Technical white paper

Best of both worlds

HP LTO-6 Media Metal Particle and Barium Ferrite

Table of contents

HP Metal Particle and Barium Ferrite LTO-6 Media

For the first fourteen years of its existence, Metal Particle (MP) technology has been the cornerstone for all Linear Tape Open (LTO) Ultrium data cartridge manufacturing. Now, with LTO-6 technology, HP is shipping a new media type, based upon Barium Ferrite (BaFe), to sell alongside LTO-6 MP. The purpose of this white paper is to discuss the differences between these two media technologies and explain how both provide the same outstanding performance that customers have come to expect from HP LTO Ultrium Storage Media.

Metal Particle

Until now, 100% of LTO Ultrium data cartridges have been manufactured using advanced Metal Particle technology. MP offers robust, tried and tested data protection. It has been the bedrock of successful backup and archiving for millions of LTO Ultrium customers since 2000: over 4 million drives and over 200 million MP data cartridges have shipped.

Metal Particle tape uses substrate material, the basefilm, which is coated with a durable and flexible polyurethane-type paint containing suspended metal particles. The particles consist of needle-shaped iron/cobalt alloy, which has been processed to enhance their magnetic capabilities and surface-passivated to ensure chemical stability. The size and shape of the metal particles and other additives give the coating the desired magnetic, electrical and physical characteristics needed to write and read data in a particular format. A backcoat is then applied to the reverse side of the substrate to control friction and ensure consistent tribology.

Barium Ferrite

Barium Ferrite is a new technology that is likely to be used in future generations of LTO Ultrium (although earlier MP media will still be supported, in the same way that LTO-6 devices can read/write to LTO-5 media and read LTO-4 media). Although the BaFe media is manufactured in a similar way to MP tape, with magnetic particles suspended in a coating on a substrate, BaFe particles are smaller in size than MP particles. That means they have superior magnetic potential which becomes significant as the areal density – and hence the capacity – of the media increases. Areal density is a key factor in understanding why BaFe is likely to be required for LTO-7 but only optional for LTO-6.

Areal density in LTO-6 and beyond

Areal density is a combination of linear density (bits down the tape) and track density (number of tracks across the tape) in the product. If the areal density is higher, therefore, the capacity of the tape is higher also.

Areal density = track density x linear density

For LTO-6 the 6.25 TB required by the format has been achieved by increasing track density by 70% – from the 1,280 tracks used on LTO-5 to 2,176 tracks used for LTO-6 – but leaving the linear density unchanged. Thus:

LTO-5 areal density = 1,280 tracks x 385 kbits/inch – native capacity is 1.5 TB

LTO-6 areal density = 2,176 tracks x 385 kbits/inch – native capacity is 2.5 TB

What that means is that although the number of recording tracks across the tape has been increased dramatically, the number of bits down the tape has remained unchanged. So compared to LTO-5, there is no need for smaller particles that can be more tightly packed together; track density accounts for all the additional native capacity that is needed to meet LTO-6 specifications.

In terms of particle formulation, therefore, LTO-5 and LTO-6 tape is essentially identical. It is just that HP engineers have increased the number of tracks for those same-sized particles to be arranged in. This is how 6.25 TB capacity has been achieved while ensuring MP performance remains as high as ever for LTO-6.

To reach the published roadmap capacities required by LTO-7 and future generations, there will need to be significant increases in both the linear density and the track density. These increases will require improvements not only to the media, but also to head and drive technologies to accommodate the reduced Signal To Noise (SNR) associated with the smaller bit sizes. Advanced signal detection schemes will allow the drive to operate at higher linear densities; enhanced error correction techniques will provide more reliable data recovery in the lower (SNR) environment; advanced giant magnetoresistance (GMR) readers and high moment writers allow for the use of smaller particles with lower magnetic moment and higher coercivity. Improvements in servo tracking performance will allow higher track densities to be achieved.

