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# The role of tape is changing but the importance of data is not

Although the use of tape is changing from a primary backup to a longer term archival model, the main reasons for using tape—low cost of ownership, portability, and ease of maintenance—remain. It does not make sense to leave most data on disk arrays on servers or storage devices for years and years. Even if there are compliance requirements to keep the data, most companies cannot predict when it will be needed—or indeed if it will ever be needed. While low-cost disks and remote online backup will become increasingly common, as a last line of defense there will remain a need for data archives that are based on removable media securely vaulted away.

## What are you relying on?

One of the ironies of using tape is that while the media is low cost today, there is no way of quantifying the potential increased value of the data in the future. In other words, a cheap tape could one day be the home for some of your most precious company information. When a critical database has to be restored, a 25% or even a 50% recovery is not what users need. That humble tape might, in the future, be worth its weight in gold or even more.

Alternatively, the impetus behind the recovery of archive data may be legal or regulatory. Inability to comply because of component failure may be regarded as seriously as deliberate breach and result in severe penalties against companies and individuals.

To ensure that users get exactly the performance they need in terms of data security, capacity, compatibility, and reliability, HP has invested millions of dollars in the most extensive testing procedures. The aim: to ensure that all HP media customers get 100% successful restores, 100% of the time.

## Going beyond industry standards

Industry format specifications, such as those agreed by the Linear Tape Open (LTO) Technology Provider Companies (TPC—HP, IBM, and Quantum), merely ensure interchange between different products. They are intended to give users confidence that any data cartridge purchased from a format-compliant supplier works in their drive and that the data written to a tape can be transferred between different types of hardware.

Generally, however, industry logo tests do not measure product quality or reliability because this would constrain a truly “open” standard where customers can choose the widest selection of products based on other factors such as cost, value, and performance, not just compatibility. Consequently, many users are unaware that the Ultrium or DAT format compliance programs do not require any detailed environmental or dynamic testing that would reveal the actual quality and reliability of the tape system.

## Real-life testing of real-life backup

To carry the HP brand, designated data cartridges must satisfy an exhaustive battery of additional procedures that relate directly to how the product is used in real-life situations when real data and real businesses are at stake.

The best possible microscope to test media is a tape drive, or rather thousands of tape drives, performing the same backup and restore tasks as end users. HP is in a unique position to do this. As a leader in hardware and media for all of the mainstream tape technologies, HP has established comprehensive R&D and manufacturing programs to scrutinize the performance of tape backup solutions under every conceivable kind of stress.

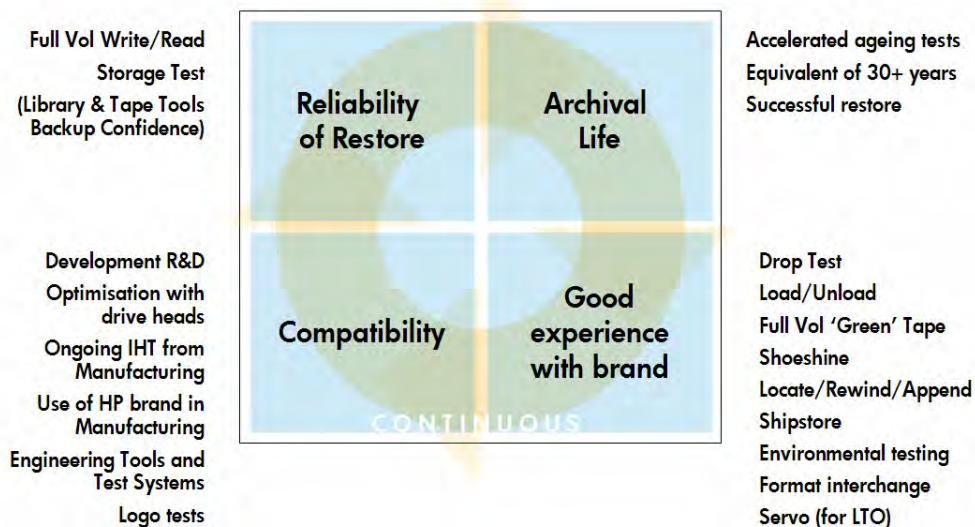
By purchasing HP branded data cartridges, you can be certain that you are selecting the most exhaustively tested product in the industry. HP tests its media to extremes so that you do not have to. And while no one can predict the future, or offer a certain guarantee, the scale, breadth, and depth of the testing gives HP more confidence that your data will be safe on HP tapes, no matter which brand of hardware you own.

