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MAGNETIC TAPE

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ABSTRACT

The move to visualization and image processing in data systems is increasing the demand for larger and faster mass storage systems. The technology of choice is magnetic tape. This paper briefly reviews the technology past, present, and projected. A case is made for standards and the value of the standards to users.

INTRODUCTION

Major changes are occurring in data storage and processing systems technology. It is hard for most of us to keep up with what is happening in our own fields, let alone what is going on in related disciplines. Even when we can see the general direction of change, it is difficult to forecast the timing and implement systems which bring all elements together at the same time to provide optimum performance, at a reasonable cost.

One fundamental change affecting all of us is the emergence of the discipline called visualization. Visualization requires storage of very large image files, e.g., megabytes per image, versus kilobytes per typical alpha numeric file (1000 to 1). The requirements of visualization have not only brought about changes in the design of processors from character to image processing, but also a recognition of the need for larger and faster storage systems.

Another major change affecting all of us is the improvement in data communications; not just satellite links, but network buses which handle high data rates with packet switching protocols for peer-to-peer and client/server communication. Using fiber optics, data of various bandwidths can be digitized, buffered, and transmitted in packets over long distances.[1] Network buses will not only facilitate more distributed computing, but also the implementation of more and larger mass storage systems.

A recent issue of Business Week lists IBM as the number one U.S. Company in terms of market value.[2] IBM's sales of magnetic storage products (disks and tape drives) are said to exceed the sales of their mainframes. Annual sales of magnetic recording products now exceed $50 billion and can be expected to grow.[3] Computer manufacturers probably sell more disks than tape drives, but the tape market itself is very large. A recent Seagate ad says that "Seagate shipped over seven million disk drives alone last year (1990)."[4] The reason for including these impressive statistics here is to help dispel any perceived notion that magnetic recording is out of date. Other new technologies such as optical recording have their place, but this paper will demonstrate the advantages of magnetic tape for large mass storage systems.

For those of us in the magnetic tape industry, we have difficulty hearing words like "peripheral" and seeing pyramid shaped icons with mainframe storage at the top, then solid state disk, then magnetic disk, then optical disk and finally magnetic tape (Figure 1). After all, what media stores all of the permanent data for long periods of time? Well, if we were processing time card charges, point of sale transactions, inventory movement, or some other batch process requiring only short term back-up, we would view the whole process the traditional way. But, if we were processing terabytes of sensor data daily and storing it for years, we would view things differently. We would want a storage technology that is very fast (e.g., HIPPI rates), uses inexpensive media, has high data integrity, uses time proven technology, and standard media and storage devices. Perhaps the stack of storage technology would be the same, only in our view the central memory and direct access storage are only little bumps on the large tape storage archives (see Figure 2).

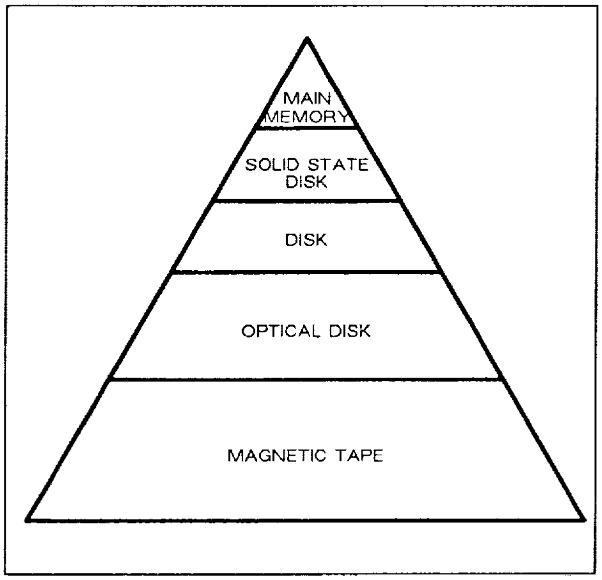


Figure 1. Typical ICON Representation of a Traditional Storage Hierarchy

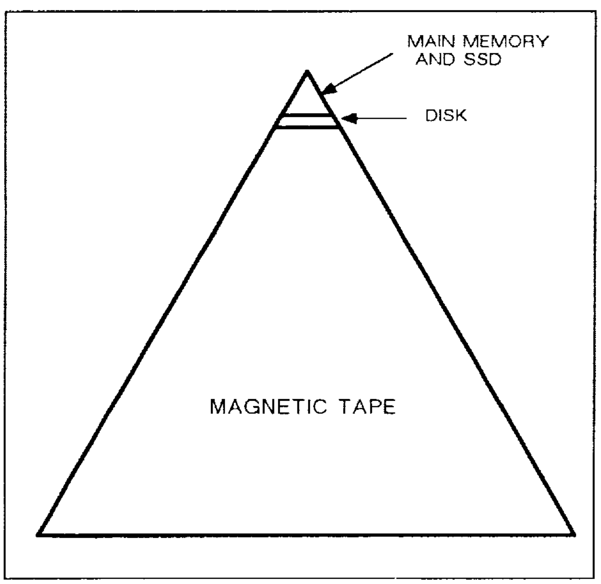


Figure 2. Storage Hierarchy for Large Mass Storage System

Humor aside, a serious attempt will be made to present magnetic tape storage in the context of the conference, i.e., Mass Storage Systems for Space and Earth Science Applications. At first, the writer was tempted to deal with magnetic recording technology from the standpoint of design, but on reflection it was decided to cover only those issues deemed most important to the audience. For those who want to delve more deeply into the design of digital magnetic data recorders, several sources of technical data are recommended. They are 1) NASA Reference Publication 1111, "High Density Digital Recording," prepared by THIC, September 1985, available from the Superintendent of Documents; 2) Magnetic Recording Handbook edited by C. Dennis Mee and Eric D. Daniel and published by McGraw Hill, 1989; 3) Magnetic Recording Handbook edited by Marvin Camras and published by Van Nostrand Reinhold, 1988; 3) The complete handbook of Magnetic Recording by Finn Jorgensen and published by TAB BOOKS INC., 1986

Other valuable sources of data are found in two IEEE publications: (1) November 1986 proceeding with a special section on Magnetic Information Storage Technology edited by Mark Kryder, Professor of Electrical and Computer Engineering and Director of the Magnetics Technology Center of Carnegie Mellon University of Pittsburgh, Pennsylvania. (2) June 1990 special issue on Magnetics incorporating an invited paper by John C. Mallinson, Fellow IEEE and Director of the Center for Magnetics Research, University of California at San Diego. The paper is entitled "Achievements in Rotary Head Magnetic Recording."

TECHNICAL PERSPECTIVE

There is a lack of public understanding, and even a lack of understanding among electrical engineers, concerning the importance of magnetic storage technology. Which came first, computers or magnetic storage? Of course magnetic storage came first ,making computers possible.[5]

Magnetic tape recorders record data differently than semiconductor memories. Semiconductor random-access memories and logic devices store 1s and 0s by controlling the state of semiconductor devices. Power for storage and readout of the devices is supplied by the memory power supply or battery back-up.

In digital magnetic recording, bits are stored by creating magnetic domains in moving magnetic media. To store strings of encoded 1s and 0s in magnetic tape, the tape must be moved past a magnetic recording head. Magnetic domains are created in the thin layer of ferromagnetic particles in the surface of the tape by the field of the drive current. Similarly, encoded 1s and 0s are read from the tape by sensing the rate of change of the magnetic flux. Domains are created in the tape at discrete intervals whose lengths are inversely proportional to the recording data rate and the speed of the media past the head.

The two most common magnetic recording techniques are illustrated in Figure 3. In longitudinal recording, modern machines typically have 9, 18, 28, 36, 42, or 84 tracks. Contemporary helical-scan recorders achieve higher track densities and higher bit densities, i.e., flux reversals per unit length of track. A rotary scan technology similar to helical scan is transverse scanning wherein the tracks are orthogonal to the direction of tape travel. This method is mentioned briefly in the next section.

Because the magnetic recording process seems complicated when its compared to semiconductor memory, why is it used? The answer is very low cost and very high storage density at high data rates. As an example, the ANSI ID-1 Helical Scan Recorder stores data on large tape cassettes at a media cost of less than two tenths of a cent per megabyte and at a density of 625 megabytes per cubic inch with data rates up to 50 MBytes per second.

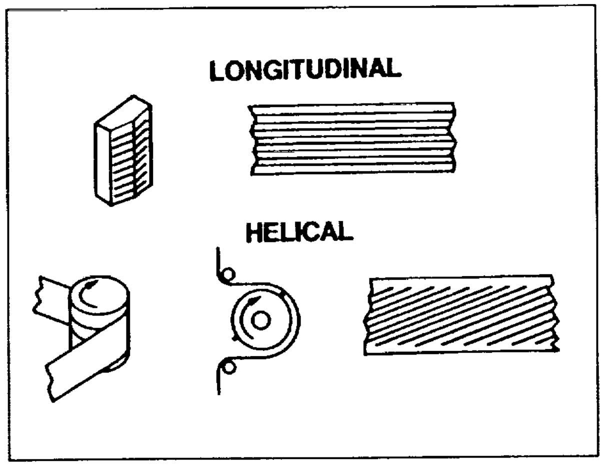


Figure 3. Magnetic Tape Recording Techniques

The energy identifying every bit of storage is stored as a domain of spinning electrons in the particulate media. These domains remain indefinitely unless demagnetized by an external field greater than the coercivity of the tape.

