MAGSTOR NANOPURE MEDIA PROCESS AND TESTING METRICS

The LTO NanoPure Media™ process reduces media error rates and lowers drive head failures by reducing excessive media surface asperities and contamination. All LTO NanoPure Media cartridges are tested and calibrated at the factory prior to shipment and the results are stored in the respective cartridge memories, enabling accurate advanced system diagnostics for media and drives.

MagStor

George Saliba

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Abstract: Over the past 20 years tape's role has evolved from a backup usage model to an archiving one, and as a result most customers now use new tapes for one-time archiving operations. The impact of newly manufactured media on tape head life and drive performance is a topic that has been discussed for decades, and the causes of head damage related to the use of "green" media are well understood. Many articles have been published describing the causes and proposing solutions, yet customers continue to report problems when using new media. In fact, the archive usage model means that drive damage caused by "green" LTO media is on the increase. A simple examination of the surface of newly manufactured media clearly shows the root cause: new media is characterized by excessive surface asperities and contamination. The asperities result in head pole tip recession, causing permanent tape-to-head separation and subsequent signal degradation, ultimately leading to drive failures. Additionally, contamination from the manufacturing process can be observed on the surface of newly manufactured media. Tape surface contaminants cause head clogging and increased drive error rates. Despite the media manufacturers' best efforts to reduce tape asperities and contamination, problems with freshly manufactured media persist. This paper demonstrates that the patent-pending NanoPure Media certification process significantly reduces error rates on new LTO media, addressing one of the main challenges of the archive usage model. Furthermore, since new cartridges are not calibrated at the factory, when a tape system fails due to excessive data errors, there is currently no reliable way to determine if the cause of the error is the drive or the cartridge, as it is not possible to account for cartridge-to-cartridge data error differences. Presently, the drive diagnosis options are lengthy, complex and costly. For example, when a tape drive fails within a media library, it is not possible to determine with certainty if the cause of the failure is marginal head performance, or the tape media itself, as both can produce data errors. In the case of a tape library, where multiple drives record data on the same cartridge, it is then virtually impossible to determine the marginal drive or cartridge that caused the error. NanoPure Media is calibrated in such a way that the root cause of the errors can be determined with certainty.

INTRODUCTION

Tape cartridges can store vast amounts of data. Today's LTO-9 cartridges can store up to 45TB of compressed capacity on a single cartridge. Tape drives are used as either stand alone or in a tape library, (also referred to as a media library), and each drive includes a data transducer or head for recording or retrieving data (such as a Giant Magneto-Resistive, or GMR head).

For the proper operation of a tape drive, the head must maintain very close proximity to the storage tape of the tape cartridge in order to faithfully record and reproduce signals. Excessive separation between the head and tape, and/or sensor damage such as scratches, nicks or other abrasions to the head itself can result in reading and writing errors or even drive failure.

When a tape drive fails within a media library, it is not possible to determine with certainty if the cause of the failure is a marginal head or tape media, as both can produce data errors

It is well established that tape to head separation increases when contaminants build up on the surface of the head. Cleaning cartridges or brushes can be used to remove contaminants. Unfortunately, these types of cleaning devices can be relatively ineffective at removing excessive deposits on the head. Further, when the sensor of the head is impacted with sufficient force by asperities (micro bumps) present in new media, the recording area of the head can be eroded, creating permanent head/media excessive separation. Also, the impact of larger media asperities on the recording elements is the primary cause of a "short" element in the head, (where adjacent channels no longer function properly); after such damage, the head is rendered unusable and the drive must be repaired. In addition, contaminants and debris can generate surface scratches that effectively create permanent separation between the tape and the sensor, thereby reducing the head signal and requiring repair to the head.

