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StorageTek T9840D FICON Performance

ORACLE

Executive Overview

Oracle's StorageTek T9840D tape drive is the fourth-generation tape drive in the highly successful StorageTek T9840 family, providing industry-leading performance and capacity. The improvements made include increased cartridge capacity to 75 GB, improved backward read compatibility, and an embedded encryption algorithm.

Introduction

The StorageTek T9840D Fibre Connectivity (FICON) tape drive provides customers with high-performance and high-capacity tape storage while protecting their media investment. This white paper describes the general and performance-related characteristics of the StorageTek T9840D FICON tape drive.

This white paper is for the exclusive use of Oracle employees. The document contrasts the StorageTek T9840D with the StorageTek T9840C. Please note that this document does not include the performance of the StorageTek Virtual Storage Manager.

All tests were run with encryption enabled and encryption disabled. Where the included graphs do not show plots for both, the results were sufficiently similar to simply show one line. Due to variations in environments, applications, and microcode levels, customers might observe slightly different results in their own datacenters.

To obtain accurate performance data, all performance measurements were conducted on a standalone IBM z9 model 2096-X02 processor running IBM z/OS version 1.9. For the purpose of these measurements, all data was transferred through a single FICON Express channel. For the multiple drive tests, a Brocade SilkWorm 48000 FICON switch was used to attach all the StorageTek T9840D tape drives to a single FICON channel path identifier. The microcode used was 1.42.707.

StorageTek T9840D Overview

The StorageTek T9840D tape drive is the fourth-generation tape drive in the highly successful StorageTek T9840 family, providing industry-leading performance and capacity.

Figure 1. External view of the StorageTek T9840D

Increased Cartridge Capacity

While using existing StorageTek 9840 media, the StorageTek T9840D increases the native cartridge capacity to 75 GB using an increased recording density. In practice, the net capacity is further increased through LZ1 data compression so that effective capacities exceeding 300 GB are typical. This increased capacity saves library slots and improves throughput by reducing mount/dismount cycles.

By increasing the number of tracks on the tape from 288 to 576, more data can be stored on existing StorageTek 9840 cartridges without slowing access times. The "access-centric" design of the StorageTek T9840D uses the same dual hub cartridge and media introduced with the StorageTek T9840A. Some advantages of the dual hub design are as follows:

- Enables midpoint loading and unloading
- Enables greatly improved access times and reduced rewind time

For access time performance comparisons, see Table 2 in the "Comparisons" section.

The StorageTek T9840D continues to use a linear serpentine recording format, reducing search and access times to specific data sets on the cartridge.

The native head-to-tape data transfer rate of the StorageTek T9840D is 30 MB/sec. When used with the FICON interface, the StorageTek T9840D is capable of read/write speeds in excess of 60 MB/sec. The faster throughput significantly reduces backup times and improves the performance of other nearline applications. When used in disaster recovery situations, the StorageTek T9840D FICON tape drive can quickly restore critical information to direct access storage devices, thus minimizing recovery time. See Figure 2.

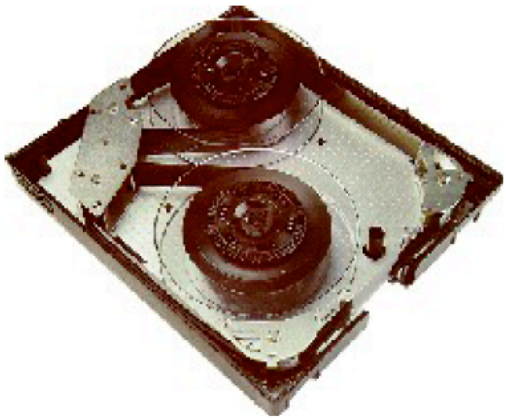

Figure 2. Internal view of StorageTek 9840 tape cartridge

Encryption Capable

All StorageTek T9840D tape drives have an embedded encryption algorithm and are supported by the StorageTek Crypto Key Management System 2.0.

Cleaning Cartridges

The StorageTek T9840D only accepts the StorageTek T9840 cleaning cartridge (U, the media identification label for StorageTek 9840 tape cartridges), which works with all of the drives in the StorageTek T9840 family. It will report "not ready" if loaded with any other cleaning cartridge.

Enhanced Legacy Read Capability

The StorageTek T9840D provides improved backward read compatibility in that it can read cartridges written on StorageTek T9840A, StorageTek T9840B, and StorageTek T9840C tape drives to facilitate migration to the StorageTek T9840D recording format. Cartridges rewritten on the StorageTek T9840D are automatically written at the higher recording density. Figure 3 shows the innovative design of the StorageTek T9840D tape head with the StorageTek T9840D writers in close proximity to the StorageTek T9840A, StorageTek T9840B, and StorageTek T9840C legacy reader. This provides high signal-to-noise ratio and low sensitivity to dropouts.

