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BSI Standards Publication

Imaging materials — Magnetic hard drives used for image storage — Care and handling

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National foreword

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Imaging materials — Magnetic hard drives used for image storage — Care and handling

Matériaux d'imagerie — Disques durs magnétiques utilisés pour le stockage d'images — Soins et manipulation

Reference number
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Foreword

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 42, *Photography*.

Introduction

Magnetic hard disk drives (HDD) are used widely for short and extended-term storage of data, including audio, still, and moving images. HDDs are popular because they are small, inexpensive, self-contained, and have very high storage capacities. The most common form of HDD comes in a semi-sealed metal housing that measures 25 mm × 100 mm × 130 mm. Each unit has a connector for power and a connector for receiving and transmitting data and commands. Each HDD of this form contains one to as many as five 89 mm diameter magnetic disks (sometimes called platters) coated on an aluminium substrate. The location of working HDDs can be internal or external to computer workstations, and can be connected singly or in groups.

There are three broad categories of HDDs.

a) Consumer. Consumer HDDs are the most common types of HDDs. They are low in cost and are made for consumer and office work.

b) Enterprise. Enterprise HHDs cost more, are subjected to additional testing at the factory, and are intended for higher performance and reliability, and more intensive usage. They are typically used as part of data centre storage systems. They usually run at a higher rotational speed.

c) Miniature. Miniature HDDs have disks with smaller diameters and are used in mobile computers, including laptop computers and mobile consumer electronic devices.

There are several operating modes for HDDs, and these are described in Clause 3. In general, the three most common modes of HDDs are

a) online,

b) online but inactive, and

c) off-line.

The main longevity issues for HDDs are failures due to natural disasters, manufacturing defects, faulty electronic components, or obsolescence of the software interface. Proper care and handling helps reduce the risk of failure from physical impact, environmental extremes, and contamination, but proper care and handling by itself will not prevent failure. Migration and the making of backup copies are also strategies to mitigate against failure. Many HDD users migrate their entire digital collections every five years. Medium- and long-term storage of data on HDDs is not endorsed. Medium- and long-term storage of data on HDDs requires frequent backup copying, system mirroring, or other procedure to mitigate the significant problems posed by the use of HDDs.

HDDs used for storage purposes should not be left inactive for several years as no experience documents the reliability of HDDs in an extended idle storage mode. Also, all electronic media, including HDDs, have the possibility of failure. Therefore, all data shall be duplicated.

This International Standard focuses on the care and handling of HDDs, as well as the preservation of data stored on HDDs. The physical media is only one component in the preservation of data on HDDs. Data preservation is dependent on a total system to ensure data integrity.

Imaging materials — Magnetic hard drives used for image storage — Care and handling

1 Scope

This International Standard concerns the storage, care, and handling of HDDs. It recommends handling procedures to maximise the effective life of the data written on magnetic HDDs. Faulty care and handling methods can cause damage to a disk and the contents written thereon. It also recommends storage practices to preserve both the hard disk media and the content encoded thereon.

The recommendations in this International Standard apply where the desired result is extended-term retention of the data encoded on the disk. The use of the phrase "care and handling" in this International Standard is restricted to the physical domain or hardware aspects of the HDD. This International Standard is not intended to address associated or relative system aspects of HDDs. With recognition that the scope of systems is covered in other standards, this International Standard precisely aims to fill a void of information on HDDs as physical media with failure mechanisms and handling risks.

This International Standard does not promote or advocate that proper physical care and handling represents the only element on the path to extended-term usage (more than two years), but rather is part of a comprehensive set of practices to mitigate risks in the long term preservation of content stored on HDDs.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
advanced technology attachment
ATA
type of protocol that interfaces the hard disk drive with the computer

Note 1 to entry: Also, see SATA.

2.2
backup
duplicate of stored data

Note 1 to entry: It is recommended to store the back-ups at a remote site in case of a disaster.

2.3
BLER
number of erroneous blocks per second measured at the input of the C1 decoder (see ISO/IEC 60908) during playback at the standard (x 1) data rate averaged over a 10 second measuring period

Note 1 to entry: Standards ISO/IEC 10149 and ANSI/NAPM IT9.21-1996 specify a maximum BLER rate of 220.

2.4
cartridge
housing for recording media

Note 1 to entry: Cartridges for removable HDDs contain only the disk and not the read/write heads or interface electronics.