Media still has an important role to play in achieving the higher capacity and this means that smaller particles are required. If MP particles were reduced in size to meet the requirement for LTO-7 they would lose their magnetic stability. This is where the improved magnetic properties of particles such as BaFe are needed. BaFe particles are most likely the leading candidate for generation 7 media. For future generations, industry and university researchers continue to develop smaller particles with better magnetic properties.

However, for today's LTO-6 generation, MP and BaFe are both equally capable of meeting all the demands required of the LTO-6 format in terms of capacity, transfer rate and, most importantly, reliability.

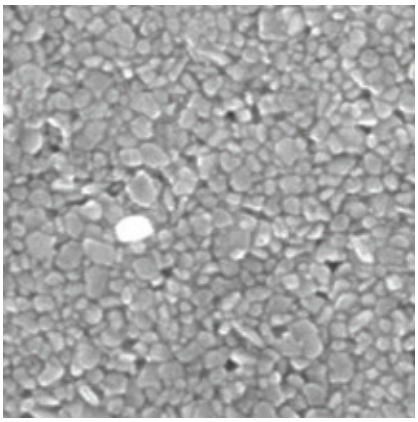
Physical characteristics of MP and BaFe media

As explained, BaFe media has better magnetic properties which lead to improved signal to noise ratio (SNR) and a better bit error rate (BER) compared to MP.

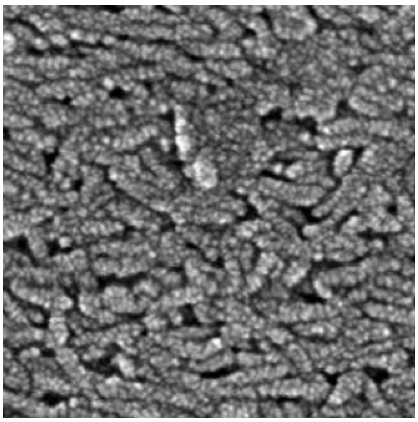
Particles and bit density

As the BaFe particles are smaller than the MP particles it is possible to fit more of them into the same space.

Barium Ferrite (BaFe)



Metal Particle (MP)



The pictures above, taken at the same magnification, show a scanning electron microscope (SEM) image of the media surface which reveals how more BaFe particles can be packed into the same physical space.

As the linear density increases – as the actual bits themselves become smaller – the number of particles per bit needs to be kept constant to prevent the bits becoming ragged and poorly defined. This is the same principle behind smaller pixels being needed to reduce the size of an image and prevent it becoming fuzzy (pixelated).

In summary, the particles have to get smaller so we can have smaller bits, and thus greater linear density. This is why BaFe is better suited to LTO-7 when the linear density will be increased. But for LTO-6 the bit density is the same as LTO-5 and hence MP is equally viable for LTO-6 as Barium Ferrite.

Particles and magnetic properties

Better magnetic properties mainly means higher coercivity and lower effective magnetic thickness (Mrt).

Coercivity

Coercivity is the resistance of the particles to having their magnetization switched (reversed). A higher coercivity is necessary because as the bits get more tightly packed, magnetic forces between them become more intense. As a result, they exert stronger demagnetizing tendencies on each other, which need to be resisted through increased coercivity.

If the particles can't adequately resist these demagnetizing influences then the signal can be obscured by the inevitable random variations (noise) in output, and errors are more likely to be made in reading the bits.

The signal to noise ratio (SNR) is better (higher) with BaFe media but not in a way that is significant for LTO-6 users. The coercivity of MP is more than sufficient to ensure outstanding reliability.

Effective magnetic thickness (Mrt)

Mrt (amount of magnetization per unit area of tape) is lower in BaFe. This is because it has an oxide composition, while MP contains a metal alloy. The lower Mrt helps to decrease the demagnetization tendency between the tightly-packed transitions. HP can still achieve an excellent signal from BaFe as well as from MP, because of our very sensitive (GMR) reading heads, so the Mrt differential is not a relevant performance factor.