At present, the diagnosis of a failed drive is lengthy, complex and costly. For example, when a tape drive fails within a media library, it is not possible to determine with certainty if the cause of the failure is a marginal head or tape media, as both can produce data errors. In the case where multiple drives record data on the same cartridge, then it is virtually impossible to determine the marginal drive that caused the error, especially when the failure is compounded by a combination of marginal heads and marginal media. Further complicating diagnosis is the fact that media is not tested prior to first use, and that each tape has naturally varying error counts depending on manufacturer, coating batch and even the physical location on the web from which the tape was cut.

Given the large number of variables, when a tape drive fails within a media library, the drive must be shipped back to the factory where it undergoes a screening process that attempts to identify the drive or drives with failed heads. Drives with suspect heads are disassembled and heads are carefully removed. Failed heads are returned to head vendors for repair. The head repair procedure is frequently proprietary to each head vendor, further complicating the entire process. Typically, the head repair includes lapping of the head, followed by testing. This "lap and test" procedure is repeated until a satisfactory result is achieved, or until the head is deemed irreparable. The head is then sent back to be installed in a rebuilt drive, and after a complete retest, the rebuilt drive is returned so that it can be reinstalled for the customer.

Despite the media manufacturers' best efforts to reduce tape asperities and contamination, problems with freshly manufactured media persist. Also, despite the efforts of drive manufacturers and automation vendors to introduce intelligent statistical methods for media and drive error tracking the wrong drive is nonetheless sent back for repairs about half the time.

The NanoPure Media process is designed to reduce the problems caused by "green" LTO media. Furthermore, NanoPure Media tapes enable the system to determine with high confidence if the cause of a failure was the media or drive. In addition, by using software applications that support NanoPure Media, the system is able to detect error rate degradation and provides customers early warnings with suggested corrective actions.

By comparing current errors with the calibration data stored in the cartridge memory, the system is able to determine with certainty if the degradation is caused by the drive or cartridge, and more importantly the system is able to provide customers with early warning alerts and suggest corrective action prior to catastrophic failure.

The NanoPure Media process comprises two steps. The first step is to clean and burnish new media prior to first use. The second step is to test each cartridge, calculate calibration factors, and store each cartridge's unique factors in the cartridge memory. The software application uses the calibration factors during normal drive operation to monitor error rates and determine if the media or drive is degrading over time. By comparing current errors with the calibration data stored in the cartridge memory, the system is able to determine with certainty if the degradation is caused by the drive or cartridge, and more importantly the system is able to provide customers with early warning alerts and suggest corrective action prior to catastrophic failure.

NANOPURE MEDIA BURNISHING AND CLEANING PROCESS

While the media manufacturing process is unique and proprietary to each primary manufacturer, the common objective for the physical media property is to create a strong, smooth and clean surface. Typically, the manufacturers add hardener material such as Chromium Oxide or Aluminum Oxide, also known as head cleaning agents (HCA), to the coating mix. The HCA materials are beneficial in cleaning the head, however the HCA dispersion process control is difficult and often results in increases in surface asperities (surface bumps) which contribute to data errors in the user environment.

The media manufacturing process also produces large amounts of contaminants, especially the slitting process, where the media is cut to the physical format used in the actual cartridge. Media manufacturers employ processes to remove contaminants from the media surface but this does not prevent debris from being observed on fresh media.

Both asperities and contaminants are the primary causes of data errors in tape drives. The first objective of the NanoPure Media process is to reduce these media asperities and contaminants. To do so, MagStor has developed a unique burnishing and cleaning process, based on a patent-pending double helix roller. The double helix roller is designed to clean and burnish the media in a gentle manner. It provides a more controlled burnishing effect than the blade cleaning method commonly used elsewhere in the tape industry.

TEST SETUP

To test the effectiveness of the NanoPure Media cleaning process and its ability to reduce asperities and contaminants, MagStor designed a controlled lab test to measure data errors before and after the burnishing/cleaning process.

