TECHNOLOGY BRIEF

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Compaq Computer Corporation

ECG Technology Communications

CONTENTS

Second-Generation 10,000-rpm Disk Drives

Compaq's customers have come to depend on Compaq 7,200-rpm disk drives for high performance and reliability. However, due to the increasing performance requirements of server applications such as online transaction processing, web services, consolidated email, and data marts; as well as workstation applications such as graphic design and video editing, customers demand even faster data access and higher data throughput from disk drives. To meet this demand, Compaq now offers second-generation 10,000-rpm (10k-II) Wide-Ultra SCSI-3 disk drives with capacities of 4.3-GB, 9.1-GB, or 18.2-GB. These drives are the next step in high-performance, enterprise-class disk drives.

In standard server benchmark tests, the 10k-II drives performed 35 percent better than high-end 7,200-rpm drives in on-line transaction processing tests and 43 percent better than 7,200-rpm drives in ServerBench® tests. For workstation performance, the 10k-II drives performed 35 percent better than 7,200-rpm drives in the Nonlinear Editing Disk Simulator (NEDS) test.[1]

This brief describes the technological advancements, benefits, and best applications for the 10k-II drive. It also discusses the above-mentioned benchmarks and their significance for helping customers choose the appropriate drives for their needs.

Please direct comments regarding this communication to the ECG Technology Communications Group at this Internet address: TechCom@compaq.com

[1] This is a Compaq internal benchmark.

Notice

Second-Generation 10,000-rpm Disk Drives

First Edition (October 1997)
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INTRODUCTION

The second-generation 10,000-rpm (10k-II) drives are Compaq's next step in high-performance enterprise-class disk drives. 10k-II drives are ideal for extremely fast data access and high data throughput required by applications such as web servers, email servers, transaction processing systems, scientific and graphic processing systems, enterprise servers, banking and reservations systems, and professional audio/video (A/V) applications.

The benchmarks discussed in this technology brief (two for servers and one for workstations) give an idea of relative performance as compared to 7,200-rpm drives. This brief discusses what each benchmark measures, how it is measured, and the results for 10k-II drives.

TECHNOLOGY AND PERFORMANCE ENHANCEMENTS

The 10k-II disk drives (Figure 1) have retained or improved such features of the first-generation 10,000-rpm (10k) drives as:

- Smaller disk size (3.0 inches)
- Improved servo motor design that provides faster seeks
- Rotational seek/sort feature
- Magnetoresistive read/write heads for greater bit density
- 80-pin single connector attachment (SCA) for hot-plug applications
- Wide-Ultra SCSI-3 interface

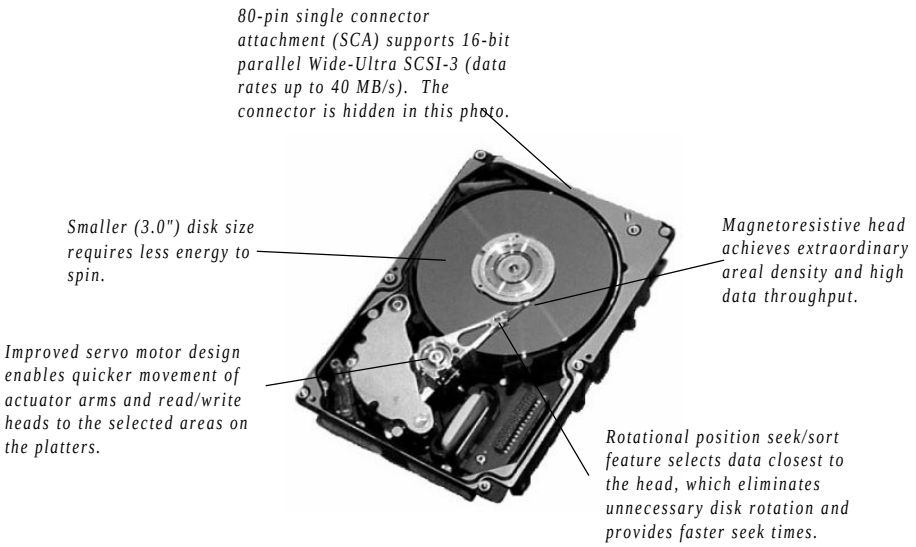

Figure 1: Technological advancements of 10k-II hard drive.

Areal density – the number of data bits per square inch of surface on media such as magnetic disk.

