Heinz Ritter

An Introduction into
Storage Media and
Computer Technology

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Computer Supplies

BASF

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Storage Media and
Computer Technology

BASF

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Contents

1. Preface

In this guide book I have compiled important information about magnetic recording media and basic expressions for data technique. In the text the reference to literature is indicated with numbers in square brackets and listed in numerical sequence in the bibliography.

For the study of this guide book no knowledge of technical expressions is required. The text, figures and tables are easily understandable. Special expressions and branch usual abbreviations are explained. They are quickly found via the alphabetical index.

Many thanks to all people concerned in our company for their help with the text and the figures.

In particular, I am grateful to Dr. Karl Uhl, Dipl.-Ing. Joachim Hack, Dipl.-Ing. Otto Dehnke and Lawyer Rainer Trieschmann for reading through and correcting all chapters.

I have also been fortunate in the extent of help concerning texts and figures from Dr. Werner Grau for the development of magnetic storage media, Dr. Eberhard Köster for the development of optical storage media, Dipl.-Ing. Bernd Roeger and Dr. Bernd Klaus Dalman for the diskette technique, Dr. Peter Rudolf and Dr. Jochen Rudolph for the MTC technique, Dipl.-Ing. Uwe Woweries for the computer tape and Dipl.-Ing. Günther Lenhard, Dipl.-Ing. Jörn Friese and Friedrich Engel for the application engineering.

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2. Introduction

This guide book covers the Storage Media for computer applications of BASF Aktiengesellschaft, meaning diskettes, magnetic tapes and disks as well as basic expressions of data technique. The chapters "Some historical facts" and "Research and Development" also include the audio and video technique. The explanation of the write/read procedures, of the technical characteristics of measurements, of oxides and the manufacturing comprise all above mentioned EDP media. Subsequently they are presented in individual chapters. The chapters "Care and Handling" of the storage media and "Research and Development" are not subdivided into individual products. They cover again all media products.

This guide book is for all those interested for their own information or having to answer verbally or in writing questions on the subject of data storage.

The contents of the guide book are based on our present knowledge and experience. A guarantee of defined properties in a legal sense cannot be deducted from this information.

Please ask your appropriate BASF sales representative for technical specifications, order codes and compatibility charts for the individual products as well as figures for reproduction. However, if you use text and/or figures and tables of this guide book please indicate for copy right reasons as source "BASF Aktiengesellschaft".

3. Important Historical Landmarks

There are many landmarks in the history of the magnetic recording. We are going to mention only a few important ones.

It all started with a Silk Thread.

The American engineer Oberlin Smith describes the principle of magnetic sound recording in an article, published the 8. 9. 1888 in the "Electrical World" [1]. An electromagnet magnetizes a magnetizable sound carrier, e.g. a silk thread with hard steel dust, in the rhythm of the sound waves captured by the membrane of a telephone and transformed into an electric current. For the reverse reproduction the magnetic pulses would be transformed into an analogue electric current activating the telephone membrane. Although this idea was brilliant, it came at a time where there were no technical possibilities to get practical results (see fig. 1).
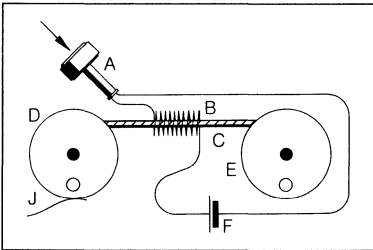
The Phonograph of Oberlin Smith   **Fig. 1**

The original drawing of Oberlin Smith (1840–1926), published in the Electrical World of 8. 9. 1888. The spoken words are transformed by the telephone A into an electrical sound signal and are recorded in the form of magnetization patterns on the sound carrier C, passing through the recording head B. F = battery, E = take up reel, D = supply reel, J = reel brake.

. . . a steel wire

The Danish physicist Valdemar Poulsen made the first practical tests in 1898 with magnetic recording. His Telegraphon, for which he used a steel wire, was a sensation on the 1900 Paris World Fair (see fig. 2).

. . . and a paper tape

28 years later the Dresden Engineer Fritz Pfleumer presents to the Berlin press a new machine. It works with a paper tape of which the surface has a coating of iron powder (see fig. 3).
However, steel wire and paper tape have aggravating disadvantages. The wire cannot be guided torsion free; the paper tape is very delicate and breaks often.

Fig. 2   The Telegraphon of Valdemar Poulsen
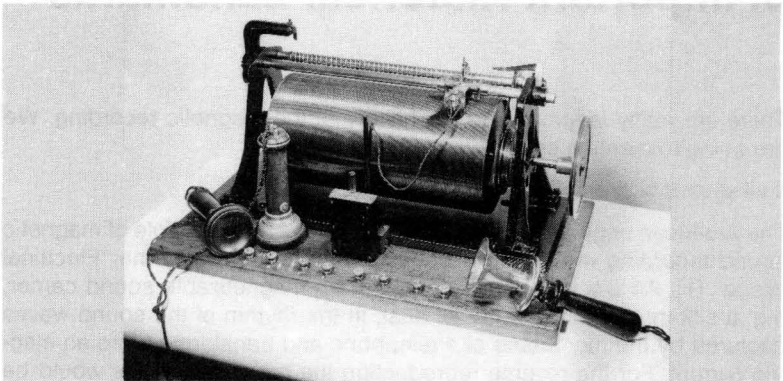
The Telegraphon of 1900 of the Danish physicist Valdemar Poulsen (1869–1942). It is the first machine working with the principle of the magnetic sound recording. A piano wire is wound on a rotating brass cylinder. When the cylinder rotates the wire is guided by two poles of an electro-magnet gliding along a metal bar. This "magnetic head" is charged with the recording, the reproduction and the erasing of the wire. Today the Telegraphon is exhibited in the "Deutsches Museum" in Munich.

Fig. 3   Fritz Pfleumer
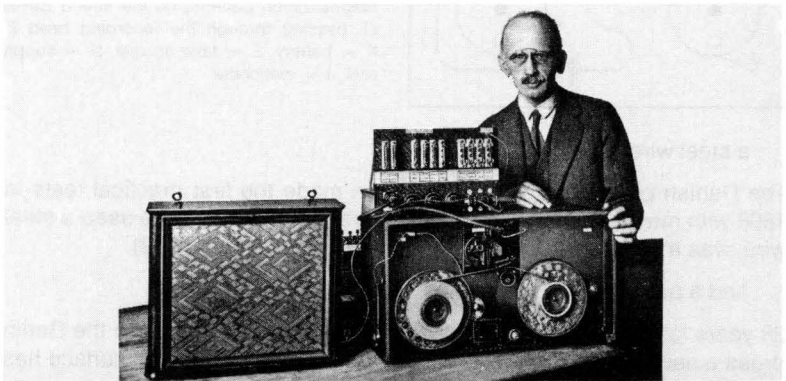
The Dresden engineer Fritz Pfleumer (about 1895–1945) with his demonstration units. In the foreground at the right side is the paper tape recorder with 300 m of paper tape for 20 minutes playing time. Steel dust is glued onto the paper. An electromagnet is responsible for the recording, the reproduction and the erasing.

3.1 Cooperation Leads to Success

In 1930 the Allgemeine Elektrizitätsgesellschaft (AEG) in Berlin, decided to start the development of a magnetophone machine, based on the Pfleumer principle. 2 years later there was an agreement of collaboration with BASF, Ludwigshafen: AEG developed the system, BASF an appropriate sound carrier [2,3,4].

This collaboration did not come by accident. On the contrary, BASF had the knowledge, necessary for the development of magnetic tape: Here, since 1925, carbonyl iron powder in the finest particles had been produced for induction coils in telephone cables and for mass cores in the high frequency technique. In addition, experience had been gathered in the manufacture of enamel paint by milling and dispersing of dyestuffs with cellulose acetate and solvents. At the same time the development of plastics had started for the production of foils and fibres [5]. Thanks to this rich experience in 1934 BASF was able to ship the first 50,000 m of magnetic tape: The tape consisted of a foil of cellulose acetate as carrier material, coated with a lacquer of iron oxide as magnetic pigment and cellulose acetate as binder. During the 1935 Radio Fair in Berlin the Magnetophone and the Magnetic Tape were presented to the public (see fig. 4).

BASF Carbonyl Iron Tape on an AEG Magnetophon K1   Fig. 4
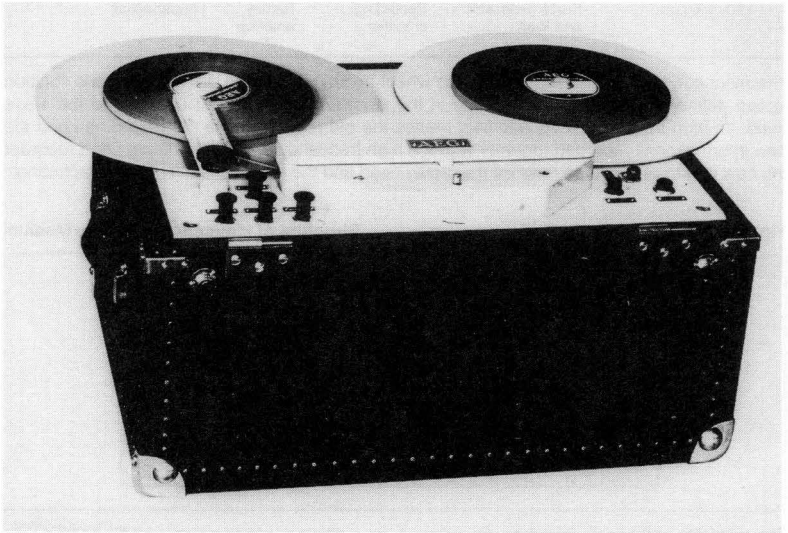
AEG Magnetophon K1 with 1 m/s tape speed and BASF Carbonyl Iron Tape, 6.5 mm width and about 600 m length.

3.2 The Principle

The build-up of the reel-to-reel audio-tape recorder (see fig. 5) and of the audio tape resp. magnetic tape (see fig. 6) show the important functions of the principle, valid until today for all magnetic storage media and systems.

Let's start with the System.

The important elements are the magnetic heads, the magnetic recording medium and the drive with constant speed (see fig. 5 and 7).

Fig. 5   **Build-up of a Reel-to-Reel Tape Recorder**
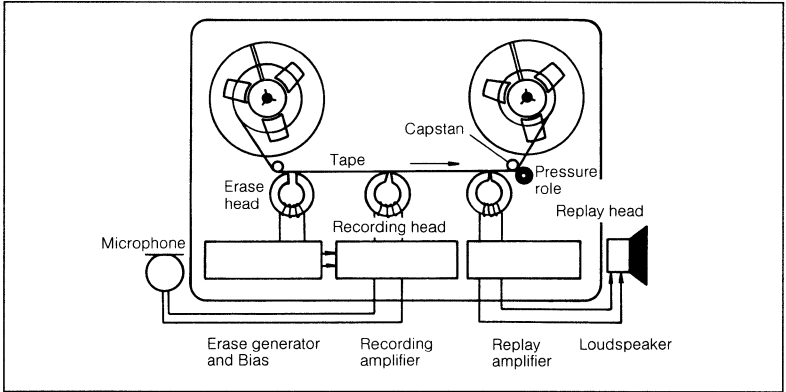
The magnetic tape is pressed by a pinch wheel against a capstan. Its diameter and rotation speed define the tape speed. The tape in the recording mode is first exposed to the erase head. Its high frequency magnetic field erases the old recording. Via the recording head the new information is recorded together with the high frequency bias. With a triple head recorder the new information can be read via the replay head and the replay amplifier during recording.

Fig. 6   **Structure of Magnetic Recording Medium**
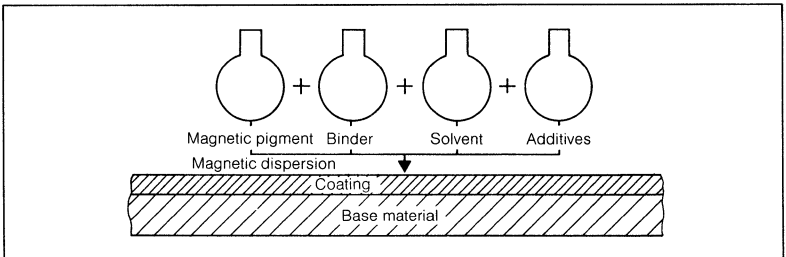
The principle of the industrial manufacturing of magnetic recording media, invented more than 50 years ago by BASF, is still valid today: A magnetizable coating on an non-magnetic base material (e.g. today polyester film, aluminium disks).

Information → Time change J (t)
  ↓
Medium → Surface distribution D   } Any number
  ↓   Any length
Information → Time change U (t)   Power less
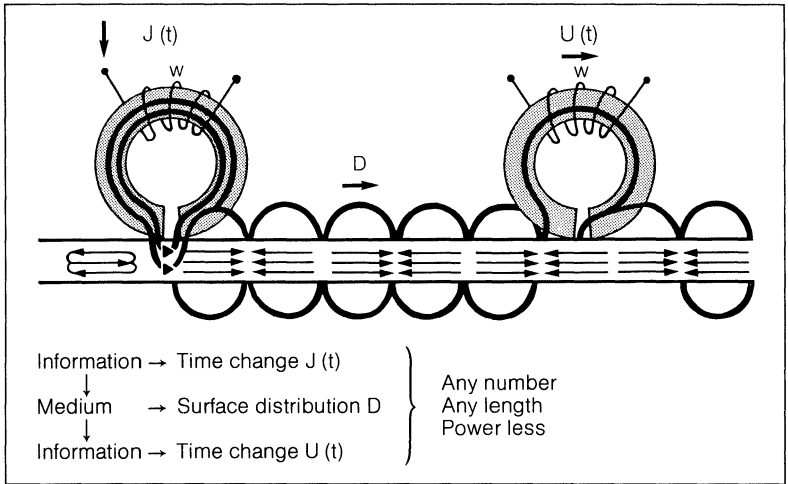
The principle of magnetic recording on a moving magnetic coated storage medium has been valid for over 50 years. This principle is also called "dynamic" (dynamos is Greek and means "power"), as together with the magnetic head the media function in a similar way as dynamic loud speakers and dynamic microphones. In all three cases mechanical movements (membrane of loudspeakers/microphones, moving magnetic coating storage media) in a magnetic field are, via suitable electromagnets, (moving coils here, magnetic heads there) transformed into sound currents.

The magnetic head forms a magnetic circle. Its ferromagnetic ring has a very high magnetic conductivity its airgap – where the magnetic flux leaks out – a very low magnetic conductivity.
According to the magnetic voltage equation, during recording the magnetic head electromagnetically transforms the amperage J passing the magnetic head via a number of windings w into magnetic fields. It is $J \cdot w = \Theta$ law of the magnetic motive force (or 1st equation of Maxwell).

According to the induction equation, during reproduction, it transforms magneto-electrically the stray magnetic fields leaking out of the magnetic coating into the read voltage U. It is: $U = B \cdot l \cdot v$. Here B is the magnetic flux density, l the conductor length and v the speed (here the tape speed, see also chapter 8).
Information in the form of a time progression of a physical unit is recorded on the surface of the magnetic coating as write current J via a magnetic transducer, called "write head" or "recording head", in the form of a local distribution of magnetizing patterns. During the reproduction the magnetizing patterns induce in the same or, as here, in a separate

transducer, called "read head" or "reproduction head" a read voltage U transformed in an appropriate way back into the information progressing in time. This may happen any time, e.g. 10,000 times, after any length of time, thus after years and without external power supply as e.g. for semi-conductor storage. An interesting fact is that one of the oldest sound recordings on tape in the BASF library dates from 1936 (see fig. 8).

Fig. 8   **Programme of a Concert of Sir Thomas Beecham**

FEIERABENDHAUS
Ludwigshafen a. Rh.

Donnerstag, den 19. November 1936, abends 8 Uhr

Einziges Konzert

des

Londoner Philharmonischen Orchesters

unter Leitung von

Sir Thomas Beecham

I.

Die Wespen des Aristophanes, Ouvertüre . . V. Williams

II.

Sinfonie Es-Dur Nr. 39 . . . . W. A. Mozart
                        Adagio-Allegro
                        Andante con moto
                        Menuett
                        Finale

III.

a) **Sommernacht am Fluß**
b) **Beim ersten Kuckucksruf im Frühling** . . . . Fr. Delius

IV.

Einleitung und festlicher Zug aus
    „Der goldene Hahn" . . . . N. Rimsky-Korssakow

—— **P a u s e** ——

V.

Sinfonie Nr. 4 G-Dur op. 88 . . . . A. Dvorak
                        Allegro con brio
                        Adagio
                        Allegretto grazioso
                        Finale (Allegro ma non troppo)

K o n z e r t l e i t u n g: Bildungsausschuß der I. G. Farben
Ludwigshafen/Rh. in Gemeinschaft mit der Mannheimer
Konzertdirektion Heinz Hoffmeister, Mannheim O 7. 16

The Programme of an orchestral recording on magnetic tape with Sir Thomas Beecham, 1936 in the "Feierabendhaus" of BASF. Today the recording is still reproducable in the same quality.

During recording and reproduction the storage medium has to be transported in front of the magnetic heads with a constant speed. The tape transport of longitudinal storage media, like that of the magnetic tape, may be realised by an appropriate number of revolutions and the corresponding diameter of the capstan and a pinch wheel. For circular storage

media like the diskette and the rigid magnetic disk this disk generally rotates with a constant number of revolutions resulting in a diameter related read/write speed.

All so-called dynamic media with magnetic coatings are fully reversible. They may be recorded, read and erased at any time. Magnetic heads, one for each function or several functions combined in one magnetic head do the writing, reading and erasing.

For computer data recording with circular storage media the same magnetic head system is charged with all three functions.

Now to the Magnetic Storage Media.

As we know from the system principle, the magnetic fields in storage coating are produced by alternating electrical currents. They are to be recorded in the magnetic coating in the form of magnetizing patterns. For this the principle of the magnetic dipoles is used (dipoles = two poles of different magnetic orientation).

During the production of magnetic tape the individual carriers of the magnetization, the oxide needles, have to be enveloped in binder material to be magnetically isolated from each other. In addition a uniform and abrasion free magnetic coating has to adhere properly on the plastic carrier and remain for decades without abrasion.

The principle of industrial manufacturing of such coated magnetogram carriers, invented by BASF, is now more than 50 years old and is today still valid for all common magnetic storage media such as audio- and video tapes, computer tapes, diskettes and rigid magnetic disks.

A magnetic dispersion, composed of a magnetic pigment, binder, solvents and additives, is coated on an unmagnetic carrier, today for flexible media a plastic foil, for rigid media an aluminium substrate (see fig. 6).

3.3 The System Decision at that Time

The magnetic sound was not yet very convincing. Its competitors were the needle sound (see fig. 9), introduced in the sound recording studios and in film studios the optical sound (see fig. 10). However, needle sound and optical sound are for reproduction only after a one time recording. On the contrary, magnetic tapes are fully reversible for recording, reproducing and erasing the information any time as often as necessary. Another advantage is the easy editing by mechanically cutting and joining of the recorded tape. Also further developments of the system and the tape are quickly realized. BASF replaced the iron powder by γ Fe_2O_3. The higher coercive force of iron oxide permits a higher recording density. By this the tape speed of originally 100 cm/s is reduced to 77 cm/s.

Spiral groove of a record

Horizontal cut

Vertical cut

Stereo cut
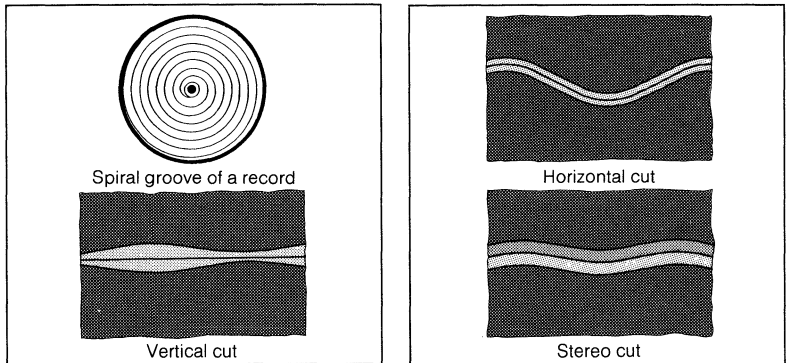
Needle sound is recorded by an engraving tool in the form of a mechanical groove into the matrix. This mechanical groove in the sound carrier may be vertical (= vertical cut) or horizontal (= horizontal cut). Today the horizontal cut is still used for the Longplay Record (= LP). For stereo the two channels are cut into the flanks of the groove (= stereo cut). The stereo cut may also be reproduced by mono players.

This increases the playing time for the same tape length. We will return in detail to the coercive force and the recording density at a later stage.

The final breakthrough in magnetic sound recording came in 1941 with the introduction of high frequency (HF) bias, reducing the disturbing noise levels considerably.

After the war all German patents were freely available, also those of BASF. The international success of the magnetic sound tapes first started in the USA [6, 7, 8, 9].
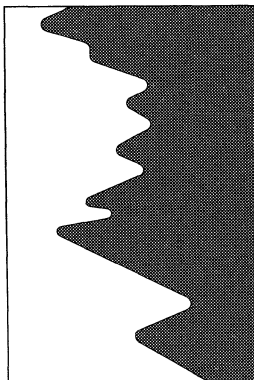
Fig. 10   **Optical Sound**

Optical sound records the sound signal photographically. Example: Single sided variable area sound track.

3.4 The HF Bias

Is a magnetic particle, thus also a magnetic pigment, exposed to a magnetization M with a definite field strength H, it produces material typical magnetizations depending upon the strength of the magnetization and the corresponding field strength. For H_1 it is M_1, for H_2 then M_2 etc (see fig. 11 a).

If the particle now leaves the magnetic field, as the magnetic tape does after passing the magnetic head, it retains a remanent magnetism (latin remanere = remain). For M_1 it is Mr_1, for M_2 then Mr_2 etc. Different H_1-, H_2-, H_3- etc values result in different Mr_1-, Mr_2-, Mr_3 etc -values. They form the remanence curve. If the recording field corresponds to a sine wave

HF Bias

Fig. 11 a–d
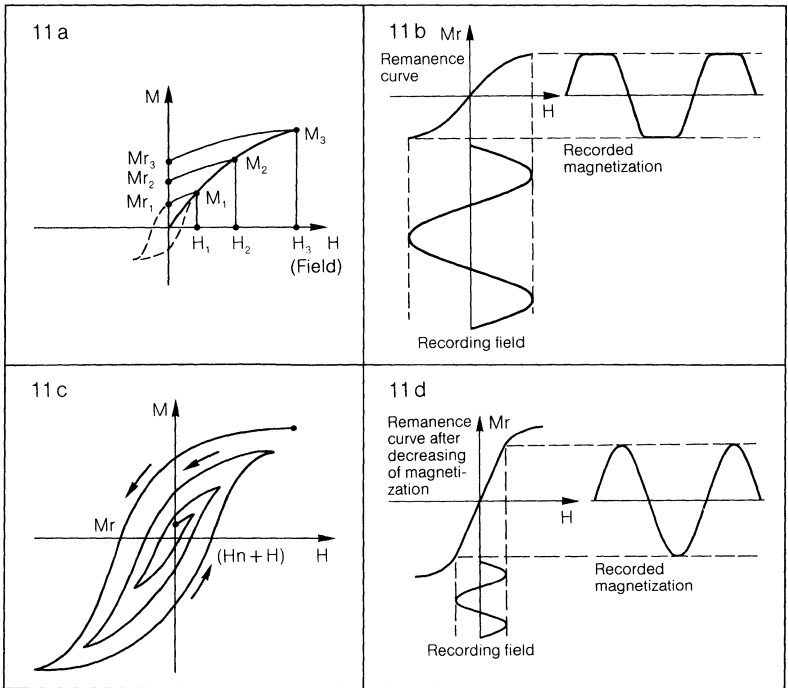
The principle of the HF (= High Frequency) bias for a sinusoidal oscillation.

because of the twisted remanence curve the remanent magnetization is a "distorted" sine-curve. Because of the rounded peaks it results in a distorted sound reproduction (see fig. 11 b). With HF bias the magnetic particle is brought into a fast decreasing alternating field Hn added to the

"signal field" H (see fig. 11 c). The magnetization M has passed the so-called hysteresis loop (see also chapter 8.3) several times, becoming smaller with the wearing off of the alternating field and finally ends in remanent magnetization Mr, corresponding to the signal field H.

In consequence the signal field H results in a remanence curve with a longer linear area because of the initial high amplitude of the auxiliary field Hn. Nearly all the magnetic particles have participated in the magnetization process. If the signal field changes again sinusoidally the reproduction magnetization (= reproduction sound) remains largely distortion free (see fig. 11 d). The superimposed "high frequency field Hn" (the frequency must be much higher than the sound to be recorded) only serves as a help for the linearization of the remanence curve, whereby the particles always start with the highest possible magnetization. They are – figuratively speaking – thouroughly "magnetically shaken".

3.5 How the Tape got into the Wide World

There are many stories, how magnetic tape got into the wide world. One of them is very amusing and is told here:

Before the invasion in Normandy the American secret service listening in Great Britain to German broadcasting made a curious observation: All speeches of political personalities could also be heard in the Reichssender Berlin, when reliable sources had reported them not to be in Berlin [10].

After the war, Major Orr of the US Army went to look for the recorder wrapped in mysteries. He was fortunate. In 1944 the allies found three fully functioning German tape recorders with HF bias and the corresponding tape material at Radio Luxembourg. Major Orr was astonished about the sound quality and immediately he recognized the importance of this invention for broadcasting to the whole world.

Major Orr had to find out how the Germans produced their tapes. He drove to BASF in Ludwigshafen on the Rhine and spoke to Dr. Karl Pflaumer, the great old man of the German magnetic tape.

He explained to him the most simple way to produce magnetic tapes.

Although Orr started in the USA immediately with the tape production he was only successful when Bing Crosby Enterprises recognized the importance of this invention. Bing Crosby and Major Orr worked together with a small electronic company, called Ampex Eletrical Company. Until 1948 all US-broadcasting stations were equipped with tape recorders. In 1951 Bing Crosby presented the first video recorder, an Ampex machine for black/white recording. In 1953 RCA followed with a colour video recorder. In 1954 DuPont started to produce a new plastic film on a polyester base, called Mylar. In the meantime in the USA and in other

countries other tape and recorder manufacturers appeared. The invention of the century had started internationally.

Based on the tape speed of 77 cm/s and a tape width of 6.5 mm the international standard was developed, starting with a tape width of 6.3 mm (= ¼″) and a tape speed of 76.2 cm/s (= 30 inch per second, abbreviated ips).

20 years after the start of the AEG tape recorder and the BASF magnetic tape at the Berlin Radio Fair the era of the home tape recorder began. Thinner and smaller tapes with better magnetic properties and further development in the recorder mechanics and electronics permitted multi track techniques and the miniaturization of the machines. This miniaturization reached a preliminary culmination in 1961 with the introduction of the Compact-Cassette.

BASF invested in new production facilities in Germany, USA, France, Indonesia and Brazil in order to cover the growing market demand for magnetic tapes.

3.6 Tape and Tape Recorder Development

The number of revolutions and the diameter of the capstan define the tape speed. The equation is: $d \cdot \pi \cdot r/s = v$

Here d is the diameter of the capstan in cm, r/s the number of revolutions per second and v the tape speed in cm/s.
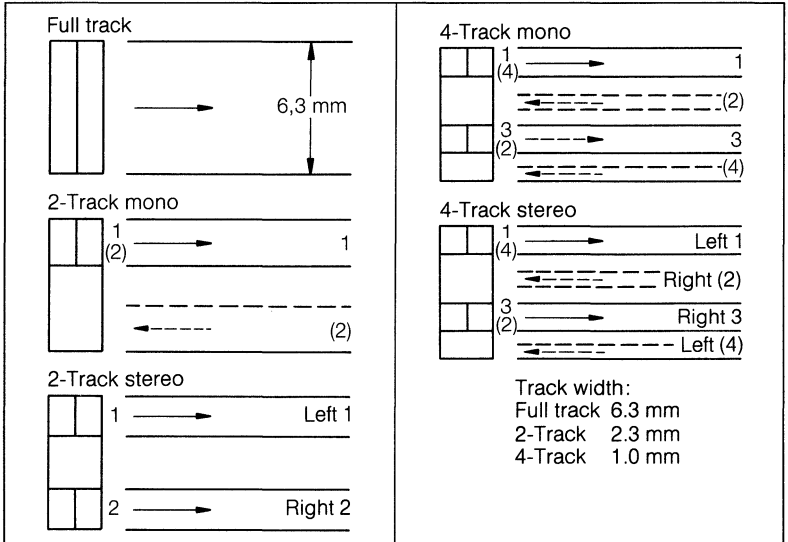
A diameter of 1 cm and 24.5 revolutions per second corresponds to a tape speed of 77 cm/s, the base for the international standard of 76.2 cm/s. Bisecting again and again the speed of 38.1 cm/s (present studio technique) results in 19.05 cm/s, 9.53 cm/s (still today usual for reel-to-reel audio tape recorders) and 4.76 cm/s. Today this is the most used tape speed as it is standardized for Compact-Cassette systems. The lowest tape speed (= 2.43 cm/s) is seldom used for common tape recorders. It serves for tape monitoring of extremely long playing times [11].

The recording area covering the total tape width, the full track system, is reserved for studio techniques (see fig. 12). For reel-to-reel recorders the tape width is subdivided into 2 tracks (= 2-track system) or 4 tracks (= 4-track system) [12].

By reducing the tape thickness the same reel size thereby holds instead of the standard tape (= 100%) first the long play tape (= 150%), then the double play tape (= 200%), the triple play tape (= 300%), the quadruple play tape (= 400%) and finally the sextuple play tape (= 600%).
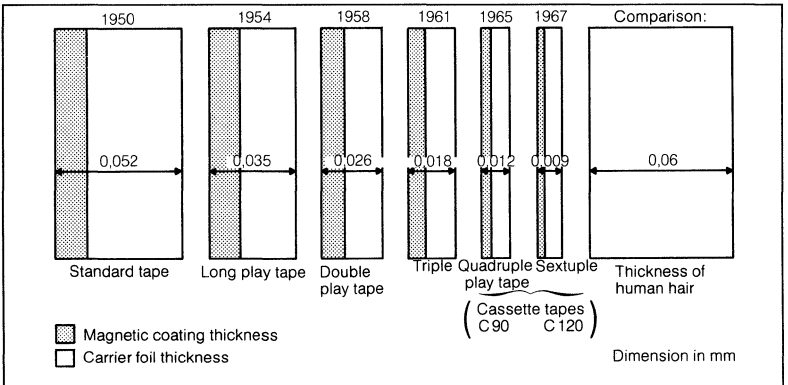
Full track

6,3 mm

2-Track mono

1
(2)   1

(2)

2-Track stereo

1   Left 1

2   Right 2

4-Track mono

1
(4)   1

(2)

3
(2)   3

(4)

4-Track stereo

1
(4)   Left 1

Right (2)

3
(2)   Right 3

Left (4)

Track width:
Full track 6.3 mm
2-Track   2.3 mm
4-Track   1.0 mm

For 2-track mono, 4-track mono and stereo the tape is rewound after the first pass, the reel is turned around and then the second pass begins. These track numbers are indicated in brackets.

1950	1954	1958	1961	1965	1967	Comparison:
0,052	0,035	0,026	0,018	0,012	0,009	0,06

Standard tape   Long play tape   Double play tape   Triple Quadruple Sextuple play tape   Thickness of human hair

(Cassette tapes
  C 90   C 120)

▨ Magnetic coating thickness
☐ Carrier foil thickness

Dimension in mm

The total thickness of the tape is the sum of the coating and the carrier thickness. The nomenclature of the tape indicates the tape length and consequently the playing time for the same reel size and tape speed in relation to the standard tape (= 100%). The Longplay Tape has 150%, the Double Play Tape 200% etc.

As the quadruple and the sextuple play tapes are nowadays offered only in Compact-Cassettes in 3.81 mm width, not the tape denominations but the corresponding Compact-Cassette denominations (C 90 and C 120) are usual (see fig. 13).

With the right choice of recorder and cassette quality on the Compact-Cassette sound frequency and volume ranges are recorded previously only known in studio recorders. This is possible inspite of the fact, that the 3,81 mm wide tape is subdivided into up to 4 parallel running tracks (see fig. 14).
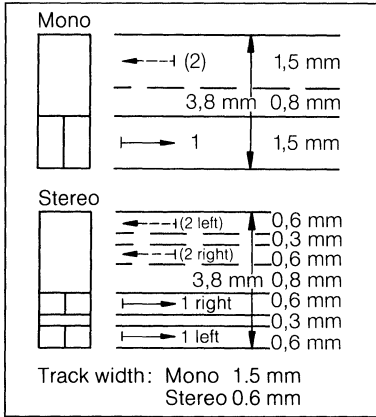
Track Position   **Fig. 14**
of the Compact Cassette

The figures in brackets are the track numbers for the second pass. For the second pass, without rewinding the tape, the cassette is turned around and re-inserted.

3.7 The Video Recording

At the beginning of the 50's magnetic video recording started in the USA. These tapes were also manufactured according to BASF principles. However, they were eight times larger than the reel-audio-tapes. This width of about 5 cm (= 2 inch) is necessary to obtain the tape width required for the chosen recording technique, i.e. the rotating head drum. The technical problem cannot be solved with the conventional audio reel-to-reel recorder technique, with fixed magnetic heads, and the tape passing for recording and reproduction in front of them, as the following calculation shows:

On tape for an audio frequency limit of 15,000 cycles per second (= 15 kilo-Hertz, abbreviated kHz) and a recording speed of 380 mm per second a space of 0.025 mm on the recording side of the tape is required: 380 mm/s : 15,000 Hz = 0.025 mm.

This space requirement we call wave length. Therefore, the equation for calculating the wave length is: $\lambda = v : f$

Here the Greek letter λ is the wave length, v is the tape speed and f the frequency.

The tape technique of that time permitted a wave length of 0.008 mm. The video signal to be recorded was 5 million Hertz. If you transform the above equation the multiplication of wave length and frequency gives the tape speed. Here: 0.008 mm $\cdot$ 5,000,000 = 40 m/s. One hour playing time corresponds to a tape length of 144,000 meter.

With a technical trick, today still in use in modified form and known as "helical scan" magnetic video recording became possible (see fig. 15).

Fig. 15 **Ampex Video-Recorder**
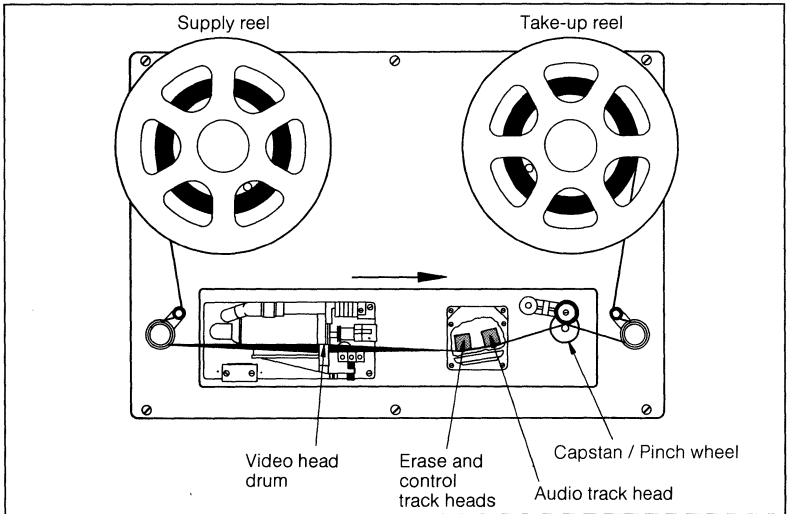
The 2 inch wide tape runs from the supply to the take-up reel. First it passes the video head drum, then the head systems for erase, control and audio. The tape is transported by the capstan and the pinch wheel.

The machine make-up of the first video recorder is similar to that of the reel-to-reel audio recorder [13,14]. The fixed mounted magnetic heads are replaced by 4 video recording and reproducing heads rotating in a video head drum. Its axis is mounted parallel to the tape transport direction.
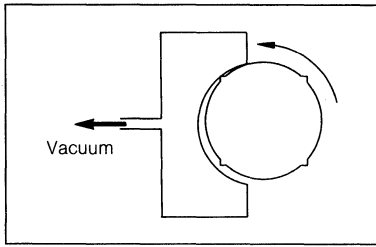
Vacuum Guide   **Fig. 16**

The 2 inch video-tape in its total width is forced by vacuum into the tape guide for correct writing and reading of the heads mounted in the video-head-drum.

The wide tape is transported with 38 cm/s (= 15 ips). For recording and reproduction the tape is sucked into a vacuum tape guide (see fig. 16).

The video tracks are recorded via the 4 video heads in the head drum, mounted diagonally to the tape transport direction (see fig. 17). For a line frequency of 625 Hz, a mains frequency of 50 Hz and a head drum of 2 inch diameter rotating with 250 revolutions per second a relative speed (= tape/head speed) of 1,600 ips, corresponding to about 40 m/s is calculated: $\pi \cdot 2$ inch $\cdot$ 250 r/s = 1,570 ips.

The victorious advance of magnetic video recording has now run for over 35 years and no cost effective alternate recording technique is known. The present TV broadcasting depends on magnetic video recording. For home use the video recorder is also widely used, first for stationary use and more and more for mobile application. By reducing the tape width from the original 2 inch (= 50.8 mm) via 1 inch (= 25.4 mm) down to 1/2 inch (12.5 mm) and even to 8 mm with the new magnetic coatings of chromium dioxide and metal film the recording of smaller wave length became possible.

Track Position of the 2″ Video Tape of the Ampex Recorder   **Fig. 17**
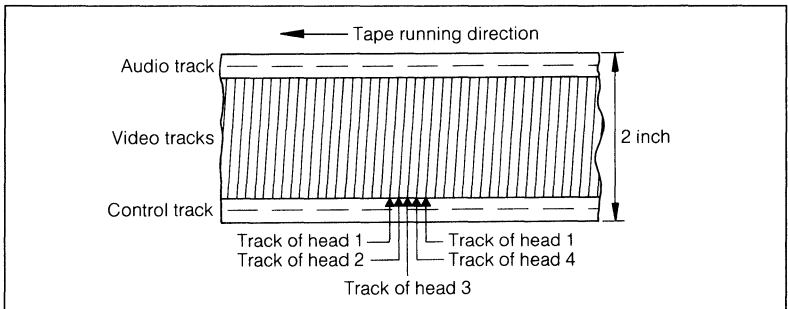
The video recording area via the 4 heads is limited above by the sound track and below by the control track.

Thus the most popular VHS system (VHS = Video Home System) works with 12.7 mm wide video tapes in cassettes with up to 4 hours playing time and a tape transport speed of only 2.4 cm/s and a relative speed (tape/head speed) of about 5 m/s (see fig. 18).
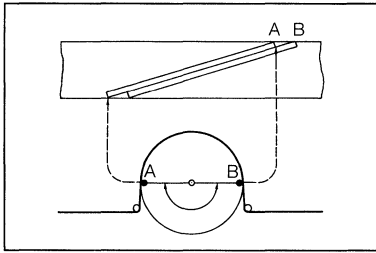

Fig. 18   Track Position of the VHS System

Head arrangement and track position of a stationary VHS-Video-Recorder. Each of the two heads records half a picture.

In the beginning of the 60's BASF started research and manufacturing of video tapes. In 1970 the build-up of a large production capacity of home and studio video tapes started. However, instead of iron oxide a small size magnetic pigment for high recording densities especially suited for home video recording was required. BASF decided to take chromium dioxide. As in 1934 at the start of audio tape manufacturing, the chemical expertise e.g. the high pressure technology, developed and in use since the turn of the century, already existed.

