable data area data check.
4-F	Unspecified.

10.2 Format 5, Bytes 8 Through 23. Sense bytes 8 through 23, for format 5, contain correctable data check information as shown below for Class C devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.

Byte 12	Record number of the record in last count field read. This byte is unreliable after a Space Count command.

Note: Counts of bytes 8 through 12 are unreliable if message code in byte 7 is either 0, 1, 4, or 5.

Byte 13	Sector number of the record in error.
Byte 14	Unspecified.
Bytes 15-17	Specifies the number of bytes processed by the control unit to the end of the data area in error.
Bytes 18-19	Error displacement location of first byte in error within the data area measured from the end of area.
Bytes 20-22	Error pattern used for error correction function.
Byte 23	Not used.

11. FORMAT 6: Usage/Error Statistics. If format bits 0-3 in byte 7 contain a 6, then the sense format indicates usage/error statistics information.

11.1 Format 6 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the usage/error statistics. Message number meanings are unspecified for Class C devices.

11.2 Format 6, Bytes 8 Through 23. Sense bytes 8 through 23, for format 6, contain usage/error statistics information as shown below for Class C devices.

Byte Number	Usage
8-11	Accumulated count of the number of bytes processed by the control unit in read or search operations. Retry operations are not included in count. Only key and data area counts are included.
12-15	Not used. Set to zero for Class C devices.
16-17	Count of the number of seek commands processed by the control unit.
18-23	Not specified; these bytes typically contain error statistics for command and data overruns. Consult the vendor's documentation for the appropriate format.

12. FORMATS 7 Through F. If format bits 0-3 in byte 7 contain hexadecimal 7 through F, the sense format is unspecified for Class C devices.

CLASS D VARIABLE BLOCK ROTATING MASS STORAGE DEVICE SPECIFICATION

1. INTRODUCTION. This specification is one of a series that supplement FIPS PUB 63, Operational Specifications for Variable Block Rotating Mass Storage (VBRMS) Subsystems. Each specification in this series specifies the track format and sense information content for a particular class of rotating mass storage device. The intent of this specification is to specify those characteristics of VBRMS subsystems which must be preserved to ensure interchangeability in normal operation, but not those characteristics needed to diagnose internal subsystem faults. Commercially available disk drives of this class usually employ a non-removable storage medium.

1.1 Scope. This specification prescribes the format and content of the 24 bytes of sense information generated by Class D rotating mass storage devices. The first eight sense bytes (bytes 0-7) are defined to contain high-level information reporting on the general state of the device resulting from the immediately preceding operation. The eighth byte identifies which of seven specified formats are employed in presenting the detailed sense information contained in the remaining 16 bytes.

1.2 Classification of Applicable Devices. Subsystems containing Class D VBRMS devices for which this specification is applicable are those that attach to the I/O Channel Interface specified in FIPS 60 and meet the following device level requirements:

Maximum Storage Capacity	=	409.8 megabytes per logical device address.
Cylinders/Address	=	959 logical user cylinders plus 5 alternate cylinders per logical device address.
Tracks/Cylinder	=	12 logical tracks per logical cylinder.
Maximum Track Capacity	=	35,616 bytes per logical track.

2. TRACK FORMAT. Track format is as defined in FIPS PUB 63.

3. SENSE INFORMATION. As described in FIPS PUB 60, sense bytes are used to supplement information contained in the status byte (see section 2.7 of FIPS 60). In general, sense information is fundamentally related to the design, operating features, and performance characteristics associated with a particular class of I/O device. Since FIPS 60 is applicable to a variety of peripheral subsystems, covering a wide range of performance characteristics and capabilities, it addresses only those items of sense information common to applicable equipment. Further details on the interpretation of information contained in the sense bytes pertaining to Class D devices are prescribed herein.

3.1 Generation and Processing. The rotating mass storage devices for which this specification is applicable provide for the generation of 24 bytes of sense information that describe any unusual conditions detected during the last operation of the subsystem as well as the actual state of the I/O device involved. The sense information is stored in the device and control unit and is transmitted to the channel in response to any of the sense commands. The sense information is cleared from the device upon acceptance of any command other than Test I/O or No-Op and by a system reset of the control unit. Note that sense bits should be set to zero when their definitions are incompatible or inconsistent with choice of design. Unused sense bits should also be set to zero. If a device has the capability to recover from

a particular error condition without software intervention, it is not necessary to generate sense information.