Conclusion

All these differences: particle size, coercivity and Mrt, give BaFe media a better signal to noise ratio (SNR) and resulting bit error rate (BER) when compared to MP media. This makes BaFe media a good choice for future generations of LTO where the linear density will be increased.

As we have discussed, however, LTO-6 linear density is unchanged from LTO-5. That is why MP media works just as well for the LTO-6 format requirements as BaFe media does.

In fact the improved magnetic properties of BaFe are invisible for LTO-6 customers as they provide no additional benefits on media capacity or transfer rate over MP.

Metal Particle and Barium Ferrite side by side testing

How can HP demonstrate the comparative performance of its two LTO-6 media products? What is the evidence that proves both MP and BaFe perform equally well on the HP LTO-6 tape drive?

The engineers in HP's storage media R&D group work with suppliers to design and develop the highest performing products and put in place world class quality control systems to ensure stable performance no matter when you purchase or use your media.

There are many methods used to accomplish this, but the most significant is that we use HP LTO drives as one of the primary test beds for determining media quality. Due to the fact that HP is both the leading LTO drive manufacturer and the leading LTO media supplier, customers get unparalleled quality, performance and support for the life of their product.

Testing to extremes of breadth and depth

With thousands of drives and cartridges at our disposal, we can look at far more examples of drive and media interaction than an end user would normally have the ability to see for themselves. HP goes the extra mile (350,000 miles of tape pulled in a single year, in fact) so our customers don't have to. But companies that only sell media do not have the resources or budget to emulate this multi-million dollar investment in inventory, equipment, time and facilities.

HP also recognizes the importance of 'Green Tape Tests'[1], which support the rapid growth of tape technology in archiving, and continues to invest in test capabilities in this specialized area. This has been a crucial part of our LTO-6 media development for MP and BaFe.

HP's real-life testing program for LTO Ultrium media goes way beyond the lab tests that ensure compliance with the Ultrium logo specification for Linear Tape Open (LTO) media. For more information on our overall quality philosophy and testing for LTO Ultrium media generations 1-5, please refer to the separate HP white paper on Extreme Testing.

So what are the LTO-6 tests and what do they reveal?

HP deploys different media test strategies to compare the performance of MP and BaFe in different customer usage scenarios.

Archive type customer	Green Tape Test : Write only at 23°C/73.4°F 50% R.H.
Incremental backup type customer	Full Volume Life Test: Write and read on single cartridge Creep Append Test: Continuously appending until volume is complete
Media stress tests	Shoeshine Test: Read first 750 MB for 25,000 cycles Locate-Rewind-Append: Space to file mark, read file 1, overwrite file 2
Metrics typically measured	Capacity written/read, Transfer rate, Error rate

Extended Green Tape Tests

Given the presence of two different tape designs for LTO-6 (MP and BaFe) it was important to answer the key question "What happens to a drive when many green tapes of one design type are used, followed by tapes of another design type?" Thus, in order to demonstrate the comparative Green Tape Test performance of LTO-6 media, two separate Extended Green Tape Tests were conducted, both of which included an element of interchange.

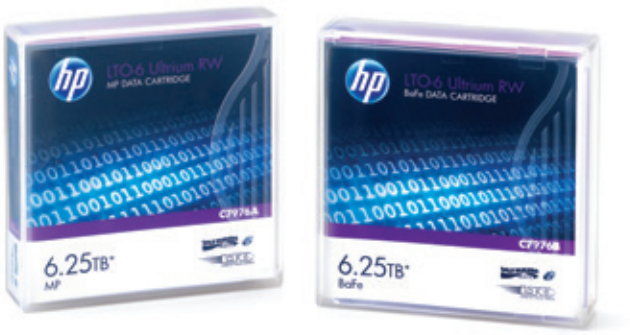
Extended Green Tape Test #1

- Write full capacity to 1,500 x HP LTO-6 MP cartridges.
- Conduct Interchange Tests using 4 x HP LTO-6 BaFe cartridges at 1,000 cartridges and 1,500 cartridges.