2.5
disk array
multiple HDDs with a common controller and file system

2.6
disk format
structure and composition of data storage on a disk

2.7
enterprise storage
ES HDDs
HDDs intended for data center storage systems with higher performance and reliability, and usually running at higher rotational speed

Note 1 to entry: These cost more than consumer HDDs, but are subjected to additional testing at the factory.

2.8
extended-term storage conditions.
storage conditions suitable for the preservation of recorded information having permanent value

2.9
fibre channel
FC
hard drive electrical-optical interconnect allowing high performance data transfer speed

2.10
file
encapsulation of data and metadata

2.11
file format
structure and composition of data and its associated metadata in a file

2.12
hard disk
writable computer storage medium consisting of an aluminum alloy platter coated with a magnetic material and a protective layer

2.13
hard disk drive
HDD
electromechanical device consisting of one or more magnetic disks (platters), read & write heads, a motor, and control electronics usually contained within an enclosure and used to store data

Note 1 to entry: Also commonly referred to as hard drives or disk drives.

2.14
integrated development environment
IDE
software application that provides comprehensive facilities to computer programmers for software development

2.15
massive array of idle disks
MAID
disk array consisting of HDDs that are normally inactive but can be powered up quickly on demand

Note 1 to entry: These HDDs can be configured as a RAID system with the data written on more than one HDD.

2.16
media
any physical material that stores data

2.17
migration
copying of data from one storage medium to another

2.18
mirrored HDDs
data storage configuration in which identical data is stored on two or more HDDs

2.19
parallel advanced technology attachment
PATA
parallel HDD interconnect protocol

Note 1 to entry: See SATA.

2.20
parity
disk management configuration which stores error correction information (checksums) on a dedicated disk for the purpose of automatic data recovery

2.21
redundant array of independent disks
RAID
disk array that employs two or more drives in combination for fault tolerance and performance

Note 1 to entry: The HDDs are always spinning and data can be written over several HDDs. There are several RAID levels, with increasing performance per level (noted below). Levels 1 – 5 still maintain a risk of total data loss.

Note 2 to entry: See the Appendix for the description of each RAID level.

2.22
reformat
copying of data file or files from one file format to another file format

2.23
refresh
copying of data files without change in file format or medium

2.24
serial advanced technology attachment
SATA
HDD interconnect protocol that is faster than parallel (PATA)

Note 1 to entry: Also see ATA.

2.25
server
computer system that provides data and software to one or more computers on a network

2.26
small computer system interface
SCSI
HDD data transfer and control protocol that allows high speed data transfer between a computer/workstation and peripherals.

Note 1 to entry: SCSI is a common interface for enterprise HDDs.

2.27
smart monitoring and reporting technology
SMART
standard diagnostic protocol built into HDDs and used to monitor the operating condition of a HDD or HDDs and report potential problems to the user

2.28
striping
segmentation of logically sequential data, such as a single file, so that segments can be assigned to multiple HDDs

3 HDD components

HDDs are magnetic storage devices consisting of one or more disks requiring a connection to a compatible computer or other host device to allow for the persistent storage of data and/or programs. The following are the components of an HDD.

3.1 Disks

HDDs contain one or more disk per HDD, each disk having a magnetic coating. Each disk is made of aluminium with a thin coating of a magnetic material covered by a protective layer. The magnetic coating is sometimes coated with a lubricant.

3.2 Motor and spindle

The disks are mounted on a common spindle usually concentric to the centre shaft of the drive motor.

3.3 Read/Write head

An electromagnetic transducer mounted on the moving end of an arm that traverses the disk reading and writing data constitutes the typical read/write head. The head floats just above the disk surface on a very thin cushion of air.

3.4 Servo head

The servo head is a separate magnetic head that is mounted on a movable arm located at the base of a spindle. Pre-written tracks located on the disk are used to track rotation of the disk and to track read/write locations on the written disk.

3.5 Control electronics

Control electronics consist of circuitry and components that control the drive sub-systems, including the heads, the disks, and the motor to enable the reading and writing of magnetic signals containing digital data. Some HDD functions are controlled by these pre-programmed electronics and some are controlled by a separate drive controller.

3.6 Interconnections

HDDs are only useful when using one of several established interconnection protocols which include physical specifications as well as logical specifications for data transfer control functions. The physical specification defines the cables, shapes of connectors, and electrical parameters. The logical specification models the data structure and the command sets.

