Magnetic Recording

Today Hard Disk Drives are the most common storage device used with the computer system. The hard disk drive is also known as Hard Disk, Hard Drive, Fixed Disk Drive or Winchester Disk Drive. The hard disk drive is used to store data and programs permanently inside the computer. The information stored in the hard disk drive does not get erased when the power supply to the computer is switched off.

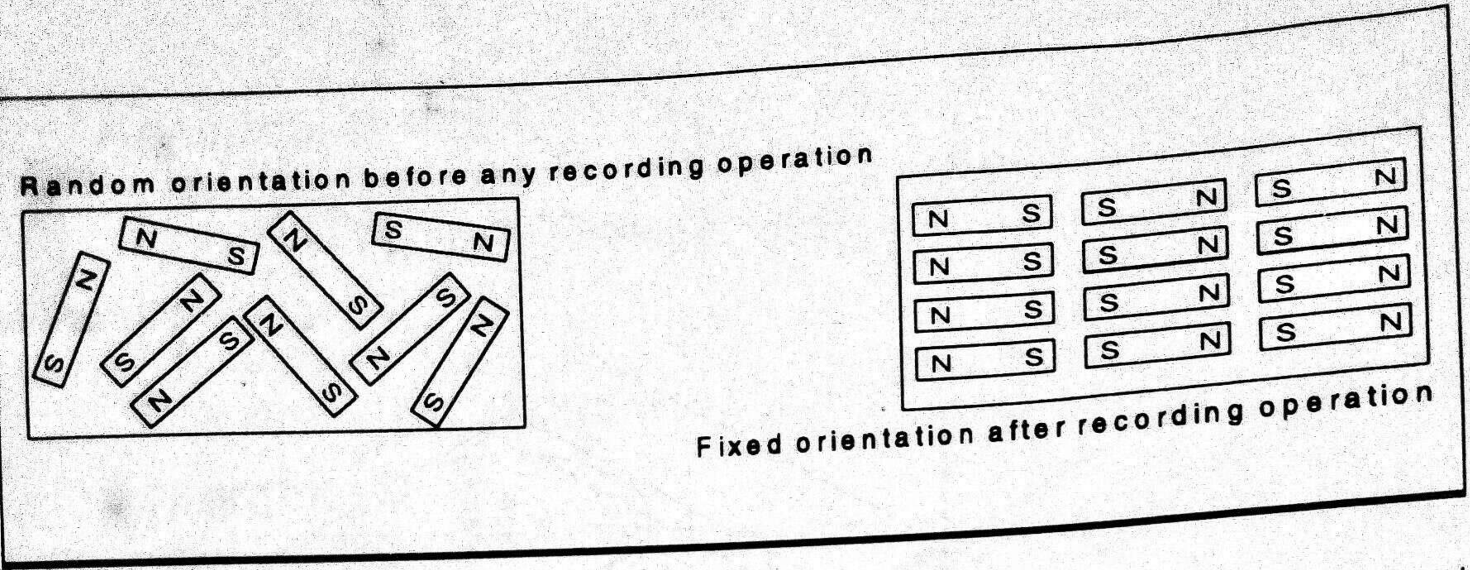

Figure 1 - 1
Random orientation of the magnetic particles on the disk surface gets properly aligned after the recording process.

This device is known as "Hard Disk Drive" because compared to the other common magnetic storage device, floppy disk, which uses flexible plastic like carrier for the magnetic recording medium; the hard disk drive uses rigid, hard, aluminum or glass as the base for recording medium.

IBM uses the name "Fixed Disk" for the hard disk drive because in the hard disk drive the disk is fixed inside the drive, one is not allowed to remove and insert the disks, as it is done in the case of floppy disk drive.

The name "Winchester" is also used for hard disk drives. This name comes from the original hard disk drive made by IBM. This drive had two sides each of which could store 30 Mega Bytes of data. This lead the IBM to code name this technology as "3030". This designation was similar to the famous Winchester 3030 rifle, so this technology also become known as Winchester hard disk drives. IBM produced this drive at its Hursley Laboratory, which is located near Winchester in England, this could be another reason for this name.

Information is stored in the hard drive using the same magnetic recording method, which is used to store songs on a audio tape or movies on a video tape. The audio or video tape does not lose its content when the power supply given to the audio or video recorder is switched off, same way the hard drive also retains the information stored in it, even when the power supply to the hard drive is switched off.

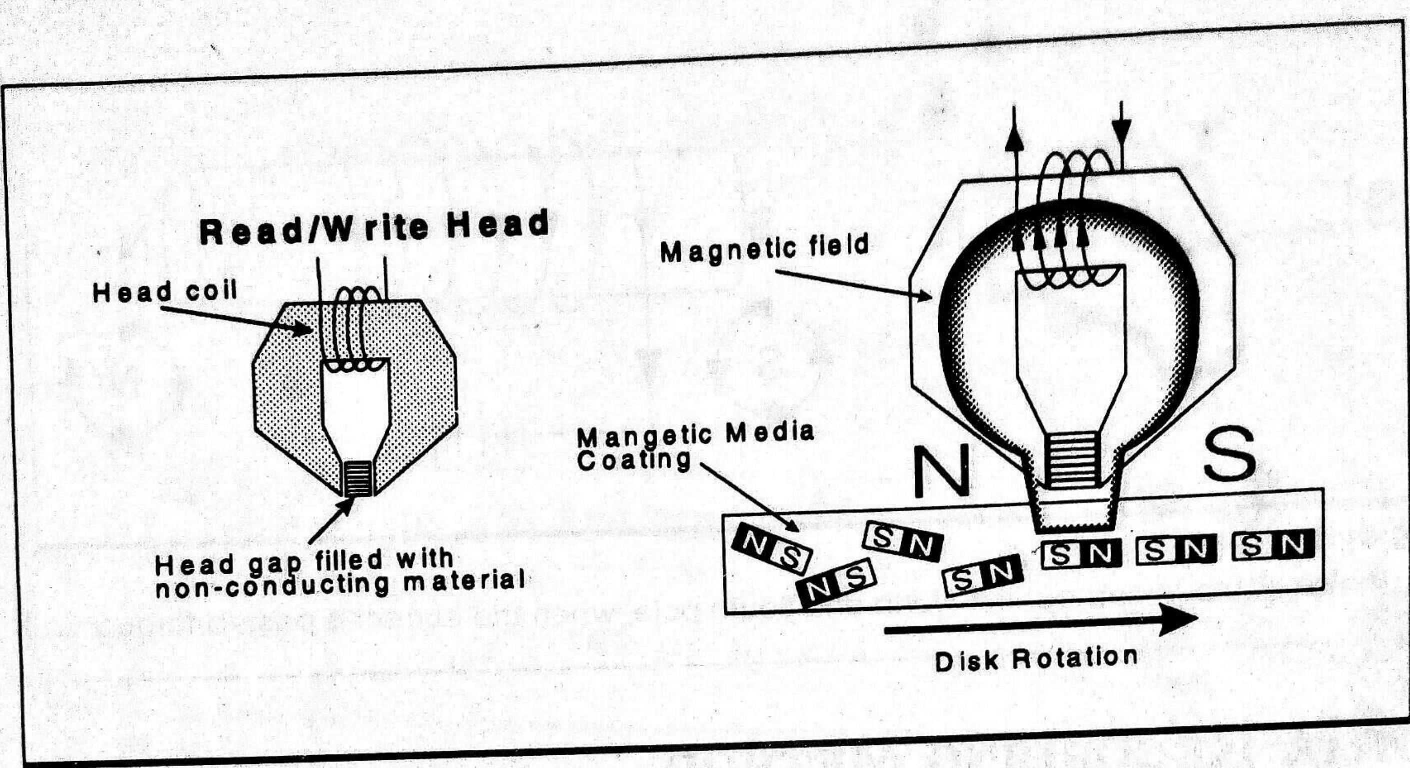

Figure 1 - 2
Magnetic Recording by the Read/Write Head.

Before starting about the Hard Disk Drives, let us see how the magnetic recording on the disk surface takes place.

MAGNETIC RECORDING

Data is stored on the recording surface of the disk in the form of Binary Digits or bits and based on the value of this bit, a 0 or a 1, the magnetic particles on the disk surface is recorded in NS (North,South) or SN (South,North) orientation.

When you buy a new hard disk, the magnetic particles of the coating on the disk surface are in a random orientation as shown in the figure 1 – 1. This coating is similar to the coating on the audio/video tapes.

Data is recorded on this surface by making these magnetic particles orient in some pre–defined order as shown in the second part of the figure 1 – 1.

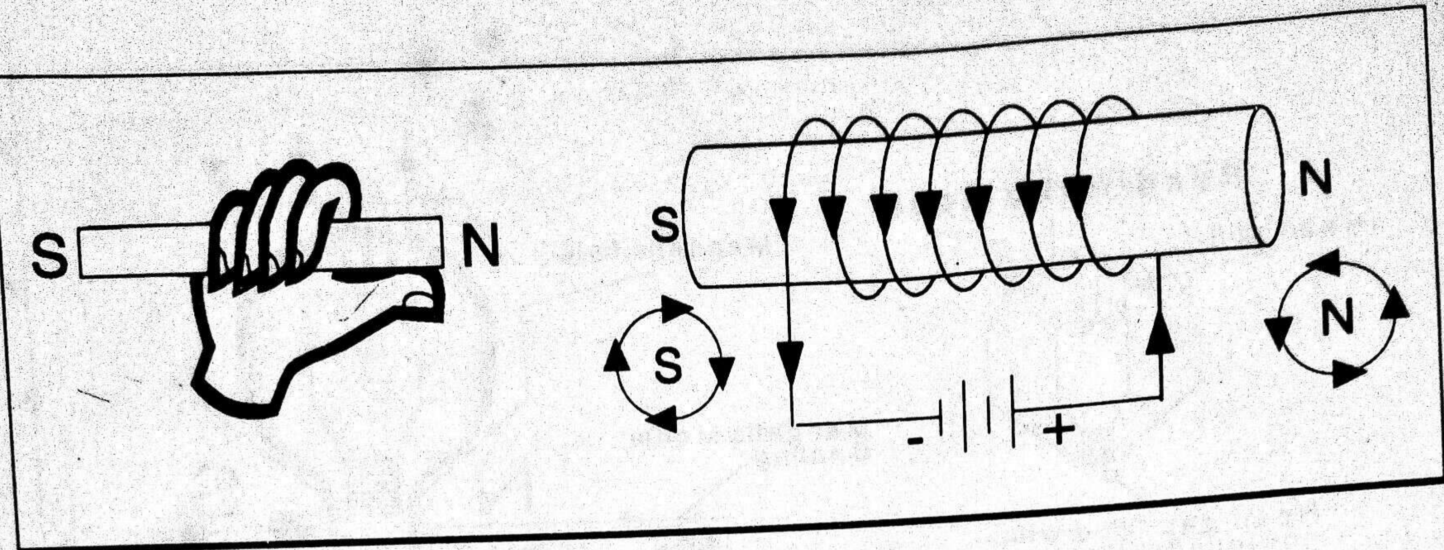

Figure 1 - 3
Right hand rule to find out the North and South pole, when the current is passed through a coil.

