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How temperature affects IT data storage

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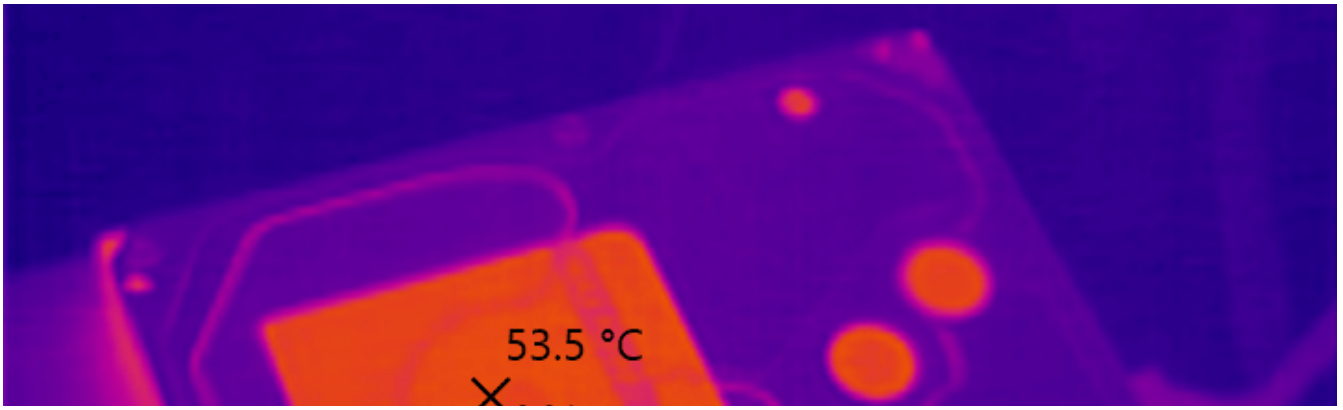
How Temperature affects IT Storage

Why is monitoring HDD operating temperature important?

It is well known that Data Center temperature monitoring (https://www.akcp.com/solutions/data-center-monitoring/) is important to improve server performance and lifespan. Increased heat conditions in your Data Center can even result in data loss. This is another reason why Data Center environmental monitoring, particularly temperature monitoring, is important.

Direct Attached Storage (https://www.theseus.fi/bitstream/10024/50996/1/Koivisto_Jari-Pekka.pdf) devices come in two common types. Hard Disk Drives (HDD) (https://www.ubuy.fi/en/search/?q=hard+disks) and Solid State drives (SSD) (https://www.mouser.fi/c/embedded-solutions/memory-data-storage/storage/solid-state-drives-ssd/). Both can be affected by temperature. In this article, we will investigate how heat affects their reliable operation and long-term storage capabilities, and how this can be managed by temperature monitoring systems.

Hard Disk Drives (Traditional Magnetic Storage)