Tests were run on randomly selected new IBM Fujifilm LTO-7 and LTO-8 cartridges, using standard Tape Drive Doctor software. In order to minimize variables, the same reference drives, a new IBM LTO-7 and LTO-8 tape drive, were used to measure the "before" and "after" data error rates. The error rates for all cartridges were recorded before and after running the double helix burnishing roller to clean and remove excessive new media asperities. By simply comparing the before and after error counts as reported by Tape Drive Doctor it is possible to quantify the effectiveness of the NanoPure Media burnishing/cleaning process.

First, a few words about the Tape Drive Doctor (TDD) tool: TDD was originally developed and patented by Quantum Corporation and later enhanced by Saliba Technologies Solutions, Inc. The purpose of the tool is to test LTO drive performance via simulated customer read/write operations, using specially calibrated cartridges. This tool is used extensively by drive repair companies. More information regarding the technology and patents can be found at TapeDrivedoctor.com.

TDD's basic routine consists of reading and writing customer data at specific tape locations, and by measuring the duration of various operations a figure of merit of drive performance is reported. TDD also interrogates drive error rates and servo defects, so that at the end of the test we have a full 360-degree result representing tape drive performance. All TDD test cartridges are calibrated to a gold standard, so that the test results are purely a measure of drive performance. All drives' quality values are linearized and normalized. The value of 3 represents the centerline drive, a lower value is better than average, and a higher value represents a worse than average drive. For a complete analysis, TDD includes all the raw error data reported by the drive as well as the actual process time and normalized performance.

LTO-7 NANOPURE MEDIA TEST RESULTS

Fig 1 shows the test results collected from eight randomly selected new LTO-7 cartridges (green media). The error rate test results were measured using Tape Drive Doctor standard software simulating a real world customer environment. All tests were conducted by MagStor labs using a standard LTO-7 IBM drive.

The first data set in the graph are the error rates observed on the "as received" cartridges prior to running the NanoPure Media process; the second set of data points are the error rate test results after running the NanoPure Media process, tested on the same standard LTO-7 drive.

Although the data collected from this test does not represent the entire range of possible LTO-7 cartridge error rates, the data shows that even in this small random sample, there are significant error rate differences between new cartridges. MagStor's test results from the new "as received" cartridges show an error rate difference of up to 219% from one LTO-7 cartridge to another, using the same IBM reference drive. Furthermore, since LTO cartridges are not tested at the factory for error rates prior to first use, the large error rate delta between cartridges cannot possibly be accounted for at the customer site without knowing the initial error rate of each cartridge, and without calibration to a known standard. This fact alone likely accounts for much of the reported difficulty in diagnosing faulty media and/or faulty drives. Essentially, as the current practice uses unknown media to test unknown drives, the results are at best unknown. For example, cartridge number VPRV would make an average drive report much worse data than expected, while cartridge E1YY would make a troubled drive look excellent.