Recent industry improvements in manufacturing and quality have led to increased areal densities in disk drives. 10k-II drives have an areal density of 1.6 Gbits per square inch as compared to 1.3 Gbits per square inch for 7,200-rpm drives. The increase in areal density means that the physical size of the disk can be reduced while maintaining or increasing storage capacity. Standard 7,200-rpm and 10k disk diameters are 3.5 inches. Compaq 10k-II drives are 3 inches in diameter.

Disks of smaller diameter requires less energy to spin, thus 10k-II drives remain cooler than first-generation 10k drives. A cooler operating temperature gives the Compaq 10k-II drives two important advantages:

- The ability to deploy 10k-II drives in a wide range of servers and workstations without the need for special cooling considerations
- The reduced risk of over-heating the 10k-II drives, thereby increasing reliability

Although the size of the enclosure has remained the same, the smaller disk size makes more space available within the enclosure. This extra space increases airflow and reduces turbulence and friction caused by the high speeds of the 10k-II drives, thereby reducing the power required to spin the drive. In addition, cooling fins added in the extra space, allow 10k-II drives to run cooler.

The decrease in disk size and the increase in speed give the 10k-II drives two significant performance advantages:

Latency – The amount of time it takes to find the data once the head has arrived at the track that contains the data.

- The smaller actuator mass and less distance to travel on the 3 inch disk dramatically reduces seek time.
- The increased spin speed significantly reduces latency.

Compatibility

Compaq offers numerous servers, storage systems and workstations that accommodate the 10k-II drives. For an up-to-date listing of compatible drives for server and storage systems, refer to http://www.compaq.com/products/servers/storage/compatibility.html. For an up-to-date listing of compatible drives for workstations and non-pluggable servers, refer to http://www.compaq.com/products/servers/storage/non-hotplug-compatibility.html.

S.M.A.R.T. Features

All Compaq Wide-Ultra SCSI server-class disk drives manufactured after 1997, (including the 10k-II) incorporate Self-Monitoring and Reporting Technology (S.M.A.R.T.). S.M.A.R.T. disk drives have the ability to inform the host when a hard drive experiences abnormal operations that are to result in drive failure.

Pre-Failure Warranty

In servers and workstations that use Compaq Insight Manager version 2.0 or later, Compaq 10k-II drives are covered by Compaq's Pre-Failure Warranty. If a drive covered by Compaq's Pre-Failure Warranty has a problem, the customer can return the drive to Compaq for a free replacement, even before the drive actually fails.[2] For more information about Compaq's Pre-Failure Warranty, see the technology brief titled Pre-Failure Warranty for Compaq Servers, document number 370A/0797.

PERFORMANCE TESTING

The system performance improvement realized by 10k-II drives depends on the specific environment in which they are used. The benchmarks discussed later in this brief are industry standards or are based on industry standards and represent a specific environment. Although helpful, these benchmarks are only applicable to the specific environment that they were designed to simulate. To clearly understand how best to apply 10k-II technology, Compaq performs tests that specifically address drive performance. Actual performance realized by an end user may vary.

[2] Compaq does not warrant third-party vendor products.

Figure 2 compares the behavior of 10k-II drives and 7,200-rpm drives in a typical server environment with drive loading of 2 percent sequential reads, 1 percent sequential writes, 58 percent random reads, and 39 percent random writes. 10k-II drives show significant improvements over 7,200-rpm drives in highly random loading environments. This gain is due primarily to the significant reductions in latency and seek time of the 10k-II drives. Some additional gain is also realized from increased bit density and sequential data rates. But in a random environment with small transfer sizes (most servers), drive performance is primarily limited by latency and seek time, as opposed to other factors such as bus speed.