## Continuous quality testing

HP understands that the interchange of media between drives and external conditions can profoundly affect the tape error rate. Increased error rates jeopardize backup, and the disruption of backups jeopardizes business continuity. To protect customers from the impact of such errors, HP puts every batch of HP media under scrutiny.

Figure 1.

### HP Branded Media Continuous Quality Testing (CQT)



Continuous Quality Testing (CQT) is the foundation of reliable restores and successful daily backup operations. CQT means that HP scrutinizes every aspect of its branded media development and production on a never-ending basis; it is the standard that is working 24 x 7 x 365 on ensuring the highest quality in tape media.

The HP media test program addresses the four main areas of concern for end-user customers:

- Restore—Will I get my data back whenever I need to restore from the tape?
- Archival life—Will the tape meet and even surpass regulatory and corporate requirements for data retention?
- Compatibility—Not just “Will it work with...?” but “Will it work to the level I am entitled to expect from the manufacturer of my tape device?”
- Good day-to-day experience—Will it survive the rigors of everyday use in a busy and challenging environment?

To address these concerns, HP has a process that starts way before assembly line and ends years in the future when someone, somewhere, takes a tape from the vault and attempts to get information back online.

## In the beginning

The influence of HP over media quality begins in the formative stages of R&D. HP media engineers are already working with manufacturers on tape technologies for the next decade.

HP collaborates with leading manufacturers to define the parameters for recording media in its drives, such as physical characteristics (for example, tape thickness), recording density (for example, number of bits/inch), and signal performance (for example, error rate). Manufacturers approach these requirements in a slightly different way; hence, each has a different name for their creation (for example, Nanocubic, NanoCAP, Tera Angstrom). But the goal is the same: the ability to create tape media products based on industry-standard formats for recording data.

In isolation, it is important to understand that magnetic particles do not ensure the safety of your data. They are a base ingredient in a long and extremely elaborate production process.

The expertise of HP in the whole tape solution ensures that you get the most from these incredible technological ingredients. As a leading provider of both drives and media, HP has a deep insight into the real-life conditions that solutions need to tolerate, day in, day out.

## What you see and what you do not see

It is not safe to assume that all tapes are the same, or that a single brand of tape always performs in the same way because no two tapes are identical. Subtle differences in manufacture—coating, edge consistency, binder composition, servo writing, and mechanical aspects of the cartridge and its components—will all have enormous impacts in daily usage. Production testing does not properly account for variable manufacturing conditions and processes. How could it? Only when you have thousands—hundreds of thousands of drives—at your disposal can you begin to accurately recreate the diversity of tape users.

HP data cartridges have to perform to the specification standards, no matter how many times they are dropped or knocked on the vault. They have to withstand extreme temperatures, and have to remain stable and reliable after being loaded in and out of a drive thousands of times. A tape might not encounter such extremes every day, but it is possible to imagine that it could happen. After all, some disaster recovery sites are located in the legs of disused oil platforms or in underground nuclear bunkers. Such demanding performance and reliability requirements were the catalysts for the creation of the industry-leading HP media specifications.

As a drive manufacturer, HP has developed several unique and proprietary engineering software tools for analyzing drive and media performance. This gives HP engineers detailed visibility of just how well a backup or restore operation has performed, and also enables HP to differentiate media performance and reliability for media from competing manufacturers. It is important to remember that while there are many media manufacturers, not all have passed the HP brand media specification tests. And products that fail HP brand qualification can still ship under the supplier's own label provided industry standards are met. But would you trust a tape that HP has rejected?

Take Ultrium 3, for example. The tape is just 8 thousandths of a millimeter thick and yet almost 800m long. There are 704 physical recording tracks divided into four data bands on a half-inch, 800-GB Ultrium tape. Its manufacture involves over 500 different processes to transform a gigantic, incredibly thin sheet of material that can be over 25km long into thousands of identical cartridges.