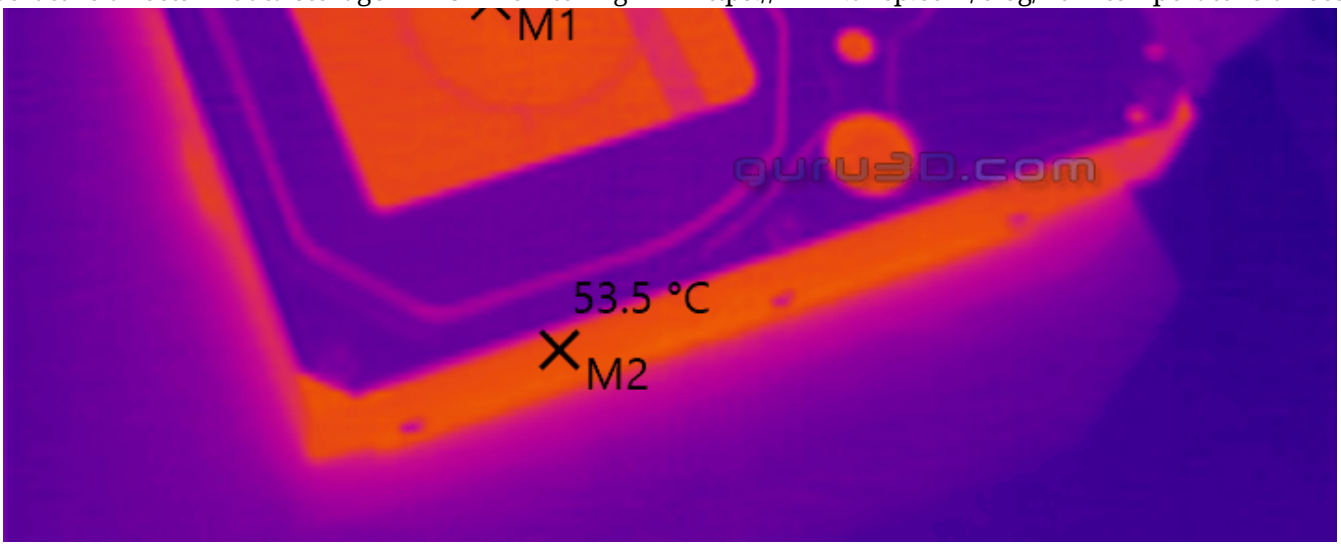


Image source: Guru3d.com (https://www.guru3d.com/articles-pages/toshiba-nas-n300-10tb-hdd-review,14.html), Toshiba NAS N300 10TB HDD review by Hilbert Hagedoorn

What is the optimal temperature for hard disk drive operation?

Most hard drive manufacturers specify a normal operating temperature between 0 °C to 60°C (32°F to 140°F). This is however not the optimal temperature range for safe and reliable operation. If you are exposed to prolonged operation at temperatures under 20°C (68°F) or above 50°C (122°F), the drive's useful life will be impaired.

If your computer has to be operated in an environment with a minimum ambient temperature less than 5°C (41° F) and/or a maximum ambient temperature greater than 50°C (122°F), you will need to choose enterprise hard drives which have an extended operating temperature range. These drives include components designed for reliable operation in low and high-temperatures.

When a hard drive is too hot or too cold mechanical and electrical issues within the drive (head misalignment, condensation, head stuck to the platter, printed circuit board issues, etc.) can occur.

According to a 2007 Google HDD study (https://research.google/pubs/pub32774/), drives that are cooled excessively could actually fail more often than those which are running a little warmer.

Nevertheless, high heat can reduce the service life of a hard drive. National Instruments tests (http://web.archive.org/web/20160511124452/http:/www.ni.com/white-paper/5730/en) noted that just a 5°C (9°F) increase in temperature can reduce a hard drive's life by as much as two years.

As drives heat up during operation, performance degradation can happen. Modern hard drives will throttle their read and write speeds when the drive reaches a critical pre-set temperature (usually around 60°C or 140°F). The performance will further decline even down to 1 MB/s until the drive is able to cool down again – according to a test run by Anandtech (https://www.anandtech.com/Show/Index/3858?cPage=3&all=False&sort=0&page=7&slug=the-worlds-first-3tb-hdd-seagate-goflex-desk-3tb-review).

Therefore, we recommend that for the safest temperature of a hard drive while running should be kept between 20°C (68°F) and 45°C (113°F).

What causes the high temperature in hard drives?

- Higher than average workload on the HDD (continuous reads & writes)
- Inappropriate cooling of the computer case and the drive (dust, failed ventilation, high ambient

temperature, drive operating in narrow enclosed space, drive gets heated by another hot component)

- Failing hard drive (bad sectors and mechanical issues)

The most important factor in keeping your drives in this thermal envelope is to regulate the ambient temperature via air conditioning. You will need to ensure your data center's temperature is within safe limits, as not only hard drives create heat but other hardware components as well (such as CPUs, RAM, etc.).

The second most important is to keep good ventilation around the drive. Compare the drive's own temperature sensors with external (out of server case) sensor readings. If there are huge differences, it will require your attention to improve the airflow of the case.

Servers need to expel as much heat as they can, as quickly as they can, to keep the hard drives and other components operating at their optimal temperatures. If the heat in the room rises quickly, the servers and their hard drives won't be able to operate within the recommended temperature ranges and will slow down, causing performance issues and possible hardware failure.

How AKCP can help?