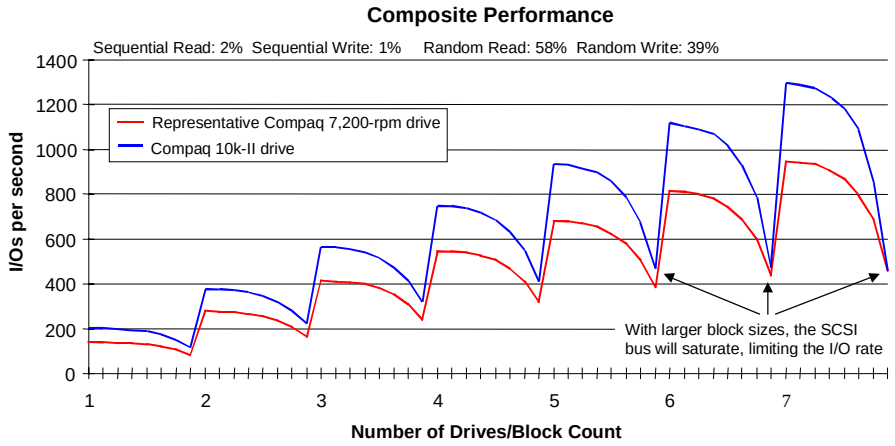

Figure 2: Composite performance of 10k-II drives and 7,200-rpm drives in a typical server environment. The x-axis indicates the number of drives on the SCSI bus. The eight marks between each number indicate the number of blocks transferred in a single input/output (I/O) (1, 2, 4, 8, 16, 32, 64 and 128 blocks of data, respectively). One block is 512 bytes. Write caching is disabled. Queuing is simple with 16 tagged commands.

Average latency is equal to one-half the time required for one rotation of the spindle.

- 10k-II latency is 1/(10,000/30) = 3 milliseconds
- 7,200-rpm latency is 1/(7,200/30) = 4.17 milliseconds

The 10k-II drive reduces latency as compared to the 7,200-rpm drive by 28 percent. 10k-II drive seek time is reduced by 30 percent as compared to the 7,200-rpm drive.

With a 17 percent reduction in their size, the disks in 10k-II drives spin 39 percent faster than the disks in 7,200-rpm drives. The linear speed at the outer diameter of a 10k-II rpm drive is faster than that of a 7,200-rpm drive. Therefore, it is possible to increase the sequential data rate, even at the outer diameter. This is usually not a significant performance factor, except in highly sequential applications such as tape backup/restore or video editing. During large sequential I/Os, as opposed to random I/Os, the SCSI bus is saturated much faster, limiting sequential performance gains with multiple drives. Typically the Wide-Ultra SCSI-3 bus is saturated with only two or three drives on the bus when performing sequential I/O operations. Sequential transfer rates in 7,200-rpm drives are sufficient to saturate the SCSI bus almost as quickly as 10k-II drives.

For the majority of server applications, the maximum transfer rate of the Wide-Ultra SCSI-3 bus (theoretically 40 MB/s) provides sufficient data throughput. However, with 10k-II drives, SCSI bus saturation can occur with multiple drives and large transfer sizes (Figure 2). Most server applications use smaller blocks (2 to 8 MB) and will rarely encounter this phenomenon. Multi-

disk workstation configurations use sequential I/O more frequently which often necessitates the addition of a second SCSI controller.

In Figure 2, performance gains from the 10k-II drive are greatest with small block transfer sizes. The large dips in performance in Figure 3 occur at 64 and 128 block transfer sizes with at least five drives on the bus and a 100 percent duty cycle.

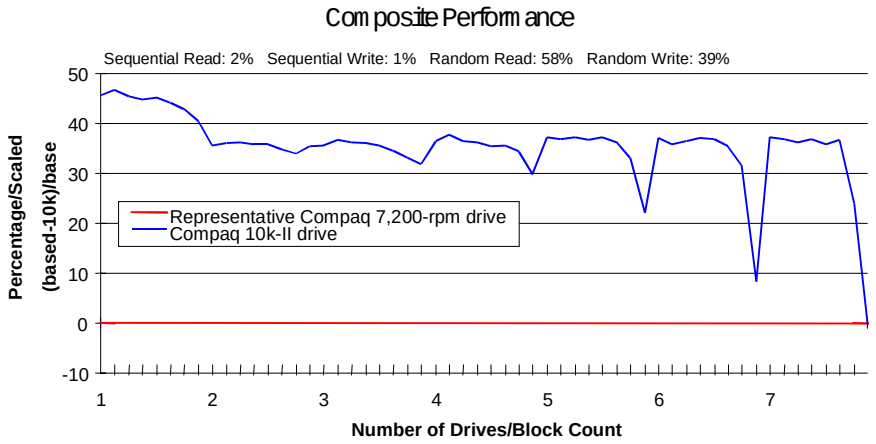

Figure 3: Percent improvement calculated using values from Figure 2.

Response time – how long it takes to perform a given task measured in seconds.

Throughput – the data transfer rate measured in KB/s.

