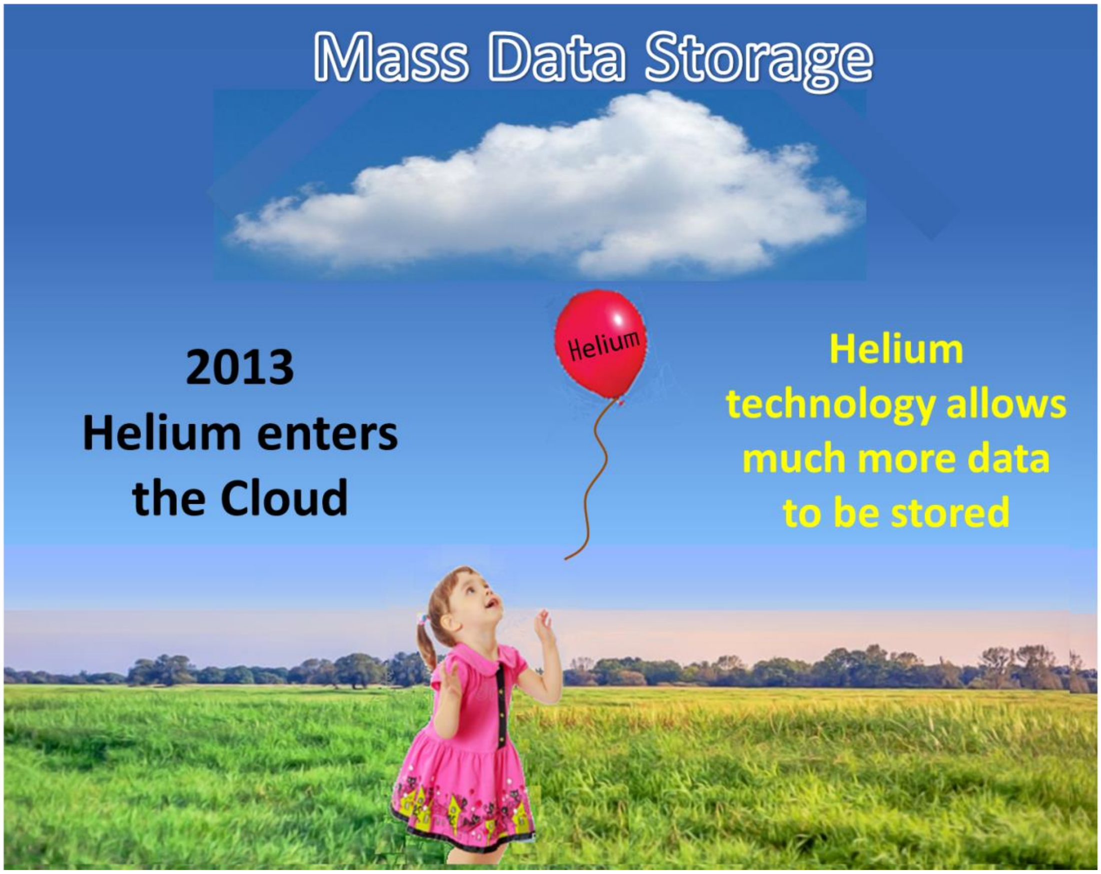
2013: HELIUM- FILLED DRIVES INTRODUCED

HELIUM TECHNOLOGY ALLOWS MORE DISKS PER HDD AND HIGHER CAPACITY



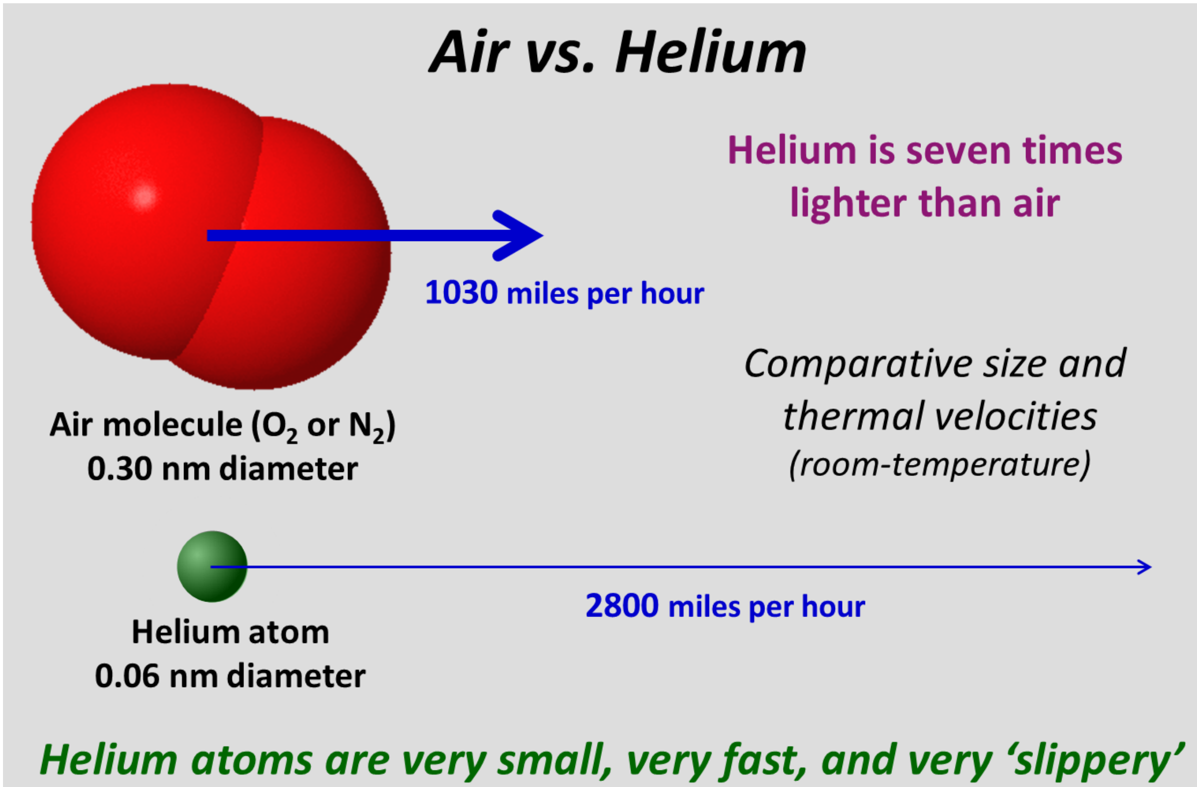
Humans create huge amounts of digital data. Much of this gets stored in massive "Databases" run by the likes of Google, Amazon, Facebook, WeChat, etc. The world-wide entirety of all this data-storage is referred to as the "Cloud". The cloud's data storage hardware resides in numerous massive power-hungry buildings often built near large rivers that can provide cheap electrical power and cooling water. Centralization into such huge data-centers has been enabled by the recent growth of inexpensive, high-speed, high bandwidth data-transmission over the internet.

Within these data-center buildings there are millions of individual storage devices. Most of the data gets stored on hard disk drives, HDDs. These drives record the data magnetically on the surface of rotating disks (typically, 3.5” diameter and 7200 rpm). To store the maximum amount of data, the drives record the largest possible number of data bits per square inch of disk surface and then also pack as many disks as possible into the form-factor.

As gains in areal-density have slowed, more attention has turned to maximizing the surface area available for data. This has included efforts to minimize servo and data overhead and even to making the disks slightly larger. However, the biggest lever is to simply squeeze more disks into the form-factor height. Aside from very basic mechanical design challenges, there are major problems that arise in two areas. First, the power consumption increases with the number of disks and the HDD temperature can become excessive. Second, the necessity of using thinner disks and thinner arms greatly aggravates the internal flow-induced vibrations and makes track-following much more difficult.

Filling the drive with Helium instead of air addresses both of these problems. The density of Helium is much lower than air. As a result, the flow inside the drive remains more laminar and less turbulent. First, this reduces the drag on the disks as they rotate leading to reduced power consumption and less temperature rise. Second, the small random forces on the disk and arms are much smaller because of both the reduced turbulence and the lower gas density. This leads to smaller vibrations being induced in the disk and actuator structures and to better track-following (this was another original motivation aside from adding more disks).

Further benefits from Helium include reduced acoustic noise (appreciated by the customers) and also better heat dissipation and more uniform temperature distribution inside the drive (The write-driver/preamplifier chip, for example, is mounted on the actuator inside the head/disk enclosure. The power levels in the chip change dramatically between read, write, and idle. This can lead to temperature induced distortions in the actuator and to mistracking.

