Vast Storage Inc.
Medium Changer DVT

By

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Revision History:

Version	Date	Comments	Contributors
1.0	01/10/2003	Initial Release	DM

Contents

1. Introduction

1.1 Overview

The Medium Changer Design Verification Test (DVT) defines and executes a set of repeatable tests and procedures to verify product compliance with manufacture's protocol and functional specifications as well as normative ANSI Small Computer System Interface (SCSI) specifications.

DVT tests and procedures defined in this document are developed, performed and maintained by Percept Technology Labs, Inc., an independent Product Test and Development firm located at 4735 Walnut St., #E, Boulder, Colorado 80301.

1.2 Executive Summary

- **Product**: Medium Changer
- **Customer**: Vast Storage Inc.
- **Open Issues**: These issues do not meet DVT testing exit criteria of severity 3, or less.

Command	Failure	Description	Severity
Test Unit Ready	Command Times Out	Test Unit Ready command times out with Unit Attention pending for a different Initiator.	2
Read Element Status	Data Overrun	Read Element Status commands issued with allocation lengths 9 to 15 bytes return partial Element Status Page Header.	3

Overall functionality and operability of Vast Storage's Medium Changer is excellent. Performance data collected from installed medium changer drives indicates this is a superior device for its class. Open issues are firmware specific and do not suggest a hardware deficiency.

A command time out precipitated by a pending Unit Attention may degrade usability for multi-initiator configurations. An initiator receiving a Check Condition may loose the bus to another initiator with a higher priority before clearing the contingent allegiance. Testing was incomplete and other commands may be affected. Regression testing is strongly recommended after a fix is implemented.

Data overrun for a valid Read Element Status command does not present the issue severity that would be expected for other device types. Driver implementations using this command generally request maximum return data lengths. Little or no impact to the end user is expected.

1.3 Reference Documents

ANSI Small Computer System Interface-2 (ANSI X3.131-1994)

ANSI Small Computer System Interface-1 (ANSI X3.131-1985)

Medium Changer Functional Specification

Medium Changer Protocol Specification

1.4 Definitions

Autoloader	Autoloader refers to a medium changer with a single primary device. Storage elements are limited in number. Cartridge movement is restricted.
Issue	An issue is a product defect or deficiency that does not meet specified thresholds as stated in product specifications or normative standards.
Library	Library refers to a medium changer with one or more primary devices. Storage elements are numerous and possibly expandable. Cartridge movement is unrestricted.
System	System or test system refers to the test platform and connected test unit(s).
Test Unit	Test unit refers to a medium changer device configured and delivered as specified in the finalized product test plan.

1.5 Company Restricted Information

2. Test Environment

2.1 DVT Test Hardware

Test platform for the Medium Changer DVT will consist of PC Workstation machines, configured with appropriate adapter board, running Windows 98, 2000 or NT.

The following adapter boards will be used:

- OPPCO 1850 SCSI Test Card
- Adaptec 29160 Host Bus Adapter (HBA)

2.1.1 OPPCO Test Card

The OPPCO Test Card System is used to implement protocol testing. The OPPCO 1850 SCSI Test Card is capable of both 16–bit wide and 8–bit narrow operation. The card can operate in single ended or low voltage differential (LVD) modes. It provides a programmable interface to the SCSI bus, mainly for low level programming support.

2.1.2 Adaptec Host Bus Adapter

Off the shelf, OEM Adaptec 29160 SCSI board, providing high speed SCSI bus communication support.

2.2 DVT Laboratory Configuration

Units under test will be located in environmentally controlled labs (temperature and humidity), in anti-static protection racks. The racks will be located in Percept's access controlled lab space.

2.3 Equipment Requirements

Networked systems for common point data management

SCSI–3 data cables

Ultra 160M LVD / SE active terminators

Uninterrupted power supply

ESD protection racks

Environmentally controlled lab space - temperature 68–78° F; humidity 30–50%

Paralan Model ST 123 SCSI Cable Tester - cable continuity and integrity verification

Verisys Model SV–3000 SCSI Bus Analyzer - Ultra Wide / Wide / LVD / SE

Extech 382860 RMS Power Meter - DC / AC maximum input 20A, AC accuracy of 0.8% + 3 digits

Verity Systems Bulk Tape Degausser

3. Test Management

3.1 Test Monitoring

Conditions continuously monitored during DVT testing:

- Host SCSI Bus and Command Protocol
- Device Errors
- Read / Write Errors
- Mechanical Failure
- Media Failure

3.2 Issue Severities

Test failures and issues are identified and classified in the table below. Issues are jointly reviewed to determine final severity rating.

