MAGNETIC TAPE MANAGEMENT

A GUIDE TO ACHIEVING RELIABLE PERFORMANCE FROM YOUR COMPUTER TAPES.

NEW REVISED EDITION WITH 6250 BPI RECORDING DETAILS.

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FORWARD

Every tape user knows that a single reel of computer tape may contain virtually priceless information: the names and addresses of thousands of customers; the records of half a million dollars in retail transactions; the vital statistics of thousands of insurance policy holders.

Such tapes may be stored in special vaults under controlled temperature and humidity — at considerable cost. Yet other precautions, seemingly more basic, are overlooked in many instances.

Tape is only a thin plastic film coated with a carefully formulated dispersion of magnetic iron oxide in a resinous binder. Nevertheless, this relatively fragile ribbon is the bridge between men and information — a critical link which deserves the benefits of every precaution, no matter how trivial it may seem.

During normal operations, wear products consisting primarily of oxide and tape backing material become loosened and tend to adhere to and build up on the tape because of its inherent static charge. Through continued tape use they become adhered to the tape surface. Finally, from frictional heat and tape tension pressures they become embedded into the tape surface. These particles are the major cause of signal-loss dropouts and it is the height of these particles — that is, the distance that the particle causes the read or write head to be separated from the tape which, at only one thousandth of an inch from the tape, a signal loss of 87 percent occurs — reducing the signal amplitude below the effective detection level of the read amplifier. In fact, transient errors begin to occur when wear particles accumulate to a height of only HALF A THOUSANDTH OF AN INCH.

Dirt and other external influences and the resultant errors become a source of wasteful processing time. For example, write checks waste valuable processing time while the drives repeatedly create and recycle and re-try the contaminated area, and insert inter-record gaps. Furthermore this process imposes a strain on the tape far in excess of that encountered during normal operating conditions, and the friction involved will tend to aggravate any oxide shedding and cause the embedding of non-transient particles. In short, one error will often create a dozen more.

This guide has been prepared to provide the data processing user with a basic understanding of magnetic tape used as a computer memory. We hope that the information will provide a better understanding of both the advantages and problems with magnetic tape as well as the techniques available to obtain the maximum life and reliability from your computer tapes.

MAGNETIC TAPE

Basically, magnetic tape is constructed by coating iron oxide particles that can be magnetized onto a thin ribbon of plastic. The three basic materials used are (1) oxide, (2) binder, (3) base material or backing.

(1) OXIDE

The oxide coating is a magnetic layer consisting of oxide particles held in a binder that is applied to the base film. The ferro-magnetic material is gamma-ferric oxide, Fe_2O_3, in the form of acicular (needle shaped) particles less than one micron in length (1/1000 of a millimeter or 0.000039 inches). It is very important that the oxide coating be both uniform and smooth. For computer tapes, this means that the coating thickness must be 0.00045 inch or less along the entire length of tape. If the oxide particles are not uniform in size, the surface of the tape will be rough, making the tape more abrasive. This may cause reduced head life and greater oxide contamination. Non-uniformity in thickness produces variations in the average signal strength.

(2) BINDER

The binder is usually composed of organic resins used to bond the oxide particles to the base material. The actual composition of the binder is considered proprietary information by each magnetic tape manufacturer. The binder must be flexible though without having the oxide chip or flake off. If the consistency of the binder is sticky, the individual tape layers will adhere to each other when wound on a reel.

(3) BASE MATERIAL OR BACKING

The most common type of backing in use today for computer tape is Mylar, the DuPont trade name for polyethelene terephthalate. The chief advantages of this polyester over other base film is its stability under varying humidity, solvent resistance, and mechanical strength.

Other backing materials are in use today such as Tenzar (a 3M Co. product), polyvinyl chloride, and Luvitherm (a Badische Anilin and Soda – Fabrik AG product).

TAPE DIFFERENCES

Many factors affect the manufacture of a suitable tape. Even though many data processing users may buy tape from the same manufacturer, the tapes may not be exactly the same. This could be a difference in either the physical or magnetic properties. For a manager selecting and using magnetic tapes, it should be an aid to have a basic understanding of the specifications for magnetic tape.

