Decades of Proven Research Underpin Seagate's Helium Drive

Technology Paper

The feasibility of using helium (*He*) inside of hard disk drives (HDD) has long been the holy grail of rotating magnetic storage. And after many decades of research and development, there is virtually no debate that replacing air with helium inside the magnetic storage enclosure improves areal density capability (lower windage-induced vibration with low-density helium), reduces the power required to spin (lower spindle power from lower-density helium), and limits increases in device temperature (higher thermal conductivity of helium). With the introduction of the 10TB Enterprise Capacity 3.5 HDD, Seagate offers its helium drive technology to a growing cloud-based data center market that is clamoring for unique and robust storage solutions.

The Early Years of Helium Drives Provide a Blueprint

In the 1960s, Control Data (one of the earliest pioneers in computer research and technology) manufactured a helium-filled rotating drum. Other companies made similar attempts to fill HDDs with helium. All of these products used external helium tanks to maintain and replenish the internal helium atmosphere. This proved to be an inefficient and prohibitively expensive configuration that produced only very small numbers of drives. The Control Data storage group eventually evolved into Magnetic Peripherals, Inc. (MPI) during the late 1970s, a storage consortium for the non-IBM computer companies.

Work restarted on helium-filled HDDs by the 1980s. In fact, IBM and Nippon Telephone and Telegraph (NTT) developed head disk assemblies (HDA), sealed in large helium-filled metal cans (drive or HDA-in-a-can). The *IBM*-can, designed for a 14-inch HDD, was the size of a short, approximately 12-inch tall, 55-gallon drum and was sealed with a standard folded and crimped *tin can* seal. At MPI, feasibility studies and research into helium HDDs were also restarted. However, the only product introduction from this effort was *Patty*—a helium HDD for NTT in Japan—widely considered a failure by NTT due to very fast helium loss through permeation. That is, the loss of helium through solid substances. The primary seal mechanism in NTT's helium HDD suffered from permeation.

By the late 1990s, there was a rapid increase in overall areal density with significant increases in bits per inch (BPI) and, especially, tracks per inch (TPI). The increased areal density necessitated the reduction in transducer fly heights with corresponding thinner head/disk coatings. The demands for increased areal density were accompanied by additional requests for higher-performing HDDs. The need for higher data throughput resulted in the introduction of 10K- and 15K-RPM Enterprise HDDs with significantly higher windage-induced vibration. A sealed HDA containing an almost pure helium environment was again resurrected as a potential solution for the future combination of even higher TPIs with thinner coatings and higher RPMs.

Decades of Proven Research Underpin Seagate's Helium Drive

The 1990s saw a steady stream of conference presentations and publications covering basic research into the use and impact of helium HDDs. But to further increase areal density, particular attention was placed on the use of very thin coatings, or even the complete removal of the head and disk coatings in helium's neutral atmosphere. Maxtor had also jumped in and started working on helium HDDs, as did Seagate in the early 2000s. In fact, both Maxtor and Seagate had independently followed very similar paths: each designed and produced an all-in-one sealed HDA design. This design path was motivated by its initial very low capital expense when compared to that required for laser welding.

Seagate Acquires Maxtor and Consolidates Helium Drive Research

By the time Seagate had acquired Maxtor in early 2006, both had developed hermetic helium-filled sealed HDAs with a compressible tin-coated C-seal located between the base and cover. This C-seal was used to seal the HDA for drive test, thereby allowing for rework (possibly requiring a new C-seal to be used) and also to seal the HDA for up to 5 years. While technically feasible, standard C-seals could only be manufactured in round shapes. Because HDAs for disk drives are not round, they required expensive custom C-seals, which in turn required high-speed tin plating lines as well as greenfield factories. One technical issue with C-seals, one that was never fully resolved, was the low shock capability of the compressed C-seal. After a shock, for instance, a helium drive could have increased helium leakage and/or helium loss through a one-time helium *burping*.

The Seagate acquisition of Maxtor resulted in significant synergies between the two helium drive development team efforts. Both companies had independently developed or covered almost the entire spectrum of design options with regard to the helium-filled sealed HDAs. The only duplicated effort was the base cover C-seal (Table 1).