Extended Green Tape Test #2

- Write full capacity to 1,500 x HP LTO-6 BaFe cartridges.
- Conduct Interchange Tests using 4 x HP LTO-6 MP cartridges at 1,000 cartridges and 1,500 cartridges.

The Extended Green Tape Tests are a clear demonstration of HP's commitment to product reliability, with each test consuming significant resources, and taking in excess of 18 months to complete. Indeed, even after completing 1,500 cartridges, and with no sign of degraded performance, the two tests are ongoing!

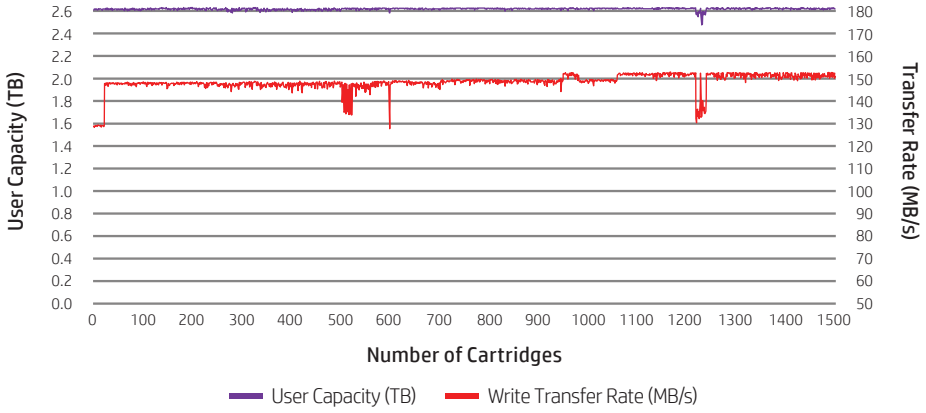


[1] A green tape is a brand new data cartridge that has never been previously used. Green Tape Tests are important because newer media is typically more abrasive than cartridges that have been used several times, and duty cycles using large quantities of green tape (eg archiving) affect tape drive performance differently from those where tapes have been rotated and used repeatedly.

Extended Green Tape Test #1 (1,500 cartridges x HP LTO-6 MP)

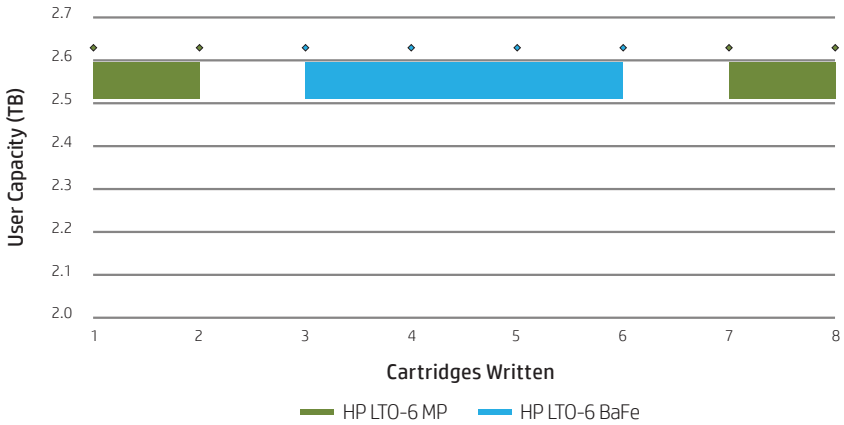
The capacity and transfer rate remained consistent throughout the test with the excellent baseline performance in these two metrics proving no significant drive degradation had occurred, despite the very high number of green cartridges used (equivalent to almost 4 PB of native data!)