These processes describe an incredible journey that goes from the drive in your datacenter to the microscopic world revealed to HP scientists. It covers a range of almost nine orders of magnitude—from kilometers (10<sup>3</sup> m) all the way down to microns (10<sup>-6</sup>m) where each step is linked to the previous to form an unbroken chain of communication yielding incredible understanding. To achieve an equivalent dynamic range, one would need to analyze the distance from the Earth to the moon, stopping every 40 cms.

The expert scrutiny of HP assesses how tape materials and components interact with drives and automation systems. Everything is measured: from precision cutting and innovative coating chemistry, to servo writing technology and archival life, to ensure that your data can be restored each time the tape is loaded.

## HP testing and qualification

The HP media testing program is designed to ensure that HP branded media will always offer maximum reliability even in the most extreme conditions. For instance, in 2005, as part of the HP media testing program, HP Ultrium 3 media was used to conduct in excess of 235,000 individual tests, equivalent to almost 1 million test hours!

Figure 2.



The HP in-house technology center has over 200 Ultrium drives—\$1M worth of hardware at any time. Drives are replaced weekly; media is replaced monthly. This rotation ensures a realistic environment for testing because using a small set of drives and media would produce results particular to just that small population. All tests must complete successfully.

Only HP branded data cartridges are used in the in-house technology center. This large-scale drive and media quality assurance testing provides extensive visibility of HP media performance, hence helping to ensure consistent performance and reliability from the millions of tapes that carry the HP name. Companies that only supply media will find it challenging to test for this because they cannot access such a huge number of drives; media may look and feel the same—but it is not.

Additional HP branded data cartridges from current production are also shipped direct to HP from suppliers within days of being manufactured for continuous monthly testing. In the rare event of an issue being discovered, affected batches can be quarantined while supply of HP media is switched to alternative qualified sources. If you only have access to one production line, your options are extremely limited.

HP media is tested extensively primarily using HP StorageWorks tape drives and automation systems. However, such testing is also highly relevant to those customers that use HP media with third-party hardware products. If a significant media issue exists, it will have disastrous consequences irrespective of the drive in which the tape is used. Thus, by ensuring that HP media is consistently of the highest quality, all users of HP media will enjoy the benefits of HP media qualification and ongoing testing programs.

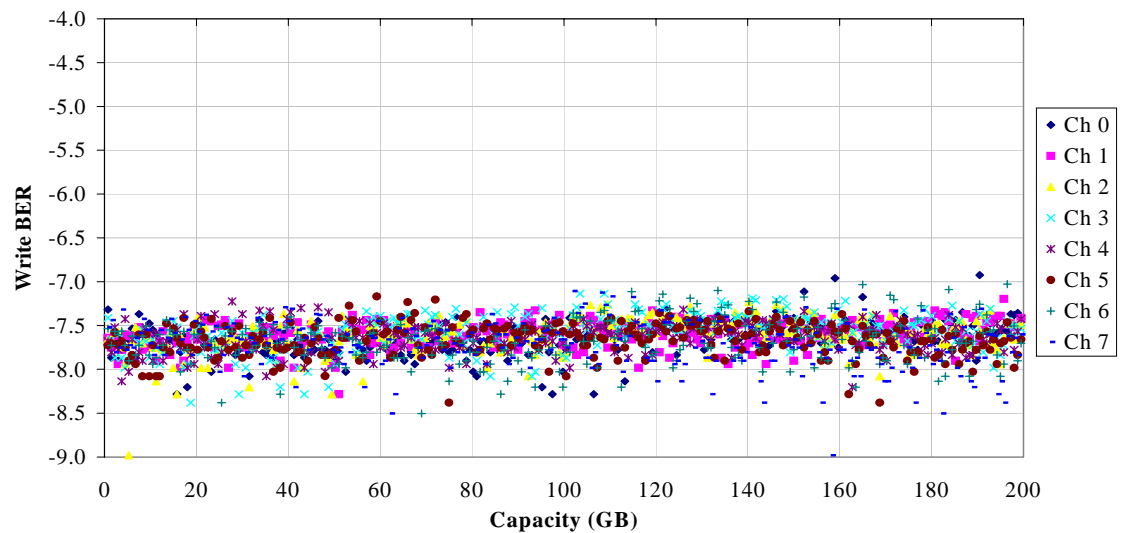
The HP team of experts, based in Bristol, UK, and Boise, USA, continually monitor and evaluate the quality of HP branded media, providing a lead to the industry in terms of continuous improvement and technological development.