HISTORICAL PERSPECTIVE

Widespread use of magnetic tape recording began in the late 1940's. Since then many recorder configurations have evolved by many manufacturers and a great many still exist with refinements. In the beginning, they were all analog machines recording complex wave forms for instrumentation, audio, and video applications. In 1956, Ampex invented transverse scan rotary recording and launched a product successfully for broadcast video recording.[6] RCA followed with its transverse scan products in 1958. These machines were called "quadrature" machines because the heads scan across the tape at a quadrature angle with respect to the direction of tape (90°).

The most significant aspect of this early rotary recording technology is that it permitted very high head to tape speeds (over 3000 inches per second) and high track density, hence high video bandwidths and large storage capacity.

Magnetic tape was selected in the early 1950's to transfer data at high speeds to and from computers.[7] These were 7-track and later 9-track longitudinal recording machines, some of which are still in service. In the 1970's and

1980's, 1/2" tape cartridges and 1/4" tape cassettes were introduced for longitudinal data recording. DATATAPE introduced its System 600, 84 channel longitudinal digital data recorder, in 1980. The System 600 machines are capable of selectable record and reproduce rates from 6.25 to 56 megabytes per second.

The earliest reference found in the literature regarding computer tape drives using rotary heads to achieve high information densities on tape (Damron, et al, 1968) is on p. 6 of chapter 4, referenced above.[7] Starting in the early 1980's, DATATAPE began producing a number of high data rate, high storage capacity helical scan recorders for DOD. Three of these machines are pictured in Figure 4. All three are still being manufactured. Please note that the RDCR-331 is a mass storage system with automated cassette handling.

Two other versions of the RDCR have been manufactured in quantity. The first uses an NEC jukebox with 3M tape cassettes in the shape of D-1 tape cassettes, but with 1" wide tape instead of 19mm (3/4") tape. The second version produced cooperatively for Masstor Corporation is being sold in commercial mass storage systems.

CONTEMPORARY DIGITAL DATA RECORDERS

By all odds, the high volume digital data recorders of recent note have been the 3480/3490, 1/2" machines manufactured by IBM, Storage Technology and others. These longitudinal machines operate with a Federal Information Processing Standard -60 (FIPS-60) Interface. Their data rate, 3-4 megabytes per second, and their modest cartridge storage capacity (200 plus megabytes) have been adequate for contemporary mainframe storage. These recorders, manufactured in the thousands, if not hundreds of thousands, sell for reasonable prices, in the range of $10,000 to $20,000 each. They are also available in large automated storage silos, e.g., Storage Technology Corporation's ACL-4000 which stores over 1 terabyte.

Also of particular note has been the success of 8mm helical scan tape recorders manufactured by Exabyte Corporation. Sold by many system integrators and re-sellers for small computer disk back-up applications, these machines are based on the use of a Sony 8mm video tape drive with Exabyte developed digital data electronics. Sold with Small Computer System Interface (SCSI), these machines operate at a burst data rate of 1.5 megabytes per second and store 2.3 gigabytes. A higher density version of this machine is available with 1638 tracks per inch (tpi) versus 819 tracks per inch and stores 5 gigabytes . Both Exabyte machines use metal particle tape. Other value-added suppliers of Exabyte Recorders include Megatape and Summus Corporation. Summus also sells the Exabyte machines with automated carousels. Both of these suppliers offer standard peripheral interfaces.

Some additional contemporary machines deserve mention. The first is the Metrum VLDS 1/2" Helical Scan tape cartridge machine based on a VHS product. In a dual channel version it is capable of a 3 megabytes per second data rate and in a single channel version 1.5 megabytes per second. In a read-after-write version, the dual channel machine is reported to be capable of achieving a corrected bit error rate (CBER) of 1 error in 10^{12} bits with a transfer rate of 1 megabytes per second. This machine is being produced in volume. It is available with an automatic cartridge changer which holds up to 600 cartridges. The machine is available with TTL, SCSI-1, VME, and VAX DRB-32 interfaces. The machines use cobalt doped gamma ferric oxide tape on standard 5.2 gigabyte cartridges, with 10 gigabyte cartridges available. The recording format on tape is proprietary to Metrum.

A higher performance transverse scan tape cartridge machine is the AMPEX DCRSi which operates at 13.4 megabytes per second and stores 47.5 gigabytes per cartridge on cobalt doped gamma ferric oxide 1" wide tape. The machine has a 96 megabyte buffer which allows read or write at any rate up to 13.4 megabytes per second. The machine is available with either a serial or 8 bit parallel TTL interface and an RS-232 or RS-422 control and status interface. Several hundred machines are in service. The tape format is Ampex proprietary.

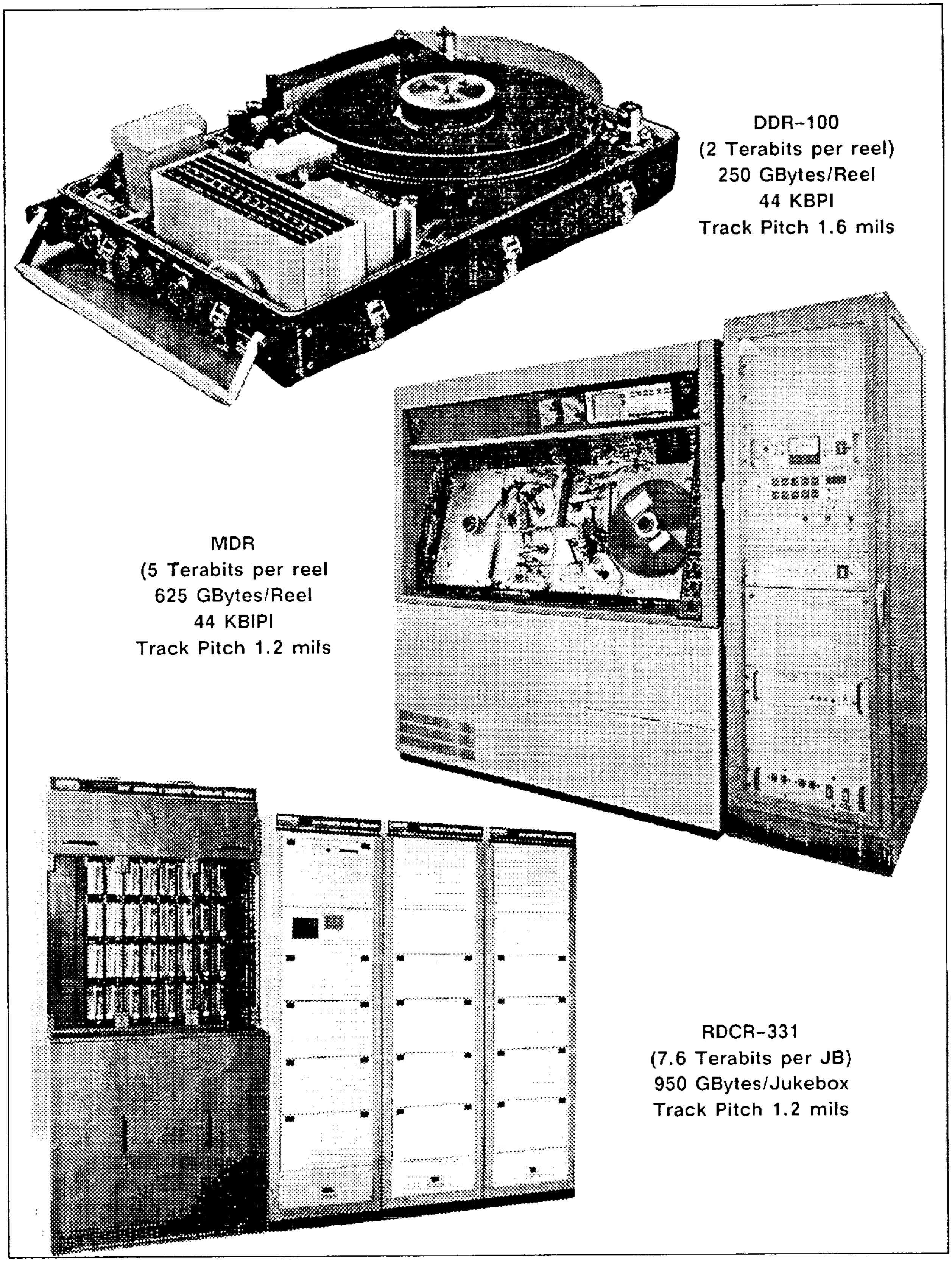


Figure 4. Recent DATATAPE Helical Scan Digital Data Recorders

Not included in this paper are detailed statistics on a series of 4mm helical scan tape cartridge machines which are based on DAT (digital audio tape) consumer products. Generally speaking, they have transfer rates of 0.19 megabytes per second, read-after-write, storage capacity of 1.25 gigabytes per cartridge, CBER < 1 error in 10^{15} bits, and SCSI-1 and PERTEC interfaces. The machines use 1400 Oersted metal particle tape available from a number of manufacturers. Systems are said to be available from Archive, Caliper, Gigatape, Gigatrend, Hewlett Packard, Hitachi, Sony, Wangtek, Wang Dat and others. There are two proposed standards. The most interesting aspect of these machines is their high data density: 61000 bpi with 535 micro-inch track spacing (1869 tpi).