BASF has been for more than 15 years the only European manufacturer of magnetic tape from chromium dioxide pigment and, world-wide, the only producer of chromium tapes with own chromium dioxide.

Todays video tape production has a range of all standard tape width and formats.

3.8 The Analogue Technique

Now we know some historical facts of magnetic recording of audio information. As we have described, it is transformed by a suitable converter (microphone) into electrical signals and these by additional transducers (magnetic heads) into analogue magnetizing patterns on the magnetic tape. The stress here is on the word "analogue", it is of Greek origin and means "according to the sense". We know that a needle instrument is mainly "analogue" and a numerical instrument "digital" (see fig. 19). Digital is of Latin origin (digitus = finger, number).

Analogue recording means e.g.: A sound frequency of 3,000 Hz corresponds to 3,000 magnetizing patterns and records musical pitch. The musical volume has different magnetizing patterns. A pianissimo part is a weak magnetization, a fortissimo part is a strong magnetization.

Todays video recording is in frequency modulation; therefore the recording is independent of amplitude deviations and these have no influence on the recording.
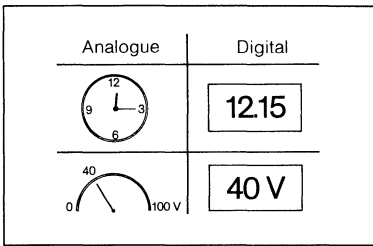
Analogue indicators work continuously, digital discontinuously as they only present the character sequences determined beforehand. In our example the time is in hours and minutes, the voltage in volts.

The storage time is counted in hours playing time. 2 hours for audio and 4 hours for video correspond to most market requirements.

The access time to the recorded information does not play an important role. The stage of miniaturization, Compact-Cassettes for audio, 8 mm or 12.7 mm cassettes for video, is sufficient.

The price/performance is excellent, as systems and cassettes of good quality are offered at low prices. The best is the enemy of the good. The development does not stand still but stays in front of the market in the form of digital techniques.

3.9 The Digital Technique

In digital techniques all information is transformed into characters (figures, letters, special characters) called data. With the introduction of the digital technique the human being as data processor (see fig. 20) is assisted by the computer. The word computer is of Latin origin (computare = to compute).
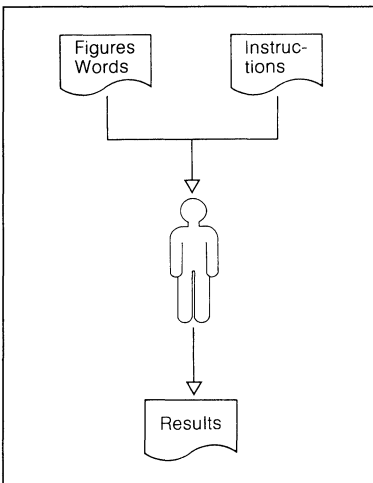
The Human Data Processor   **Fig. 20**

The human being has to process figures and words. He follows instructions. He picks up the data and instructions via his senses (eyes and ears). His brain stores and processes the information. He makes the results visible or audible.

How much faster the computer works than the human being was demonstrated in 1890 by the German-American Hollerith during the 11th American census. The first mass storage medium was the punch card (fig. 21). The input step for digital data processing is the transformation of the information into internationally standardized character sets. The base for these character sets is the binary system (binary is Latin for "two values").

The numbers 1 and 0 are taken as the basis. The smallest information unit is 1 bit, abbreviated from binary digit, meaning figure of two values. A defined number of bits, mostly 8 bits, are 1 byte and in consequence one character. 1,024 characters are one Kilobyte, abbreviated KB, 1,024 Kilobytes are one Megabyte, abbreviated MB. International codes define the bit combination for the different figures, letters and special characters. Example: In the American Standard Code for Information Interchange, abbreviated ASCII, the 8-bit-sequence for the letter S is the byte: 01010011. The digits 1 and 0 are easily realized technically. A perforation in the punch card, a change of direction of the electrical current in the computer or of the magnetization in the magnetic coating (instead of north to south then south to north) may represent the "1". This is only in order to improve the understanding of the history, the subject will be covered in detail in chapter 4.
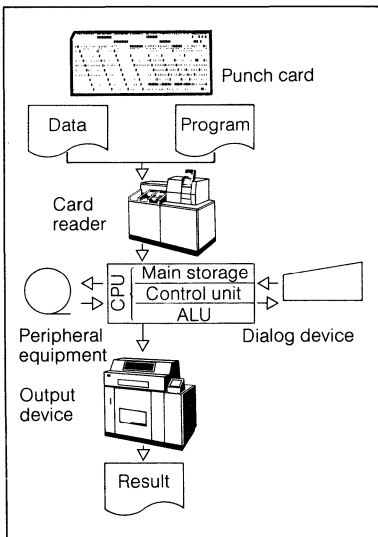

Punch card

Data

Program

Card reader

CPU — Main storage / Control unit / ALU

Peripheral equipment

Dialog device

Output device

Result

Fig. 21   The Computer as Data Processor

The computer has to process the data. It gets its instructions in the form of a program. Data and programs are entered by input units (comparable to the human senses) into computer. The data and the programs are stored in the main storage unit. Controlling and processing are done by the control unit. The ALU (= Arithmetic and Logic Unit) is for arithmetic and logic operations. The results are accessible for the outer world via output units (e.g. printers, monitors).

3.10 Analogue or Digital Recording?

This formulation of the question may be chosen for every kind of information processing. This is valid for data techniques and for audio/video techniques.

Thanks to the error correction facilities the digital technique guarantees recording/reproduction and copy qualities practically identical to the original. Digital video techniques also permit special effects like frame in frame reproduction with changed speed – slow or fast motion – mosaic pictures as well as flick free and noise free stills.

With the exception of special applications, for data technology the digital technique is chosen. It is a matter of great consequence for computers of large and medium size and also for personal computers, abbreviated PC.

In audio techniques the digital technique is gaining importance. Coded information may be made, by error correction, practically error free. Which means, even after any manipulation – cutting and mixing operations etc. – it is like the original.

A large repertoire digital records, under the name CD (= Compact Disks), are already offered in the commercial world. However, until now video disk systems do not have a great market penetration. The audio and/or video information is written and read optically with a laser beam (laser is the abbreviation of "Light wave Amplification by Stimulated Emission of Radiation"). However these disks are not reversible, they are read only disks and not suitable for writing, reading and erasing by the enduser.

Digital tape cassettes = Digital Audio Tape, abbreviated DAT are already on the market.

It will take some time to introduce a digital home video system into the market. First the price/performance ratio of a VHS system with playing times of 4 hours must be reached. The problem here is the required high storage capacity for recording of colour video films of long playing time and simultaneously miniaturization (see video recording).

For the converting of present analogue recordings into digital techniques appropriate special equipment is available (see fig. 22).

Digital techniques are already installed in audio and video studios. In musical recording studios the recording is mostly a digital magnetic tape recording. This is then the master tape for copies of all standard formats such as CD, LP (= analogue Long Play Record) or Compact-Cassette.

Fig. 22   **Analogue/Digital Conversion**
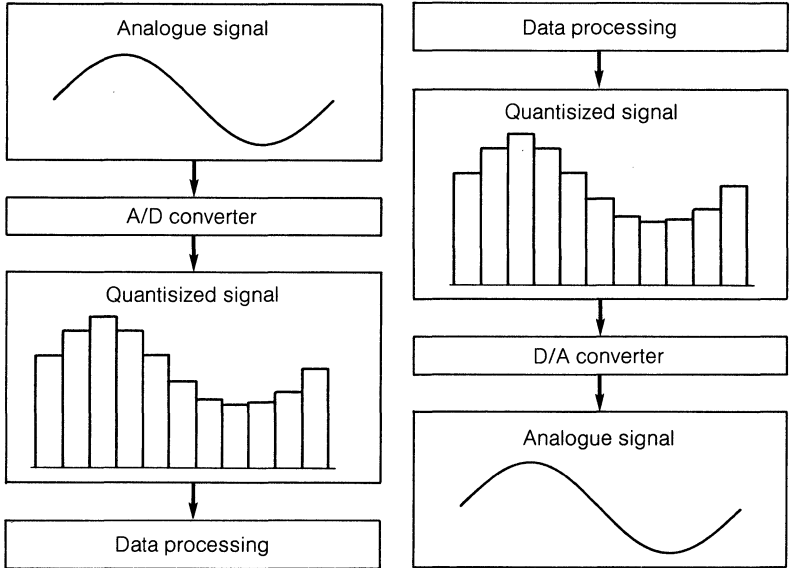

During recording the analogue signal is fed into an analogue/digital converter. Its output is a digital signal in quantisized form. Then this digital information is processed in the usual way of electronic data processing, also remote. At the reproduction, the quantisized signal is transformed via a digital/analogue converter back into the analogue signal. This is required e.g. for the functioning of a loudspeaker, working analogically.

It is thanks to digital techniques in video studios, that the pictures rotate or fade away.

International standard committees work on formats for digital video recording. One of the proposals re-introduces the quatruplex head drum of the 50's, however, it is differently configured and includes a track position, permitting not only analogue but also digital sound recording (see fig. 23).

Whilst for analogue home video recording 2 heads, each with half a picture, record the video signal, because of the high information density, for digital studio recorders the video signal is subdivided onto 4 heads.
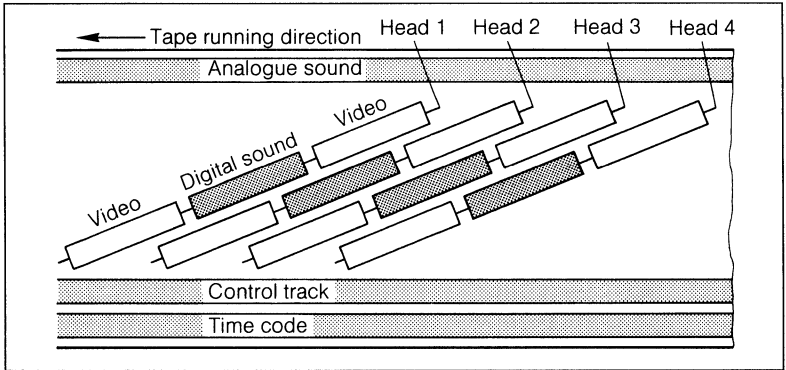
Simplified graphic of the digital format D1 of video recording.

As usual for the digital data recording, correction bits are added to the recording signal in order to reconstruct, if necessary, with its help during the reproduction of the original signal. For the analogue recording the error correction, like the compensation of drop-outs, is only reserved for the reproduction (see fig. 24).

Block Diagram Video Recording   **Fig. 24**
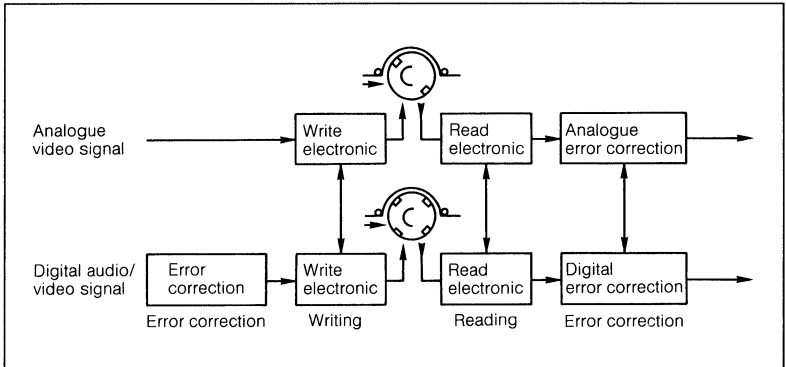
Simplified block diagram for analogue and digital magnetic helical scan video recording. For the analogue recording the error correction is usually provided only for the replay, for digital recording for recording and replay.

3.11 Data Recording

The sound and picture recording required record and replay of the information at any time, mainly in full, and in high fidelity. Data processing and digital technique appeared later. Here, as always, the data processing and not only the reading and writing of the total storage contents of the data recording media, had highest priority.

For data techniques the magnetic storage systems serve as input/output units. All of the magnetic storage media, longitudinal ones like magnetic tapes, also called computer tapes, and circular ones like flexible disks (= diskettes) or rigid magnetic disks (e.g. in the fixed disk drives) are to be seen as part of a storage hierarchy, in which the different storage systems are arranged according to the criteria such as storage capacity, access time and costs per stored bit (see box 1).

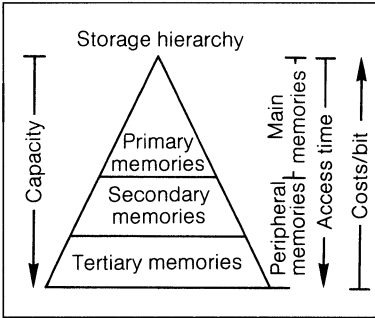**Box 1**   **Storage Hierarchy**

The storage hierarchy is presented in the form of a pyramid (see fig. 25), subdivided into primary, secondary and tertiary storage systems. The storage capacity, expressed in KB or MB, is small for the primary storage, larger for secondary and the largest for tertiary storage. However, the access time – expressed in milli seconds (= ms) – is fast for primary storage and slow for tertiary storage.

Fast storage units have higher costs per stored bit than the slow units. The primary storage is also called main storage (see fig. 21). For the main storage we find different denominations. A ROM is a Read Only Memory and it keeps its contents after switching off the power supply. However, a RAM, a Random Access Memory, looses its contents after the switching off and must be reloaded again, when the computer is switched on again. At first the main storage units were made out of relays, then out of valves, later out of transistors. Today they are highly integrated semiconductors with many transistors and integrated devices on a small silicon chip (= chip).

The speed of the main storage units increased from 10 instructions per second for relays up to more than 10 mips (= million instructions per second) for the chips. They have on a few square millimeters, microscopically reduced in size 10thousand electronic circuits. Typical main storage capacities for mainframes are several gigabytes, for personal computers (= PCs) of the higher performance class several hundred megabytes.

> Typical secondary storage media is the magnetic disk, typical tertiary storage media is the magnetic tape. Circular storage media, as known from the long playing record, have direct (= random) access to the stored information. Therefore, these magnetic disks also serve as RAMs. However, contrary to the electronic RAMs, they do not loose their contents after switching off the power supply.

Storage Hierarchy   **Fig. 25**

For selection of the storage units several criteria are valid. The pyramid and the arrows give some examples.

3.12 Computer Tape

In the USA IBM started magnetic data recording on computer tape in the early 50's [15,16,17].

The tape is built up according to the BASF magnetic tape parameters (see fig. 6), however with 12,7 mm (= 1/2 inch) being double the width of the reel-to-reel sound recording tape.

Whilst the audio and video recording began in analogue technique, the magnetic data recording immediately started in digital technique. This was system and application dependent. An error in the analogue audio and video recording certainly was inconvenient, however, it was only registered in a limited way by the radio listener and the TV viewer. However, in data recording an error may result in completely wrong information.

The users, meaning the large banks, insurance companies or government bodies would not tolerate unreliable data processing. Data security was the highest priority as it is still today. For magnetic tape, as a longitudinal storage medium, the idea of subdividing the information onto several tracks running parallel was taken from audio/video techniques, however, by bit parallel recording of the individual bits in the form of vertical

Fig. 26   **Track Position of the Reel-to-Reel Computer Tape**

		0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	G	H	I	J	K	L	Z
1st Track		I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
2nd Track	Zonea area	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
3rd Track		I	I	I	I	I	I	I	I	I														I
4th Track		I	I	I	I	I	I	I	I	I											I	I	I	I
5th Track										I	I								I	I				I
6th Track	Numeral area				I	I	I	I						I	I	I	I							
7th Track				I	I			I	I			I	I			I	I					I	I	
8th Track		I		I		I		I		I		I		I		I		I		I		I	I	I
Parity track		I			I		I	I			I			I		I	I			I		I	I	
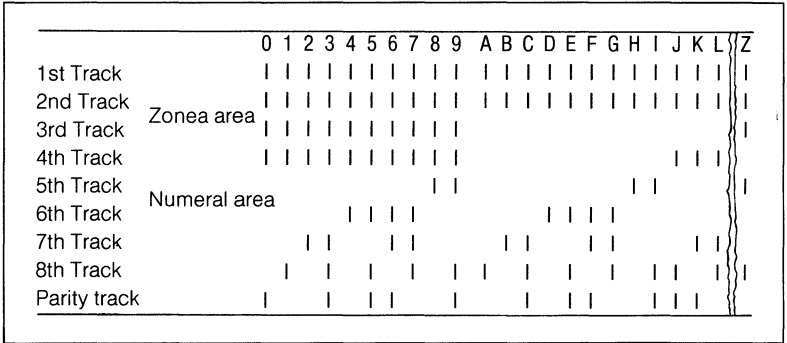
8 of 9 tracks are carrying user data. $2^8 = 256$ characters can be represented. The information on the parity track (parity bit) completes the number of the binary ones within one byte to an uneven result.

lines. One vertical line represents one byte and consequently one letter or figure or, as generally said, one character (see fig. 26).

Initially the characters were built up out of 6 bits, later out of 8, as the 6 bit code did not offer a sufficiently large character set. As it is a binary code, representing 0 and 1, 2^8 results arithmetically in 256 characters. In addition to the 8 user information tracks for 8 bits of each byte there is 1 parity track for control bits. This ninth track is also the clock track. With defined directions of the magnetization, or change of direction of the magnetic flux the recording method is standardized as to which direction of the magnetic flux during the recording (= writing) and the reproduction (= reading) represents the 0 or the 1.

The writing/reading is done in a start/stop operation mode. For this mode the tape transport as known from audio and the video techniques (figures 5 and 15) is not suitable. Vacuum columns prevent an excessive mechanical stress of the tape in this operation mode (see figure 27).
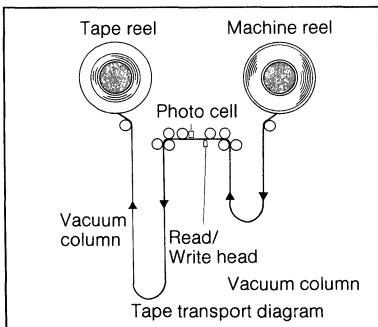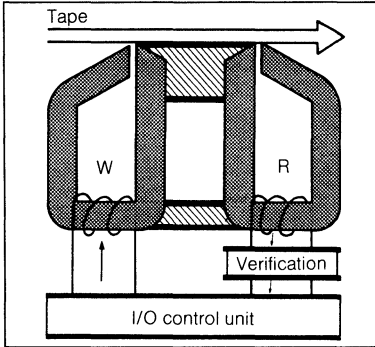

Tape reel   Machine reel
Photo cell
Vacuum column
Read/Write head
Vacuum column
Tape transport diagram

Fig. 27   **Structure of a Tape Unit**

This is a unit for start/stop operation mode. Vacuum columns prevent a too strong mechanical stress of the tape and compensate the inertia of the tape reels during fast read/write operations.
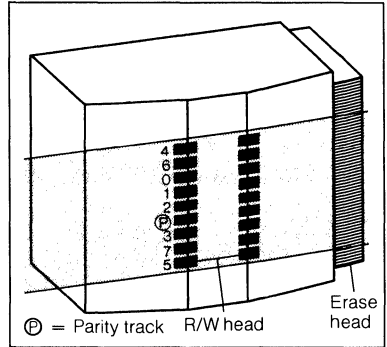
The read/write head is a physical unit. After each write operation the recorded data is read and compared with the original data stored in the I/O control unit. If it does not correspond the system starts several retries and eventually passes the defective part of the tape.

On most tape drives the read/write and the erase heads (the latter in full track version) are usually combined in one head assembly.

During the reading and writing operation the tape passes in front of a fixed Read (= R) / Write (= W) head assembly. It has a 9-track-head system (see figures 28 and 29). Therefore, a separate head reads and writes each of these tracks. An input/output control unit (= I/O) buffers the original data, compares the write with the read data and records the next byte, only if the original data correspond to the read data. If they do not correspond the system starts several retries until they correspond or eventually passes the defective part of the tape.

We have explained this procedure in detail because it happens in this or a modified version repeatedly in digital data recording (chapter 4).

The reel-to-reel computer tape has been a low cost and space economic mass storage medium in the large EDP centres since the beginning of the 50's.

Since then, the recording density has increased from 100 to 6,250 bytes/inch. Only in the middle of the 80's, with the IBM 3480, a new magnetic tape technique appeared on the market: a tape subsystem with a magnetic tape cartridge, tape width 12.7 mm (= 1/2"). The many advantages of this new cartridge cause a growing number of EDP centres to replace the reel-to-reel tape by MTC (= Magnetic Tape Cartridge). Computer tapes and MTCs are part of the BASF product range. You will find more information on this subject in chapter 10.3.

3.13 Rigid Magnetic Disks

IBM started the market introduction of magnetic disk storage at the end of the 50's, first with fixed disks, then later with disks to be removed by the user [18]. The new removable storage medium is called the "Magnetic Disk Pack". The build-up of coating and substrate of the individual disks correspond to the BASF coating principle of a magnetic tape (see fig. 6). The substrate, however, is no longer a flexible plastic film but a rigid aluminium disk. Several disks mounted vertically form the magnetic disk pack.

The number of disks and the number of recording sides are system dependent (see fig. 30).

Cylinder concept
Cylinder 000   Cylinder 202

Access arm with 20 Read/Write heads

2400 rpm
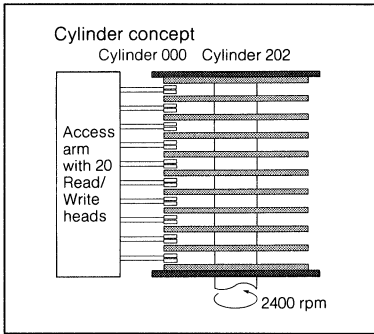
Fig. 30   **The Cylinder Concept**

The grouping of circular tracks, one per disk side, equidistant from the axis of rotation and with the same track number is called a "Cylinder".

The disk drive is equipped with an access arm with one read/write head each per recording side.

For the writing and reading of data only one head system is required.

The head is no longer in contact with the magnetic coating (see fig. 31) as is usual with flexible media. It flies on an air cushion, in order not to damage the magnetic coating (see fig. 32).

Fig. 31   **Contact Recording**

Longitudinal recording
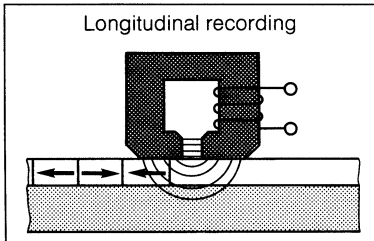
For flexible recording media the magnetic heads of most systems types are in contact with the magnetic coating.

Fig. 32   **Air Bearing Recording**

Longitudinal recording
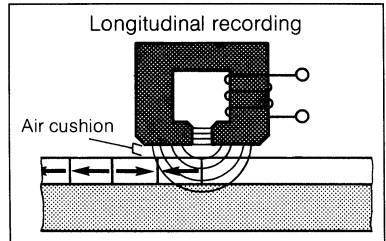
Air cushion

For rigid media the magnetic heads fly on an air cushion over the magnetic coating.
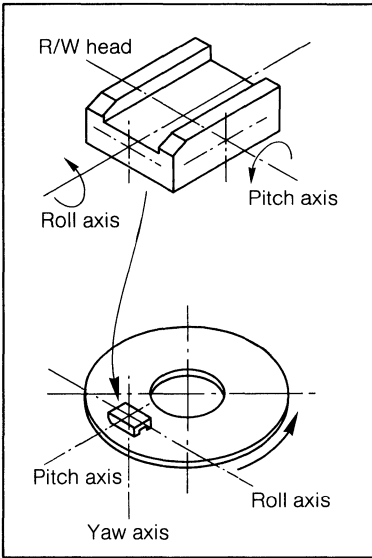
The magnetic heads for air bearing recording are mounted in sliders permitting a constant flight height in relation to the rotating rigid disk surface.

Specially constructed air bearing sliders with built-in R/W heads are required (see fig. 33). Each surface is recorded with circular, concentric tracks (see fig. 34). The grouping of these circular tracks, one per disk side, equidistant from the axis of rotation and with the same track number is called a "cylinder" (see fig. 30). The recording is no longer as with computer tape bit parallel but bit sequential, meaning one bit after the other on one track. However, for the sake of a fast access time, by electrical switching to the individual magnetic heads first all tracks of the same cylinder are written, before the access arm jumps to the next cylinder.

Comparison Long Play Record to Magnetic Disk **Fig. 34**
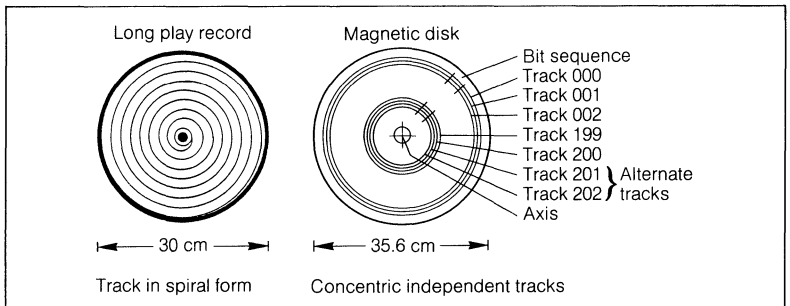
The long play record has a spiral groove, the rigid and flexible magnetic disks have circular, concentric independent tracks.

The recording density is indicated by the number of bits per inch (= bpi), the track density by the number of tracks per inch (= tpi) of disk radius (see fig. 35). The recording density is the base for the number of bytes per track, the track density for the number of tracks per recording side.
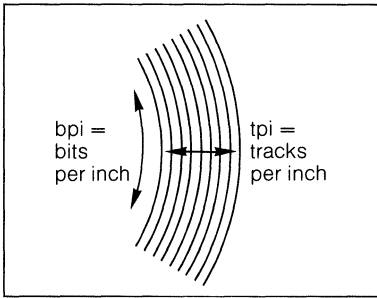
Fig. 35   **bpi/tpi**

The linear recording density is indicated in bpi, the radial track density in tpi via the disk radius.

The storage capacity of disk packs is calculated like follows:

Number of bytes per track · number of tracks per surface · number of recording surfaces. A current 100 MB disk pack for example:
13,030 bytes/track · 404 tracks/surface · 19 surfaces = 100 MB.
Doubling the number of tracks, e.g. from 404 to 808 per surface, results in doubling the storage capacity, if all other characteristics are unchanged.
Each recording surface is subdivided into sectors, up to a recording density of 2,200 bpi and a track density of 200 tpi by punched notches for index and sector recognition.
The index notch marks the track beginning (see fig. 36).
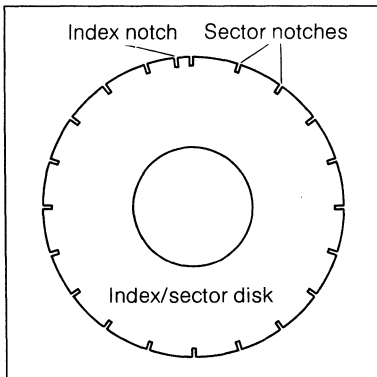
Fig. 36   **Index/Sector Notches**

The subdivision into sectors for hard sectoring of the rigid magnetic disks is done by punched index and sector notches.

These so-called "hard sectors" are replaced by "soft sectors" for higher recording and track densities. These consist of servo information, written with a servo track writer by the media manufacturer in the form of read-only-information on one of the recording sides. This is because for these track densities the temperature expansion of the aluminium disk is in the order of the track distance.

The servo track writing consists of track positioning relating to the user data tracks of the corresponding cylinder, index recognition, synchronisation of the read/write operation in the form of a clock and the track reference for all read/write heads (see fig. 37).
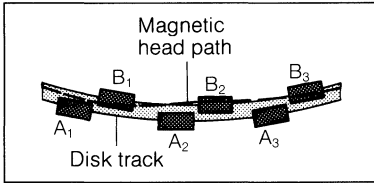
Servo Track Writing **Fig. 37**

A part of the recording area, e.g. one of the recording sides, is reserved for the servo tracks. The media manufacturer pre-records the servo information here. When writing or reading a storage medium with several recording sides, one on top of the other, the servo head reads the servo information. If it reads track offset, to say it in a simplified way a stronger A than B signal, the control electronic corrects the path of the servo head and in consequence the path of all other read/write heads above and below.

Head-to-Disk-Distance and Magnetic Coating Thickness **Fig. 38**
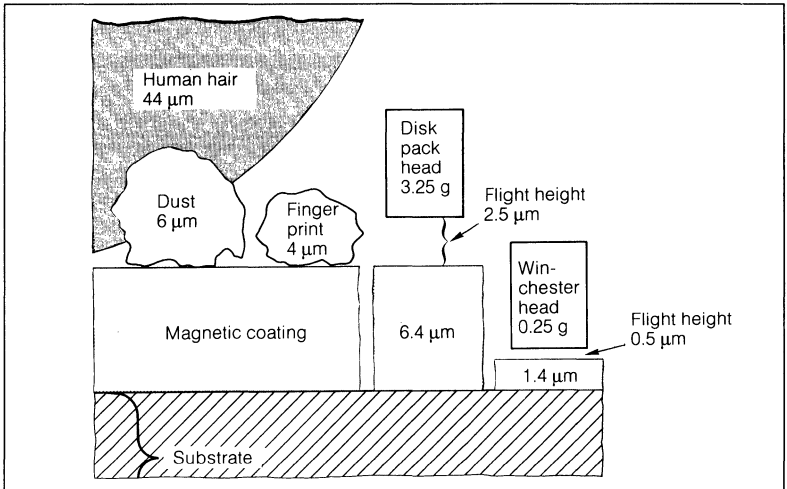
In Winchester technology the head-to-disk-distance, the thickness of the magnetic coating and the weight of the head system have been reduced. The HDAs are hermetically sealed and built into a housing in order to create the clean-room conditions necessary for the high recording and track densities.

3.14 Winchester Technology

High recording densities result in short track distances of the magnetic recording. The original concept, to build the magnetic heads into the drive and the magnetic disks into a removable disk pack is no longer suitable because of the tolerances of the magnetic head mounting. Because of the high recording density, the flight height of the magnetic heads drops below a thousandth of a millimeter. Smoke particles, finger prints and dust particles represent contaminations influencing the head flight height and consequently the data security during writing and reading (see fig. 38). The solution to this is (named after a code word) Winchester Technology. It started with the 14″ disk. The first products in Winchester Technology were removable storage media. They were called "Data Modules" [19].

The storage capacity of 35 MB and 70 MB per module, with two modules in one cabinet consequently max. 140 MB was only sufficient for a short time. Higher recording and track densities required built-in head-disk-assemblies (= HDAs) in the disk subsystem (see figures 39 and 40). The capacity has increased to 5,000 MB per cabinet or 5 GB (GB = Gigabyte, giga = 1 billion (American: 1 trillion).

Fig. 39   **Rigid 14″ Disks**

A = Magnetic disk pack

B = Data module

C = Magnetic disk cartridge front loader

D = Magnetic disk cartridge top loader
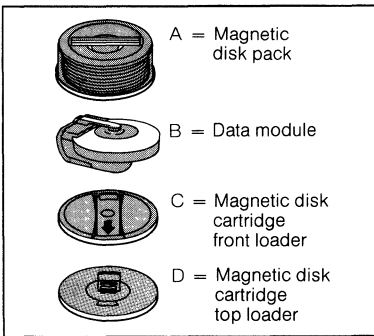
In this technique the rigid disks are used in the form of removable storage media Data Modules (B), Magnetic Disk Packs with 3 to 11 disks (A) and Magnetic Disk Cartridges with 1 disk as front loader (C) and top loader (D).

Fig. 40   **HDA**

Disks   Heads   Servo motor
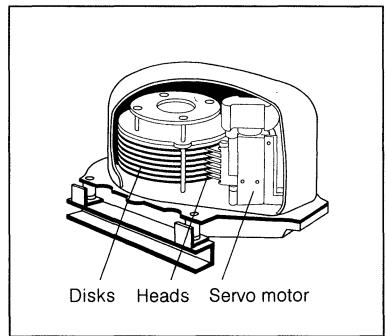
The diagram shows a HDA (= Head-Disk-Assembly) of a mainframe disk subsystem.

Fixed disks drives have not been, however, limited to the mainframes for a long time. Modern Personal Computers have in addition to a diskette drive a fixed disk drive, mainly in the disk size of 5.25″, but also already

in the disk size of 3.5″. The storage capacity increases from 10 to 300 MB and more.

The Winchester technology brings innovations:

Autoloading magnetic heads of low mass and magnetic disks with lubricant, permitting the starting and stopping of the heads off the disk: The charge and discharge mechanism of the former disk pack drives can be dropped.

The low costs of heads and head gliders permit two heads per disk surface: This halves the distance per magnetic head system and consequently shortens access times.

Magnetic disks, disk spindles, axis, head gliders and magnetic heads are hermetically sealed in a housing, primarily as removable storage (= data module), later as fixed disk drive (= HDA):

Less prone to errors because of the clean room conditions.

Each head only reads the data written by itself: High recording and track density.

Block Diagram of a Diskette Drive   Fig. 41
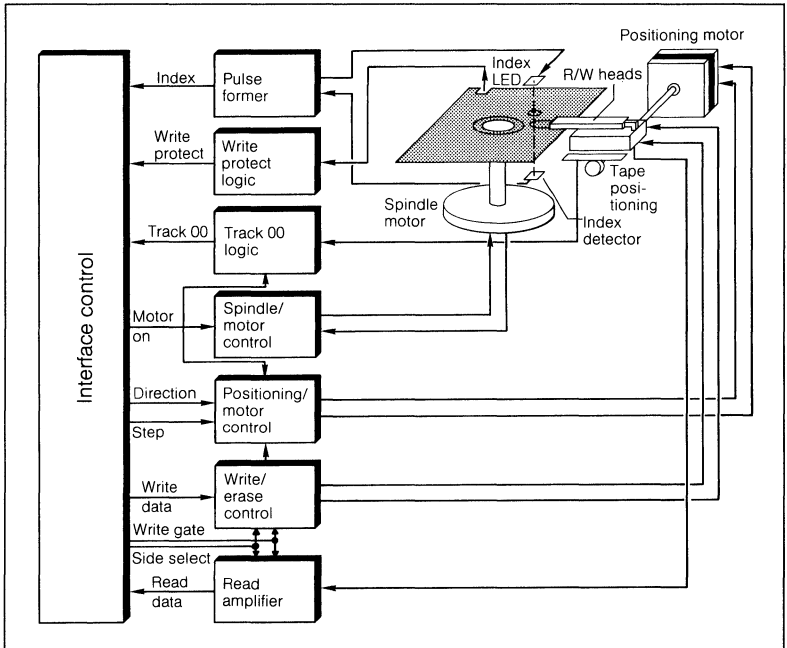
All input and output operations for control, write and read data pass via the interface. The arrows indicate the direction of the dataflow.

3.15 Flexible Magnetic Disks

The flexible magnetic disk appeared at the start of the 70's [20]. The outer diameter came from a phonographic record press. Initially, the magnetic disk with a size of 8″ (= 20 cm) was used without a protecting jacket, later with the protecting jacket as read only storage for diagnostic and micro programs, then as removable storage for the writing and reading of user data.

This new medium, called "Diskette" came at the right moment. It replaced the data entry via keyboard to punch cards (= key-punch), to magnetic tape (= key-to-tape) and to rigid magnetic disks (= key-to-disk), in the EDP centers. For computers of medium size (mini computers), for the new generation of micro computers, also called Desk Computers, Personal Computers and Home Computers diskette drives are low cost storage units (see fig. 41). However, the Maxi-Diskette is too large for this computer class. In the first miniaturization came the Mini-Diskette, in the second the Micro-Diskette (see fig. 42). The Mini- and Micro-Diskette, as low cost removable storage, the mini fixed disks as micro computer mass storage are standard features of the Personal Computers. Decentralised data processing connected to the mainframe (= on-line) or as stand-alone equipment (off-line) is gaining importance.

Fig. 42   **Diskette Sizes**

Mini-Diskette 5.25″
approx. 130 mm

Maxi-Diskette 8″ approx. 200 mm

Micro-Diskette 3.5″
approx. 90 mm
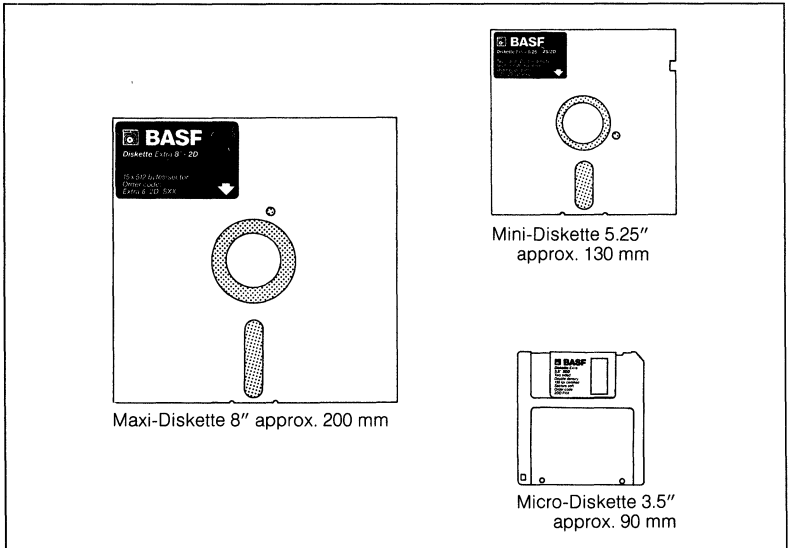
The edge length in inch or millimeter defines the diskette size.

3.16 The Brand Name

In the world of magnetic recording media manufacturer identification plays an important role. More and more users, especially in data processing, only purchase branded articles. They do not want to pay later for the risk of operational and long time behaviour troubles because they had a slightly lower purchase price.

BASF recognized the importance of registered trade marks very early. One of the oldest is the "Horse & Lion" mark (see fig. 43). It embellished the first packagings for broadcasting audio tapes and the reel-to-reel sound recording tapes for home use (see fig. 44). On these reel-to-reel audio tapes the spiral in the square can also be seen. This trade mark is printed on packing and advertising material in a defined red colour.

Horse & Lion Trade Mark   **Fig. 43**

This is the story of the BASF Horse & Lion trade mark.

On a Saturday during 1889 a special train from Stuttgart transported 84 company officials and other staff members of the Stuttgart subsidiary to Ludwigshafen on the Rhine. As a result of this move the joint venture of 1873 between the Badische Anilin & Soda-Fabrik and the Siegle & Knosp company, Stuttgart, was finalized by a central administration. The new trade mark with the horse out of the coat of arms of the town of Stuttgart and the Bavarian lion out of the then valid coat of arms of the town of Ludwigshafen/Rhine are still today a vivid sign of the joint venture.

BASF Registered Trade Mark   **Fig. 44**
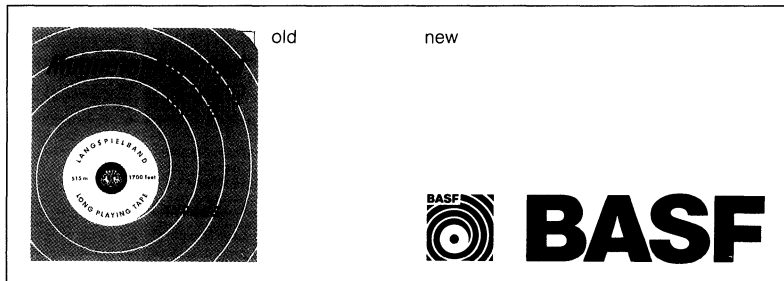
With the earlier studio and home recorder tapes the Horse & Lion trade mark was still prominently placed. With progressive miniaturization of the packing a new trade mark, still valid today for all retail packages of magnetic recording media was created: The spiral in the red square – symbolizing the sound waves – and the company trade mark BASF.