BENCHMARK PERFORMANCE

Benchmark tests are used to measure the performance of servers, workstations, PCs, and subsystem elements. Benchmark tests run real or synthetic business applications on systems to produce performance scores. Performance is typically measured as response time and as throughput. There are many types of benchmarks and the benchmark that will most accurately correlate to the system performance a customer experiences depends upon the application (for example, transaction processing or video editing) and type of system (server, workstation, subsystem element). This paper describes the following benchmarks:

- OLTP for servers
- ServerBench
- NEDS for workstations

On-line transaction processing (OLTP) measures the performance of transaction processing systems in terms of response time, throughput in kilobytes per second (KB/s), and I/O operations per second (I/Os/s). ServerBench measures the performance of application servers in a client/server environment. The Nonlinear Editing Disk Simulator (NEDS) simulates the type of disk transfers generated under a variety of compressed and uncompressed video editing workloads. Other benchmark results for the 10k-II drives can be found at http://www.compaq.com/products/servers/storage/10k2.html.

The performance of any disk drive or drive array depends on a variety of factors, including the presence of file system and hardware data caches, the spindle speed, the performance of the disk controller, the tuning of the drivers, and the type of workload. Disk workloads are so diverse and so dependent on the type of application that it is almost impossible to write a "general-purpose" disk benchmark that produces meaningful results. Thus, the best way to benchmark a disk subsystem is to measure or simulate the behavior of real applications.

Table 1 is a summary of benchmarks for the 10k-II drives.

TABLE 1: PERCENT IMPROVEMENT OF 10K-II DRIVES OVER 7,200-RPM DRIVES

Application/Environment[1]	Actual Benchmark Result (%)	Compaq Modelling[2] (%)
Servers – 9.1-GB drives		
On-line Transaction Processing		
7 data drives RAID 0	30-40	41
7 log drives RAID 5		30
ServerBench		
1 drive	40	50
7 drives RAID 0	22-71	48
7 drives RAID 5	42	48
Workstations – 4.3-GB drives		
Pro-Engineer[3]		
Play from disk	20	26
Record to disk	-	18
Operating	-	49
NEDS[4]		
NTSC: VideoPump (Uncompressed)		
Play from disk	35	23
Record to disk	53	49
Rendered F/X	59	55
NTSC: Targa 1000/2000 Pro (Compressed)		
Play from disk	23	27
Record to disk	65	63
Rendered F/X	18	83
NTSC: Targa 2000 DTX/RTX (Compressed)		
Play from disk	24	27
Record to disk	60	63
Rendered F/X	31	74
Dual Stream read	10	72

1. The application running on a particular hardware platform creates a unique environment into which the drives are placed and tested.

2. Compaq studies the SCSI bus activities of various applications and benchmarks to determine the environments in which drives will operate. Models are constructed characterizing various environment in which drives will operate, including: percent sequential/random read/write, Q-depth and reordering, distribution of data transfer sizes, size of sequential transfers, ranger over which random seeks occur, number of drives on the SCSI bus, effect of write cache (on or off).

Low-level test data is gathered covering all of these variables for all Compaq disk drives. A weighted averaging technique is then used, combining the test data with the model, to produce a performance prediction for each of the various environments to which drives will be subjected.

3. A product of Parametric Technologies Corporation.

4. Nonlinear Editing Disk Simulator, a benchmark created by the Compaq Workstations Division. It measures the performance of a disk subsystem under various video editing workloads.

Server Benchmarks

All server benchmark testing discussed in this paper and on the web site was performed using 10k-II 9.1-GB drives and 7,200-rpm 9.1-GB drives.

On-line Transaction Processing

Figure 4 depicts IOmeter[3] tests that simulated an on-line transaction processing disk workload. IOmeter generated the I/Os per second on the horizontal axis. IOmeter gradually increased the number of I/Os sent to drives on the SCSI bus. On the vertical axis, the response time (latency) of an individual I/O was measured for each of the levels of I/O activity. The more I/Os generated per second, the longer the time (in milliseconds) the drives needed to respond.