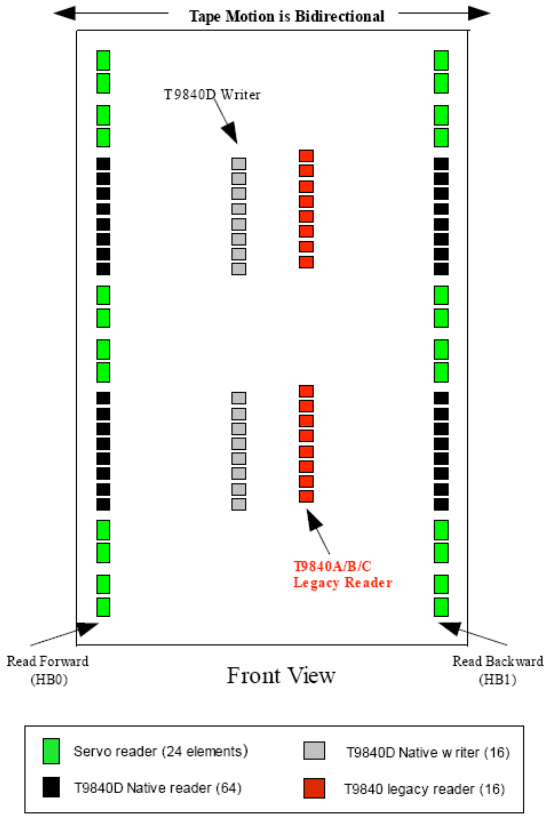

Figure 3. Innovative tape head design of the StorageTek T9840D

Data Cartridge Guidelines

Separate media pools/subpools for StorageTek T9840A, StorageTek T9840B, StorageTek T9840C, and StorageTek T9840D tape drives should be created and managed when more than one drive type exists in the same library system. Guidelines for creation and maintenance of media pools/subpools are located in the StorageTek Automated Cartridge System Library Software and StorageTek Host Software Component documentation. The guidelines using mixed drive types are as follows:

- StorageTek 9840D drives can read tapes previously written by StorageTek T9840 family drives (StorageTek T9840A, StorageTek T9840B, and StorageTek T9840C).
- StorageTek T9840D drives can overwrite tapes written by StorageTek T9840A, StorageTek T9840B, and StorageTek T9840C drives.
- StorageTek T9840A, StorageTek T9840B, and StorageTek T9840C drives cannot read or append to StorageTek T9840D written tapes.
- StorageTek T9840A, StorageTek T9840B, and StorageTek T9840C drives can overwrite StorageTek T9840D written tapes (in the StorageTek T9840A, StorageTek T9840B, and StorageTek T9840C formats).

StorageTek VolSafe Guidelines

- StorageTek T9840D drives will not overwrite StorageTek T9840A, StorageTek T9840B, and StorageTek T9840C VolSafe tapes containing customer data.
- StorageTek T9840D drives will read StorageTek T9840A, StorageTek T9840B, and StorageTek T9840C VolSafe tapes.

Drive Display Message Changes

For rackmounted tape drives, when a cartridge is loaded, the operator panel window indicates the following:

- **Ready F**. The loaded data cartridge tape is write protected by the cartridge write-protect switch in the locked position. If a read attempt fails on a StorageTek T9840A/StorageTek T9840B drive, retry on a StorageTek T9840C/StorageTek T9840D drive. (Note: The write-protect switch position detection overrides data density format identification.)
- **Ready H.** The loaded data cartridge tape is write enabled by the cartridge write-protect switch in the (StorageTek T9840A/StorageTek T9840B) unlocked position, and contains data written in the high-density format by a StorageTek T9840C/StorageTek T9840D drive. Reload with low-density data cartridge tape, or intentionally overwrite from beginning of tape (BOT). (Note: StorageTek T9840A and StorageTek T9840B drives cannot read, write, or append high-density data files.)
- **Ready L.** The loaded cartridge tape is write enabled and contains data written in the low-density (StorageTek T9840C/StorageTek T9840D) format by a StorageTek T9840A/StorageTek T9840B drive. Use for read-only jobs, or intentionally overwrite from BOT. (Note: Low-density data files can be read, but not revised nor appended by a StorageTek T9840C/StorageTek T9840D drive.)
- **Ready U.** The drive is online, loaded with a write-unprotected (write-enabled) cartridge tape, and the data density format matches the drive model (StorageTek T9840A/StorageTek T9840B: low; StorageTek T9840C/StorageTek T9840D: high). The drive can read, write, and append data. StorageTek T9840A and StorageTek T9840B operator panels are identical except for button color (StorageTek T9840A: yellow; StorageTek T9840B: purple; StorageTek T9840C: green; StorageTek T9840D: dark gray); and each panel has a specific model label.

Fibre Connectivity Architecture Implementation

The StorageTek T9840 FICON tape drives implement native FICON direct-attach interfaces, often referred to as a "1x1" architecture. This means each drive, such as the StorageTek T9840D FICON, can be connected directly to a FICON channel or FICON director/switch without intervening equipment (see Figure 4).

Oracle enables any number of drives to be attached to the FICON channel, within the architectural limits of FICON. This flexibility gives customers the greatest performance and availability while minimizing costs.

Compare this with a shared control unit–based architecture, which contains multiple protocol converters that introduce configuration limitations. The IBM solution introduces performance bottlenecks by allowing only four FICON channels into a solitary controller with only two internal Fibre Channel paths, and a limited number of IBM System Storage TS1120 and IBM System Storage TS1130 tape drives. All of this added hardware significantly increases the total cost of ownership (TCO) and introduces failure points, which would make *all* the drives in the subsystem unavailable.