Extended GTT#1 (HP LTO-6 MP): Capacity and Transfer Rate vs. Cartridges Written

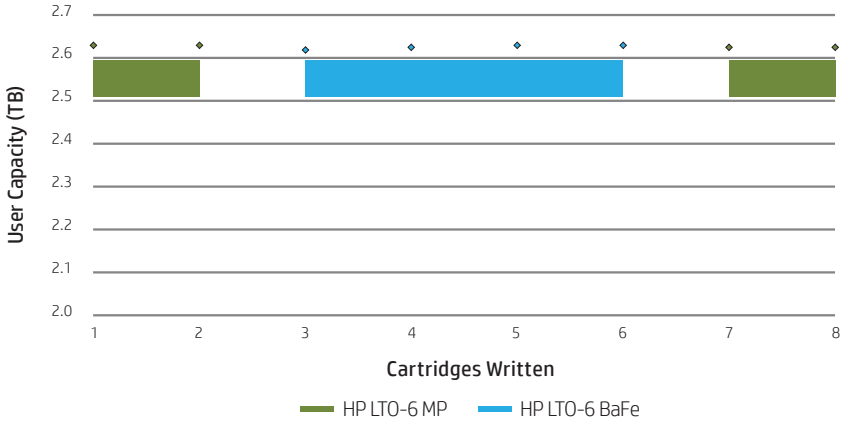


It was also important to show that from an interchange perspective, running extended numbers of green cartridges of one design type did not affect the performance when using a different media design (and vice versa). Thus, as part of the Extended Green Tape Test #1, 4 x HP LTO-6 BaFe cartridges were tested after 1,000 x HP LTO-6 MP cartridges, and then again after a further 500 cartridges (ie 1,500 x HP LTO-6 MP cartridges in total).

Interchange Test (using 4 x HP LTO-6 BaFe cartridges) after 1,000 x HP LTO-6 MP cartridges



Interchange Test (using 4 x HP LTO-6 BaFe cartridges) after 1,500 x HP LTO-6 MP cartridges

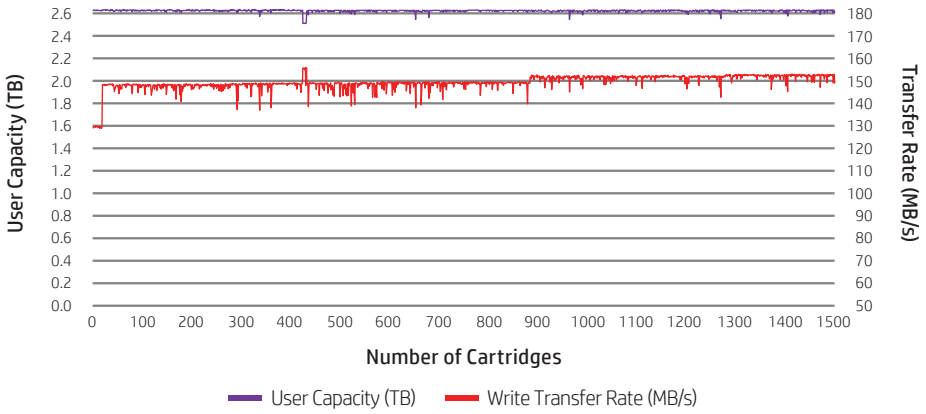


It is clear from both Interchange Tests that full capacity was maintained throughout, ie there was no significant drive degradation, indicating stable performance and excellent durability.

Extended Green Tape Test #2 (1,500 cartridges x HP LTO-6 BaFe)
The second Extended Green Tape Test followed the same procedure as the first, except this test used HP LTO-6 BaFe cartridges, with the Interchange Tests conducted using 4 x HP LTO-6 MP cartridges.