We have multiple solutions for monitoring your data center. Whether you are looking for a few temperature and humidity (https://www.akcp.com/akcp-products/single-port-temperature-humidity-sensor/) sensors for your computer room or rolling out a multi cabinet monitoring solution, AKCP has an end-to-end data center monitoring solution including sensors and AKCPro Server DCIM (https://www.akcp.com/akcp-products/akcpro-server/) software. Our Rack+ (https://www.akcp.com/rack-plus/) solution is an integrated intelligent rack or aisle containment system. Pressure differential sensors (https://www.akcp.com/akcp-products/cabinet-analysis-sensor/) check proper air pressure gradients between hot and cold aisles. RFID Cabinet locks (https://www.akcp.com/akcp-products/rfid-swing-handle-lock/) secure your IT infrastructure.

AKCP provides both traditional wired and wireless data center monitoring solutions. Our Wireless Tunnel™ System (https://www.akcp.com/solutions/wireless-tunnel-system/) builds upon LoRa™ technology (https://en.wikipedia.org/wiki/LoRa), with specific features designed to meet the needs of data center monitoring. Wireless sensors give rapid deployment, easy installation, and a high level of security. It is the only LoRa based radio solution that has been designed specifically for critical infrastructure monitoring, with instant notifications and on sensor threshold level checking.

Hard Drive Long-term storage temperatures

When a hard drive is used as long-term data storage, it will usually fare better than SSD drives (as we will examine in the SSD section). When turned off, a hard drive could be safely stored between -40°C (-40°F) and 70°C (158°F), but it will vary between models. Western Digital recommends that a standard consumer drive's storage temperature be between 12°C (53.6°F) and 33°C (91.4°F). You would also need to choose a storage location that isn't humid, or in direct sunlight.

After storing a hard drive at a higher or lower temperature, you should allow the drive enough time (at least 2-3 hours but longer if there are bigger differences) to heat up to room temperature before you attempt to use it. If the ambient temperature is not highly fluctuating around the drive (higher or lower than 15-20 degrees), as magnetic storage it will most likely keep your data safe and readable even many years later after it has been turned off.

Other than the environmental conditions around the drive, you would not need to worry about the data retention of a hard drive. It is permanent magnetic storage and no need to be turned on to "refresh the stored data". Therefore, it is still recommended that you use hard drives for off-site or external data storage of your backups – they are still more cost-effective and reliable for this application.=

SSDs (Solid State Flash Memory Storage)