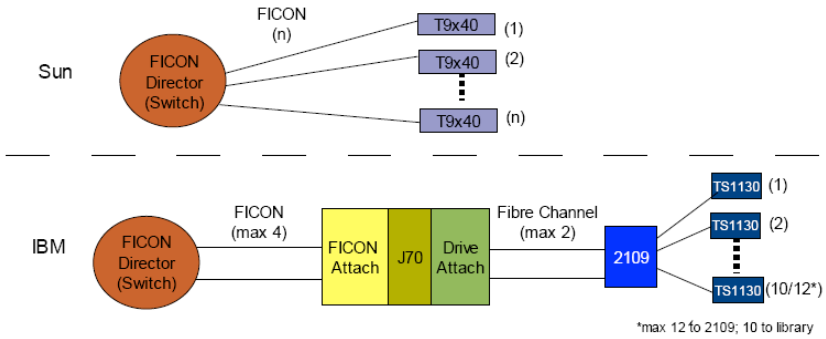

Figure 4. Oracle versus IBM FICON implementation

The Oracle 1x1 architecture has been the architecture preferred by customers since it was introduced with ESCON several years ago. With FICON, the 1x1 architecture continues to be the best choice for numerous reasons:

- Greatest flexibility in channel and subsystem configurations
- Greatest performance, which reduces backup and recovery times
- Highest reliability because there is less equipment and no single point of failure to multiple drives
- Lower TCO for the same throughput

StorageTek T9840D Performance

This section covers the performance of the StorageTek T9840D FICON drive in detail.

Block Size

Figure 5 compares the read/write data transfer rates of the StorageTek T9840D with those of a StorageTek T9840C FICON tape drive at various block sizes using 4:1 data compression. As shown,

performance benefits are most significant using 65.5 KiB blocks, up to 22 percent on writes, and up to 32 percent on reads.[1]

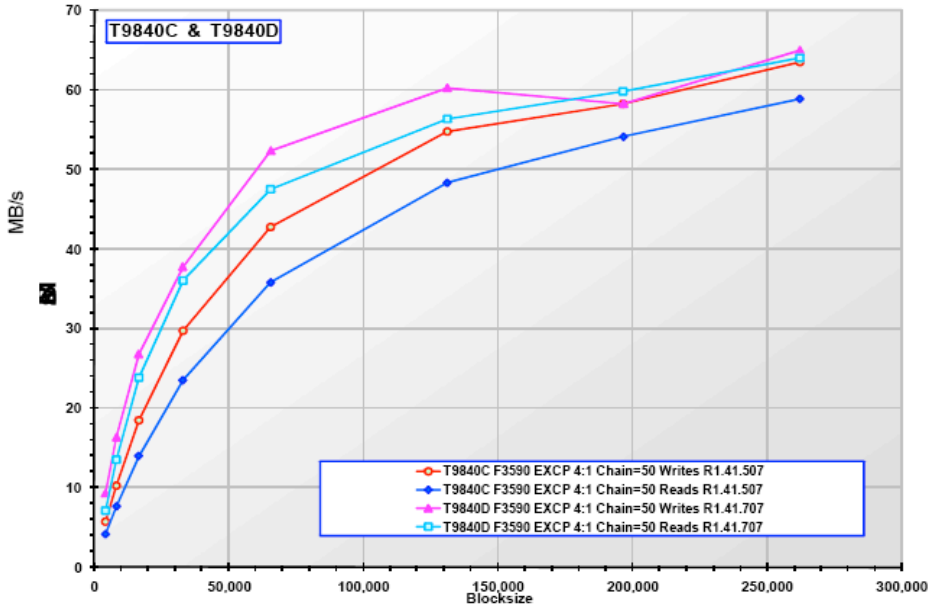

Figure 5. Read/write rates with 4:1 data compression

Figure 5 can also be used to estimate the performance of applications based on their block sizes. Table 1 lists some applications and their respective block sizes. Note that maximum performance can be achieved using large block applications such as the StorageTek Extended High-Performance Data Mover (ExHPDM) utility.

TABLE 1. APPLICATION BLOCK SIZES

APPLICATION	BLOCK SIZE
IBM Data Facility Hierarchical Storage Manager	16 KiB
FDR	64 KiB
ExHPDM	256 KiB

Figure 6 shows information similar to that depicted in Figure 5, except that uncompressed or 1:1 data compression was used. For certain applications that read/write uncompressed data, their performance can be estimated from this chart.

[1] The IEC standard [1] is used in which an "i" is inserted between the SI prefix and base unit to indicate that the prefix is a power of 2, rather than the "default" power of 10.