Issue Severity Classifications

Severity 1	**Severe** (can include any of the following) • Unrecoverable data or command error • Mechanical failure • Safety issue
Severity 2	**Serious** (can include any of the following) • Recoverable data or command error • Incorrect response to a valid SCSI command • Test unit is unable to perform the function requested
Severity 3	**Moderate** (can include any of the following) • Performance degradation • Specification deviation • Command completed, but failed to meet a specification • Out of specification part
Severity 4	**Minor** (can include any of the following) • Usability error • Documentation error • Minor anomaly noted during testing

3.3 Issue List

All issues (as defined above) noted during DVT testing are logged. Each issue is document with:

- Issue Number
- Severity Level
- Related Test Script
- Associated Command / Message / Signal
- Failure Type (hardware / software / media / specific condition)
- Description
- Documentation (logs / bus trace / engineering notes)
- Date (opened / closed)
- Status (open / closed / evaluate fix)
- Firmware Level (found / fixed)
- Resolution

3.4 DVT Entrance Criteria

Two (2) functional test units are delivered to Percept's test lab. Add-on hardware, as prescribed in the finalized "Medium Changer Test Plan", is preinstalled.

Media is supplied to populate one-half of total storage elements.

A minimum of one (1) cleaning tape is supplied.

Cabling and termination is supplied for each test unit.

Final "Medium Changer Functional Specification" document is supplied.

Final "Medium Changer Protocol Specification" document is supplied.

Normative ANSI SCSI interface specification is identified.

"Medium Changer Test Plan" document is approved.

3.5 DVT Exit Criteria

All test areas defined in the finalized "Medium Changer Test Plan" are completed with no severity 1, 2, or 3 issues unresolved. All tests are 'Pass / Fail' criteria. Failed tests will receive an 'Issue Severity' as defined above.

4. Medium Changer DVT

Each test script in the Medium Changer DVT is designed to validate a specific device subsystem. Test scripts fall into the following general categories:

- SCSI Protocol Verification
- SCSI Command Set Verification
- Functional Verification
- Performance Testing

Testing was conducted at Percept Technology Labs January 6, 2003 through January 10, 2003.

Medium Changer DVT Set Up

4.1 SCSI Protocol Verification

Protocol verification tests are designed to test the target device at the logical level. The target device is tested to verify SCSI signals, bus phases, and connections. Results are logged and compared against SCSI specifications. Protocol failures are analyzed by SCSI bus trace inspection in conjunction with logged test results. The I_T_L (initiator, target, logical unit) nexus is examined along with messages and commands issued to identify and document incorrect responses.

Hardware: PC w/ ISA slot
OPPCO 1850 SCSI Interface Card
SCSI Bus Analyzer

Software: Windows 98 (preferred) running a DOS window
OPPCO Monitor Program, release 8-2002

Description	Pass / Fail
Identify's Logical Unit Number	Pass
Contingent Allegiance	Fail

4.1.1 Identify's Logical Unit Number

Description: Identify's Logical Unit Number (LUN) Test is designed to verify a targets ability to respond to Identify Messages with valid and invalid LUN values.

Method: The device under test is cabled to the host platform via the OPPCO HBA along with a SCSI bus analyzer. The OPPCO Monitor Program is opened. The bus analyzer is initialized. A bus device reset is issued through the Monitor Program and "Identify's LUN" test is launched. When the test terminates, the Monitor log and bus trace are saved.

Test Results: **Pass**

The medium changer responded correctly to all test cases. Commands tested in addition to Inquiry and Request Sense were Initialize Element Status, Log Sense, Log Select, Mode Sense, Mode Select, Move Medium, Position To Element, Prevent / Allow Medium Removal, Read Buffer, Read Element Status, Release, Reserve, Test Unit Ready, and Write Buffer.

Test Cases:

Command	LUN	Results
Inquiry	Target's	Good Status w/ return data byte 0 = device type
Request Sense	Target's	Good Status
All Other CDBs	Target's	Command Validation / Rejection
Inquiry	Unsupported	Good Status w/ return data byte 0 = 0x7F
Request Sense	Unsupported	Good Status
All Other CDBs	Unsupported	Check Condition w/ Sense - LUN Unsupported

4.1.2 Contingent Allegiance

Description: The Contingent Allegiance Test is designed to verify a target's ability to preserve sense data for an initiator following the return of Check Condition. Specific actions are performed to verify pending sense is retained until cleared. This is a multi-initiator test.

Method: The device under test is cabled to the host platform via the OPPCO HBA along with a SCSI bus analyzer. The OPPCO Monitor Program is opened. The bus analyzer is initialized. "Contingent Allegiance" test is launched within the Monitor Program. When the test terminates, the Monitor log and bus trace are saved.