3.2 Summary of Format. The first eight bytes (0-7) of sense information provide high level information concerning general device status and condition. Sense byte 7 also identifies one of seven different formats, numbered 0-6, by which the remaining bytes 8-23 are to be interpreted. Three of these formats, numbered 1, 2, and 3 are employed for reporting manufacturer-related maintenance and diagnostic information. Two of the formats (formats 4 and 5) are used to report on device data errors. One format (format 0) is used to report on programming and system checks. Format 6 is used to report device usage/error statistics. Further details regarding the definition of these seven formats as well as the specifications for their contents are provided in sections 4 through 12 that follow for Class D VBRMS devices.

4. High-Level Sense Bytes 0-7. The first eight sense bytes contain high level information for Class D devices, as defined in section 1.2.

4.1 Byte 0: Common.

Bit	Designation	Interpretation
0	Command Reject	Indicates: (1) Invalid command code. (2) Invalid command sequence. (3) Invalid or incomplete argument transferred by a control command. (4) Track formatted without home address. (5) Write portion of file mask violated. (6) Write command issued when write protection mechanisms enabled. Bit 6, byte 1, will also be set. (7) Format write attempted on defective track. (8) A record zero count field of a defective track that points to itself or an alternate track (replacing a defective track) that points to itself.
1	Intervention Required	Indicates: (1) Addressed device not attached to system. (2) Addressed device not ready. (3) Addressed device in maintenance mode and unavailable for use.
2	Bus Out Check	Indicates the control unit has detected a parity error in the data transferred from the channel.
3	Equipment Check	Indicates an unusual hardware condition somewhere in the device or control unit. The condition may be further defined in bytes 7 through 23.

4	Data Check	Indicates: (1) A correctable data error detected in information received from a device. The correctable bit 1, byte 2 will be set, and correction data will be in bytes 15 through 23. (2) An uncorrectable data error detected in information from a device. The condition is defined in byte 7.
5	Overrun	Indicates insufficient channel transfer rate to keep up with device transfer rate, on either a read or a write operation. When writing, the remaining portion of the record area is padded with a replicated data byte. Overruns may be retried by the control unit and if the retry eliminates the overrun the overrun condition is not posted.
6-7	Not Used	Set to zero for Class D devices.

4.2 Byte 1: Control Unit/Device State.

Bit	Designation	Interpretation
0	Permanent Error	Indicates an error not able to be recovered: (1) Control unit retry has been attempted and was unsuccessful. (2) No system error recovery procedure required or desirable. This bit overrides any other sense bit settings and indicates that system error recovery procedures are not required.
1	Invalid Track Format	Indicates: (1) An attempt made to write data exceeding track capacity. (2) Index encountered at unexpected point during a read or search operation. (3) A previous operation attempted to write data exceeding the track capacity; this operation resulted in a record written into index.
2	End of Cylinder	A multitrack read or search attempted to go beyond the cylinder boundary.
3	Message to Operator	May be optionally used to report permanent failures in alternate control units or paths.
4	No Record Found	Indicates a programming error due to two index points being sensed in command chain with no intervening Read in home address or

		data area, or without an intervening Write, Sense, or Control command.
5	File Protected	Indicates the file mask has been violated by: (1) Seek command. (2) Multitrack read or search.
6	Write Inhibited	Indicates a write command issued when write protection mechanism is enabled. Byte 0, bit 0 will also be set.
7	Operation Incomplete	Not used for Class D devices, shall be zero.

4.3 Byte 2: Device/Media State.

Bit	Designation	Interpretation
0	Not Used	Set to zero for Class D devices.
1	Correctable	Indicates that the data error indicated by bit 4, byte 0 is correctable. Bytes 15 through 23 contain error recovery information.
2	First Logged Error	May be optionally used to indicate that the allowed error rate for temporary data or seek checks has been exceeded and the device is set in the logging mode.
3	Environmental Data Present	Bit 3 is set to indicate that bytes 8 through 23 contain usage or error statistics, or error log information. Byte 7 indicates the format for bytes 8 through 23. Bit 3 is set with format 6 when a usage or error counter overflows or when a Read and Reset Buffered Log command is executed. It is set with formats 1, 4, and 5 when the control unit is in force error log mode.
4-7	Not Used	Set to zero for Class D devices.