External connector protocols attach HDD's to drive controllers and computers. Examples of internal protocols are IDE, PATA, and SATA. Examples of external protocols are the four-pin firewire (IEEE 1384) cable or the USB cable. SCSI is an example of an internal and external specification. For use of features like SMART and temperature monitoring, a 40-pin cable for information along with a four pin power cable is required. Some interconnection standards include power to the drive while others require a separate power supply. There are several standards in each category which are subject to change.

4 Possible physical configurations

4.1 Disk arrays

Several HDDs, in most of the cases mounted in 19-inch wide racks and controlled by a computer, are called disk arrays.

4.2 Single HDD

A single HDD can be read using a small desktop enclosure that is connected through cable to a computer.

5 Access and usage options

5.1 Online HDDs (connected and powered)

Disk arrays can be powered constantly, and can be instantly accessible. However, continually operating HDDs in this state will consume power and can wear out the moving elements sooner. Disks that are operated constantly are continuously accessible by the host system and can perform self-monitoring operations. RAID-5 is the most commonly used disk array configuration. RAID-5 has a potential problem because the data can be lost if a second error is detected during the time that the system is correcting an error. RAID-6 does not have this problem, but RAID-6 requires more memory than RAID-5. See Annex A.

To avoid data loss, RAID systems shall not be powered off during error-checking or rebuilding operations.

5.2 Online but inactive HDDs (connected, not spinning)

MAID disk arrays of HDDs will last longer because they are normally idle (powered off). Also, since they are normally idle, they use much less power than a RAID system.

5.3 Off-line (not connected, not spinning)

HDDs can be disconnected completely from host systems and can be placed on shelves in an archive the same way that tapes and films are stored. They shall be sample-tested once each year. HDDs stored on shelves have the potential danger of not being usable in the future if the system software is changed without checking that all of the different types of HDDs on the shelves are compatible with the new software. This will require the guidance of an experienced technician or information technologist.

These three usage options for HDDs are all capable of maintaining persistence of data but differ in accessibility.

Table 1 — Hard disk drive usage options

	Connected	Spinning
Online	Yes	Yes
Inactive	Yes	No
Offline	No	No

6 Reliability

To ensure the integrity of the data on an HDD, the drive shall be turned on and checked a minimum of once every two years.

Disk arrays can be configured so that each HDD is fully tested in automated mode for errors on a periodic basis. If an HDD has excessive errors, it can either be copied automatically or the computer can flag the problem for the operator to decide on the proper course of action.

It is widely recognised that redundancy is a fundamental practice in ensuring the reliability of an archival storage system. Redundancy can be implemented through HDD system architectures as well as through institutional practices. Current system architectures that implement redundancy features through various technologies include both RAID-6 and MAID-6 systems. From an institutional practice perspective, redundancy can be implemented through creating mirror images of data on multiple HDD storage systems. This practice creates a copy of the contents stored on an HDD, in whole, onto one or more additional HDDs. The mirror HDD shall be stored off site to avoid loss of data in case of a local disaster. For added insurance, it is advisable that the HDD storage systems used as mirrors of each other are not duplicate brand and model numbers that can share a potential common failure mechanism.

7 Data quality

The integrity of raw, uncorrected data on HDDs shall be checked periodically. If the error rate has increased significantly, the data shall be copied onto a different disk. Procedures are available to check and copy or migrate data automatically. Technologies are available (see 2.27, SMART) which can monitor error rates, warn of high error levels, and determine if the data shall be rewritten. Both enterprise and desk top classes of HDDs have a SMART utility that can warn of dangerously high error rates. The SMART utility outputs can be used by computer software to determine if the drive data records shall be rewritten.

End-of-life is the occurrence of any loss of information. Ideally, each specimen is tested until the first loss of information occurs. Realistically, this is impractical. This International Standard considers maximum BLER to be a high-level estimate of the performance of the system. IEC 60908 states that the BLER averaged over any 10 s shall be less than 3×10^{-2}. At the standard (1X) data rate, the total number of blocks per second entering the C1-decoder is 7 350. Thus, an equivalent limit on BLER is 220 blocks per second. A BLER of 220 is an arbitrary level chosen as a predictor of the onset of uncorrectable errors and thereby end-of-life. A BLER of 220 corresponds to an upper limit for error correction. As a result, lower BLER discs are recommended to use for longer-terms of storage.