Test Results: **Fail**

Initiator IDs 0, 3, 4, and 7 were enabled for testing. The target device was set to SCSI ID 2. A Bus Reset was issued. Test Unit Ready was issued by IID 0. A Check Condition was received, but Request Sense was not issued. Instead, Test Unit Ready was issued by IID 3. Test Unit Ready command timed out for IID 3 with Unit Attention pending for Initiator ID 0.

Test Cases:

Condition	Course of Action	Results
Bus Reset	Test Unit Ready (TUR) followed by Request Sense issued by each enabled Initiator ID (IID)	For each IID, a check condition was returned for TUR with Unit Attention (UA) recovered by Request Sense
Bus Reset	Inquiry followed by TUR and Request Sense issued by each enabled IID	For each IID, Good Status w/ data for Inquiry and UA recovered by Request Sense following TUR
Device Reset	Select Initiator issues Device Reset; TUR followed by Request Sense is issued by each enabled IID	For each IID, a check condition was returned for TUR with UA recovered by Request Sense
Bus Reset	TUR issued by each enabled IID, except Request Sense deferred for selected IID	***Command timed out following deferred Unit Attention***
Invalid CDB	Invalid command issued by select IID with Request Sense deferred, TUR and Request Sense issued by all other enabled IIDs	***Incomplete***
Abort Message w/ Identify	Invalid command issued by select IID with an Abort followed by Request Sense deferred, TUR issued by all other enabled IIDs	***Incomplete***
Concurrent Invalid CDBs	Invalid commands issued by selected IIDs with Request Sense deferred, TUR for all other enabled IIDs; Test case for concurrent capable targets	***Incomplete***

4.2 SCSI Command Set Verification

Supported medium changer commands are checked to verify functionality. Tests defined in section 4.2 are referred to collectively as "SCSI DVT suite". The suite is divided into functional and exception testing. Functional command processing and execution are verified using legal sequences. Exception and error handling are checked using illegal sequences.

Hardware: PC w/ PCI slot
Adaptec 29160 SCSI Interface Card
SCSI Bus Analyzer

Software: Windows 98, 2000 or NT
Percept Test Manager ~ MC

Command	Exception Pass / Fail	Functional Pass / Fail
INITIALIZE ELEMENT STATUS W/ RANGE	Pass	Pass
INQUIRY	Pass	Pass
READ ELEMENT STATUS	Pass	Fail

4.2.1 Initialize Element Status with Range

Description: The Initialize Element Status with Range command, operation code 0xE7, causes the medium changer to examine the specified storage elements for cartridge presence. The following command field keywords affect the configuration of the Initialize Element Status with Range command:

Byte 1 / Bits 5 – 7	LUN
Byte 1 / Bit 0	Range
Bytes 2 & 3	Starting Element Address
Bytes 6 & 7	Number of Elements
Byte 9 / Bit 7	NBL

Exception Testing

For each Command Descriptor Block (CDB) byte, every combination of Reserved bits is set and the command issued. A Check Condition is expected. Request Sense is issued and the returned sense data compared to expected values.

Invalid bits in the CDB's LUN field are set and the command issued. A consistent medium changer response is anticipated across all invalid LUNs.

Test Results: **Pass**

Exceptions were received for all combinations of reserved bits within each CDB byte tested. Reserved bits 1–4 byte 1, all bits bytes 4, 5, 8, and bits 0–6 byte 9 were tested and returned the expected Illegal Request "invalid field CDB", ASC 24h, ASCQ 0h. The SKSV, C/D, and BPV bits were set with the field and bit pointers correctly assigned.

An exception was received for all nonzero combinations of bits within the LUN field. The Illegal Request "invalid LUN", ASC 25h, ASCQ 0h was received. The SKSV, C/D, and BPV bits were set with the field and bit pointers correctly assigned.

Functional Testing

Initialize Element Status with Range is issued using in succession every valid Starting Element Address with the corresponding remaining Number of Elements. Test adapts to current medium changer addressing. Good Status is expected for all commands.

Test Results: **Pass**

There were no problems or issues associated with the Initialize Element Status With Range command. The test completed with default medium changer addressing as well as all modified address schemes used during functional testing.