4.4 Byte 3: Model Dependent Diagnostic.

Bit	Designation	Interpretation
0-7	Model Dependent	The interpretation of this byte is model dependent and is not specified. Consult vendor's documentation for its meaning.

4.5 Byte 4: Physical Device Identification.

Bit	Designation	Interpretation
0	Model Dependent	This bit, if used, contains model dependent information.
1-2	Not Used	These bits are set to zero for Class D devices.
3-7	Device Physical Address	Indicates the complete physical address of the device identified with the sense information. Consult vendor's documentation for the format of the physical device address.

4.6 Byte 5: Cylinder Address.

Bit	Designation	Interpretation
0-7	Cylinder Low Address	For formats 0, 1, 2, 4, and 5, identifies the low-order cylinder address of the latest seek argument from channel. The meaning of this byte is model dependent for formats 3 and 6.

4.7 Byte 6: Cylinder High and Head Address. The use of this byte is model dependent for formats 3 and 6.

Bit	Designation	Interpretation
0-1	High Cylinder Address	For formats 0, 1, 2, 4, and 5, identifies the high-order cylinder address of the most recent access position. Bit 0 has a weight of 512 and bit 1 has a weight of 256.
2-3	Not Used	For formats 0, 1, 2, 4, and 5, set to zero for Class D devices.
4-7	Head Address	For formats 0, 1, 2, 4, and 5, identifies the head address. Bit 4=8, bit 5=4, bit 6=2, and bit 7=1.

4.8 Byte 7: Format/Message Designation.

Bit	Designation	Interpretation
0-3	Format	Indicates the format of bytes 8 through 23 as follows, in hexadecimal: 0 programming or system check 1 device equipment check 2 control unit equipment check 3 control unit control check

		4 uncorrectable data check 5 correctable data check or data check with displacement information 6 usage/error statistics 7-F Not used for Class D devices.
4-7	Message	Indicates the specific nature of the error conditions for each of the above formats. The messages for Class D devices are shown below under the description for each of these formats.

5. FORMAT 0: Control Unit Program/System Check. If format bits 0-3 in byte 7 are all zero, then the sense format indicates programming or system check information associated with the control unit.

5.1 Format 0 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the programming or system check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class D devices.

5.2 Format 0, Bytes 8 Through 20. Sense bytes 8 through 20, for format 0, are not specified for Class D devices.

5.3 Format 0, Byte 21. Sense byte 21, for format 0, contains the ID of the control unit.

5.4 Format 0, Bytes 22 Through 23. Sense bytes 22 through 23, for format 0, may optionally contain an unspecified model dependent symptom code, or they may be zero.

6. FORMAT 1: Device Equipment Check. If format bits 0-3 in byte 7 contain a hexadecimal 1, then the sense format indicates equipment check diagnostic information associated with the device.

6.1 Format 1 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the device equipment check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class D devices.

6.2 Format 1, Bytes 8 Through 23. Sense bytes 8 through 23, for format 1, contain information relating to device equipment checks that is manufacturer-dependent and is not specified.

7. FORMAT 2: Control Unit Equipment Check. If format bits 0-3 in byte 7 contain a 2, then the sense format indicates equipment check diagnostic information associated with the control unit.

7.1 Format 2 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the control unit equipment check. Message number meanings for Class D devices are:

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class D devices.

7.2 Format 2: Bytes 8 Through 23. Sense bytes 8 through 23, for format 2, contain diagnostic manufacturer-dependent information relating to control unit equipment checks. This information is not specified for Class D devices.

8. FORMAT 3: Control Unit Control Check. If format bits 0-3 in byte 7 contain a 3, then the sense format indicates control unit control check diagnostic information associated with the control unit.

8.1 Format 3 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the control unit control check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class D devices.

8.2 Format 3, Bytes 8 Through 23. Sense bytes 8 through 23, for format 3, contain diagnostic information relating to control unit control checks. This information is not specified for Class D devices.