DATA RECORDING METHOD

The magnetic recording on the disk surface is done by a magnetic read / write head, which is similar to the read / record head of an audio / video tape recorder.

The read / write head of the disk drive is an electro–magnet whose polarity can be switched by changing the direction of the electric current through it.

The construction of a hard disk drive head is basically as shown in the figure 1 – 2, it is a U–shaped conductive piece of material. This U–shaped material is wrapped with a coil of conductor wire, through which the electric current can be passed to magnetize the head.

A small gap in the section of the head that touches the disk surface is used to concentrated the ~~generated~~ magnetic flux to the surface of the disk. Normally, this gap is filled with a non–magnetic material, such as glass or ceramic.

When the current is passed through the coil, a magnetic field is generated on the head. When the magnetic field reaches the head gap, the magnetic field pass through the disk media beneath the head gap and goes to the other side of the head.

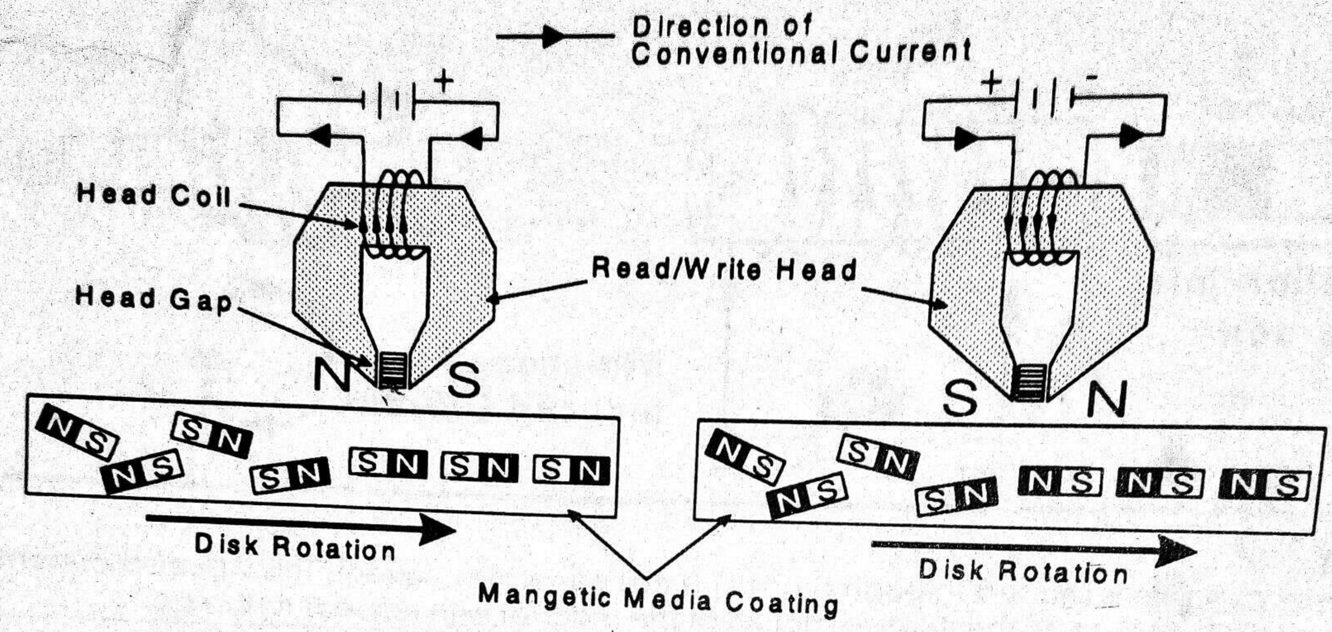

Figure 1 - 4

Random orientation of the magnetic particles on the disk surface gets properly aligned after the recording process.

As shown in the figure 1 – 2, when the magnetic field passes through the recording media on the disk surface, it aligns the polarity of the magnetic particles on the disk media.

The polarity of the disk media will depend on the direction of the magnetic field and the direction of the magnetic field will depend on the direction of the flow of electric current through the head coil.

By changing the direction of flow of current through the head coil the polarity of the magnetic particles on the disk media can be arranged in "NS" (North–South) or "SN" (South–North) orientation.

This magnetic recording works on the principles of magnetic field around an coil of conductor wire carrying electric current as explained next

Writing on a Magnetic Surface

When writing any information on the disk surface the principles of magnetic field around a coil of conductor wire, carrying electric current is at work.

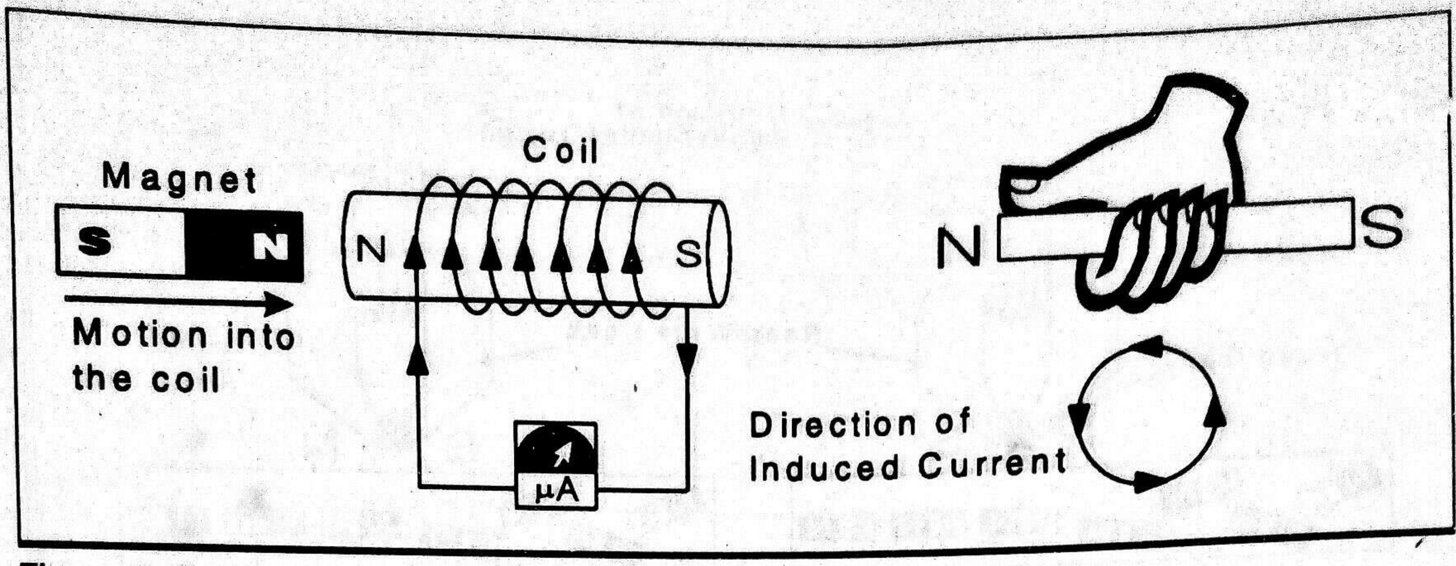

Figure 1 - 5

When a magnet is moved through a coil, the coil generates current. This induced current is generated because of the relative motion of the magnet with respect to the coil.

According to this principle, when current is passed through a coil made of conductor wires, it generates a magnetic field.

The magnetic polarity i.e. which side of the coil will be south and which will be north, can be found out by using the "right–hand rule" as shown in the figure 1 – 3.

According to the right–hand rule if the coil is grasped with the fingers of the right hand curled around the coil in the direction of the current flow, then the thumb points to the north pole of the coil.

This rule is for the conventional current which flows in the circuit from the positive terminal to the negative terminal, for the electron flow, left–hand rule is used.

Writing on the Disk Surface

As shown in the figure 1 – 4, data is written to the disk by applying the magnetic field to a small area of the disk. The magnetic field is produced by supplying current to the head coil of the read / write head.

The magnetic field produced by the head, forces the particles on the disk surface to align themselves along the axis of the applied field.

As we already know, the direction of the current through the head coil determines the orientation of the particles of the magnetic coating.

This direction of the current flow represents the information that is to be written on the disk surface, current flow in one side could be for storing binary digit 1 and flow in the reverse side could be for storing binary digit 0.

The binary digit is the most basic form of data storage inside computer. A combination of these digits represent a character. Normally a combination of 8 bits known as byte is used to represent a character.

Reading from a Magnetic Surface

When reading any information from the disk surface, the principles of the induced current on a conductor wire due to the change of magnetic field is at work.

According to this principle, if the movement of electron or current flow through a conductor wire produce a magnetic field, then its reverse is also true i.e. the change of magnetic field across a conductor must produce "movement of electron" or current through the conductor.

This produced current is called an "induced current", because there is no direct connection between the magnet and the conductor. The current is induced because of the relative motion of the magnet with respect to the conductor

This direction of the induced current is determined using the Lenz's law. According to the Lenz's law, when a magnet is moved into a coil or away from a coil, the direction of the induced current is such that, the magnetic field produced in the coil by the induced current should oppose the action that has produced the current itself.

As shown in the figure 1 – 5, when the North pole side of a magnet is brought close to a coil connected to an ammeter, the magnetic fields start to cut across the conductor of the coil.

As the magnet is brought further close, the change in the field cutting the conductor wire forces the electron in the conductor to move and this movement of electrons produce current in the coil.

The direction of this current should be such that it should oppose the action of moving the north pole closer to the coil.

We know that to oppose a north pole we need another north pole, as the same poles repel each other.