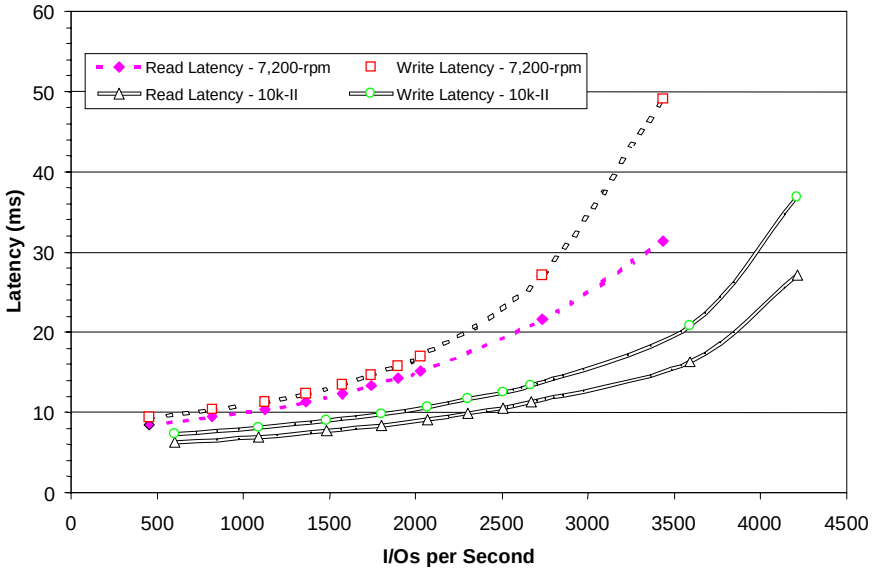

Figure 4: Response versus throughput. 7,200-rpm 9.1-GB versus 10k-II 9.1-GB drives. Cache disabled. 2k I/Os. 100 percent random access: 67 percent reads, 33 percent writes.

The objective of the OLTP test is to find the point at which the percentage increase in I/Os generates an equal percentage increase in latency (the point at which a 1:1 linear increase is reached). This point is determined for each drive type and is the number of I/Os/second that each drive type can sustain. The percentage increase is calculated using the following formula:

$$\frac{\text{10k-II I/Os per second} - \text{7,200-rpm I/Os per second}}{\text{7,200-rpm I/Os per second}}$$

Figure 4 shows that 10k-II drives reach a 1:1 linear increase somewhere above 3,500 I/Os per second which is a 35 percent improvement when compared to the 7,200-rpm drives, which reach a 1:1 linear increase around 2,600 I/Os per second.

ServerBench

ServerBench measures the performance of servers in a client/server environment. ServerBench produces several results, but one of its primary results is an overall throughput score for a server. It can also do disk-drive-intensive tests. Because this is a synthetic benchmark, it can be used to stress disk drives especially hard.

[3] A standard performance benchmark tool available from Intel. It allows input of various models (like those developed by Compaq) and then tests the performance of a drive or of several drives given those model inputs.

The ServerBench test setup is an application-server environment. Data and applications exist on the server. The client PCs act primarily as front-ends to provide access to the applications. ServerBench can be used to test different servers as they provide a variety of services to clients running Microsoft Windows 95 or Windows NT.

ServerBench yields a throughput metric that is reported as transactions per second (TPS). ServerBench tests server performance as the number of clients increases in varying intervals from one to 1,000.[4] It delivers a throughput metric at each interval and combines the TPS scores for different transactions using a weighted mean. The results indicate how well a server handles a variety of client/server operations. Higher numbers indicate better performance. ServerBench allows comparisons of different application servers and is a good tool for examining how changing parameters and software affect server performance.

Using ServerBench 4.01 in the test environment described in Table 2, Compaq engineers measured the performance of a Compaq ProLiant 1600 application server. Figure 5 compares the performance results using a single 10k-II drive configured for RAID 0 to the results using a single 7,200-rpm drive configured for RAID 0. The 10k-II drive achieves 30 to 50 percent performance gain.

Figure 6 compares the performance results when using seven-disk RAID 5 drive arrays, one array with 10k-II drives and the other with 7,200-rpm drives. In this configuration, the Compaq 10k-II drives provide a performance improvement of approximately 42 percent over 7,200-rpm drives.