9. FORMAT 4: Data Check. If format bits 0-3 in byte 7 contain a 4, then the sense format indicates uncorrectable data check information associated with the device.

9.1 Format 4 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the uncorrectable data check.

Hexadecimal Number	Meaning
0	Home Address (HA) area Error Correcting Code (ECC) uncorrectable.
1	Count area ECC uncorrectable.
2	Key area ECC uncorrectable.
3	Data area ECC uncorrectable.
4	Data synchronization in HA area unsuccessful.

5	Data synchronization in count area unsuccessful.
6	Data synchronization in key area unsuccessful.
7	Data synchronization in data area unsuccessful.
8-F	Unspecified.

9.2 Format 4, Bytes 8 Through 23. Sense bytes 8 through 23, for format 4, contain uncorrectable data check information, as shown below for Class D devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Number of the record in last count field read.

Note: Contents of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 or 4 (error occurred in HA), 1 or 5 (error occurred in count area).

Byte 13	Sector number of the record in error.
Byte 14	Model dependent and unspecified.
Byte 15	For permanent errors, this byte contains the offset last used for retrying a data check. If the error was not permanent, this byte provides the offset required to recover from the error. Use of this byte is optional.
Bytes 16-20	Not used.
Byte 21	Control unit ID.
Bytes 22-23	Fault symptom code, interpretation of codes not specified.

10. FORMAT 5: Correctable Data Check. If format bits 0-3 in byte 7 contain a 5, then the sense format indicates correctable data check information.

10.1 Format 5 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the correctable data check. Message number meanings for Class D devices follow:

Hexadecimal Number	Meaning
0	Correctable home address data check.
1	Correctable count area data check.
2	Correctable key area data check.
3	Correctable data area data check.
4-F	Not used.

10.2 Format 5, Bytes 8 Through 23. Sense bytes 8 through 23, for format 5, contain correctable data check information as shown below for Class D devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Record number of the record in last count field read. This byte is unreliable after a Space Count command.

Note: Counts of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 (error occurred in HA), 1 (error occurred in count area), 4, or 5.

Byte 13	Sector number of the record in error.
Byte 14	Unspecified.
Bytes 15-17	If byte 2, bit 3=0, bytes 15-17 specify the number of bytes processed by the control unit to the end of the data area in error. If byte 2, bit 3=1, byte 15 contains the head offset, byte 16 contains the control unit ID, and byte 17 is not used.
Bytes 18-19	Error displacement location of first byte in error within the data area measured from the end of area.
Bytes 20-21	Error pattern used for error correction function.
Bytes 22-23	Not used.

11. FORMAT 6: Usage/Error Statistics. If format bits 0-3 in byte 7 contain a 6, then the sense format indicates usage/error statistics information.

11.1 Format 6 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the usage/error statistics.

Hexadecimal Number	Meaning
0-7	Not used.
8	Channel A overruns.
9	Channel B overruns.
A	Channel C overruns.
B	Channel D overruns.
C-F	Not used.

11.2 Format 6, Bytes 8 Through 23. Sense bytes 8 through 23, for format 6, contain usage/error statistics information as shown below for Class D devices.

Byte Number	Usage
8-11	Accumulated count of the number of bytes processed by the control unit in read or search operations. Retry operations are not included in count. Only key and data area counts are included.
12-15	Not used. Set to zero for Class D devices.
16-17	Count of the number of access moves processed by the control unit.
18	Not used. Set to zero for Class D devices.
19	Contains the number of data overruns that occurred on the channel specified in the message table of byte 7.
20	Contains the number of command overruns that occurred on the channel specified in the message table of byte 7.
21	Control Unit ID.
22-23	Not used.

12. FORMATS 7 Through F. If format bits 0-3 in byte 7 contain hexadecimal 7 through F, the sense format is unspecified for Class D devices.

CLASS E VARIABLE BLOCK ROTATING MASS STORAGE DEVICE SPECIFICATION

1. INTRODUCTION. This specification is one of a series that supplement FIPS PUB 63, Operational Specifications for Variable Block Rotating Mass Storage (VBRMS) Subsystems. Each specification in this series specifies the track format and sense information content for a particular class of rotating mass storage device. The intent of this specification is to specify those characteristics of VBRMS subsystems which must be preserved to ensure interchangeability in normal operation, but not those characteristics needed to diagnose internal subsystem faults. Commercially available disk drives of this class usually employ a non-removable storage medium, and have two spindles, each with two access mechanisms, in a single unit. Each access mechanism has its own device address, thus a single unit typically contains four logical devices.