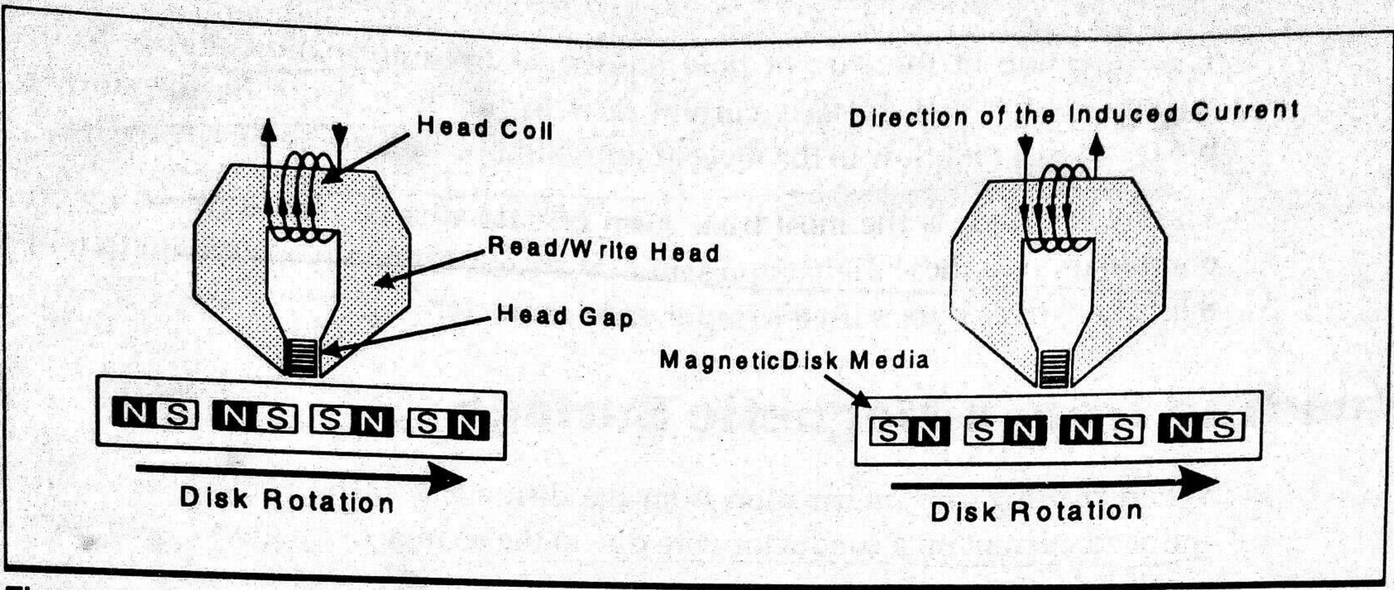

Figure 1 - 6

Reading of the information stored on the disk surface, by the Read/Write head.

The current produced in the coil should be such that the side of the coil facing the incoming magnet should produce a north pole to repel the incoming north pole of the magnet.

The direction of the conventional current to produce the north pole at the left end of the coil according to the right–hand rule will be as shown in the figure 1 – 5 i.e. in a anti–clockwise direction, when looked from the north end or the left side of the coil.

In the opposite case, when the magnet is moved away from the coil, the current produced in the coil should opposes the action of the north pole being moved away.

In this case the current produced is such that the left end of the coil is made a south pole to attract the north pole of the magnet being moved away.

This property of the magnet and coil to generate induced current is used to read the information stored on the disk surface.

Reading from Disk Surface

When the read/write head passes over the surface of the disk, an electric pulse is induced in the read/write head circuitry for each change in the orientation of the magnetic particle on the disk surface.

The state of this electric pulse tells the read/write head whether the information on the disk surface is a 0 or a 1.

This is shown in the figure 1 – 6.

The magnetic recording shown in this figure is not the correct representation of the recording method used by the computer in the real situation, because, to enable the read/write head sense the information recorded on the disk, there should be a orientation change for each recorded bit of information.

A current is produced on the head only if there is a change in the direction of the magnetic particle on the disk surface, if all the magnetic particles of the disk surface are oriented in the same direction then there will not be any current produced on the read/write head of the drive.

As you can see in the first part of the figure 1 – 7, if bit 1 is stored as NS and bit 0 is stored as SN, then 1101 will be stored as NS NS SN NS magnetic flux on the disk surface.

When this data is read back, it will produce signal on the r/w head at only two places as shown in the figure.

In this method, without any additional information just by seeing these two pulses it is very difficult to predict what is the data stored at that location.

To overcome this problem, an additional signal is stored with each data bit. This signal is called clock signal. This clock signal is always stored before the data bit and is always in the opposite orientation of the data pulse preceding it.

This method of data recording is shown in the second part of the figure 1 – 7. As shown in this figure, a clock bit is always attached before each data bit.

This clock bit is always stored in the opposite orientation of the bit preceding it, so there will always be a current or pulse generation for the clock signal because of the flux reversal of the magnetism.

After the clock bit, if the data is 1 then the next bit i.e. the data bit is oriented in the reverse direction compared to the clock bit, if the data bit is 0 then the next bit, i.e. the data bit is oriented in the same direction as the clock bit.

When the data is 0, i.e. if the clock bit and the data bit orientation are same then there will not be any data pulse and no current generation on the r/w

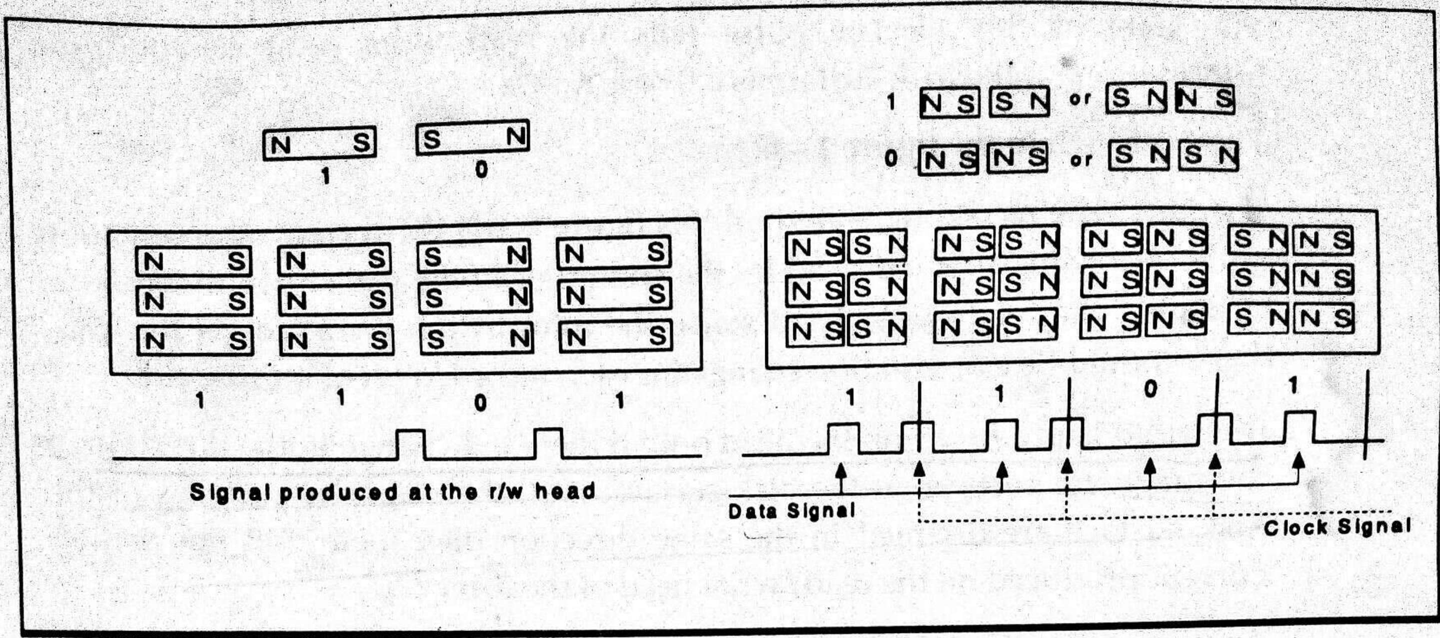

Figure 1 - 7

Storing of the information on the disk surface with the clock signal.

head. when the data is 1, i.e. if the clock bit and the data bit orientation are not same then there will be a data pulse on the r/w head.

If the data is recorded in the forms of clock and data bits as explained above, a clock pulse will be required for each bit of data. If a recording method could reduce the number of clock pulses required to store the data without destroying any data bit, then that recording method will be able to store more data in the same space i.e. the storage density of the recording medium will increase.

To increase the storage density of the recording medium most of the recording or encoding schemes try to limit the number of clock pulses to the very minimum.

Data Encoding Method

When the data is received from a serial digital circuit, it is in a format known as NRZ or Non–Return to Zero. This is the most common format of data output by a parallel to serial shift register.

This format is shown in the figure 1 – 8, in this format a pulse is used to store the binary digit 1 and no pulse or a blank is used to store binary digit 0. but

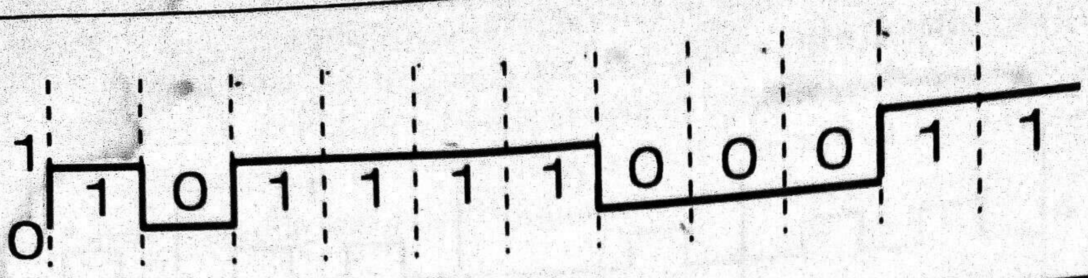

Figure 1 - 8

NRZ or Non Return to Zero data format.

this format is not compatible with the magnetic recording method used to store data on the disk surface.

The reason is the read / write coil will not produce any induced voltage when the head is moved parallel to a non–changing field of magnetic flux.

As shown in the figure1 – 6, the only time a current will be induced in the head (in a read operation) is when a change in the orientation of the magnetic particle is encountered i.e on a transition from "NS" to "SN" or from "SN" to "NS".

If all the binary 1's are stored as "NS" magnetic particle on the disk surface then during the time intervals when the head is passing over a series of 1s, no voltage will be induced. This could lead to problem as the synchronization between the interfacing circuitry and the incoming data, which is read from the disk could be lost.

After some time the disk interfacing circuitry will not be able to tell when a bit has started and when it has ended.

A very easy solution to this problems as we have seen would be to record a clock signal with the data signal for synchronization purposes.

As writing a clock bit with each data bit would require double space for the data storage, another alternative method, which is normally used in the disk storage method, is to encode the date that is to be written to the disk.

This encoding is normally done using some data encoding technique from which the clock synchronization information can be separated, without any loss of the data information.