Table 1. Seagate's and Maxtor's Respective Developments of HDAs

Seagate	Maxtor
Base cover C-seal	Base cover C-seal
Glass feedthrough assemblies including advanced designs with multiple pins in one glass seal and epoxy mounted low temperature co-fired ceramic (LTCC) flat interconnect	Epoxy-sealed stick-through pin molded plastic assembly
Wrought aluminum base and cover	Diecast aluminum bases and covers with double epoxy impregnation
Epoxy-sealed spring load elastomer ball fill valves	Swage ball fill valve
Cover compression capture of spindle and actuator shafts without through holes or external screws	Super seal metal foil covered heat attached PSA/engineering hot melt aperture seals

Seagate continued to develop the heat-attached, metal-foil covered engineering hot-melt pressure-sensitive adhesive (PSA) as a final seal and developed the subsequent production expertise to help ensure a 5-year life span. In addition, Seagate developed and patented an initial laser-welded-final cover HDA concept, and later demonstrated the laser-welded-final covers to both diecast and wrought aluminum base production. Other sealed drive designs were rejected because they were overly complex.

Seagate and Maxtor also investigated and developed the following related technologies:

- Hermetic bulkhead connector—read/write and power connections between the internal head stack assembly (HSA) and the external printed circuit card assembly (CCA).
- Hermetic aluminum bases and covers
- Fill valves
- Aperture seals

Helium Gains Acceptance in the Face of Other HDD Developments

Meanwhile, growth in HDD areal density had slowed, which had the effect of decreasing any immediate need for helium HDDs. Also, the switch from 3.5-inch to 2.5-inch form factor mission-critical drives with high RPMs had the similar effect of decreasing interest in helium HDDs. The smaller 2.5-inch form factor disks, sometimes combined with the use of airflow control features (i.e., disk separator plates), had dramatically reduced the airflow-induced turbulence. Clearly, this also delayed the immediate need for helium HDDs. As areal density growth continued to slow, and in order to increase HDD capacity on a standard 3.5-inch 7200-RPM HDD, it therefore became necessary to add disks (platters). HDDs went from four to five disks and, eventually, went to six standard 3.5-inch disks per drive. Due to form factor height restrictions, however, it was not possible to increase the number of standard 0.050-inch thick disks.

Furthermore, the use of a higher number of thinner disks is not possible because the windage induces turbulence and makes 7200-RPM tracking impossible at the desired TPIs. The only way to reduce windage in air-filled HDDs is to significantly lower the spindle speed (RPM). However, the largest part of the business-critical market is not willing to accept lower RPMs due to the performance and throughput loss. This means that helium HDD technology is the only viable path forward for delivering higher capacities because it will allow for an increased number of thinner disks.

Another factor that influences the recent acceptance of helium HDDs is the up to 25% lower power consumption that comes from switching to lower-density helium. In fact, the power savings—up to 2 watts—can significantly add to the overall system power savings possible when in a server farm filled with helium HDDs. The lower run temperature of helium HDDs also contributes to these significant system-level power savings by reducing server fan speeds and air conditioning.

The need for both higher disk counts and lower power for business-critical HDDs is resulting in real interest and market demand for helium drives. And now that the helium drive market is seen as viable, Seagate is able to select from their already developed helium sealing designs and technologies to launch the 10TB Seagate® Enterprise Capacity 3.5 HDD.

Based on this, Seagate selected the following combination of technology features:

- Multi-step forged, wrought-aluminum base
- Initial-final-cover sealed HDA design with a laser-welded-final cover
- Epoxy-bonded in LTCC flat hermetic interconnect
- Internal HDA digital environmental sensors used to measure relative humidity, helium pressure and temperature
- Internal HDA environmental control module (ECM) to control relative humidity and out-gassing
- Epoxy-sealed spindle shaft and wire leads
- Multilayer final seal of final cover fill port

10TB Seagate Enterprise Capacity 3.5 HDD and HGST's Helium Drive—Compared

In addition, when you compare the 10TB Enterprise Capacity 3.5 HDD drive with HGST's helium drive (6TB and 8TB), there are major differences (Table 2).