4. Writing and Reading

Here, in a very simplified form, we explain how data is recorded (= written) magnetically and reproduced (= read). We also explain the nomenclature currently in use.

4.1 Wave Length and Flux Changes

The maximum deviation of a sound oscillation or the peak value of a sine wave is called "Amplitude" (see fig. 45).

Peak value of a sine curve

Amplitude $U_{max.}$ U_{pp}

For a sinusoidal read voltage:
U_{pp} = Read voltage output peak to peak
$U_{max.}$ = Peak value amplitude of read voltage
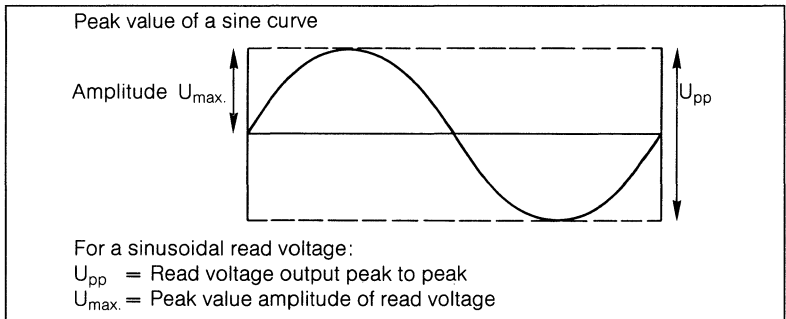
The peak value of a sine wave is called "amplitude". Each change of direction of the writing current corresponds to change of direction of the magnetic flux.

In analogue sound recording the microphone transforms the sound event (pitch, volume) into an electrical alternating current. The change of direction of the microphone membrane corresponds to the direction of the electrical current. The force of the membrane deviation creates the sound volume, the number of oscillations per second the pitch.

In the magnetic head this signal current is transformed into a magnetic field. Each change of direction of the writing current corresponds to a change of direction of the magnetic flux, called "flux change". The length of a recorded oscillation and the space required on the magnetic recording medium is the "wave length" (see fig. 46). It is calculated, as shown for the video recording for example, with the equation: $\lambda = v : f$. For the audio and video recording, thanks to modern magnetic pigments, wave lengths of 1–2 thousandth millimeter and less are normal (see fig. 47).
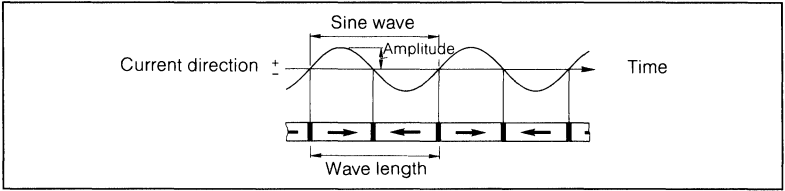
The length of a sinusoidal oscillation and the corresponding space for the recording on the magnetic carrier is called "wave length".

Examples of Wave Lengths   **Fig. 47**

Storage medium	v in mm/s	f in Hz	λ mm	μm
Reel audio tape	190	19,000	0.01	10
Compact-Cassette	47.6	19,000	0.002	2
1/2″ Video tape	2,000	2,000,000	0.001	1

According to the equation $\lambda = v : f$ the above wave lengths in millimeters and micrometers have been calculated.

In data techniques the recording is digital. Only zeros and ones are recorded. Therefore, it must be defined, which magnetization pattern corresponds to a zero or to a one. Thus: the zero passage of the amplitude (fig. 46) may be defined as a "1". For each "1" the direction of the writing current is changed, corresponding to a flux change in the magnetization (see fig. 48).
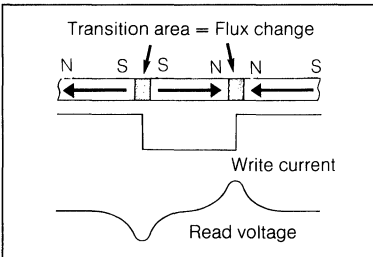
Flux Changes   **Fig. 48**

A 1 has been represented as flux change on the data carrier. In the read operation it is recognized via the read voltage.

4.2 The Character Codes

International character codes define which bit sequence as a byte corresponds to what character. The most usual codes are the EBCDIC-code

(= Extended Binary Coded Decimal Interchange Code, see fig. 49) and the ASCII-code (= American Standard Code for Information Interchange, see fig. 50).

Fig. 49 **EBCDIC-Code**

Hexa-decimal ►	Binary ▼►	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
		0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
0	0000																
1	0001																
2	0010																
3	0011																
4	0100	blank									·	?	.	□	(	+	‡
5	0101	&										|	$	*	)	;	¢
6	0110	−	/										,	%	__	−	±
7	0111										"	:	#	@	'	=	√
8	1000		a	b	c	d	e	f	g	h	i						
9	1001		j	k	l	m	n	o	p	q	r						
A	1010			s	t	u	v	w	x	y	z						
B	1011																
C	1100	>	A	B	C	D	E	F	G	H	I						
D	1101		J	K	L	M	N	O	P	Q	R						
E	1110			S	T	U	V	W	X	Y	Z						
F	1111	0	1	2	3	4	5	6	7	8	9						

EBCDIC (= Extended Binary Coded Decimal Interchange Code) is an enlarged 8-bit-IBM-BCD Code with 16 special characters. The hexadecimal number 53 of figure 50 corresponds for the digit 5 to the binary value 0101, for the digit 3 to the value 0011.

4.3 The Recording Methods

Generally, for data security reasons, the bit patterns are not directly recorded in the form as defined in the character codes. If for example the flux changes only for the "one" and if there are several "zeros" in the character without flux changes, for high recording densities the system might not recognize them. Therefore different international recording methods have been standardized. The most important will be explained in the following.

00	(0)	NUL	20	(32)		40	(64)	@	60	(96)	
01	(1)	SOH	21	(33)	!	41	(65)	A	61	(97)	a
02	(2)	STX	22	(34)	"	42	(66)	B	62	(98)	b
03	(3)	ETX	23	(35)	#	43	(67)	C	63	(99)	c
04	(4)	EOT	24	(36)	$	44	(68)	D	64	(100)	d
05	(5)	ENQ	25	(37)	%	45	(69)	E	65	(101)	e
06	(6)	ACK	26	(38)	&	46	(70)	F	66	(102)	f
07	(7)	BEL	27	(39)	'	47	(71)	G	67	(103)	g
08	(8)	BS	28	(40)	(	48	(72)	H	68	(104)	h
09	(9)	HT	29	(41)	)	49	(73)	I	69	(105)	i
0A	(10)	LF	2A	(42)	*	4A	(74)	J	6A	(106)	j
0B	(11)	VT	2B	(43)	+	4B	(75)	K	6B	(107)	k
0C	(12)	FF	2C	(44)	,	4C	(76)	L	6C	(108)	l
0D	(13)	CR	2D	(45)	–	4D	(77)	M	6D	(109)	m
0E	(14)	SO	2E	(46)	·	4E	(78)	N	6E	(110)	n
0F	(15)	SI	2F	(47)	/	4F	(79)	O	6F	(111)	o
10	(16)	DLE	30	(48)	0	50	(80)	P	70	(112)	p
11	(17)	DC1	31	(49)	1	51	(81)	Q	71	(113)	q
12	(18)	DC2	32	(50)	2	52	(82)	R	72	(114)	r
13	(19)	DC3	33	(51)	3	53	(83)	S	73	(115)	s
14	(20)	DC4	34	(52)	4	54	(84)	T	74	(116)	t
15	(21)	NAK	35	(53)	5	55	(85)	U	75	(117)	u
16	(22)	SYN	36	(54)	6	56	(86)	V	76	(118)	v
17	(23)	ETB	37	(55)	7	57	(87)	W	77	(119)	w
18	(24)	CAN	38	(56)	8	58	(88)	X	78	(120)	x
19	(25)	EM	39	(57)	9	59	(89)	Y	79	(121)	y
1A	(26)	SUB	3A	(58)	:	5A	(90)	Z	7A	(122)	z
1B	(27)	ESC	3B	(59)	;	5B	(91)	[	7B	(123)	{
1C	(28)	FS	3C	(60)	<	5C	(92)	\	7C	(124)	l
1D	(29)	GS	3D	(61)	=	5D	(93)	]	7D	(125)	}
1E	(30)	RS	3E	(62)	>	5E	(94)	^	7E	(126)	~
1F	(31)	US	3F	(63)	?	5F	(95)	_	7F	(127)	DEL

NUL	Null	DLE	Data Link Escape
SOH	Start of heading	DC1	Device Control 1 (PRT SELECT)
STX	Start of text	DC2	Device Control 2
ETX	End of text	DC3	Device Control 3 (PRT DESELECT)
EOT	End of transmission	DC4	Device Control 4
ENQ	Enquiry	NAK	Negative Acknowledge
ACK	Acknowledge	SYN	Synchronous Idle
BEL	Ring Bell	ETB	End Transmission Block
BS	Back Space	CAN	Cancel
HT	Horizontal Tab	EM	End Medium
LF	Line Feed	SUB	Substitute Character
VT	Vertical Tab	ESC	Escape
FF	Form Feed	FS	File Separator
CR	Carriage Return	GS	Group Separator
SO	Shift Out	US	Unit Separator
SI	Shift In	RS	Record Separator

ASCII (= American Standard Code for Information Interchange).
The hex character 53 for the letter S, later used as an example, correponds for the 5 to the binary 0101 and for the 3 to the binary 0011, as mentioned in caption 49. It results in the 8-bit-character 01010011 of the letter S.

4.3.1 NRZ

A binary recording method (see fig. 51), representing only the binary digit 1 ("1" bit) by a single magnetic flux change between two magnetization stages in between one track element.

NRZ is used for reel-to-reel computer tapes and recording densities of 556 and 800 bpi. It offers a relatively high recording density, it is, however, error prone.
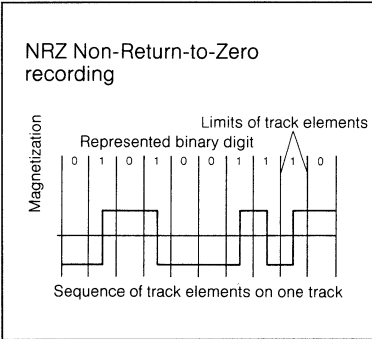
Fig. 51   **NRZ Recording Method**

The recording method NRZ is used for reel-to-reel computer tape with recording densities of 556 and 800 bpi.

4.3.2 PE

A binary recording method subdividing each track element into two parts (see fig. 52). These are magnetically saturated in the opposite sense, whereby each direction of the flux transition (bit flux transition) is allocated to one of the two binary digits. If the same binary digit is succeeding an additional flux transition is necessary (= phase transition) at the limits of the track elements.

PE is used for reel-to-reel computer tapes at a recording density of 1600 bpi. Lower error rate than for NRZ is possible but additional space is required for bit flux and phase transitions.
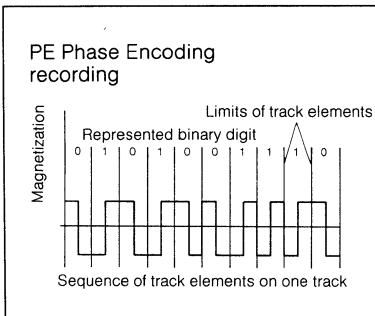
Fig. 52   **PE Recording Method**

Recording method for reel-to-reel computer tape with recording density of 1,600 bpi.

4.3.3 GCR

GCR is also called 4/5 NRZ as one word of 4 data bits is to be converted into a group of 5 bits (fig. 53) and then recorded in NRZ (fig. 54). GCR is the standard recording method for the recording density of 6,250 bpi.

A group code method is also used for the 18 track recording of the Magnetic Tape Cartridge for the IBM 3480 and compatible drives.

GCR Data Conversion   **Fig. 53**

4 Data bits are converted into 5 recording bits. In this 5-bit-group there are never more than two zeros in sequence and never two zeros at the end. The arrows point out the data and recording groups, represented in figure 54 for the NRZ recording.

Data				Recording group				
Positions in the groups								
1	2	3	4	1	2	3	4	5
or				or				
5	6	7	8	6	7	8	9	10
0	0	0	0	1	1	0	0	1
0	0	0	1	1	1	0	1	1
0	0	1	0	1	0	0	1	0
0	0	1	1	1	0	0	1	1
0	1	0	0	1	1	1	0	1
0	1	0	1	1	0	1	0	1
0	1	1	0	1	0	1	1	0
0	1	1	1	1	0	1	1	1
1	0	0	0	1	1	0	1	0
1	0	0	1	0	1	0	0	1
1	0	1	0	0	1	0	1	0
1	0	1	1	0	1	0	1	1
1	1	0	0	1	1	1	1	0
1	1	0	1	0	1	1	0	1
1	1	1	0	0	1	1	1	0
1	1	1	1	0	1	1	1	1

GCR Recording   **Fig. 54**

The data and recording groups, marked in figure 53, are here recorded in NRZ.

GCR = Group Coded Recording

A | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |

B

4 bit word coded into group of 5

C | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |

D

A = Binary order of 3·4 bits
B = Transmission to NRZ
C = Conversion GCR 3·5 bits
D = Result NRZ
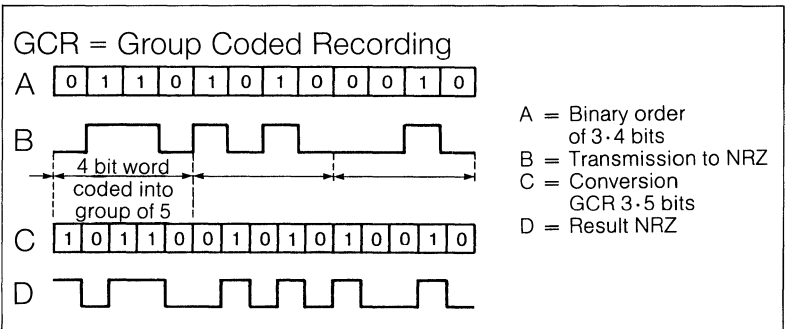
4.3.4 FM/MFM

These recording modes are used for diskettes (see fig. 55). The bit cell length, meaning the track length on the diskette, given by the system in the form of a clock frequency for the writing of a bit, corresponds in FM to 8 micro seconds, in MFM only 4 micro seconds [21]. Thereby the linear recording density, meaning bit for bit one after another, may be doubled. In the case of FM each bit cell is marked by the recording of a clock bit, but in the case of MFM there is no longer sufficient space for the clock bit. Clock bits are only written in critical areas.

Fig. 55   **FM/MFM**

Diskette/format example for 5.25″
Encoding – FM/MFM/MMFM

| FM | = **Frequency modulation for single recording density** |
Write data bits at the center of the bit cell.
Write clock bits at the leading edge of the bit cell.

| MFM | = **Modified frequency modulation for double recording density** |
a) Write data bits (D = 1-bit) at the center of the bit cell.
b) Write clock bits at the leading edge of a bit cell if:
   no data bit is written in the previous bit cell, and
   no data bit will be written in the present bit cell.

MMFM = **MFM, further modified**
a) Write data bits (D = 1-bit) at the center of the bit cell.
b) Write clock bits at the leading edge of a bit cell if:
   no data bit or clock bit is written in the previous bit cell, and
   no data bit will be written in the present bit cell.

$T = 8\,\mu s$ for FM
$T = 4\,\mu s$ for MFM and MMFM

For single recording density there is enough space on the track to mark the beginning of a bit cell by a clock bit. For double recording density, however, the so-called Modified Frequency Modulation (= MFM) method, this clock bit has to be dispensed. Clock bits are only written if this is absolutely necessary to prevent read errors.

4.4 The Bit Cell and the Window

Let's take for our explanation as an example the diskette. In a bit cell the one or zero is magnetically represented on the diskette. The bit cell length corresponds to the recording density. This is indicated for diskettes in bpi. The equation 1:bpi gives us the bit cell length in inches. Let's continue our calculation with full figures. Diskettes have today recording densities up to 10,000 bpi. Consequently this corresponds to bit cell lengths down to 1 micro inch, changed into the metric system therefore down to 2.5 micro meter. In this bit cell, for FM and MFM (see fig. 55), data and clock bits are written.

However, the bit cell length cannot only be seen as a physical size, namely the length of the magnetizing area on the diskette, but also as a time frame for the recording and reproduction. For FM it is 8 micro seconds and for MFM 4 micro seconds. Therefore the read electronic has a time window in order to recognize the data bits. As they represent a flux change, this must be recognized in the time window in form of a read pulse (1 bit). See also figures 48 and 56. For different reasons the write length of the data bits, given by the oscillation, does not correspond to the read length. The window length, expressed in micro seconds, must be chosen in a way, that in the window only the bit to be read, but not an earlier or later recorded neighbouring bit, is recognized.

As for FM and MFM no data bit is set for the zero, the read electronic has also to recognize this information.

If read errors appear, the diskette is not responsible. The design of the read electronic with error detection also plays an important role.

Bit Cell Length and Read Window   **Fig. 56**

A = Substrate thickness   in μm
B = Magnetic coating thickness   in μm
C = Physical bit cell length   in μm
D = Gap width   in μm
E = Time length of bit cell   in μs
F = Time length of read window   in μs
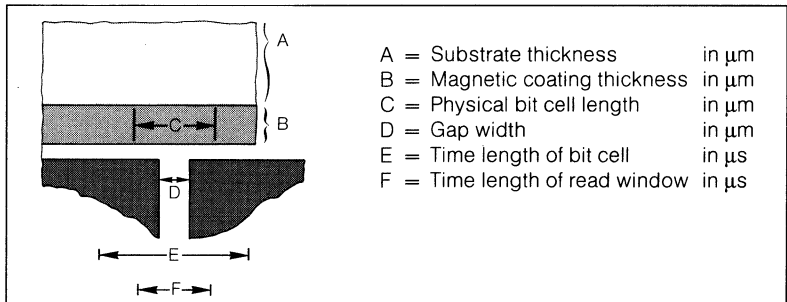
C passes the read window in the time E and must be read in the time F.

4.5 A Practical Example

We want to write the letter S on the diskette and read it afterwards. We take the letter S as an ASCII character. In ASCII-code (see fig. 50) for S the hexadecimal figure 53 is indicated. Hexadecimal values (Greek/Latin for the word and consequently the figure sixteen) are transformed with the table of fig. 49. The 5 of our hexadecimal number 53 corresponds to the binary 0101 and the 3 to the binary 0011. Therefore our hexadecimal number 53 is a binary 01010011 (see fig. 57).

The simplified block diagram of a personal computer shows how the letter S, entered via the keyboard, is fed into the read/write head of a diskette drive (fig. 58). For the recording (see fig. 59) we first transform the serial storage data into the correct recording mode, here into MFM write data (see also fig. 55). For each 1 the direction of the write current is changed (see fig. 60) and consequently the magnetic flux changes direction on the track. It results in the track position on the diskette. The reading of the letter S is described in fig. 61. The block diagram shows the individual stations starting with the reading of the magnetic track in the sector and up to the output of the digital read pulses. Below is the graphical description of the different signal forms [22].

Fig. 57   **The Letter S as ASCII Character**

S: 01010011 (8 bits = 1 byte)

■ 0
□ 1
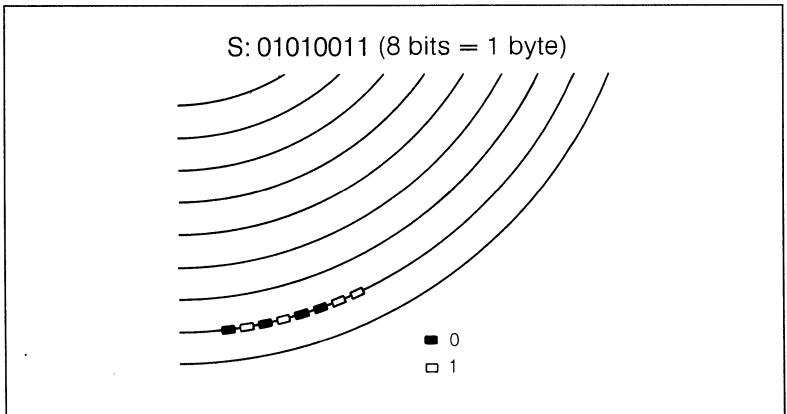
Please see also figures 49 and 50.

The Writing of the Letter "S" Fig. 58
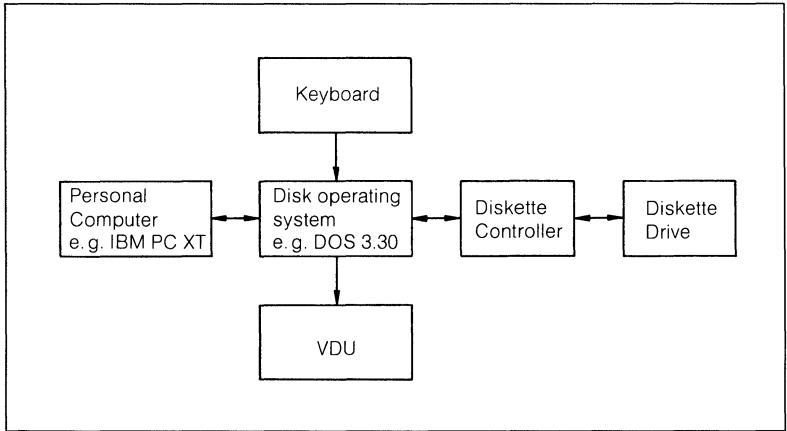
By pressing the key "S" a binary code character is produced – here controlled by the operating system DOS 3.30 of an IBM compatible PC- an ASCII code as indicated for "S" in figure 57. "Operating System" is a package of detailed programs for the control of the micro computer.

The Recording of the Letter "S" Fig. 59

	"S"
A	Serially-recorded data
B	MFM write data
C	Write current
D	Magnetization patterns of one track
E	Diskette tracks
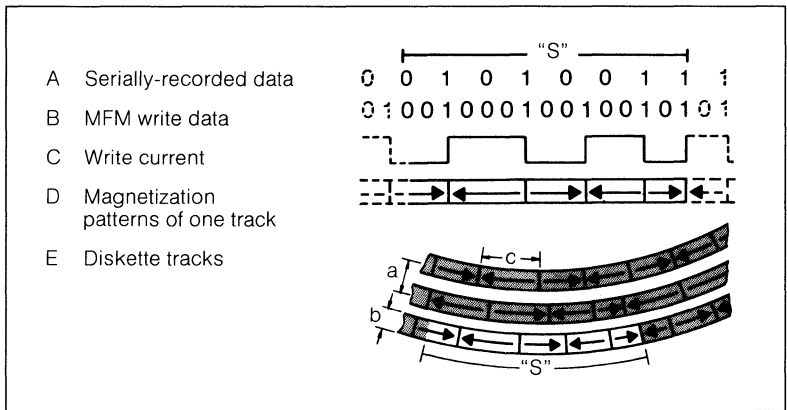
The binary character, known from figure 57 for the letter "S", is transformed for diskette drives with single recording density into the FM code, for those with double recording density into the MFM code (here MFM, see A and B).
By the write current (C) of the magnetic head (see fig. 60) the magnetization pattern (D) of the letter "S" is produced.
The magnetization pattern on the Diskette (E is another scale) are recorded in concentric tracks. Here a) stands for track distance, b) for track width and c) for flux transition distance.

Fig. 60   **The Read / Write Head**
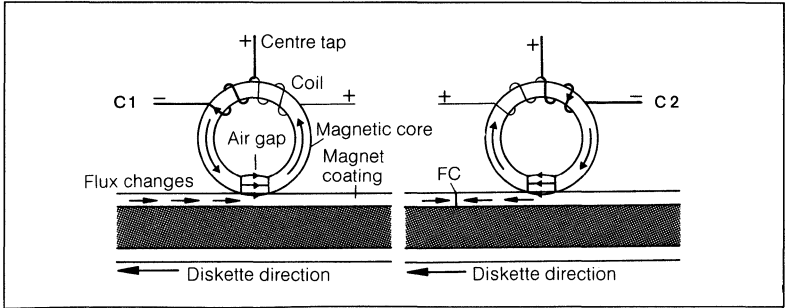
The values 0 and 1, known from figure 57 for the letter "S", are to be recorded in the track of the diskette by changes of the direction of the magnetic flux, so called flux changes (= FC). This is achieved by reversing the poles of the write current C. C1 shows the magnetic recording to the right, C2 to the left.

Fig. 61   **The Reading of the Letter "S"**
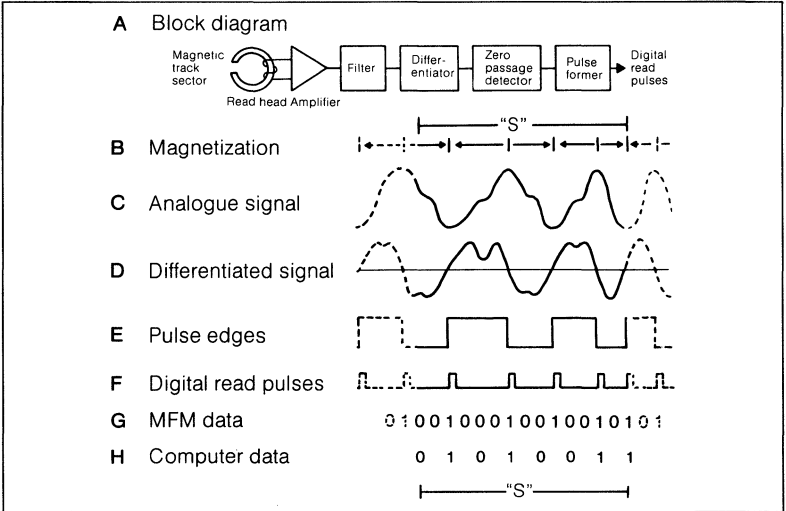
If the magnetization patterns, as shown in figure 59 (E), are to be read again, the magnetic head, known from figure 60, changes its function. Now the write head becomes a read head. The magnetization patterns (B) recognized by the read head (see block diagram A) is amplified and leaves the filter in the form of an analogue signal (C).
After passing the differentiator the zero passages show the ones of the MFM signal (D).
The zero passage detector transforms them into pulse edges (E). Then the pulse former produces digital reading pulses (F) corresponding to our letter "S". Via the controller of the diskette drive the read signals are transformed into computer data and processed (e.g. output via VDU of the letter "S").

4.6 A Review

The BASF invention of the 30's became a universal magnetic recording medium.

Magnetic storage media have been a BASF operational field for more than 50 years in audio, for more than 25 years in data techniques and for more than 20 years in video techniques. BASF is Europe's No. 1 for research and development and one of the top manufacturers world-wide of magnetic recording media with production facilities in Germany, USA, France, Brazil and Indonesia.

Without these audio, video and data storage devices todays level of world-wide communication is unthinkable. In this network in many areas magnetic storage systems are used. They bridge the time lapse between planets and continents, they are the archives for direct access and they produce the data back-up.

Data Techniques especially have progressed considerably in the past decades. The following introduction shows what it has to offer today.

5. Data Technique, an Introduction

This short introduction into data techniques, Electronic Data Processing (= EDP), with emphasis on micro computer techniques is a simplified presentation of the hardware and software according to the state of the art. Simultaneously the most important expressions of data techniques are explained (see also boxes 2, 3, 4). Further explanations of definitions are to be looked up in the appropriate standards (e.g. DIN, ISO).

5.1 Computer

The denomination "computer" (Latin origin: computare) is an umbrella definition for all EDP installations. Supplementary expressions like "mainframe", "mini" and "micro" inform us of the computer performance, others like "desk top", "lap top", "hand-held" and "portable" about its dimensions and again others like "Hobby", "Personal" or "Office" something about its users.

5.2 Hardware

"Hardware" is an umbrella definition for all computer assemblies of mechanical, electric and electronic devices. Hardware is the computer itself with its Central Processing Unit (= CPU), its internal and external memories or storage units, its peripheral equipment like rigid magnetic disks (removable and also fixed disks), its tape and diskette drives, its printers and all other units for data entry, data output and networks. In the following we explain the most important ones.

5.2.1 General Configuration Survey

The data processing is done by so-called "processors". The CPU is the central data processing unit [23]. The build-up is shown in the general configuration survey of a COMPAREX mainframe (see fig. 62). The remark in the box construction processor concerning the IBM family informs us about the compatibility to IBM operating systems.
COMPAREX is an affiliated company of BASF [24].
The micro computer functions principally like a mainframe. With the help of a very simplified block diagram and an exploded view of a micro computer (see fig. 63 and 64) we explain, how data is processed.

Main Memory

MSE 128 MB · MSE 128 MB
MSE 128 MB · MSE 128 MB
MSE 128 MB · MSE 128 MB
MSE 128 MB · MS 128 MB

(MSE: Main Storage Extension)
(MS: Main Storage)

IBM 370 Architecture
IBM 370 Extended Architecture

Buffer Storage 256 KB

Instruction Processor

Standard

Optional

Storage Control

Working Storage 1 MB

Service Processor

Main Console

Subconsole

CHP 1   **Channel Processors**   CHP 0

CHP · CHC · CHG CHG · CHG

CHC · CHG CHG

CHP · CHC · CHG CHG

CHC · CHG CHG

Power Distribution Units

(CHP: Channel Processor, CHC: Channel Control, CHG: Channel Group)

The diagram shows a general system configuration of a mainframe of the COMPAREX Informationssysteme GmbH. The 3-layer storage organisation (work storage, main and buffer storage) reduces the effective main storage access time. Two input/output processors (IOP) reduce the input and output times.

The configuration of the mainframe as shown in fig. 62 corresponds for the micro computer to the CPU with RAM, ROM and I/O interface. Drawn in is some peripheral equipment, connectable to the micro computer. The CPU as the central processor is the heart of our micro computer. Its processing performance – expressed in word size or mips – should not be too small. The ROM is a Read Only Memory, initialized by the system manufacturer with certain parts of the operating system. The contents of the RAM have to be re-loaded after each start of the system (see also box 2). Both are internal memories, comparable with the different storage layers of the mainframe.

The I/O interface is the connection to all subsystems outside the computer. Outside does not mean "outside the computer housing". It only means: No direct connection to the CPU and the internal devices. These are micro chips connected via a bus system and may communicate among each other with high speed without being hindered by the slower peripheral equipment.

Fig. 63   **Block Diagram of a Micro Computer**
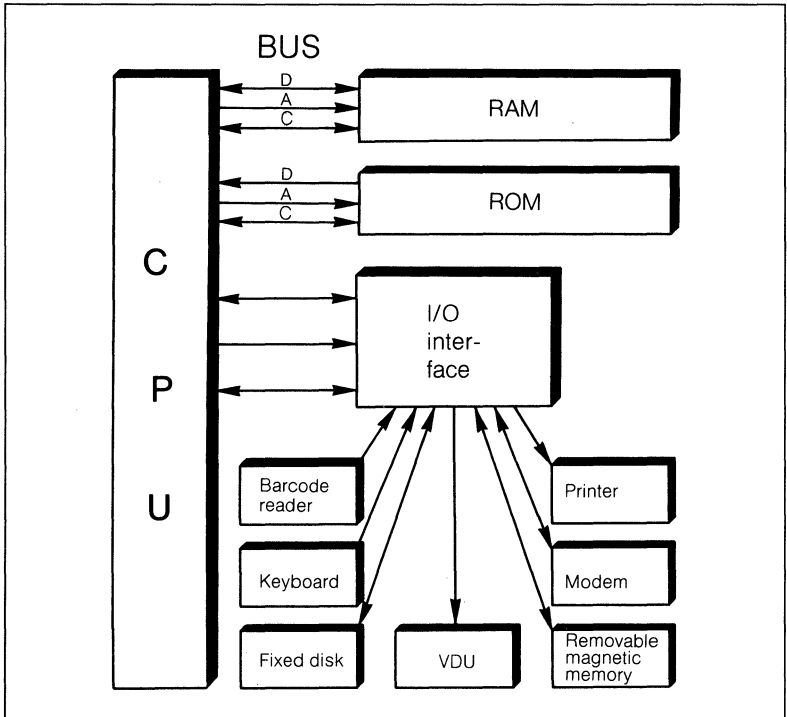
A simplified scheme shows the functioning of a micro computer without power supply and clock generator, but with peripheral equipment. The micro computer consists of the CPU, the internal semiconductor storage (ROM and RAM) and the I/O interface. These components are linked with the address bus (= A), the control bus (= C) and the data bus (D). Via the I/O the peripheral equipment is connected. The arrows show the flow direction of the information and their functioning as input device (e.g. keyboard), output device (e.g. VDU = Video Display Unit) or combined input/output units (e.g. fixed disks or removable magnetic memory). From the peripheral units the information flows via the I/O into the micro computer. During the processing they are stored in the internal memories. The CPU controls the program step by step as indicated by the internal program and data storage and sends the data when the processing is terminated via the I/O to the output devices.
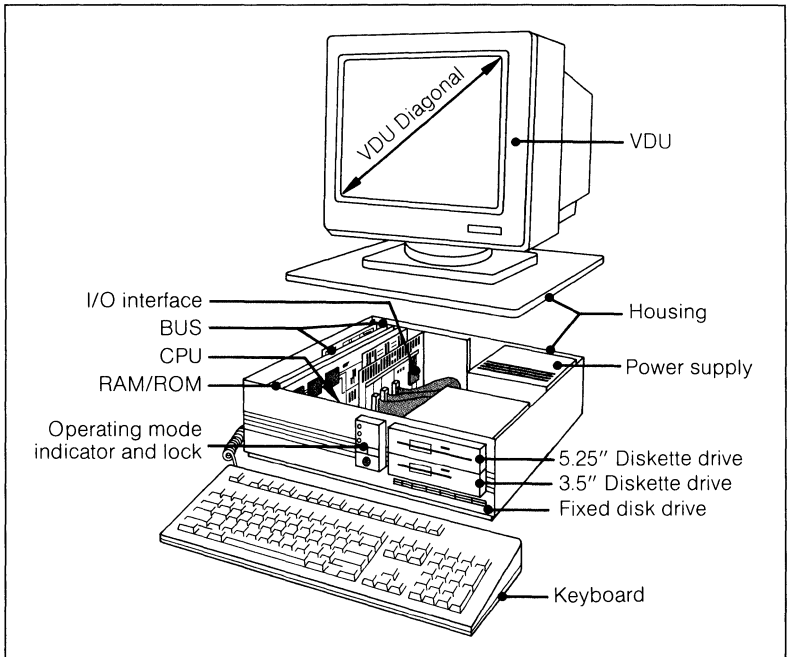
The exploded view shows the important assemblies of a personal computer as known from the block diagram (fig. 63).

The data processing starts with data entry. The digitalization of the data (see chapter 3.9 digital techniques) and consequently the data entry may be done e.g. via the keyboard, the scanning of digital figures, e.g. product numbers in the form of a bar code via a bar code reader, or the input of graphics via a scanner. Digital data may also be entered via external memories or networks.

The data, entered via the I/O interface, is stored intermediately in the RAM and processed step by step by the operating system and the application program and again intermediately stored in the internal memories.

The bus, aligned to the word size of the micro computer, serves the communication between the internal devices of the data (= data bus), control information (= control bus) and the addresses for internal storage (= address bus). When the computer job is terminated, the data is either directly output (= e.g. via the printer) or – for later continuation of the data processing – indirectly in the form of a back-up on the external mass storage systems (e.g. diskette, fixed disk).

5.2.2 Keyboard

The keyboard (see also fig. 49, 50, 58) transforms the entered characters into the binary code. For different applications there are different keyboards (see fig. 65).
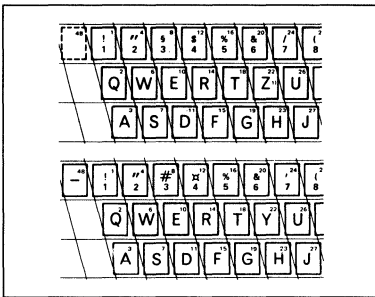
Fig. 65   **QWERTZ/QWERTY**

A look at the first six letters shows you: This is a QWERTZ key board, meaning a German type writer keyboard and this a QWERTY keyboard for data entry, meaning the international one. See also AZERTY (box 4) for the French keyboard.

5.2.3 VDU

There are monochrome and colour Video-Display-Units (= VDUs) of different sizes and resolutions. For specific applications like DTP a full size VDU is recommended, as it offers a better view for the editing of a complete page (see fig. 64).

5.2.4 Diskette Drives

Almost every PC is equipped with at least one diskette drive. Diskettes are used for software loading, exchange and back-up of data. We have already presented the diskettes in chapter 3.15 (see also fig. 41 and 42) and will cover this subject in detail in chapter 12.

5.2.5 Fixed Disk Drives

All mainframes and most PCs for professional use are equipped with fixed disk drives, called "fixed disks" (see fig. 66). They differentiate in access time in milliseconds and storage capacity in Megabytes, for
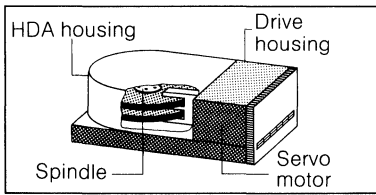
mainframes in Gigabytes. As the operating system and the loaded application programs require storage space on the fixed disk, the size should not be too small in order to have sufficient space for user data. A regular dumping of the fixed disk data contents onto diskettes or magnetic tapes is recommended, so that in the case of a fixed disk failure a new start is possible.

5.2.6 Tape Drives

As we know from chapter 3, tape drives have served as mass storage since the 50's. However, reel-to-reel drives are increasingly replaced by the Magnetic Tape Cartridge (= MTC) systems. For PCs there is a tendency to streamers (see also chapters 7, 9 and 10).

5.2.7 Printers and Scanners

Printers serve for data output on paper or transparencies, scanners (see fig. 67 and 68) for input and digitalization of graphics and photos (see also chapter 5.3.2 for graphic programs).

Flatbed Scanner   **Fig. 67**
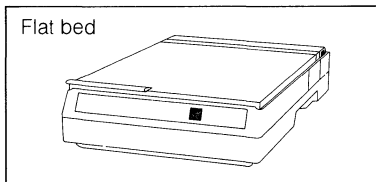
The lid covering the flatbed is opened and the document to be scanned put on the flatbed. Pages of books or brochures or of paper and cardboard of different thickness may be scanned. Each document has to be inserted manually.

Single Page Scanner   **Fig. 68**
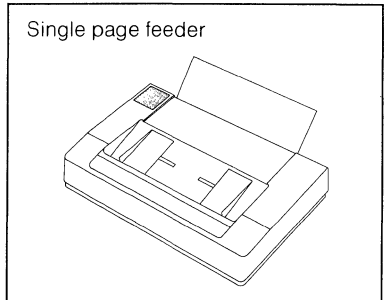
Automated document feeding, however, only for paper of defined thickness.