## Overview of HP tests

The primary focus of the HP CQT is error rate. It indicates the reliability of the write (backup) and read (restore) processes, together with the associated “margin” for each process. Poor error rate indicates that the backup or restore operation may be slow or even fail, whereas good consistent error rate indicates an optimum data transfer process with excellent performance. Error rate is the fundamental measure of product performance.

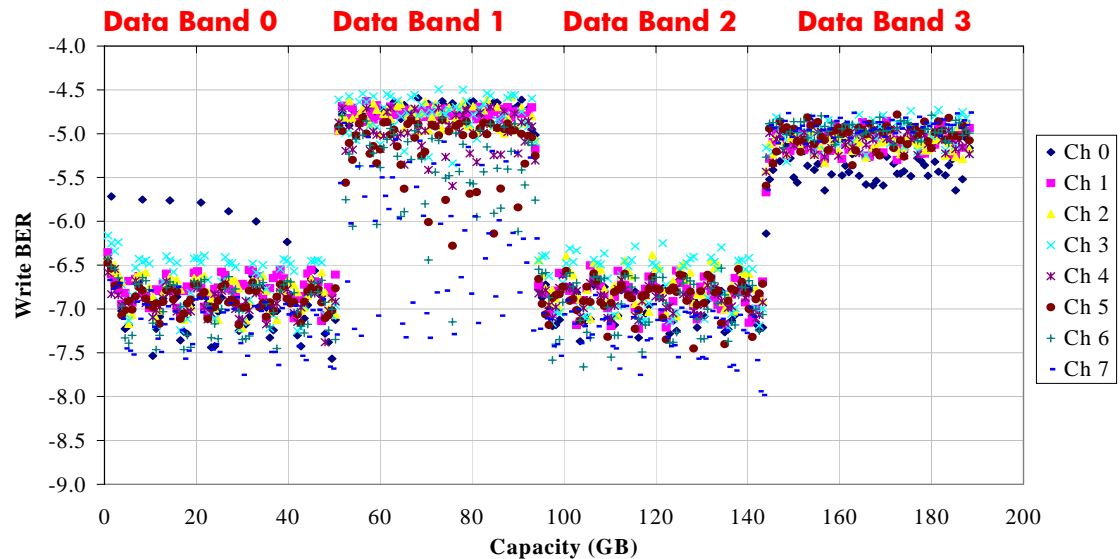
A typical write bit error rate (BER) following a full volume write operation using an HP Ultrium 2 cartridge is shown in Figure 3. The BER was stable and low, and this helped to ensure an excellent backup.

Figure 3.



A (third-party) Ultrium 2 cartridge bought from the market was also tested. A full volume write operation showed that this cartridge exhibited very poor error rate in Data Bands 1 and 3 (that is, the top half of the tape). Indeed, the cartridge actually failed to back up the full capacity, while the poor error rate associated with Data Bands 1 and 3 risked compromising any future restore operations. Failure analysis revealed the tape exhibited significant coating defects, on areas that corresponded to the poor BER in Bands 1 and 3.

Figure 4.