This booklet will not explain the specifications in detail but attempts to give the manager a better understanding of the various requirements which determine magnetic tape's performance. Here are some of the most common requirements.

Dimensions

Length (Common)	1200 feet, plus 20 feet, minus 0 feet
	2400 feet, plus 50 feet, minus 0 feet
Width (Common)	0.498 inch, plus or minus 0.002 inch
Thickness	
Base material	0.00145 inch ± 10%
Oxide coating	0.00045 inch or thinner
Total	0.0019 inch ± 0.0003 inch

Physical Properties

Discontinuity	No splices are allowed which may deposit adhesive under pressure and/or cause a reduction of strength.
Cleanliness	The surface of the base and coating should be free from any dust, foreign matter, loose oxide, or flakes.
E Value	The radial distance between the outside layer of the tape and the outside of the reel. Generally, should not be less than one-eighth of an inch when wound on a 10½ inch reel.
Coating roughness	Roughness of the oxide surface
Backing roughness	Roughness of the polyester surface
Layer-to-layer adhesion	The adhesion of the oxide surface to the polyester surface of the next layer on the reel. This may, in unwinding, cause holes in the oxide coating or cinching resulting in errors.
Coating-to-backing adhesions	The force required to remove the oxide coating from the polyester surface. This is essential in preventing oxide coating removal under pressure encountered in the reel.
Curvature	Departure from a straight line of the longitudinal dimension of the tape (same direction as tape motion).
Cupping (humidity stability)	Departure across a tape at right angles to its length from a flat surface due to the different expansion characteristics of the coating and backing material.
Tensile strength	Shock tensile or elastic characteristic. The resistance of the backing to breakage or the ability to withstand the application of high force loads.

Yield strength	Yield force. The resistance of the backing to stretching.
Creepocity (elongation under stress)	The ability of the backing to return to its original length after stretching.
Wear resistance	The ability of the tape to resist the abrading action encountered on a magnetic tape transport.
Compatibility	The performance of other tapes must not be adversely affected by use of this tape on a tape transport.

Electrical Requirements

Coating Resistivity	The electrical resistance of the coating which is an indication of the ability of the tape to dissipate a static charge.
Signal Dropouts	A measure of temporary and permanent signal errors for the tape leaving the manufacturer's factory.
Average peak output	The average peak output on a magnetic tape referenced to the N.B.S. Amplitude Reference Tape SRM 3200.
$\emptyset$ — H Properties	A measurement of the oxide coating to retain the magnetism once the magnetizing force is removed.
Noise	False signals after erasure. Should not be greater than 10% of average peak output when the tape is saturated in one direction.

II GENERAL THEORY OF MAGNETISM

An artificial magnet can be formed by placing a bar of iron or steel in a coil of insulated wire and passing a current through the coil as shown in Figure 1. As the current passes through the coil, magnetic poles are formed as indicated with N representing the north pole and S the south pole. The bar is now magnetized.

The molecular theory of magnetism is illustrated in Figure 2. Figure 2A shows a piece of unmagnetized iron where each molecule is considered to be a tiny magnet. These molecular magnets are arranged in a random manner. The magnetism of each of the molecules is neutralized by adjacent molecules and no external magnetic effect is produced. When a magnetizing force is applied to the iron bar, the molecules align themselves so all N poles point in one direction and all S poles point in the other direction as shown in Figure 2B.

An artificial magnet may be classified as permanent or temporary depending on its ability to retain its magnetic strength after the magnetizing force has been removed.

Hardened steel and certain alloys are relatively difficult to magnetize and are said to have low permeability because the magnetic lines of force do not easily permeate, or distribute themselves readily through the steel. These materials, however, do retain a large part of their magnetic strength and are said to be permanent. This ability of a material to retain its magnetic strength is referred to as the retentivity of the material.