8 Interoperability/Compatibility

The interoperability and compatibility of hardware becomes an issue as new standards are created and hardware available in the marketplace continues to change. These factors promote obsolescence of existing technologies. When obsolescence of a technology occurs, the risk of incompatibility and lack of interoperability between the existing technology and the new technology is increased. Although this fact is widely recognised, there are no standardised methods for risk migration which addresses interoperability and compatibility. These issues are outside the scope of this International Standard. It is recommended that interoperability and compatibility not be assumed and that concern be given to obsolescence factors when choosing a new technology for data storage.

9 Migration

Procedures shall be established for migrating data. Migration can be done automatically. Checks on error rates shall be performed during the migration cycle.

In archives, the data can be used frequently or infrequently, in connected or disconnected mode. Frequency of use can dictate the configuration used. Since most of the data stored in archives is rarely used, HDDs do not need to be spinning, except for occasional integrity testing. Often-used HDDs can be maintained in online mode but idle until activated.

10 Environmental factors

10.1 Temperature and humidity

In operating conditions, the maximum temperature shall be 35° C, but the recommended operating temperature shall be (22,5 ± 2,5) °C. The air around HDDs shall always be moving to draw away the

heat. A small, quiet external fan might be required. Also, a computer or an HDD shall not be operated on a soft surface because this can restrict air flow.

The maximum operating humidity shall be 60 % RH.

HDDs can withstand higher than recommended temperatures and humidity for short periods of time, such as when being shipped. When shipping HDDs, they shall be well insulated to decrease the effects of changing shipping environments as well as to protect them if dropped.

10.2 Condensation

Moisture condensation can occur when moving HDDs from cool conditions to warm, humid environments. The dew point temperature is the temperature at which moisture begins to condense on a surface. The more humid the air is, the higher the dew point temperature. When the temperature of the environment is below the dew point temperature, moisture will condense. HDDs shall not be subjected to temperature/humidity conditions which cause moisture condensation. Such condensation can cause contaminants or moisture to invade the HDD housing. It also can cause corrosion of the connectors. These problems can be prevented by following recommended acclimatisation procedures (see 10.3).

10.3 Acclimatisation

Acclimatisation is the process of allowing an HDD to warm up above the dew point temperature, thereby avoiding condensation. It can be accomplished by placing the HDD in a staging area at conditions that will not result in condensation for a sufficient period of time. An alternate procedure is to place the HDD in a closed enclosure (e.g. a plastic bag) until it has warmed to a temperature above the dew point.

10.4 Magnetic fields

The magnetic coercivity of the disk is very high. It is unlikely that the written data on an HDD would ever be affected by normal ambient magnetic fields in an archival environment. Magnetic fields below 30 gauss will not harm the written data.

11 Possible failure mechanisms

11.1 Physical shock

HDDs are precision mechanisms and shall be handled gently to avoid physical shock. Shock limits are much lower in operating mode than in non-operating conditions. During operation, shock can damage the disk if the head is on the disk. Desktop computers and HDDs shall never be moved while the power is on and the disk is revolving. HDDs shall be placed carefully on a cushioned surface when not connected. When shipping HDDs, each HDD shall be totally surrounded with padding, such as small bubble wrap.

11.2 Plugging/unplugging connectors

It is extremely important to take great care when plugging and unplugging connectors. Many connectors utilise dense rows of small pins as connection points. Each of these points is fragile and easily deformed or broken. Carelessness can result in loss of access to data. In extreme events where inaccurate connections are made, permanent disk damage and loss of data can be the consequence.

Connection and disconnection of these interfaces shall always be performed with the power off. When connecting or disconnecting an internal HDD in a computer, all power shall be turned off and the computer shall be unplugged. Due to the risk of electrostatic discharge, proper handling techniques (See 11.9.1) shall be utilised at all times.

11.3 Head-to-disk stiction

Historically, HDDs have had major problems caused by the ultra-smooth magnetic heads sticking to the mirror-finish on the disk/platter. This condition is called stiction. Many HDD manufacturers have alleviated stiction problems by parking the head off the disk when the disk is not spinning.

11.4 Heat

The most common reason for failure of electronic components in an HDD is high heat. To alleviate such failures, good airflow around the area where the HDD is located shall be provided. Adding a small and quiet external fan will help increase disk life.

11.5 Humidity

The disks (platters) in some HDDs can corrode due to moisture condensation caused by moving the HDD too rapidly from a cold environment to a warm environment (see 10.2 and 10.3). Furthermore, long term exposure to high humidity can cause corrosion to connectors.