1.1 Scope. This specification prescribes the format and content of the 24 bytes of sense information generated by Class E rotating mass storage devices. The first eight sense bytes (bytes 0-7) are defined to contain high-level information reporting on the general state of the device resulting from the immediately preceding operation. The eighth byte identifies which of seven specified formats are employed in presenting the detailed sense information contained in the remaining 16 bytes.

1.2 Classification of Applicable Devices. Subsystems containing Class E VBRMS devices for which this specification is applicable are those that attach to the I/O Channel Interface specified in FIPS 60 and meet the following device level requirements:

Maximum Storage Capacity	=	630.2 megabytes per logical device address.
Cylinders/Address	=	885 logical user cylinders plus 1 alternate cylinder per logical device address.
Tracks/Cylinder	=	15 logical tracks per logical cylinder.
Maximum Track Capacity	=	47,476 bytes per logical track.

2. TRACK FORMAT. Track format is as defined in FIPS PUB 63.

3. SENSE INFORMATION. As described in FIPS PUB 60, sense bytes are used to supplement information contained in the status byte (see section 2.7 of FIPS 60). In general, sense information is fundamentally related to the design, operating features, and performance characteristics associated with a particular class of I/O device. Since FIPS 60 is applicable to a variety of peripheral subsystems, covering a wide range of performance characteristics and capabilities, it addresses only those items of sense information common to applicable equipment. Further details on the interpretation of information contained in the sense bytes pertaining to Class E devices are prescribed herein.

3.1 Generation and Processing. The rotating mass storage devices for which this specification is applicable provide for the generation of 24 bytes of sense information that describe any unusual conditions detected during the last operation of the subsystem as well as the actual state of the I/O device involved. The sense information is stored in the device and control unit and is transmitted to the channel in response to any of the sense commands. The sense information is cleared from the device upon acceptance of any command other than Test I/O or No-Op and by a system reset of the control unit. Note that sense bits should be set to zero when

their definitions are incompatible or inconsistent with choice of design. Unused sense bits should also be set to zero. If a device has the capability to recover from a particular error condition without software intervention, it is not necessary to generate sense information.

3.2 Summary of Format. The first eight bytes (0-7) of sense information provide high level information concerning general device status and condition. Sense byte 7 also identifies one of seven different formats, numbered 0-6, by which the remaining bytes 8-23 are to be interpreted. Three of these formats, numbered 1, 2, and 3 are employed for reporting manufacturer-related maintenance and diagnostic information. Two of the formats (formats 4 and 5) are used to report on device data errors. One format (format 0) is used to report on programming and system checks. Format 6 is used to report device usage/error statistics. Further details regarding the definition of these seven formats as well as the specifications for their contents are provided in sections 4 through 12 that follow for Class E VBRMS devices.

4. High-Level Sense Bytes 0-7. The first eight sense bytes contain high level information for Class E devices, as defined in section 1.2.

4.1 Byte 0: Common.

Bit	Designation	Interpretation
0	Command Reject	Indicates: (1) Invalid command code. (2) Invalid command sequence. (3) Invalid or incomplete argument transferred by a control command. (4) Track formatted without home address. (5) Write portion of file mask violated. (6) Write command issued when write protection mechanisms enabled. Bit 6, byte 1, will also be set. (7) Format write (other than Write Home Address or Write R0) attempted on defective track. (8) A record zero count field of a defective track that points to itself or an alternate track that points to itself. (9) An attempt was made to write an invalid Home Address. Note: When Class E devices are attached to channels (which otherwise would not be fast enough for Class E devices) via an optional Speed Matching Buffer feature (not specified in this document), other causes of command reject are possible.
1	Intervention Required	Addressed device not attached to system.
2	Bus Out Check	Indicates the control unit has detected a parity error in the data transferred from the channel.