## Testing to ensure basic format compliance

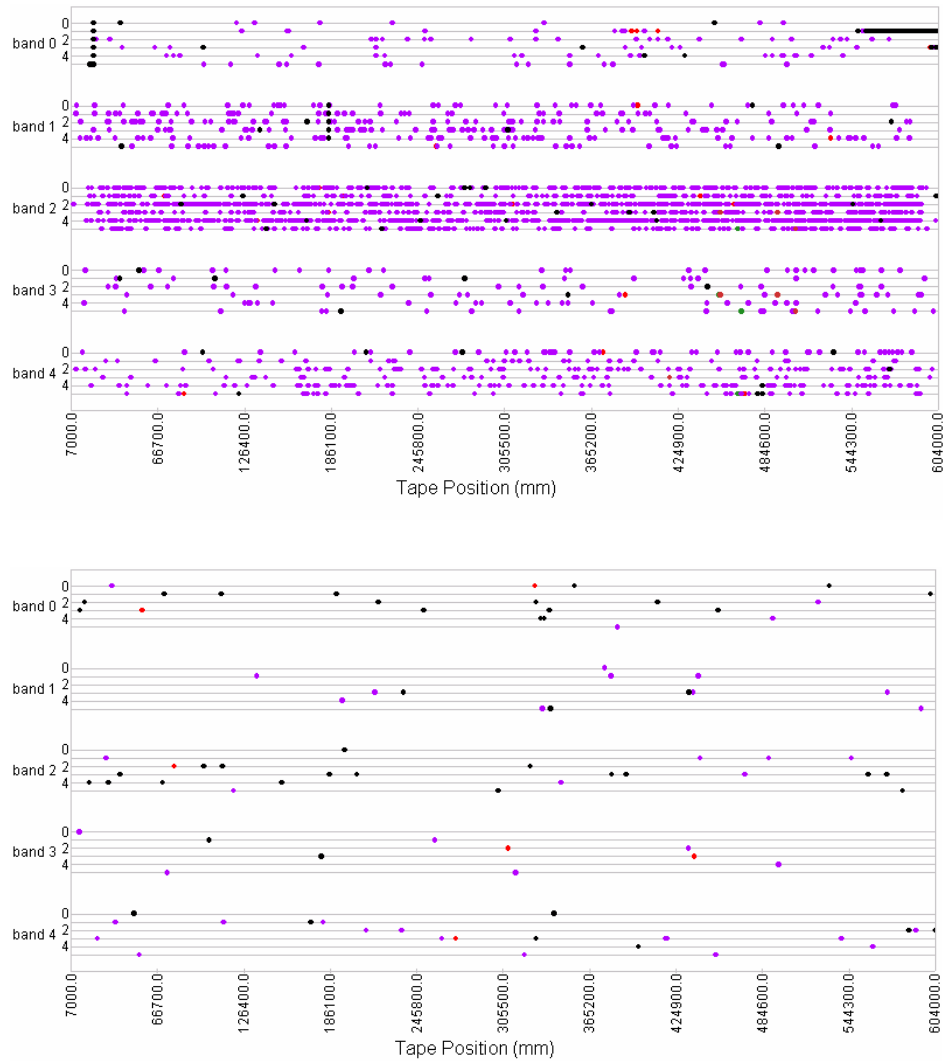
Compared to the prevailing industry standards, which require testing 66 cartridges for initial Ultrium 1, 2, or 3 format compliance tests (with re-evaluation taking place every 12 months), HP tests a minimum of 440 data cartridges. The data cartridges are taken from at least two separate manufacturing batches. Quality monitoring is an ongoing process where every batch is scrutinized. Other LTO-certified media are guaranteed to interchange between HP and third-party drives as well, but the LTO logo does not guarantee a minimum, consistent level of quality.

All Ultrium drives rely on a tape servo pattern to accurately position the drive head on the relevant area of tape. The precise format of the servo pattern is specified in the relevant Ultrium format, and is written to the tape during the media manufacturing process. It is imperative that the servo pattern is accurate and of consistent quality, otherwise there is a risk that the backup or restore operation may not complete successfully. It is far better to prevent this now than in six years when your tape is the only source of archived data.

As a drive manufacturer, HP engineers have developed a unique servo specification that lists the requirements for all key servo pattern parameters for HP Ultrium media. HP engineers have also developed unique tools and software that enable the quality and performance of the servo pattern to be evaluated against the HP servo specification.

One such specification relates to the maximum number of servo defects allowed on each servo track. The fewer defects the better, since too many defects could result in a product failure. As indicated in Figure 5, not all media is the same—the first graph showing a third-party brand tape (bought from the market) with high numbers of servo defects, and second graph showing an HP branded tape with extremely low numbers of servo defects.

Figure 5.



## Testing to ensure good day-to-day experience

### Full volume “green tape” test

This test requires no capacity loss or significant error rate degradation when a series of full volume write and read operations are conducted using at least 100 new (“green”) cartridges. This is a unique test to HP and verifies sustained product performance for those customers who use brand new cartridges for each and every backup and restore operation.

### Full volume “life” test

This test requires no capacity loss or significant error rate degradation when 300 full volume write/read operations are conducted using a single cartridge. This is a unique test to HP and verifies sustained product performance for those customers who use the same cartridge for each and every backup and restore operation.