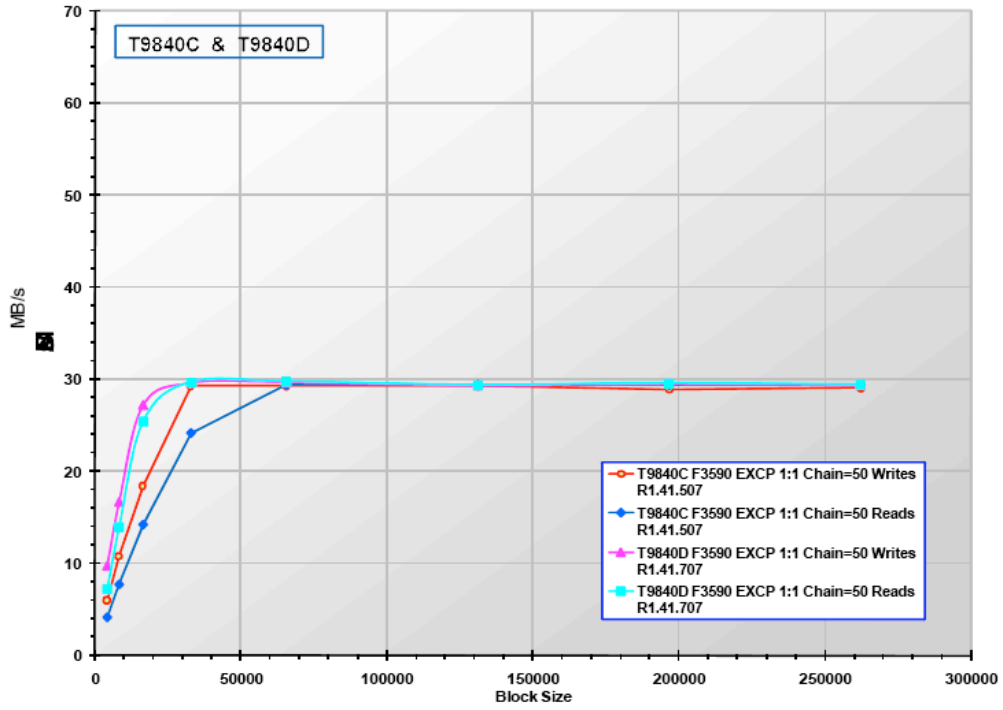

Figure 6. Read/write rates with 1:1 data compression

Figure 7 shows data for ∞:1 data compression for various block sizes. Figure 8 compares the compressed and uncompressed read/write data with various block sizes.

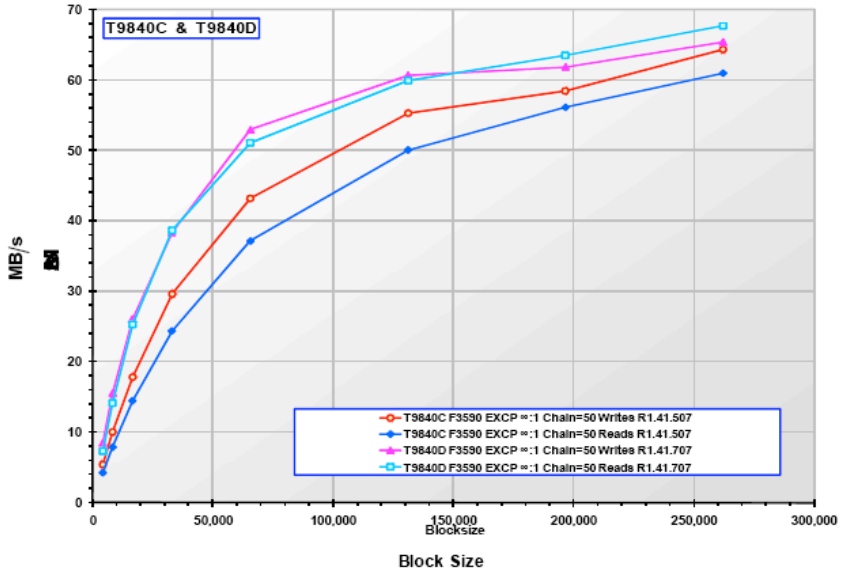

Figure 7. Read/write rates with ∞:1 data compression

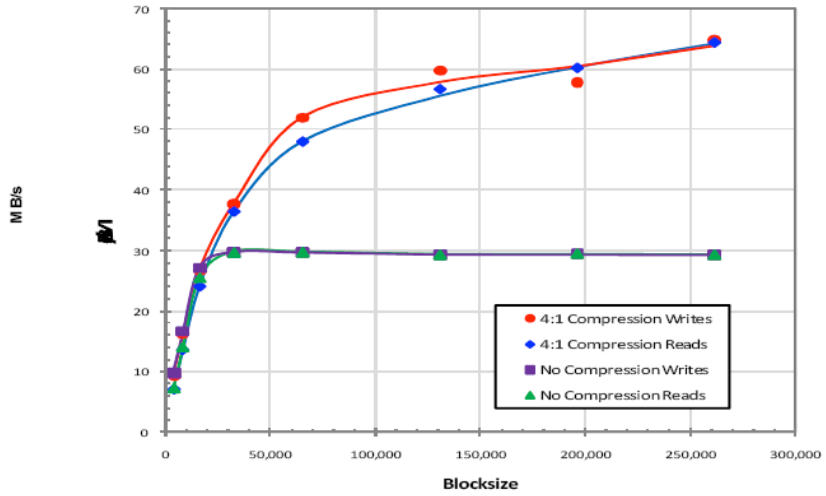

Figure 8. StorageTek T9840D tape drive compressed and uncompressed read/write rates versus block size

Chain Length

Figure 9 shows the benefits of using longer chain lengths, that is, chaining more read or write commands into a single channel program so that more blocks are transferred per `START SUBSHCNNEL` instruction.