3	Equipment Check	Indicates an unusual hardware condition somewhere in the channel, device, or control unit. The condition may be further defined in bytes 7 through 23.
4	Data Check	Indicates: (1) A correctable data error detected in information received from a device. The correctable bit 1, byte 2 will be set, and correction data will be in bytes 15 through 23. (2) An uncorrectable data error detected in information from a device. The condition is defined in byte 7.
5	Overrun	Indicates insufficient channel transfer rate to keep up with device transfer rate, on either a read or a write operation. When writing, the remaining portion of the record area is padded with a replicated data byte. Overruns may be retried by the control unit and, if the retry eliminates the overrun, the overrun condition is not posted.
6-7	Not Used	Set to zero for Class E devices.

4.2 Byte 1: Control Unit/Device State.

Bit	Designation	Interpretation
0	Permanent Error	Indicates an error not able to be recovered: (1) Control unit retry has been attempted and was unsuccessful. (2) No system error recovery procedure required or desirable. This bit overrides any other sense bit settings and indicates that system error recovery procedures are not required.
1	Invalid Track Format	Indicates: (1) An attempt made to write data exceeding track capacity. (2) Index encountered at unexpected point during a read or search operation. (3) A previous operation attempted to write data exceeding the track capacity; this operation resulted in a record written into index.
2	End of Cylinder	A multitrack read or search attempted to go beyond the cylinder boundary.

3	Message to Operator	May be optionally used to report permanent failures in alternate control units or paths.
4	No Record Found	Indicates a programming error due to two index points being sensed in command chain with no intervening Read in home address or data area, or without an intervening Write, Sense, or Control command.
5	File Protected	Indicates the file mask has been violated by: (1) Seek command. (2) Multitrack read or search. Note: If the optional Speed Matching Buffer feature is employed, other unspecified events may cause this bit to be set.
6	Not Used	Set to zero.
7	Operation Incomplete	Not used for Class E devices, it is set to zero.

4.3 Byte 2: Device/Media State.

Bit	Designation	Interpretation
0	Not Used	Set to zero for Class E devices.
1	Correctable	Indicates that the data error indicated by bit 4, byte 0 is correctable. Bytes 15 through 23 contain error recovery information.
2	First Logged Error	May be optionally used to indicate that the allowed error rate for temporary data or seek checks has been exceeded and the device is set in the logging mode.
3	Environmental Data Present	Bit 3 is set to indicate that bytes 8 through 23 contain usage statistics or error statistics, or error log information. Byte 7 indicates the format for bytes 8 through 23. When set with byte 1, bit 3, the message to the operator is defined by byte 7 ('01'=sense data logged for device or '02'=sense data logged for controller). See byte 2, bit 2 for additional information about this bit.
4	Intent Violation	This bit is used with the optional speed matching buffer feature; otherwise it is not used and set to zero. If the speed matching

		buffer feature is installed, this bit is set when: (1) An update write operation is attempted on a record whose size differs from the record size parameters. (2) An update write is attempted on RO and the data area is not 8 bytes in length. (3) A record is not detected after home address during execution of a Write CKD Next Track, Write Update Data, or Write Update Key and Data command.
5	Imprecise Ending	This bit is used only with the optional speed matching buffer feature; otherwise it is not used and is set to zero. This bit is set if an abnormal channel program termination occurs and the status presented is for a previously executed command.
6-7	Not Used	Set to zero for Class E devices.

4.4 Byte 3: Model Dependent Diagnostic.

Bit	Designation	Interpretation
0-7	Model Dependent	The interpretation of this byte is model dependent and is not specified. Consult vendor's documentation for its meaning.

4.5 Byte 4: Physical Device Identification.

Bit	Designation	Interpretation
0	Model Dependent	This bit, if used, contains model dependent information.
1	Fixed Heads	This bit is set to indicate that the device has fixed heads.
2	Bad Path	This bit is set to indicate that the logical path between the control unit and device has a permanent error and the path is unavailable.
3	Not Used	Set to zero for Class E devices.
4-7	Device Physical Address	Indicates the complete physical address of the device identified with the sense information. Consult vendor's documentation for the format of the physical device address.

4.6 Byte 5: Cylinder Address.

Bit	Designation	Interpretation
0-7	Cylinder Low Address	For formats 0, 1, 2, 4, and 5, identifies the low-order cylinder address of the latest seek argument from channel. The meaning of this byte is model dependent for formats 3 and 6.