Another helical scan storage system of note is the Masstor M-960 Cart Machine which operates with the Masstor M-1000 storage Library. These machines are 2 terabyte libraries with FIPS-60 Interfaces and are operated on-line for large enterprises.

HIGH PERFORMANCE 19MM HELICAL SCAN DIGITAL DATA RECORDERS

Several years ago, an industry and government working group was formed to generate a standard for a new 19mm digital data recorder (ID-1). The ID-1 standard would permit D-1 Digital Broadcast Tape Drives to be used with changes to the tape footprint and with new digital data electronics. The data electronics would incorporate Reed Solomon RS 4/5 Error Correction Circuitry and other desirable attributes, e.g., Scan Block ID and longitudinal search and annotation tracks. The machines would be available from several manufacturers and tape cassettes recorded on one manufacturer's machine could be reproduced on another's. This would avoid or at least mitigate the problem anticipated by some "that eternal copying from one format to the next will be necessary".[8] (If, in fact, some images may be required to be stored for very long periods, photographic film may be the media of choice, e.g., witness civil war photographs.)

The ID-1 Working Group included representatives from the following organizations (see Table 1):

Ampex
Bow Industries
Datatape Incorporated
Fairchild Weston (now Loral)
Honeywell (now Metrum)
Odetics
Memorex
RCA (now GE)
Sandia
Schlumberger
Sony
U.S. Government (NASA and DOD)

Table 1. ID-1 Standard Working Group

The dedicated effort of many individuals over an extended period of time resulted in the approval of the Standard by the American National Standards Institute, Inc., on December 7, 1989. It is identified as ANSI X3.175-1990, American National Standard for Information Systems - 19mm type ID-1 Recorded Instrumentation - Digital Cassette Tape Format; Secretariat, Computer and Business Equipment Manufacturers Association.

In the last two years, new ID-1 products have been announced by most of the companies represented on the working group. They include GE, Metrum, Loral, Sony, and Datatape. The cost to bring such new products to market is estimated to be in the millions of dollars, if not tens of millions of dollars.

At first the writer had planned to tabulate the performance values for the products offered, but on reflection, it was recognized that a mistake might be harmful. At any rate, the data recorded by one manufacturer can be reproduced by any other, right? Yes, we expect it can, but the data might not be useable, if the data has been compressed or encrypted, and the reproducer does not have the equivalent decompression or decryption equipment. The same applies to the use of external buffers and/or enhanced interleaving/error correction techniques. Because of this, an ANSI Working Group has been formed to draft a standard for the use of ID-1 machines modified to meet computer peripheral recorder requirements and meetings are in process.

It should be noted that the ANSI ID-1 standard does not prescribe data rate for recording or reproduction. Because of speed scaling, the foot print on tape is the same regardless of data rate, within limits. Accordingly, some manufacturers are offering machines with lower maximum data rates.

In the meantime, Datatape has announced the availability of a Variable Rate Buffer which can be used with the Datatape DCTR-LP series machines to provide read-after-write and rewrite capability with rates up to 50 megabytes per second using standard computer control and status interfaces with ECL data channels. The DCTR-LP machines can also be used with a CHI Systems interface to operate over a HIPPI channel with IPI-3 protocol. CHI Systems has also announced the availability of its IPI-3 and VME bus interfaces with other manufacturer's ID-1 products. The block diagram of CHI Systems HIPPI-DCTR-LP interface is shown in Figure 5.

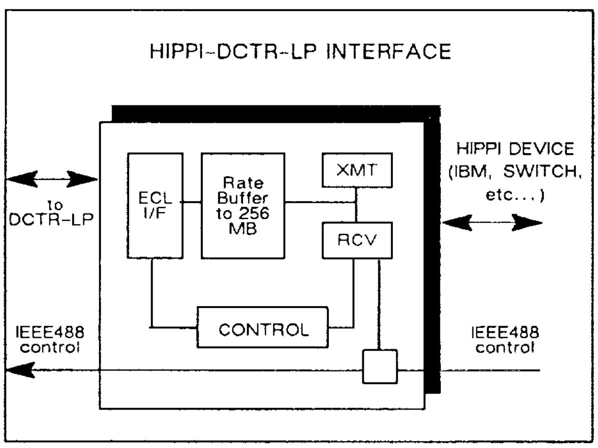


Figure 5. Chi Systems DCTR-LP ID-1 Interface

The Datatape Variable Rate Buffer has up to 448 megabytes of dynamic ram in order to buffer recorder data at rates up to 50 megabytes per second and to provide read-after-write and rewrite.

Some of the features of the Datatape ID-1 machine are illustrated in the following paragraphs as generally representative of all ANSI standard ID-1 machines. It will be noted that some of the illustrations include characteristics representative of MIL-STD-2179, e.g., zero azimuth tracks which are available from Datatape and others, but, generally speaking, this presentation is intended to highlight ID-1 azimuth recording tracks in which alternate scans are recorded with the azimuth shifted fifteen degrees; first in one direction, then the other. While azimuth recording may cause a slight reduction in SNR when exactly on track, the advantage achieved in raising tracking tolerances is considered advantageous for all concerned and is in keeping with the ANSI X3.175 standard.

A comparison of ferro fluid pictures of 0 degrees azimuth and +/- 15 degrees azimuth recording is shown in Figure 6.

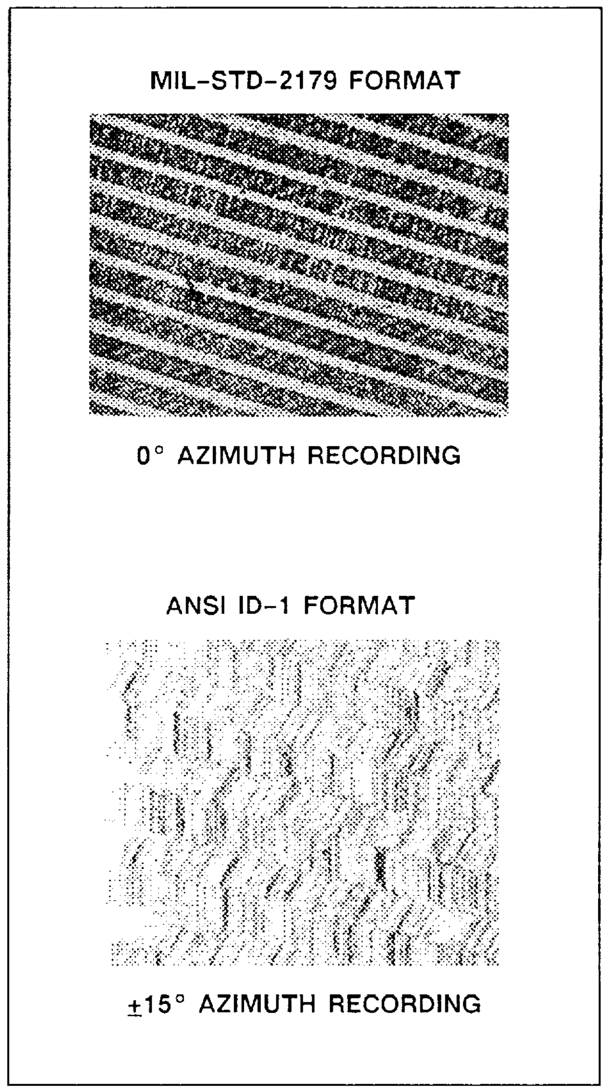


Figure 6. Azimuth Recording

Performance parameters of MIL-STD-2179/ ANSI ID-1 Data Recorders are shown in Figure 7.

To provide the reader with an appreciation for the head-to-tape interface for an ANSI ID-1 recorder, the tape format and the Datatape DCTR-LP series scanner is shown in Figure 8.

The thing to note is that at 10,380 RPM the head is literally moving at over 90 miles per hour along a track which is narrower than the diameter of an average human hair.

	SMPTE D-1 DTTR	400 Mbit/s RECORDER	300 Mbit/s RECORDER	200 Mbit/s RECORDER
DRUM DIAMETER	2.95 IN	2.95 IN	2.95 IN	2.95 IN
ACTIVE WRAP ANGLE	257°	256°	257°	258°
AZIMUTH	0°	+15° OR 0°	+15° OR 0°	+15° OR 0°
TRACK PITCH	1.8 MIL (45 µm)	1.8 MIL (45 µm)	1.8 MIL (45 µm)	1.8 MIL (45 µm)
SCANNER RATE	149.9 R/S	173.1 R/S	173.1 R/S	173.1 R/S
NUMBER OF HEADS	4	8	6	4
TAPE VELOCITY	11.3 IN/S	26.1 IN/S	19.5 IN/S	13 IN/S
HEAD-TO-TAPE SPEED	1401 IN/S	1632 IN/S	1625 IN/S	1619 IN/S
USER DATA RATE	179 Mbit/s	400 Mbit/s	300 Mbit/s	200 Mbit/s
TAPE DATA RATE	225.1 Mbit/s	533 Mbit/s	400 Mbit/s	265 Mbit/s
INSTANTANEOUS HEAD DATA RATE	78.7 Mbit/s	93.9 Mbit/s	93.5 Mbit/s	92.6 Mbit/s
LINEAR DENSITY	56 Kbit/IN	57 Kbit/IN	57 Kbit/IN	57 Kbit/IN
SPEED/RATE RANGE	SINGLE SPEED	8:1	8:1	8:1
CHANNEL CODE	RANDOMIZED	8/9 DC FREE CODE FOR VARIABLE SPEED. ANSI- ID-1 ALSO INCLUDES RANDOMIZING		
BER WITH ERROR CORRECTION	$1X10^{-6}$ W/ECC	$1X10^{-10}$ W/ECC (R/S)	$1X10^{-10}$ W/ECC (R/S)	$1X10^{-10}$ W/ECC (R/S)