Table 1   **Printer Types**

Types:	Character Printer				Line Printer				Page Printer
Impact:	Impact		Non Impact		Impact		Non Impact		Non Impact
Technique:	Fully Formed	Dot Matrix	Thermo	Ink-Jet	Fully Formed	Dot Matrix	Thermo	Ink-Jet	Laser

Printers may be subdivided (see table 1) into three groups:
a) according to the number of printed characters per printing operation into character, line and page printer
b) according to the impact mode into impact and non impact printers
c) according to printing techniques into fully formed printer (fig. 69), dot matrix printer (fig. 70, 71, 72), thermo printers, ink-jet-printer (fig. 73) and laser printers (fig. 74)
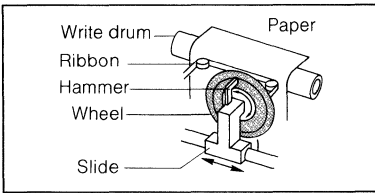
Fig. 69   **Daisy Wheel Printer**

The best known example for a fully formed printer is the daisy wheel printer. The wheel mounted on a slide, positions by right or left turn by the shortest way the type to be printed into the hammer position for impact on the ribbon and the paper.
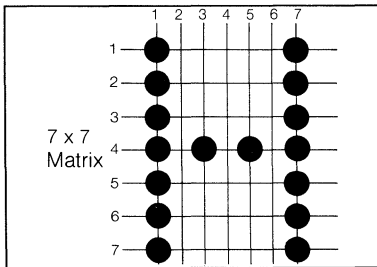
Fig. 70   **Dot Matrix**
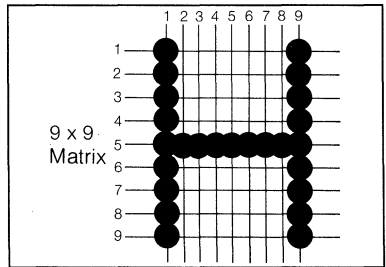
The letter quality of a matrix character is defined by the number of dots.
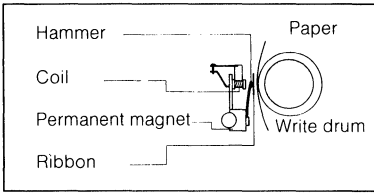
Dot Matrix Line Printer   Fig. 71

All characters of a dot matrix line printer are mounted on a hammer bank. The figure shows the principle for one of the hammers. The permanent magnet retains the hammer in the start position. For the impact it is electromagnetically (see coil) released and hits with the other hammers of the same line simultaneously against the ribbon and with it against the paper in order to print in one operation the complete line.
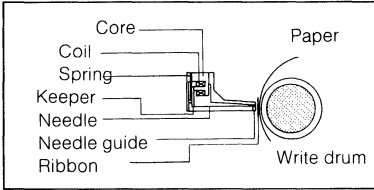
Needle Printer   Fig. 72

Dot matrix printer in the form of needle printers produce the dot matrix by a number of needles. The figure shows electromagnetically driven needles for the impact on the ribbon and its impact on the paper. The higher the needle number, the better the printing quality.

Ink-Jet-Printer   Fig. 73
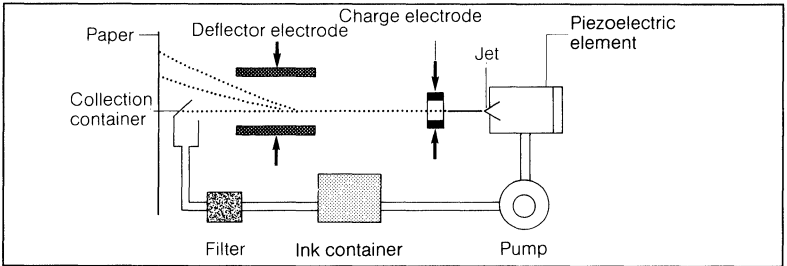
As an example of an ink-jet-printer here a continuous one is shown with a continuously flowing ink jet. The piezoelectric transducer disperses the ink into individual ink drops. In this model the individual drops for a certain character are statically charged differently and placed on the paper via a deflector electrode corresponding to its charge force. The greatest part of the drops remains uncharged and is re-used.
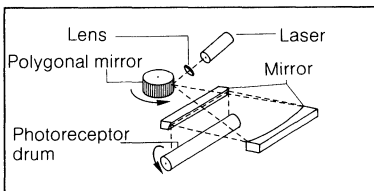
Laser Printer   Fig. 74

With a sophisticated technique the characters are transmitted in the form of a digital screen process picture onto a photoreceptor drum, with a laser beam via a mirrorsystem. The usual dry copier only transmits an analogue screen process picture.

5.2.8 Data Networks

With suitable hardware and software data may be transmitted via local networks (e.g. from office to office, from storey to storey or even from building to building) but also via modems or acoustic couplers and private or public networks. In this case they offer a world-wide access to data bases and electronic mail boxes.
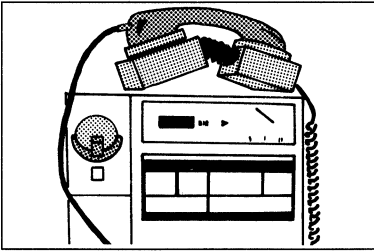
Fig. 75   **Acoustic Coupler**

Transforms digital electrical signals of the computer into analogue sound signals for data transmission by the telephone network.

5.3 Software

The computer is a universal system. With the so-called "software" it becomes a system for a specific application. The software is subdivided into operating system and application software.

5.3.1 Operating System

The software package of a digital computer system which together with the characteristics of the computer is the base of the possible operating methods of the digital computer system and which especially controls the execution of the programs is called the "operating system" (abbreviated "OS"). Because of the dominant role of IBM we differentiate between IBM compatible and IBM non compatible operating systems. The application software, offered in the market, must function under the respective operating system. Informations like .. "suitable for DOS 3.30" or .. "for OS/2" mean that the programs function without problems under these IBM operating systems.

5.3.2 Application Software

Application software may be written by the user himself or by software specialists with program languages (such as COBOL, BASIC). They may also be purchased in specialized shops in the form of standard packages for specific users (e.g. electricians) or applications (word processing, data bases, Desk Top Publishing (= DTP) or graphics programs). Common practice is to guide the user with menus (see figure 76) or windows by mouse operation (see figures 77 and 78).
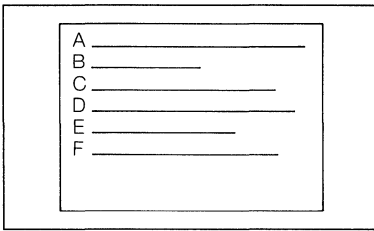
Menu   Fig. 76

In the menu technique the user is guided via multiple choice answers, listed in a menu. Via entry menus he comes to submenus. For simplicity reasons we have listed in our menu only multiple choice letters. Usually there are indicated complete texts such as: "Insert" or "Delete" etc.
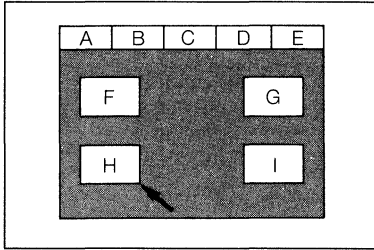
Windows   Fig. 77

In the window technique the user is not guided through the program by a menu but by windows on the screen. He selects the appropriate window – mostly by clicking the mouse button – and additional windows appear until he has reached the targeted program position. For simplicity reasons in our figure we have marked the windows by letters. Usually there is text or symbols contained in the windows.

Mouse   Fig. 78

Top view of the mouse with function keys   Bottom view of the mouse with command roll
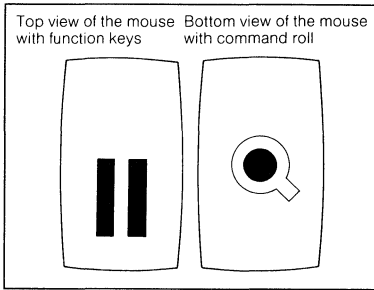
In the window technique the user may select the individual windows with a control instrument, connected by cable to the micro computer: the mouse. Moving the mouse on a base plate directs the cursor on the screen. There are optical and mechanical mouse versions. In the optical mouse two diodes, situated on the bottom plate of the mouse recognize by reflection from a special base plate the direction of the movements. The mechanical mouse (see our figure) transforms the movement of a ball into electrical control signals. By clicking the function keys of the mouse in the appropriate window the commands are entered into the system. If it is a mouse oriented program the mouse has only to be connected with the micro computer. Otherwise a special mouse software has to be loaded.

If several of the programs are in simultaneous access they should run under a mutual user access facility (e.g. GEM Desk Top or MS Windows).

Word processing programs permit the easy editing of text, data bases the aligning of the data corresponding to defined search criteria (see fig. 79) and Desk Top Publishing (see fig. 80) the editing of text with different fonts together with graphics or drawings on one side and graphic programs the creation of vector or pixel oriented graphics.

Hierarchical system

Network

Relational system
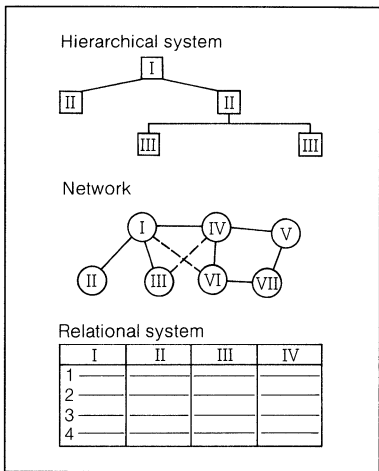
Fig. 79 **Data Bases**

Data bases are data files structured, stored and queried according to determined criteria. In the hierarchical data base the data is aligned in a tree structure on several hierarchical levels. In networks the data is presented in the form of interconnected records and in relational data bases the data is arranged in the form of tables. Which data base management system (= DBMS) is chosen depends on the application and the availability of appropriate computer systems.

Fig. 80 **Desk Top Publishing**

Scanner

Software

Graphics   DTP   Text

Laser printer

WYSIWYG-VDU

Composed page

Mouse
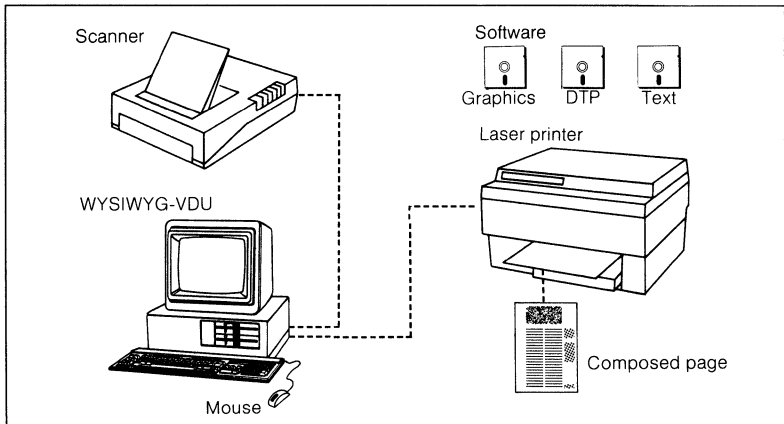
With suitable hardware including high resolution scanners, if possible WYSIWYG screens (WYSIWYG = What You See Is What You Get, meaning e.g. full screen VDUs), laser printers and DTP, word processing and graphic software complete pages may be composed and printed with a PC.

Acoustic coupler	transforms digital electric signals of the computer into sound signals for data transmission by the telephone network (see fig. 75).
Address bus	bus for marking the storage position.
ALU	Arithmetic and Logic Unit.
AT	Advanced Technology, PC of the upper performance class.
Baud	measuring unit for step speed. In EDP the transmission speed expressed in bit/s.
BIOS	Basic Input Output System, a micro program for system close control.
Bus	Internal conductors, see also address bus, data bus and control bus. The size of the bus often corresponds to the word size of the computer.
Clock	abbreviation of "clock frequency". A periodical pulse sequence for the signal element timing. High clock frequencies correspond to high throughput speeds.
Clock frequency	internal signal element timing, expressed in MHz, for PCs ranging from 8 to 25 MHz (see also clock).
Control bus	for internal control signal transmission (see also bus).
CPU	Central Processing Unit.
Cursor	positioning display signal on the screen.
Data bus	for internal data transmission (see also bus).
dpi	dots per inch. The resolution of scanners and phototype setters.
Electronic mail box	an electronic mail box e.g. in a data base where data may be deposited and called off by the authorized user.
EDP	Electronic Data Processing.
Fixed disk drives	fixed installed drives with several coated magnetic disks. Storage capacity for PCs up to several hundred Megabytes, for mainframes several Gigabytes.
GB	1 Gigabyte = 10^9 Bytes.

Box 2 Continuation **Configuration Definitions**

Interface	a definition (e.g. in X 25) of – physical characteristics (e.g. mechanical, electrical, functional properties) – transmission data (e.g. instruction for data transmission block) – packet format (e.g. how much data for one packet). For parallel interfaces, e.g. Centronics, named after the printer manufacturer Centronics, the data is transmitted simultaneously in several parallel running conductors, for serial interfaces (e.g. RS 232) bit after bit in serial sequence.
I/O	Input/Output interface
ISDN	Integrated Services Digital Network, public network.
LAN	Local Area Network for office communication.
Mainframe	large size EDP installation.
Mass storage	mostly magnetic storage devices like tape/fixed disk or diskette drives.
mips	million instructions per second. The computer throughput speed (mainly for mainframes) is measured in mips.
MODEM	MOdulator DEModulator for transmission of digital data into private or public networks.
Multi-tasking	several programs run simultaneously.
Multi user system	System for simultaneous access by several users.
Off-line	logically or physically disconnected from the computer.
On-line	connected to the computer.
PC	Personal Computer = micro computer.
Processor	like ALU. A typical type is Intel 80386.
RAM	Random Access Memory, main read/write storage of the CPU.
ROM	Read Only Memory of the CPU.
Scanner	abbreviation of „image scanner".
Utilities	utility routines like data organisation systems offered by the system manufacturer.
Word size	8 bit, 16 bit, 32 bit are word sizes. The higher the bit number the faster the computer, as with one clock pulse one word is processed.

Assembler	is a translator program that transforms (= assembles) program instructions of a machine oriented program language into a machine language.
BASIC	Beginners All Purpose Symbolic Instruction Code, a problem oriented program language.
Bit map	see pixel graphics.
Cartesian co-ordinate system	the set of numbers which locate a point in space with respect to a number of reference points.
COBOL	Common Business Oriented Language, a problem oriented language for commercial/economic areas.
Compiler	e.g. a BASIC compiler, is a program that transforms or compiles a problem oriented BASIC program into an executable machine code.
DTP	Desk Top Publishing.
FORTRAN	FORmular TRANslation. A problem oriented language for mathematical tasks.
GEM	Registered Trade Mark of the software manufacturer Digital Research.
IBM	Registered Trade Mark of International Business Machines Corporation.
MS	Abbreviation of the software manufacturer Microsoft.
MS-DOS	Microsoft Disk Operating System for micro computers with 16 bit processors, distributed by IBM as PC-DOS.
MS-OS/2	MS Operating System for 24 and 32 bit processors.
Page composition software	combines type setting, graphics, editing and page layout as necessary for DTP.
Page description languages	(PDL), a printer software permitting the printer to build-up a full page based on the information received from the computer (e.g. PostScript).
Page layout	The subdivision of the page into text blocks, eventually with different character fonts, images and graphics.
PC-DOS	MS-DOS for IBM PCs.
PC-OS/2	MS-OS/2 for IBM PCs.
Pixel graphics	a code technique for computer graphics, fixing each pixel.

Presentation graphics	for the presentation of statistics/figures as bar charts, pie charts, curve charts and geographical diagrams.
UNIX	an operating system of Bell Laboratories, distributed by AT & T.
User surface	a utility or a supplement to the operating system to call off all other application programs, mainly by symbol controlled mouse operation.
Vector graphics	a code technique for computer graphics by which the drawing itself is fixed by a number of lines according to the cartesian coordinate system.
WYSIWYG	What You See Is What You Get, a denomination for full page VDU's.

Box 4   **Pheripheral Definitions**

AZERTY	position of the first 6 letters of the French keyboard (see also QWERTZ and QWERTY).
Chain printer	a line printer with a character set on a chain.
Character printer	prints in each operation one character (e.g. daisy wheel printer).
Daisy wheel printer	a serial character printer with exchangeable type wheels.
Dot matrix	Matrix = latin for "origin", "source", here a character composed of individual dots (see fig. 70).
Dot matrix printer	character or line printer.
dpi	printing or scanning quality indicated in dots per inch.
Drum printer	a line printer with a character set on a drum.
Fully formed printer	prints in each operation one complete character (character printer) or a line composed of complete characters (line printer).
Ink-jet printer	character or line printer with dot matrix produced by a jet of ink.

Impact printer	a character or line printer with impact of the printing system on the paper for each printing operation. Examples: needle printer, wheel printer.
Laser printer	a page printer, functioning similar to a dry copier by producing an electrostatic print form on a photoreceptor drum, however, not analogue, but digital in the form of a matrix image.
LCD	Liquid Cristal Display.
LED	Light Emitting Diode.
Line printer	prints in each operation one line (e.g. print band technology).
Needle printer	a dot matrix printer. Its dots are produced by the impact of needles on the paper.
Non-impact printer	a printer without impact of the printing device onto the paper. Examples: laser printer, ink-jet printer.
Page printer	prints in each operation one page (e.g. laser printer).
Printer resolution	for a laser printer up to 300 dpi, for a Linotronic 300 to 2,540 dpi.
QWERTY	position of the first 6 letters of the international keyboard for data entry (fig. 65).
QWERTZ	position of the 6 first letters of the German typewriter keyboard (fig. 65).
Screen Resolution	number of dots per character (e.g. $8 \cdot 10$ or $10 \cdot 15$) or matrix dots (e.g. $640 \cdot 200 = 128,000$ dots).
Screen size	in inches as screen diagonal (e.g. 12″) or in number of lines and columns (e.g. $25 \cdot 80$ or $34 \cdot 80$ or $34 \cdot 132$), see also fig. 64.
Steel tape printer	a line printer with several character sets on a steel tape.
Thermo printer	character or line printer. The characters are produced by a thermal effect with a special thermo ribbon and/or thermo printing head.
Thermo reaction printer	produces characters/figures directly on special paper.
Thermo transfer printer	produces by thermal means characters/figures with a special ribbon on normal paper.

6. Manufacturing of Magnetic Storage Media

6.1 Production Process

In a modified version (fig. 81), we show here again the known basic principle of the industrial manufacturing of magnetic storage media, illustrated in figure 6.

We have called the base material "substrate" (Latin origin: "substratum"). This passive carrier material is for rigid magnetic disks an aluminium disk, for flexible media a plastic foil.

The binder is a polyurethane resin, with a solvent part called lacquer. The solvent is recuperated in the drying channel. The additives are also very important, however, not for understanding the production process. Therefore, the basic components of our principle process are the binder, the magnetic pigment and the substrate as the carrier of the magnetic coating.

You can find these initial stages in the production steps no. 1 and 2 of our flow chart of the production process (see fig. 82) and in the detailed chart in chapter 6 and 7.

Fig. 81   **The Principle of Manufacturing Magnetic Storage Media**

Magnetic pigment   Binder

Dispersion

Magnetic coating
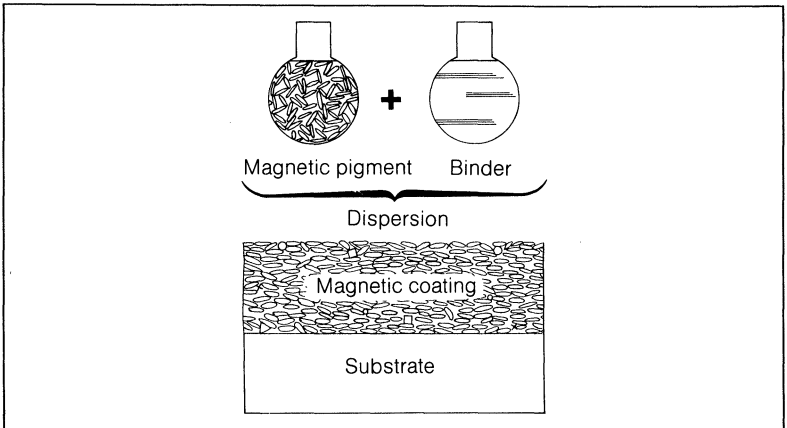
Substrate

The principle known from fig. 6 is here presented in a simplified form. For over 50 years, oxide and binder in the form of a dispersion to be coated onto a neutral substrate is the process of manufacturing magnetic storage media. For rigid media, like the magnetic disks in fixed disk drives, the substrate is an aluminium disk, for flexible media like tapes and diskettes, a plastic film.
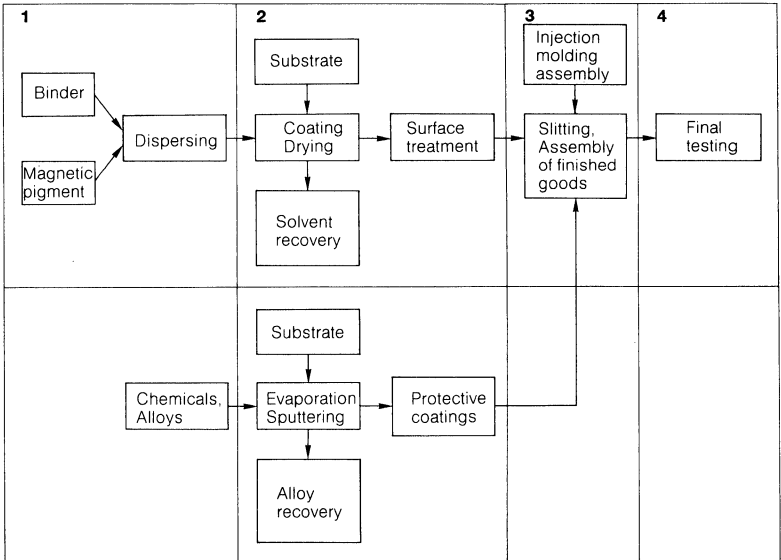
The stations 1 and 2 show different production procedures for magnetic coatings: Above for particular coatings, below for evaporated and sputtered coatings.

Both diagrams show the high vertical integration of manufacturing – from the raw material to the finished storage media – all production steps under one control. This guarantees constant product properties.

After surface treatment, for flexible storage media the coated butt roll, and for rigid media the coated and surface treated disks are the unfinished products.

The upper part of the flow chart shows magnetic coatings with magnetic pigments in the form of magnetic particles.

The base materials for the lower part are chemicals and alloys. The layers on the substrate are produced by evaporation or sputtering. We return to these production technologies in chapter 14. In chapter 6 we remain with coatings with magnetic pigments in the form of magnetic particles and the storage media produced with this technique.

It is now made clear from the diagram that a combination of chemical and engineering competence is required, which BASF has had for years, to manufacture magnetic storage media, not only for this product family, but also according to the different product methods.

It begins from basic research, via the process engineering technologies and the construction of our own manufacturing and testing installations up to the control of automatic production and test processes of the final products in many areas of consumer and industrial products.

Fig. 83   **Binder and Oxide Manufacturing**
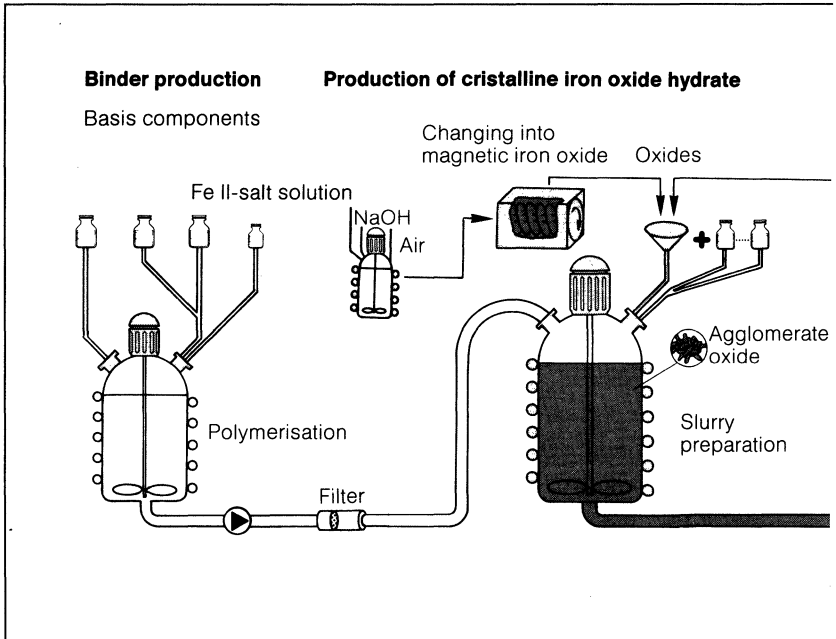
Based on monomer components the binder production is a polymerisation on site. Therefore the binder without any intermediary steps can be mixed with the oxide. There are different oxide classes. In the above figure the most used ones, iron oxide and chromium dioxide are shown. Iron compound (iron-II-salt) and caustic soda lye (NaOH) are used chemically to make iron oxide. For chromium dioxide the raw materials are: chromic acid, chromium oxide green and additives. The raw material is mixed. The intermediary product, the mash, is exposed in

6.2 Binder and Oxides

For the production of the raw materials with their basic components – the magnetic pigments and the binders – and their finely defined combination – the formula – the competence of major chemistry is required (see fig. 83).

The know-how of the formula, its transmission into the manufacturing process and the resulting user advantages are grouped in table 2.

Binder and Oxide Manufacturing **Fig. 83**

Production of chromium dioxide

High pressure reactor

Dispersing

Dispersed oxide

Mixing of the raw materials

Filter

Buffer tank for magnetic dispersion
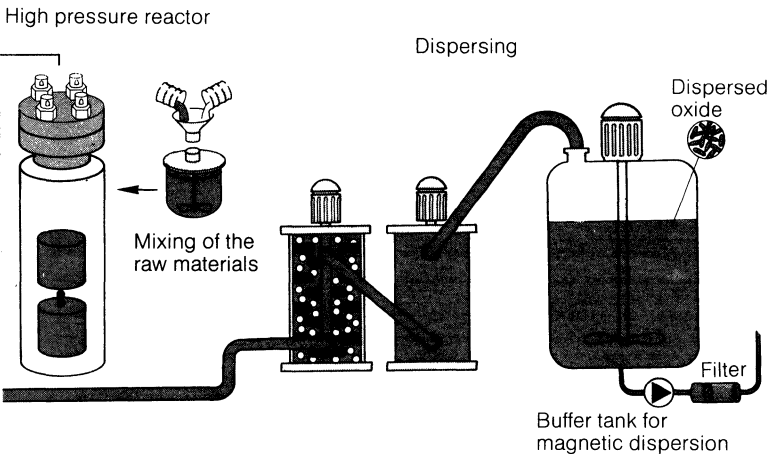
cans to a high pressure reaction (= high pressure and high temperature) and processed in additional operations into micro structured chromium dioxide particles.

The mixture of binder and oxide is dispersed in so-called ball mills. The balls of these rotating mills guarantee an extremely homogenous intermixture: A binder coating to cover each individual oxide particle. The finished magnetic dipersion is put for intermediate storage in buffer tanks and from there transported to the coating installation.

Manufacturers know-how	User Advantages
Own Binder development and production.	
Optimum coating of oxide by finely balanced viscosity control and in consequence high packing density of the oxide.	High storage media lifetime. Minimum abrasion balanced media flexibility. Constant output level.
Polyurethane binder with high flexibility. Not sensitive concerning stock and climate conditions.	High durability in archiving.
Own know-how in development and manufacture of pigments of uniform particle size guarantees sharper transitions of magnetization between the different bit cells.	Best precondition for high recording density. Uniform quality, no fluctuations due to changing supplier.
Know-how in construction and operation of dispersing equipment, in the manufacture and use of dispersion aids.	Reliable adhesion of the coating. Signal output level corresponds to upper limit of international standards.
Form stable processing of pigment crystals in finest repartition for coating of homogene high packing density, high life expectancy and antistatic equipment.	Well equipped for high recording density. No static charge. High life expectancy. High drop-out security. Favourable signal-to-noise ratio.
Low head abrasion.	High head life expectancy.
Optimum formula.	Homogeneous coating thickness.

Binder

The binder is a special dispersion. A corresponding construction guarantees the defined position in the molecule of basic elements with distinctive characteristics in order to provide the binder with the combination of properties to be suitable for the specific requirements of the individual storage medium (see fig. 84, 85, 86).
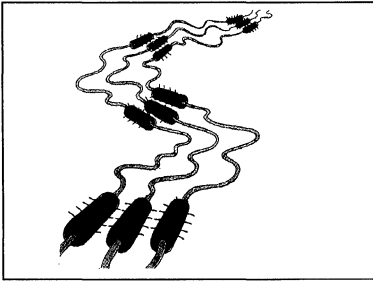
Series connection of hard and soft segments in elastic polyurethanes.
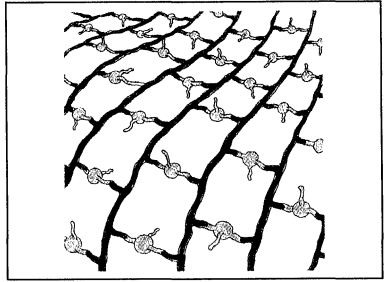
Chemically reticulated hard polymers.
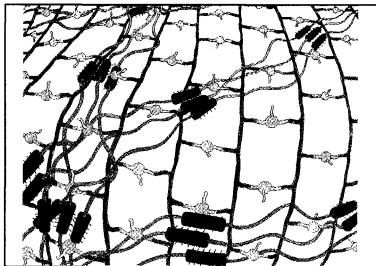
Polymer Network   **Fig. 86**

During the reticulation a uniform wide-meshed network is produced whose peculiar structure provides the material with high toughness and elasticity.

Magnetic Pigments

The BASF production range includes all present pigment classes, iron oxide, chromium dioxide and metal pigments.

Whilst e.g. the manufacturing process for the iron oxide may be relatively simple, for chromium dioxide a high pressure process is necessary (see fig. 83).

For the magnetic storage media, presently offered in the market, magnetic pigments are used for longitudinal magnetic recording. Vertical recording and the corresponding requirements for the oxides are covered in chapter 14.

6.3 Anisotropic Pigments

For longitudinal recording on longitudinal storage media (e.g. computer tapes) parallel to the coating direction of the magnetic coating a magnetic field is created, resulting in the physical turning (= orientation) into longitudinal direction of the pigment particles in the still wet coating.

After the drying operation the oxide particles in the coating do not further change their position. For recording their magnetical flux direction is changed. This magnetic orientation before the drying process improves the magnetic properties in the tape running direction. The expert calls this pigment property of orientation "anisotropic".

However, if in the web coating process a coated butt roll is produced for later transformation into diskette magnetic disks, the orientation magnet is switched off. Rigid aluminium disks e.g. for later inclusion in fixed disk drives, are produced by the spin-coating technique. Here, the rotation speed of the aluminium disk and the intensity of the coating jet define the coating thickness. Several magnets aligned in circumferential direction provide the magnetic orientation in a circular direction before the coating is dried. The magnetic values like remanence and coercive force will be explained in chapter 8.

6.4 Iron Oxide, Chromium Dioxide, Metal Pigment

The choice of the right pigment for the individual storage medium depends on a number of factors (see box 5). The length of the metal pigments must be small in relation to the flux change length to be recorded. For even higher recording densities there are finely structured metal pigments or instead of particulate coatings evaporated or sputtered ones (see also chapter 14).

6.5 Which Pigments for which Storage Media?

The storage medium is only one of many components of a magnetic recording and reproduction system. The system manufacturer defines the

Box 5   **Flux Change Length / Pigment Particle Size**

In fig. 87 we show the relation of flux change length and pigment particle size.
The wave length as per fig. 46 corresponds for the data technique to two flux change lengths. Such flux change lengths we have drawn in fig. 87 A).
B) and C) show once again the equation for calculating the wave length and the relationship of flux change length to wave length.
D) shows a simplified calculation for the Compact-Cassette recording, rounding up the tape speed from 4.76 cm/s to 4.8 cm/s and the limit frequency up to 20,000 Hz.

As the calculation for the diskettes is not so simple, we did not execute it but only indicate the values for the FC-length (FC = flux change). Beside it the head gap length can be seen (see also fig. 56).

Please now compare under E) the particle sizes of the different oxide classes with the above indicated flux change lengths.

Normal iron oxide is sufficient for the standard diskettes. Because of the high recording density, for High-Density diskettes Co-Fe (= Cobalt doped iron oxide) has been chosen (see also "coercive force" in chapter 8.3).

For the top quality Compact-Cassettes and the 1/2 inch wide video and computer tapes for the new MTC systems BASF takes the chromium dioxide, as this high performance pigment brings the best results for the recording of small flux change lengths.

A) Flux change

B) Equation for wave length: $\lambda = \frac{v}{f}$

C) Flux change length: $1/2\ \lambda$

D) Compact-Cassette: $\lambda = \frac{4,8\ cm/s}{20\ 000\ Hz} = 2,4\ \mu m$ (Wave length)

$1/2\ \lambda = 1,2\ \mu m$ (Flux change length)

E) Oxide particle size:

	$\gamma\ Fe_2O_3$	Fe_2O_3 Co doped	CrO_2 I	II	III
Length:	0.5 μm	0.3 μm	0.2 μm	0.4 μm	0.3 μm
Diameter:	0.05 μm	0.03 μm	0.02 μm	0.04 μm	0.03 μm

F) Example diskette:

Diskette 5.25"	tpi	FC-length in μm	Gap width in μm
Standard	48/96	4.6	2.5
High-Density	96	2.7	1.0
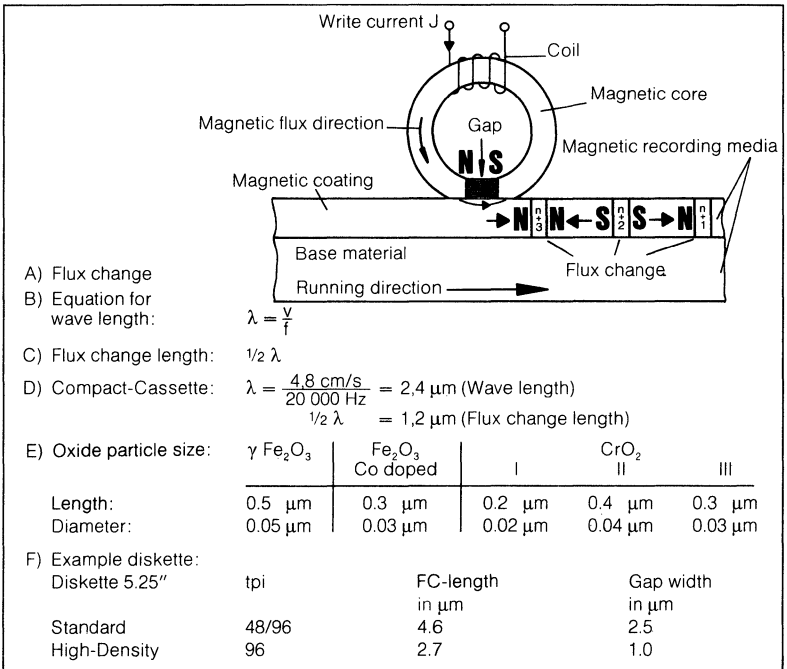
specification for the storage system and the independant media manufacturer develops a storage medium meeting the system requirements. The word "compatibility" is of the highest importance. That means, the storage media must function on the system and in data exchange between users of the same systems.

6.6 Coating

We have previously mentioned the coating of rigid media (e.g. magnetic disks for fixed disk drives) so we limit ourselves here to the coating of flexible storage media for EDP (diskette magnetic disks and magnetic tapes).

Here, the know-how of Physicists, Process Engineers and Mechanical Engineers is required in order to construct, to run in accordance with the different products of high technology the web coating installations (see fig. 88) and to keep them in constant operation by a specialized on-site-service.

These installations are suitable for the operation of flexible substrates from 6 to 80 micron thickness. The thinner foils are used for the audio/video technique, the thicker foils are used for computer tape and diskette butt rolls.

Fig. 88   **The Web Coating**
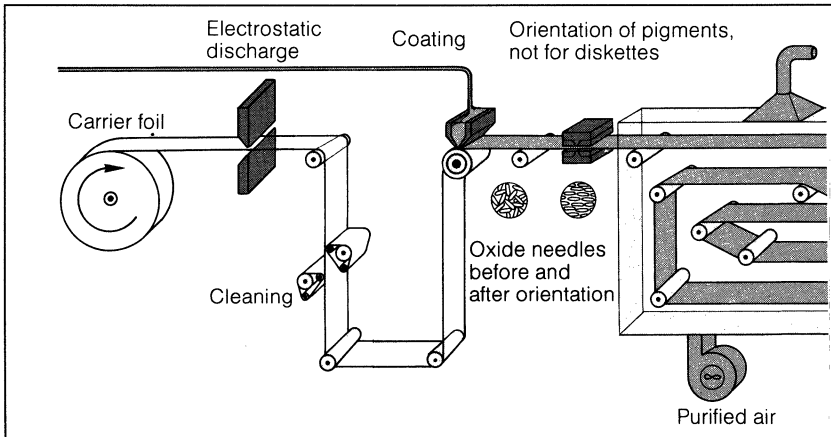
The uncoated carrier foil passes all manufacturing steps and leaves the web coating installation in the form of a coated butt roll. First comes the electrostatic discharge of the carrier foil. This prevents the attraction of dust. The foil passes for single sided coated storage media (e.g. computer tape) once, for double sided coated storage media (e.g. magnetic disks for diskettes) twice through the installation. The dispersion is coated according to the specifica-

The coating thicknesses are 0.5 to 15 microns. The substrate and coating thickness is listed for the individual products in the technical characteristics or the product range. The higher the recording density, the thinner the coating thickness. Therefore, High-Density Micro-Diskettes have a coating thickness of only 0.9 micron.

The carrier foil passes through an electrostatic discharge process, a cleaning station and then the coating station. The pigment needles in the still wet coating (only for tape butt rolls, not for diskette butt rolls) are magnetically orientated in a longitudinal direction. The coating is dried by evaporation of the dispersion solvent which leaves the drying channel by an air exhaust for recovery later.

During the coating process laser scanners detect coating defects and radiometric scanners measure and correct the coating thickness.

Plastic coated steel rollers and heated steel rollers compress and polish the coating. The unfinished product, leaving the web coating installation, is the coated butt roll, being exchanged for an empty take-up hub for the next butt roll by a so-called "flying change".

The butt roll is then tested according to the specified properties and only released for further processing if it corresponds to the stringent BASF criteria for the individual product. Diskette butt rolls then go to the punching, tape butt rolls to the slitting station.

The Web Coating   **Fig. 88**

Air exhaust for solvent recovery · Testing · Calandering · Winding · Laser scanner for coating defect detection · rough · smooth · Steel roll · Plastic coated steel roll · Coated butt roll · Radiometric thickness scanner · Purified air
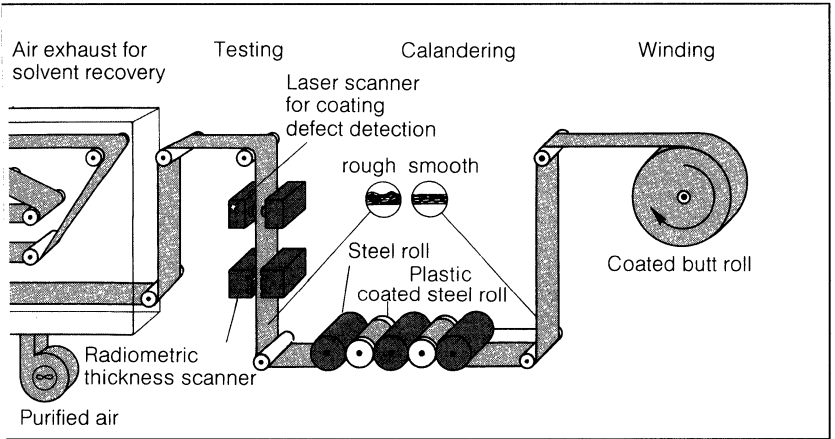
tions. For longitudinal storage media (not for diskettes) the oxide needles are magnetically oriented lengthwise. After the drying channel the coated foil passes an in-line radiometric thickness scanner and a laser scanner for coating defect detection and leaves the installation in the form of a coated butt roll.