Soft iron has a high permeability and is called a temporary magnet due to the fact that it can retain only a small amount of its magnetic strength when the magnetizing force is removed.
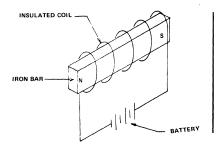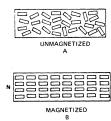
Figure 3 shows the magnetic field around a bar magnet. This field consists of imaginary lines along which a magnetic force acts. These lines emanate from the north pole of the magnet and enter the south pole, returning to the north pole through the magnet itself, thus forming closed loops. The entire quantity of magnetic lines surrounding a magnet is called magnetic flux and the number of lines per unit area is called flux density.

If a bar magnet is bent to form a loop without the ends touching as shown in Figure 4, it still remains a magnet with a north pole and a south pole and with a magnetic field that is of shorter length and greater concentration than the bar magnet.

One important characteristic of the imaginary lines in a magnetic field is that they tend to take the path of least resistance, or in other words flow through the material that has the greater permeability. Air offers more resistance to the lines of force than a piece of iron or steel.
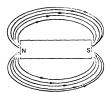
Figure 3. Magnetic Lines of Force

Figure 4. Magnetic Field of Horseshoe Magnet

If a piece of iron is brought into close proximity to the gap of the horseshoe magnet as shown in Figure 5, the lines of force will tend to bend so as to flow through the iron.

The piece of iron will become magnetized by the lines of force flowing through it. This characteristic of magnetism, referred to as induction, is utilized in the process of magnetic recording.
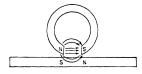

Figure 5. Lines of Force Inducing Magnetism

Figure 1 Forming an Artificial Magnet

Figure 2 Molecular Theory of Magnetism

If an electric current flows through a conductor (piece of wire) a magnetic field is built up around the current carrying conductor. Referring again to Figure 1, where a coil of wire is placed around a piece of iron and a current flows through the coil, the magnetic field of the coil magnetizes the iron bar. A device of this type is called an electromagnet.

An electromagnet is composed of a coil of wire wound around a core of soft iron. If an electric current flows through the coil, the core becomes magnetized with a particular polarity. If the direction of the current flow is reversed, the polarity of the magnetized core will reverse.

The core of the electromagnet may be in the shape of the horseshoe magnet as in Figure 4. An electromagnet of this configuration is basically the type of device used as a write head in a magnetic tape recorder.

In Figure 6, an electromagnet is shown with a magnet being passed close to the gap. As the magnet is passed, its lines of force will flow through the core of the electromagnet and a current will be induced in the coil. This is basically the idea behind reading information from a magnetic tape.
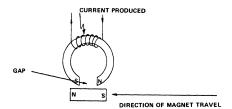

Figure 6. Inducing Current in a Coil

III MAGNETIC RECORDING

General

The fundamental method of magnetic recording involves the magnetization of minute areas of the surface of a highly retentive magnetic material. In order to reproduce the recorded information, the magnetic state of the material is read back by using the retained or residual magnetic flux to induce a signal in the read circuits. The method, commonly called surface recording, is used to record information on magnetic tape.

Magnetic surface recording is based on the interaction between a material (magnetic tape) and a magnetic head (transducer) in relative motion with respect to each other.

It was pointed out in the General Theory of Magnetism that a horseshoe magnet has an air gap through which a magnetic field or magnetic flux is present. This magnetic field is comprised of invisible lines of force that emanate from the north pole of the magnet and enter the south pole making a closed loop. The write (recording) head used in magnetic tape recording is basically an electromagnet similar to the horseshoe magnet discussed earlier.

Figure 7A is a simplified drawing of a write head. In this illustration current is not flowing in the coil and consequently a magnetic field is not present. In order to generate a magnetic field, a current must be induced in the coil as shown in Figure 7B. In this case current is flowing as indicated by the arrows and an electromagnet is formed with north and south poles as shown. A magnetic field is produced with lines of force as indicated. In Figure 7C, the direction of current flow has been reversed. It should be noted that the poles of the electromagnet are also reversed and therefore the direction of the lines of force are in the opposite direction. From this explanation, we can next see what occurs when a magnetic tape is brought into contact with the head. The fact has already been pointed out that magnetic tape is constructed of a plastic

base, coated with a material that has the capability of being magnetized and to retain that state of magnetization for an indefinite period of time.