Figure 7. MIL-STD-2179/ANSI ID-1 Data Recorders

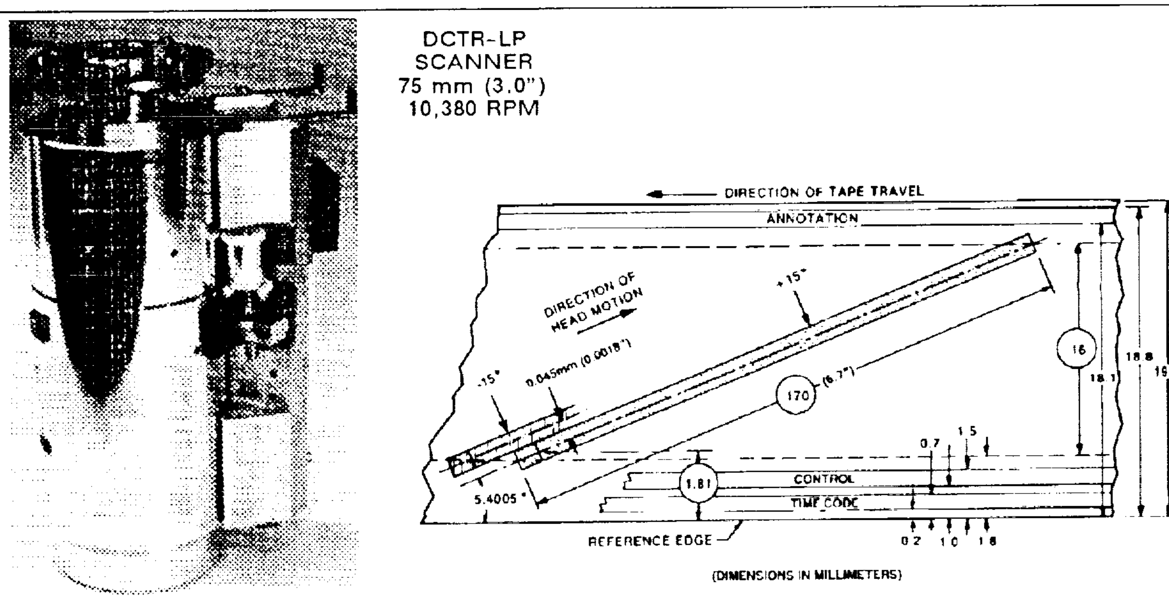


Figure 8. Tape Format and DCTR-LP Scanner

Perhaps more remarkable is the nature of the head itself shown in Figure 9. The head gap length is only 0.3 micro-meters. This is one half the wavelength of visible light (average 0.6 µm). Therefore, since the gap length is shorter than the wavelength of light, the headgap cannot be viewed directly with an optical microscope. It is viewed only by a scanning electron microscope (SEM). Is it any wonder then that optical 3.5" and 5.25" disks have linear recording densities of only 31.8 kilobits per inch (kbpi) compared to 57 kbpi for the ID-1 machine, 75 kbpi for the 8mm Helical Scan Machine, and 38 kbpi for the 3480.[9] The point to be made in comparing the linear density of the magnetic recorders to the optical disks is not to say that the magnetic recorder is superior, per se. They are in the same general ball park with regard to linear track density, but tape has other obvious advantages like data rate, capacity, and cost per megabyte.

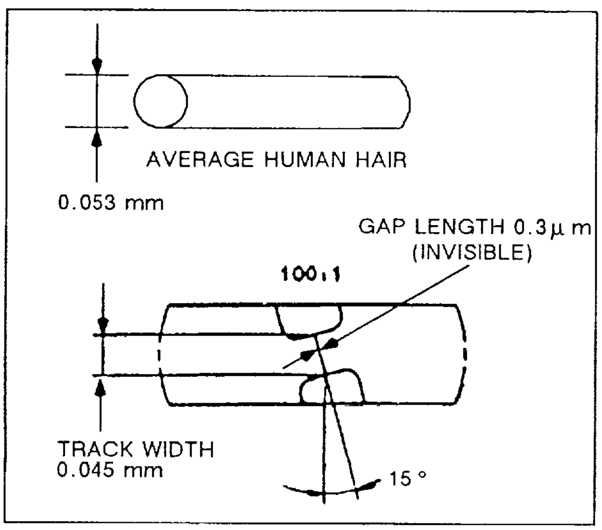


Figure 9. ANSI ID-1 Record Head used on DCTR-LP Series Recorders

The rotary headwheel for the DCTR-LP series ID-1 machines is shown in Figure 10. There are 16 sections on the rotary transformer making it possible to use up to 8 record heads and 8 reproduce heads to achieve a 50 megabytes per second data rate. It should be noted that to go from 25 megabytes per second to 50 megabytes per second it is not necessary to push the record and reproduce circuitry for higher frequency performance; it is merely necessary to use more circuits, i.e., head drivers, pre-amps, equalizers, etc.

The tape cassettes used in the ANSI ID-1 machines are shown in Figure 11. Please note that 13 µm tape is listed as well as 16 µm tape even through, at this time, only 16 µm thick tape (0.4") tape is being used in ID-1 machines.

The Datatape ID-1 Laboratory Machine, the DCTR-LP series, is illustrated in Figure 12. These machines are designed for 19-inch rack mounting either as one unit 30 inches deep or as two units side by side (see Figure 12). This laboratory version of the Datatape DCTR uses a tape drive developed by BTS in Germany together with the data electronics unit developed at Datatape in Pasadena.

An airborne version of the ID-1 machine is shown in Figure 13. It has been designed to meet MIL-E-5400 environments. This machine is manufactured in Pasadena, except for the scanner which is made in the Datatape, Santa Clara, California Facility.

The ID-1 machines designed for digital data collection and for mass storage with data buffering, represent a broad industry push to satisfy a generation of digital data storage requirements. A conservative approach has been taken in advancing the ID-1 designs as noted below:

1. Track Spacing: 0.045mm (0.0018") The tracks are contiguous on tape (no lost space) and the tracks are generous, both in width and bit density. This is important when using the machine for recording or reproducing short bursts where longer time intervals are not available, e.g., to lock-up head tracking servos.

2. The 850 Oersted tape also represents a conservative design approach. It uses cobalt treated gamma ferric oxide tape which has been proved in over 20 years of service.

3. High data rates and storage capacities are achievable with current designs, i.e., 50 megabytes per second vs 15 megabytes per second for the D-2 based digital data recorder discussed briefly below.

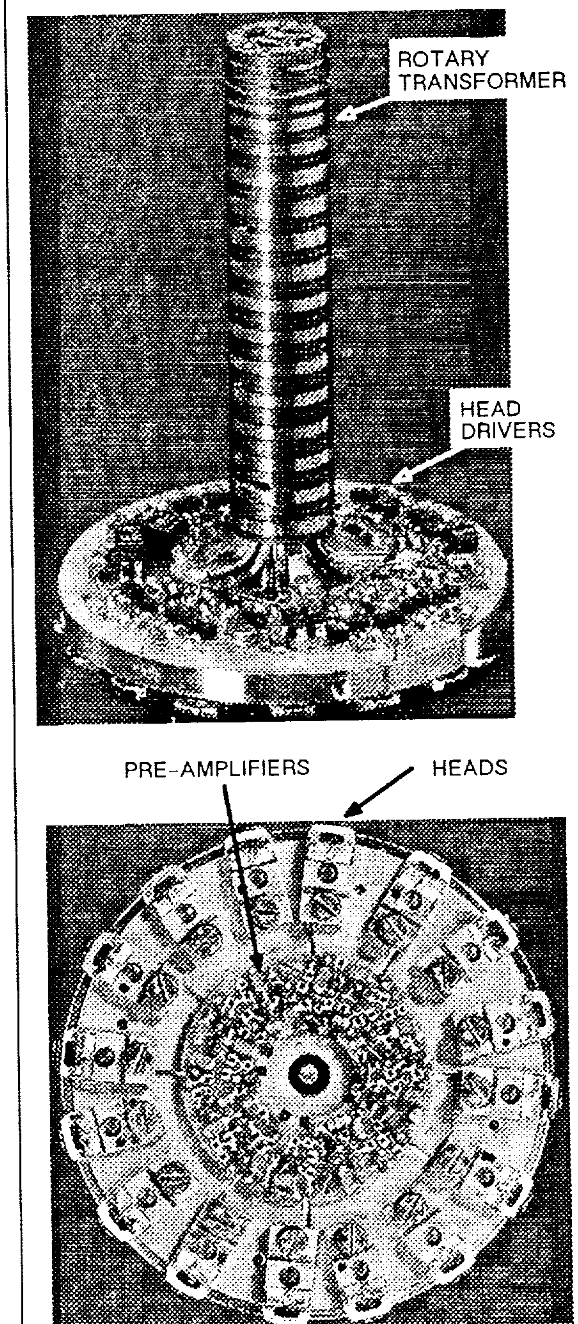
4. With multiple suppliers of equipment designed to standards, it is highly unlikely that a user will get caught with an archive and no way to reproduce the data.