4.7 Byte 6: Cylinder High and Head Address. The use of this byte is model dependent for formats 3 and 6.

Bit	Designation	Interpretation
0-1	Not Used	These bits are set to zero for formats 0, 1, 2, 4, and 5.
2-3	High Cylinder Address	For formats 0, 1, 2, 4, and 5, identifies the high-order cylinder address of the most recent access position. Bit 2 has a weight of 512 and bit 3 has a weight of 256.
4-7	Head Address	For formats 0, 1, 2, 4, and 5, identifies the head address. Bit 4=8, bit 5=4, bit 6=2, and bit 7=1.

4.8 Byte 7: Format/Message Designation.

Bit	Designation	Interpretation
0-3	Format	Indicates the format of bytes 8 through 23 as follows, in hexadecimal: 0 programming or system check 1 device equipment check 2 control unit equipment check 3 control unit control check 4 uncorrectable data check 5 correctable data check or data check with displacement information 6 usage/error statistics 7 control unit to device path checks 8 device equpment checks 9-F Not used for Class E devices.
4-7	Message	Indicates the specific nature of the error conditions for each of the above formats. The messages for Class E devices are shown below under the description for each of these formats.

5. FORMAT 0: Control Unit Program/System Check. If format bits 0-3 in byte 7 are all zero, then the sense format indicates programming or system check information associated with the control unit.

5.1 Format 0 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the programming or system check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class E devices.

5.2 Format 0, Bytes 8 Through 20. Sense bytes 8 through 20, for format 0, are not specified for Class E devices.

5.3 Format 0, Byte 21. Sense byte 21, for format 0, contains the ID of the control unit.

5.4 Format 0, Bytes 22 Through 23. Sense bytes 22 through 23, for format 0, may optionally contain an unspecified model dependent symptom code, or they may be zero.

6. FORMAT 1: Device Equipment Check. If format bits 0-3 in byte 7 contain a hexadecimal 1, then the sense format indicates equipment check diagnostic information associated with the device.

6.1 Format 1 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the device equipment check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class E devices.

6.2 Format 1, Bytes 8 Through 23. Sense bytes 8 through 23, for format 1, contain information relating to device equipment checks that is manufacturer-dependent and is not specified.

7. FORMAT 2: Control Unit Equipment Check. If format bits 0-3 in byte 7 contain a 2, then the sense format indicates equipment check diagnostic information associated with the control unit.

7.1 Format 2 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the control unit equipment check. Message number meanings for Class E devices are:

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class E devices.

7.2 Format 2: Bytes 8 Through 23. Sense bytes 8 through 23, for format 2, contain diagnostic manufacturer-dependent information relating to control unit equipment checks. This information is not specified for Class E devices.

8. FORMAT 3: Control Unit Control Check. If format bits 0-3 in byte 7 contain a 3, then the sense format indicates control unit control check diagnostic information associated with the control unit.

8.1 Format 3 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the control unit control check.

Hexadecimal Number	Meaning
0	No message
1-F	Unspecified for Class E devices.

8.2 Format 3, Bytes 8 Through 23. Sense bytes 8 through 23, for format 3, contain diagnostic information relating to control unit control checks. This information is not specified for Class E devices.

9. FORMAT 4: Data Check. If format bits 0-3 in byte 7 contain a 4, then the sense format indicates uncorrectable data check information associated with the device.

9.1 Format 4 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the uncorrectable data check.

Hexadecimal Number	Meaning
0	Home Address (HA) area Error Correcting Code (ECC) uncorrectable.
1	Count area ECC uncorrectable.
2	Key area ECC uncorrectable.
3	Data area ECC uncorrectable.
4	Data synchronization in HA area unsuccessful.
5	Data synchronization in count area unsuccessful.
6	Data synchronization in key area unsuccessful.
7	Data synchronization in data area unsuccessful.
8	Home Address (HA) area ECC uncorrectable and access offset active.
9	Count area ECC uncorrectable and access offset active.
A	Key area ECC uncorrectable and access offset active.
B	Data area ECC uncorrectable and access offset active.