Figure 8A shows the write head without current flowing in the coil, therefore, a magnetic field is not present and no change takes place on the surface of the magnetic tape. In Figure 8B, the head is shown with current flow as indicated and the resulting magnetic field. The magnetic field flows through the surface of the tape and changes the polarity of a small area as indicated. The current direction is reversed in Figure 8C and as shown, the reverse condition exists on the surface of the tape.
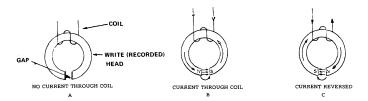

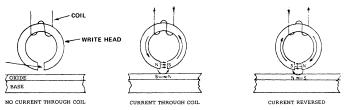Figure 7. Simplified Drawing of Write (Recording) Head

Figure 8. Writing on Magnetic Tape

It was previously pointed out that surface recording is dependent on relative motion between the record head and the tape. Figure 9A shows the relationship of a fixed recording head with magnetic tape moving in the direction shown. The illustration also shows one cycle of an alternating current and the resulting current flow through the coil. It should be noted that the current flow through the coil reverses during a change from a positive alternation to a negative alternation and the polarity of the recorded information on the tape also reverses.

Only one cycle has been shown to help explain the process of recording on tape. This could be continued for any number of cycles with each one establishing two definite areas of magnetized tape of opposite polarity as shown.

In the read (reproduce) operation, a previously written tape will be moved in the vicinity of the read head gap. The read head is quite similar in construction to the write head.

Figure 9B will be used in the explanation of a read operation. Again a stationary head is used with the tape being moved in the direction as shown. As the tape is passed under the read head the changing polarity of the recorded information on tape will induce a current in the read head coil. Note that a current is produced in the coil only when the magnetic field on the tape changes. When the information is read from tape, it in no way alters the magnetic state of the tape so a recorded tape can be read an indefinite number of times.

In the preceding discussion we have been concerned with an alternating current inducing a change in the magnetic state of the tape.

In recording digital information, used with digital computers, we are concerned with writing information represented by pulses which represent the binary states of "1" and "0."

While there are numerous schemes for recording digital information, only two are used widely today for computer data processing.

The first recording method that will be explained is the Non-Return-to-Zero, Change on Ones (NRZI). The second recording method is the phase encoding modulation (PE) mode.
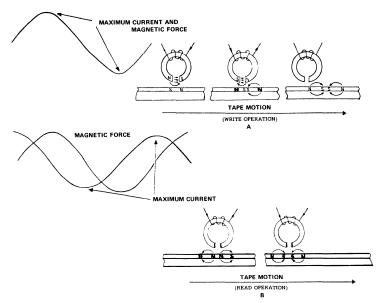
Figure 9. Writing and reading with Tape Motion Relative to Heads.

NRZI Mode

Figure 10 shows the write current applied to the coil of the write head, the flux configuration of the magnetized particles on tape, and the signal developed as the tape is read.

Note that a change in the write current occurs only when a "1" is to be recorded and during the period when "0's" are recorded the write current remains at the same level. A change in the flux pattern on tape occurs only when the write current changes ("1" is to be recorded). A change in the flux pattern on the tape does not occur if the write current does not change ("0's" are recorded).

During a read operation, a read signal is produced only when a change in the flux pattern on tape is encountered signifying that a "1" had been recorded. When a change in the flux pattern is not present, "0's" are read.

The advantage of NRZI recording is that more bits of information than flux changes can be written on and read from the tape. The disadvantage is that there is not a positive magnetic mark on the tape for each bit causing reduced reliability in recovering data from from an NRZI tape.
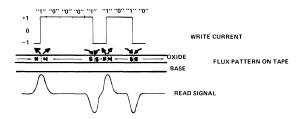

Figure 10. NRZI Recording

Phase Encoding Modulation Mode

The phase encoding modulation method (PE) records both "1" and "0" bits on tape by means of changes in current direction through the write head. As the current changes direction, the magnetic flux at the write head also changes direction. As the tape passes under the write head, the magnetic particles in the tape are aligned in a direction relative to the direction of the magnetic flux. The particles that are magnetized in one direction represent "1" bits, while the particles magnetized in the opposite direction represent "0" bits. Figure 11 illustrates the writing method used assuming the erase head flux is positive. Thus, a "1" is written when the head flux switches from negative to positive. The opposite is true when a "0" is written.
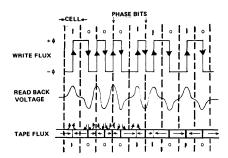