Ampex Corporation has announced a new R-90 product based on using their VPR-300 D-2 Rotary Digital Video Broadcast Machine for digital data storage applications. Some of its published features are listed in Table 2 below.

- Helical scan recorder
- 15 Megabyte per second transfer rate
- IPI-3 interface
- 300 inch per second shuttle speed
- 150 inch per second search speed
- Accepts three sizes of cassettes
  - Small cassette holds 25 gigabytes
  - Medium cassette holds 75 gigabytes
  - Large cassette holds 165 gigabytes
- Less than one permanent read error per 10^{12} bytes read
  - Interleaved Reed-Solomon ECC
  - Read-after-write with selectable rewrite
  - Automatic reread for soft errors

Table 2. Ampex R-90 Recorder Features

Ampex has initiated an effort to establish an ANSI standard for the R-90 machine. So far, to the writers knowledge, no other manufacturer has announced plans to manufacture a compatible machine, but all of the ID-1 manufacturers will be represented on the working group.



SEPARATE POWER REGULATORS ON HEAD WHEEL FOR HEAD DRIVERS AND PRE-AMPLIFIERS

DATA RATE	NUMBER RECORD HEADS	NUMBER REPRO HEADS	HEAD DRIVERS	PRE-AMPS
200 Mbit/s	4	4	4	4
300 Mbit/s	6	6	6	6
400 Mbit/s	8	8	8	8

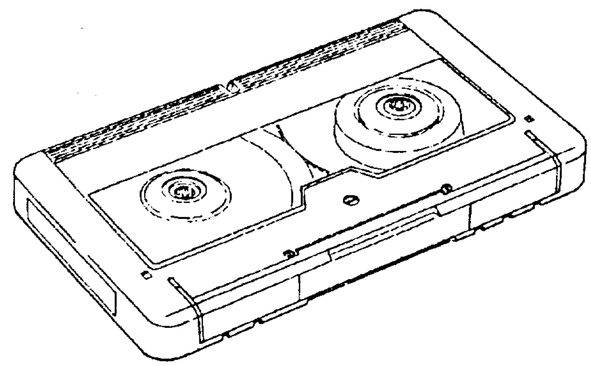
Figure 10. Rotary Headwheel for the DCTR-LP Series ID-1 Machines

CASSETTE STORAGE

	16 µm TAPE	13 µm TAPE
D-1S	$1.1X10^{11}$ BITS	$1.5X10^{11}$ BITS
D-1M	$3.4X10^{11}$ BITS	$4.5X10^{11}$ BITS
D-1L	$7.6X10^{11}$ BITS	$1X10^{12}$ BITS

RECORD TIME AT 200 Mbit/s

D-1S	9.5 MINUTES	12 MINUTES
D-1M	30 MINUTES	37 MINUTES
D-1L	66 MINUTES	82 MINUTES



TAPE

COERCIVITY: 850 Oe

ENHANCED IRON OXIDE

USABLE TAPE LENGTH	16 µm THICK (0.6 MIL)	13 µm THICK (0.5 MIL)	CASSETTE SIZE
D-1S	620 FEET	735 FEET	1.3 IN X6.77 IN X4.29 IN
D-1M	1,922 FEET	2.319 FEET	1.3 IN X10.0 IN X5.9 IN
D-1L	4,298 FEET	5,318 FEET	1.3 IN X14.4 IN X8.1 IN

Figure 11. ANSI ID-1 Tape Cassettes

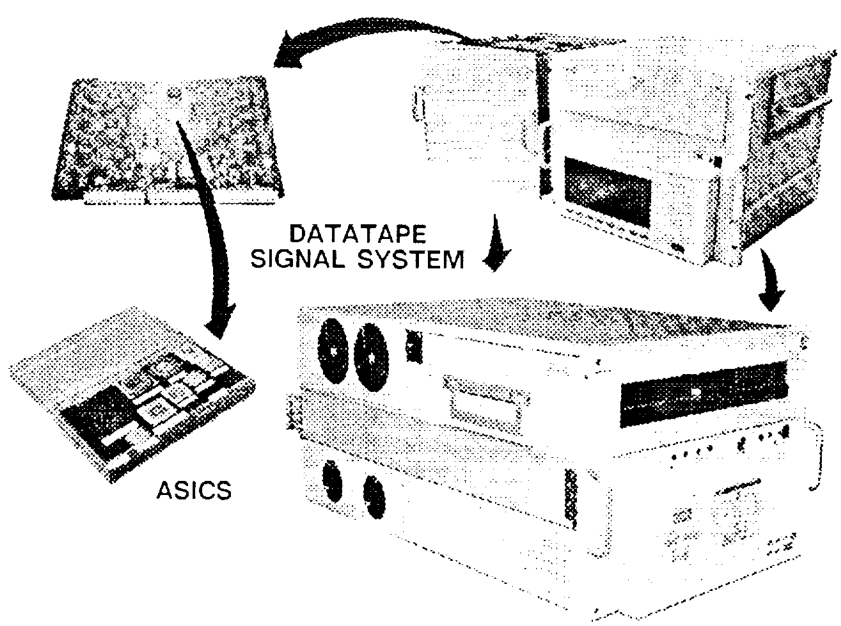
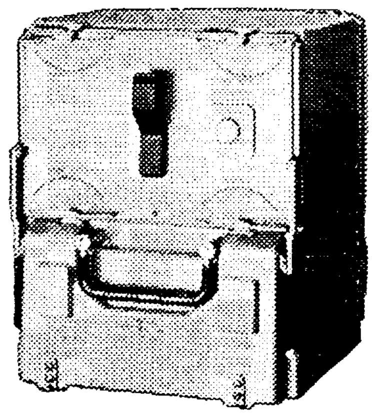
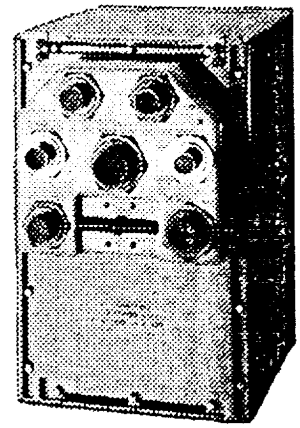


Figure 12. Datatape ID-1 Laboratory Machine, the DCTR-LP Series



TAPE TRANSPORT UNIT
(TTU)



RECORD/REPRODUCE UNIT
(RRU)

Figure 13. Airborne ID-1 Machine, the DCTR-A120

FUTURE DEVELOPMENT

New and exciting developments are evolving from research in magnetic tape recording, particularly with respect to tape and magnetic heads.

It seems that everywhere you turn there is a new recorder product using metal particle 1400 or 1500 Oersted tape, e.g., 4mm DAT, 8mm, 1/2" M-2/D-3, and 19mm D-2. Since the magnetic field required to magnetically saturate the metal particle tape is higher than for conventional tapes, new heads are required. Ferrite heads saturate at lower field strengths. Accordingly, new heads such as metal-in-gap heads have been widely used.

DATATAPE and Kodak Research Laboratories have developed new metal laminated heads which work very well with higher coercivity metal particle tape. These heads have permitted an increase of per channel data rates from 50 to 200 megabits per channel. This means that a machine with 8-record and 8-reproduce channels will be able to operate at 1,600 megabits per second (200 Megabytes per second), a rate substantially higher than that required for HDTV.

We are following closely, on-going development of barium-ferrite as well as metal particle tape, and we look forward to the panel discussion at this conference.

SUMMARY

The machines required for storage and retrieval of bit files of any length are more demanding than those designed for streaming disk back-up or continuous video recording. Data integrity and reliability are absolute requirements. In addition, data recorded on a cassette in one machine must be reproducible in another machine.

To achieve these goals, great care must be exercised in the design of tape guidance and servo coupling between the scanner control track, the tape drive capstan and reel motors; but most importantly, designs must be generous where it also counts, i.e., track width and bit density.

All tape recorders experience errors when writing and reading data to and from magnetic tape. The approach must be to minimize the factors which contribute to errors (tape quality and tracking) and to incorporate robust error correction means to improve performance (interleaving, coding, and write-read and rewrite).

The ANSI ID-1/DD-1 machines incorporate the desirable features for current generation high speed, high capacity digital data recorders. The next year should prove to be very exciting as the new generation of 19-mm machines enter service in data storage applications.

ACKNOWLEDGMENTS

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REFERENCES

1 Mukherjee, Biswanath, "Integrated Voice-Data Communications over High-Speed Fiber Optic Networks," Computer, IEEE Computer Society, February 1991, pp. 49-57.

2 The Top 1000 U.S. Companies, Business Week, 1991 Special Issue, 1991, pp. 100-208

3 Wood, Roger, "Denser Magnetic Memory," IEEE Spectrum, May 1990, pp. 32-38

4 Advertisement by Seagate, Computer Technology Review, May 1991, pp. 24-25.

5 Kryder, Mark R. and Seger, Paul J., "The special section on Magnetic Information Storage Technology," Guest Editor, Proceedings of IEEE, Vol 74, No. 11, Nov. 1986, pp. 1475-1476.

6 Mallinson, John C., "Achievements in Rotary Head Magnetic Recording," Proceedings of the IEEE, Vol. 78, No. 6, 1990, pp. 1004-1006.

7 Cannon, Max R. and Seger, Paul J., "Data Storage on Tape." Magnetic Recording Handbook, C. Dennis Mee and Eric D. Daniel, McGraw-Hill, 1990, pp. 815-882.