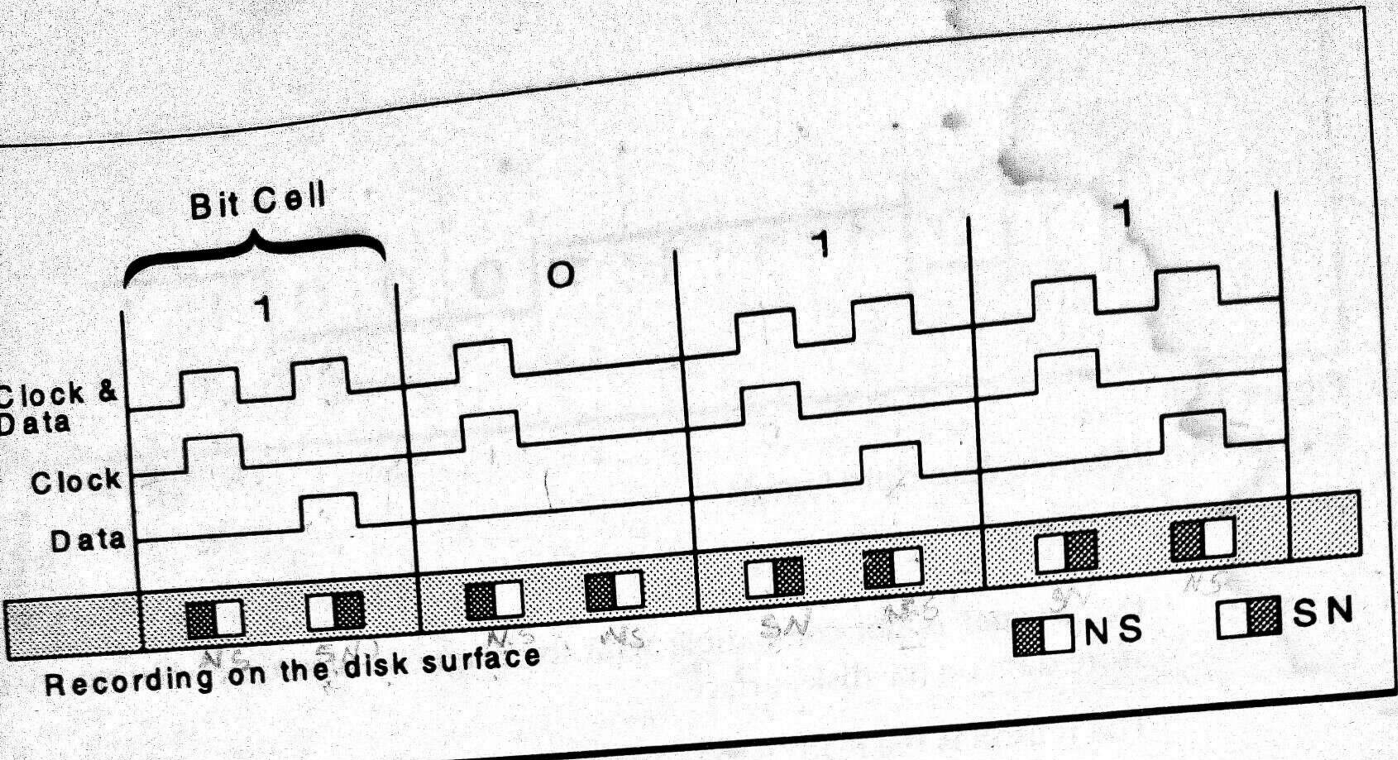

Figure 1 - 9
Data recording on the hard disk surface using FM data encoding scheme.

Three most common encoding methods are know as

- FM encoding method
- MFM encoding method
- RLL encoding method

Let use see these data encoding methods in detail

FM Encoding Scheme

FM or Frequency Modulation was the original data encoding scheme used for storing the data on the magnetic recording surface.

This method of data encoding is also known as the "single density recording", as this method was used to write to the single density floppy diskettes.. This method was popular in the 1970s and is no longer used today.

In this method a clock signal is put with every data signal on the recording surface. This clock signal is used for synchronizing the read operation, as there will always be a clock signal, whether the data signal is there or not.

Let us see one example, suppose you want to store the binary digit 1011 on a magnetic recoding media using the FM recording technique. In this FM method of data recording a 1 bit is stored as two pulses (one clock pulse and one data pulse), and a 0 bit is stored as a one pulse and one gap or no pulse (1 clock pulse and one "no pulse" to show that it is a 0 bit).

- a binary digit 1 is stored as two pulses (PP)
- a binary digit 0 is stored as one pulse and one "no pulse" (PN)

A clock pulse and data pulse together is called a "bit cell", as they represent one bit of information.

For example a binary number 1011 will be stored as

```
PP PN PP PP
```

A pulse is recorded on the recording medium as a change in the direction of the magnetic field from the last magnetic field and a "no pulse" is recorded as no change in the direction of the magnetic field from the last magnetic field, i.e. if the last magnetic field was NS then a pulse or bit 1 is recorded as SN, and a no pulse or a 0 is recorded as NS.

For example 1011 or PP PN PP PP will be stored as

```
NSSN NSNS SNNS SNNS
```

This encoding method is shown in the figure 1 – 9. In this figure binary digit 1011 is stored using the FM method of data recording, each 1 bit is stored as two pulses (clock and data) and 0 is stored as one clock pulse only.

When using the FM encoding technique, the synchronization signal will always be available for the disk read operations.

FM method of data recording is also known as (0,1) Run Length Limited (RLL) recording. The reason behind this name is, in a series or in a running length the minimum number of 0s is zero, i.e. you can have two pulses next to each other without any 0 or "no pulse" in between and the maximum

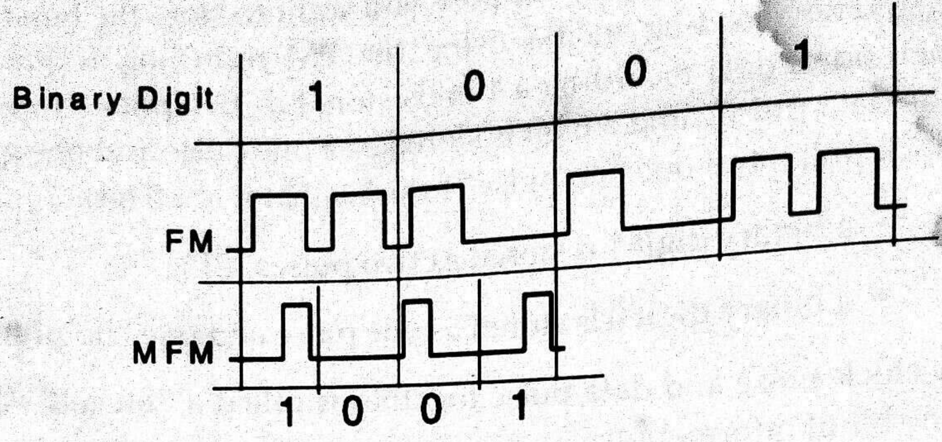

Figure 1 - 10
Data recording using FM and MFM data encoding scheme.

number of 0s is one, i.e. you will never have more than one position without a 0 or "no pulse" signal.

MFM Encoding Scheme

More data can be stored on the same surface or the data storage density can be increased, if the number of pulses required to store the data can be minimized.

When minimizing the pulses, one should be careful that the number of no pulses together should not be very long, otherwise the disk controller may go out of synchronization with the data.

The MFM (Modified frequency modulation) method of data storage, by reducing the number of pulses, is able to store more data without any data and synchronization loss.

In MFM recording the 0s and 1s are encoded as given below

- 1 is always stored as a no pulse, and a pulse (NP)
- 0, when preceded by another 0, is stored as a pulse, and no pulse (PN)
- 0, when preceded by a 1, is stored as two no pulses (NN)

If you store 1001 on the disk surface using the MFM storage method, it would be stored as

```
NP NN PN NP
```

As you can see, this requires only three pulses in MFM method, let us store the same data using the FM method of data recording

```
PP PN PN PP
```

Total six pulses are required to store the same data using the FM method.

In this MFM method of data recording the minimum number of 0s together is one and the maximum number of 0s is three, this is a (1,3) RLL, Run Length Limited data recording, i.e. in MFM recording there will always be at least one "no pulse" signal i.e two pulses will never come together, and the maximum number of positions without any pulse will never be more than three.

This guarantee of at least one "no pulse" between the pulses and the number of pulses required to store the data being less than the FM encoding scheme made the MFM scheme write the pulses closer together, denser on the disk surface, compared to the FM data recording.

In overall effect of this scheme was a recording in double the density of the FM recording. This MFM recording is used for the Double Density (DD) and High Density (HD) floppy disk recording, older hard disk drives also used this MFM recording method.

The advantage of MFM over FM can be understood from the figure 1 – 10, on the average fewer pulses are required to read or write in MFM.

This makes it possible to record data at a higher density using MFM as opposed to FM. The MFM technique will allow twice as many bits to be stored in a given length of disk space as FM.

The disadvantage of MFM is that the circuitry required to encode and decode the data is more complex.

RLL Encoding Scheme

The RLL encoding or the Run Length Limited encoding is the most common encoding scheme used in the hard disk storage. This encoding scheme can be more accurately called as 2,7 RLL encoding because in this scheme in a series or in a running length the minimum number of 0s next to each other is two, and the maximum number of 0s together can not be more than seven.

The RLL encoding scheme can store 50 percent more information than MFM encoding scheme on a given surface and it can store three times as much information as the FM encoding scheme.

The Run Length Limited name comes from the minimum number (Run Length) and maximum number (Run Limit) of "no pulse" values allowed between two pulses.

Many different schemes of different Length and Limit have been tried, but only two schemes 2,7 RLL and 1,7 RLL have achieved popularity. As we have already mentioned the FM scheme can be referred to as 0,1 RLL and MFM scheme can be referred as 1,3 RLL.

Initially the RLL encoding scheme was not used, because the drives were not capable enough to store the data in RLL density. As the quality of the drives improved use of RLL increased.

As the RLL encoding stores data denser than the FM or MFM encoding, it provides much faster data transfer rate compared to the other encoding schemes.

The 2,7 RLL provides very high density (1.5 times MFM) data recording, but it is not as reliable as the 1,7 RLL which provides 1.27 times the MFM density. This makes most of the drive manufacturers to use the 1,7 RLL for their hard disk drives.

For the RLL encoding, an encoder/decoder (Endec) table is used to find the pulse signal to be used for different data bit groups. Thousands of different translation tables are possible for the 2,7 RLL encoder, as an example let us see the Endec table used by the IBM to convert bit information to the pulse signal.

Data Bit	Pulse Encoding
10	NPNN
11	PNNN
000	NNNPNN
010	PNNPNN
011	NNPNNN
0010	NNPNNPNN
0011	NNNNPNNN

You can check in the above table that for any combination of 0s and 1s there will not be less than two "no pulse" situation and at the same time there will not be more than seven "no pulse" situation next to each other at a time.

If you study this table then you might think that this table does not contain enough information to encode all the possible bit combination, for example if you want to encode a byte 10001100 to proper RLL pulse signal then the

bit 10 can be encoded as NPNN

bit 0011 can be encoded as NNNNPNNN

finally when you look in the table, you will find that there is no information given about how to convert the remaining bit 00.

In this type of situation one must remember that the RLL controller is not used to encode single byte of information, instead it converts the entire collection of bytes to be sent to the hard drive.

The controller includes bit from the next byte to complete a bit combination that can be encoded. In the above example if the next byte is 10110011, then by adding the first two bit of this byte to the previous bit combination 00, we will get a bit combination given in the table

00 from last byte, and 10 from this byte will give 0010 which can be converted to NNPNNPNN.

If the last byte of the data contain a bit combination that is not given in the table then the controller adds the excess bits required to encode the byte, and encodes it. During the decoding the excess bit is removed from the byte.

To store 10001111 using different data encoding schemes, you need

PP–PN–PN–PN–PP–PP–PP–PP, i.e total 13 pulses in FM scheme

NP–NN–PN–PN–NP–NP–NP–NP, i.e. total 7 pulses in MFM scheme and

NPNN–NNNNPNNN–PNNN, i.e. total 3 pulses in 2,7 RLL scheme

As you can see in the above comparison when the FM scheme requires 13 pulses to store a byte, the MFM requires only 7 pulses and for the same byte 2,7 RLL requires only 3 pulses.