Figure 11. Phase Encoding Modulation Recording

Since the flux must go in a specified direction to write a data bit, it is sometimes necessary to establish the proper starting polarity for each bit. For example, if a "1" has been written, the flux is positive. In order to write another "1", the flux must return to a negative state before another "1" can be written. There is no problem if there is an intervening "0", since a "0" is written by a negative-going flux change. However, if two "1's" are to be written in succession, the flux must go negative before the second "1" can be written. This flux transition between two data bits is defined as a phase bit. The phase bit does not contain information. It only establishes the proper polarity if two identical bits ("1" or "0") are to be written in succession.

A cell is the time needed to transfer one data bit of information. Cell timing is maintained by the tape controller. A magnetic flux change is required for each of the 1600 data bits written per inch of tape and also for each phase bit written. Depending upon the pattern written, the total number of flux changes per inch will vary between 1600 and 3200 to write 1600 bits per inch.

By contrast with NRZI recording, PE requires two flux changes per bit of information. Because this is technically possible today, we are able to define each bit recorded both by one or two flux changes and a fixed polarity which have greatly enhanced the ability to recover data from a tape. Please note that single error recovery schemes utilizing lateral and longitudinal parity bits do not correct the magnetic flux on the tape itself.

IV COMPUTER TAPE WRITING/READING

General

Present day industry standards for compatible recording formats consist of a seven-track or nine-track NRZI recording scheme and a nine-track phase encoding modulation scheme. Figure 12 shows a recorded magnetic tape after it has been developed chemically.

Figure 12. Actual Recording on Magnetic Tape

NRZI

A line (frame) of tape data consists of a six-bit or eight-bit character and a parity (check) bit. Tracks 1 through 6 (seven-track format) or 1 through 3 and 5 through 9 (nine-track format) hold the character while track 7 (seven-track format) or 4 (nine-track format) holds the parity bit (Figure 13 and 14).

Data is recorded in one of two formats: binary or binary coded decimal (BCD). Tape is binary (seven-or nine-track format) if data is recorded just as it is represented in the core memory storage of the computer. In BCD format (seven-track only), digits, characters, and special symbols are represented in core storage by six-bit binary numbers.

5

Figure 13. Tape Format — Seven Track NRZI

NOTE: A 48-BIT COMPUTER WORD WOULD BE WRITTEN ON TAPE WITH 8 FRAMES
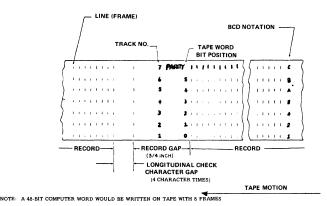
The formats also differ in the selection of parity bits. The parity bit in binary format is chosen so that the total number of "1" bits in any line is odd. In BCD format the total number of "1" bits must be even. The format is selected by the computer which also designates the correct parity bit that accompanies each character.

Recorded data on the tape is arranged in groups called records and files. A minimum of one line of information constitutes a record. Adjacent records are separated by a 3/4 inch (seven-track format) or 0.6-inch (nine-track format) unrecorded area (inter-record gap). A longitudinal record check (LRC) character is recorded in coded format at end of each record; the number of "1's" in each record track is made even. The nine-track record is followed by an LRC and a character redundancy check (CRC) character. The CRC is also recorded in coded format. The LRC is ineffective if two bits are dropped but the CRC is valid in all cases because it is the result of a half add of all bits in the record by the tape controller.

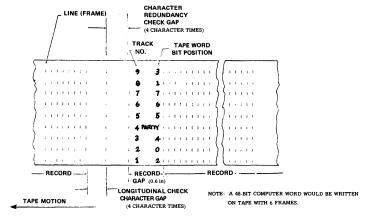NOTE: A 48-BIT COMPUTER WORD WOULD BE WRITTEN ON TAPE WITH 6 FRAMES.