8 Mallinson, John G., "Magnetic Tape Recording: Archival Considerations," Tenth IEEE Symposium on Mass Storage Systems, IEEE Catalog No. 90CH2844-9, May 1990, pp. 58-60.

9 Katzive, Bob, "Product Projections," IIST Workshop VI, Lake Arrowhead, October, 1990, Session VII, p. 2.

MAGNETIC TAPE

HARRISS ROBINSON

DATATAPE INCORPORATED

23 JULY 1991

OVERVIEW

- DATA STORAGE AND PROCESSING ENVIRONMENT
- MAGNETIC TAPE TECHNICAL PERSPECTIVE
- CONTEMPORARY DIGITAL DATA RECORDERS
- HIGH PERFORMANCE 19mm HELICAL SCAN DIGITAL DATA RECORDERS
- FUTURE DEVELOPMENT
- SUMMARY

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DATA STORAGE AND PROCESSING ENVIRONMENT

- MOVE TO VISUALIZATION REQUIRES
  - VERY LARGE FILES FOR IMAGES VS ALPHANUMERIC FILES (1000 TO 1)
  - CHANGES IN DESIGN OF PROCESSORS

- IMPROVED DATA COMMUNICATIONS THROUGH NETWORK BUSES

  HIGH DATA RATES

  PACKET SWITCHING PROTOCOLS

  FIBER CHANNELS

  DISTRIBUTED COMPUTING

  MORE AND LARGER MASS STORAGE SYSTEMS

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MAGNETIC RECORDING IS A ROBUST TECHNOLOGY

- ANNUAL SALES OF MAGNETIC RECORDING PRODUCTS EXCEED $50 BILLION
- IBM IS LARGEST US COMPANY IN TERMS OF MARKET VALUE *
  — $74,996,000,000 (GM W/EDS AND HAC — $29,838,000,000)
- SEAGATE SHIPPED SEVEN MILLION DISK DRIVES IN 1990
- SALES OF MAGNETIC TAPE PRODUCTS SOARED IN 1990
  (IBM STORAGE TECHNOLOGY, EXABYTE, ET. AL.)

* Business Week, May 1991

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MAGNETIC TAPE TECHNICAL PERSPECTIVE

- Which Came First Magnetic Storage or Computers?
- Magnetic Recorders Store Data Differently Than Semiconductor Memories
  - Semiconductor Memories Store 1s and 0s by Controlling The State of Semiconductor Devices
  - Magnetic Recorders Store 1s and 0s as Domains of Spinning Electrons in a Thin Layer of Ferromagnetic Particles

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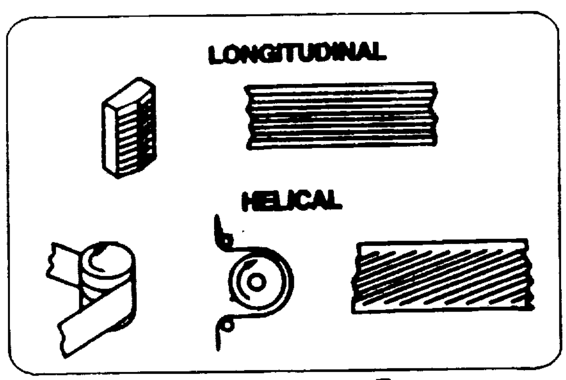
MAGNETIC TAPE TECHNICAL PERSPECTIVE

- Common Recording Techniques
  - Longitudinal Tracks (9, 18, 28, 42, 84 TRACKS)
  - Rotary Scanning
    - Helical
    - Transverse



Magnetic Tape Recording Techniques

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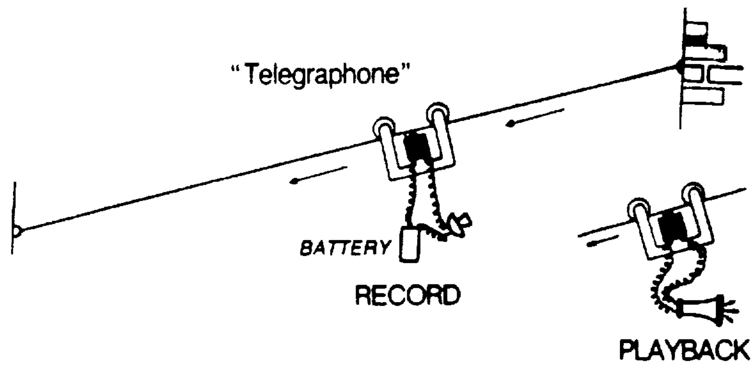
HISTORICAL PERSPECTIVE

- FIRST MAGNETIC RECORDING BY PAULSEN 1898



(Magnetic Recording Handbook, by Marvin Camras)

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HISTORICAL PERSPECTIVE (Cont'd)

- LATE 1940s - BEGINNING WIDESPREAD USE OF LONGITUDINAL ANALOG RECORDING OF COMPLEX WAVEFORMS (INSTRUMENTATION, AUDIO, AND VIDEO)
- EARLY 1950s - 7-TRACK AND LATER 9-TRACK LONGITUDINAL RECORDERS SELECTED FOR COMPUTER DIGITAL DATA RECORDING
- 1956 AMPEX INVENTED TRANSVERSE SCAN FOR VIDEO BROADCASTING TV RECORDERS
- 1958 - RCA INTRODUCED TRANSVERSE SCAN VIDEO BROADCAST MACHINES FOR TV BROADCAST
- 1968 - DAMRON, et. al., EARLIEST USE OF ROTARY HEADS TO ACHIEVE HIGH INFORMATION DENSITY FOR COMPUTER DATA (AMPEX)

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HISTORICAL PERSPECTIVE (Cont'd)

- 1970s AND 1980s –
  - 1/4-INCH AND 1/2-INCH TAPE CARTRIDGES WERE INTRODUCED FOR LONGITUDINAL DIGITAL DATA RECORDING
  - DATATAPE INTRODUCED SYSTEM 600, AND 84-TRACK DIGITAL DATA RECORDER WITH SELECTABLE RECORD AND REPRODUCE RATES FROM 6.25 TO 56 MBPS
- 1980s – DATATAPE INTRODUCED SEVERAL HIGH DATA RATE, HIGH STORAGE CAPACITY, HELICAL SCAN DIGITAL RECORDERS FOR DoD. (SEE NEXT VG)
  - THE RDCR IS A MASS STORAGE SYSTEM WITH AUTOMATED CASSETTE HANDLING
  - MODIFIED RDCR TAPE DRIVES ALSO USED WITH NEC JUKEBOX
  - RDCR ALSO USED IN COMMERCIAL MASS STORAGE SYSTEM SOLD BY MASSTOR CORPORATION

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CONTEMPORARY DIGITAL DATA RECORDERS

- 3480/3490 IBM, STORAGE TECHNOLOGY, et. al.
  - LARGEST SALES VOLUME PRODUCT
  - 1/2-INCH LONGITUDINAL TAPE (CARTRIDGE)
  - FIPS-60 INTERFACE
  - DATA RATE: 3–4 MBPS
  - STORAGE CAPACITY: 200 MB
  - SALES PRICE OF TAPE DRIVES: $10,000 TO $20,000 EACH; CARTRIDGE APPROXIMATELY $6 EACH
  - AVAILABLE IN STORAGE TEK™ ACL–4000 AUTOMATED STORAGE SILOS (UP TO 6000 CASSETTES STORING OVER 1 TERABYTE)

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CONTEMPORARY DIGITAL DATA RECORDERS (Cont'd)

- 8-mm Helical Scan Recorders
  - Manufactured by EXABYTE Using SONY 8mm Tape Drive With EXABYTE Electronics
  - Sold Through System Integrators and Resellers for Small Computer Disk Back-up Applications
  - SCSI Interface
  - Standard Version
    - Burst Data Rate: 1.5 MBPS
    - Storage Capacity: 2.3 GB
    - 812 Tracks per inch
  - Higher Density Versions
    - Burst Data Rate: 3.0 MBPS
    - Storage Capacity: 5.0 GB
    - 1638 Tracks per inch
  - Uses Metal Particle Tape
  - Value Added Suppliers: MEGATAPE, SUMMUS, et. al.