## Rigorous environmental interchange testing

In contrast to limited interchange using a single data cartridge, on a single drive under one or more test conditions, HP thoroughly checks its storage media for full interchange between multiple tapes on multiple drives in all the following conditions:

- 50°F/10°C and 80% R.H. cold and wet
- 50°F/10°C and 10% R.H. cold and dry
- 113°F/45°C and 10% R.H. hot and dry
- 113°F/45°C and 24% R.H. hot and ambient
- 84°F/29°C and 80% R.H. hot and wet

During full volume read and write passes, the error rate must remain within stringent performance levels that have been determined by HP engineers. Data is continuously written to and read from the tapes for 24 hours at each environment. The benefit for the user is that the drive and media are robust enough to withstand sustained use in all conditions, not just in controlled environments such as an IT datacenter. HP facilities allow this test to run continuously.

Figure 6.



The HP tests also examine a wide range of performance by using several drives and several cartridges to ensure complete consistency of results, as opposed to a narrower, customized test involving a single data cartridge.

## Tough drop testing

In the LTO format specifications there are no cartridge drop test requirements. However, HP testing evaluates HP branded Ultrium data cartridges against a minimum standard of fragility, and verifies that there shall be no irreversible loss of function to a data cartridge following a 0.75 m drop on a concrete floor. This requirement shall be met when 20 data cartridges are dropped successively on their top and bottom faces, and edges. In separate tests, this requirement shall apply when the data cartridges are dropped by themselves, in their library cases, or any packaging configurations.

The benefit to the user is that the data cartridges are robust enough to withstand daily use and transportation (for example, to an offsite storage solution) without being damaged or causing data loss.

## Extensive testing of operation “load”/“unload”

In the LTO Ultrium format specifications, there are no loading or unloading requirements. However, HP has led the development of LTO technology in this area and proposed several format changes that increase the reliability of the leader pin assembly, a core component of the load/unload operation. This test uses an automated mechanism cycle of load, grab Leader Pin Assembly (LPA), thread (with a few meters of tape wound onto a take-up reel), unthread, park LPA, and unload. Each cycle is repeated a minimum of 20,000 times.

An increasing number of HP Ultrium drives are being integrated into library automation systems. As a result, the load/unload performance of HP branded media is actually assessed in three different drive orientations—horizontal, tape path up, and tape path down—rather than just a single horizontal orientation. This is to replicate how the drive and media are used in real working environments. The maximum failure rate, in any drive orientation, is one in 100,000 loads. HP also assesses the firmware recoverable retry rate, using proprietary HP test software in combination with HP Ultrium drives. Such firmware recoverable events are transparent to the user but a high re-try rate maybe indicative of a suboptimal cartridge design. In an automation environment, this could ultimately lead to a backup or restore operation being interrupted due to a badly seated cartridge.

The benefit to the user of the HP load/unload tests is that the cartridge leader mechanism is robust enough to perform effectively throughout its expected use and will not break causing damage and disruption to the drive. This in turn prevents a backup having to be repeated or costly downtime while the drive is repaired. In addition, the cartridge will load successfully into a drive without the risk of a poorly seated cartridge introducing further downtime (even after the cartridge has experienced several thousand load operations).

## Locate/rewind/append testing

This test measures the ability of a section of the tape to withstand repeated stress (that is, file locate, retrieve, and append operations) in a highly demanding customer environment (84°F/29°C, 80% R.H.). During the logo compliance tests, a “locate-rewind” cycle is repeated 250 times.

HP performs an equivalent test to the logo test, except that HP testing is 1000% more stressful as the tape is passed through the drive 2,500 times. The benefit to the user is that the data cartridge performs under the most extreme daily conditions, reducing the number of failed backups and restores and minimizing the risk of disruption to the network.

## Large-scale for shipping and storage

The common industry solution is that the ship and store standard measures whether a single data cartridge can be shipped, stored, and used once. This test is performed using a single piece of media on a single drive.

The HP qualification plan ensures that HP branded Ultrium media can be shipped and used repeatedly. The test is performed on five test-bed drives in an environmental chamber under the following environments:

- Store the test data cartridges for two days at (50°F/10°C, 10% R.H.)
- Store the test data cartridges for two days at (120°F/49°C, 15% R.H.)
- Store the test data cartridges for two days at (84°F/29°C, 80% R.H.)