Figure 14. Tape Format - Nine Track NRZI

A file consists of a group of records. Adjacent files are separated by recording an end of file mark following the last record in the file. The file mark normally consists of an octal 17 (BCD) and its check character (also an octal 17).

Phase Encoding Modulation

The identification burst shown in Figure 15 identifies the phase encoding modulation method of recording information to the controller. The burst consists of alternate "1's" and "0's" (1600 flux reversals per inch) written on track 4 only. During the burst, all other tracks are erased. A minimum gap of 0.6 inch must exist between the burst and the first block of data.

A data block consists of a preamble, data, and a postamble as shown in Figure 15. The preamble identifies the beginning of a block and consists of 41 characters. The first 40 characters are "0's" in all tracks and the last character is a "1" in all tracks.
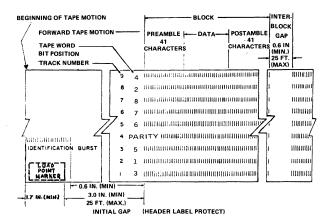

Figure 15. Tape Format — Phase Modulation

The postamble identifies the end of the data block. It consists of 41 characters which are a mirror image of the preamble; that is, the first character is a "1" in all tracks and the last 40 characters are "0's" in all tracks. The postamble also identifies the data block when performing a reverse read operation.

Data is recorded on the nine tracks shown in Figure 15. Track 1 is the track closest to the operator; the remaining eight tracks are numbered consecutively from 2 through 9. The track versus bit assignments are as follows:

Track:	1	2	3	4	5	6	7	8	9
Bit:	2	0	4	P	5	6	7	1	3

Track 4 is used to check character parity on information in the other eight tracks. If an even number of "1's" is written in the eight information tracks, a "1" will be written in track 4 to give an odd parity check. If an odd number of "1's" are written in the eight information tracks, an "0" will be written in track 4.

V   TAPE ERRORS

General

In the preceeding sections, we have discussed magnetic tape in general and its application to writing and reading data bits on a computer tape drive. When there is loss of intimate contact between the head and the tape, the signal is diminished to the point where it cannot be resolved by the read head (See Figure 16). This is called an error and may be either temporary or permanent depending upon the tape drive's ability to recover the missing bit by retrial (rewriting and/or rereading) of the affected area of the tape. While there are several types of tape errors, the most common is the signal dropout. Other types of tape errors include noise, skew, and signal amplitude changes usually found as marginal errors.
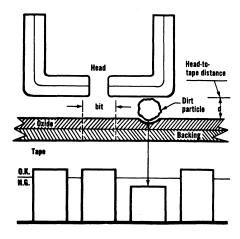

Figure 16.

Dropout Errors

Dropout errors result when the strength of the read signal is less than the threshold level (clipping level voltage) that is set into the tape drive. The clipping levels are determined by the computer manufacturer's specifications but may be adjusted locally by the customer engineer to improve data recovery.

Suppose a tape transport has a threshold level of 35% when doing a read after write operation. This means that the read signal from the tape must be at least 35% of the normal read signal. Therefore, if the normal read signal is 10 volts, the actual read signal must be greater than 3.5 volts to be accepted.

Threshold levels for tape evaluators or certifiers are usually set higher than those of tape transports in which the tape is used. If not, the evaluator may accept a marginal tape that could fail the next time it is used on the computer tape transport.

When checking for dropout errors, the evaluator or certifier writes "1" bits on the tape. These "1" bits are immediately read back. If a bit can not be read (read signal below clipping level), a dropout error has occured.

Most dropout errors occur because of tape contamination. About 90% of these errors are defects caused by oxide build-up. Oxide rubs off the tape and is later redeposited. This causes the tape to separate from the head and decreases the read signal strength.

Noise Errors

Noise errors result when the strength of the read signal is more than the threshold level of the tape drive when no signal should be present as in an interblock gap area. Again, the threshold levels are determined by the computer manufacturer.

Suppose the threshold level is set for 10% of the standard "1" signal. If the standard "1" signal is 10 volts, a read signal greater than 1.0 volt would be detected as a noise error.