Figure 9 was created using an Execute Channel Program (EXCP) application in which the chain length was explicitly specified. However, coding `DCB=BUFNO=nnn` in data definition statements can be used with several of the other access methods to control the chain length of channel programs. This is accomplished indirectly by specifying the number of buffers used by the access method. For example, a Queued Sequential Access Method (QSAM) will, on average, transfer BUFNO/2 blocks per I/O operation from the application.

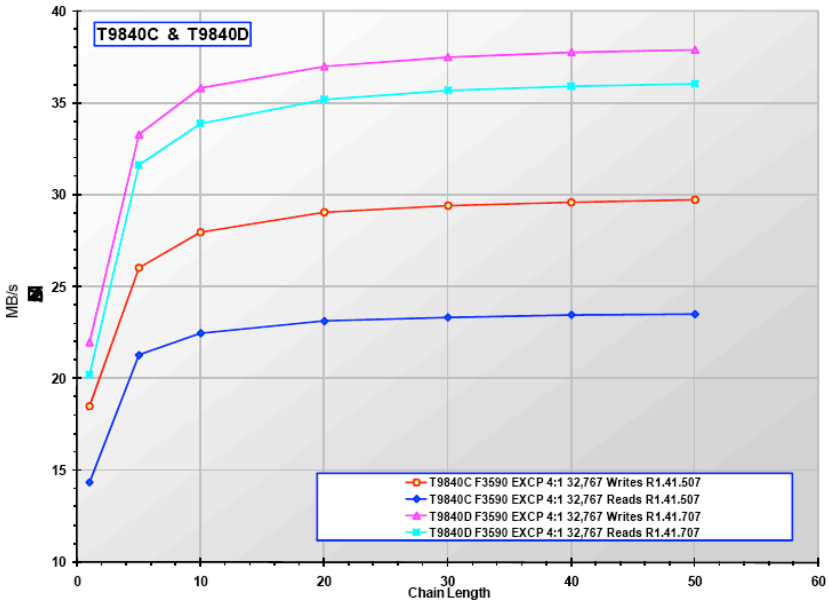

Figure 9. Read/write rates versus chain length

Figure 10 shows the StorageTek T9840D read/write data for 4:1 compressed data and uncompressed data. The chain length using different block sizes is shown in Figure 11.

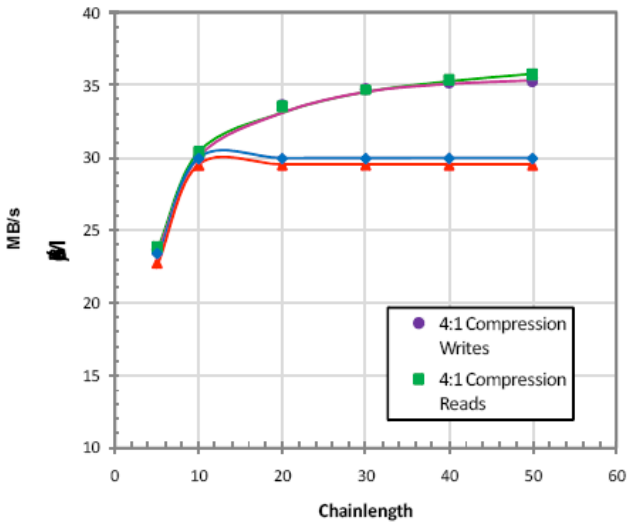

Figure 10. StorageTek T9840D compressed and uncompressed read/write data versus chain length

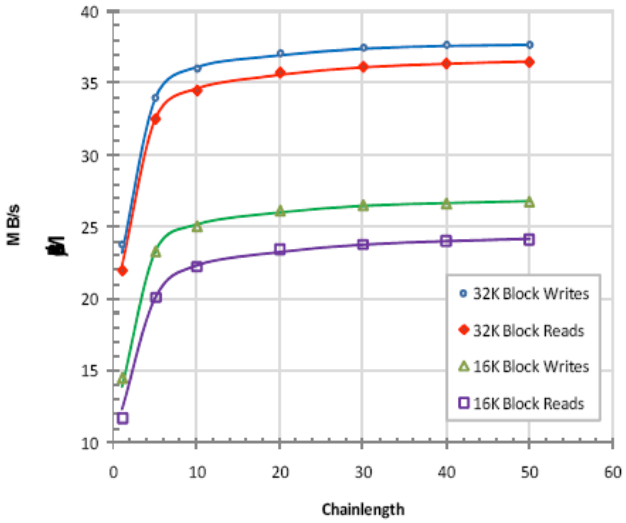

Figure 11. StorageTek T9840D read/write versus chain length

Compression

The StorageTek T9840D continues the use of an LZ1 data compression algorithm, which is implemented in the hardware. Data compression not only allows for greater effective storage capacities but also improves throughput, as shown in Figures 12–14.