4.2.2 Inquiry

Description: The Inquiry command, operation code 0x12, requests the medium changer return information about its device parameters. The following command field keywords affect the configuration of the Inquiry command:

Byte 1 / Bits 5 – 7	LUN
Byte 1 / Bit 0	EVPD
Byte 2	Page Code
Byte 4	Allocation Length

Objective: Test and verify the following:

- "Unit Attention" is maintained through an inquiry command.
- "Check Condition" is returned for each command with illegal bit combinations.
- Issue an Inquiry command for every supported page at all allocation lengths and verify the number of bytes returned is correct and the returned data is identical to product specifications.
- An Inquiry command issued to an invalid LUN returns the correct data and number of bytes.

Exception Testing

For each CDB byte, every combination of Reserved bits is set and the command issued. All invalid Page Codes are issued at every Allocation Length with and without vital product information enabled. In all cases, a Check Condition is expected. Request Sense is issued and the returned Sense data compared to expected values. Invalid bits in the CDB's LUN field are set and the command issued. A consistent medium changer response is anticipated across all invalid LUNs.

Test Results: **Pass**

Exceptions were received for all combinations of Reserved bits within each CDB byte tested. Reserved bits 1–4 byte 1 and all bits bytes 3 and 5 were tested and returned the expected Illegal Request "invalid field CDB", ASC 24h, ASCQ 0h. The SKSV, C/D, and BPV bits were set with the field and bit pointers correctly assigned.

Exceptions were received for all Inquiry commands issued with the EVPD bit clear and set for each invalid Page Code from 0x01 to 0xFF at every Allocation Length from 0x00 to 0xFF. All commands returned the expected Illegal Request "invalid field CDB", ASC 24h, ASCQ 0h. The SKSV, C/D, and BPV bits were set with the field and bit pointers correctly assigned.

An Inquiry command for each supported page was issued for all nonzero combinations of bits within the LUN field. Good Status and data was received for all commands. In all cases the medium changer returned a value of 0x7F for the Peripheral Qualifier / Device Type byte 0 (i.e., target not capable of supporting a physical device on this LUN / unknown or no device type). The standard Inquiry data page (EVPD 0h, page code 0h, allocation length 56 bytes), the supported vital product page (EVPD 1h, page code 0h, allocation length 6 bytes), and the unit serial number page (EVPD 1h, page code 80h, allocation length 22 bytes) all returned the expected data length and content (see also Identify's Logical Unit Number Test).

Functional Testing

An Inquiry command is issued at every Allocation Length, 0x00 to 0xFF for each supported page. The medium changer supports the standard Inquiry data page, supported vital data product page, and unit serial number page. The number of bytes returned must be equal to the allocation length or page size which ever is least. The data returned is compared to expected values.

Test Results: **Pass**

The standard Inquiry data page, EVPD 0h, Page Code 0h, was issued for each allocation length from 0x00 to 0xFF. For each allocation length greater than 56 bytes, the returned data did not exceed 56 bytes and the requested byte count was returned for all allocation lengths less than or equal to 56 bytes. Each command issued returned the expected data values.

The supported vital product page, EVPD 1h, Page Code 0h, was issued for each allocation length from 0x00 to 0xFF. For each allocation length greater than 6 bytes, the returned data did not exceed 6 bytes and the requested byte count was returned for all allocation lengths less than or equal to 6 bytes. Each command issued returned the expected data values.

The unit serial number page, EVPD 1h, Page Code 80h, was issued for each allocation length from 0x00 to 0xFF. For each allocation length greater than 22 bytes, the returned data did not exceed 22 bytes and the requested byte count was returned for all allocation lengths less than or equal to 22 bytes. Each command issued returned the expected data values.

It was verified that Unit Attention is maintained through an inquiry command. On Adaptec HBA platforms, Test Unit Ready issued after a system power cycle for the medium changer returned the appropriate check condition. The HBA generated Inquiry was trapped and verified on a bus trace along with the subsequent Test Unit Ready command. On OPPCO HBA platforms, a Bus Reset followed by an Inquiry and Test Unit Ready returned correct data and sense (see Contingent Allegiance Test).

4.2.3 Read Element Status

Description: The Read Element Status command, operation code 0xB8, returns the data created by the Initialize Element or Initialize Element with Range commands. The returned data provides the status of supported element types. The following command field keywords affect the configuration of the Read Element Status command:

Byte 1 / Bits 5 – 7	LUN
Byte 1 / Bit 4	VolTag – Volume Tag
Byte 1 / Bits 0 – 3	Element Type Code
Bytes 2 & 3	Starting Element Address
Bytes 4 & 5	Number of Elements
Bytes 7 – 9	Allocation Length

Exception Testing

For each Command Descriptor Block (CDB) byte, every combination of Reserved bits is set and the command issued. A Read Element Status command is issued for each invalid Element Type Code. A Check Condition is expected for each command. Request Sense is issued and the returned sense data compared to expected values.