TABLE 2: SERVERBENCH TEST ENVIRONMENT

Server Disclosure	
Machine name and manufacturer	Compaq ProLiant 1600
Number and type of CPUs, including clock speed	2-x Pentium II 300 MHz
CPU cache	512 KB (internal); 512 KB (external)
System RAM	128 MB
I/O bus	PCI 66 MHz
Hard disk controller	1 Smart-2DH Array Controller
Type of hard disks	Compaq, Fujitsu, IBM, Western Digital; 9.1 GB and 18.2 GB
Number of hard disks	7 drives and 1 drive
Disk organization	RAID 0 and RAID 5
Disk controller driver	CPQARRAY.SYS 3.13
Network controllers	2 Compaq Intel/100 TX
Network controller driver	N100NT.SYS 3.00.06
Network operating system	Microsoft Windows NT 4.0 SP3
Any relevant modifications to default network operating system parameters	None
Test script name	Sys_60g.tst

[4] Actual numbers are determined by the benchmarker.

Client Testbed & Controller Disclosure	
Network type (10Base T, Token Ring, etc.)	100 Base-TX
Number of clients and type of clients	60 Compaq DeskPro 4000s
Number and type of hubs/concentrators (full duplex, switching, etc.)	5x SynOptics 28115 Switches
Number of clients/segment	15
Client CPU type and speed in percentages	200 MHz Pentium with MMX - 100%
Client network controller broken down by percentages	Embedded Netelligent 10/100 TX
Client network software name and version (drivers, protocols)	Win95 driver for IPX/SPX
Size of any client network cache	None
Controller network software name and version (drivers, protocol)	Win95
ServerBench Disclosure	
Modifications to test script	Added 2 and 6 clients
ServerBench version	4.01

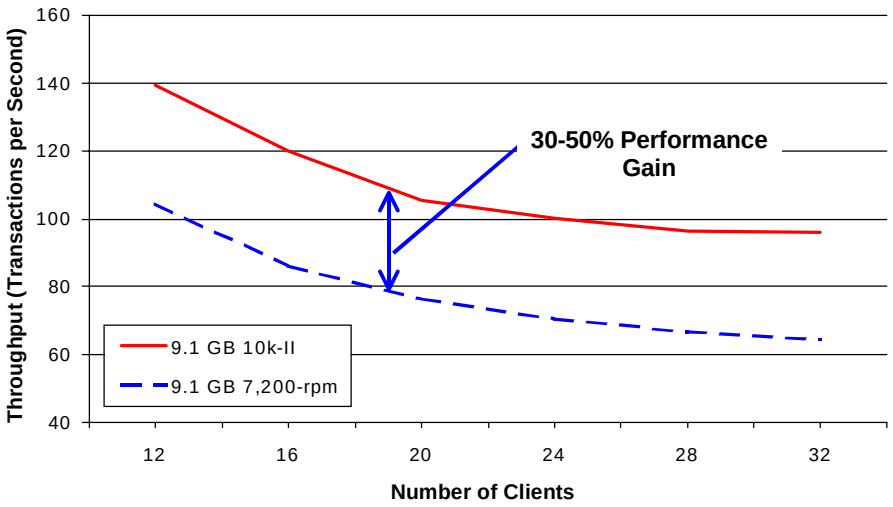

Figure 5: Single drive comparison. Single drives configured as RAID 0 Array ServerBench 4.01 under Windows NT 4.0.

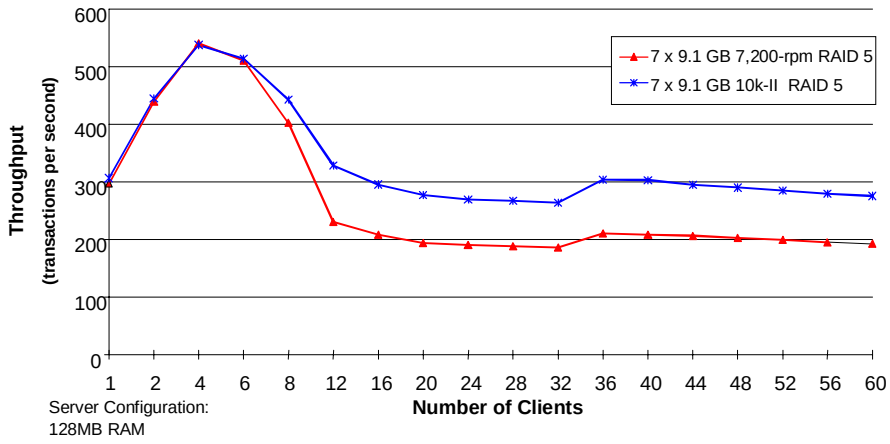

Figure 6: ServerBench, RAID 5, seven disk RAID 5 Array ServerBench 4.01 under Windows NT 4.0.