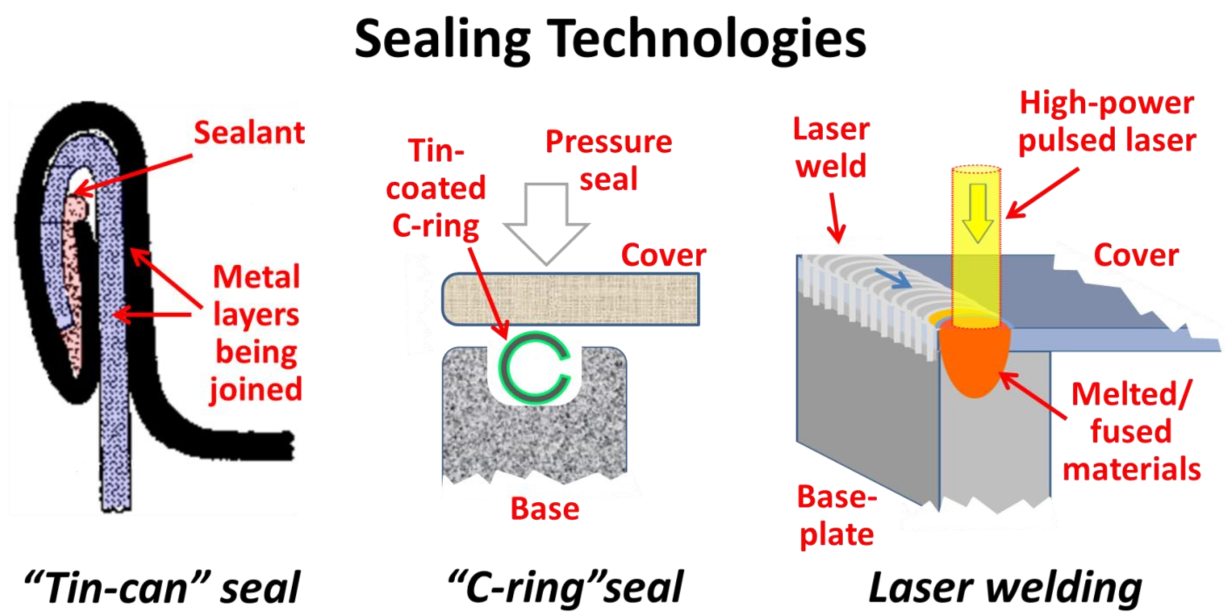


The problem with Helium is how to get it to stay inside the drive! Helium has been called the ultimate escape artist. It has the smallest atomic radius and the least affinity for other substances (doesn't stick to anything). Helium has very high permeance and readily diffuses through many materials. Polymer sealants and gaskets are particularly susceptible. Metals provide more of a barrier (hence metallized party balloons for Helium).

The areas of challenge for a Helium HDD include sealing the through-chassis electrical connections, sealing the Helium fill-valve, and finally sealing a lid on the entire structure. Porosity in the baseplate is minimized by carefully-designed high-pressure vacuum casting or by forging the base and is further helped by the application of an impermeable coating. The through-chassis connection is with metal-glass technology or co-fired ceramic connector. The final seal is achieved by adding an extra aluminum cover over the conventional stainless-steel lid. This aluminum cover is then precision laser-welded to the aluminum base completing the seal.

The advantages of using Helium have been long appreciated. In the 1950s, Remington-Rand working on their Univac computer developed prototypes of a 16,500 rpm Helium sealed drum memory though these did not become commercial products. Remington was bought by Sperry in 1955. As an interesting aside, Sperry was responsible for the inertial navigation gyroscopes that were subsequently deployed in Polaris Intercontinental Ballistic Missiles and then in the Apollo space program. These gyroscopes ran at 24,000 rpm in a sealed Beryllium sphere containing pure Helium at one-half atmospheric pressure.

The first Helium-filled disk-drive, the DDC-7301, was introduced in 1965 by Digital Development Corporation of San Diego. This was followed by a series of drives shipped in the 70's. An interesting maintenance feature of these drives was the "routine (6-9 months) replacement of the helium supply cylinder".



Serious efforts with Helium continued over many years. The major HDD suppliers like IBM and Control Data pursued various approaches but these efforts were invariably thwarted by the difficulty of developing cost-effective reliable sealing technologies. Typically these attempts tried to use the same technology that was so successful in sealing 'tin cans' for foodstuffs. In 1982, NTT introduced the PATTY and GEMMY drives with the intention of using Helium, however the final versions shipped with air.