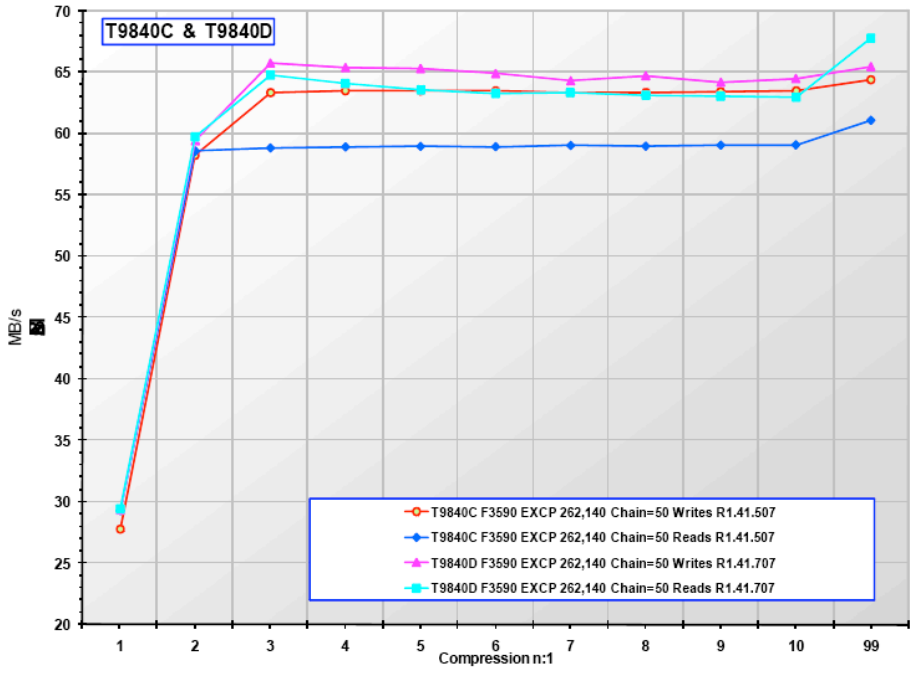

Figure 12. Read/write rates versus data compression

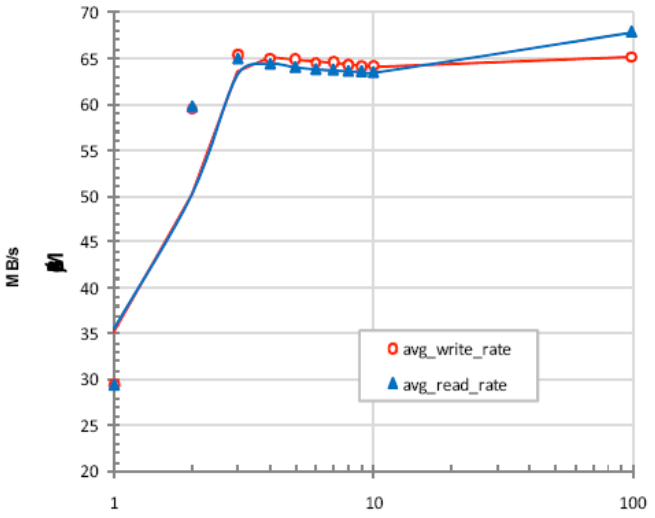

Figure 13. StorageTek T9840D read/write rate versus the EXCP data compression ratio

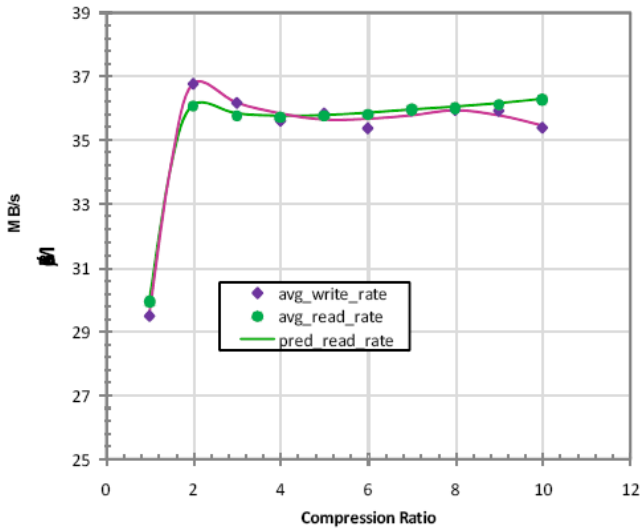

Figure 14. StorageTek T9840D read/write rate versus the QSAM data compression ratio

Distance

FICON is specified to operate at distances of up to 100 km without severe performance degradation. At this time, optics are available to support distances of up to 35 km before repeaters are required. Measurements of a StorageTek T9840D tape drive at simulated distances from 0 km to 30 km using several block sizes are shown in Figure 15.