Workstation Benchmarks

All benchmarks that simulate a workstation environment were run with 10k-II 4.3-GB drives and 7,200-rpm 4.3-GB drives.

Nonlinear Editing Disk Simulator (NEDS)

Nonlinear video editing is one of the most demanding applications when it comes to disk performance. To record and play video, the disk subsystem must have enough bandwidth to sustain the full-frame rate required by the video format being edited.

To aid in designing a disk array to support uncompressed nonlinear video; a simple benchmark was created to simulate the type of disk transfers generated in this environment. The I/O routines in this benchmark match those used in the prototype Compaq SoftImage|DS Hardware Abstraction Layer. The benchmark was eventually modified to simulate other resolutions and compression levels.

10k-II drives provided increased performance over the standard 7,200-rpm drives. Figure 7 shows the performance of typical video editing operations. Record to disk refers to the type of workload encountered when capturing video from an external source to a disk array for later editing. Play from disk refers to the workload encountered when playing back the finished video clip from the disk array to an external recorder or monitor. Rendered F/X refers to the type of file access used to generate special effects and transitions (fades, wipes, dissolves, etc.) on a pre-existing video clip on the disk array. For play from disk, the 10k-II drives showed a 35 percent improvement. Record to disk improved by 53 percent, and effects rendering showed a 59 percent improvement.

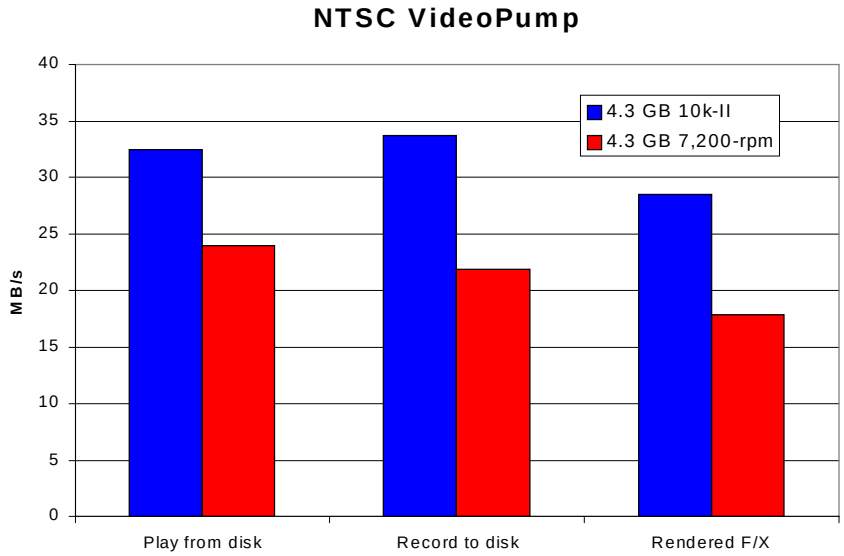

Figure 7. Results of performance benchmark using Compaq's NEDS simulator.

RECOMMENDED APPLICATIONS FOR 10K-II DRIVES

Higher data transfer rates and faster disk access make 10k-II drives an excellent solution for:

- *Transaction-intensive applications* – High performance in transaction processing is primarily a function of the random access I/O rate or the number of disk accesses per second. Banking and airline reservations systems are examples of transaction processing applications in which changes are made to a large database of information from many terminals
- *Groupware applications* – This class of software helps work groups attached to a local area network organize their activities. Typically, groupware contains random access I/O applications that support the following operations:
  - Scheduling meetings and allocating resources
  - Email
  - Password protection for documents
  - Telephone utilities
  - Electronic newsletters
- *Digital A/V and graphics visualization applications* – Digital A/V applications demand the highest level of hard drive performance. Video editing professionals need to capture and play back video at 30 frames per second. If the drive performance is inadequate, frames will be dropped or image quality will suffer. A single 10k-II drive can provide full-screen, broadcast quality video at data rates from 11.3 to 16.8 MB/s, without the added cost of a drive array.

CONCLUSION

10k-II disk drives continue Compaq's tradition of providing high-performance solutions for demanding server and workstation applications. Engineering enhancements have reduced latency and improved operating characteristics. As a result, the 10k-II drives offer increased reliability when used in a wide range of Compaq servers and workstations. Applications such as transaction processing, CAD/3-D, image processing and nonlinear video editing will benefit because of improvements made to the 10k-II drives.