11.6 Air quality and particulates

Excessive particulate matter in the environment such as dust and debris can restrict air flow and the proper functioning of fans, leading to high temperatures. Excessive dust and debris can also affect the interfacing of connectors. The computer filter shall be cleaned regularly when dirty.

11.7 Magnetic degradation

The high capacity of HDDs in conjunction with high operating heat has a possible negative aspect. Because magnetic particles are so close together, a strong magnetic particle can change the state of a much weaker particle. This is called super-paramagnatism. Most HDD manufacturers use methods to decrease this problem. It can also be reduced by operating the HDD at a cooler temperature.

11.8 Run time

Manufacturers specify that HDDs can perform well for a very large number of power-on hours (disk running), and as many as 100 000 on/off cycles. Since drives used in an archive typically are not subjected to high power-on hours or on/off cycles, these are not issues except when they operate in RAID systems which run continuously.

11.9 Shelf life

HDD manufacturers commonly specify their drives for a shelf life of at least five years. To avoid data loss, the SMART output should be checked occasionally (see Clause 7).

11.9.1 Electrostatic discharge (ESD)

Some HDDs have electronic circuitry exposed when the HDD is removed from the computer/workstation. If the electronic printed-circuit boards are exposed, these circuit boards shall not be touched because fingers or other contact can discharge high-voltages and damage the electronics.

12 Obsolescence issues

12.1 Software

Software shall be upgraded only after confirming that all of the various types of HDDs in the archive can still be properly read. Software upgrades shall be performed on the backup computer which shall be

identical to the primary computer. If a problem arises, the software shall not be upgraded or the HDDs shall be migrated to a disk format which is compatible with the new software.

12.2 Hardware

The computer/workstation can have an electronic component failure or the HDD inside the computer can fail to function properly. It is recommended that at least one identical computer and one backup internal HDD be available. The backup computers/workstations shall normally be powered off.

13 Transportation and shipping

At all times during transportation and shipping, care shall be taken to protect HDDs from physical shock, such as being dropped.

13.1 Freighting

Shipping and transport of HDDs shall be accomplished by the fastest and safest overnight or two-day service with insistence on a signed return receipt. Surround the HDDs with at least one inch of insulation to protect them from shock and from temperature and relative humidity extremes.

Copies of originals shall not be shipped in the same package with the originals.

13.2 Shipping containers

Shipping containers shall be sealed to ensure that water and contaminants do not enter the package during transit. Containers shall be built solidly to accommodate a heavy load. The HDDs shall be packed with sufficient shock protection (e.g. small diameter bubble-pack on all six sides). The bottom of the carton should have two layers of bubble pack or padding. Use of static-dissipative packaging shall be use when shipping HDDs. Fibre-filled packing material shall not be used.

13.3 Time out of storage

Because of the danger of theft and damage, HDDs shall be out of their home storage area for the minimum time possible. At no time shall they, or the containers/trucks in which they are being moved, be left unattended in open areas.

14 Disaster

Different types of disasters can result in exposure to a range of specific stresses. Short-term exposure to extreme heat or contaminants during disaster situations might not result in total loss of data on HDDs. Typically, HDDs are semi-sealed in metal housings and have a pin-sized hole to equalise air pressure. Even with such a small orifice, polluted air can enter the drive housing and cause loss of data.

14.1 Initial handling following a disaster

As soon as a disaster site has been secured against possible injury to personnel, all HDDs shall be removed from the site to avoid any additional damage. Specialist data recovery services can be used to recover information on the disks.

14.2 Fire

Fire can expose HDDs to smoke, soot, water, chemicals, and heat, as well as mechanical impact, stress, and environmental extremes resulting from damage to buildings.

14.3 Earthquakes

Earthquakes can cause mechanical impact and stress, as well as dust contamination, water damage from flooding, and exposure to environmental extremes.

14.4 Heat and temperature extremes

If exposed to very high temperatures, some of the electronics and plastics in HDDs can melt. The HDD should not be operated until it has been acclimatised into suitable conditions, and until inspected for damage. If extensive damage has occurred, a specialist should be contacted to perform data recovery.

14.5 Smoke, soot, and contamination

Smoke can leave an oily film on the outside of HDDs. Soot and other contaminants shall be cleaned off at the earliest opportunity. For cleaning instructions contact the manufacturer of the HDD or consider contacting a specialised HDD cleaning and recovery service.