C	Data synchronization in HA area unsuccessful and access offset active.
D	Data synchronization in count area unsuccessful and access offset active.
E	Data synchronization in key area unsuccessful and access offset active.
F	Data synchronization in data area unsuccessful and access offset active.

9.2 Format 4, Bytes 8 Through 23. Sense bytes 8 through 23, for format 4, contain uncorrectable data check information, as shown below for Class E devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Number of the record in last count field read.

Note: Contents of bytes 8 through 12 are unreliable if message code in byte 7 is either 0, 4, 8, or C (error occurred in HA), or 1, 5, 9, or D (error occurred in count area). These bytes are also unreliable after a Space Count command if an uncorrectable ECC error occurred.

Byte 13	Sector number of the record in error. This byte is unreliable if the message code in byte 7 is 0, 1, 4, 5, 8, 9, C, or D.
Byte 14	Model dependent and unspecified.
Byte 15	If byte 2, bit 3 is set, this byte contains the head offset last used for retrying a data check.
Bytes 16-20	Not used.
Byte 21	Control unit ID.
Bytes 22-23	Fault symptom code, interpretation of codes not specified.

10. FORMAT 5: Correctable Data Check. If format bits 0-3 in byte 7 contain a 5, then the sense format indicates correctable data check information.

10.1 Format 5 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the correctable data check. Message number meanings for Class E devices follow:

Hexadecimal Number	Meaning
0	Correctable home address data check.
1	Correctable count area data check.
2	Correctable key area data check.
3	Correctable data area data check.
4-7	Not used.
8	Correctable home address data check with offset active.
9	Correctable count area data check with offset active.
A	Correctable key area data check with offset active.
B	Correctable data area data check with offset active.
C-F	Not used.

10.2 Format 5, Bytes 8 Through 23. Sense bytes 8 through 23, for format 5, contain correctable data check information as shown below for Class E devices:

Byte 8	High-order cylinder byte of the last count field read.
Byte 9	Low-order cylinder byte of the last count field read.
Byte 10	High-order head byte of the last count field read.
Byte 11	Low-order head byte of the last count field read.
Byte 12	Record number of the record in last count field read. This byte is unreliable after a Space Count command.

Note: Counts of bytes 8 through 12 are unreliable if message code in byte 7 is either 0 or 8 (error occurred in HA), or 1 or 9 (error occurred in count area).

Byte 13	Sector number of the record in error.
Byte 14	Unspecified.
Bytes 15-17	If byte 2, bit 3=0, bytes 15-17 specify the number of bytes processed by the control unit to the end of the data area in error. If byte 2, bit 3=1, byte 15 contains the head

	offset, byte 16 contains the control unit ID, and byte 17 is not used.
Bytes 18-19	Error displacement location of first byte in error within the data area measured from the end of area.
Bytes 20-23	Error pattern used for error correction function.

11. FORMAT 6: Usage/Error Statistics. If format bits 0-3 in byte 7 contain a 6, then the sense format indicates usage/error statistics information.

11.1 Format 6 Message Numbers. The message bits 4-7 in byte 7 contain numbers further identifying the usage/error statistics.

Hexadecimal Number	Meaning
0-7	Not used.
8	Channel A overruns.
9	Channel B overruns.
A	Channel C overruns.
B	Channel D overruns.
C	Channel E overruns.
D	Channel F overruns.
E	Channel G overruns.
F	Channel H overruns.

11.2 Format 6, Bytes 8 Through 23. Sense bytes 8 through 23, for format 6, contain usage/error statistics information as shown below for Class E devices.

Byte Number	Usage
8-11	Accumulated count of the number of bytes processed by the control unit in read or search operations. Retry operations are not included in count. Only key and data area counts are included.
12-15	Not used. Set to zero for Class E devices.
16-17	Count of the number of access moves processed by the control unit but not including recalibrate or retried seeks.
18	Not used. Set to zero for Class E devices.
19	Contains the number of command overruns that occurred on the channel specified in the message table of byte 7.

20	Contains the number of data overruns that occurred on the channel specified in the message table of byte 7.
21	Control Unit ID.
22-23	Not used.

12. FORMATS 7 Through F. If format bits 0-3 in byte 7 contain hexadecimal 7 through F, the sense format is unspecified for Class E devices.

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