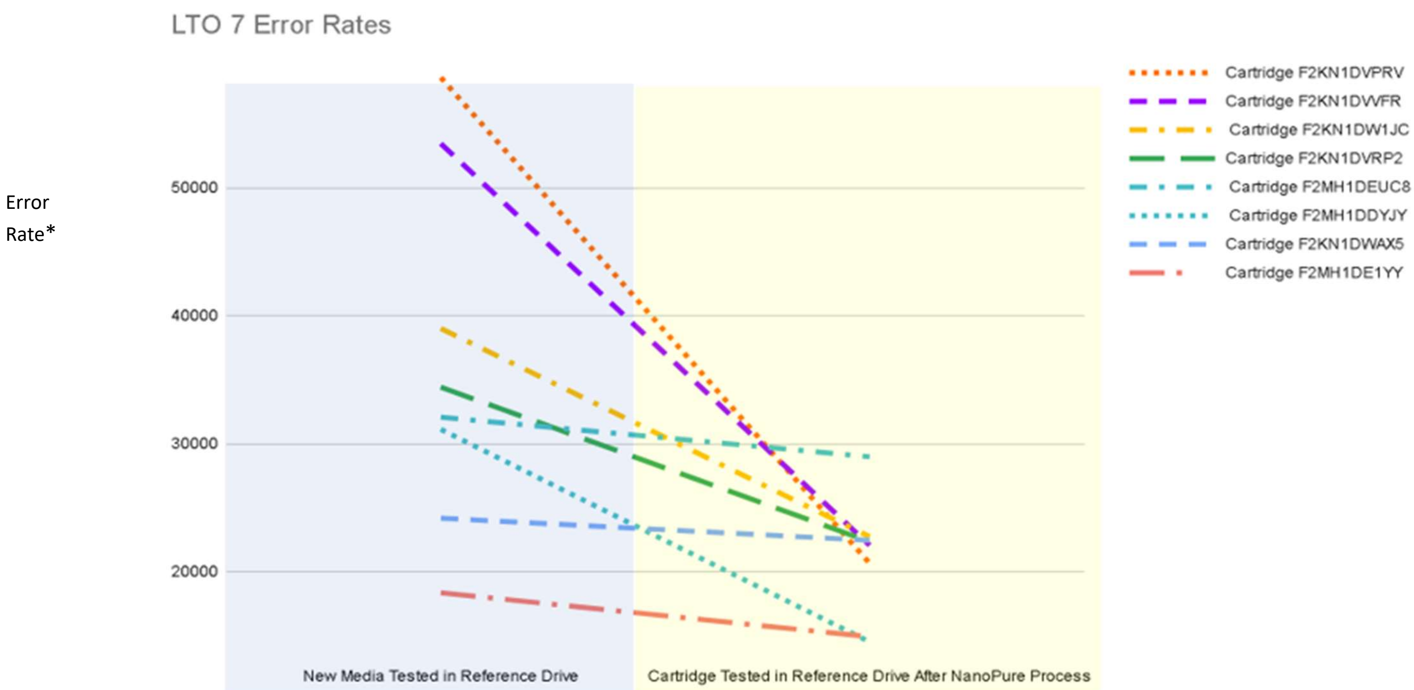

Figure 1

*The error rate shown in the graph is the count of write errors detected during the test cycle. An error is recorded when the read after write verification process detects a block with error(s) that cannot be corrected by the Error Correction Code. In this case the drive rewrites the defective block further down the tape, in a non-defective location.

Cartridge ID	F2KN1DVPRV	F2KN1DVVFR	F2KN1DVRP2	F2KN1DW1JC	F2MH1DEUC8	F2MH1DDYJY	F2KN1DWAX5	F2MH1DE1YY
Error Rate								
New Media	58630	53468	34427	39015	32078	31130	24183	18355
After NanoPure Process	20658	22068	22347	22743	28986	14515	22453	14918
Difference	183.81%	142.29%	54.06%	71.55%	10.67%	114.47%	7.70%	23.04%
Average for Typical New Media	36410.75							
Average for NanoPure Media	21086.00							
Average Error Rate Reduction	42%							

To quantify the benefits of the NanoPure Media process, we simply compare the “before” and “after” LTO-7 error rate data as measured by MagStor labs. The data shows significant improvements in error rates in all the cartridges after running the NanoPure Media process. In fact, the worst performing cartridges VPRV and VVFR show such an improvement in error rates that their performance approaches that of the best cartridges. The improvement in error rates depends on a cartridge’s initial condition: cartridges that start with higher error rates benefit more from the process, while others that show lower initial error rates benefit less. This is to be expected, as some tapes exit the manufacturing process cleaner and smoother than others. For this LTO-7 sample, MagStor data shows on average a 42% reduction in error rates.

By comparing the before and after data error rates, we can quantify the benefits of the NanoPure Media process in reducing the presence of media surface asperities and contaminants. The average 42% reduction in errors, and the absence of any increases in cartridge error rate, confirms that the double helix roller’s cleaning and burnishing method is effective, gentle, and does not damage the media.