7. Finishing

Under this umbrella definition we group for the diskette butt roll material the punching, for the tape butt roll material the slitting and for both product families the testing of the magnetic disks/pancakes, the manufacturing of the systems parts like diskette jackets/tape cartridge shells, the loading of magnetic disks/tapes into the shells/cartridges and the system tests.

As the measuring and testing technology in the sense of quality control has a very high importance, we will cover the subject of on-line and off-line tests separately in chapter 8, so here we will only mention a few points.

7.1 Computer Tape

The automatic slitting unit (see fig. 89) also tests the 1/2″ wide computer tape across all track widths with error control of all tracks. Further off-line runs on certifiers are an additional quality assurance. Different reel sizes, rings and plastic canisters are available for the enduser. We will return to them in chapter 9.

Fig. 89   **The Computer Tape Finishing**
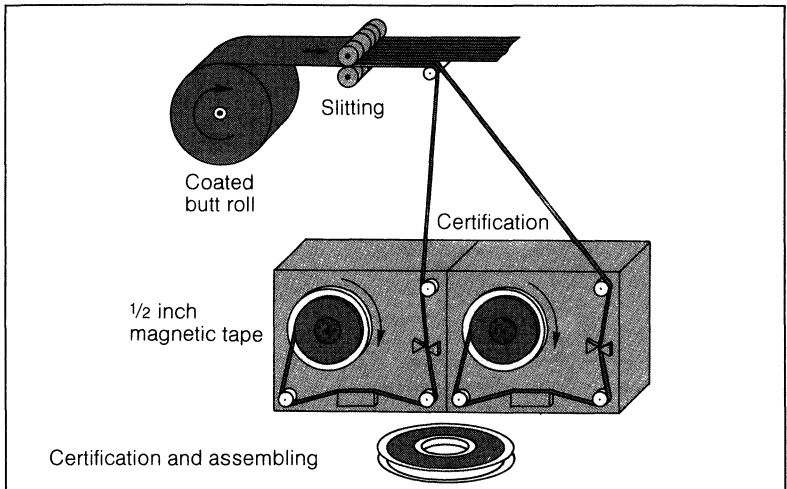
For reel-to-reel computer tape the coated butt roll is cut into 1/2″ wide tapes and simultaneously in-line tested under simulated system conditions across the total tape width. These so-called pancakes are assembled with standard reels of different diameters and plastic rings or canisters to the final sales product. In addition to the in-line test there are further off-line certifications.

7.2 Magnetic Tape Cartridges

In chapter 10 we will present the different EDP cartridge systems. For the finishing (see fig. 90) we describe the most important and the most modern one: The Magnetic Tape Cartridge (= MTC) for the IBM 3480 and compatible systems.

In the form of an expansion of the production facilities at the Willstätt factory for a cost of 170 million DM, the fully automated MTC manufacturing installation was built. It includes the new building for the injected parts of the shell (= C0), its automated transport to the C0 assembler, the supersonic welding of the C0, the cartridge loader and the MTC system tester. We return to the MTC in the chapter "The Measuring and Testing" (chapter 8) and for the presentation of the magnetic tape cartridges (chapter 10).

The MTC Finishing   **Fig. 90**

Supersonic welding

Shell
Brake button
Write protect
Reel
Shell
Leader block
Assembled cartridge (= C0) tester
Coated butt roll
Pancake
Slitting Certification
Cartridge loader
MTC system tester
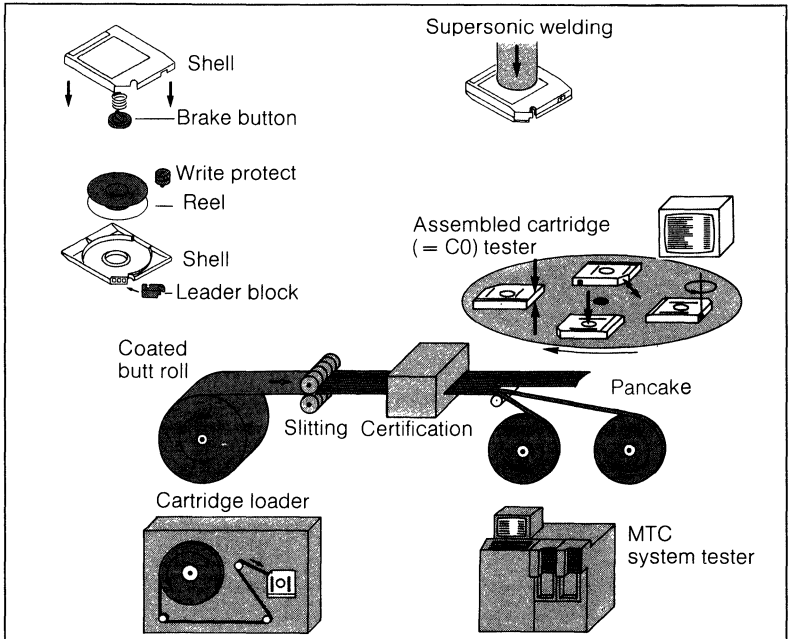
In parallel running automatic production facilities the empty shell (= C0) and the pancake are manufactured and tested. In the cartridge loader the 1/2″ wide magnetic tape is automatically inserted into the C0 and the leader block fastened. As all MTCs leave the production site, 100% error free, they are tested piece by piece in the MTC system tester.

7.3 Diskettes

A high vertical manufacturing integration is also required here (see fig. 91), if all production steps, for quality control, are to be consistant. Whilst some production steps – however, because of the varying magnetic disk sizes on different machines – are identical for the 3.5″, 5.25″ and 8″ diskette (punching, surface treatment, disk tests), the 3.5″ and the 5.25″/8″ differ in the jacket/shell production. For the 3.5″ Micro-Diskette the shell is a semi-rigid plastic, the individual parts are manufactured in injection moulding machines, with a metal head shutter and a metal centre core. For 5.25″/8″ diskettes the jacket is of flexible jacket material, that is formed in the automatic folder into an envelope, open at the top and after the disk loading, sealed on all sides. All diskettes pass the certifier and are tested 100% error free ex factory.

Fig. 91   **The Diskette Finishing**

Diskette 3.5″

Shell — Liner

Jacket production

Jacket material — Liner

Punching disks

Surface treatment

Coated butt roll

Diskette assembler

Diskette certifier
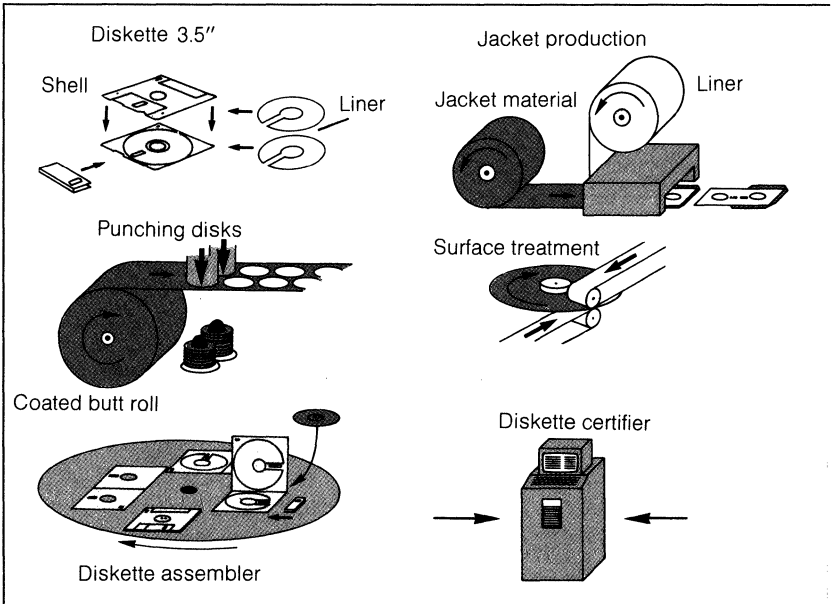
Out of the coated butt roll the individual magnetic disks are punched with high precision and then surface treated and tested. There are parallel runs for diskette sizes 5.25″ and 8″ the jacket and liner production with the circular automatic folder, and for diskette size 3.5″ the manufacturing and assembling of the semi rigid plastic shell. Finally the diskettes of all sizes pass the diskette certifier and leave the factory 100% error free.

7.4 Packaging and Shipping

Storage media pass an erasing field (see fig. 92), before it is passed for shipment. A sophisticated logistic procedure is required for shipping to over 100 countries being covered by the world-wide BASF distribution network.

Erasing

Packaging
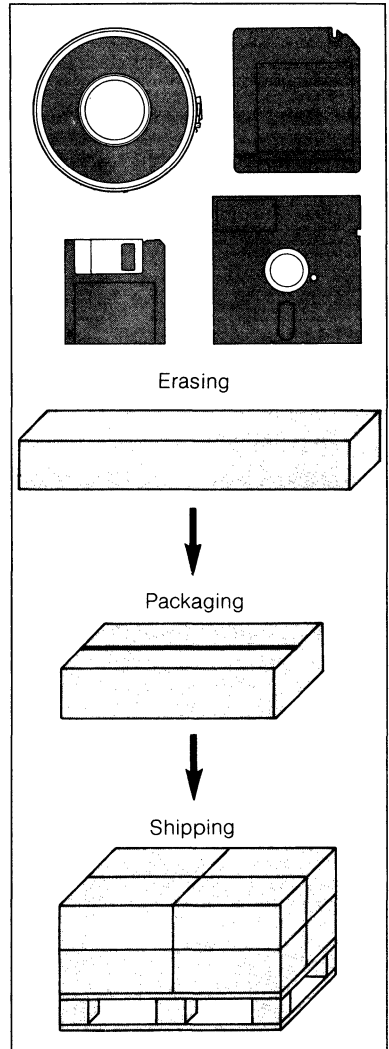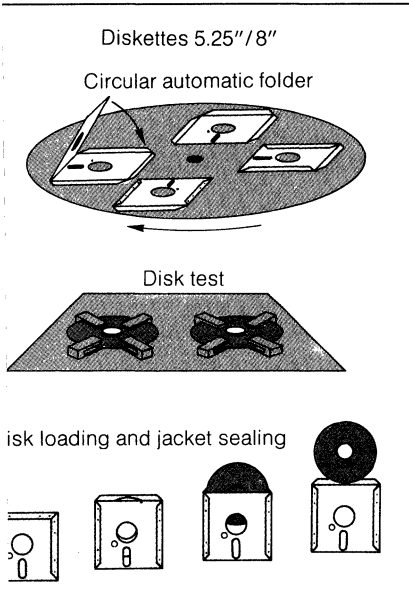
Shipping

All magnetic storage media pass an erasing zone for the erasing of test signals before packaging and shipping in more then 100 countries world-wide.

Diskettes 5.25″ / 8″

Circular automatic folder

Disk test

isk loading and jacket sealing

8. Measuring and Testing

In this chapter we explain the measuring and test technique and the most important technical specifications, listed in the data sheets with the appropriate characteristics (see also boxes 6 and 7). This is a help for the non-technically interested person to compare the mechanical, magnetic and electro-magnetic properties of the storage media of different manufacturers.

The SI (= System International) units are standardized in DIN 1301 (ISO 1000). The internationally used abbreviations of some of the SI units as used in this brochure are listed in this box.

They are easier to learn, if the names of the famous personalities are known to whose honour the initial letters have been chosen.

A   Electric Current unit Ampère after André-Marie Ampère (1775–1836), French Physicist and Mathematician.

A/m   Magnetization (= magnetic field strength).

G   formerly used for Magnetic Polarization unit Gauß, after Carl-Friedrich Gauß (1777–1855), German Mathematician and Astronomer. 1 G $= 10^{-4}$ T.

H   Self Inductance unit Henry after Joseph Henry (1797–1878), American Physicist. 1 H = 1 Wb/A.

N   Force unit Newton after Sir Isaac Newton (1643–1725), English Physicist and Mathematician. 1 N = 1 kg $\cdot$ m/s².

Oe   formerly used for magnetization unit Oersted after Hans Christian Oersted (1777–1851), Danish Physicist.
1 Oe $= \frac{10^3}{4\,\pi}$ A/m = 79,58 A/m.

T   Magnetic Polarization (= Induction) unit Tesla after Nicola Tesla (1856–1943), American Physicist and Electro Technician, 1 T = 1 Wb/m².

V   Electric Tension unit Volt after Alessandro Count Volta (1745–1827), Italian Physicist. 1 V = 1 W/A.

W   Electric Power unit Watt after James Watt (1736–1819), Inventor of the Steam-Engine. 1 W $\cdot$ s = 1 N $\cdot$ m.

Wb   Magnetic Flux unit Weber after Wilhelm Eduard Weber (1804–1891), German Physicist, 1 Wb = 1 V $\cdot$ s.

Ω   Electric Resistance unit Ohm after George Simon Ohm (1789–1827), German Physicist. 1 Ω = 1 V/A.

8.1 Measuring Techniques

For a high vertically integrated manufacturing, beginning with the raw materials via the intermediate products up to the sales products, for all production steps, it must be determined, which properties are to be measured.

If the measuring technique is determined, the sample product to be measured passes the test unit. The measured, individual, actual values produced are then compared with the specified standard values. If the tested sample meets the standard specification, it passes to the next test station. If it does not meet the standards here, it leaves the production line (see fig. 89, 90, 91, 93, 94).

The specified values are taken from the specifications of the storage system manufacturer or, if they are already standardized, from the industrial standards, but also from the house standards of the media manufacturer. The test procedures and even the test equipment are also mainly standardized, so that the test results of the media manufacturer A can be compared with those of the system manufacturer B.

SI-Prefixes   **Box 7**

In DIN 1301 (ISO 1000) the prefixes and symbols for decimal parts and multiples of SI units are standardized. The symbol of a prefix is considered to be combined with the single unit symbol to which it is directly attached, forming with it a new symbol. Example: The symbol "m" of the prefix "milli" in front of the single unit symbol "m" (= meter) is "mm", meaning "millimeter".

The following DIN 1301/ISO 1000 prefixes are used in the different chapters of this brochure. In deviation of DIN we have taken KB instead of kB for Kilobyte as the capital K ist more used in the EDP field. Otherwise kilo is "k".

Prefix	Symbol	Factor
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
deca	da	10^{1}
hecto	h	10^{2}
kilo	K	10^{3}
mega	M	10^{6}
giga	G	10^{9}
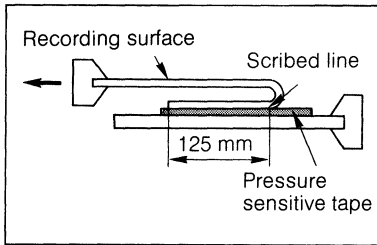
There are different procedures to test the adhesion of the magnetic coating on the base material. In this method a double sided pressure sensitive adhesion tape of defined specification is used. The test conditions state a minimum force, expressed in N/mm, at which any part of the coating first separates from the base material.
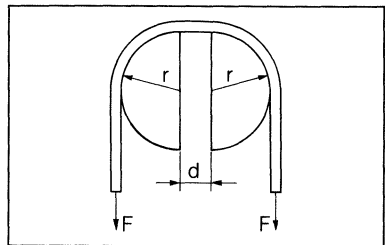
In this procedure the electrical resistance of magnetic coating surface is measured for a definite d.c. voltage between two electrodes placed at a defined distance. The values are indicated in Ohm, Kilo Ohm or Mega Ohm (see also box 7).

If the standards are minimum requirements, the media manufacturers are free to fix the test levels so that, for their own products the results are above the minimum requirements. This may then be used for advertising.

For mass manufacturing not only are the individual samples important but the average quality of the manufacturers products in comparison to those of the competitors. Only volume tests of the products offered in the market give a true survey and permits the positioning of the manufacturers brand.

If magazines or independent test institutions take over this task, they normally can only cover a part aspect as – especially for life endurance tests – these tests are very time consuming and expensive.

For such tests BASF buy back from the market their own products, compare them with the actual production and with competitors products bought in the market.

If for a BASF diskette test 50 test criteria are chosen for each diskette type to be tested and if 5 diskette types with 10 pieces each from 20 competitors are the test lots, this corresponds to a volume of 50,000 test values. Even EDP data entry and evaluation of the test values requires several man/months.

8.2 Physical Properties

Magnetic storage media on open reels as in computer tapes is being increasingly replaced by storage media for which the magnetic tape or the magnetic disk and the surrounding plastic envelope/shell of flexible or semi-rigid plastic are system components.

8.2.1 Mechanical Properties

Therefore an automatic tester checks piece by piece each MTC shell in all of the important mechanical parameters (see fig. 95-98). BASF tests are more stringent than the standard.

The shell height is an important mechanical function and an indirect measurement for the quality of the welding.

Test Automat Station 1   **Fig. 95**

ANSI: +0.5/−0.32 mm
BASF: +0.1/−0.15 mm
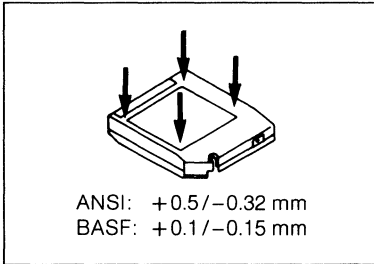
Shell height

Test Automat Station 2   **Fig. 96**

BASF: 3 N min
7 N max
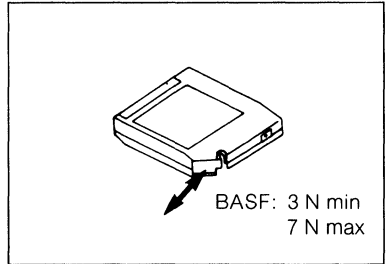
Push/pull force of the leader block

Test Automat Station 3   **Fig. 97**

BASF: 2 N min
8 N max
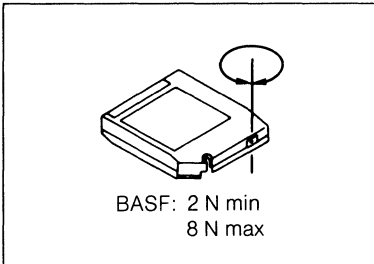
Torque of the write protect

Test Automat Station 4   **Fig. 98**

BASF: 3 N min
12 N max
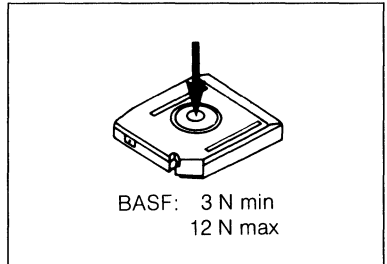
Spring force

The automatic tester for empty cartridges (called C0) checks all important measuring points (7 in total) according to our stringent test criteria. These are: C0-height, push/pull forces of the leader block, torque of the write protect, spring force, reel brake, several reel functions and C0-dimensions.

Also all jacket and shell values of the diskettes are tested. The centre hole of the diskette magnetic disk will have a narrow distribution of hole diameters (see fig. 99).

BASF Diskette   Industrial standard

−25 µm   0   +25 µm   −25 µm   0   +25µm

The punching and curing techniques of a highly developed technology guarantee that the actual disk of the BASF Diskette will have a narrow distribution of hole diameters, which will give repeated precise mounts into the drive unit.

Value
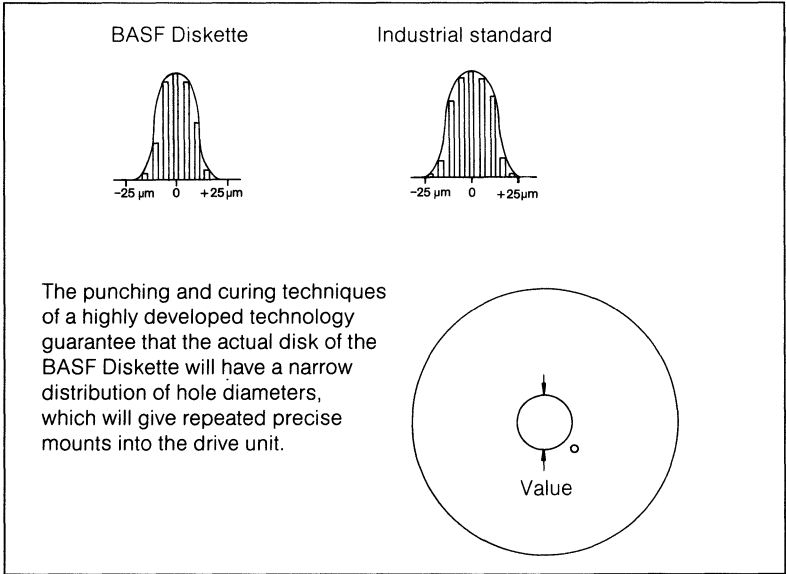
The other mechanical properties like width, length, total thickness of the storage media must be within narrow tolerances.
This is one of the pre-conditions for a high track fidelity, no interchange problems (exchange of recorded storage media between systems), good contact magnetic coating/magnetic head and optimum read/write behaviour.

8.2.2 The Electrical Resistance

The electrical restistance of the coating (see fig. 94) must also be within standardized values. If it is too high, there is a too strong static charge of the storage medium, whereby electrical parasite signals are created and dust particles attracted.

8.2.3 Other Physical Properties

For diskettes the torque, meaning the starting and the current torque, have also to be defined. Specially developed materials and their processing according to specifications into jackets and shells, liner and magnetic disks are the pre-conditions for an optimum torque behaviour of the diskettes.

Among the physical properties numbered are also the coefficient of linear hygroscopic expansion (indicated in percent of relative humidity, abbreviated $\%$ r.h.) and the coefficient of thermal expansion of the disk indicated per degree Celsius, the flammability and the toxicity.

Magnetic storage media is self-extinguishing and non-toxic. This means they do not continue burning in a carbon dioxide atmosphere according to international definitions of materials, that exclude the danger of toxic health risks when used in the intended manner.

8.3 Magnetic Properties

We return to the hysteresis curve which we already know from the HF bias (see fig. 11). It shows us the most important magnetic properties of the tested storage media.

8.3.1 Coercive Force

The higher the recording and track density the greater the coercive force of the magnetic coating. For normal recording densities such as the reel-to-reel computer tape and the standard diskettes iron oxide or – for High-Density diskettes – Cobalt doped iron oxide (= CoFe) are sufficient. For higher recording densities such as for the Magnetic Tape Cartridge for the IBM 3480 and compatible systems and also for $\frac{1}{2}''$ home video recording tapes a high performance oxide like chromium dioxide is best. For even higher recording densities new coating technologies like evaporation and sputtering (see chapter 14) replace the particulate coatings. An example is magnetic storage media with a metal film coating (see fig. 100).

Another magnetic value is the magnetic particle orientation ratio (= squareness ratio). For circular storage media, like the diskettes, it has to be as small as possible, e.g. smaller than 0.6 and for longitudinal storage media as great as possible, e.g. greater than 2. It indicates the relation of the remanent magnetization longitudinally and diagonally to the recording direction. If the squareness ratio is too high for diskettes, there is a high modulation (see also chapter 8.4). If it is too small for longitudinal media it has a negative influence on the recording.
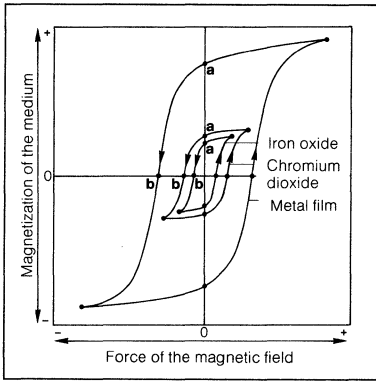
Fig. 100   **Magnetizing Curves of Different Materials**

The remanent magnetization (a) and the coercive force (b) are low for iron oxide, higher for chromium dioxide and very high for metal film materials. For high recording and track densities materials with high remanent magnetization and coercive force are required.

8.3.2 Hysteresis Loop

The hysteresis loop (hysteresis is Greek for following behind) shows the relation of the magnetic field strength H to the magnetic induction B (see fig. 101).

The coercive force H_c (Latin coercere = cohesion by force) is the magnetic field strength H for which B = 0.

The remanent magnetization B_r (Lat. remanere = to remain) is the remaining induction for H = 0.

The starting point of the hysteresis loop is the field free, unmagnetic stage of the material with H = 0 and B = 0. If exposed to an outer magnetic field the magnetic coating is magnetized along the initial curve or instep (path 0 to $+B_s$). B_s is the saturation magnetization.
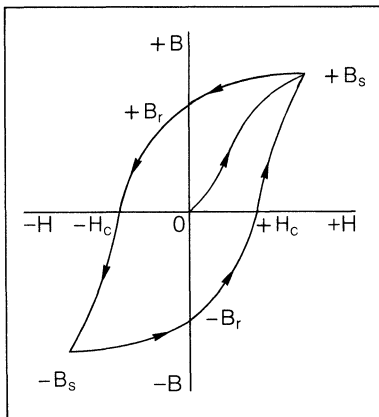
Fig. 101   **Hysteresis Loop**

Formation of a Hysteresis Loop.
B = Magnetic induction
H = Magnetic field strength
H_c = Coercive force
B_r = Remanent magnetization
B_s = Saturation magnetization

If from a defined material dependent field strength all dipoles are oriented, the saturation magnetization is reached. Reducing H corresponds to the curve $+B_s$ to $+B_r$. It cuts the B axis in the remanence point $+B_r$. If an opposite field strength $-H$ is produced, the flux density reaches zero at $-H_c$. If the field strength is increased further, the curve $-H_c$ to $-B_s$ is passed and the saturation magnetization is reached in the opposite direction. If the field strength is reversed, the curve passes the points $-B_r$, $+H_c$ and $+B_s$. The reversal of the direction of the magnetic field is called "flux change" (see fig. 46, 48, 51, 52, 54, 55, 59, 60, 61).

8.4 Electromagnetic Properties

Whilst the mechanical and magnetic values to a large extent are system independent, this is not the case for other electromagnetic properties. For each individual storage medium it is defined under what system conditions the values are measured.

For some EDP storage media (e.g. Magnetic Tape Cartridges = MTCs, tape width 12,7 mm = 1/2″) there are standards for "recorded" and for "unrecorded" storage media, for others (e.g. diskettes) standards for the data exchange with defined recording modes (e.g. MF and MFM).

For those interested, the corresponding standards may be ordered from the relevant standard committees. We have listed the most important addresses (see box 8).

It would go beyond the limits of this chapter to explain all definitions and test methods. We will only explain the most important definitions, appearing in the BASF data sheets.

Sources for International Standards **Box 8**

DIN	is the abbreviation for "Deutsches Institut für Normung e.V.". DIN-brochures can be ordered from Beuth-Verlag GmbH, 1000 Berlin 30.
ECMA	European Computer Manufacturers Association, 114, Rue du Rhône, CH-1204 Genf.
ISO	International Organisation for Standardisation via ECMA.
ANSI	American National Standards Institute, Inc. 1430 Broadway, New York, N.Y. 10018, USA.
NBS	National Bureau of Standards, Gaithersburg, M.D. 20899, USA.

8.4.1 Signal Amplitude/Read Voltage

Different definitions like signal amplitude, average peak output, output voltage, read voltage and read amplitude etc. are used to define how strong the read signal has to be for the reproduction of the data to be in the tolerances of the standards. It is common practice to indicate the signal as percent in relation to a reference storage medium.

For Mini-Diskettes e.g. it is the test frequency 1f with 125,000 ± 125 fc/s (= flux changes per second) for the track 00 and the test frequency 2f with 250,000 fc/s for the track 34/79. The track 00 as the outer track with a greater diameter in comparison to the inner track (tracks 34 or 39 for single track density, track 79 for double track density) because of the greater distance between two subsequent bits has the higher read amplitude. It has not to surpass a certain value (< 130% of the reference diskette). The read voltage of the inner track, because of the weaker read amplitude caused by the shorter bit distance, should not be below a certain value (> 80% of the reference diskette). The values refer to the reference diskette of the Physikalisch-Technische Bundesanstalt (= PTB) in Braunschweig. See also resolution.

8.4.2 Missing Pulse (= drop-out)

A missing pulse is the dropping of the read amplitude below a standardized average amplitude value (see also fig. 102). BASF measures the diskettes at a more critical test level than the standards, for BASF Diskette Extra at 50% and for BASF Diskette Maxima® even at 60%.

"Missing Pulse Zone", or to be more exact "1-Track-Missing Pulse Zone" is defined for the MTC as follows:

A missing pulse zone begins with a missing pulse and ends when 64 consecutive flux transitions are detected or a length of 1 mm of tape has been measured. The missing pulse zone rate shall be less than one in $8 \cdot 10^6$ flux transitions recorded.

"Coincident Missing Pulses Zones" for the MTC are given, if under defined conditions two or more missing pulses simultaneously appear on parallel running tracks.

8.4.3 The Resolution

The resolution is a measuring value for the relationship of the signal strength of different frequencies. This relationship, expressed in percent in relation to a reference diskette or a reference magnetic tape is a minimum requirement. In the interest of a high data security this minimum requirement should guarantee that a too great output amplitude difference of different signals does not occur.

In diskette technology, e.g., the output amplitude should not be too high ($<$ 130% for the outer tracks) and not too low ($>$ 80% for the inner tracks, e.g. track 78 or 79). In addition the standard minimum requirements for the resolution is the relationship of the signal strengths ($=$ output amplitude) of two frequencies 2f/1f, measured on the inner track, for the 5.25″ diskettes of at least 80% for single density recording and at least 90% for double density recording respectively 80% for the 3.5″ diskettes, always in relation to a reference diskette.

BASF Storage Media have a magnetic coating of homogenous and – because of the high recording density required – reduced thickness and a high coercive force of the magnetic particles. Therefore, the average resolution of the BASF Storage Media under test conditions is better than the minimum requirements of the specific standards.

8.4.4 Overwrite

Overwrite is used for diskettes and MTC as a single magnetic head system that is used for writing, reading and erasing. The erasing is an overwriting of the old information with new information.

After overwriting the residual level of the original signal should not surpass a determined maximum level. ·

Overwrite for track 00 for the HD-Mini-Diskette of $<$ 150% means: The residual signal of the original 1f recording after overwriting with 2f on track 00 is below 150% in relation to the residual signal of a reference diskette.

8.4.5 Signal-to-Noise-Ratio

Signal-to-Noise-Ratio abbreviated S/N or SRN is called the difference of the signal amplitude to the noise power of the magnetic storage medium and/or the hardware system (see fig. 102).
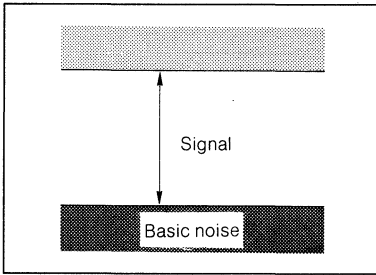
The S/N is usually expressed in decibels (see table 3).

The basic noise depends on the electrical band width of the read channel.

A variation of the S/N are the NB-SRN and the BB-SRN for the MTC.

NB stands for Narrow Band, BB for Broad Band. Band is the abbreviation of measuring frequency band width.

In the standards (e.g. ISO 9661 or ECMA 120) the measuring procedure and the frequency band width for the spectrum analyzer is indicated to make these measurements.

Table 3   **Excerpt of the Decibel Table of the Output Level Relations**

Relation smaller than one Negative dB-Value Prefix "−"	dB	Relation greater than one Positive db-Value Prefix "+"
1.000	0	1.000
0.891	1	1.122
0.501	6	1.995
0.316	10	3.162
0.100	20	10.00
0.0316	30	31.60
0.0100	40	100
0.003	50	316
0.001	60	1,000
0.0003	70	3,160
0.0001	80	10,000
0.00003	90	31,600
0.00001	100	100,000

Decibel is a logarithmic unit for output level relations (sound pressure or voltage relations). The denomination is composed of the word deci (= a tenth) and the name Bel after the American inventor of the telephone, Alexander Graham Bell (1847–1922).
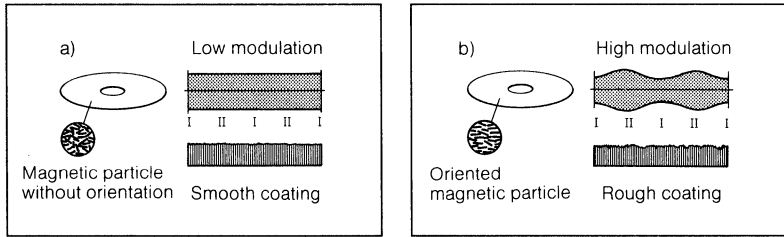
In the figure a) the oxide particles are distributed without orientation (left circle) and lead to a low modulation (right curve). In the figure b) they have a preferred magnetic orientation and in consequence the modulation is higher.

8.4.6 Modulation

The modulation of the read amplitude, abbreviated "modulation", is the periodical change of the read amplitude (= read voltage) per track circumference of a rotating storage medium.

If, as shown in the left part of fig. 103, a homogeneous distribution (= no orientation of the magnetic particles) of the pigments is reached in the web coating of diskette material, the diskette only shows a low modulation.

However, if the pigment distribution has a preferred orientation, as shown in the right part of the figure, the read voltage is always then higher, when during the rotation of the diskette, the track runs parallel to the direction of the orientation. The consequence is a high modulation.

According to ECMA the variation of the read voltage must be below 10% (see fig. 104). BASF Diskettes reach average values of only 3%. The homogeneous distribution of the pigment particles and the uniform coating thickness are, for these, important factors.

Modulation According to ECMA   **Fig. 104**

M = Modulation
I = average maximum amplitude
II = average minimum amplitude

$$M = \frac{I - II}{I + II} \cdot 100\%$$
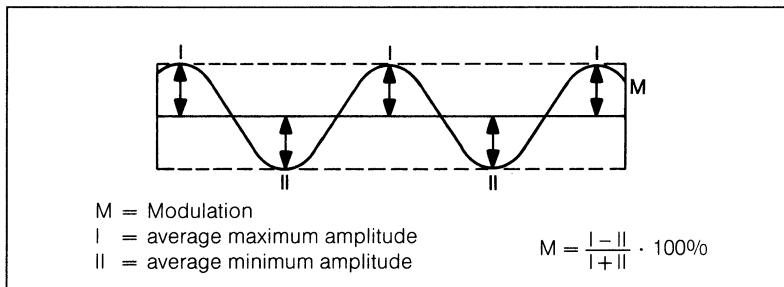
The modulation values for diskettes are calculated according to the above ECMA equation.

8.5 Environmental Conditions

For all magnetic storage media, in the technical requirements of the manufacturer the environmental conditions for operation, storage and transport are indicated.

Temperature and humidity play an important role here, as shown in the climate chart for diskettes (fig. 105).

Persons wearing glasses know the condensation of humidity on their spectacles when an extreme change in temperature occurs – from the

Fig. 105   **Climate Chart**
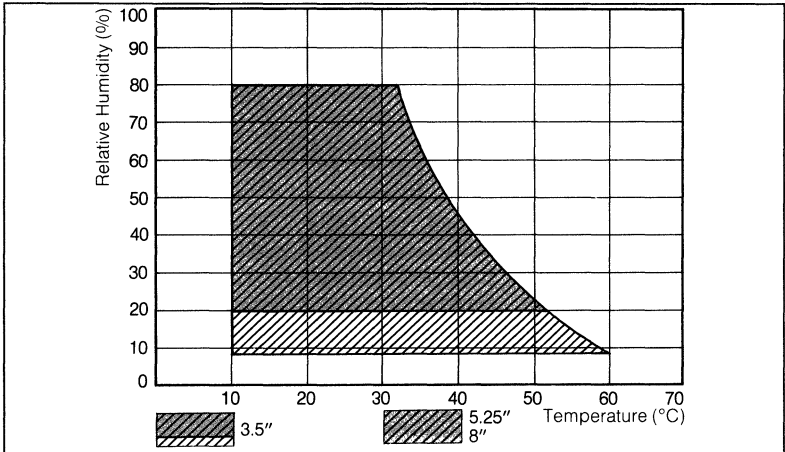
The climate chart shows the recommended range of temperature and humidity for the operation of diskettes taking into consideration a maximum wet bulb temperature of 29 °C. For storage and transport, the limits mentioned in the standards can be applied without restriction.

humid, cold external atmosphere into the controlled office temperature and humidity. They can imagine that a condensation of humidity on diskettes and magnetic tapes cannot be recommended. In such a case the magnetic storage media have to be initially acclimatized.

A basic rule: Optimum operating conditions prevail for temperatures and humidity values as they are standardized for mainframes in large EDP centers and for PCs in office atmospheres.

From the cold or from the hot into this atmosphere transported magnetic storage media for EDP use should be acclimatized for several hours to acclimatize them to the new atmosphere. Without such an acclimatization the storage media have no time to adjust to the dimensional changes provoked by the great change in humidity and temperature. Consequence: Malfunctions and unfavourable error behaviour.

8.6 Durability Properties

Advertising statements such as "100% Life Time Warranty" which are often used in several countries are of no help to the user because they relate to manufacturing defects and do not state clearly the data life time and the drive dependent resistance to wear and tear.

If we take the average human life expectancy of 72 years (see fig. 106) the magnetic recording has already surpassed this life time.

Some time ago, the voice of the Austrian Emperor Franz-Josef (1830–1916) was played back from the original wire on a telegraphone (see fig. 2) at the Austrian Academy of Sciences (österreichische Akademie der Wissenschaften) in Vienna.

His famous words, recorded on the 20. 9. 1900 during the World Exhibition in Paris, "Diese Erfindung hat mich sehr interessiert und ich danke für die Vorführung derselben" (This invention was very interesting for me and I thank you for the presentation of the same) have been a standard statement for such occasions in order not to applaud or to disappoint any inventor by using more or fewer words.

BASF still has in its archive an orchestra recording of 1936 by Sir Thomas Beecham (see fig. 8). This means a magnetic tape recording of over 50 years old.

The definitions connected to the duration of electrical devices, installations and systems are standardized (examples DIN 40041 and DIN 40042).

Human Life Expectancy   **Fig. 106**
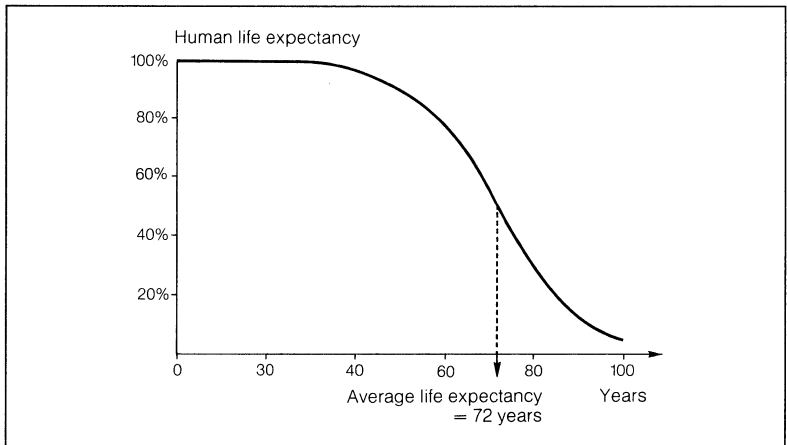
The average human life expectancy is 72 years.

However, for EDP storage media some definitions are commonly used which are different for the individual products.

For diskettes the life endurance is indicated in million head passages on one track with a maximum signal loss of 80% of the output signal (see also chapter 12).

For the Magnetic Tape Cartridge for the IBM 3480 and comparable systems artificial ageing is simulated according to ECMA-, ANSI-, ISO- and IBM standards resp. specifications.

Therefore the tape lengths are tested with the number of head passes, valid for this test. Dependent from the tests the number of permanent read errors and/or temporary write errors are counted.