In 2006, Seagate acquired Maxtor. Both companies had been working on Helium HDDs and both had converged on the use of a compressible C-ring seal between the base and cover. Typically these are formed from spring steel with a malleable coating such as tin that conforms and seals the surfaces. This type of seal was found to provide a reasonably effective seal (up to 5 years) while potentially allowing re-work on drives that failed in manufacturing.

The first Helium drive, shown on right, was shipped by HGST in 2013
(Cross-section shows two extra disks squeezed into the same 1-inch height)

HGST (now Western Digital) finally achieved lasting success with Helium technology in 2013 with the Ultrastar® He6, a 3.5-inch, 7200 rpm drive offering 6 TeraBytes capacity. The lead engineer was A. Aoyagi. During drive bring-up and testing, the Helium was temporarily contained by a conventional cover-plate. When the drive was qualified, a final impermeable cover was laser-welded to seal the drive. This drive packed seven disks and eight arms (increased from five disks and six arms) into the standard 1-inch height (the 'arms' carry the read/write heads and extend between the disks). The use of Helium drives was highlighted in the role they played in storing the massive quantity of data involved in creating the first ever image of a black hole.

T. Hayakawa, K. Uefune, A. Aoyagi, K. Suzuki, T. Chawanya of HGST receive the JSME Technology Award 2016 for the "Development of Helium sealed high capacity HDD". (*courtesy A. Aoyagi*)

In 2016, Seagate announced it was shipping in volume a 10 TeraByte drive (also on 7 disks) that used Helium Technology. The lead engineer was N. Gunderson. A major difference in technology from HGST was the use of a forged aluminum base. Forging largely avoids the porosity associated with die-cast aluminum (aside from leakage concerns, porosity can affect the quality of the laser weld). Additionally the Seagate drive included a MEMS device that continuously monitored the internal Helium pressure.

More recent products have seen the number of disks increase from seven to eight disks (UltraStar He12) in April 2017 and then to nine disks (Toshiba MG07ACA) in March 2018. Disk thicknesses have dropped accordingly from 1.27 mm to 0.635 mm. The thinner disks and actuator/arm structures make the drives more susceptible to external shock and vibration and all these drives employ high-bandwidth secondary 'microactuators' to help follow the tracks.

As of March 2020, Helium is used in all high-capacity drives for data-centers. These come from all of the three remaining HDD manufacturers (Western Digital, Seagate, and Toshiba).

Note: N. Gunderson (Seagate) provides a comprehensive discussion on the history and technology of Helium-sealed drives [see reference below].

CONTEMPORARY DOCUMENTS

- R. Kaneko, Y. Koshimoto, "Technology in compact and high recording density disk storage", IEEE Trans. Magn., Vol. 18, No 6, pp. 1221-26, Nov 1982 ➔

- R. Kaneko, Y. Koshimoto, "Technology in compact and high recording density disk storage", IEEE Trans. Magn., Vol. 18, No 6, pp. 1221-26, Nov 1982 ➔

- L. Mearian, "6 TB Helium filled hard drives take flight, bump capacity 50%", Computer World, Nov. 4, 2013 ➔

- “HGST UltraStar He6 Data Sheet”, Western Digital public document, 2014 ➔
- “Beyond Air. Helium Takes You Higher”, Helioseal® Technology, Western Digital Brochure, 2015 ➔
- A. Aoyagi et al., “Development of Helium Sealed High Capacity Hard Disk Drive”, JSME, Information, Intelligence, Precision Equipment Division, Jan 2016 ➔
- N. Gunderson, “Decades of Proven Research Underpin Seagate’s Helium Drive”, Seagate Technology paper, TP686.1-1602US, Feb, 2016 ➔
- C. Ludeman, “The Rise of Helium”, Western Digital Blog, July 20, 2017 ➔
- L. Sharp, “Our Helium-Sealed Technology Awarded Prestigious JSME Medal and on Display in Tokyo Museum”, Western Digital Blog, Aug. 10th, 2017 ➔

MORE INFORMATION

- “Enable the impossible: the challenge of Helium sealing”, Japan Society for Mechanical Engineering Magazine, Vol. 121, No. 1191, pp. 44-45, Feb 2018 (in Japanese) ➔
- Cindi Grace, “What Does Helium Have to Do with the Black Hole Image?”, Western Digital Blog, April 2019 ➔
- T. Coughlin, “Black Hole Storage”, Forbes (online) , April 2019 ➔