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LTO-8 NANOPURE MEDIA TEST RESULTS

Fig 2 shows the test results collected from eight randomly selected LTO-8 new cartridges (green media). The error rate test results were measured using Tape Drive Doctor standard software simulating a real world customer environment. All tests were conducted by MagStor labs using a standard LTO-8 IBM drive.

The first data set in the graph are the error rates observed on the “as received” cartridges prior to running the NanoPure Media process; the second set of data points are the error rate test results after running the NanoPure Media process, tested on the same standard LTO-8 drive.

Although the data collected from this test does not represent the entire range of possible LTO-8 cartridge error rates, the data shows that even in this small random sample, there are significant error rate differences between new cartridges. MagStor’s test results from the “as received” cartridges show an error rate difference of up to 163% from one LTO-8 cartridge to another, using the same reference IBM reference drive. Furthermore, since LTO cartridges are not tested at the factory for error rates prior to first use, the large error rate delta between cartridges cannot possibly be accounted for without knowing the initial error rate of each cartridge, and without calibration to a known standard. This fact alone likely accounts for much of the reported difficulty in diagnosing faulty media and/or faulty drives. Essentially, since the current practice uses unknown media to test unknown drives, the results are at best unknown. For example, cartridge number 501H would make an average drive report much worse data than expected, while cartridge 53P8 would make a marginal drive look excellent.