BASF has more stringent test criteria by testing twice: Once before and once after the environmental test according to the same criteria.

The valid properties are listed in the specification for the BASF MTC.

For a high durability of the EDP storage media a number of criteria have to be considered:

– Pigment composition for an excellent coating resistance.
– Favourable binder/pigment interaction for best coating adherence and lowest abrasion.
– Surface treatment and additives for an outstanding tape resp. disk/ head behaviour.
– Special liner of high absorbtion and cleaning force dimension properly fastened (for diskettes).
– Jackets/cartridges of high stability, exact fitting and developed for high mechanical and thermal drive stress far above the minimum standard requirements.
– Carrier foil of best uniform quality and high temperature resistance.
– Low friction coating/back side (for tape) and disk/head/liner (for dis- kette).

8.7 Performance Characteristics

The operating systems of mainframes recognize all malfunctions which happen during operation, classify them and register in which form the system has corrected them.

8.7.1 EREP

The error data may be queried and presented by statistical programs. The most well-known is the EREP (EREP = "Environmental Record Edit- ing and Print program").

The presentation is subdivided into the different function groups resp. into machines and their media.

It would be too much to explain here in detail how an EREP is evaluated.

Based on the example of an EREP for the IBM 3480 and comparable systems we only want to show what has to be considered.

The EREP should inform us, for what subsystem and period it has been run.

Therefore, each EREP statistic carries a header with the abbreviated denomination, e.g. "Subsystem Exception 3480" and the operating period (industrial day and year). By fixing "limits" the "exception report" may be restricted to systematic errors and to drop unimportant ones. The limits are indicated separately for hardware, media (= volumes) and for temporary write and read errors (= TEMP.WRT and TEMP.RD). Another subdivision is into absolute error count (= CT) or relative error count (= without denomination).

The standard limits for the MTC are:

TEMP WRT	(CT)	TEMP RD	(CT)
40	(3)	200	(1)

This means e.g. for "40(3)" that only events of 3 and more errors or with errors zones of 40 or less MB per TEMP.WRT are counted.

Besides the exception report the "TEMPORARY ERROR SUMMARY" is important. It contains per spindle or DEVNO/CUA (= DEvice NOmber/ Control Unit Addressed) all temporary error events (without respecting the set limits), the error correction mode and a summary with average performance characteristics of all error categories.

Evalution of the EREP

In the outline of this introduction we only give a simplified explanation:

1. Directly connectable to the storage medium are the AVERAGE PERMANENT VOLUME ERRORS.

   Permanent errors are principally listed in the exception report and in the "3480 PERMANENT RECOVERED ERROR SUMMARY". Here, the detailed information is available in hex. coded form concerning the error causes and their correction for technical evaluation.

2. Indirectly connectable to the storage medium are the AVERAGE TEMPORARY WRITE ERRORS.

   In the exception report, TEMPORARY WRITE ERRORS are related to the individual cartridges.

Each cartridge has a VOLID (= VOLume IDentification). The exception report lists the different VOLIDs, subdivided into those found only on one spindle and those on two or more spindles. By comparison between error prone drives and VOLIDs and with the help of additional voluminous EREP statistics the error producing drives resp. volumes may be isolated and correction measures may be taken.

If inspite of our factory system test BASF Magnetic Tape Cartridges are indicated in the EREP or do not reach the standard performance set by the system manufacturer the competent BASF sales representative or application engineer will readily take the EREP for analysis and evaluation.

8.7.2 PEP

In addition, BASF has developed a program (PEP = Performance Evaluation Program), allowing the user easy care of his cartridge library by recommending, based on some EREP data, the exchange of defective cartridges and by showing graphically the system performance characteristic over a certain time period. BASF application engineers train the operators in the use of the EREP and the PEP on demand.

8.8 Other Technical Characteristics

The technical characteristics like track density, track width, track position, track position tolerances and tape speeds in cm/s (centimeter per second) or ips (= inches per second) and also the diskette revolution in rpm (= revolutions per minute) are internationally standardized.

8.8.1 Track Position of Diskettes

An explanation may be needed for the equation to calculate the track position of the diskettes.
For the Mini-Diskette with a single track density of 48 tpi e.g. the normal radius of the centre line of the individual tracks in millimeter is calculated with the equation:

$$R_n = x - \frac{n}{48} \cdot 25.4 \text{ mm.}$$

Where:
x = 57.150 mm for page 0
x = 55.033 mm for page 1
each time for the location of the outer track 00.
n = numerical value of the track number (n = 0 to 34 or 39 for 48 tpi).
The different x-values result from the fact that for the 5.25″ diskette the tracks on side 1 compared to the tracks on side 0 in relation to the same track number are for 48 tpi offset by 4 tracks, for 96 tpi by 8 tracks, in the direction of the centre.
For Mini-Diskettes with double track density the following equation is applied:

$$R_n = x - \frac{n}{96} \cdot 25.4 \text{ mm.}$$

As an example we calculate the radius for the track 39 of side 0, single track density:

$$R\,39 = 57.150 \text{ mm} - \frac{(39 \cdot 25.4)}{48} \text{ mm}.$$

R 39 = 57.150 mm – 20.638 mm = 36.512 mm.
The radius of track 39 on side 0 is 36.512 mm.

8.8.2 Storage Capacity of Magnetic Tape

The storage capacity of magnetic storage media depends on a number of factors. These are e.g. recording mode, track density, recording density and – for diskettes – number of recording sides (1 or 2).
For longitudinal storage media such as magnetic tapes, the block length must also be considered. The most important definitions, including the block, are explained in box 9.

For a computer tape of 730 m length for different block lengths the storage capacity of the same tape length differs from about 20 to about 120 MB (see fig. 107).
On the Magnetic Tape Cartridge of the IBM 3480 or comparable systems 32-KB-blocks are usually recorded. The tape length of 171 m has 6,500 blocks à 32 KB. This corresponds with 32 KB · 6,500 to 208,000 KB or about 210 MB.

Storage Capacity of the Computer Tape   **Fig. 107**

Recording methods	Number of tracks	Recording density		Tape capacity in MB for block length of	
		Bit/mm	Bit/inch	2 KB	4 KB
NRZ	9	32	800	18.6	20.6
PE	9	63	1,600	30.3	36.5
GCR	9	246	6,250	90	120

The storage capacity of the computer tape depends on the recording method, the recording density and the block length. For a tape length of 730 m (= 2,400 ft) the lowest capacity of 18,6 MB is for NRZ, 800 bpi and 2 KB block length, the highest of 120 MB for GCR, 6,250 bpi and 4 KB block length. For 32 KB block length the capacity for GCR increases up to 165 MB.

Box 9   **Definitions of Information Processing**

The following definitions from DIN 44300 and DIN 66010 have been translated into English.

These are definitions which are not explained in detail in any of the chapters. However, others have been explained in other parts of this publication. All definitions of the boxes, the texts or the tables are listed in the Alphabetical Index.

Denomination	Definition
Average peak output (tape)	The peak-to-peak measured and arithmetically averaged. The average is calculated for a defined number of flux changes.
Block	A sequence of elements considered for technical or functional reasons as a unit.
CRC-character	Cycle Redundancy Check character.
Digital data, discrete data	Data, only composed of characters.
ECC-character	An Error Correction Code for a sequence of binary characters.
File	A combination of records in a context for data processing. This combination has a file name.
Flux transition	The transition of one saturation stage into another one.
Flux transition density	The number of flux changes of a track per longitudinal unit (magnetic tape) or radian unit (diskette).
Read amplitude (diskette)	The peak-to-peak measured and arithmetically averaged. The average is calculated for a defined number of flux changes.
Record	A set of related data or words treated as a logical information unit.
Sector	For diskettes and rigid disks: part of a track. It consists of fields for sector identifier and data block and the corresponding buffer fields.
Sector identifier	is the sector address recorded at the beginning of the sector.
Track number	The tracks are consecutively numbered with a track number, beginning with 0.
Word	A sequence of characters considered as a unit in a defined relation.

8.8.3 Storage Capacity of Diskettes

For diskettes the calculation of the storage capacity is a little more complex. For interested readers we have compiled this for the most common diskette formats.

The storage capacity of a diskette gives how many Bytes, Kilobytes, abbreviated KB or Megabytes, abbreviated MB, can be stored formatted or unformatted (table 4).

Storage Capacities for 3.5″ / 5.25″ Diskettes   **Table 4**

Type	Storage Capacity	
	unformatted	formatted
5.25″ 1S/2D	250 KB 250 KB	160 KB 180 KB
5.25″ 2S/2D	500 KB 500 KB	320 KB 360 KB
5.25″ 2S/HD	1,600 KB	1,200 KB
3.5″ 2DD 3.5″ 2HD	1,000 KB 2,000 KB	720 KB 1,440 KB

Formatting reduces the free capacity. All diskettes "sectors soft" can be formatted by the user, e.g. in case a diskette with a certain format has to be written with a different format for another purpose or another micro computer system.

Some examples follow for standard diskette formats.

The storage capacity of a formatted diskette is calculated with the number of the recording sides · number of tracks · number of sectors · number of bytes per sector.

With 48 tpi, 40 tracks will be recorded in the head window, with 96 tpi, however, 80 tracks. For the Micro-Diskette 80 tracks are recorded with a track density of 135 tpi.

For one-sided Mini-Diskettes 5.25 1S/2D the 1S stands for 1 recording side, and the 2D for double recording density. The single recording density corresponds to 128 Bytes per sector, the double recording density to 2 · 128 Bytes = 256 Bytes per sector. As the type nomenclature does not mention the 96 tpi, this diskette is tested for a single track density of 48 tpi and also for 40 tracks (39 data tracks and 1 index track). For this format the recording side is subdivided into 8 sectors.

This corresponds to the following calculation:

1 Side · 40 Tracks · 8 Sectors · 512 Bytes = 163 840 Bytes.

1 Kilobyte (= KB) corresponds to 1,024 Bytes.

163,840 Bytes : 1,024 = 160 KB.

For 9 sectors, otherwise same conditions, the calculation is like follows:

1 · 40 · 9 · 512 Bytes = 184,320 Bytes : 1,024 = 180 KB.

For the two-sided Mini-Diskette 5.25 2S/2D the capacity values have to be multiplied by 2. For 8 sectors therefore 2 · 160 KB = 320 KB and for 9 sectors 2 · 180 KB = 360 KB.

For the High-Density Mini-Diskette more tracks and sectors can be recorded due to a magnetic coating with higher coercivity for a higher rotation number (Standard Mini 300 rpm, HD-Mini 360 rpm) and a higher track density (96 tpi instead of 48 tpi).

Therefore the 5.25 2S/HD calculation is:

2 Sides · 80 Tracks · 15 Sectors · 512 Bytes = 1,228,800 Bytes : 1,024 = 1,200 KB = 1.2 MB.

Now to the Micro-Diskettes:

The 3.5 2DD Micro-Diskette having a smaller recording area requires for 80 tracks a track density of 135 tpi. With 9 sectors and 512 Bytes per sector as the 5.25 2S/2D, there is the following result:

2 Sides · 80 Tracks · 9 Sectors · 512 Bytes

= 737,280 Bytes : 1,024 = 720 KB.

The High-Density Micro-Diskette has, as the HD-Mini-Diskette, more sectors and reaches:

2 · 80 · 18 · 512 Bytes = 1,474,560 Bytes : 1,024 = 1,440 KB = 1.44 MB.

9. Computer Tape

The 1/2″ reel-to-reel computer tape used in mainframes will be increasingly replaced by the Magnetic Tape Cartridge (= MTC) for the IBM 3480 and comparable systems. However, as long as no other suitable MTC systems are offered, the reel-to-reel systems remain installed in mini computer installations.

BASF Computer Tapes of the latest production may also be used either on systems of the 1st generation with NRZ recording at 800 bpi or on those systems of the 3rd generation with GCR recording and 6,250 bpi and also for all magnetic head profiles (see figures 51, 52, 53, 54, 107, 108, 109).

Profiles of Magnetic Heads   **Fig. 108**

Baby Bottom   Outrigger
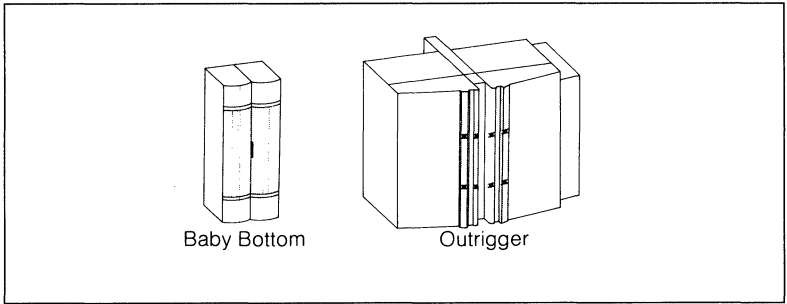
The BASF computer tape is suited for all usual magnetic head profiles such as "baby bottom" and "outrigger" and all current magnetic head materials such as chromium, ceramics and ferrite.

Recording Densities for Computer Tape   **Fig. 109**

2400 ft Tape 9 tracks	Record- ing mode	max. BPI	max. fci	ips	2400 ft Tape max. theo- retical capacity in MB
1. Generation	NRZ	800	800	25–125	22
2. Generation	PE	1,600	3,200	25–200	44
3. Generation	GCR	6,250	9,042	25–200	180

The BASF computer tape is suited for all current recording densities, recording methods and tape speeds.

9.1 Data Backup of Magnetic Disk Systems

Computer tapes are primarily used for the data backup of magnetic disk systems. In large EDP installations daily backups and several tape copies are usual. The time/space/cost expenses are in certain areas to be considered. The trend for mainframes is going to automatic magnetic tape cartridge backup with less operator handling. As the storage capacities of the magnetic disk systems thanks to higher recording and track densities have increased more and more, also the number of tapes necessary for backup copies rose, if the total disk contents have to be dumped. Also the read/write time of reel-to-reel computer tapes with 5 minutes for a 730 m tape of 165 MB capacity is too long (see also table 5).

Table 5   **Comparison of Storage Capacity Magnetic Tape / Magnetic Disk System**

Disk System	Capacity in MB	No. of Tapes à 730 m / 2,400 ft Recording Density 6,250 BPI		R/F
		4-KB-Block 120 MB	32-KB-Block 165 MB	
IBM 3340	70	0.6	0.4	R
IBM 3330-1	100	0.8	0.6	R
IBM 3330-11	200	1.7	1.2	R
IBM 3344	280	2.3	1.7	F
IBM 3370-A02	730	6.1	4.4	F
IBM 3380-AK4	7,560	63	46	F

Whilst for removable disks (R) as magnetic disk packs or data modules mainly 1 computer tape was sufficient, the tape requirements for modern fixed disk drives (= F) is quite high. Here, the MTC with faster read/write time and higher capacity is required.

9.2 Supply Range and Specifications

The BASF Computer Tape on reel is 12,7 mm (= 1/2″) wide and up to 1,100 m (= 3,600 ft) long.
The BASF Computer Tape Product Range and the BASF Computer Tape Specification give details about the available versions and the technical characteristics.
Only the most important information follows. The computer tapes are supplied in different lengths and versions (see table 6).

Type / Version	Description
CB A-3 K	90 m (300 ft) in Plastic Box
CB A-3 W	90 m (300 ft) in Wright-line Ring
CB A-6 K	180 m (600 ft) in Plastic Box
CB A-6 W	180 m (600 ft) in Wright-line Ring
CB A-12 S	365 m (1,200 ft) in Slim-line Canister
CB A-12 W	365 m (1,200 ft) in Wright-line Ring
CB A-12 R	365 m (1,200 ft) in BASF Ring
CB A-12 T	365 m (1,200 ft) in Poly bag
CB A-24 S	730 m (2,400 ft) in Slim-line Canister
CB A-24 R	730 m (2,400 ft) in BASF Ring
CB A-24 W	730 m (2,400 ft) in Wright-line Ring
CB A-24 T	730 m (2,400 ft) in Poly bag
CB A-24 C	730 m (2,400 ft) in Easy load I
CB A-24 D	730 m (2,400 ft) in Easy load II
CB A-24 E	730 m (2,400 ft) in Easy load III
CB A-36 W	1,100 m (3,600 ft) in Wright-line Ring
CB A-36 E	1,100 m (3,600 ft) in Easy load III

The type nomenclature, explained as an example for the most common version CB A-24 E is composed of the abbreviation CB (= Computer Band, Computer Tape), the tape characteristic, here "A", the length in feet (24 for 2400 ft = 730 m) and the ring or canister version (E = Easy Load III).

All tapes are equipped with the magnetic coating facing inside (fig. 110), tape characteristics A (see fig. 111) and write protect ring (fig. 112).

The archiving installation and the used tape subsystems define the requirements of the customer concerning plastic box, slim-line canister or plastic rings of different versions (see fig. 113–115). The majority of computer tape is supplied in self loading rings, stackable with suspension hooks (= Easy Load III).

Tape winding
— Hub end
— Rim end
— Rear surface
— Magnetic surface
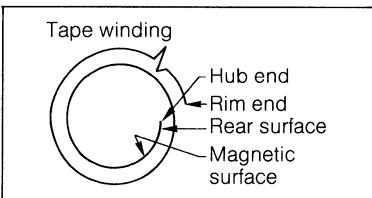
Tape Winding of Computer Tape   Fig. 110

The tape winding for the reel-to-reel computer tape is with coating on the inside.

Fig. 111   **Photoreflective Markers**
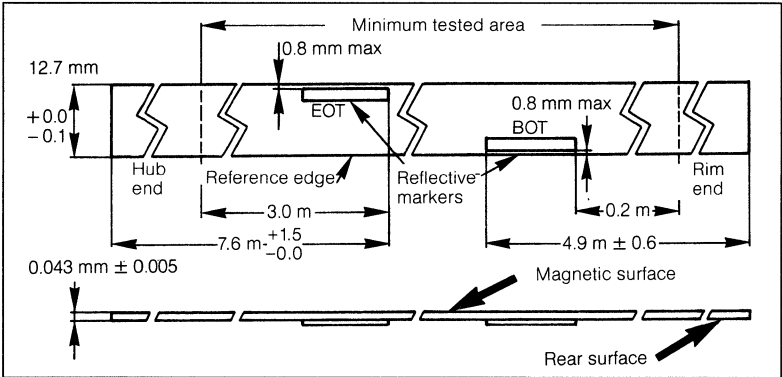
Reel-to-reel computer tapes are marked at the beginning with a BOT and at the end with an EOT marker. BOT = beginning of tape, EOT = end of tape. The marker position as shown in the above figure is the most used one, also called finishing A. Other finishings, no longer used, differ from A by the leader tapes.
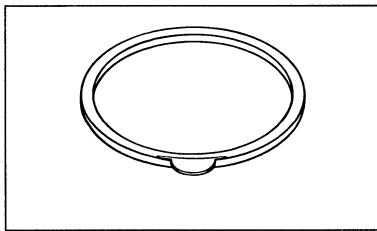
Fig. 112   **Write Protect Ring**

For reel-to-reel computer tape the write protection is a ring, called write protect ring. Inserted: writing/reading, not inserted: only reading.
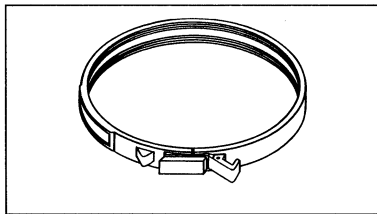
Fig. 113   **Wright-Line Ring**

Wright-line rings, abbreviated "W" in the BASF order code, are flexible plastic rings for the tape length of 90 m (= 300 ft), 180 m (= 600 ft), 365 m (= 1,200 ft), 730 m (= 2,400 ft) and 1,100 m (= 3,600 ft). Wright-line is a registered trade mark of the Wright Line, Inc., Worcester, MA, USA.
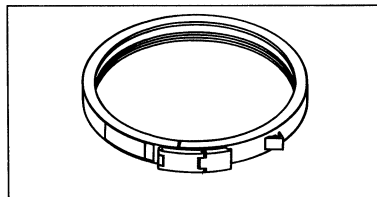
Fig. 114   **BASF Ring**

BASF ring abbreviated "R" in the BASF order code, is a rigid plastic ring for tape length of 365 m (= 1,200 ft) and 730 m (= 2,400 ft).

Easy load I

Easy load II
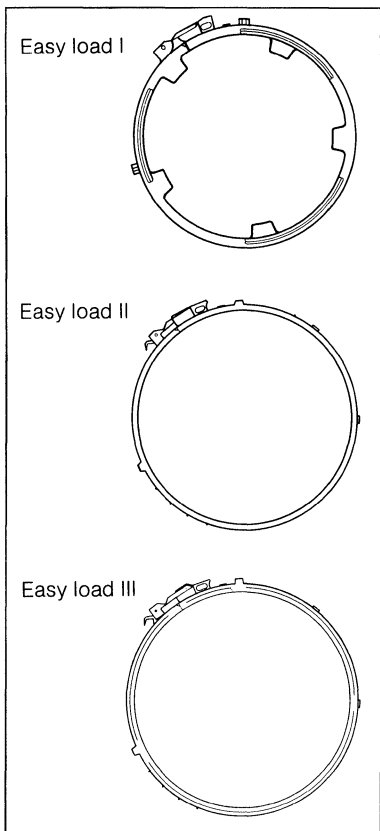
Easy load III

Easy Load Rings Fig. 115

Easy load rings are available as easy load I, II and III.

The easy load I was the first self threading cartridge for the IBM 2420 with a width of 30 mm, stackable, however without hook.

The easy load II with a width of 23 mm resulted in a store room economy of 40%. It is not stackable and has a hook.

The most modern version is the easy load III, 23 mm wide, stackable, with hook.

10. Magnetic Tape Cartridges

In the EDP field magnetic tape cartridges are increasingly more important in the market. They protect the tape against handling errors and require less space. However, there are different cartridge and tape versions in the market. We will present in the following the most important:

Data Cassettes (also Compusettes) with 3.81 mm tape
Data Cartridges with 1/4″ tape
Magnetic Tape Cartridge for the IBM 3480 with 1/2″ tape.

10.1 Data Cassette 3.81 mm

The 3.81 mm data cassettes (= Compusettes) do not work in start/stop mode but for a continuous data back-up in streamer mode.

The data cassette, a derivation of the audio Compact-Cassette, is offered in two housing forms, in the Compact-Cassette housing and in the ECMA housing. Because of the low demand BASF has ceased the production of the Compusette I (= Compact-Cassette housing). Still in the product range is the Compusette II with ECMA housing (see fig. 116) with 86 m (= 282 ft) long and 3.81 mm (= 0.15″) wide computer tape quality.

The tape is recorded in two separate tracks. For data security reason they have the same contents. The recording mode is according ECMA standards.

Fig. 116   **Compusette II**

1 Write protect	4 Roller	7 Computer tape
2 ANSI notch	5 Pressure spring	8 Tape pack
3 Hub	6 Pad	
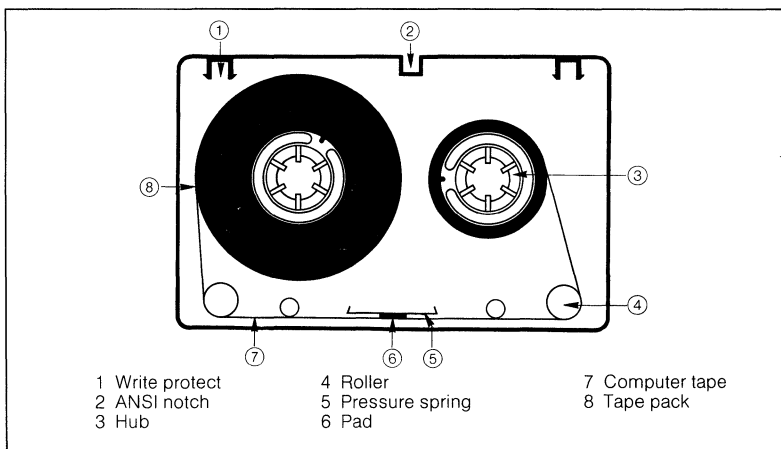
The figure shows the Compusette II with housing according to ECMA/ISO.

The data cassette had lost market importance because of the low storage capacity (a few Megabytes), for sometime a new standard committee, called D/CAS (= working group Data Cassettes Drive Compatibility) has coordinated the further development of the cassettes and the drives. Therefore, the data cassettes may once more gain importance in the market.

10.2 Data Cartridge 1/4″

This cartridge (see fig. 117) developed by the 3M Company and available for years for compatible streamer drives has a more complicated construction than the above mentioned data cassette.

As the tape transport elements have been transferred from the drive into the cartridge, this is relatively expensive and the drive relatively inexpensive.

The Data Cartridge has two different sizes, a full size cartridge (length 15.2 cm · width 10.1 cm · height 1.7 cm) and a mini cartridge (length 8 cm · width 6 cm · heigth 1.4 cm).

The Data Cartridge is also called "QIC Cartridge" (= "Quarter Inch Cartridge Standards Organization, Inc.").

Data Cartridge   **Fig. 117**

1 Belt guide roller	6 Tape guide roller	10 Head window shutter
2 Drive belt, structured	7 Tape guide pin	11 Base plate
3 Hub	8 Mirror for	12 Screwing point
4 Computer tape	BOT/EOT recognition	base plate/housing
5 High-speed drive roller	9 Write protect	
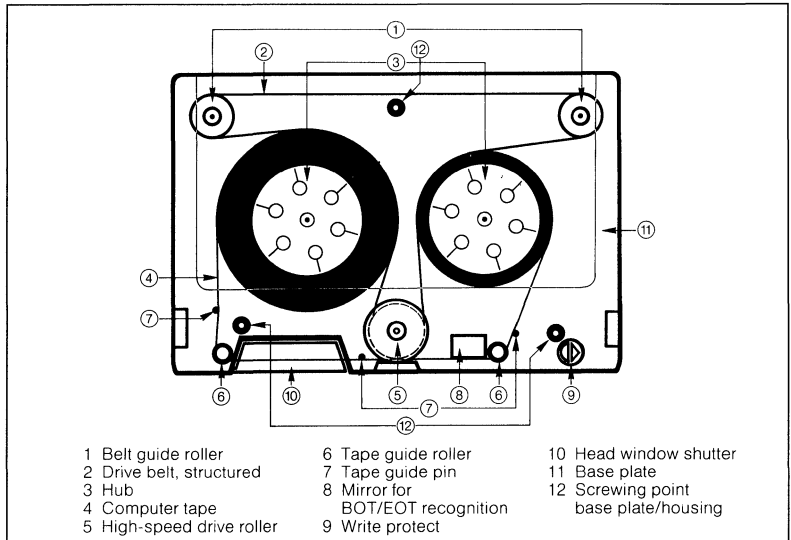
The 1/4″ magnetic tape cartridge is used for backup of micro and mini computer systems with fixed disk drives. It is available in different types and versions.

The BASF product range leaflet gives information about the available types. A survey is given in table 7.

The DCs with higher coercive force are for higher track densities and recording densities of 10,000 to 12,500 ftpi (= flux transitions per inch), drive dependent. With the exception of the DC 2000 HS (= mini format) all others are maxi format.
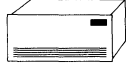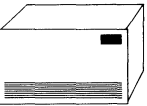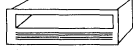
The Data Cartridge is well established as back-up storage for small fixed disk drives of micro computers, as the storage capacities start from 2.9 to 320 MB (see fig. 118 and 119).

For data exchange on systems with the same recording formats the cartridges must be compatible. In spite of this there are possibilities for quality improvements of the individual suppliers. So e.g. the tape hub assembly and the drive belt rollers assy have been reconstructed in order to create a constant tape path plane even after a high number of passes (see fig. 120, 121).

Table 7   **¼″ Data Cartridge / Type Survey**

Type	Coercive force	Length	Recording density		Capacity	Tracks
	Oe	ft	bpi	ftpi	MB	Number
DC 300 L	310	300	1,600		2.9	4
DC 450 L	310	450	1,600		4.3	4
DC 450 LS	310	450		10,000	45	9
DC 600 H	550	600		12,500	60	15
DC 600 HS	550	600		12,500	120–320	32
DC 2000 HS	550	205		12,500	40	24

	20 MB–40 MB	85 MB	170 MB	340 MB–700 MB
Fixed disk drive	20 MB–40 MB	85 MB	170 MB	340 MB–700 MB
Streamer drive	QIC-40 QIC-100	QIC 24	QIC 120/SCSI QIC 150/SCSI	QIC 320/SCSI QIC 600
BASF Data Cartridges	DC 2000 HS	DC 300 L– DC 600 HS	DC 600 HS	DC 600 HS

The streamer drives and the BASF data cartridges of the appropriate QIC standards correspond to the current fixed disk drives of micro and mini computer systems.

Format	Formatted capacity (MB)	Cartridge type	Corrected bit failure rate	Interface (intell.)	Interface (basic)	Magnetic head type
Cartridge drive						
QIC-24	60	DC 600 H DC 600 HS	10^{-10}	QIC-02 QIC-104 (SCSI)	QIC-36	
QIC-120	125	DC 600 H DC 600 HS	10^{-10}	QIC-02 QIC-104 (SCSI)		QIC-105
Mini cartridge drive						
QIC-40	40	DC 2000 HS	10^{-14}	QIC-108 (SCSI)	QIC-107 (flexibel)	QIC-106
QIC-100	20 or 40	DC 2000 HS	10^{-12}	QIC-108 (SCSI)	QIC-103	QIC-102

Here, in the frame of the QIC family the most important characteristics of the cartridge drives and the compatible BASF cartridge types are shown.

Tape hub assembly

Belt guide roller

Tape guide roller

Secured components improve tape path and steering plane

No vertical movement

An improvement of the tape guide components minimizes vertical tape movement and creates a constant tape path plane.

Spec. max.   0.7

0.5

Track position   0.3

0.1

(0.001″)   − 0.1

− 0.3

− 0.5

Spec. min.   − 0.7

0   400   2,500   5,000

▬ BASF   Number of passes

— Standard
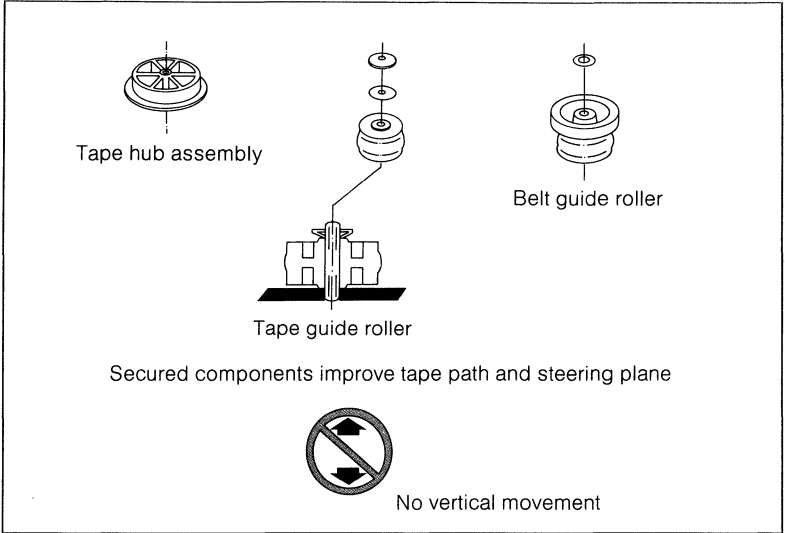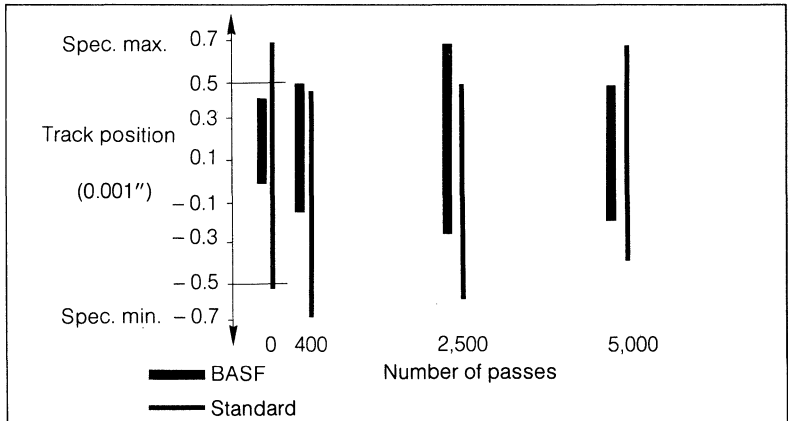
By an improvement of the tape path mechanics (see also fig. 120) a track fidelity is reached, also after a high number of passes, well within the tolerances granted by the specification.

10.3 Magnetic Tape Cartridge ½″ (MTC)

This cartridge has many names in the market. The most used is "MTC". The cartridge is used for the IBM 3480 and comparable systems. As the MTC has a high market penetration, we will describe on it in more detail.

10.3.1 The New Computer Tape Technology

Because of the standardization of the data exchange on reel tapes, for more than 30 years the reel-to-reel tape system had been valid and more than 10 years after the market introduction of the IBM 3420 in 1973, in 1984, with the IBM 3480 a brand new computer tape technology was first installed with a Magnetic Tape Cartridge (fig. 122), a new recording method (fig. 123) and a high storage capacity by simultaneously reducing the read/write time [25,26,27,28]. A comparison of reel-to-reel computer tape to magnetic tape cartridge (see table 8) shows the advantages of the new technology.

MTC Cartridge   **Fig. 122**
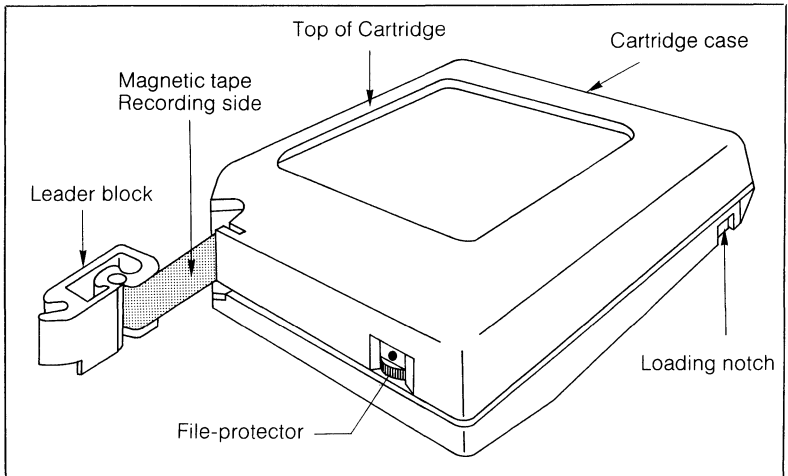
The magnetic tape is wound on a reel and hermetically enclosed in a cartridge, inaccessable to the user. After charging the cartridge the leader block is automatically inserted and fixed to the take up reel of the system. When discharging the cartridge the tape is automatically rewound onto the case reel and the leader block re-inserted into the cartridge. This prevents operator errors.
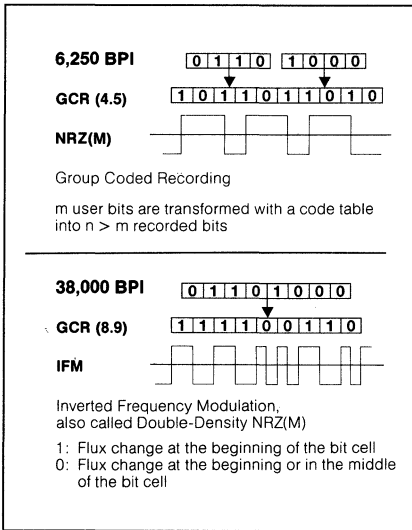
Fig. 123   MTC Recording Method

6,250 BPI   `0 1 1 0` `1 0 0 0`

GCR (4.5)   `1 0 1 1 0 1 1 0 1 0`

NRZ(M)

Group Coded Recording

m user bits are transformed with a code table
into n > m recorded bits

38,000 BPI   `0 1 1 0 1 0 0 0`

GCR (8.9)   `1 1 1 1 0 0 1 1 0`

IFM

Inverted Frequency Modulation,
also called Double-Density NRZ(M)

1: Flux change at the beginning of the bit cell
0: Flux change at the beginning or in the middle
   of the bit cell

For the MTC the GCR recording method, known from the reel-to-reel computer tape, has been modified (IFM). Whilst for GCR the 8 bits of the byte are subdivided into groups of 4 data bits and the corresponding 5 recording bits, for IFM the groups include 8 data bits and the corresponding 9 recording bits.

Table 8   **Comparison Reel-to-Reel Computer Tape / Magnetic Tape Cartridge**

Properties	Reel-to-Reel Computer Tape	Magnetic Tape Cartridge
Data density BPI	6,250	38,000
Recording density FC/mm	356	972
Number of tracks	9	18
Storage medium 1/2 inch tape	iron oxide	chromium dioxide
Drive	vacuum columns	reel-to-reel servo controlled
Magnetic head system	laminated	thin film
Tape container	10.5″ reel	cartridge 12 · 10.5 · 2.5 cm
Data buffering	no	yes, 512 KB
Transfer rate in MB/s	1.25	3
Tape length in m	730	171
Storage capacity in MB (for 32K-Blocks)	165	210
W/R Duration in about for a capacity of	5 minutes 165 MB	1.5 minutes 210 MB
Library floor space	100%	about 25%
For use on robots	no	yes

With the MTC of 12 · 10.5 · 2.5 cm edge length a new industry standard has been created. For the same dimensions by using a thinner and consequently longer tape, or by a higher data and/or recording density and also by doubling the track number the present storage capacity may be increased many times in the future (see also chapter 14).

The new cartridge system offers principal advantages compared to existing reel-to-reel systems. Some examples:

− Higher data security and higher data transfer rates.
− Shorter Write/Read duration.
− Lower media and service costs.
− Less floor space for systems and media.
− Easier handling and automatic cartridge loaders.
− Micro processor controlled tape run without capstan and vacuum columns.
− Automatic tape insertion by leader block and its fastening on the system take-up-reel and automatic rewinding of the tape into the cartridge before its ejection.
− Better service techniques and therefore more availability of the system.
− No reflector markers and no fastened tape markers. BOT (= Beginning Of Tape) and EOT (= End Of Tape) are electronically recognized by tape length comparison of the system.
− Labelling areas at the narrow edge side for volume/serial number (identification number of the cartridge, given by the user, see also chapter 8.7.1, EREP) and others for contents (see fig. 124).
− Write protect by turning a button (see fig. 127).
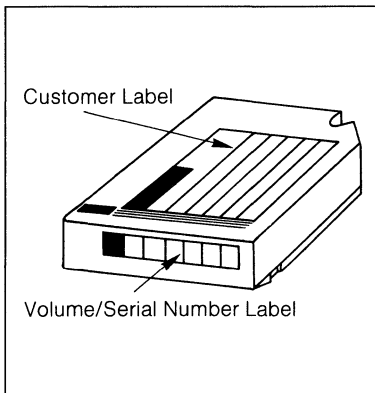
MTC Labels   **Fig. 124**

The MTC itself is marked by a volume/serial number label for identification of the individual cartridge. The contents, changed by each new recording, is marked by a customer label to be replaced for each change of contents.

Customer Label

Volume/Serial Number Label

One year after the market introduction by the system manufacturer BASF was world-wide the first manufacturer of an MTC of our own fully integrated large scale production and is today world-wide the only manufacturer, with every production step in house, from the chromium dioxide production via the binder-, the dispersion manufacturing, the plastic injection of the shell parts to the system test (see fig. 83, 88, 90, 125, 126, 127).