Invalid bits in the CDB's LUN field are set and the command issued. A consistent medium changer response is anticipated across all invalid LUNs.

Test Results: Pass

Exceptions were received for all combinations of Reserved bits within each CDB byte tested. All bits bytes 6, 10 and 11 were tested and returned the expected Illegal Request "invalid field CDB", ASC 24h, ASCQ 0h. The SKSV, C/D, and BPV bits were set with the field and bit pointers correctly assigned.

An exception was received for every invalid Type Code including unsupported import export element type 3h. Illegal Request "reserved type code", ASC 24h, ASCQ 0h was received. The SKSV, C/D, and BPV bits were set with the field and bit pointers correctly assigned.

An exception was received for all nonzero combinations of bits within the LUN field. The Illegal Request "invalid LUN", ASC 25h, ASCQ 0h was received. The SKSV, C/D, and BPV bits were set with the field and bit pointers correctly assigned.

Functional Testing

Read Element Status is issued with every boundary permutation of Start Element Address, Number of Elements, and Allocation Length. Specific intermediate values are also tested. These values are replicated using every permutation of valid Type Codes and Primary Volume Tag bit. The entire collection of commands is repeated with different address schemes. Using the Mode Select command the default medium changer addressing is used as well as different combinations of element types at the high and low address boundaries. All returned Read Element Status data is parsed and compared against expected values for each specific command issued.

Test Results: Fail

Read Element Status commands issued with allocation lengths 9 to 15 bytes return partial Element Status Page Header. Expecting only eight bytes of Element Status Data Header.

4.3 Functional Verification

Description: Exercise the medium changer across all supported medium change SCSI commands and verify device functionality. Some illegal sequences will be issued to force Check Conditions. Tape drive and medium changer interoperability will be verified.

RAN Test Script

Tapes are loaded randomly. A mix of various length records and file marks are written. Forward and backward space operations are performed followed by Read Position to confirm correct positioning. The test continues until the specified cycle count is completed. The tape is returned to its storage location.

REV Test Script

Tapes are loaded and unloaded in reverse order. A small data set of various record lengths are written and read. Illegal moves are requested and expected Check Conditions are verified. Attempted illegal moves include: move a tape to an occupied slot, move a tape from a empty slot, move a tape to a full drive, and move a tape from a empty drive. The test continues until the specified cycle count is completed.

SEQ Test Script

Tapes are loaded and unloaded sequentially. A small data set of various record lengths are written and read. Illegal moves are attempted when tape drive media removal is prevented. The expected Check Conditions is verified. After each move command is issued, medium changer inventory is verified. The test continues until the specified cycle count is completed.

Additional Test Scripts

A **SCAN** script issues Initialize Element Status with Range commands and collects timing data. Average scan times with and without bar code scans are collected. The test continues until the specified cycle count is achieved. Using Initialize Element Status with Range forces the medium changer to re-examine its inventory. The command is issued with the Range bit clear, resulting in a complete inventory update.

Test scripts are executed in a group as an operation cycle. Medium changer element addressing is changed after each operation cycle using **NEW_ADDR**. This script issues Mode Select Page 0x1D to establish a new element-addressing scheme before the next operation cycle. High and low boundary settings as well as default addressing for each supported element type is accomplished. This ensures that SCSI functional verification is executed over a wide range of operating parameters.

Test Results: **Pass**

Forced errors tested in RAN, REV and SEQ returned the expected Check Condition and sense data. A total of 1,800 load cycles (pick cartridge, move, load, write / read, unload, and cartridge return) completed successfully. Load cycles were distributed over nine address schemes. The following table summarizes testing.

Command	Test Script	Cycles
Move – random load	RAN	900
Move – reverse load	REV	450
Move – sequential load	SEQ	450
I.E.S. w/ Range	SCAN	450
Mode Select	NEW_ADDR	9

4.4 Performance Testing

4.4.1 Medium Changer Physical Timings

Description: Measure and verify the time required to complete various medium changer physical operations.

Method: Measure Initialize Element Status time and average one-way cartridge move times. Timings are collected during SCSI functional verification testing.

Test Results: **Pass**

Scripts RAN, REV and SEQ were each executed with a cycle count of 100, without any failures. SCAN was executed with a cycle count of 100 both with and without Bar Code Scan. The resulting data is summarized in the following table.

Physical Timing	Condition	Average Time
Move Medium	one-way	8 seconds
Initialize Element Status	with bar code scan	38 seconds
Initialize Element Status	without bar code scan	38 seconds

4.4.2 Drive Data Transfer Rates

Description: The "System Performance" test measures write and read transfer rates of installed medium changer drives. A "Loop IES" script runs the medium changer, forcing changer activity during write and read cycles.