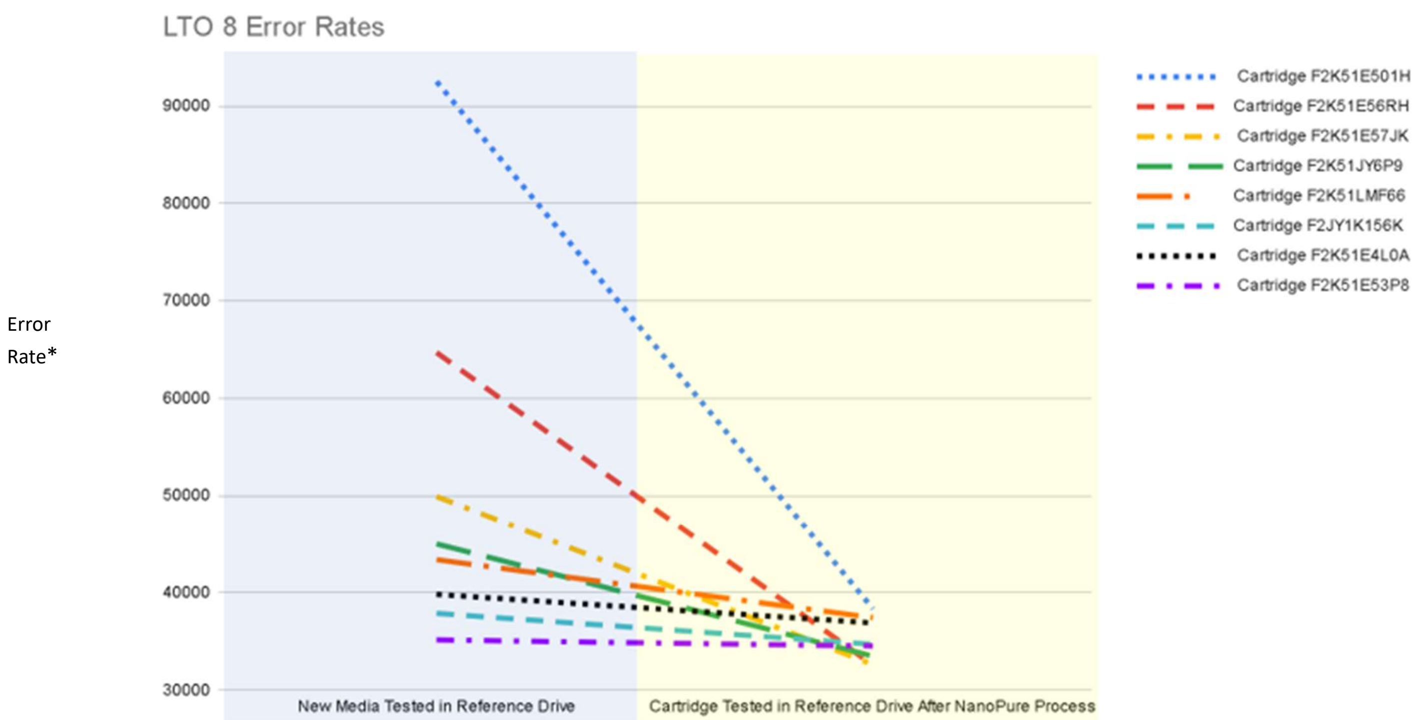

Figure 2

*The error rate shown in the graph is the count of write errors detected during the test cycle. An error is recorded when the read after write verification process detects a block with error(s) that cannot be corrected by the Error Correction Code. In this case the drive rewrites the defective block further down the tape, in a non-defective location.

Cartridge ID	F2K51E501H	F2K51E56RH	F2K51E53P8	F2K51E57JK	F2K51E4L0A	F2K51JY6P9	F2K51LMF66	F2JY1K156K
Error Rate								
New Media	92528	64696	35153	49917	39832	45017	43392	37879
After NanoPure Process	38352	32570	34529	32628	36895	33475	37440	34708
Difference	141.26%	98.64%	1.81%	52.99%	7.96%	34.48%	15.90%	9.14%
Average for Typical New Media	51051.75							
Average for NanoPure Media	35074.63							
Average Error Rate Reduction	31%							

To quantify the benefits of the NanoPure Media process, we simply compare the “before” and “after” LTO-8 error rate data as measured by MagStor labs. The data shows significant improvements in error rates in all the cartridges after running the NanoPure Media process. In fact, the worst performing cartridge 501H show such an improvement in error rates (59%) that its performance approaches that of the best cartridges. The improvement in error rates depends on a cartridge’s initial condition: cartridges that start with higher error rates benefit more from the process than others with lower initial error rates. This is to be expected as some tapes exit the manufacturing process cleaner and smoother than others. For this LTO-8 sample, MagStor data shows on average a 31% reduction in error rates.

By comparing the before and after data error rates, we can quantify the benefits of the NanoPure Media process in reducing the presence of media surface asperities and contaminants. The average 31% reduction in errors, and the absence of any increases in cartridge error rate, confirms that the double helix roller’s cleaning and burnishing method is effective, gentle and does not damage the media.

NANOPURE MEDIA CARTRIDGE CALIBRATION PROCESS

As noted above, diagnosis of a failed tape drive is currently a lengthy, complex and costly process. With currently available tools it is difficult, if not impossible, to determine with certainty if the cause of a failure is a defective drive or defective media. There remains an unmet need for methods and systems that can determine with certainty the cause of data failures in the field, and eliminate the need for costly and extensive factory diagnosis and associated head removals and tests. Additionally, methods and systems are needed to deterministically test tape drives and media at a customer site without disrupting the customer’s normal tape operations.

Again, as noted above, the large deltas observed in cartridge error rates in MagStor’s test of new LTO-7 and LTO-8 media show that there are wide variations in the quality of new media. This fact likely accounts for much of the reported difficulty in diagnosing faulty media and/or faulty drives.

In the event of a problem, software that supports NanoPure Media, along with an intelligent diagnostic cartridge, is able to determine if the drive or the tape cartridge is at fault

NanoPure Media cartridges are tested and calibrated at the factory using standard drives. The calibration factors are stored in the cartridge memory according to a patent-pending calibration method. This calibration data can be used at any time during the life of the cartridge to determine the media quality and detect any potential media degradation. The NanoPure Media monitoring process consists of three simple steps: first collect the error data during normal operation; then normalize the data to a standard; and then apply the NanoPure Media calibration factor stored in the cartridge memory.