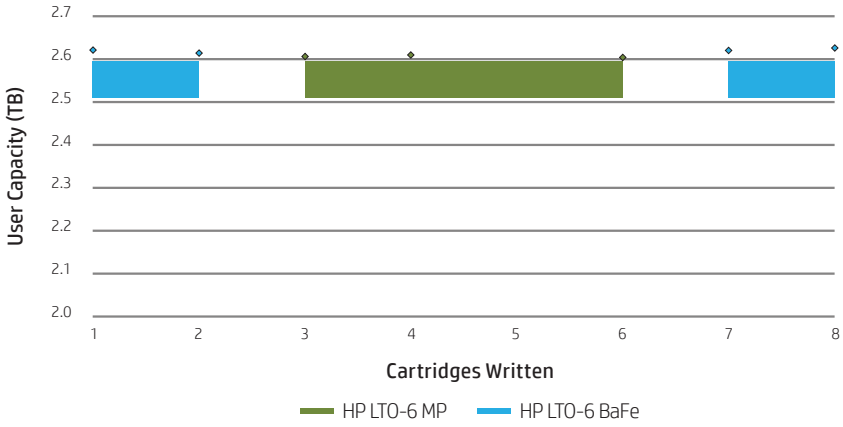
As the graph below shows, the capacity and transfer rate remained very stable throughout the test, again showing no significant drive degradation.

Extended GTT#2 (HP LTO-6 BaFe): Capacity and Transfer Rate vs. Cartridges Written

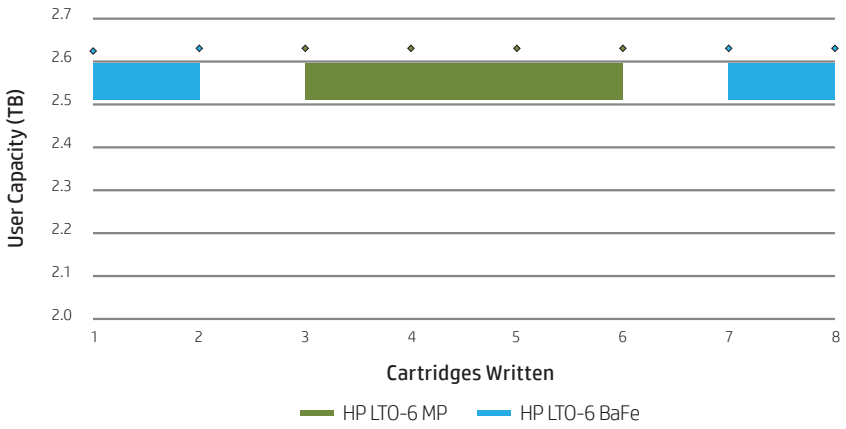


As explained, this Interchange Test was conducted using HP LTO-6 MP cartridges to verify that running an extended number of green HP LTO-6 BaFe cartridges did not affect the drive performance when using HP LTO-6 MP cartridges.

Interchange Test (using 4 x HP LTO-6 MP cartridges) after 1,000 x HP LTO-6 BaFe cartridges



Interchange Test (using 4 x HP LTO-6 MP cartridges) after 1,500 x HP LTO-6 BaFe cartridges



For all practical purposes – what a customer would actually notice in terms of backup reliability and performance – the results for BaFe and MP are indistinguishable in HP Green Tape Testing.

Full Volume Life Test: write and read on single cartridge in ambient and 29°C/84.2°F 80% R.H. conditions

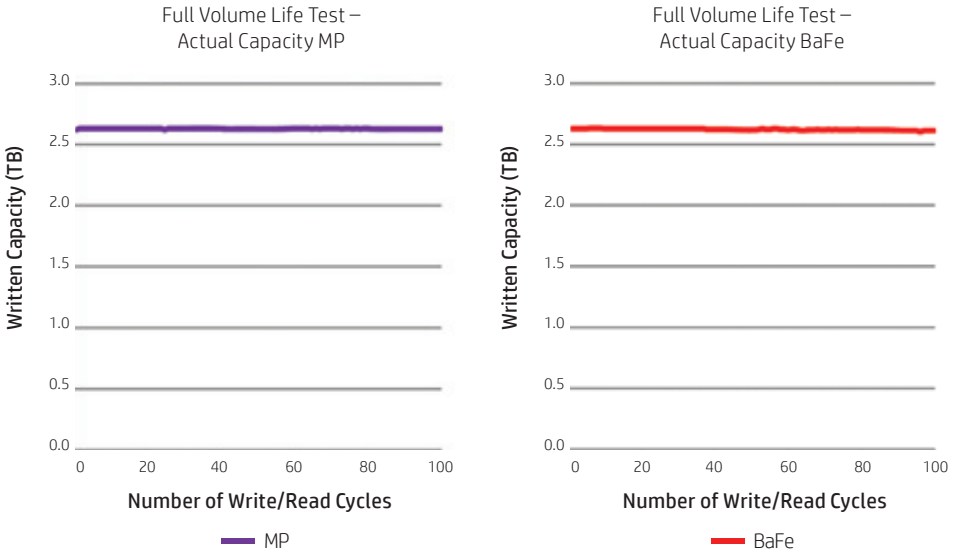
HP conducts Full Volume Life Testing in two different environments to examine and ensure the performance of both MP and BaFe tapes across a broad spectrum of conditions. Both ambient and 29°C/84.2°F 80% R.H. (hot/wet) conditions are used.