Method: The tape drive specific "System Performance" test will execute multiple passes, recording transfer rates for block sizes ranging from 512 bytes to 512 Kbytes. Each test pass will consist of writing and reading 10 GBytes of data in the selected block size. Concurrently, Initialize Element Status commands will be issued to the medium changer.

Two system configurations will be tested:

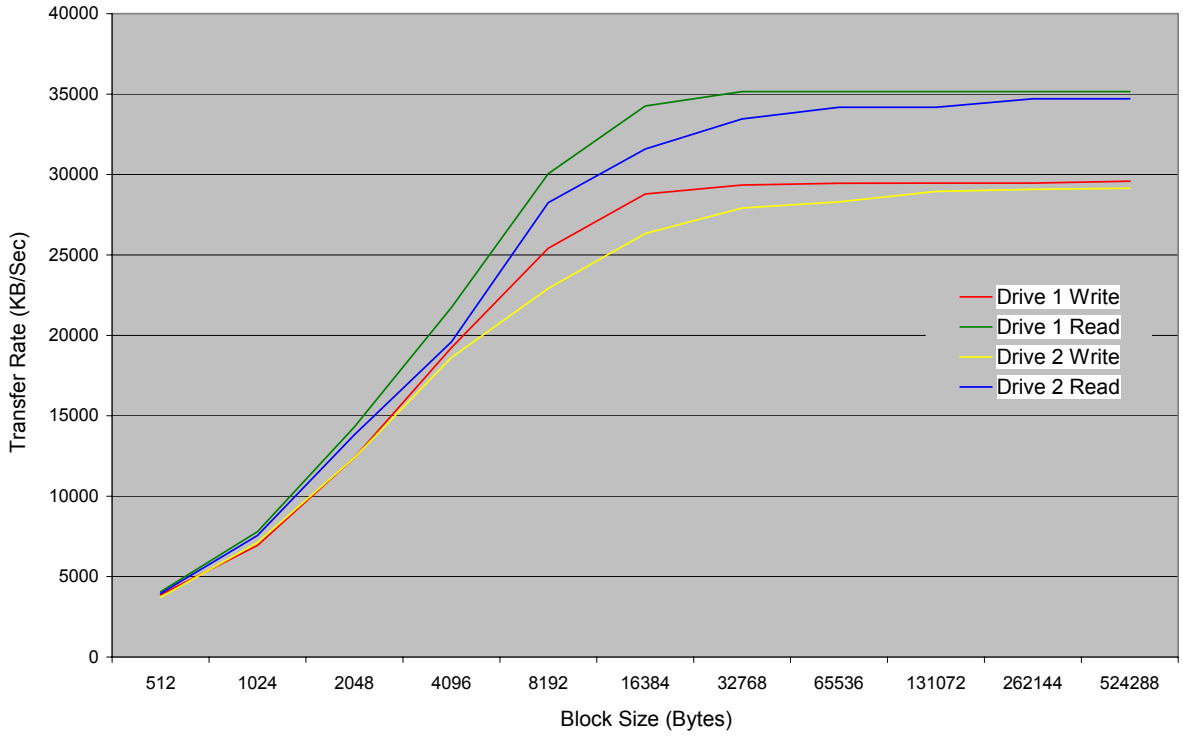
- single bus, single host
- dual bus, single host each bus