Fig. 125   **User Advantages**

#	Advantage	#	Advantage
1	Uniform product quality	8	Error behaviour
2	Data security	9	Abrasivity
3	Lifetime	10	Wear
4	Data interchangeability	11	Tape slacking
5	Mechanical reliability	12	Scratch proof of the shell
6	Temperature stability	13	Guaranteed data capacity
7	Crash proof	▷	BASF production share

High vertical integration of the production permits quality control in each manufacturing step. We have numbered the user advantages in above figure. These numbers relate to the different production steps (see fig. 126).

Fig. 126   **Production Steps**

BASF production share 100%	1	2	3	4	5	6	7	8	9	10	11	12	13
Tape													
CrO$_2$ pigment	1	2	3			6			9	10			
Binder	1		3			6				10	11		
Carrier foil	1	2				6		8			11		
Additives	1	2	3			6		8	9	10	11		
Dispersing	1	2						8	9	10			
Coating	1	2		4				8	9	10			
Cutting	1	2		4				8			11		
Pancake = intermediate product													
C0-shell (shell without tape)													
Raw materials	1	2	3		5	6	7					12	
Injection moulding	1	2		4	5								
Assembling	1	2		4	5								
Welding	1	2	3		5		7						
Automatic tester	1	2		4	5								
MTC = tape (pancake) + C0-shell													
Finishing	1	2	3	4				8			11		13
System test	1	2		4	5			8			11	12	13
Packaging	1	2				6	7						

Raw materials / Process engineering

Defined product characteristics are targeted for the different manufacturing steps to guarantee all these user advantages (see fig. 126). The different hatchings show the share of BASF in the production. In most steps it is 100%.

The 11 system items
of the MTC are:

 1 Top shell
 2 Base shell
 3 Hub
 4 Center core
 5 Flange
 6 Brake button
 7 Spring
 8 File protect selector
 9 Leader block
10 Insert
11 Tape
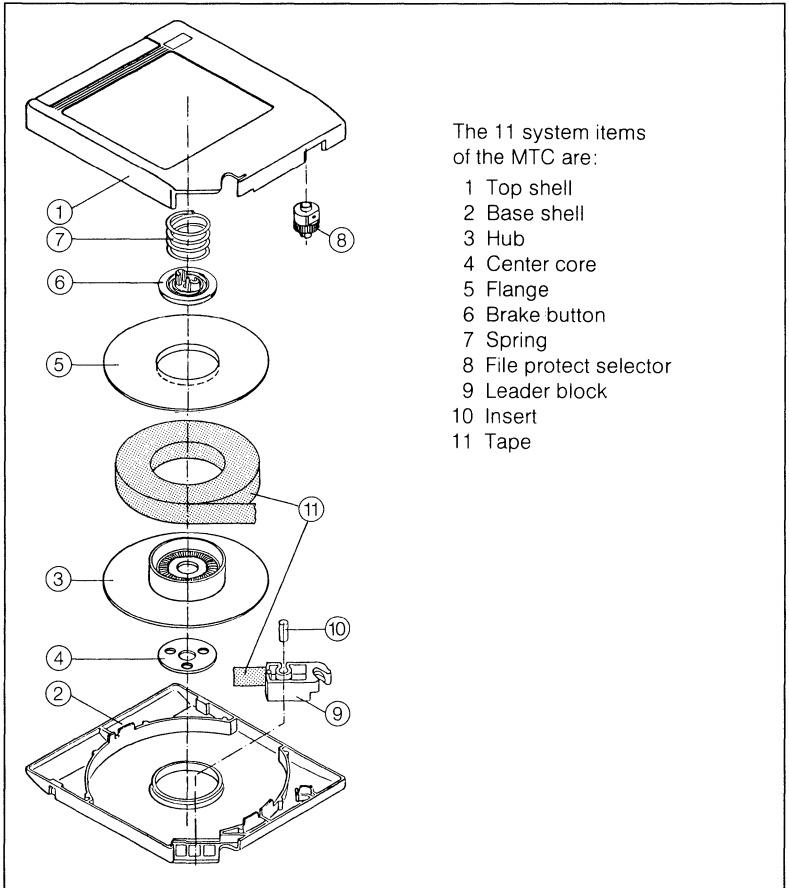
10.3.2 More Stringent Test Criteria

More stringent test criteria like environmental tests (see fig. 128 and 129), excellent signal-to-noise ratio (fig. 130) and interference measures of the surface (see fig. 131) offer an even higher data security. The technical characteristics of the BASF Magnetic Tape Cartridge (MTC) are listed in a separate brochure (see also chapter 8).
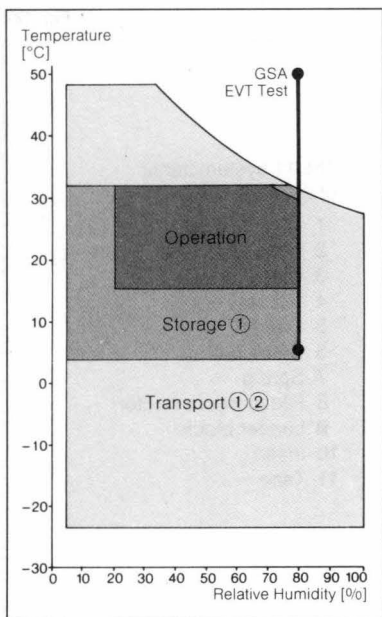
Fig. 128   **Environmental Test**

In the Environmental Test according to GSA No. W-T-0051 C, the BASF MTC is exposed to a stressful climate. Here, we simulate artificial ageing. Then we test twice: once before and once after the environmental test according to the same criteria. BASF emphasizes data security.

1 Acclimatization at operating conditions at least 24 hours before use.

2 Valid only for unrecorded BASF Magnetic Tape Cartridges and only for maximum duration of 10 days, whereby no condensation is permitted.

Fig. 129   **ECC Errors**

Our most stringent test criteria show: For the BASF MTC a decrease in ECC errors for 400 passes. In consequence our tapes improve in longtime use. ECC = Error Correction Code error, this has no importance for the user as it is corrected in flight, and with a limited range is recommended by the system manufacturers.
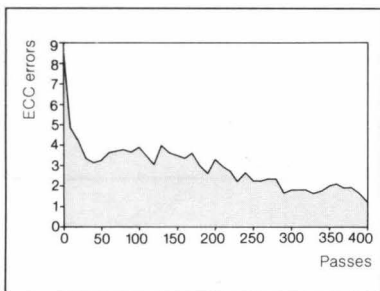
Fig. 130   **Signal-to-Noise-Ratio**
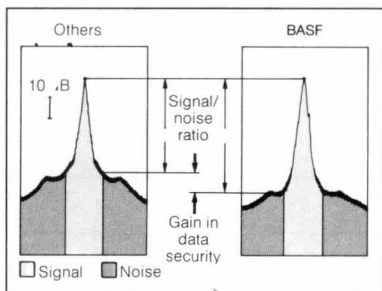
The excellent S/N (= Signal-to-Noise-ratio) of the BASF MTC offers a gain in data security, also maintained for many years of use.

11. Magnetic Disks

Rigid magnetic disks are used for fixed disk drives and – with decreasing tendency – for removable disk media. The fixed disk drives have HDAs (see fig. 40) and the removable disk storage units data modules, magnetic disk packs and magnetic disk cartridges (see fig. 39). The HDAs for mainframes have diameters of 14″, for PCs they have 2″, 3″, 3.5″ and 5.25″ [29].

The data modules (removable HDAs) have been replaced, some time ago, by fixed installed HDAs. The magnetic disk packs (see fig. 132) and the magnetic disk cartridges (see fig. 133) lose more and more market importance, as, with the introduction of fixed disk technology, the development of removable storage systems has not been continued.

Fig. 132   **Magnetic Disk Pack**

Disk Pack
BASF 1268

Removable Cover
Screw
Trim Shield
Spindle Lock
Thrust Bearing
Washer, Thrust
Weight
Nut
Washer, Flat
Top clamp ring
Recording surfaces
Servo surface
Spacer
Pin, Index
Hub
Bottom clamp ring
Screw
Removable bottom cover

Storage capacity 80 million bytes.
Operational control through servo information
pre-initialized.
Comparable to CDC 877 and equivalent packs.

The exploded view shows an example of a magnetic disk pack (BASF 1268).

good   bad
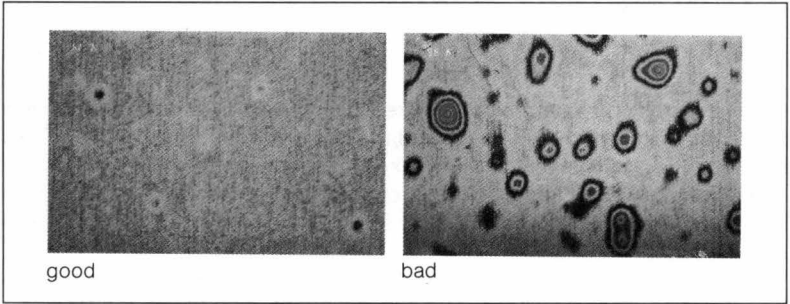
Micro rough surfaces must show a defined structure. Defective surfaces show tape defects recognisable in the interference picture by mulitple rings. The micro roughness must be aligned optimally in order to guarantee the flight characteristics of the tape above the magnetic head systems, influencing the head durability.

10.3.3 Anti Theft Protection

Anti theft systems are offered for prevention of an illegal removal of a cartridge from the EDP center.

10.3.4 Future Developments

Already today, work is being carried out on further developments of this magnetic tape cartridge system. Here, it is important, that the new systems are compatible to the present installed ones. In other words, cartridges written today must also be read on future systems so that the expensive transfer of stored data, as it has to be done for the transfer from reel-to-reel to MTC systems is not necessary a second time.
The possibilities for the MTC are covered in chapter 14.
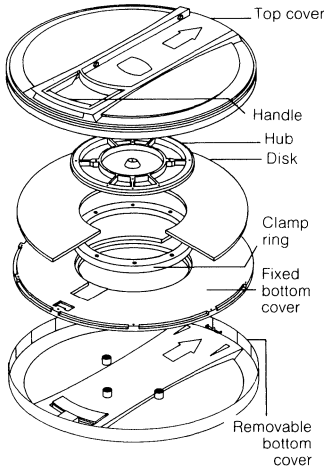
BASF 681
Disk Cartridge

Frontloader

Storage capacity up to
16 million bytes.
Operational control through
servo information pre-initialized.

Comparable to CDC 1204
and equivalent cartridges.

Labels: Top cover, Handle, Hub, Disk, Clamp ring, Fixed bottom cover, Removable bottom cover
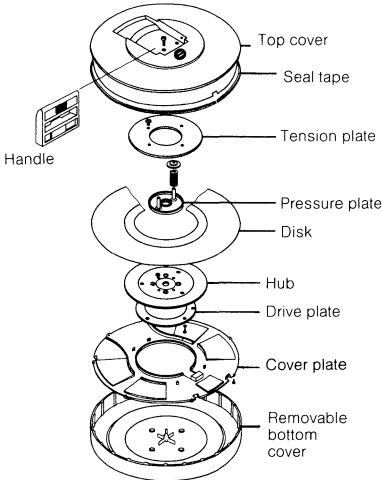
BASF 641
Disk Cartridge

Toploader

Large storage capacity.
May be used universally
with toploader drives.
Comparable to IBM 5440
and equivalent cartridges.

Labels: Top cover, Seal tape, Handle, Tension plate, Pressure plate, Disk, Hub, Drive plate, Cover plate, Removable bottom cover

The exploded views show a front loader (BASF 681) and a top loader (BASF 641).

The production of magnetic disks we have already covered in chapter 6. Let's cast a retrospective glance on the extensive product range of removable 14″ storage media, manufactured by BASF for 20 years. Tables (table 9) with market data and technical characteristics (table 10) give you an overview.

Table 9   **14″ Removable Storage Disks / Market Data**

Type	Class	Example of use	Market-introduction	Product Range 88
611	MDC	IBM System 3	1969	no
631	MDC	IBM System 3	1972	yes
641	MDC	IBM System 3	1971	yes
671	MDC	Wangco T 2412	1979	no
681	MDC	CDC 9448 (Phönix)	1980	yes
616	MDP	IBM 2311	1968	no
621	MDP	IBM 2314	1968	yes
622	MDP	Siemens 4580	1974	no
624	MDP	Univac 8440	1974	no
626	MDP	IBM 3330-1	1972	yes
1246	MDP	IBM 3330-11	1975	yes
1246 C	MDP	BULL MSU 0450	1977	yes
1255	MDP	Calcomp T 25	1979	no
1258	MDP	Calcomp T 80	1980	no
1263	MDP	CDC 9766	1980	yes
1268	MDP	CDC 9762	1978	yes
1370	DM	IBM 3340	1975	no
1375	DM	IBM 3340	1975	no

MDC = Magnetic Disk Cartridge
MDP = Magnetic Disk Pack
DM = Datamodul

Type	Disks	Capa-city	Tracks/Surfaces		Record-ing Density	Track Density	Thickness Substrat/Coating	
	Number	MB	Number		bpi	tpi	mil*	μm
611	1	1.17	200 +	3	1,100	100	50	6.4
631	1	2.5	200 +	3	2,200	100	50	3.5
		5	400 +	6	2,200	200	50	3.5
641	1	2.5	200 +	3	2,200	100	50	3.5
		5	400 +	6	2,200	200	50	3.5
671	1	12	400 +	8	4,400	200	75	1.4
681	1	16.2	808 +	15	6,038	384	75	1.4
616	6	7.25	200 +	3	1,100	100	50	6.4
621	11	29.17	200 +	3	2,200	100	50	3.5
		58.34	400 +	6	2,200	200	50	3.5
622	11	54.81	400 +	6	2,200	200	50	3.5
624	10	116.7	400 +	7	4,400	192	75	1.9
626	10	100	404 +	7	4,040	192	75	1.9
1246	10	200	808 +	7	4,040	370	75	1.4
1246 C	10	200	808 +	15	4,040	384	75	1.9
1255	3	54.7	808 +	7	4,040	370	75	1.4
1258	3	82.1	808 +	7	6,060	370	75	1.4
1263	10	300	808 +	15	6,038	384	75	1.4
1268	3	80	808 +	15	6,038	384	75	1.4
1370	4	70	696 +	2	5,636	300	75	1.4
1375	4	70**	696 +	2	5,636	300	75	1.4

*   1 mil = 1/1000 inch = 25.4 μm
** of which 0.5 MB fixed

12. Diskettes

Diskettes of all types, quality characteristics and order codes are to be found in the Diskette Guide Book [22].
In this brochure we only show the most important characteristic features.
Please see also chapters 3, 4 and 5.
The characteristic features are shown in the following table.

Table 11   **Diskette Comparison**

Diskette Type	Maxi		Mini				Micro		
Properties	1D	2D	1S/2D	2S/2D	2S/2D 96 tpi	2S/HD	1DD	2DD	2HD
Size in inch	8	8	5.25	5.25	5.25	5.25	3.5	3.5	3.5
tpi	48	48	48	48	96 100	96 100	135	135	135
Sides	1	2	1	2	2	2	1	2	2
Side detection	J	J	Standard						
Tracks per side	77	77	40	40	80	77 80	80	80	80
Storage capacity in MB unformatted	0.8	1.6	0.25	0.5	1.0	1.6	0.5	1.0	1.6 2.0
Recording density in bpi	6536	6815	5536	5876	5922	9869	8187	8717	17434
Coating thickness in μm	2.5	2.5	2.2	2.2	2.2	1.2	1.8	1.8	0.9
Cartridge (C)							C	C	C
Flexible Jacket (F)	F	F	F	F	F	F			
Write protect	A	A	Standard						

The diskette type nomenclature consists of the diskette size (see fig. 42). This may be Maxi (= 8 inch edge length), Mini (= 5.25″) or Micro (= 3.5″). In some cases, e.g. ECMA literature, the sizes are also indicated in millimeters (Maxi = 200 mm, Mini = 130 mm and Micro = 90 mm). The build-up of the diskettes is different (see figures 134–136).

Build-up of a Maxi-Diskette   **Fig. 134**

1 Permanent diskette label
2 Temporary identification label
3 Spindle/hub access
4 Index/sector hole
5 Oxide coated polyester disk
6 Liner
7 Head window
8 Sealed protective plastic jacket
9 Write protect notch
   Optional: A for ANSI
             B for BASF
   Note: ANSI also used
            for Shugart
10 Stress relief notches
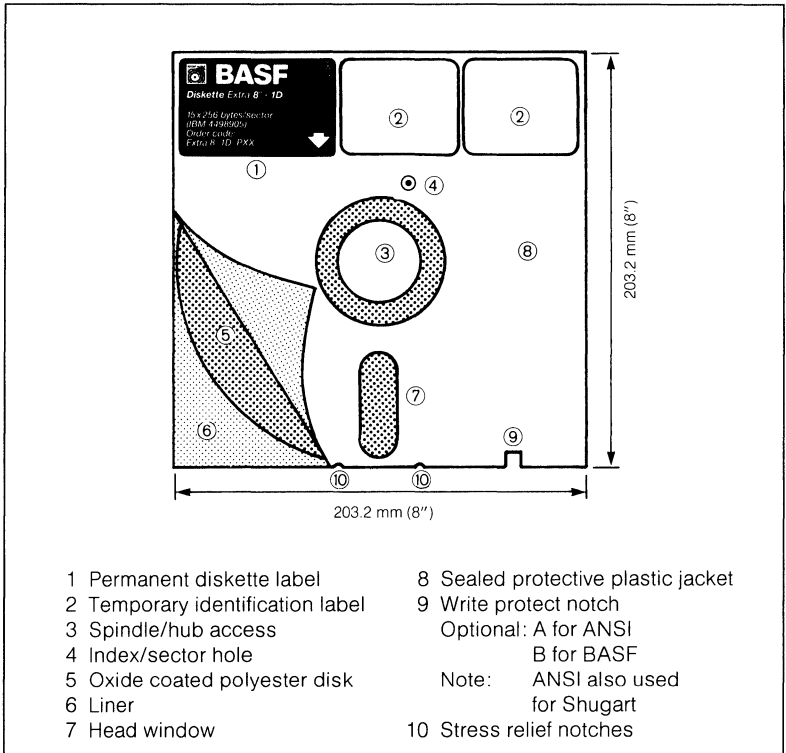
The 8″ diskette, also called Maxi-Diskette, is losing market importance. It is being replaced by the 5.25″ Mini-Diskette and the 3.5″ Micro-Diskette.

Fig. 135   **Build-up of a Mini-Diskette**

1 Permanent diskette label
2 Temporary identification label
3 Spindle/hub access
4 Index/sector hole
5 Oxide coated polyester disk
6 Liner
7 Head window
8 Sealed protective plastic jacket
9 Write protect notch (ECMA)
10 Stress relief notches
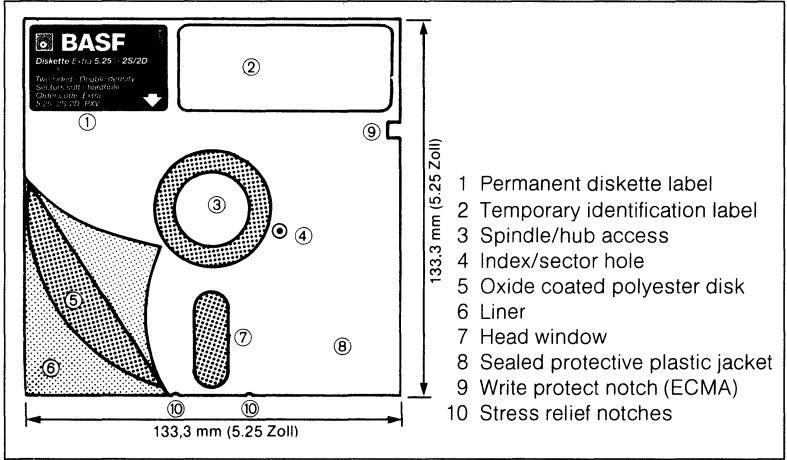
The 5.25″ diskette, also called Mini-Diskette, has the largest market distribution. However, the trend goes in the direction of the 3.5″ Micro-Diskette.

Fig. 136   **Build-up of a Micro-Diskette**

Front side
1 Semi-rigid jacket (shell/cartridge)
2 Flexible Disk
3 Label area
4 Write protect
5 Head window

Reverse side
6 Centre metal core
7 Centre and drive openings
8a Head window shutter (closed)
8b Head window shutter (open)
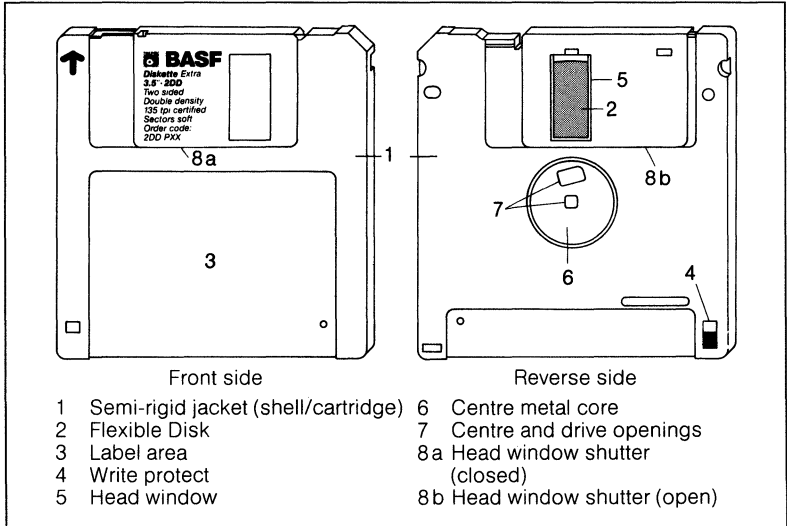
More and more the Micro-Diskette replaces the Maxi- and Mini-Diskettes. Thanks to its semi-rigid shell with metal core and metal shutter it is very robust and less exposed to handling errors than the other diskette sizes.

Next there is a leading "1" or a "1S" for factory tested single sided and a "2" or a "2S" for double sided recording. Diskettes with a "1" are suitable for single head drives (figure 137), diskettes with a "2" for single head and dual head drives (see fig. 138).

Single Head Drive   **Fig. 137**
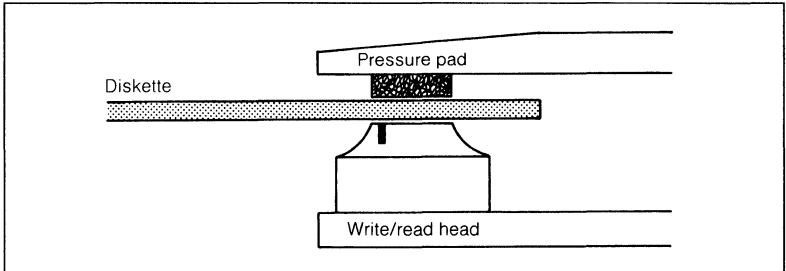
Single head drives only read/write on one side of the diskette. A pressure mechanism presses the diskette on side zero. Single head drives require only diskettes tested on one side, e.g. Diskette 5.25" 1S. Of course, double sided diskettes may be used also, e.g. Diskette 5.25" 2S, although only one of the sides will be used. 3.5" micro diskette drives are only offered normally as dual head drives.

Dual Head Drive   **Fig. 138**
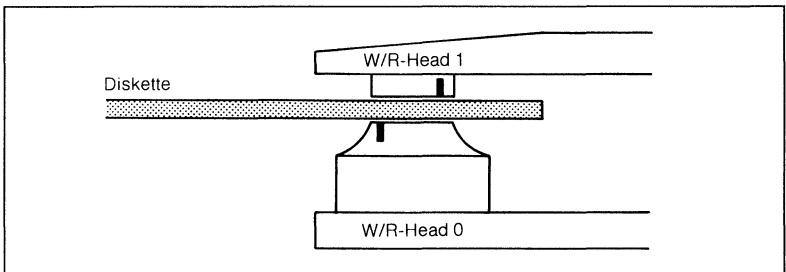
In dual head drives one head each is provided for side zero and side one of the diskette. This means two heads, therefore dual head drives. Only two sided tested diskettes should be used, e.g. Mini-Diskette 5.25" 2S/2D or 2S/2D 96 tpi or Micro-Diskette 3.5" 2DD.

For the Mini- and Micro-Diskette the micro computer system automatically recognizes the recording sides, for the Maxi-Diskette the position of the index/sector hole is different for single sided, double sided and flip-over diskettes (see fig. 139).

Flip-over diskettes permit, for single head drives, the writing/reading of one side and – after taking the diskette, turning it over (= flip-over) and reinserting it – the writing and reading of the other side of the diskette.

In our table 11 "J" stands for "jacket side detection". From the track density in tpi is calculated the number of tracks per recording side for the recording area. For the Mini-Diskette a track density of 96 tpi is sufficient for 80 tracks. For the Micro-Diskette, for the same track number, a track density of 135 tpi is required.

In chapter 8.8.3 we have already explained the calculation of the diskette storage capacity, for double recording density (in the nomenclature one "D" for the Maxi- and Mini-Diskettes, "DD" for the Micro-Diskette) and for high recording density (= High Density, abbreviated "HD"). Here, we see the corresponding bpi values.

The higher the recording density, the thinner the magnetic coating as we see from the example of the HD diskettes.

Fig. 139   **8″ Diskettes / Recording Sides**

Index/
sector hole
right but
next to
centre line

1. 8″ one sided
single/double density.
BASF Diskette
type 1D.

Index/
sector hole
right but
away from
centre line

2. 8″ two sided
single/double density.
BASF Diskette
type 2D.

2 index/
sector holes
right and
left of
centre line

3. 8″ reversible or flip-over
single/double density.
BASF Diskette
type 2N.
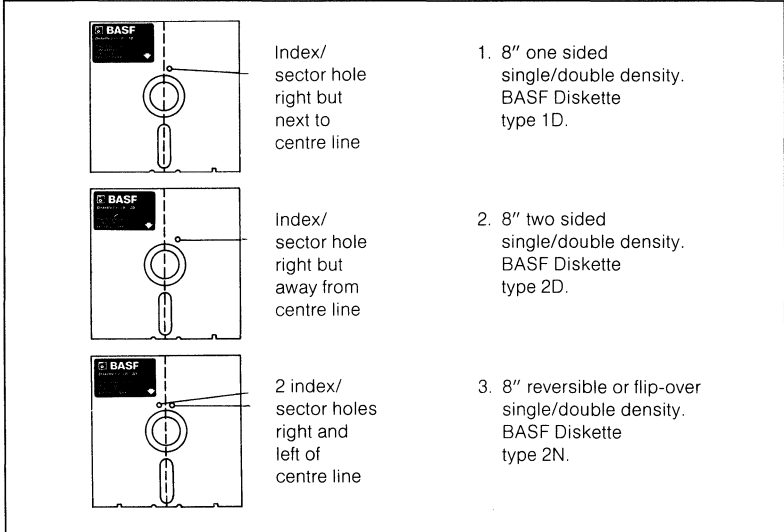
In 8″ diskettes the index hole is not always in the same place as it is for the 5.25″ Mini-Diskette with one or two sides. The position of the index hole can be seen in this figure.

All diskettes have a protective envelope (semi-rigid shell for the 3.5"Micro-Diskette, flexible jacket for the Maxi- and Mini-Diskettes), a liner and the magnetic disk (see fig. 140).

Sectional Drawing of a Diskette   **Fig. 140**
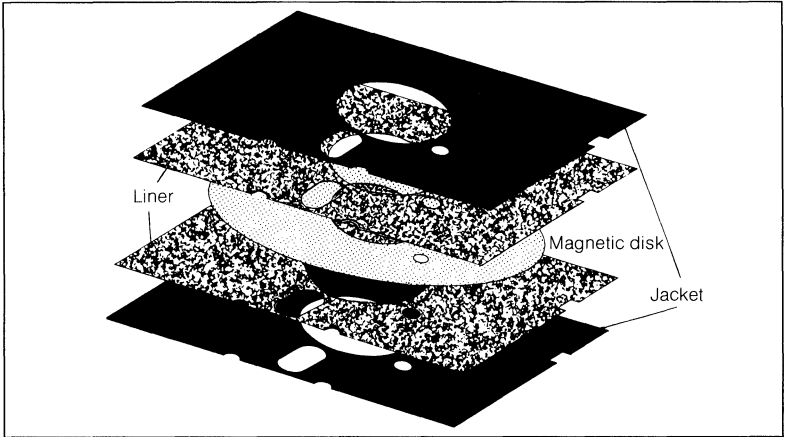
Each diskette consists of a flexible (8" and 5.25") or rigid (3.5") jacket, a liner inside the jacket for self cleaning and torque improvement of the magnetic disk and the magnetic disk itself, also called flexible disk.

Write Protect   **Fig. 141**

On 8" diskette the disk is "protected" (will read only) when the notch is **uncovered.**

On 5.25" diskette the disk is normally "protected" when the notch is **covered.**

On 3.5" diskette the disk is "protected" when the write protect window is **uncovered** (slider down).
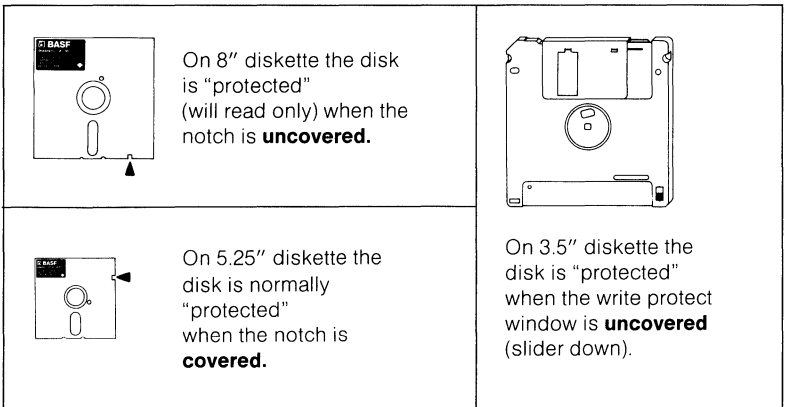
The position and function of the write protect notch are different for the 8", 5.25" and 3.5" diskettes.

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The write protects are different. Write protect A (= ANSI) for the Maxi-Diskette means that the jacket has a corresponding notch. The Maxi-Diskette may also be ordered without this notch (see fig. 141). The write protect is standard for the Mini- and Micro-Diskettes (see fig. 135 und 136).

The contents of the diskette boxes is different for the individual types and is indicated in the product range (see fig. 142).

Fig. 142   **Contents of a Diskette Box**

Telescope box of 10

Diskette in sleeve

Write protect tabs

Self adhesive labels
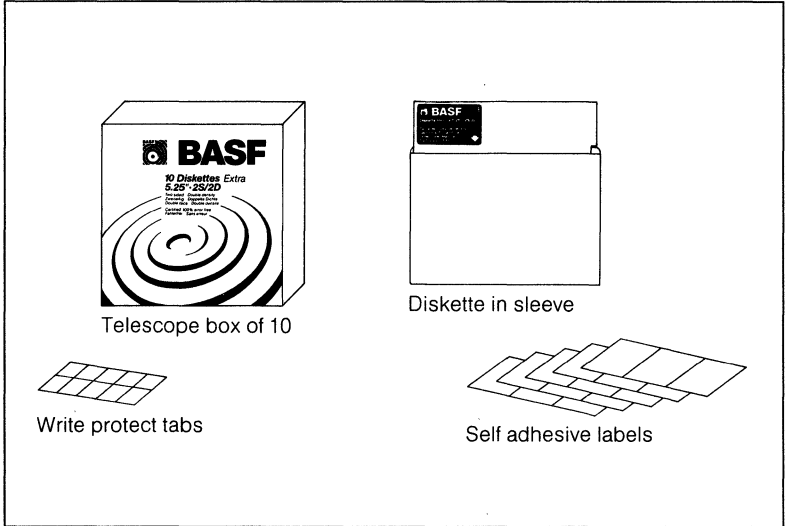
All diskettes, here the example shows a Mini-Diskette, as standard packing are supplied in a box with of 10 pieces and self-adhesive labels in several colours. For the 5.25″ and 8″ diskettes the supply range includes write protect tabs and one sleeve per diskette as protection against dust.

So far we have covered the characteristic features of the individual diskette sizes and types.

Concerning quality, the manufacturer may make additional statements above the minimum requirements of the standards, as for the BASF Diskette Extra and Maxima® (see fig. 143).

Such quality advantages give a security reserve for the application under unfavourable operating conditions.

® is a registered trade mark of the BASF Aktiengesellschaft.
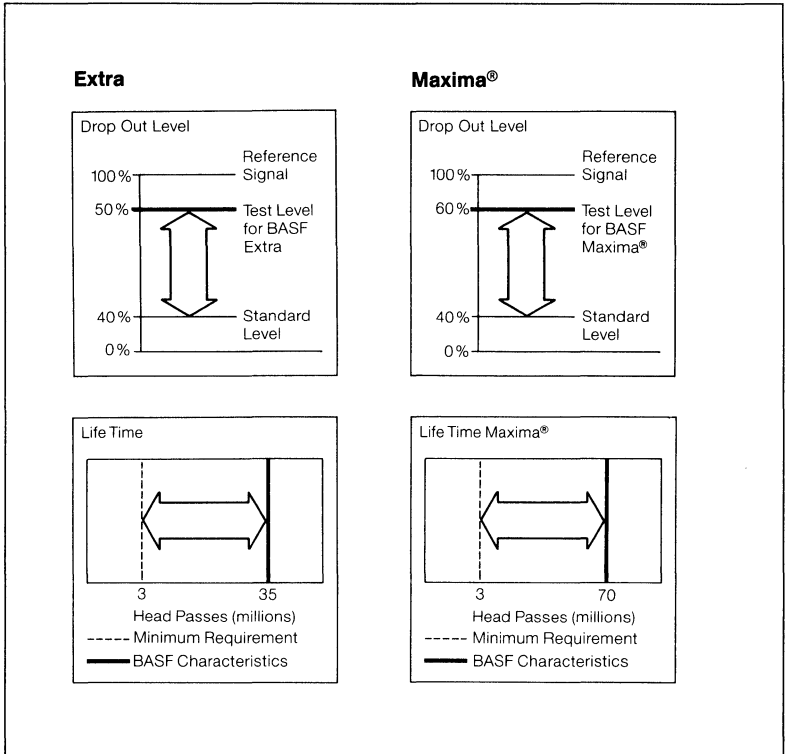
BASF 3.5″ and 5.25″ diskettes are supplied under the product names "Extra" and "Maxima®". The reverse of the packaging shows the quality differences (in above figure Drop Out Level and Life Time).

® is a registered trade mark of the BASF Aktiengesellschaft.

13. Care and Handling

In this chapter we will give, for all magnetic removable storage media, some basic rules for the organisation, the care, and handling of EDP storage media that should be applied.
Data losses may happen in two different ways:
– lack of data backup
– wrong handling of the storage media.

13.1 Data Backup

In most commercial EDP installations, from the PC to the mainframe, the data is first secured on fixed disk for data security. Only some low cost or portable PCs work without fixed disks. Here, the data is secured on diskettes.
If we do not count other applications as in the loading of programs and the exchange of programs on storage media, the majority of the storage media is used for the backup of fixed disk drives.
In large EDP centres like those of BASF in the flow chart (see fig. 144) it is marked which data, when and how long, inside the EDP centre or outside, has to be archived.
There is also special software available such as "Tape Management Systems" controlling the data backup and archiving.
Then, in case of break down of the EDP centre, e.g. by fire, a compatible system may be immediately started with the externally stored backup tape copies.
So a big mailing house, in such a case, thanks to the outside stored backup tapes, in another EDP centre, could immediately inform the customers by circular letter that all shipments would arrive with only a small delay.
There are different possibilities to protect data storage media against theft. Magnetic Tape Cartridges e.g. can be equipped with security tags, triggering an alarm when transported via screening pannels. Diskettes may be ordered with the companies name and may be marked with a current serial number in order to find out immediately e.g. people using non-company-diskettes as storage medium for illegally obtained information.
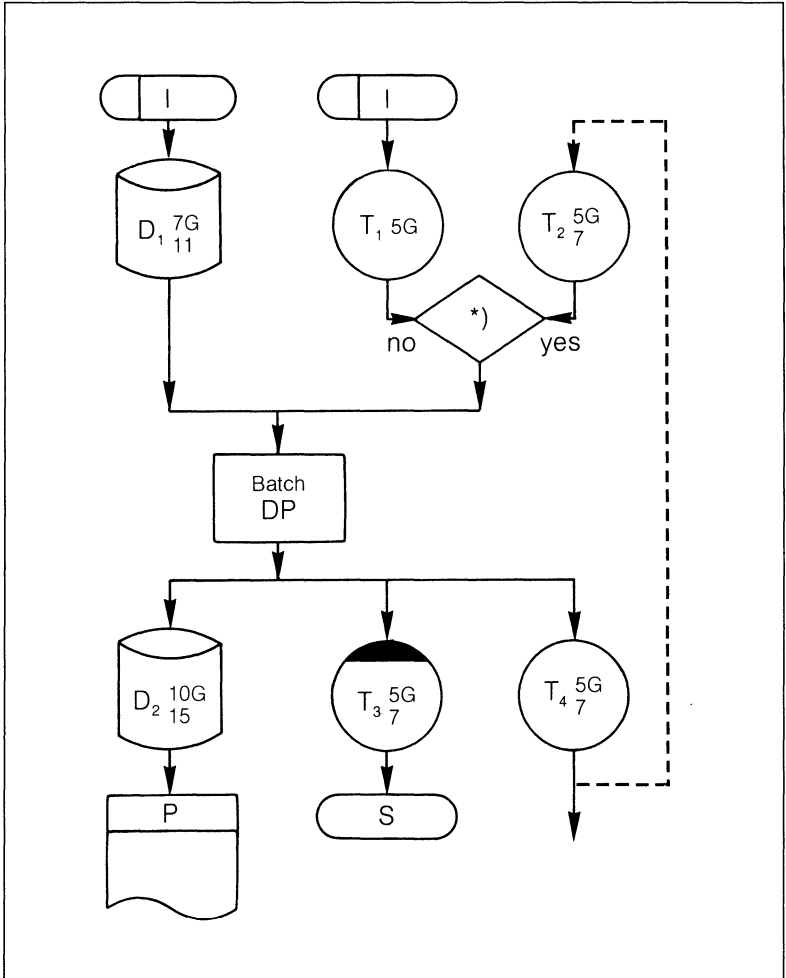
The simplified flow chart shows the data interfaces (I), the base data (D₁) and the result data (D2) on disk systems, the backup on magnetic tape for daily data files (T₁), several days data files (T₂) and for the results (T₃) after data processing (DP). The results are required for the next period (T₄) and for security copies (S), to be stored outside the building, recognizable by the black hat on T₃. The print-out (P) comes directly from the disk subsystem. The other figures shown in the symbols as e.g. the 7G and the 11 in D₁ determine the number of generations of data (here 7, as 7 generations) and for which period the data is stored (here 11 as for 11 days).

13.2 Cartridge Technology

The cassette technology, known for years in the audio and video technique (here: cartridge technology) helps to prevent operator errors.
Many errors result from incorrect handling of the storage media. These errors will be prevented by the trend away from the reel-to-reel computer tape to Magnetic Tape Cartridge and from the 8″ Maxi- and 5.25″ Mini-Diskettes in flexible jackets with open access to the head window and the spindle access to the 3.5″ Micro-Diskettes with semi-rigid shells, metal shutters and metal cores. By constructive measures, the magnetic storage media has been taken away from access by the user.

13.3 Handling of Storage Media

The user in a large EDP centre usually is an operator, normally with training in the correct handling of storage media. However, the PC-user takes the PC and the corresponding accessories like diskettes and data cartridges as problem free working materials and may probably not consider the damage caused by unproper handling.
Care and handling of diskettes is covered in detail in the Diskette Guide Book [22].