Most noise errors are due to lack of oxide. A cut in the tape can cause noise errors because the tape has been erased and the polarity of the flux from the tape is in only one direction. Due to a lack of oxide at a cut or scratch, a flux change occurs and a "1" is read back as a noise error.

Skew Errors

Skew errors are detected by observing the time relationship of the two channels on the opposite edges of the tape. Skew is caused by misalignment of the tape on the drive. If the tape is curved, it will not move by the head in a straight line. This will cause one of the outside channels to either lead or lag the other in respect to time. This is a serious problem in a computer system since all tapes should be compatible with each other. Skewed tape may be the result of improper control in the tape slitting operation where precise tolerances must be maintained or can result from tape that has been stretched during usage.

Level Errors (Average Amplitude)

Level errors are of two types, high level and low level. Magnetic tape is required by specifications to have a particular output and this should not vary by any great amount. Specifications generally call for the level to be maintained at ±10%. This would mean a tape with an output of 10 volts could not have an output any greater than 11 volts or any lower than 9 volts. The 10 volts comes from a master level tape that is used in the calibration of the tape drives. Level errors are the result of oxide coating thickness variations which can come from the manufacturing process or worn tapes.

VI KEEPING TAPES RELIABLE

Removal of Errors From Tapes

By far the most common type of errors are signal dropouts caused by loose oxide particles resulting from normal wear of the tape. These may be easily cleaned from the tape when they first occur; however, repeated use of a tape will cause these error-causing particles to become firmly adhered and finally embedded in the surface of the tape (See Figure 17).
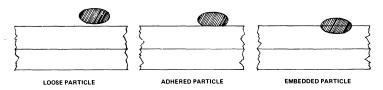

LOOSE PARTICLE   ADHERED PARTICLE   EMBEDDED PARTICLE

Figure 17.

It should be obvious that a regular scheduled program of cleaning tape will be far more effective than occasional cleaning of tapes after dozens of uses.

There are some permanent errors which cannot be removed by any means; for example, a crease in the tape or a crater in the oxide. Removable errors generally appear as oxide flakes or clumps. These may usually be cleaned off the tape. The following is a list of error types:

CLEANABLE	PERMANENT
Oxide clump	Coating streak
Loose oxide	Hole in oxide
Fibrous or hairlike particle	Crater
Metallic particle	Crease
Dirt inclusion	Damaged edge
Backing chip	

Effects of Packing Density

Figure 18 illustrates the effect of signal loss due to head-to-tape separation for different recording densities. Note that separation causes a greater signal loss at higher recording densities. NOTE: A tape may fail at 3200 fci that performed satisfactorily at 800 bpi if it is not cleaned to remove the smaller dirt particles causing high density errors.
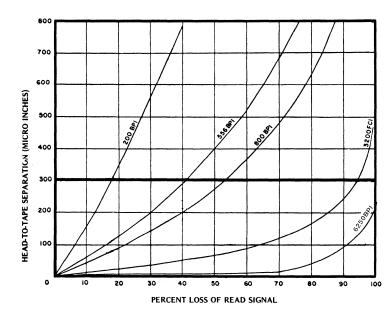

Figure 18. Effect of Tape Separation on Read Signal

Effects of Head Format Conversion
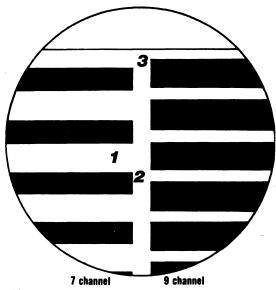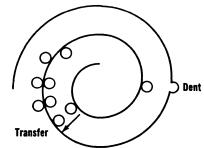

7 channel   9 channel

Figure 19.

It is important to recognize the factors affecting the performance of a tape when converting from 7 to 9 channel operation or vise-versa. Example (1) shows that dirt particles that escape undetected in a 7 channel format may cause errors in 9 channel usage. Example (2) illustrates the reverse effect. Example (3) points out that the 9 channel write/read format is much closer to the edge of the tape with the result that edge damage-caused errors will be more frequently found. The result of these findings is that tapes must be well cleaned and, if older, tested before reliable performance is to be expected from 7 channel tapes converted to 9 channel usage. To a lesser degree, the same comments apply to usage of 9 channel tapes in 7 channel format.