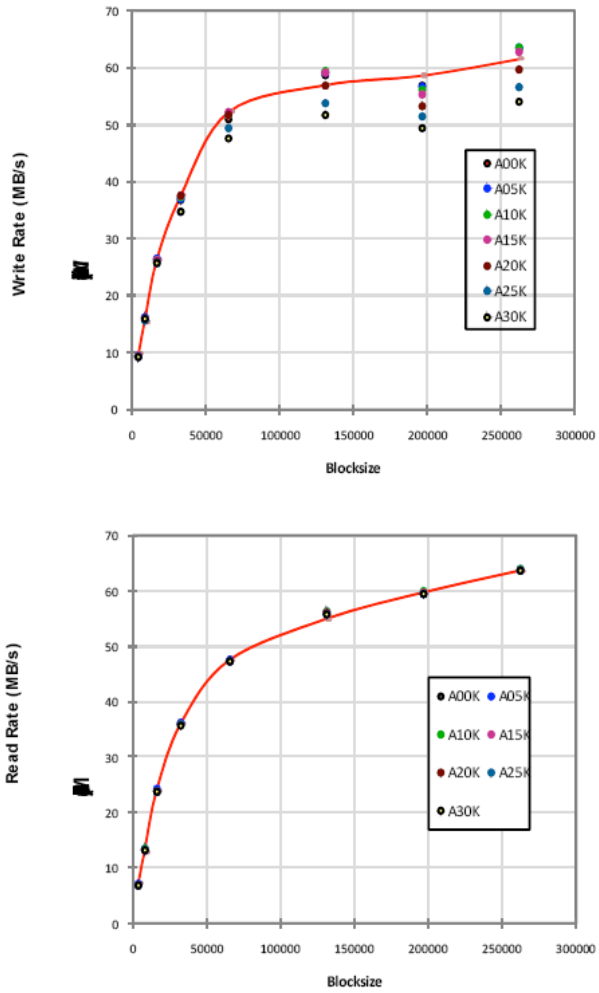

Figure 15. StorageTek T9840D read/write rates versus distance

Channel Loading

In typical configurations, several StorageTek T9840D FICON tape drives would be attached to a single FICON channel via a FICON switch. Figure 16 shows the results of different block sizes as drives are added to the channel using a QSAM application. Figure 17 was created using an EXCP application. A complete description of how the channel loading tests are performed is given in the appendix (eighth reference).

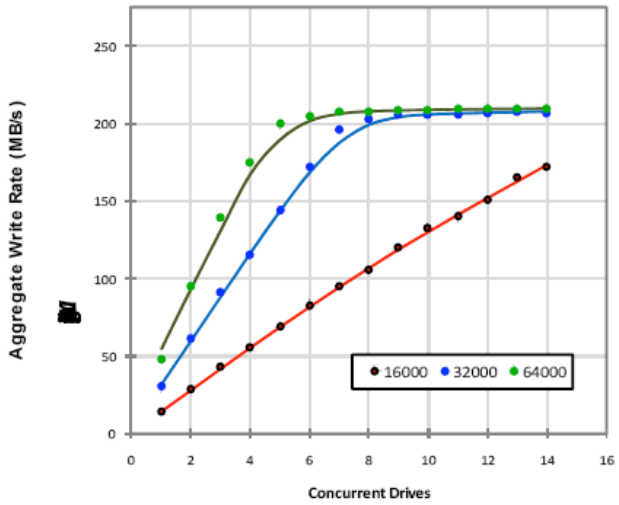

Figure 16. StorageTek T9840D QSAM channel loading

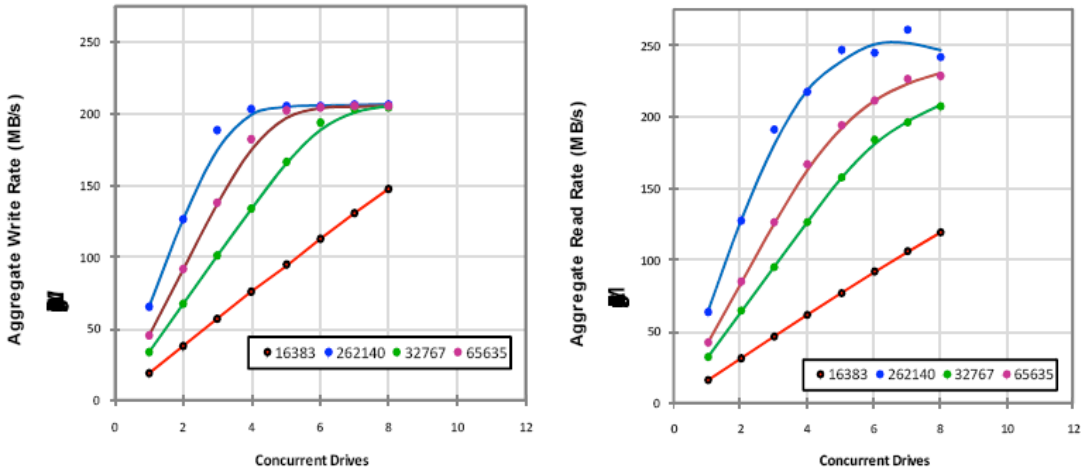

Figure 17. StorageTek T9840D EXCP channel loading

Comparisons

Like the StorageTek T9840D, the StorageTek T10000B has a similar FICON interface, but the native head-to-tape speed of the StorageTek T10000B is much faster than the StorageTek T9840D, as shown in Figure 18.