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CONTEMPORARY DIGITAL DATA RECORDERS (Cont'd)

- 1/2-Inch METRUM VLDS Helical Scan Tape Cartridge Machine
  - Manufactured By METRUM Using a MATSUSHITA VHS Tape Drive with METRUM Electronics
  - Sold In Volume Directly By METRUM
  - TTL, SCSI-1, VME, and VAX DRB Interfaces
  - Single Channel Version
    - Data Rate: 1.5 MBPS
    - Cassette Storage Capacity: 5.2 GB (10 GB AVAILABLE)
  - Dual Channel Version
    - Data Rate: 3 MBPS
    - Cassette Storage Capacity: 5.2 GB (10 GB AVAILABLE)
    - Read-After-Write Version CBER: 1 ERROR IN 10^{12} BITS
    - Cobalt Doped Gamma Ferric Oxide Tape
    - Available With Automatic Cartridge Changer Holding Up to 600 Cartridges

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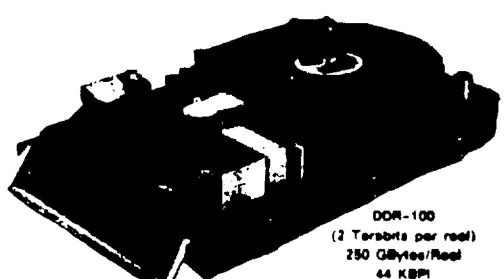
CONTEMPORARY DIGITAL DATA RECORDERS (Cont'd)

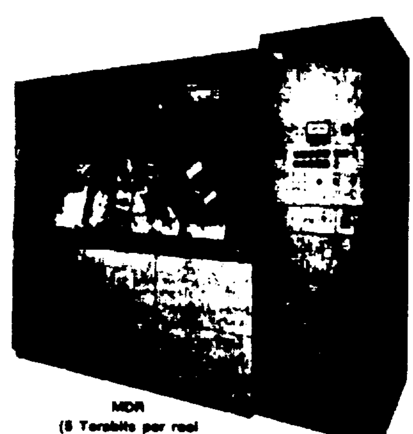
- 1-INCH AMPEX DCRSi TRANSVERSE SCAN MACHINE
  - DATA RATES UP TO 13.4 MBPS USING A 96 MB BUFFER
  - STORES 47.5 GB PER CARTRIDGE
  - AVAILABLE WITH EITHER A SERIAL OR 8-BIT PARALLEL TTL INTERFACE AND RS-232 OR RS-422 CONTROL AND STATUS INTERFACE
  - COBALT DOPED GAMMA FERRIC OXIDE TAPE
  - THE TAPE FORMAT AND TAPE CARTRIDGE ARE AMPEX PROPRIETARY
  - SEVERAL HUNDRED MACHINES ARE IN SERVICE

CONTEMPORARY DIGITAL DATA RECORDERS (Cont'd)



DDR-100
(2 Terabits per reel)
250 GBytes/Reel
44 KBPI
Track Pitch 1.6 mils

RDCR-331
(7.6 Terabits per JB)
950 GBytes/Jukebox
Track Pitch 1.2 mils



MDR
(5 Terabits per reel)
625 GBytes/Reel
44 KBPI
Track Pitch 1.2 mils

CONTEMPORARY DIGITAL DATA RECORDERS (Cont'd)

- 4-mm HELICAL SCAN TAPE CARTRIDGE MACHINES
  - Available From: ARCHIVE, CALIPER, GIGATAPE, GIGATREND, HEWLETT PACKARD, HITACHI, SONY, WANGTEK, WANG DAT, et. al.
  - Transfer Rates of 0.19 MBPS, Read-After-Write Capability 1.25 GB per Cartridge, CBER < 1 Error in 10^{15} Bits, SCSI-1 and Pertec Interfaces
  - Two Proposed Standards
  - High Density - 61000 BPI and 1869 TPI
- Masstor M-960 Helical Scan Cart Machine
  - Up to 8 M961 Helical Scan Storage Modules @ 110 GB Each
  - M-1000 User Capacity 1,011 GB
  - Stores Up to 6 Terabytes w/Data Compression
  - Information Storage and Retrieval on Line, Centralized, Erasable, Mainframe Attached, System Managed Storage Unit With Application Software
  - Supports From 4 to 8 IBM Hosts (4.5 MBPS)

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HIGH PERFORMANCE 19-mm HELICAL SCAN DIGITAL TAPE RECORDERS

- April 1986 - Industry and Government Working Groups Formed to Generate a New ANSI Standard for a 19mm ID-1 Instrumentation Recorder
- Use SMPTE std 19-mm Digital Video TV Tape Drives with each Mfgrs Newly Designed Digital Data Electronics
  - Scan Tracks on Tape to be Continuous Instead of Segmented Component Video Format
  - Use RS 4/5 ECC, Scan Block ID, and Longitudinal Search and Annotation Tracks
  - Crossplay of Cassettes Could be Demonstrated

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HIGH PERFORMANCE 19-mm HELICAL SCAN DIGITAL TAPE RECORDERS

- ID-1 WORKING GROUP INCLUDED REPRESENTATIVES FROM

  AMPEX
  BOW INDUSTRIES
  DATATAPE INCORPORATED
  FAIRCHILD WESTON (NOW LORAL)
  HONEYWELL (NOW METRUM)
  ODETICS
  MEMOREX
  RCA (NOW GE)
  SANDIA
  SCHLUMBERGER
  SONY

  U.S. GOVERNMENT (NASA AND DoD)

- APPROVAL OF NEW STD-7 DECEMBER 1989

  ANSI X 3.175-1990 - 19mm TYPE ID-1 RECORDED INSTRUMENTATION - DIGITAL CASSETTE FORMAT; SECRETARIAT, COMPUTER AND BUSINESS EQUIPMENT MANUFACTURERS ASSOCIATION

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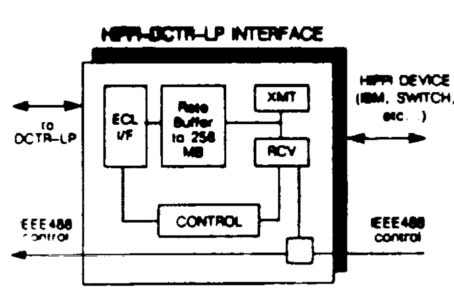
HIGH PERFORMANCE 19-mm HELICAL SCAN DIGITAL TAPE RECORDERS

- NEW PRODUCTS ANNOUNCED IN LAST TWO YEARS BY

  GE, METRUM, LORAL, SONY, AND DATATAPE

- DATATAPE INCORPORATED VARIABLE RATE BUFFER TO OPERATE UNDER PROTOCOL CONTROL FROM MATCHING ID-1 RECORDER TO HOST SYSTEM DATA RATES (0 TO 50 MBPS) AND PROVIDE READ-AFTER-WRITE AND REWRITE
- SYSTEM ALSO PROVIDED BY DATATAPE AND OTHERS WITH CHI SYSTEMS INTERFACE



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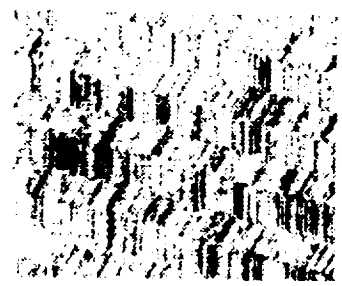
HIGH PERFORMANCE 19-mm HELICAL SCAN DIGITAL TAPE RECORDERS

- ANSI X3.175 STANDARD SPECIFIES AZIMUTH RECORDING, BUT NON-AZIMUTH RECORDERS ARE AVAILABLE FOR MIL-STD-2179

MIL-STD-2179 FORMAT

0° AZIMUTH RECORDING

ANSI ID-1 FORMAT



+15° AZIMUTH RECORDING

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HIGH PERFORMANCE 19-mm HELICAL SCAN DIGITAL TAPE RECORDERS

- PERFORMANCE PARAMETERS OF ANSI ID-1 RECORDERS

	SMPTE D-1 DTTR	400 Mbit/s RECORDER	300 Mbit/s RECORDER	200 Mbit/s RECORDER
DRUM DIAMETER	2.95 IN	2.95 IN	2.95 IN	2.95 IN
ACTIVE WRAP ANGLE	257°	256°	257°	258°
AZIMUTH	0°	+15° OR 0°	+15° OR 0°	+15° OR 0°
TRACK PITCH	1.8 MIL (45 μm)	1.8 MIL (45 μm)	1.8 MIL (45 μm)	1.8 MIL (45 μm)
SCANNER RATE	149.9 R/S	173.1 R/S	173.1 R/S	173.1 R/S
NUMBER OF HEADS	4	8	6	4
TAPE VELOCITY	11.3 IN/S	26.1 IN/S	19.5 IN/S	13 IN/S
HEAD-TO-TAPE SPEED	1401 IN/S	1632 IN/S	1626 IN/S	1619 IN/S
USER DATA RATE	179 Mbit/s	400 Mbit/s	300 Mbit/s	200 Mbit/s
TAPE DATA RATE	225.1 Mbit/s	533 Mbit/s	400 Mbit/s	265 Mbit/s
INSTANTANEOUS HEAD DATA RATE	78.7 Mbit/s	93.9 Mbit/s	93.5 Mbit/s	92.6 Mbit/s
LINEAR DENSITY	56 Kbit/IN	57 Kbit/IN	57 Kbit/IN	57 Kbit/IN
SPEED/RATE RANGE	SINGLE SPEED	8:1	8:1	8:1
CHANNEL CODE	RANDOMIZED	8/9 DC FREE CODE FOR VARIABLE SPEED. ANSI- ID-1 ALSO INCLUDES RANDOMIZING		
BER WITH ERROR CORRECTION	1X10-6 W/ECC	1X10-·0 W/ECC (R/S)	1X10-10 W/ECC (R/S)	1X10-10 W/ECC (R/S)

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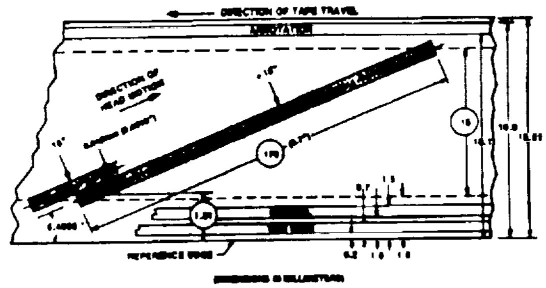
HIGH PERFORMANCE 19-mm HELICAL SCAN DIGITAL TAPE RECORDERS