Capacity

In this test, we examine the capacity achieved on an MP LTO-6 cartridge compared to a BaFe LTO-6 cartridge across multiple Full Volume cycles. Both MP and BaFe cartridges have achieved the required 2.5 TB native capacity (again, the capacity is actually slightly higher due to built-in extra margin).

Write and read transfer rate

In this test, we examine the write and read transfer rate achieved on an MP LTO-6 cartridge compared to a BaFe LTO-6 cartridge across multiple Full Volume cycles. Both MP and BaFe cartridges achieve the expected LTO-6 performance that make the drive capable of writing up to 1.4 TB/hr of data.

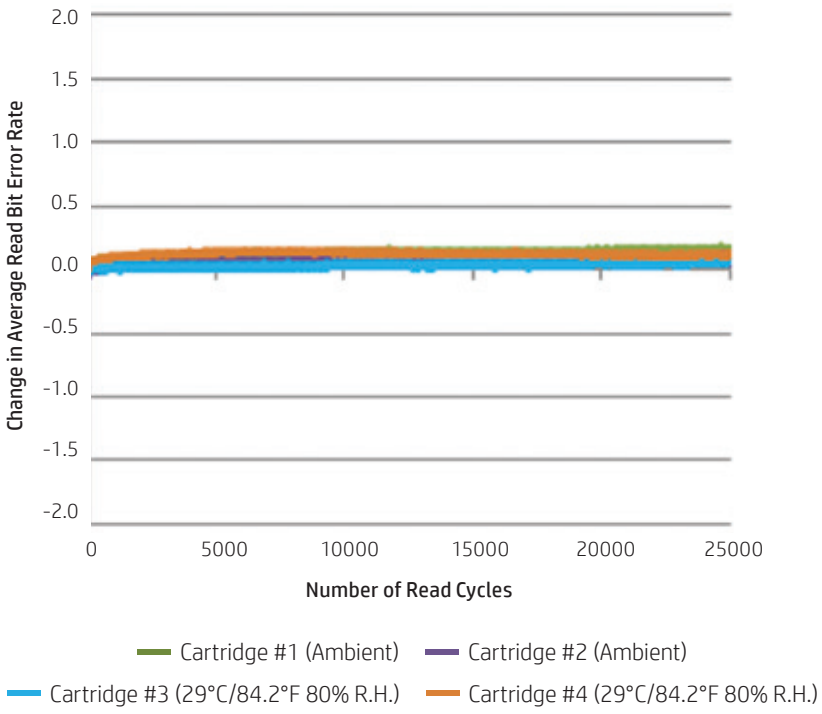


Shoeshine Test: read first 750 MB for 25,000 cycles

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 multiple times and at the end of the test, there should be no loss of performance.

This test is also repeated at both ambient and 29°C/84.2°F 80% R.H.



Creep Append Test: continuously appending until volume is complete

HP also conducts Creep Append Testing in two different environments to examine and ensure the performance of both MP and BaFe tapes in similar conditions to the Full Volume Life procedures. Both ambient and 29°C/84.2°F 80% R.H. (hot/wet) conditions are used in a process where data is written to the tape in small increments until the volume is full. This echoes a pattern of use where partial amounts of data might be written to a tape across multiple backup activities.