14.6 Water and moisture

If an HDD is submerged in water or exposed to very high humidity, moisture can intrude into the drive housing potentially causing catastrophic failure. It is possible to reduce or to eliminate moisture from HDDs using a laboratory oven at about 50 °C or a vacuum chamber. HDDs shall be dried as soon as possible after moisture entry or exposure, to avoid possible corrosion and damage to data.

15 Staff training

15.1 Purpose

The effective care and handling of HDDs is enhanced by a regular staff training program. The purpose of such a program shall be to achieve the following goals:

— a high level of technical competence among staff, especially in the care and handling of HDDs and the data they contain;

— familiarity with the functional characteristics of equipment;

— awareness of required safety procedures including fire control and chemical, biological, electrical hazard avoidance;

— knowledge of policies and procedures governing work.

15.2 Training paths

An effective training program shall consist of at least two paths, one for new staff and one for continuing staff. All staff, whether staff is paid or volunteer, shall receive regular training. The formal training program shall be supplemented by frequent supervision. Each organisation shall develop a program fitted to its individual circumstances and needs. The training program shall be updated regularly as equipment, software, procedures, and needs change.

15.3 Schedule for training

All staff shall receive training within one month of commencing work. Continuing employees shall receive updating training sessions at least once each year.

15.4 Update of training

The staff training program shall be revised and updated whenever major changes occur (e.g. staff changes, major equipment changes, significant redirection of mission and services).

15.5 Content of training

Staff training should include the following components:

a) Mission, goals, and objectives of the organisation;

b) Position descriptions stating the roles and responsibilities of each staff member;

c) Published standards and a bibliography of other information relevant to the work of the repository;

d) Guidelines governing access to the materials;

e) Maintenance schedules and procedures for equipment used in the facility;

f) Cataloging, labelling, and shelf arrangement;

g) Physical facilities issues and concerns (e.g. location of fire alarms and emergency shut-off valves);

h) Occupational health and safety;

i) Instruction on handling of HDDs;

j) Actions to take if a disaster occurs.

16 Minimum handling requirements checklist

The following compose the minimal maintenance requirements that shall be performed routinely to properly handle and care for HDDs, and provide maximum protection of data stored on them.

a) Schedule a cleaning of the computer air filter twice a year unless once each year is found to be sufficient.

b) Add a small external fan on each computer to increase the airflow within the computer.

c) Add one or two backup computers that are identical to the primary computer.

d) Additional backup systems shall be maintained, such as duplicate HDDs stored offsite and in different geographical locations, mirrored data systems, and web-based storage as secondary backup.

e) Perform an error test of all HDDs once each year.

f) Maintain a room environment of less than 25 °C and less than 60 % RH.

g) Turn off power before moving HDDs.

h) Prior to installing new software or upgrades, test the new software on an identical backup computer system.

i) When turning off a computer with a running HD, wait at least 5 sec before turning the computer back on.

Annex A
(normative)

RAID and MAID levels

Level 0 – Striped Disk Array without Fault Tolerance: Provides data striping (spreading out blocks of each file across multiple disks but no redundancy. This improves performance but does not deliver fault tolerance. If one drive fails then all data in the array is lost.

Level 1 – Mirroring and Duplexing: Level 1 provides twice the read transaction rate of single disks and the same write transaction rate as single disks.

Level 2 – Error-Correcting Coding: Not a typical implementation and rarely used, Level 2 stripes data at the bit level rather than the block level.

Level 3 – Bit-Interleaved Parity: Provides byte-level striping with a dedicated parity disk. Level 3 cannot service simultaneous multiple requests and is rarely used.

Level 4 – Dedicated Parity Drive: A commonly used implementation of RAID, Level 4 provides block-level striping (like Level 0) with a parity disk. If a data disk fails, the parity data are used to create a replacement disk. A disadvantage to Level 4 is that the parity disk can create write bottlenecks.

Level 5 – Block Interleaved Distributed Parity: Provides data striping at the byte level and also stripe error correction information. This results in improved performance and fault tolerance though a risk still exists of total data loss.

Level 6 – Independent Data Disks with Double Parity: Provides block-level striping with parity data distributed across all disks. Level 6 provides greater robustness than the other levels.

Annex B
(informative)

Websites and general information

The following websites have useful information.

www.IDEMA.org, International Disk Drive Equipment and Materials Association. Current as of June 14, 2012.

www.snia.org, Storage Networking Industry Association. Current as of June 14, 2012.

http://cmrr.ucsd.edu/, Center for Magnetic Recording Research, University of California, San Diego.

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