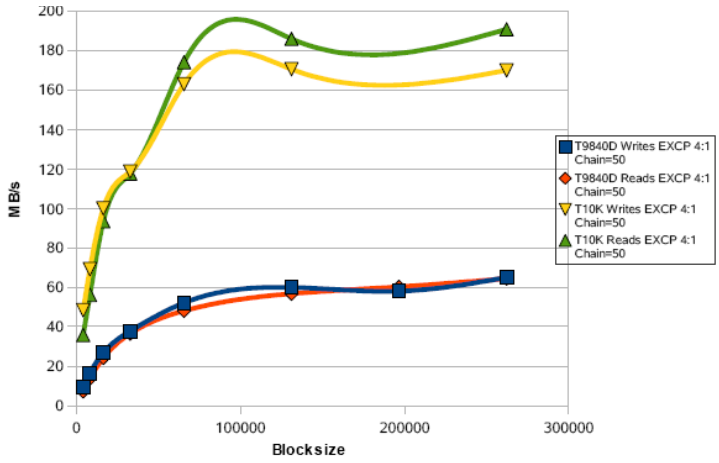

Figure 18. StorageTek T9840D FICON versus StorageTek T10000B FICON

Unlike the dual hub access-centric design of the StorageTek T9840 tape drives, the StorageTek T10000 series uses a single hub storage-centric design. This enables the StorageTek T10000B to store up to 1000 GB of uncompressed data, 13 times that of the StorageTek T9840D. With its data compression feature, the StorageTek T9840D can typically store at least 300 GB of data on a single cartridge.

Although the single hub cartridge of the StorageTek T10000 media enables more tape to be stored and greater capacity, it is not midpoint load/unload capable like the StorageTek T9840 media. Therefore, the access and rewind times on the StorageTek T10000B are longer than the StorageTek T9840D. A comparison of access times is shown in Table 2. Table 3 shows some miscellaneous specifications.

TABLE 2. ACCESS TIMES

METRIC	STORAGETEK T10000B		STORAGETEK T10000A		STORAGETEK T9940B	STORAGETEK T9840D	STORAGETEK T9840C
	STD	SPORT	STD	SPORT	9940	9840D NATIVE	9840C NATIVE
Load/thread to ready (s)	16.5	16.5	16.5	16.5	18	8.5	6.5
Avg search time (to midtape) (s)	46	14	46	14	45	8	8
Max search time (to end of tape [EOT]) (s)	91	23	91	23	82	16.5	16
Avg rewind time (from midtape) (s)	48	13	48	13	45	8	8
Max rewind time (from EOT) (s)	91	23	91	23	90	16	16
Unload time (s)	23	23	23	23	18	12.5	11.5

TABLE 3. MISCELLANEOUS SPECIFICATIONS

METRIC	STORAGETEK T10000B		STORAGETEK T10000A		STORAGETEK T9940B	STORAGETEK T9840D	STORAGETEK T9840C
	STD	SPORT	STD	SPORT	9940	9840	9840
RECORDING FORMAT	Linear serpentine		Linear serpentine		Linear serpentine	Linear serpentine	Linear serpentine
CAPACITY							
Uncompressed native capacity (GB)	1000	240	500	120	200	75	40
Tape length (m)	917	267	917	267	692	271	271
Number of tracks	1152		768		576	576	288
Recording channels	32		32		16	16	16
Wraps	36		24		36	36	18
Areal density ($Mb/inch^2$)	796		400		221	230	114
Linear bit density ($kb/inch^2$)	285		215		157	163	162
PERFORMANCE							
Data transfer rate, native (MB/sec)	120		120		30	30	30
Uncorrected bit error rate	$1x10^{-19}$		$1x10^{-19}$		$1x10^{-18}$	$1x10^{-18}$	$1x10^{-18}$
Data buffer (MiB)	64	64	256	256	64	3.4	3.295
Tape speed—read/write (m/s)	2.0	3.74	2.0	4.95	3.4	3.4	3.295
Tape speed—search/locate (m/s)	9		9.5		10	8.0 8.3 8.3	9

Tape speed—high speed rewind (m/s)	9.5	9.5	8.0	8.3	8.3
POWER					
Amperage	88/264 V AC @ 48/63 Hz	88/264 V AC @ 48/63 Hz	100/240 V AC @ 50/60 Hz	88/264 V AC @ 48/63 Hz	100/240 V AC @ 50/60 Hz
Consumption	• 61 W (drive) • 90 W (w/ power supply)	• 58 W (drive) • 90 W (w/ power supply)	Not available	85 W	65 W
Operating heat output	420 Btu/hr	420 Btu/hr	280 Btu/hr	212 Btu/hr	280 Btu/hr

Conclusion

The StorageTek T9840D tape drive is the fourth-generation tape drive in the highly successful StorageTek T9840 family, providing industry-leading performance and capacity. The improvements made include increased cartridge capacity to 75 GB, improved backward read compatibility, and an embedded encryption algorithm. Oracle's StorageTek T9840D FICON tape drive provides customers with high-performance and high-capacity tape storage while protecting their media investment.

Appendix: References

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