Test Results: **Pass**

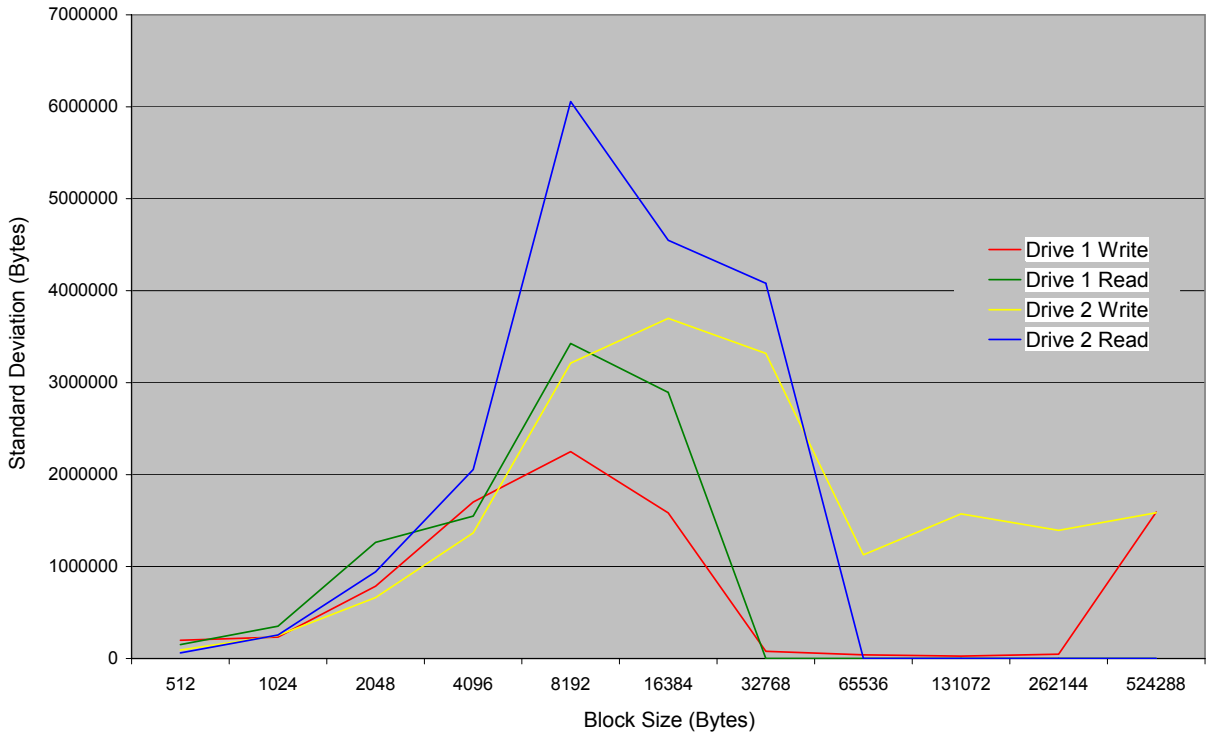
The "System Performance" test was run simultaneously on two drives, in each of the configurations outlined above, without any failures. For each of the specified block sizes, the test ran ten write and read passes. Results were averaged. Standard deviation was calculated. The results are shown in the graphs below.