A full volume write operation is conducted prior to the cartridges entering the environmental chamber. After storage, a full volume read operation is performed. The error rate must remain within HP specified levels.

## Shoeshine testing for high duty cycle automation

In the LTO compliance procedures, there are no shoeshine tests. The HP testing procedure measures the ability of the media to withstand repeated passes over the tape head by simulating excessive repositioning or error recovery on a short length of tape. This is particularly relevant to the library environment where media may be frequently loaded or unloaded by the operating system.

Data is written to a short section of tape (approximately 9 feet). The tape is rewound, the data is read, and error rate checked. This “rewind–read–error check” procedure is repeated 25,000 times and at the end of the test, there should be no loss of performance. The benefit to the user is that the tape withstands very intensive use even if it is restricted to a small part of the tape. This is especially relevant to library customers who may be using named tapes for specific applications and who only fill the same part of the tape each time data is written.

## Reliable interchange testing

In the LTO compliance procedures, there are no format type interchange tests conducted. In contrast, HP testing ensures that there are no compatibility issues with HP branded Ultrium data cartridges. Data is written and read using all supported Ultrium format generations, for example, HP StorageWorks 960 drives are used to write/read HP Ultrium 3 media, write/read HP Ultrium 2 media, and read HP Ultrium 1 media. This is very relevant to library customers who may have different generations of tape media within a single library unit. The error rate must remain below a strictly specified level at all times during the test.

## Testing to ensure archival stability

Particulate media (for example, DDS and Ultrium) incorporate a binder system to hold the magnetic particles in place and to the substrate. Early binder systems could suffer from hydrolysis (that is, the binder could absorb moisture and eventually degrade leading to debris). However, today's advanced binder systems used in HP media products are far more tolerant to high humidity conditions, and as such, binder hydrolysis no longer poses any risk.

Signal degradation is another factor that could affect the archival properties of tape media. Historically, signal loss would occur due to oxidation of the magnetic particles (that is, a chemical reaction would reduce the magnetic strength of each particle and as a result, the read back signal strength would diminish). However, there have been several improvements to metal particle technology in recent years and the magnetic particles used in all HP media incorporate an extremely effective "armor coating." This passivation layer, as it is termed, surrounds and protects the magnetic particles, effectively eliminating the oxidation process completely. Hence, there is no significant signal reduction during the read back (restore) process, even after prolonged periods of storage. HP Ultrium media also utilize high coercivity particles and hence such media is far less susceptible to stray magnetic fields (again helping to ensure ongoing data integrity and restore reliability).

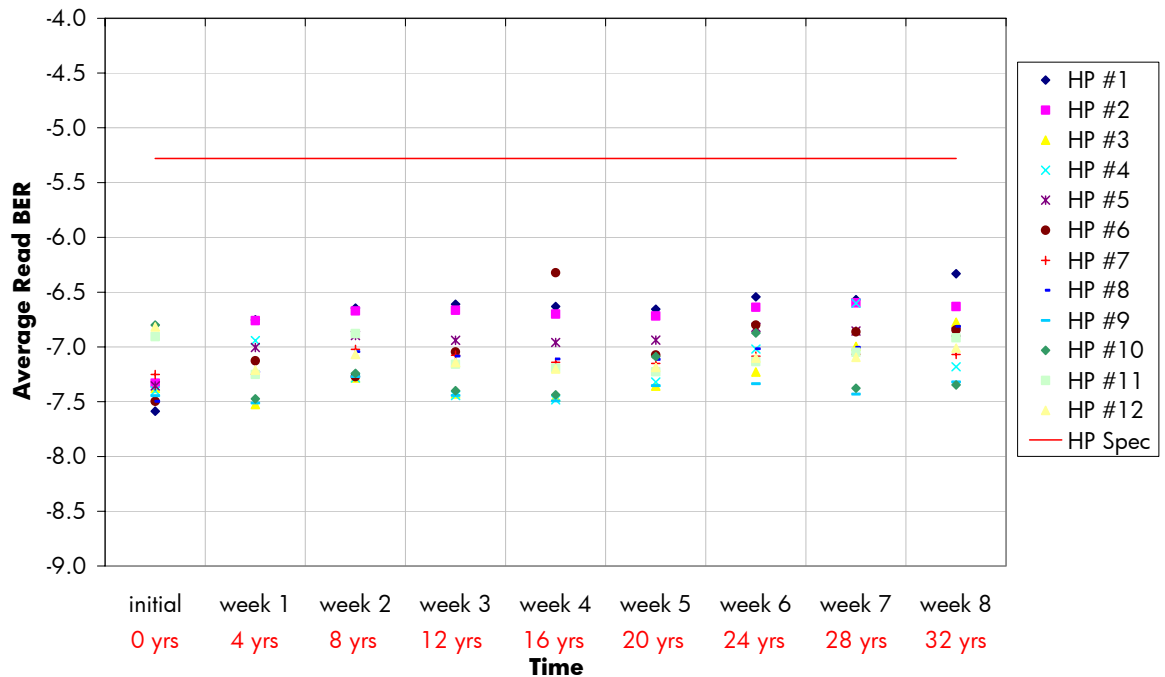
Any loss of magnetization would result in a reduced signal, and hence poorer error rate. This could ultimately compromise the integrity of the data backup. Thus, for archiving, it is essential that tapes are designed to resist the effects of both particle oxidation and binder hydrolysis. To demonstrate archive life, it is necessary to conduct accelerated ageing tests. Such tests give an indication of how the magnetization will degrade over an extended period of time, and whether hydrolysis is likely to occur.