As the number of pulse required to store the data using RLL encoding is very less compared to other encoding schemes, one can increase the clock rate three times of FM or 1.5 times of MFM when writing the RLL data onto the disk.

Even with increased clock rate, the physical maximum and minimum distance between the any two pulse on the disk surface will remain almost same on all the three encoding schemes. This is possible because of the different number of pulses required in different schemes.

In other word we can say that even though the data storage density of the RLL is more than the data density of other schemes, the actual pulse density on the disk surface remains same. Only when these pulses are decoded one gets more data from RLL encoded storage, compared to other schemes.

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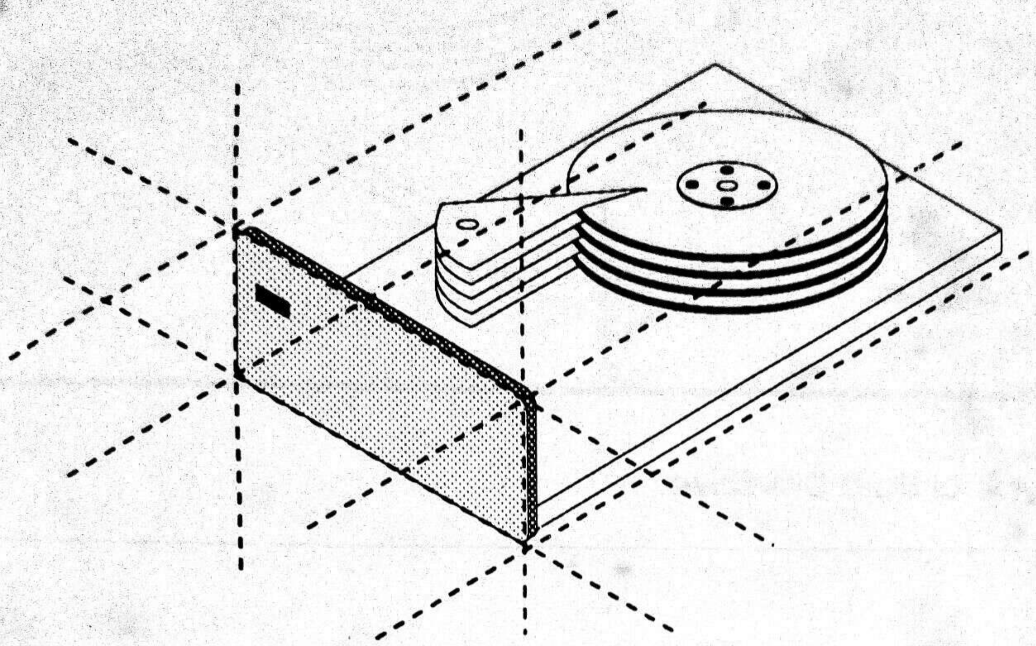

Hard Disk Drive

In the last chapter you saw how the magnetic data recording takes place on a disk surface. In this chapter we will study about the construction of a typical Hard Disk Drive, its different parts, what are their jobs and different types of these parts used in the drive construction.

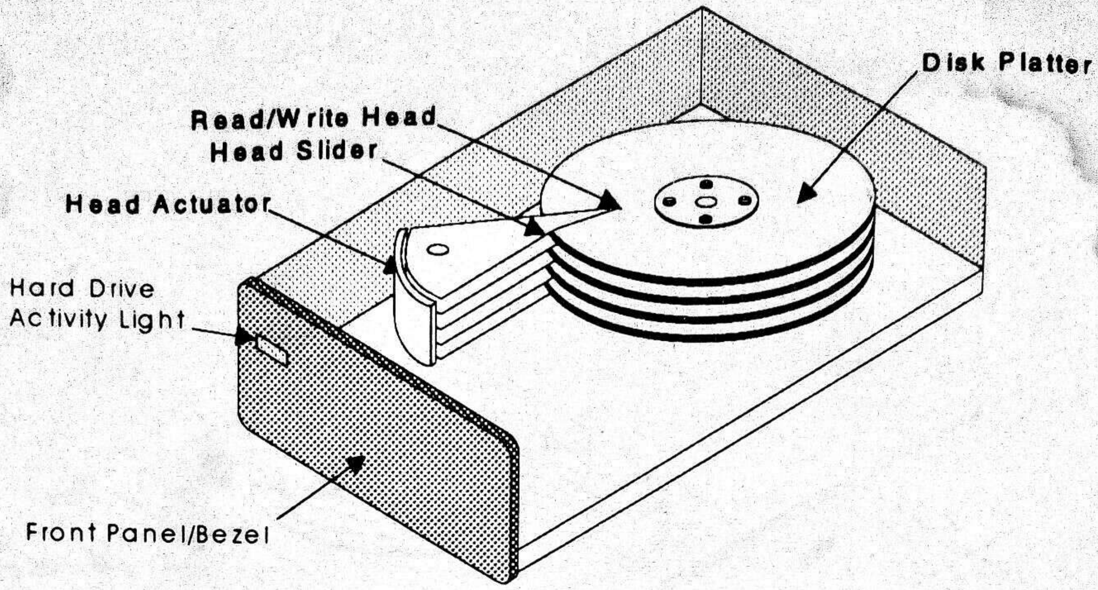

Figure 2 - 1

Components of a typical Hard Disk Drive.

HARD DISK DRIVE COMPONENTS

Let us see the different parts of a hard–disk drive. There are many different capacity and size hard disk drive available in the market, but the basic component inside them are almost same. A typical hard disk drive contains the following components.

- Disk Platter
- Read / Write Head
- Head Arm / Head Slider
- Head Actuator Mechanism
- Spindle Motor
- Logic Board
- Air Filter
- Bezel
- Cable & Connectors

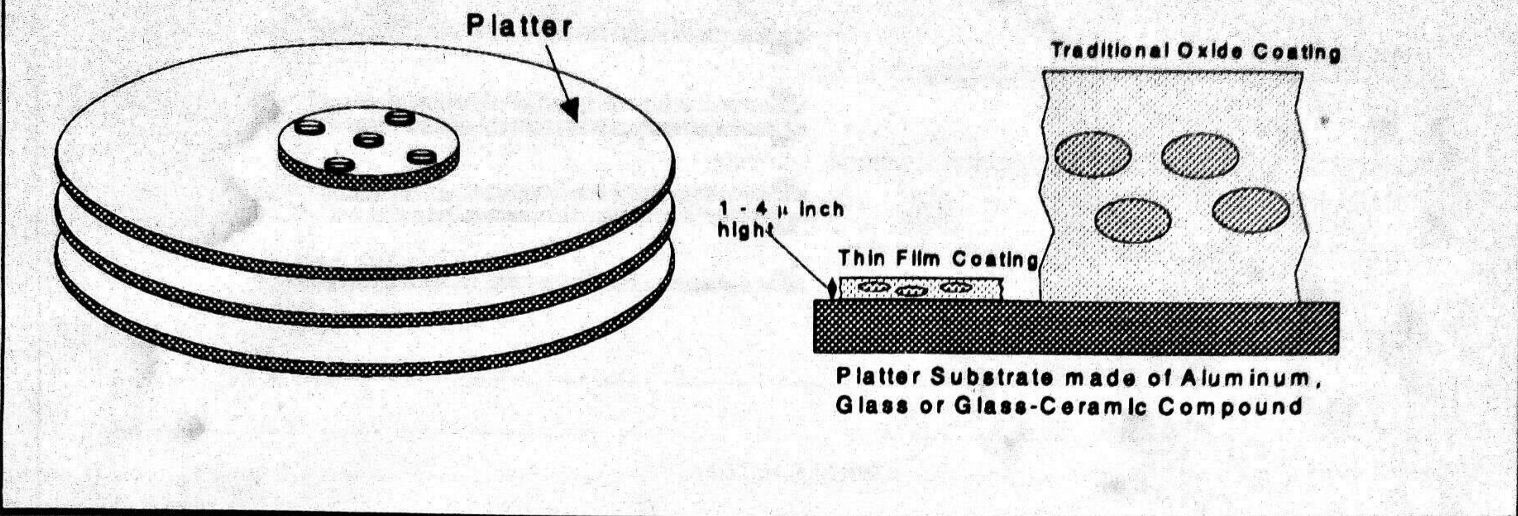

Figure 2 - 2

Disk Platter and the media coating on the platter.

Disk Platter

Figure 2–2, shows the platter construction inside a hard disk drive. As shown in this figure the hard disk drive contains a number of platters, or the circular shaped disks on which the information is magnetically recorded.

The platter size (i.e. the diameter) is called the form–factor of the hard drive, and one refers the hard drive size by its platter's diameter. There were many different platter sizes in use, but some of the common platter sizes are given below

- $5\frac{1}{4}$ inch, (actually 5.12 inch)
- $3\frac{1}{2}$ inch, (actually 3.74 inch)
- $2\frac{1}{2}$ inch
- $1\frac{1}{8}$ inch
- $1\frac{1}{3}$ inch

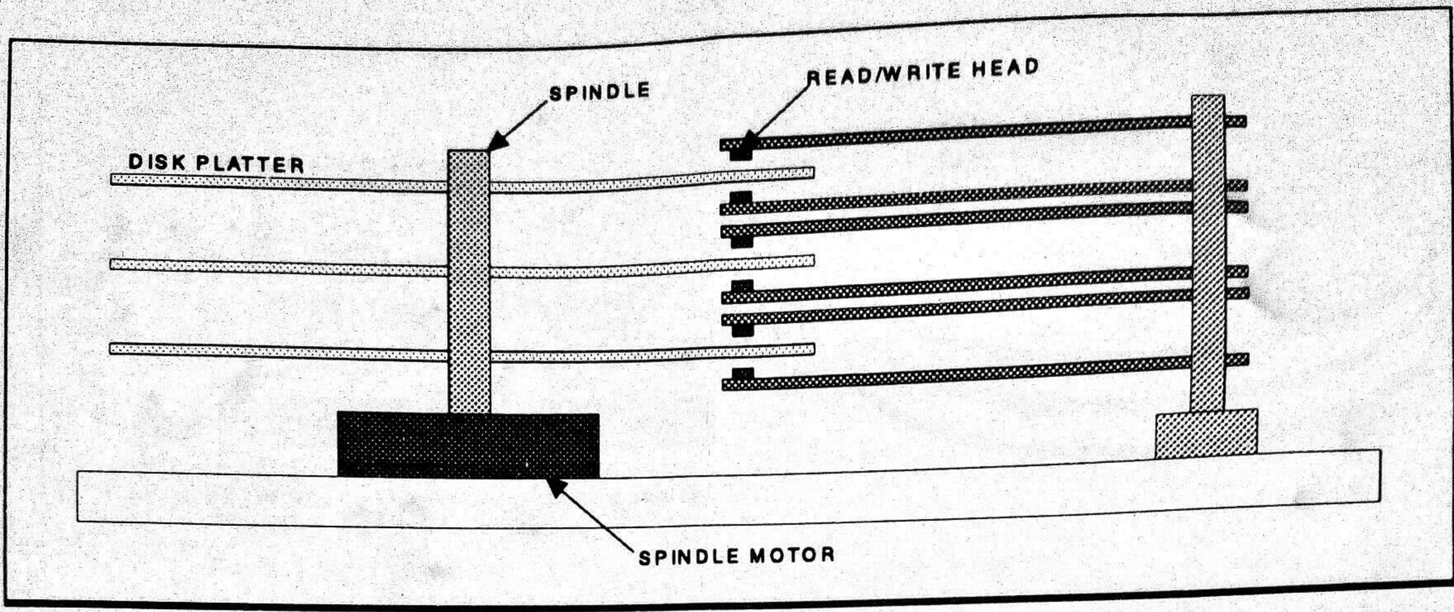

Figure 2 - 3

Hard disk drive construction.