Two Drives, Single Bus, Single Host

Average Transfer Rate

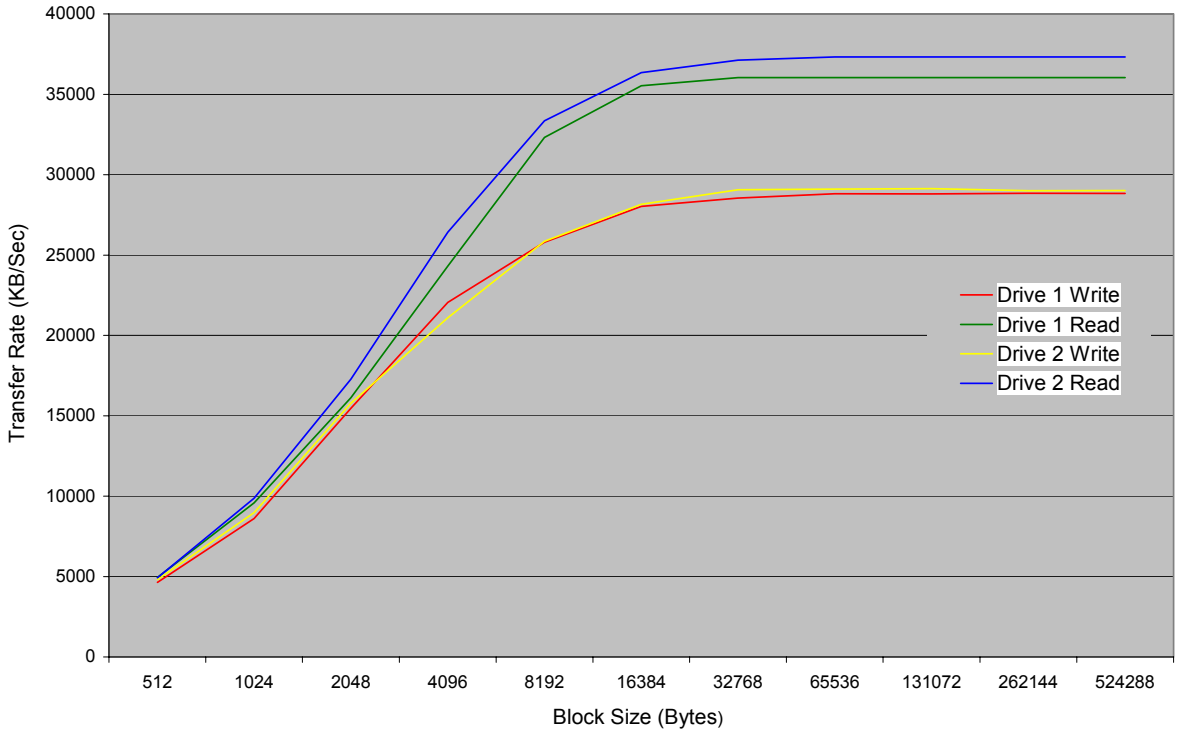


Standard Deviation

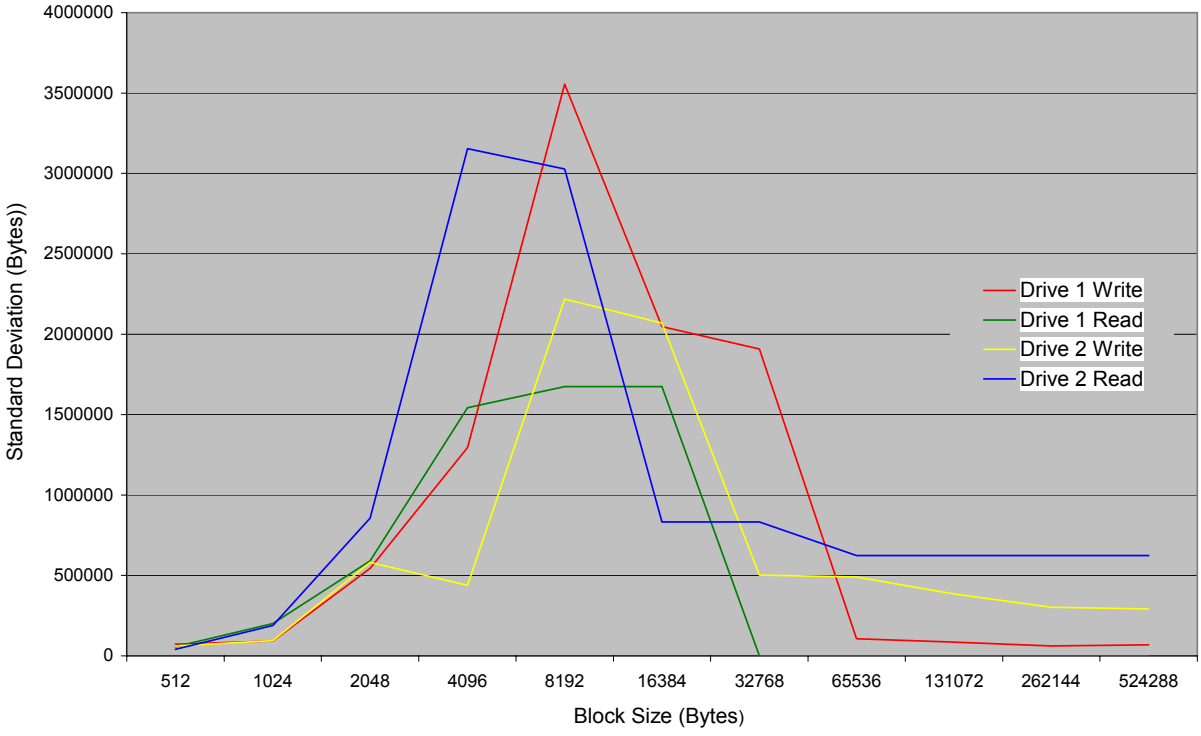


Two Drives, Dual Bus, Single Host Each Bus

Average Transfer Rate



Standard Deviation



4.4.3 Power - On To Selection Time

Description: This is a manual test of medium changer power-on to selection time. The SCSI-2 recommended value is ten (10) seconds. It is assumed that a reasonably accurate measurement of power-on to selection time can be manually captured, since the significant value is in units of seconds.

Method: The device under test is cabled to the host platform via the OPPCO HBA along with a SCSI bus analyzer. The OPPCO Monitor Program is opened. The device is powered off. A SCSI bus trace is started. Inquiry, Request Sense, or Test Unit Ready is issued from the Monitor program interface simultaneously with turning the device on. The command is issued every second until status is returned. For each bus trace captured the time between the first Arbitration / Selection generated by the command and the first Status Byte returned by the device is measured. An average time is computed for each command.

Test Results: **Pass**

The medium changer responded within the recommended ten (10) seconds for all commands issued.

Test Cases:

Command	Iterations	Average Results
Inquiry	10	8 seconds power-on to selection time
Request Sense	10	9 seconds power-on to selection time
Test Unit Ready	10	8 seconds power-on to selection time