Table 2: Seagate 10TB Enterprise Capacity 3.5 HDD vs. the Helium Drive From HGST

	Seagate	HGST
Sealed Base Design	Wrought aluminum base: Forged to near net shape in a multi-step process from an aluminum 6061 extrusion	Diecast aluminum base: Dense external skin but with internal porosity between the aluminum walls
Final Cover Laser Weld	A modulated continuous wave laser to weld the final cover to the forged base	Uses a pulsed laser to weld the final cover to the diecast base
Hermetic Feedthrough for HSA	Epoxy bonded in low-temperature, co-fired ceramic interface	Soldered in, pin-in-glass feedthrough molded on a flat steel plate
Internal HDA Environmental Sensors	Uses high-accuracy digital MEMS sensors	No digital environmental sensors in the sealed HDA

Sealed Base Design

The 10TB Enterprise Capacity 3.5 HDD solution has no porosity because the drive is equally dense throughout, meaning that cracks are not likely to occur. As a result, the Seagate drive does not need an additional epoxy injection. In addition, the weld lip has no risk of porosity either—an issue that could cause weld imperfections.

Although HGST may have solved their early production yield issues that centered on porosity in their base die castings, they still employ a workaround to seal possible porosity-induced crack growth that occurs over time and temperature variations.

Final Cover Laser Weld

HGST employs a pulsed laser to weld the final cover to the diecast aluminum base. The resultant weld is less than half the width of their 1mm-wide weld lip that the final cover sits on, and has led to field returns due to handling damage that resulted in helium leak failures.

On the other hand, Seagate uses a modulated continuous wave laser to weld the final cover to the forged wrought base. This resultant weld is the full width of the 1mm-wide lip that the final cover sits on. It is a more robust cover weld design and more resistant to damage.

Hermetic Feedthrough for HSA

HGST uses a soldered-in, pin-in-glass feedthrough molded on a flat steel plate. This, in fact, derives from 1960s aerospace technology. It is also used for three-pin contacts in refrigeration/AC and engines. However, hermetic feedthrough has two significant issues:

1. It has to be soldered in to the aluminum base, which creates a bimetallic interface that is prone to cracking with thermal cycling.
2. Its delicate stick-through pins and 1990s connectors have had a measurable field defective parts per million (DPPM) issue from open or degraded connections.

Seagate uses an epoxy bonded in low-temperature, co-fired ceramic interface. This technology enables higher data rate heads that require higher connector pin counts. It passes multiple extreme temperature thermal cycles and uses HDD standard compression connectors that have proven field reliability.

Internal HDA Environmental Sensors

Except for a low accuracy thermistor for temperature measurement, the HGST helium drive has no digital environmental sensors.

Decades of Proven Research Underpin Seagate's Helium Drive

Seagate uses high-accuracy digital MEMS sensors for measuring temperature, pressure and relative humidity. These measurements are used to improve the reliability and read/write performance of the head-disk interface as well as to monitor the quality of the sealed-in helium environment.

Conclusion

Seagate's high performance and high pin count-capable LTCC flat-hermetic interconnect, along with its non-porous forged aluminum wrought base, allows for strong, thin cross-sections, robust full-width laser-welded-final cover and digital environmental sensors for monitoring the internal HDA environment for precise control of head-to-disk clearance for long-term reliability and R/W (read/write) performance.

With an eye to even higher capacities to meet the cloud-based exabytes that are on the horizon, Seagate is building a solid foundation of enterprise-class technologies and solutions to increase throughput and areal density in HDDs.

seagate.com

AMERICAS Seagate Technology LLC 10200 South De Anza Boulevard, Cupertino, California 95014, United States, 408-658-1000
ASIA/PACIFIC Seagate Singapore International Headquarters Pte. Ltd. 7000 Ang Mo Kio Avenue 5, Singapore 569877, 65-6485-3888
EUROPE, MIDDLE EAST AND AFRICA Seagate Technology SAS 16–18, rue du Dôme, 92100 Boulogne-Billancourt, France, 33 1-4186 10 00