The 3 1/2 inch size platter is currently most common with the Personal Computers, and the 2 1/2 inch is common in the portable/laptop computers.

The latest 1 1/3 inch drives are very small, almost the wristwatch size, these drives are very rugged and available in the 100MByte or more storage capacity.

Number of platters on the hard disk drive can be as low as 1 and as high as 10 or more, but 2 or 3 platters are most common.

These platters were made from aluminum alloy because of their strength and light weight. Being a metal the aluminum is not thermally stable i.e. they expand and contract with the change in the temperature.

This has lead the drive manufacturers to use glass and glass–ceramic compound as platter on their drives. glass and glass–ceramic platter allows the drive to be smaller with higher storage density.

In 3 1/2 inch and 2 1/2 inch hard drives almost all the drives are made using the glass or glass–ceramic platter.

The material using which the platter is made is called the substrate of the disk, on this substrate the magnetizable media (oxide of some ferrous material) is coated. This media coating stores information magnetically.

Two type of recording media is common with the hard–disk drives, they are

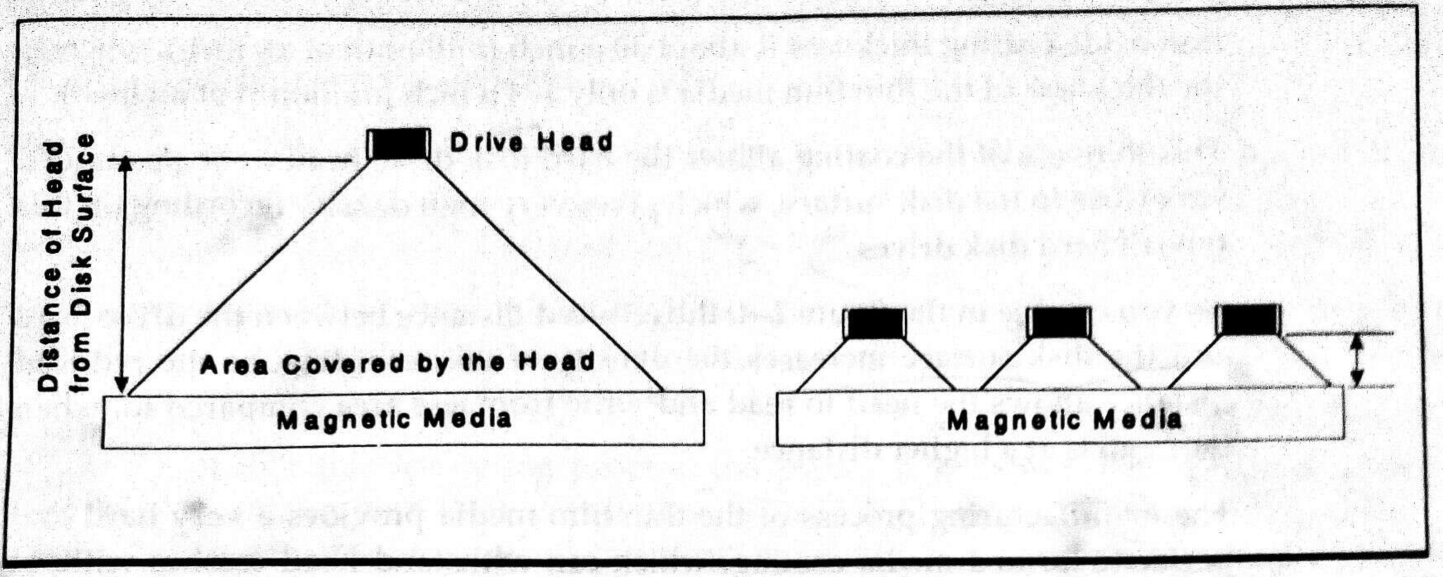

Figure 2 - 4

Reduced read/write head distance from the disk surface increases the storage density of the disk.

- Traditional, Iron Oxide media
- Thin Film media

Iron Oxide Media

Initially all the hard disk drives platter surface was coated with some iron oxide compound. This media gives around 30 μ inch (millionth of an inch) thick coating on the platter surface.

As the drive density increased it is found that this type of coating is not useful for higher density recording, another drawback with this type of coating was, it was very soft and any crash of the drive head on the platter used to make permanent defect on the media coating.

A platter coated with iron oxide compound looks brown or amber in color.

Thin Film Media

The limitations of the iron oxide coating has made the hard drive manufacturers to look for some alternative, and the thin film media coating is the result of this.

As the name suggests and as you can see in the figure 2–2, the thin film media coating is very thin compared to the traditional iron oxide coating. The iron oxide coating thickness is about 30 μ inch (millionth of an inch), whereas the thickness of the thin film media is only 1–4 μ inch (millionth of an inch).

This thinness of the coating allows the hard disk drive head to be positioned very close to the disk surface, which gives very high density recording on this type of hard disk drives.

As you can see in the figure 2–4, the reduced distance between the drive head and the disk surface increases the density of the recording, as the reduced distance allows the head to read and write from less area compared to, when the head is at a higher distance.

The manufacturing process of the thin film media provides a very hard and perfectly formed media coating, which can withstand head crashes without destroying the coating.

The traditional iron oxide coating is manufactured by coating the platter surface with a semi liquid coating of the iron oxide compound. Later the plater disk is spin at very high rotation speed to evenly spread the coating on the platter surface.

Once the media spreads evenly across platter surface, the surface is cured and polished. The polished surface is finally coated with some lubricating material, which protects the surface from minor crashes.

The thin film media is created on the platter surface using two different process, they are

- Plating process
- Sputtering process

Plating Process

In the plating process, as the name suggest the media is produced using electroplating process. In this process the platter substrate is immersed in different chemicals to coat the plater surface with a very uniform 2 to 3 micro inch (μ inch, millionth of inch) thick cobalt alloy coating.

Sputtering process

The sputtering process provides better thin film coating compared to the plating process. This process provides thinnest, hardest and finest media surface.

In the sputtering process the platter substrate is first coated with a layer of nickel phosphorus and then on this surface cobalt alloy material is deposited using a sputtering process.

For this sputtering process, the platter is kept in a near vacuum, and 1–2 micro inch thick cobalt alloy is deposited on the platter surface. Once the cobalt is deposited, a very hard 1 micro inch protective carbon coating is applied to this surface.

This carbon coating makes the disk surface almost un–destructible. This coating allows the hard disk to survive almost any head crash.

These advantages of the sputtering process is making it one of the most common disk media creation process, the other process i.e. the plating process is almost not used anymore.

Only problem with this process is the high cost involved in its process, which makes it costlier than other surface making process. But the positives points of this process makes it more viable despite this shortcoming.

When looked at a disk surface made using the thin film process, it looks like a silver mirror surface.

Read/Write Head

Read/write head is used to write any information on the disk surface and to read the written data back, without any data loss. A hard disk drive contains one read/write head for each side of its platter. For example if a drive contains 3 platters then total six read/write head will be used to read the two (top & bottom) sides of each platter.

All the head used in a disk drive system are connected together and moved in and out on the disk surface as a single unit, one can not move different head in different order.

Inside the hard disk, when the disk is at rest i.e. not spinning, then the head is in direct contact with the disk surface. As the disk starts to spin, because of its

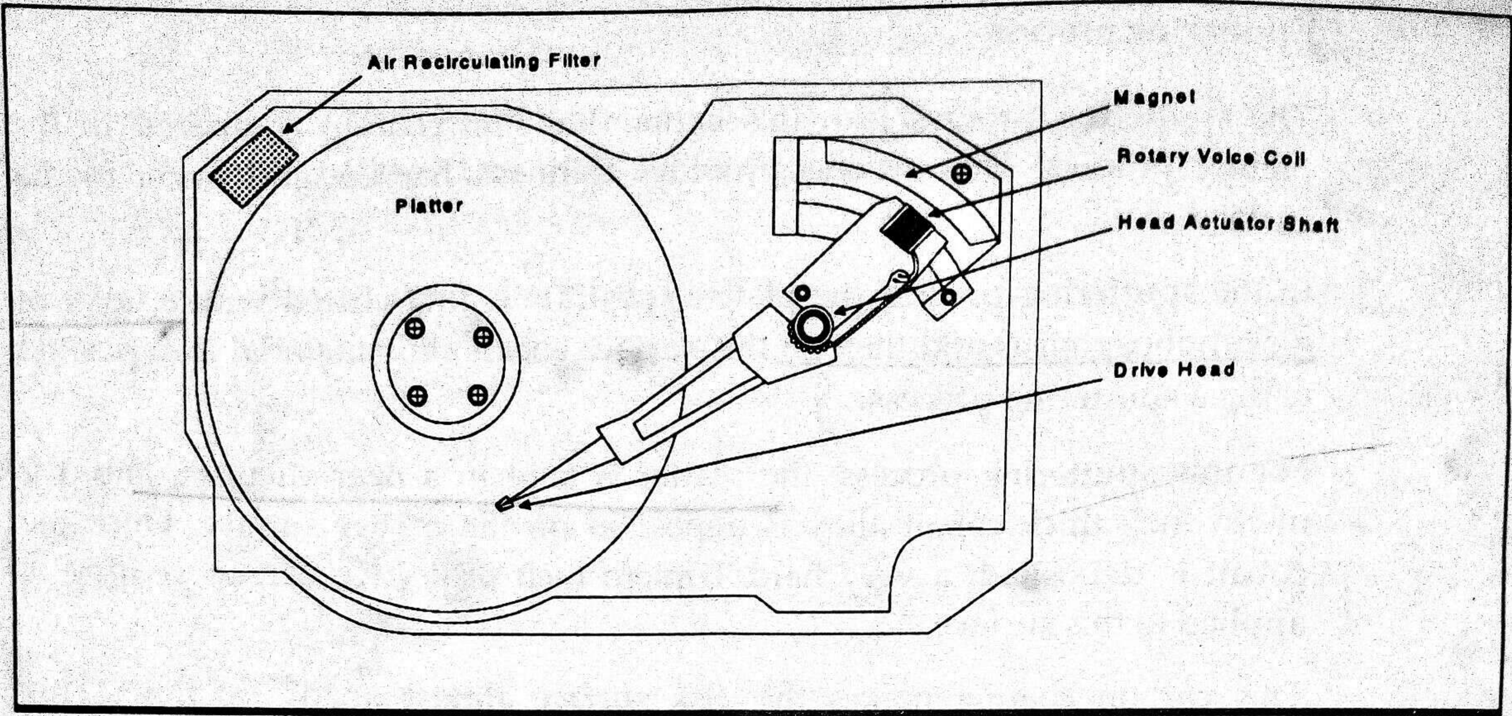

Figure 2 - 5

Internal components of the hard disk drive.

very high rotation speed, air pressure develops under the head. This pressure lifts the head from the disk surface and the head starts to float on an air cushion, 3 to 10 μ inch (millionth of inch) above from the disk surface.