- ANSI ID-1 TAPE FORMAT AND DATATAPE DCTR-LP SCANNER



NOTE TOP SPEED OF SCANNER AT 10,380 RPM THE HEADS ARE LITERALLY MOVING AT OVER 90 MPH ALONG A TRACK THAT IS NARROWER THAN A HUMAN HAIR

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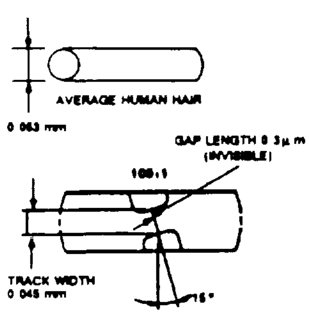
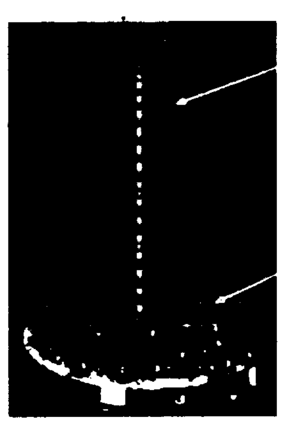
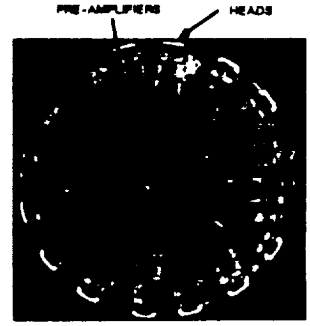
HIGH PERFORMANCE 19-mm HELICAL SCAN DIGITAL TAPE RECORDERS

- ANSI ID-1 RECORD HEAD USED ON DCTR-LP SERIES RECORDERS







SEPARATE POWER REGULATORS ON HEAD WHEEL FOR HEAD DRIVERS AND PRE-AMPLIFIERS

DATA RATE	NUMBER RECORD HEADS	NUMBER REPRO HEADS	HEAD DRIVERS	PRE-AMPS
200 Mbit/s	4	4	4	4
300 Mbit/s	[illegible]	[illegible]	[illegible]	[illegible]
400 Mbit/s	[illegible]	[illegible]	[illegible]	[illegible]

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AVERAGE DIAMETER OF A HUMAN HAIR*
(MILS)

DONOR	M/F (SEX)	MEASURED BY J. UDELL	L. VAIL	D. HOSKINS	MEAN
1. J. UDELL	(M)	2.0	2.0	2.0	2.0
2. H. ROBINSON	(M)	1.4	1.3	1.3	1.4
3. L. VAIL	(M)	2.3	2.3	2.3	2.3
4. M. VIERIA	(M)	2.7	3.0	2.7	2.8
5. K. STOFFERS	(F)	2.3	2.2	2.1	2.2

AVERAGE THICKNESS 2.1
(0.053 mm)

*DATA TAKEN AT DATATAPE 4/25/90

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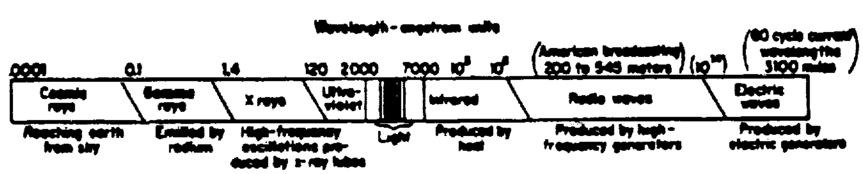
TERMINOLOGY / CONVERSION FACTORS

WORD	ABREV.	BYTES	BITS	NO. BYTES
BYTE	B	1	8	1^0
KILOBYTE	KB	1,000	8,000	10^3
MEGABYTE	MB	1,000,000	8,000,000	10^8
GIGABYTE	GB	etc	etc	10^9
TERABYTE	TB	↓	↓	10^{12}
PETABYTE	PB	↓	↓	10^{15}
EXABYTE	EB	↓	↓	10^{18}
HARIBYTE	HB	(PROPOSED HERE TODAY)		10^{21}



Frequency X wavelength = velocity (2.99796 x 10^{10} cm per sec) = (186,000 miles per sec.; 1 angstrom = 10^{-10} m = 3.937 x 10^{-9} in.

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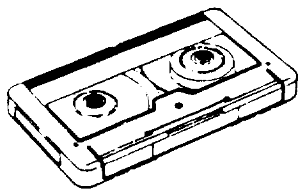
HIGH PERFORMANCE 19-mm HELICAL SCAN DIGITAL TAPE RECORDERS

- ANSI ID-1 TAPE CASSETTE



USABLE TAPE LENGTH	16 μm THICK (0 6 MIL)	13 μm THICK (0 5 MIL)	CASSETTE SIZE
D-1S	620 FEET	735 FEET	1 3 IN X6 77 IN X4.29 IN
D-1M	1.922 FEET	2.319 FEET	1.3 IN X10.0 IN X5.9 IN
D-1L	4.298 FEET	5.318 FEET	1 3 IN X14.4 IN X8.1 IN

CASSETTE STORAGE

	16 μm TAPE	13 μm TAPE
D-1S	1 1X10^{11} BITS	1 5X10^{11} BITS
D-1M	3 4X10^{11} BITS	4 5X10^{11} BITS
D-1L	7 8X10^{11} BITS	1X10^{12} BITS

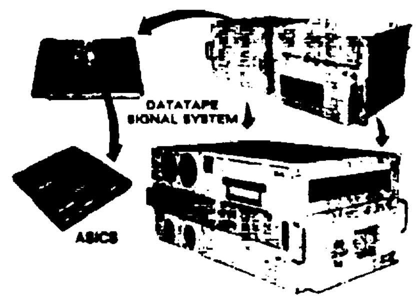
RECORD TIME AT 200 Mbit/s

	16 μm TAPE	13 μm TAPE
D-1S	9 5 MINUTES	12 MINUTES
D-1M	30 MINUTES	37 MINUTES
D-1L	66 MINUTES	82 MINUTES

TAPE

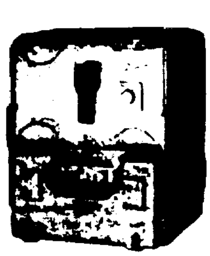
COERCIVITY 850 Oe
ENHANCED IRON OXIDE

- DATATAPE ID-1 DCTR-LP SERIES LABORATORY RECORDER

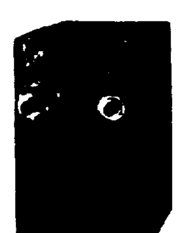


HIGH PERFORMANCE 19-mm HELICAL SCAN DIGITAL TAPE RECORDERS

- DATATAPE ID-1 DCTR-A120 SERIES AIRBORNE MIL-E-5400 RECORDERS



TAPE TRANSPORT UNIT (TTU)



RECORD/REPRODUCE UNIT (RRU)

HIGH PERFORMANCE 19-mm HELICAL SCAN DIGITAL TAPE RECORDERS

- ID-1 CONSERVATIVE DESIGN APPROACH
  - TRACK SPACING 0.045mm (0.0018")
  - 850 OERSTED GAMMA FERRIC OXIDE TAPE
  - HIGH DATA RATES ACHIEVED TO 50 MBPS
  - MULTIPLE SUPPLIER OF EQUIPMENT DESIGNED TO STANDARDS
- AMPEX R-90 HELICAL SCAN RECORDER BASED ON USING AMPEX VPR-300 D-2 ROTARY DIGITAL VIDEO BROADCAST MACHINE FEATURES
  - Helical scan recorder
  - 15 Megabyte per second transfer rate
  - IPI-3 interface
  - 300 inch per second shuttle speed
  - 150 inch per second search speed
  - Accepts three sizes of cassettes
    - Small cassette holds 25 gigabytes
    - Medium cassette holds 75 gigabytes
    - Large cassette holds 165 gigabytes
  - Less than one permanent read error per 10^{12} bytes read
    - Interleaved Reed-Solomon ECC
    - Read-after-write with selectable rewrite
    - Automatic reread for soft errors

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FUTURE DEVELOPMENT

- HIGH COERCIVITY TAPE
  FROM 850 OERSTED TO: TBD
- HIGH PERFORMANCE HEADS
  FROM FERRITE TO METAL-IN-GAP, TO METAL LAMINATED HEADS
- PER CHANNEL DATA RATES FROM:
  50 TO >200 MBPS ∴ 8-CHANNEL MACHINE WILL BE ABLE TO OPERATE AT OVER 1,600 MBPS (>200 MBPS), A RATE SUBSTANTIALLY HIGHER THAN REQUIRED FOR HDTV

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SUMMARY

- Machines Required For Storage of Bit-Files of Any Length are More Demanding Than Streaming Disk Back-Up or Continuous Video Recording
  - Data Integrity and Reliability Are Absolute Requirements
  - Data Recorded On A Cassette In One Machine Must Be Reproducible In Another Machine
- Designs Should Be Generous, e.g., Track Width and Bit Density
- Sound Approach is to Minimize Factors Which Contribute to Errors (Tape Quality and Tracking) and Incorporate Robust Error Correction (Interleaving, Coding, and Write-Read and Rewrite).
- ANSI ID-1/DD-1 Machines Incorporate the Desirable Features for Current Generation High Speed, High Capacity Digital Data Recorders.

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