Thanks to the data stored in cartridge memory, uncertainty over tape-to-tape variability is eliminated. In the event of a problem, software that supports NanoPure Media, along with an intelligent diagnostic cartridge, is able to determine if the drive or the tape cartridge is at fault, and if either must be retired. Importantly, since error and calibration data is stored in the cartridge memory, diagnostics can be performed at the customer site with minimal disruption to normal tape operations. Remote system connectivity and tracking are not required.

CONCLUSION

Based on MagStor labs' test results, the NanoPure Media process reduces media error rates by removing large surface asperities and contaminants. By testing each tape cartridge and storing the corresponding calibration factors in the cartridge memory, NanoPure Media accurately accounts for cartridge-to-cartridge error rate differences, and enables new system capabilities to determine with certainty if a given cartridge or drive is the cause of a failure.

When NanoPure Media runs with supported intelligent software, the predictive system reduces customer disruption, eliminates the need for the costly troubleshooting of the cause of failures and extensive factory diagnosis and associated costs.

The NanoPure Media manufacturing process reduces media error rates, lowers drive head failures by reducing excessive media surface asperities and contamination.

All current NanoPure Media cartridges are tested at the factory and the calibration factors are stored in the respective cartridge memories enabling accurate media and drive advanced system diagnostics.

For more information or to order NanoPure Media, contact MagStor at info@magstor.com, or 1-844-MAGSTOR (624-7867)

ABOUT SALIBA TECHNOLOGIES

George Saliba is the President and Chief Executive Officer of Saliba Technologies, Inc. located in Boulder Colorado.

For the past twelve years at Saliba Technologies, George invented and led the development of multiple advanced data storage products

Saliba technologies provides consulting services to multiple LTO tape companies and continues to advance the tape drive and media technologies and have filed a number of patents applicable to advancement to LTO drive and media technologies and the Global Storage Solution technology, “GSS”.

During his tenure at Saliba Technologies, Mr. Saliba continues to provide Technology & IP consulting to multiple Fortune 500 companies in the field of disk, tape and data storage systems.

Prior to Saliba Technologies, George was the Chief Technology Officer (CTO) and the primary inventor at Quantum Corporation where he filed a large number of patents and technology advancements to LTO drive and media technologies. Mr. Saliba was responsible for the development of the very successful DLT and SDLT families of tape and Automation data storage products at Quantum Corporation. George was the primary inventor of the DLT and Super DLT tape product line and was instrumental in the explosive growth of the DLTtape and SDLTtape. He is credited for inventing multiple tape technology advances and completing, ahead of the competition, 8 consecutive leadership DLT and SDLT tape products DLT became the industry standard for tape storage products worldwide, shipping over 100 million tape cartridges. Mr. Saliba also was responsible for the development of all the DLTtape media and DLTStor Tape Automation.

The success of these products resulted in the phenomenal growth of Quantum’s business from $200 Million to over $1 Billion. George Saliba is known in the industry as “Mr. DLT” and more recently as “Mr. LTO”.

George has over 110 issued patents covering various data storage technologies. He has published extensively in the magnetic recording field. George earned BSEE and MSEE degrees from the University of Colorado and holds BT1 and BT2 degrees in Electrical Engineering from Ecole Des arts et Sciences.

ABOUT MAGSTOR

MagStor® Is a recognized leader in tape backup solutions to enterprise and media and entertainment users globally. Since 2006, operating as our parent company Magnext, we are the ONLY tape hardware manufacturer and service provider solely focused on the needs of the tape hardware market. Our investments in engineering include our innovative NanoPure Media™ system and patented Thunderbolt 3™ equipped tape drives and libraries. All with a focus on improving the usability of tape hardware for users in the Zettabyte era.

FOR MORE INFORMATION OR TO ORDER NANOPURE MEDIA, EMAIL info@magstor.com