Initially hard disk drive heads used to float at a height of 200–300 μ inch, but as the technology improved, this height reduced, todays head float at a very close distance of 3–5 μ inch from the platter surface.

This very close distance between the head and the disk surface is the reason of making the hard disk drive completely sealed unit. When the head is floating on a height of 3–5 μ inch on a disk which is rotating at a speed of 3,600 to 7,200 RPM (Rotations Per Minute), any small dust particle may seem like a mountain. When the head hits a dust particle at this speed, at may scratch the disk surface and permanently damage the drive.

The hard disk drive is manufactured and serviced in a room known as "class 100 clean room", in this type of room there will be less than one hundred dust particles of 19.7 μ inch size, when one cubic foot of air is checked.

Generating and maintaining this type of clean environment is very costly, which makes very few company to go in for the hard disk drive repair/maintenance work.

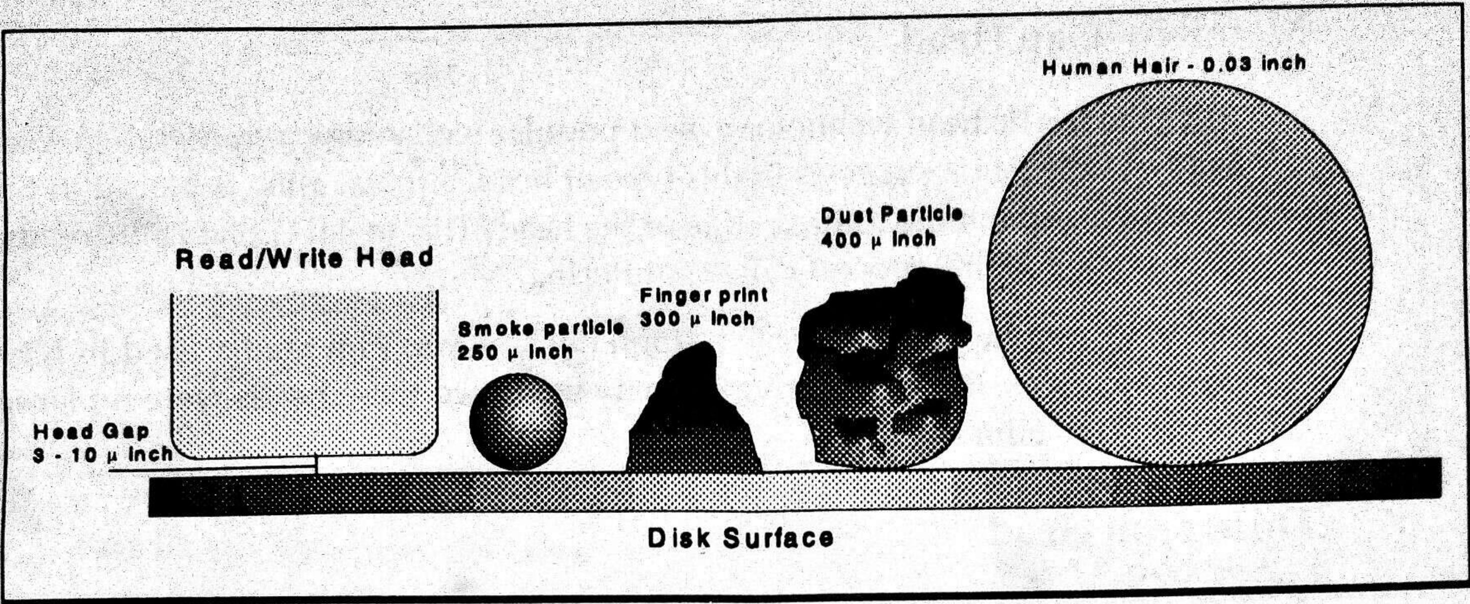

Figure 2 - 6

Size of dust and some other particles compared to the head and disk surface distance.

Different type of head are used with the hard disk drives for read/write purpose, some of them are

- Ferrite head
- Metal–in–gap head
- Thin film head
- Magneto–resistive head

Ferrite Head

This was the original hard disk drive head made by the IBM for their Winchester disk drives. This head is made of iron–oxide core wrapped with electro–magnetic coils.

To write any information using this head, the coil is energized, which produces magnetic field on the disk surface. To read the information stored on the disk surface this head is passed over the disk surface and the induced current generated in the coil is used to read the data.

As this type of head can not be used to store higher density data, this type of head is obsolete today.

Metal–in–Gap Head

After the ferrite head technology, next popular technology was Metal–in–Gap head. As the name suggests in this type of head, a metal alloy is placed in the recording gap, on the trailing edge of the head. This metal is placed using the vacuum depositing process called sputtering.

Metal–in–gap head could write to high density thin film media used in high capacity drives. But as the drive capacity increased these heads were replaced by the Thin–Film head.

Thin–Film Head

Thin–Film head are very small and light weight heads which can be used as close as 2 μ inch (micro–inch, millionth of inch) or less to the disk surface.

These head are produced using a photo–lithographic process similar to the process used to make semiconductor chips.

In this head, instead of the iron–oxide core, a iron–nickel alloy core is used, which is 2–4 times magnetically more powerful. The head gap of this head is very narrow, and is completely enclosed with a hard aluminum material, which protects the head from any crash with the disk surface.

Initially this type of head were very costly compared to the ferrite and metal–in–gap heads, but as the technology to manufacturer them improved and as the demand grew, they become competitive to the other head designs.

Currently most of the high capacity hard disk drives use the thin–film head design, but the magneto–resistive head design may replace them from this position.

Magneto–Resistive Head

Magneto–Resistive head is a new head design, invented by the IBM. This design is considered superior to all other current head designs. currently most of the 3 1/2 inch drives with 1 Gigabyte or more capacity use this head design, as the storage density of the hard disk drives increase further, slowly all the drives will use the Magneto–Resistive Head.

This head design works on a different principle compared to the other head designs. We have already told that all the other head designs use the voltage

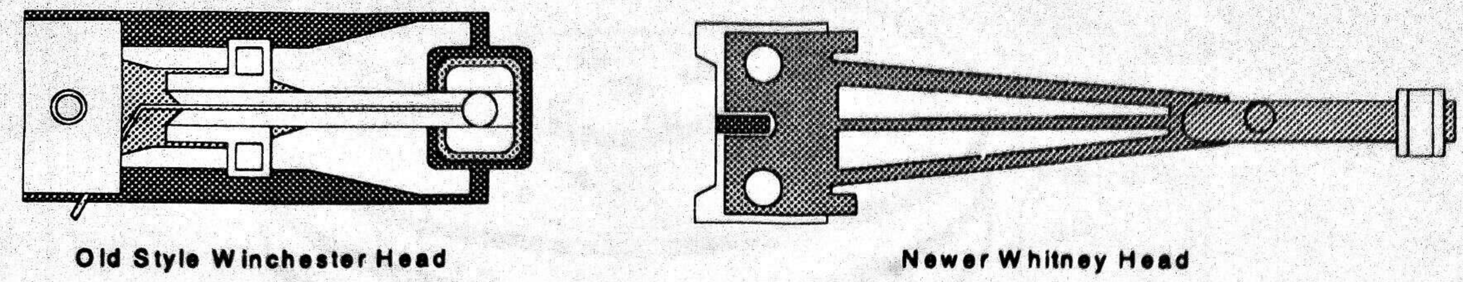

Figure 2 - 7

Read/Write head of the hard-disk drive.

generated by the magnetic field on the coil to read the data stored on the disk surface, but the Magneto–Resistive head works on the principle that when a magnetic field is present near a conductor, the resistance of the conductor changes.

To read the data stored on the disk surface using this principle, a small current is flown through the drive head, and any change in the resistance is measured by measuring this sense current. This type of head design makes the head 3–4 times more powerful than the Thin–Film Head.

This head design is used only to read the data stored on the disk surface, to write data one still requires a separate head. This head design requires two separate heads, one for writing and another for reading.

Requirement for two heads is a drawback, but this has some advantage as well. Traditionally when the same head is used to read as well as to write, the head gap used to be a compromise between the best gap required for writing and the gap required for reading. A narrow gap works best when the data is read from the disk surface, as it will be less susceptible to the nearby magnetic information and a wide gap is better for writing on the disk surface as a wide gap provided deeper flux penetration on the media.

When two different head are used for writing and reading, one can provide the best gap for reading on the reading head and for writing on the writing head. On a Magneto–Resistive Head based system the read head will be based on the Magneto–Resistive design and will have a very narrow head

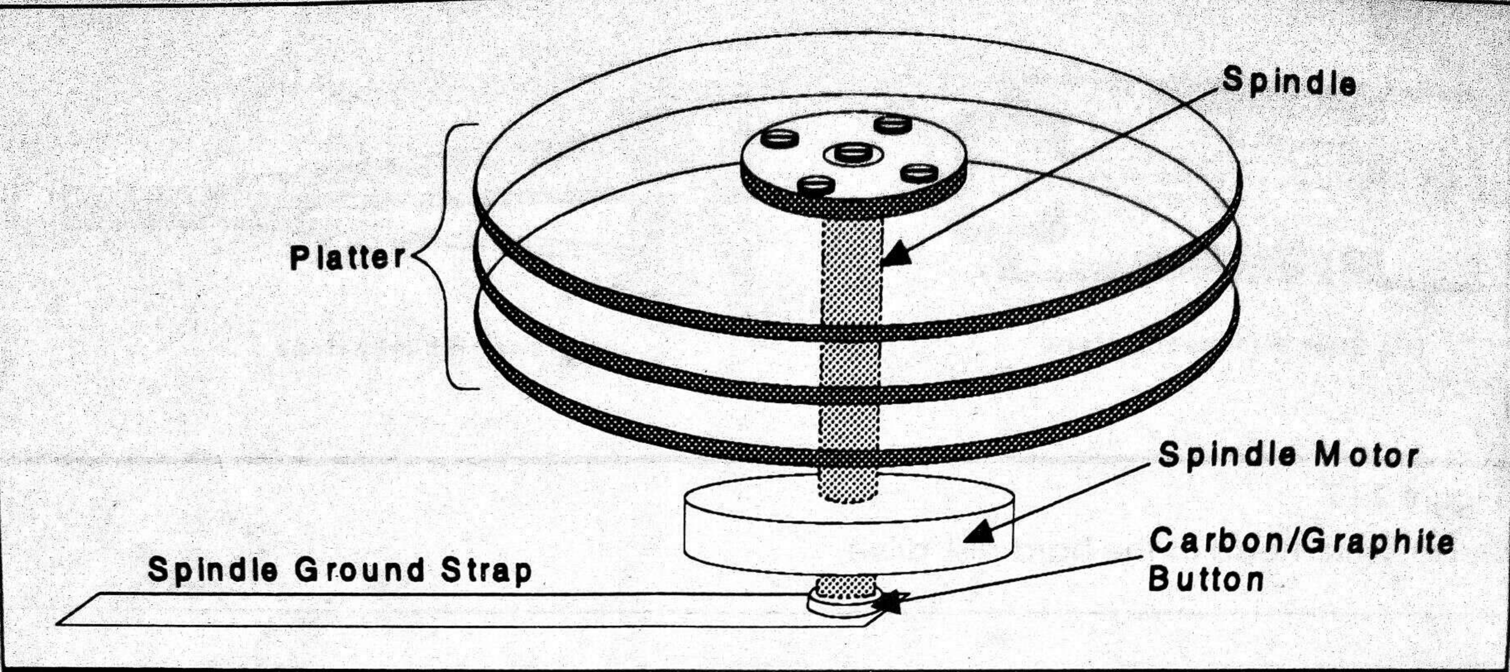

Figure 2 - 8
Spindle and Spindle Motor of the Hard-disk Drive.

gap, and the write head can be based on the Thin–Film Head design with a wide head gap.