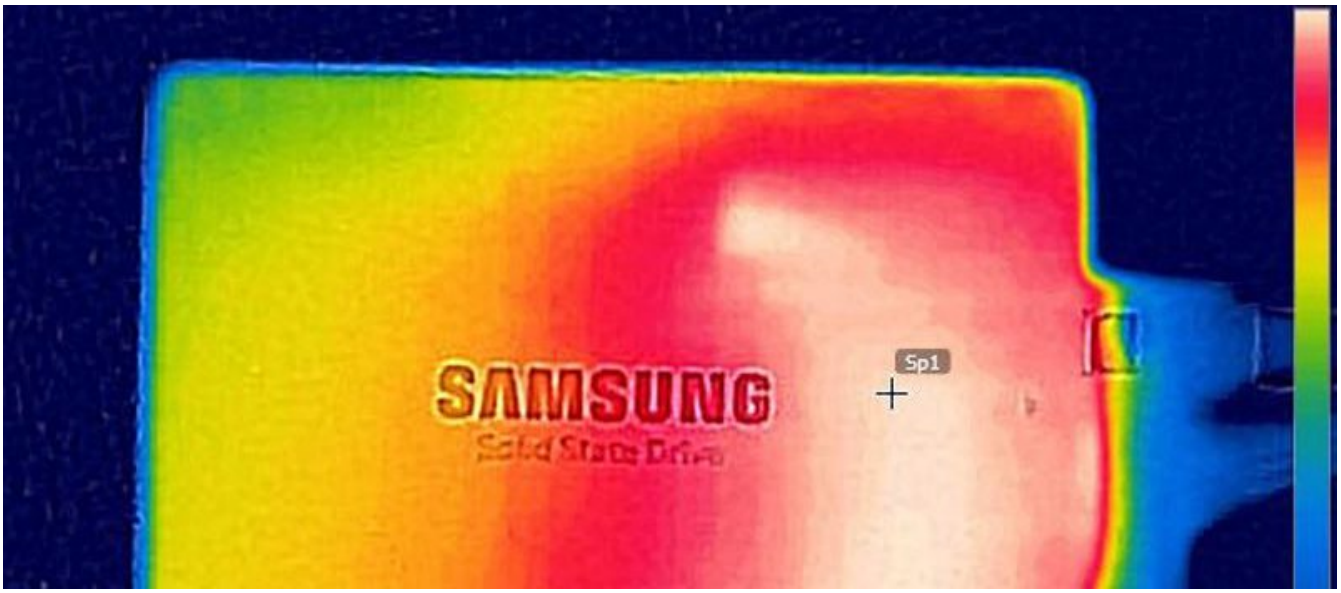


Image source: Harddrivegeek.com (https://harddrivegeek.com/ssd-temperature/), Safe SSD Operating Temperature: Is Your SSD Running Too Hot?

SSD Working Temperatures

Solid-state drives can also get very hot during operation, even though they have no moving parts in them and consume less power. Generally, they get even warmer than the average hard drives by about 10°C. Most SSDs on the market are rated for running within a temperature range of 0ºC up to 70ºC (32ºF to 158ºF).

M2 SSDs and PCI-E SSDs could easily reach this thermal limit quicker due to their exposed memory and controller chips which are operating at high bandwidth and speed, therefore it is always recommended that you use a heatsink on these SSD types and provide good computer case ventilation.

Case studies like the ones from Facebook (https://www.digitaltrends.com/computing/facebook-study-finds-no-correlation-between-ssd-reads-and-failure-rate/) and Digitaltrends (https://www.digitaltrends.com /computing/facebook-study-finds-no-correlation-between-ssd-reads-and-failure-rate/) have found that the hotter your SSD operates, the quicker it will wear out the flash memory inside the drive. This is mostly a concern for data centers where these drives need to run 24/7.

Therefore, for reliability, it is recommended that you keep the SSD's operating temperature range between 30ºC and 50ºC (86ºF to 122ºF).

During normal operation (disk reads & writes) for shorter periods, the SSD's temperature can normally rise by 5-20°C compared to the idle temperature. However, under heavy load, it is normal to see even more increased temperatures for short periods of time.

Just like modern HDDs, most SSDs implement thermal throttling as a safety feature if a drive gets too hot. As the driver approaches the 70ºC (158°F) limit that most manufacturers set, the more likely it is that the drive will start to slow itself down to prevent failure. The SSD will slow down drastically until the temperatures return to a reasonable range (around 50ºC or 122°F), at which point the drive's standard performance should return.

What causes High SSD Temperatures?

- Higher than average workload on the SSD (continuous reads & writes)
- Inappropriate cooling of the computer case and the drive (dust, failed ventilation, high ambient temperature, drive operating in narrow enclosed space, drive gets heated by another hot component)
- Performance and power-saving feature issues with the SSD controller firmware or the computer's mainboard – it is recommended to upgrade your SSD's firmware more often
- Failing drive (bad blocks and electrical issues)

The general recommendations for keeping the SSDs within optimal temperature range are the same as with hard drives: keep the ambient temperature regulated, and provide ample airflow for the drive.

AKCP's datacenter monitoring solutions (https://www.akcp.com/solutions/data-center-monitoring/) can help you monitor both storage types and your servers.

Long-term storage temperatures

Unlike hard drives, for SSDs it is more important to avoid large differences between the operating temperatures and the storage temperatures if the drive is powered off for a while (several months or more).

Flash data retention is dependent on the ability to determine the level of charge stored in each flash cell. Over time this charge will deteriorate and must be refreshed, else the data stored in the flash cell will be lost. When the flash is powered (normal operating), the cells are periodically refreshed to "top off" and restore lost charge.

However, when the flash is not powered (as in storage) the cells are not refreshed and their charge degrades with time. The rate of charge loss (detrapping) or data retention is related to the storage temperature: it is accelerated with higher temperatures and slows with lower ambient temperatures.