Locate-Rewind-Append: space to file mark, read file 1 overwrite file 2

This test measures the ability of a section of the tape to withstand repeated stress (ie file locate, retrieve and append operations) in a highly demanding customer environment such as those found in large-scale automation installations.

This test is also repeated at both ambient and 29°C/84.2°F 80% R.H.

HP MSL Automation Product Testing

In addition to these intensive 'media specific' tests, which are designed to stress the media often beyond normal limits, HP also conducted a variety of 'real life' tests using MSL4048 libraries, HP LTO-6 drives and both MP and BaFe media.

In MSL Automation Product Testing there are a total of 10 different backup, restore, append and space scenarios within one test plan. The scenarios range from large backup/restore events to small incremental backup/appends. The rough sequence is as follows:

- Randomly load the cartridge from slot 1-40.
- Perform Scenario 1.
- Move cartridge back to slot 'X' and randomly choose the next cartridge.
- Perform Scenario 2.
- Then perform each Scenario 3 through to 9.
- Perform Scenario 10.
- Move cartridge back to slot 'X' and randomly choose the next cartridge.
- Restart from step number 1.

Archival testing

Signal degradation is a factor that could affect the archival properties of MP tape media. Historically, signal loss would occur due to oxidation of the magnetic particles (ie 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 MP technology in recent years and HP LTO-6 MP incorporates 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 LTO-6 MP tape also utilizes high coercivity particles so the media is less affected by stray magnetic fields (again helping to ensure ongoing data integrity and restore reliability). HP LTO-6 BaFe tape is even less susceptible to signal degradation caused by oxidization than MP.

Both media types are extremely stable, therefore, for long term storage even when exposed to different climates or polluted environments.

To demonstrate this, HP has conducted a number of specific archival tests that simulate accelerated ageing on both HP advanced MP and HP BaFe LTO-6 media. In both cases, the parametrics for both media types are so similar that a customer would notice no difference between them.

For detailed information on HP LTO-6 media archival testing, please refer to the white paper – 'Extreme Testing and Reliability for HP LTO-6 Media'.

Conclusion

Ultimately, tape drives are the best form of microscope to examine media quality and performance. That's why we use large numbers of HP LTO-6 drives to scrutinize MP and BaFe LTO-6 data cartridges. HP understands that backup and archiving is not some disconnected IT process removed from the rest of business activities. One day, the survival of your business could depend on restoring data from one of our tapes.

HP drives are completely media agnostic and offer unsurpassed performance across the full array of media available for LTO-6. Thanks to the exhaustive testing we have conducted, HP is certain that users will observe no difference when using MP-only, BaFe-only or a mixture of both media types in their HP StoreEver LTO-6 drive.

Some companies have chosen to offer MP media. Others have chosen to offer BaFe. The nature of the format permits this, provided that the interchange specification is met. Ultimately, however, all MP and BaFe tapes are simply LTO-6 products and all cartridges that pass logo certification are supported by compliant LTO-6 drives.

HP has chosen to offer both types of LTO-6 media because we feel it is the best way of meeting the needs of all our customers. Both HP media formulations offer the same outstanding performance on HP's LTO-6 drives and both products can be used on other, non-HP platforms. That is the continued benefit of the LTO Ultrium open format, the world's most successful tape backup and archiving technology.

Additional resources
Device compatibility: hptapecompat.com
HP LTFS technology: hp.com/go/ltfs
HP LTO Ultrium: hp.com/go/ultrium
HP LTO tape drives and tape automation: hp.com/go/tape
HP TapeAssure: hp.com/go/tapeassure

Learn more at
hp.com/go/storagemedia

Sign up for updates
hp.com/go/getupdated

Share with colleagues

Rate this document

Follow HP Storage Media

4AA4-4613ENW, May 2014, Rev. 1