13.3.1 Loading and Unloading

Here, close attention is required for reel-to-reel computer tape, as the tape is directly accessible. Easy load rings are for automatic loading and unloading of the computer tape in the drive. For all other rings and for plastic cans the operator has to remove the tape and to load it manually into the drive.
Here are some recommandations for the correct handling of reel-to-reel computer tapes:
– Lift and handle the tape reel by its hub.
– Use minimum contact or pressure on the flanges.
– Do not make direct contact with the tape.
– Thread the tape correctly before starting the tape transport.
– Remove the write enable rings from the recorded tape before placing it into the library. (Some tape management systems do not require this removal).
– Replace broken reels.
– Only splice a broken computer tape in order to copy it and destroy it afterwards.
– Do not stack the computer tapes horizontally but vertically.
– Do not leave computer tapes mounted on turned off tape transports.
– Label all tapes correctly.
– Return to the library all computer tapes no longer in use.

Load diskettes gently into the drive. Insert the 8″ and 5.25″ diskettes after use into the sleeves. Avoid finger contact with the magnetic disks in the head window. Permanent labels are for the diskettes themselves, self-adhesive labels for their contents. These are first to be labelled and then to be fastened to the diskette and to be replaced for change of contents by new ones and not to be stuck one upon the other. Diskette jackets should not be secured by rubber tapes or paper clips. They are not to be bent or damaged by heavy objects (see fig. 145).

Mechanical Damage   **Fig. 145**
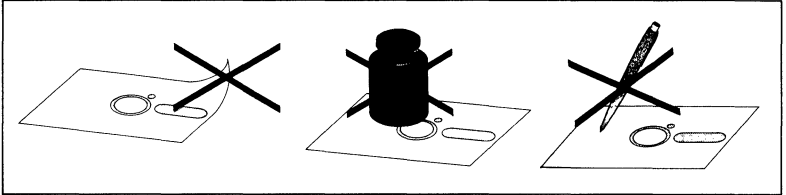
All magnetic storage media – here demonstrated for the diskette – should be protected against mechanical stress, in order not to damage the data media themselves, the magnetic tapes and the magnetic disks.

13.3.2 Signal Losses

All storage media must be transported, operated and stored according to the appropriate specifications. If this basic rule is ignored, read errors may occur. However, in the digital recording technique, these only appear, if the signal losses are very high in relation to the reference level, and if these occur over a great number of flux changes, so that they can no longer be corrected [30].

The information is stored in the form of a defined magnetization pattern in the magnetic coating. In the digital magnetic storage technique for each flux change the magnetic coating is magnetically penetrated. This is not the case in the analogue magnetic recording techniques. In sound recording, e.g., low volume high frequencies are transformed into weak magnetic fields, high volume low frequencies into strong and large magnetic fields. Therefore, in analogue recording under certain conditions on the tape a fortissimo part may copy through on a pianissimo part in the tape winding above or below (= print through) [31].

For digital recording the print through does not play a role, for several reasons, e.g. because of the same strength of the magnetic fields for each flux change. Therefore, it is not listed in the specifications.

The surface of the magnetic coating must not be contaminated by foreign bodies. Otherwise the storage media loses contact with the head and a signal loss may occur, even if it does not lead to a data loss (see also fig. 38).

Compared to the analogue recording, the digital storage technology offers on the subject of data security a number of advantages:

– The full magnetization of the coating and the same signal strength of the read voltage for all flux changes, in the frame of the standardized tolerances, for faultless storage media and for properly aligned systems.
– The missing pulse standard level, system dependent of up to 40% of the reference level.
– The recording modes developed for excellent recognition of the bits, even under unfavourable conditions.
– The error compensation by adding security bits.

Fig. 146   **Magnetic Tape Cartridge Transport**
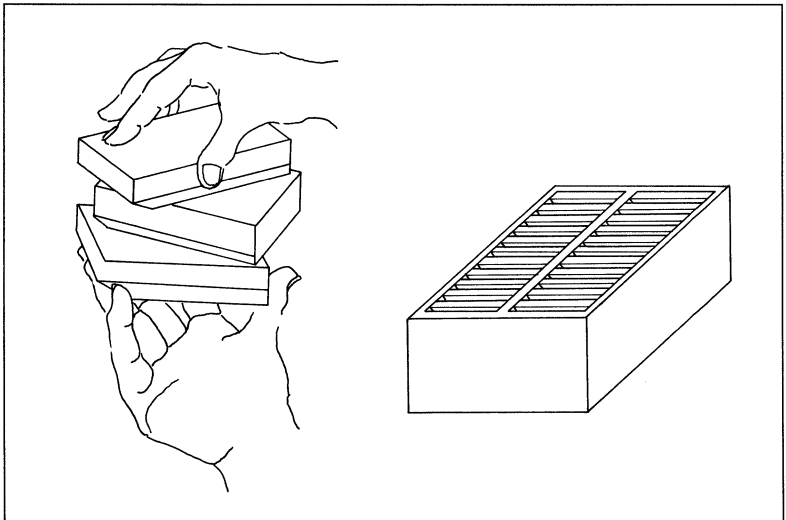
An unsupported transport of the magnetic tape cartridges is problematic. In an unfavourable case a drop from this height may result in fine hairline cracks in the case. These cannot be seen with the naked eye. They may, however, lead to malfunctions.

13.3.3 Internal Transports

"Internal transport" means a transport under the same climatic conditions.

When transporting EDP storage media within the EDP centre or – for PCs- within the offices, damages of the computer tapes, Magnetic Tape Cartridges or diskettes should be prevented. Computer tapes have to be transported vertically in racks on transport cars, MTCs must not be balanced between the hands in stacks, as this may lose stability and the MTCs may fall (see fig. 146) causing shell damage. Diskettes should be transported in inter-office-communication in padded envelopes, which should be labelled beforehand.

13.3.4 External Transports

If EDP storage media are transported from one building to another one through an unclimatized outer area or shipped via car, railway or by plane, then the transport conditions concerning temperature, humidity and foreign magnetic fields, prescribed for the individual media, have to be respected. These are indicated in the specifications of the system and the media manufacturer.

After transportation, recorded media should be read or re-recorded, when the acclimatization, indicated in the specifications, has been respected. If in exceptional cases recorded EDP storage media have been exposed to extreme temperature and humiditiy values, it is recommended as a precaution, to copy the data immediately and to rectify any affected media.

13.3.5 Fire Recommendations

As a fire precaution important data stored on magnetic storage media, are to be protected and stored in fire proof vaults or safes. Flammable tightly closed metal or plastic containers are fire resistent for a short time. All BASF Storage Media are self-extinguishing and non toxic.

13.3.6 Water Recommendations

If EDP storage media are damaged by water pipe breaks or inundations, they are to be stored separately from good media and to be listed based on the still available labels.

Reel-to-reel tapes should then be wound on slow running winder tables onto new reels, MTC tapes taken out of the shells and mounted into new shells and the magnetic disks of diskettes protected by new jackets/shells.

For this procedure, the magnetic tapes/magnetic disks are to be initially cleaned and then equipped with new system components. BASF has already helped in such salvage operations several times in order to make water damaged EDP storage media "system conform" for the copying onto new tapes/diskettes.

13.3.7 Influence of External Magnetic Fields

An external magnetic field, which erases the magnetic recording of an EDP Storage medium, must have a higher magnetic force than the coercive field strength of the magnetic storage medium itself [32,33,34].

The coercive force is indicated in A/m (formerly in Oerstedt = Oe). Typical values for standard diskettes are 22,000 A/m (= 275 Oe), for HD-diskettes 50,000 A/m (= 625 Oe), for reel-to-reel computer tapes 22,000 A/m (= 275 Oe), for chromium dioxide Magnetic Tape Cartridges 41,400 A/m (= 520 Oe) and for Data Cartridges 25,000 A/m (= 310 Oe) resp. 44,000 A/m (= 550 Oe).

As the magnetic field of the earth has only 40 A/m (= 0.5 Oe), it does not influence the magnetic recording of the storage media.

The distance between the magnet and the storage medium is important. A common permanent magnet, as used in the office as paper magnet [35], put on a magnetic coating, shows effects in the form of signal losses, however, not necessarily data losses. Tests have shown, however, that at a distance of only 76 mm (= 3 inches) to the computer coating no data losses can be found. Consequence: Keep this minimum distance!

As there are, however, much stronger permanent magnets, they should not come into the vicinity of stored data, so that data losses are prevented.

No data losses have been found for magnetic storage media exposed to airport metal detectors, radar systems, high voltages and X-rays.

Airport metal detectors are the most common external magnetic fields used during the transport of storage media. Magnetic fields of up to approx. 400 A/m (= 5 Oe) have been measured. There are plans to drop these values down to 95 A/m (= 1.19 Oe).

Most equipments operating with AC/DC currents and producing magnetic fields such as power transformators in EDP units are always correctly encased in magnetic shielding. In spite of this, attention should be paid to external magnetic fields (see fig. 147).
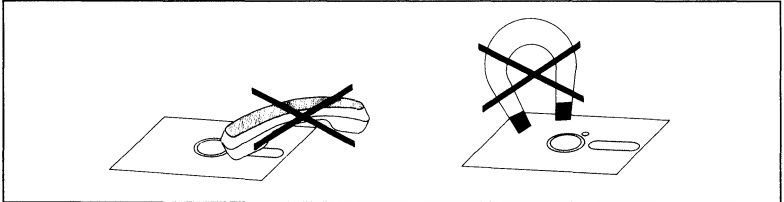
Electromagnets and permanent magnets may influence the recording of magnetic storage media. Therefore, please keep a minimum distance of 3 inches (= 76 mm) from permanent magnets and electromagnets.

13.3.8 Influence of Light and Laser Beams

As long as the laser beam is not strong enough, to burn the storage medium thermically, there is no danger.

13.3.9 Influence of Electro Static Electricity

If the media is operated under the valid operating temperatures and humidity values the low electrical resistance of the coated surface of BASF Storage Media help to prevent electrostatic charges. If the humidity is too low the electrostatic charge is increased. Consequently dust particles are deposited, leading to contamination (see also fig. 38).

13.3.10 Clean Room Conditions

The storage systems operate in modern large size EDP centres mostly under clean room conditions, guaranteed by air-over pressure, air locks, company rules concerning clothing, smoking, eating and drinking in the computer room by providing separate rooms for printers and other peripheral equipment.
For PC use these optimal conditions are not always available. The user should look for a proper working station and that storage media are not unnecessarily exposed to dust and contamination.

13.3.11 System Maintenance

In the form of routine system maintenance the magnetic heads and other systems parts in contact with the storage media should be cleaned and demagnetized. Cleaning of the storage media is done by the selfcleaning effect of the liner for diskettes and for tapes it is only necessary, if there is a strong contamination.

13.3.12 Long Time Archiving

Although all magnetic storage media may be written any time and as often as required, for intended long term archiving only new, unused or absolutely error free media should be chosen, as the cost of the media is insignificant compared to the value of the data.
The respective and valid environmental conditions for existing or planned archives are important.

13.3.13 Data Erase Units

Users who want to erase a large number of EDP storage media, turn to bulk erasers. They erase in a few seconds and in one operation the complete contents of the storage medium by exposing it to a high magnetic field. Users who want an even higher security for important data, have the storage media destroyed.

13.3.14 Destruction of Storage Media

It cannot be recommended to give away used storage media to other users, even, if they have been erased beforehand.
A reconstruction of the contents may be possible, under certain conditions. Data storage media no longer required should be destroyed, especially when it has important data.
In most countries, as in the Federal Republic of Germany, normal magnetic storage media may be disposed of in communal waste disposals. For larger quantities, e.g. for computer tapes, specialized companies offer to the customers empty lockable transport containers. They are filled and accompanied to the waste incinerating installation by personnel of the customer and if requested they receive a confirmation of the incineration.
Some EDP installations prefer to shred the media in specially constructed machines which work similar to the document shredders and afterwards the shredded material is incinerated.

14. Research and Development

In the following we consider a little about the trend of research and development for data storage media.

14.1 Optical and Magnetic Storage Disks

Both are rigid or semi-rigid disks. For rigid magnetic storage disks the information is transformed via the magnetic head (see fig. 148) into magnetic flux changes, these are recorded in the form of tracks on the magnetic coating and read via the same magnetic head. A substrate for the magnetic coating is an aluminium disk.

Magnetic Disk   **Fig. 148**
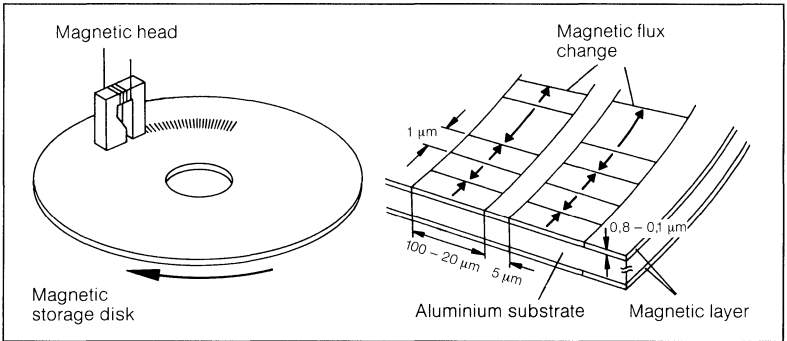
Magnetic disk storage units record the information via a magnetic head as magnetization changes in the form of tracks in the magnetic coating. At any time the disk may be written, read, erased and re-written. The magnetic coating has as substrate for rigid media an aluminium disk, for flexible disks a plastic film.

In optical data storage, digital data is recorded and reproduced on a disk by means of the beam of a diode laser focussed via a lense (see fig. 149). A decisive advantage of optical storage is the distance of several millimeters between lens and the storage layer. The storage layer can then be protected with a transparent substrate by sandwiching two substrates with the layer inside.

In addition, optical techniques offer a very efficient automatic track following of the laser beam based on the track and sector information impressed into the substrate. Consequently optical data storage is able to provide interchangeable data carriers of ultimate data density and data security that will effectively complement magnetic tape and disk as mass storage media.

The optical disks will be advantageous wherever large quantities of data have to be stored on interchangeable carriers as with magnetic tapes, but have to be accessed in a short time similar to magnetic fixed disks [36,37,38].

Fig. 149 **Optical Disk**
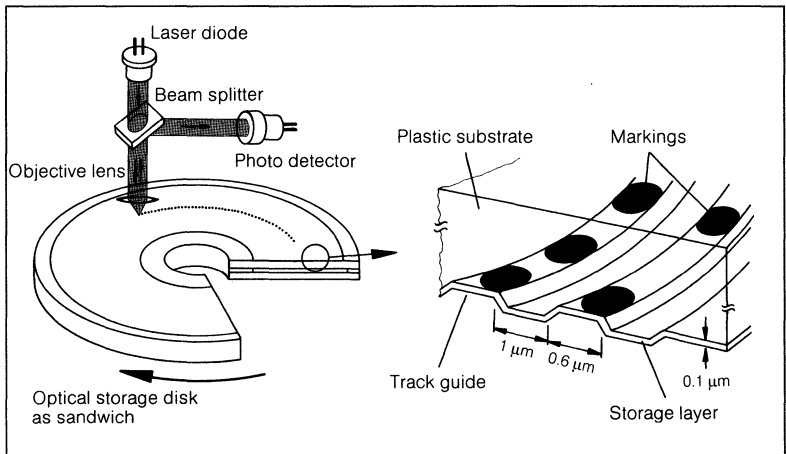
Optical disk systems record and read the digital information via an optical lens with a well focussed beam of a diode laser. Automated tracking is guaranteed by the track and sector information pressed into the substrate. The storage coating is covered by a protective coating, as the distance between lens and storage coating may be several millimeters.

The optical storage units may be subdivided into three classes:

ROM (= Read Only Memory)

Similar to a phonographic record optical readable information is impressed. An example is the CD (= Compact Disk). It is especially suitable for the distribution of large quantities of machine readable data.

WORM (= Write Once – Read Multiple)

A data storage to be written once, suited for the dumping of large data quantities to be archived without changes, at the place of creation. These may be interesting with the appropriate operation systems for limited applications and are already presented in the market.
For WORM disks e.g. a specially developed layer of dye is suitable, produced by low cost spin coating.

RWM (= Read Write Multiple)

Overwritable read/write storage similar to the actual magnetic disk storage without the disadvantage of dust sensitive read/write transformers.
For RWM disks TMO-disks (see fig. 150) are appropriated (TMO = Thermo-Magneto-Optic). They have a magnetizable storage layer. For writing its magnetization is changed by using a magnetic field and a laser spot. For reading the magnetooptic Kerr effect is used.
A world-wide distribution of the WORM and RWM-disks can only be achieved if an international standard is fixed for the specification of the recorded and unrecorded disks.

14.2 Horizontal and Vertical Recording

The tendency to increase continuously the height of recording densities reaches the practical and physical limits for the presently used technology of horizontal recording on storage media with oxide pigments, enveloped by binder, and magnetic heads in ring form [39].

Fig. 150   **TMO Disk**
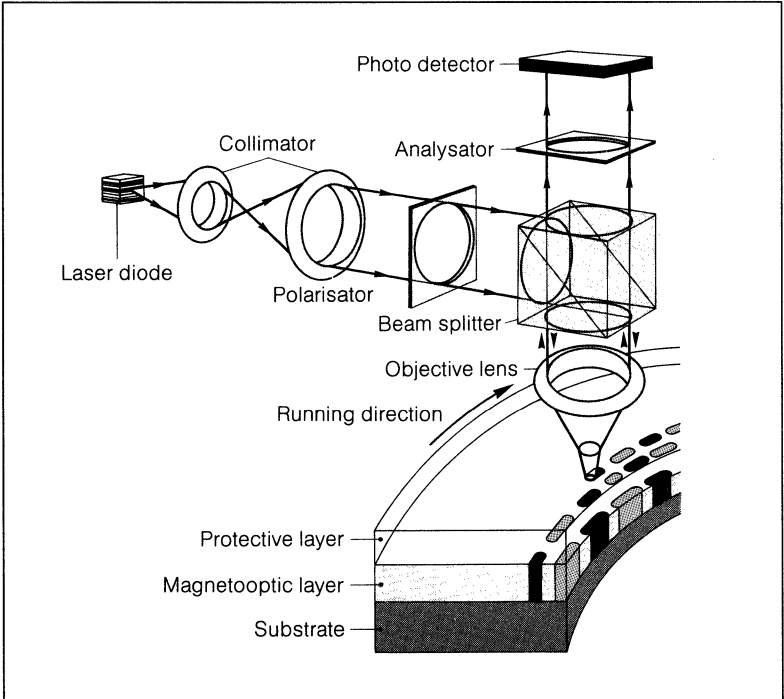
TMO disks (TMO = Thermo Magneto Optic) may be written many times. During the writing by local heating with a well focussed laser beam marking dots are changed in their magnetic orientation. The information is read by the so-called magnetooptic Kerr effect.

An alternative is pure metal layers of magnetic metals or metal alloys. Usually a vertical, space saving recording (see fig. 151) with special thin film heads (see fig. 152) is best suited here.
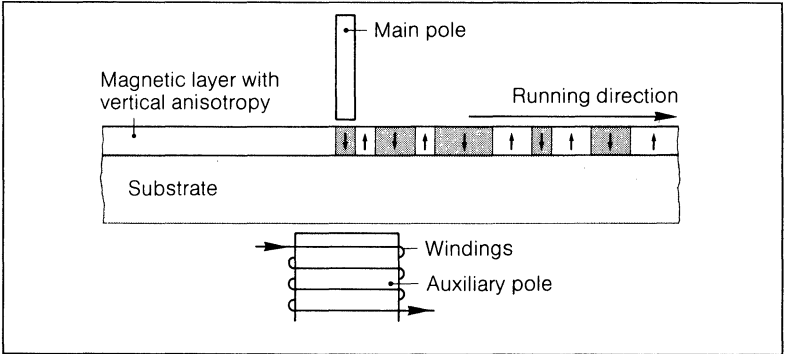
Contrary to the horizontal recording the magnetic orientation is perpendicular to the magnetic coating for perpendicular recording.
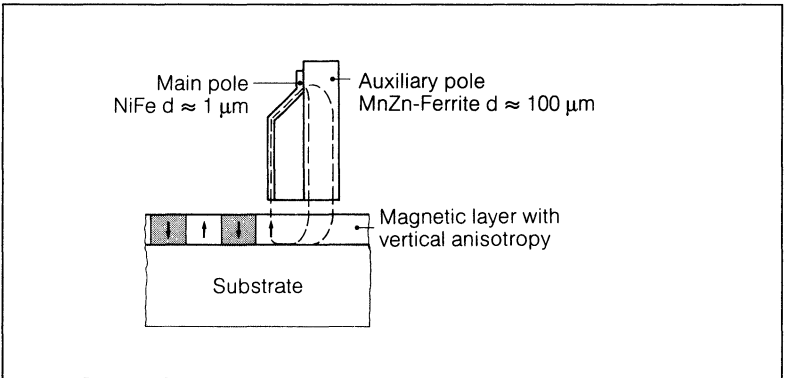
The thin film head for the perpendicular recording consists of a thick ferrite with high magnetization, also called auxiliary pole, and a thin film element, also called main pole. The magnetic coating with perpendicular anisotropy consequently has a pre-orientation for perpendicular recording.

14.3 Other Tape Recording Methods

The helical scan for 8 mm video tapes (see fig. 153 and 154) and R-DAT (see fig. 155 and 156) permits the use of magnetic tape cassettes of the smallest dimensions, highest recording densities in conventional and analogue recording techniques [40].

A comparison of the magnetic tape recording methods (see fig. 157) shows the state of the art 1988 and the future.

For audio, video and data technique the trend goes to digital recording in the helical scan mode.
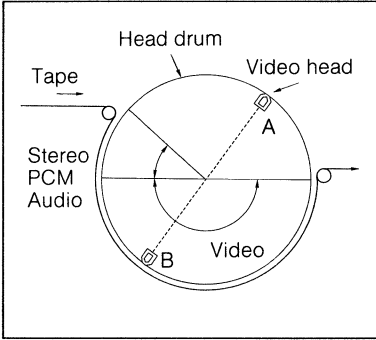
Fig. 153　　　　　　**8 mm Video Head Drum**

The head drum with two heads for helical scan video recording. As for the low tape transport speed of 2 cm/s the longitudinal sound recording does not guarantee a good sound quality the sound alternatively may be recorded in PCM (= pulse code modulation) or FM (= frequency modulation) together with the video signal via the video head.

Fig. 154　　　　　　　　　　　　　　**Track Position 8 mm Video**
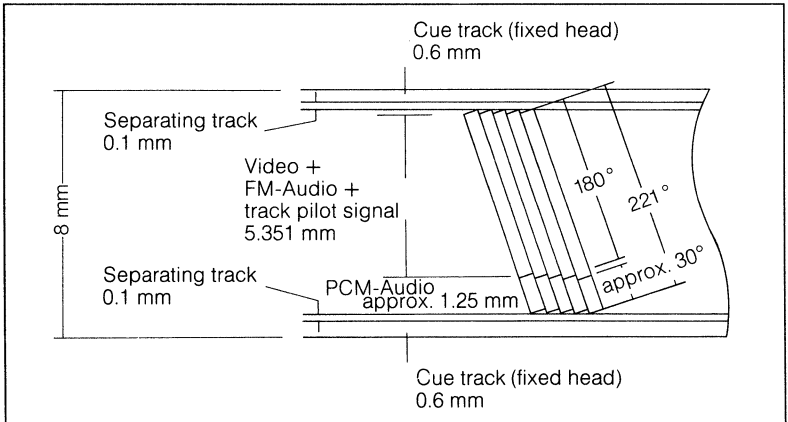
The image is recorded by the helical scan, the sound either longitudinally or in helical scan as FM or PCM audio signal.
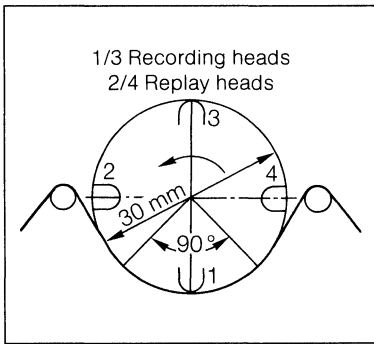
R-DAT Head Drum **Fig. 155**

For R-DAT the sound signals are recorded with 2 or 4 heads (for off-tape-monitoring) in PCM mode. The tape transport of 8,15 mm/s and the tape/head speed of 3,13 m/s permit, thanks to the digital technique, a high recording quality for low system and cassette dimensions.

R-DAT Cassette **Fig. 156**
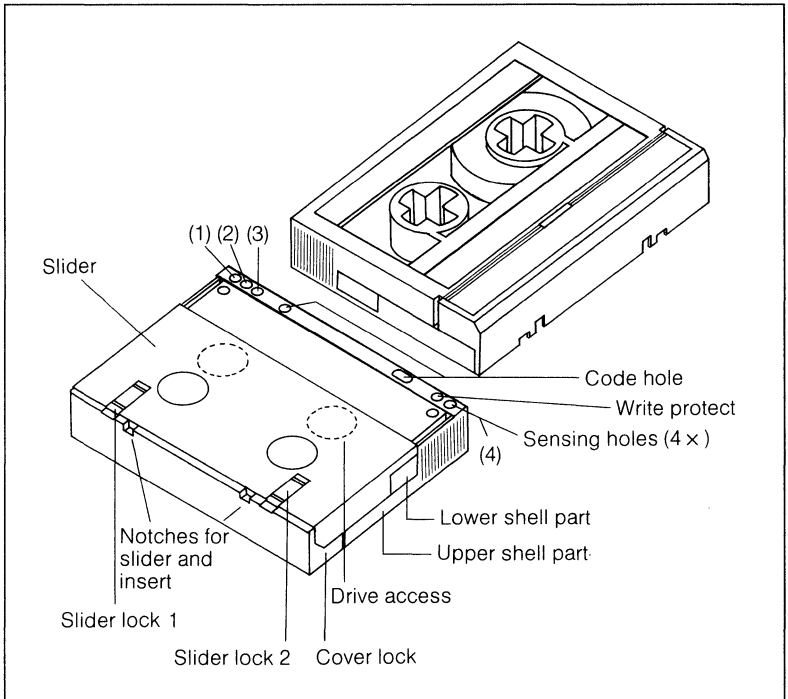
Compared to the data cartridge the R-DAT cassette of 73 mm · 54 mm · 10.5 mm has a simple construction. For a tape length of 60 m the playing time is 120 minutes.
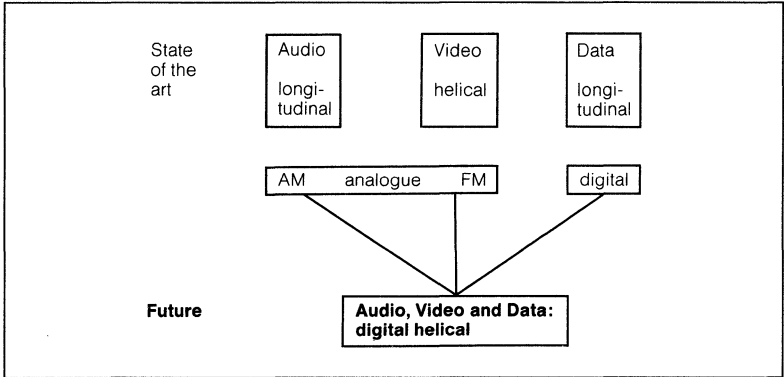
While until now in the audio/video technique the analogue recording as amplitude modulation (= AM) for audio signals and as frequency modulation (= FM) for video signals predominated, also here the trend is in the direction of the digital technique. The helical scan system will gain more importance for digital recording on magnetic tape.

14.4 Track Density and Recording Density

Storage media in the market such as 3.5″ diskettes and Magnetic Tape Cartridge (= MTC) for IBM 3480 and comparable systems have actually not yet reached their limits in track and recording density. Therefore, a doubling of the track density from 18 to 36 tracks for the MTC (see fig. 158) may be reached, if the system manufacturer plans, with MTCs already shipped. This of course would mean a full MTC compatibility.

Fig. 158   **MTC Track Density**
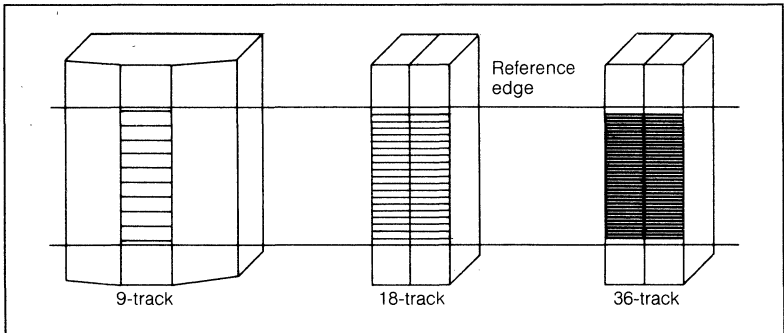
The jump from 9 tracks of the reel-to-reel tape to 18 tracks of the MTC is a doubling of the track density. If the read/write parameters of future (for example 36 tracks) systems permit the use of the present magnetic tape cartridges, then BASF MTCs will be compatible.

For 3.5" diskettes the industry standard in 1988 corresponds to an unformatted storage capacity of 1 MB with 8,717 fci for the standard and 2 MB with 17,434 fci recording density (fci = flux changes per inch) in the case of HD-Diskettes, for a track density of 135 tpi. The tendency goes to unformatted storage capacities here of up to 10 MB for flux change densities of above 30,000 fci and track densities of above 400 tpi.

These figures are based on the actual recording mode MFM.

14.5 Recording Mode

Higher recording densities may also be reached by changing the recording mode. See figure 159 for the purpose of comparison MFM (= Modified Frequency Modulation) with RLL (= Run Length Limited).

RLL / Codes Comparison   **Fig. 159**

An increase in recording capacity is also reached by using another recording code. This has been the case for diskettes by changing from FM method (= Frequency Modulation) for single recording density to the MFM method (= Modified Frequency Modulation) for double recording density and would be the case when changing the diskettes from the MFM to the RLL method (Run Length Limited).

a) Modulation method

| NRZ data | 0 | 0 | 1 | 1 | 1 | 0 |

FM
MFM
MMFM
(1.7) RLL
(2.7) RLL

b) FM method

	Data	Code
FM Code	0 1	10 11
MFM Code	0 1	X0 01
MMFM Code	0 1	X0 01

c) RLL method

(1.7) RLL Code		(2.7) RLL Code	
NRZ Data	Code	NRZ Data	Code
01	X00	000	000100
10	010	10	0100
11	X00	010	100100
0001	X00001	0010	00100100
0010	X00000	11	1000
0011	010001	011	001000
0000	010000	0011	00001000

14.6 Magnetic Thin Films

High recording and track densities and vertical recording require "Magnetic Thin Films" instead of the magnetic pigments in the binder. These magnetic thin films are produced by evaporation (see fig. 160) or sputtering (see fig. 161) [41].

For a ME tape (ME = Metall Evaporated) by evaporation on a plastic foil a magnetic layer is produced, above it a protecting coating and on the reverse side a back coating (see fig. 162).

TMO disks are manufactured in the process of cathode sputtering in vacuum chambers and the TMO layer is deposited on plastic substrates which were produced by an injection molding process.
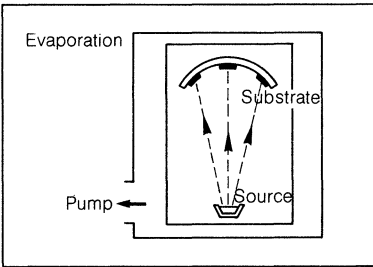
Fig. 160   **Evaporation**

With the evaporating of an ME tape (ME = Metal Evaporated), the metal layer is evaporated in a vacuum. The magnetic material is evaporated by an electron beam and condenses at the base film. By selection of the range of impact angle the magnetic properties of the layer can be influenced.
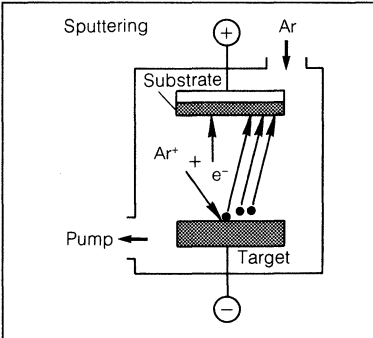
Fig. 161   **Sputtering**

While sputtering (= DC cathode sputtering) within a vacuum chamber the substrate is the anode and the target, a thick piece of the selected metal alloy, is the cathode. The sputter gas, here Argon, is filled into the chamber, until the required pressure is reached. Now the gas is ionized by a glow discharge. The positive Argon ions are accelerated to the negative target and sputter off by their kinetic energy neutral atoms from the target surface. These sputtered particles are deposited on the substrate.
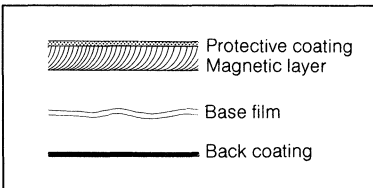
Fig. 162   **ME Tape**

Build-up of an ME tape (ME = Metal Evaporated).

14.7 Performance Tape/Disk

Tape and disk will continue to exist side by side. Their performance (see fig. 163) has to be judged according to different criteria [42].
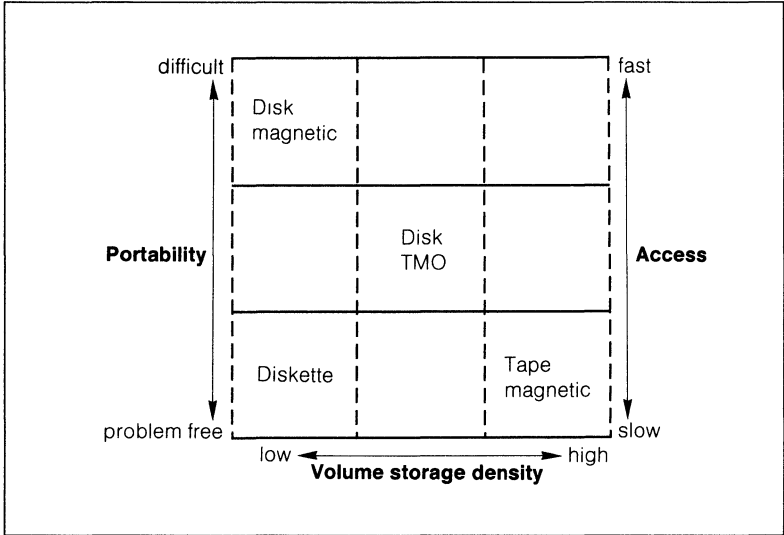
For exchangeable storage media such as diskette, TMO disk and magnetic tape portability is problem free, for rigid disks difficult. Circular media offer a fast, longitudinal media a slow access to the stored data.

Portability, meaning exchange in the form of removable storage media, is difficult for rigid magnetic disks. Until now magnetic disk cartridges and magnetic disk packs with a diameter below 14″ have no market importance for this (see fig. 132 and 133). Diskette and tape exchange, however, are without problems and TMO disks are also portable.

With the same relative speed, in relation to access, rotating media are always fast, tape form media are always slow. For volume storage density, the magnetic tapes are on top, followed by the TMO disks and with the lowest volume storage density the flexible and rigid magnetic disks.

14.8 Area Density for Storage Media

The area density for storage media is calculated by multiplying track density and longitudinal density (= recording density) (see fig. 164).

Fig. 164   **Area Density for Storage Media**

	Track density tpi	Longitudinal density bpi	Area density bpi^2
MTC	36	25,000	$9 \cdot 10^5$
DAT	1,800	61,000	$1 \cdot 10^8$
Diskette	135	27,000	$3.5 \cdot 10^6$
Metal film disk 5″	1,600	25,000	$4 \cdot 10^7$
TMO disk	15,000	17,000	$2.5 \cdot 10^8$

The area density in bpi^2 is calculated based on the track density in tpi and the recording or longitudinal density in bpi.

14.9 Primary, Secondary and Tertiary Storage

If we look at the known storage hierarchy (fig. 25) in view of the future (see fig. 165), the semi-conductor memories are the primary storage, the magnetic disks, the TMO and – for specified applications – also the diskettes are the secondary memories. The optical disks, magnetic tapes and diskettes for backup elements form the largest group of tertiary storage media, supplementing each other in the individual market segment. Magnetic disks, magnetic tapes and diskettes, today, still have an advantage, as there are already corresponding industry standards. The optical disks and the corresponding systems must still reach market importance and become a standard. In addition, they have to offer a comparable price performance in order to replace the actual magnetic storage systems.
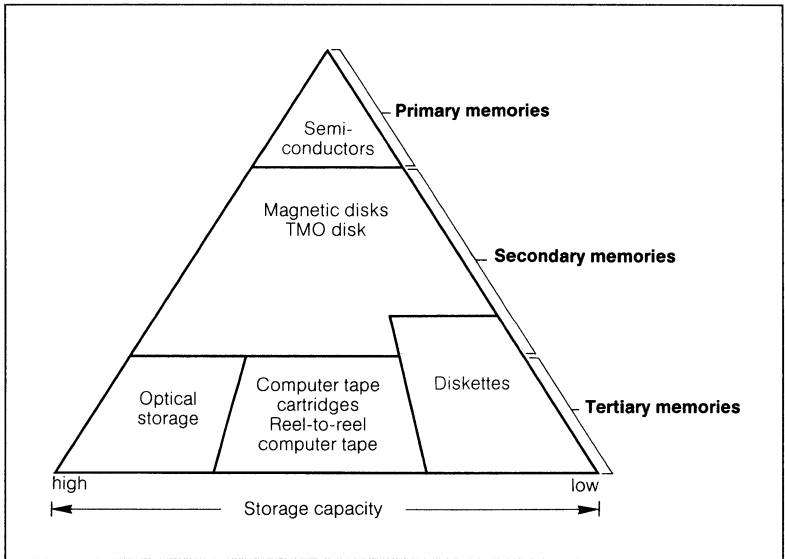
In figure 25 primary, secondary and tertiary storage is explained. Semiconductor storage is primary storage, magnetic disks, TMO disks and under certain conditions also diskettes are secondary storage, optical disks, magnetic tapes and diskettes for backup are tertiary storage.

14.10 Summary

Magnetic and optic storage systems will supplement each other.
For the development and manufacture of these media, BASF can profit from a decade of know-how in basic research, in chemistry, in the complete magnetic technique, in process engineering and measuring techniques.

15. Figure Index

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Figure Index

Figure Index

16. Table Index

17. Box Index

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19. Alphabetical Index

Heinz Ritter was born in Paderborn, Germany, in 1927 and attended the local Grammar School "Theodorianum". After an industrial and technical education he joined BASF in 1951 and is today in the Operating Division Information Systems Manager Marketing Support EDP Media. For several years whilst in BASF Information Systems, he dealt with publications, talks and training courses for the trade, concerned with magnetic recording and Electronic Data Processing. He is the author of "Tape Questions – Tape Answers" (out of print) and the "Diskette Guide Book".
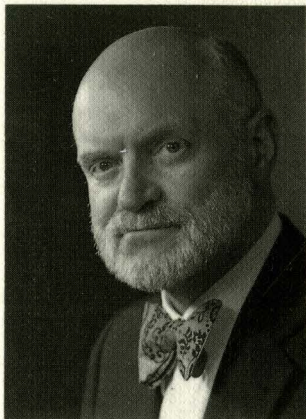
This booklet "An introduction into Storage Media and Computer Technology" is intended to provide guidance and assistance for the trade, for data storage media and for computer users. All technical expressions are explained in the text.

A voluminous index serves for quick reference to the individual expressions and their explanations in the text.