One disadvantage with the Magneto–Resistive head design is these heads are very delicate and susceptible to the electro–static discharge. During the manufacturing these head needs to be handled very carefully and because of its high sensitivity it requires good shielding to protect it from stray magnetic fields.

Head Arm/Head Slider

The arm on which the read/write head of the disk drive is located is called the head slider.

These sliders are made in a catamaran sailboat shape as shown in the second part of the figure 2–7, the central portion of the slider carries the read/write head over the disk surface.

A common slider size in todays 3 1/2 inch hard disk drive is 0.08 x 0.063 x 0.017 inch. Slider of this size is called a "Nano Slider", because of its small size.

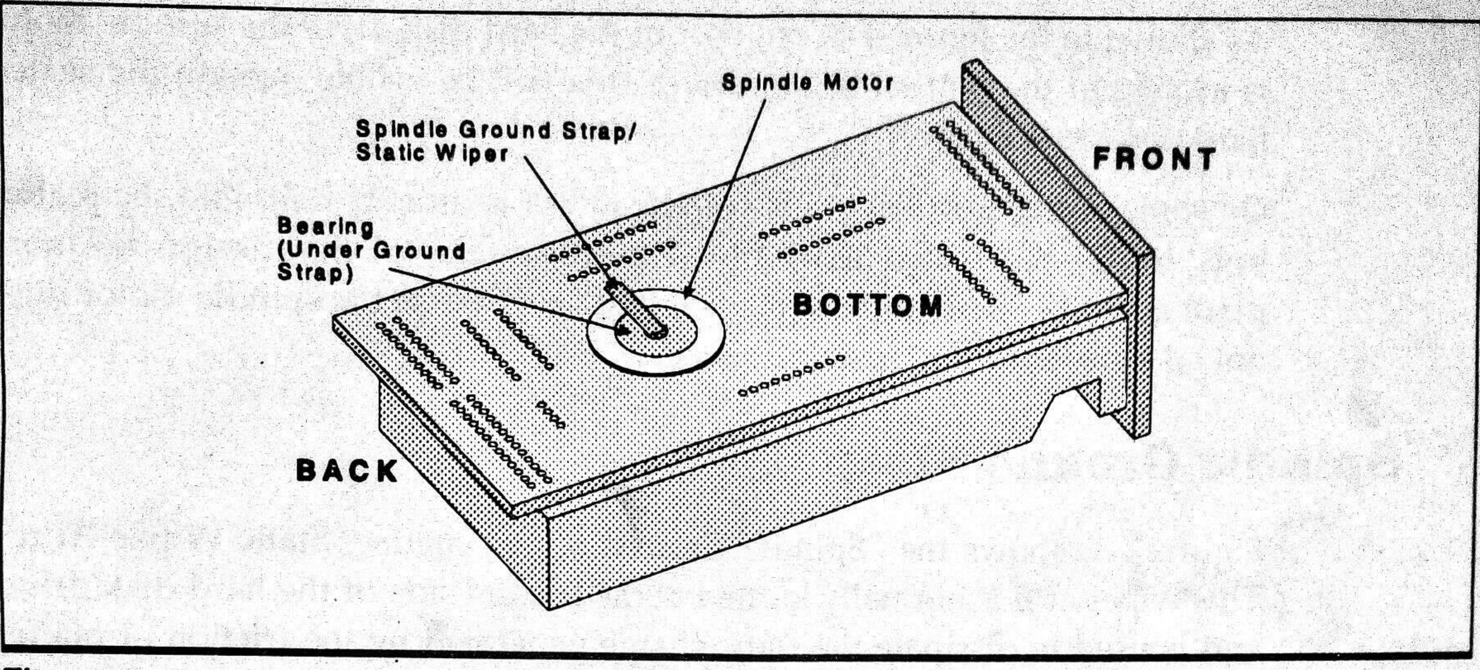

Figure 2 - 9

Spindle motor ground strap on the hard-disk drive.

A small size slider has many advantages, such as the lower weight allows for faster acceleration and deceleration which makes the disk access faster. The reduced size requires less leading space on the disk surface, reducing the wasted area on the disk surface.

Disk drive manufacturers provide special textured patterns on the head slider surface to keep the slider at a constant height from the disk surface, during the disk operation.

Spindle Motor

Spindle motor is the main motor which rotates the hard disk drive's platters. It is called the spindle motor because this motor is directly connected to the spindle on which the platters are connected. On some drives the spindle is connected to the spindle rotation motor through some belts or gears.

Directly connecting the motor to the spindle makes the hard disk's spindle rotation noise and vibration free.

This motor works on a feedback loop to automatically adjust the disk's rotation speed. A hard disk platters rotates at around 3,600 to 7,200 RPM (Rotations Per Minute) or more.

As shown in the figure 2–8, on most of the hard disk drive the spindle motor is located at the bottom of the drive. This will be visible outside the sealed hard disk assembly.

On some of the new drives the spindle motor is directly built into the platter hub, inside the sealed assembly. The advantage of this design is, more platters can be used on the same height disk drive, as the spindle motor does not take any additional vertical space.

Spindle Ground Strap

Figure 2–9, shows the "Spindle Ground Strap" or the "Static Wiper Arm". This wiper arm is normally located at the bottom side of the hard disk drive, and is used to dissipate the static charge generated by the friction of platter and air inside the hard disk drive.

This wiper arm is visible on most of the hard disk drive from a hole in the bottom circuit board, if the board does not contain any cutout then by removing the board you can locate the wiper arm.

If this static discharge arm is not provided then the static built inside the hard disk drive may discharge through the read/write head, destroying the data on the hard disk and even the read/write head.

This arm is normally made of copper and connects to the spindle through a carbon or graphite button. Most often with the use this button becomes flat, the flat area of the button cause the discharge arm to vibrate, this is the main reason behind the high–pitched noise generated by most of the old hard disk drives.

Logic Board

Other than the read/write head, spindle motor, head movement assembly, the hard disk also contains a logic board to control all these different parts of the hard disk drive. This logic board is also used to interface the hard disk drive with the computer.

A hard disk drive may contain one, two or even three logic boards, at the top, at the back and at the bottom of the drive. Some type of the hard disk such as the IDE type contains the drive controller circuit on the drive logic board itself.

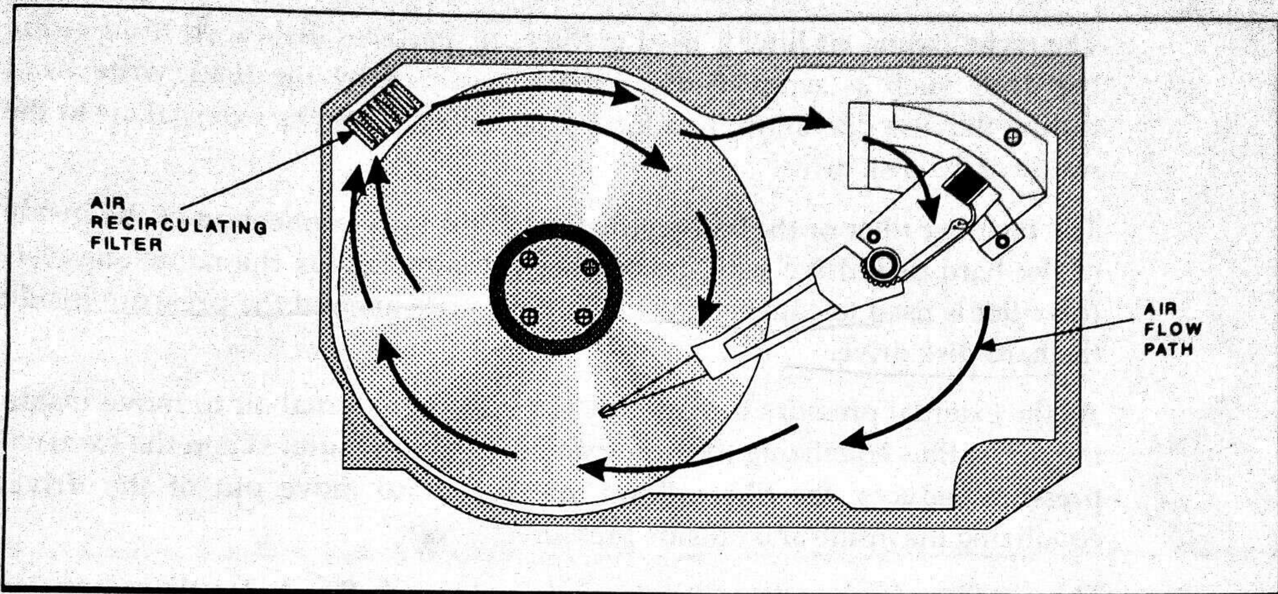

Figure 2 - 10
Air filter to filter the air circulated inside the hard-disk drive.

Many a time the hard disk failure is due to the failure of this logic board, a power problem or some other problem may destroy the logic board on the hard disk drive. On this type of disk if the mechanical parts are in good condition then one can bring the drive to life by just replacing the dead logic board with a new board of the same type.

Air Filter

Most of the people think that inside the hard disk drive there is vacuum. But this is not true, the hard disk drive will not work in a vacuum condition, because the read / write head needs air to float on the disk surface.

Most of the hard disk drive when used in a very high altitude, such as mountain tops, or inside aeroplane, where air pressure is very low, will not work. For this type of application, one would require special hermetically sealed, airtight hard disk drives, which will have air inside the hard disk drive, but is completely sealed from the outside.

Most of the hard disk drive will have two air filters, one is called recirculating air filter and the second is called breather filter.