For example, if a drive's active temperature is only 25-30°C (77-86°F) and the power off is 55°C (131°F), the data retention can be as short as one week!

However, this is generally not an issue, as the storage temperature will be lower than the active temperature of the drive. Generally, you should not need to be concerned with the storage temperatures of SSDs, as long as they are not over 40°C (104°F).

National Instruments has a good article (https://www.ni.com/en-th/support/documentation/supplemental/18/effects-of-temperature-on-ssd-endurance.html) examining the SSD behavior in high storage temperatures and another article regarding SSD endurance (https://www.ni.com/en-th/support/documentation/supplemental/12/understanding-life-expectancy-of-flash-storage.html).

SSD endurance is defined by the amount of data that can be written to a flash-based drive before it becomes unreliable, where reliability is dictated by being able to read data back from an unpowered drive after a set duration of unpowered storage.

There are several conditions that must be met when an SSD manufacturer is determining the endurance rating for their drives:

- The drive must maintain its capacity, meaning that it cannot retire so many blocks that the user capacity would decrease.
- The drive must meet the required UBER (number of data errors per number of bits read) spec as well as be within the functional failure requirement.

- The drive must retain data without power for a set amount of time to meet the JEDEC spec.

After wearing out, client SSDs would need to be able to hold their data for one year at 30 °C (86 F), or for enterprise SSDs for 3 months at 40°C (104°F), both of which are above typical room temperature.

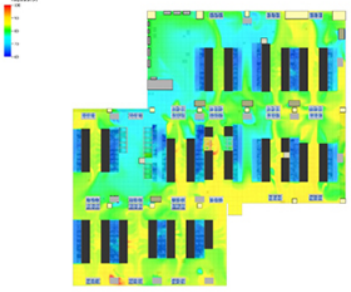
Important: all these endurance conditions are described for a drive that has already reached its maximum number of data writes (worn out), i.e. if a drive is rated at 100TB, it must meet these specs after 100TB of writes.

If the drive is not worn out (has not yet reached its maximum write capability) the data retention capability will be much better: for new drives, it is considerably higher, typically over ten years for MLC NAND-based SSDs.

Anandtech has a great article (https://www.anandtech.com/show/9248/the-truth-about-ssd-data-retention) to explain this in further detail.

Industry Articles and News (https://www.akcp.com/about-akcp-2/akcp-news/)

(https://www.akcp.com/blog/temperature-monitoring-support-the-vaccine-cold-



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Temperature Monitoring Supports Vaccine Cold Chain

Using temperature sensors to monitor the vaccine cold chain can ensure effective and viable vaccines are delivered.

Find out more (https://www.akcp.com/blog/temperature-monitoring-support-the-vaccine-cold-chain/)

How Containment Saved Energy for Saudi Aramco Data Centers

How Containment Saved Energy for Saudi Aramco Data Centers

Find out more (https://www.akcp.com/blog/how-a-cold-aisle-containment-helped-saudi-aramcos-energy-consuming-data-centers/)

Establishing a Drug Stability Budget for Transport

How much exposure can temperature sensitive pharmaceutical products handle? How is the drug stability budget calculated?

Find out more (https://www.akcp.com/blog/drug-stability-budget-during-storage-and-transit/)

Case Study: North Point Ministries Data Center

North Point Community Church has 7 locations within the greater Atlanta Georgia area, and 400 affiliated churches worldwide. With live broadcasts of services and on-demand replays to their congregation the church has invested heavily in IT infrastructure. A 20+ rack data center was established which required an environmental and power monitoring system. AKCP were selected for the project.

Dual temperature and humidity sensors were installed at racks and CRAC vents to monitor environmental conditions. Ensuring that the servers are running at optimal temperatures increases longevity and reliability of the equipment.

Read more… (https://www.akcp.com/case-study/akcp-monitors-north-point-ministries-community-church/)

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About AKCP

AKCP established in the USA in 1981, has 30+ years experience in professional sensor solutions. AKCP created the market for networked temperature, environmental and power monitoring in the data center. Today with over 150 employees and 200,000 installations, AKCP is the world's oldest and largest manufacturer of networked wired and wireless sensor solutions.

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