Previous research<sup>1</sup> has shown that storing tapes at a constant environment of 140°F/60°C, 90% RH for 7 days is approximately equivalent to storing the same tapes at 77°F/25°C, 60% RH for a period of 4 years. Thus, to verify the archival properties of HP media, 12 x HP Ultrium 3 WORM cartridges were stored in an environmental chamber at the aforementioned elevated temperature and relative humidity conditions. Data was initially written to (and read from) each tape to obtain a series of "initial" read error rates. The cartridges were then stored in an environmental chamber at 140°F/60°C, 90% RH for 7 days, after which the data was re-read, and the cartridges returned to the chamber for a further 7 days of storage at 140°F/60°C, 90% RH. This sequence was repeated until the cartridges had been stored for a total of 8 weeks at the elevated temperature and relative humidity conditions. Figure 7 shows the average read error rates for the 12 x HP Ultrium 3 WORM cartridges, at each stage of the archival storage test.

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<sup>1</sup> Yamamoto et al, "Study of Corrosion Stability in Metal Particulate Media," *IEEE Transactions on Magnetics*, Vol. 26, No. 5, 1990.

Figure 7.



The tapes exhibited excellent performance with low stable read error rates throughout, even after 8 weeks of storage in the accelerated environment (equivalent to 32 years storage at ambient conditions). Such results help demonstrate that HP Ultrium tapes have outstanding archival properties.

## Conclusion

A typical Enterprise customer may have tens or even hundreds of tape drives in their organization. But this number is still dwarfed by the hundreds of thousands of devices that are used in HP testing. While an isolated pollutant may eventually contaminate an entire river, only by scrutinizing the whole waterway can the source of the threat be traced. Similarly, examples of low-level detail obtained by HP include servo quality, envelope flatness, media noise spectrum, and even the tape's frictional characteristics. None of this is remotely visible on the production line or in the datacenter.

HP listens and learns. Many features that you see on HP products are a direct result of your feedback, including pre-labeled media, anti-static shells, better leader pin design to prevent drive damage, robust cartridges to withstand impacts, and the introduction of differently colored cartridges to make sure you never load the wrong media into your drives.

Ultimately, tape drives are the best form of microscope to examine media quality and performance. HP continuously uses vast numbers of these to scrutinize its own branded media. The scale of media examination, and depth of scrutiny is unrivalled by any other media supplier. It is not boasting; it is a fact. Only by having the most reliable media can HP offer you the most reliable restore. HP understands that backup is not some disconnected IT process removed from the rest of business activities, for one day; the activity could depend on the backup.

In the end, HP sees its role not just as a tape supplier, but as the custodian of your data. When you entrust your data to an HP tape, HP wants you to feel it is as safe as it would be in your own hands.



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