Our experience has been that about 10% of a tape library averaging 3 years in age will need replacement because of edge damage and embedded dirt particles causing excess errors in a 9 channel format usage that did not cause problems in a previous 7 channel format.

Effects of Long-Term Storage Upon Tape Performance

Figure 20 illustrates the effect of tape particles located on the backing side of a tape during writing during long-term (6 months or more) storage of the tape. It is possible to completely pass a read after write check yet have problems in recovery of the data from a tape after prolonged storage. Again, the solution lies in regular cleaning of the tape on a Computer-Link Model 101 off-line tape cleaner since tape drive cleaning stations work only on the oxide side of tapes. If a tape is deformed by a dirt particle, the "tent pole" effect of the dent will result in a permanent read error even though the data was reliably recorded in the surface oxide layer. This type of physical damage (similar to a crease, wrinkle, or fold in the tape surface) also produces head-to-tape separation that cause permanent errors.

Transfer   **Dent**

SMALL DIRT PARTICLE TRANSFER AND DEFORMATION DURING LONG-TERM TAPE STORAGE.

Figure 20.

Another type of error has recently been encountered in data processing installations now using the self-threading, single-capstan type of high speed tape drives. Errors caused by wrinkles or cinches in the tape have caused tape drive "hangs" in which the tape drive malfunctions and stops or the tape itself is broken.

We believe that the cause of this problem can be traced back to older style drives which rewound tapes with a varying tension pattern because of their reel to reel, stop and then rewind in the vacuum columns, mode of operation. (IBM 729, 2401 Series).
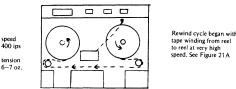

speed 400 ips

tension 6–7 oz.

Rewind cycle began with tape winding from reel to reel at very high speed. See Figure 21A

Figure 21A.

The lower tension was caused by the air trapped in the layers caused by the high speed.

Then the drive stopped when the tape was about 2/3's rewound:

Speed: 0 ips
Tension: 0 oz.

Then the tape loaded into the vacuum columns and rewound at normal speed (75 or 112.5 ips) back to the bot marker. See Fig- 21B

speed: 75,112.5 ips

tension: 9 oz.

Figure 21B.

If we make a graph of the tension pattern in these tapes after rewinding, they would look like this: See Figure 21C.

tension (oz.)

OR

6 oz.

9 oz.

eot   bot

Figure 21C.

Because the speed and acceleration of the 3420-7 is greater than these older generation 729 and 2401 drives, we have seen problems that were caused years ago now resulting in tape drive hangs and jams again causing very expensive reruns. Our analysis has shown that these problems generally are caused by uneven tension areas occuring during rewind on the old style tape drives (and sometimes too low tension on old style tape cleaners). When such a tape is mounted on the high speed drives, the tension change in the pack causes wrinkling or cinching on the tape which would ordinarily be bypassed as a temporary write error, but which sometimes causes a hang up in the drive because the tape is thicker at this point and therefore jams in the drive. See Figure 21D.

WRINKLE   CINCH

Figure 21D.

Because an ordinary tape tester or evaluator doesn't differentiate between this serious problem and an ordinary temporary write error type dropout, Computer-Link has added an optional wrinkle/cinch error detector to its Series 1000 evaluator in order to identify such tape conditions. This technique helps find tapes with storage tension type errors that cause reruns.

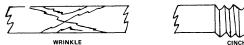Incidentally, we would suggest that tapes be rewound after being in long-term storage retention before attempting to read them on the new high speed tape drives. This should insure uniform tension in the tape pack and help avoid this type of damage. BUT, beware of any older tape cleaners or evaluators that wind tapes at 7 oz. or less since the specifications for the modern computer tape drives is 9 oz. winding tension. Machines with too low winding tension will cause these cinching problems just as quickly as the old style tape drives.

Effects of Water Damage to Tapes

Our experience with magnetic tapes that have become soaked with water as a result of floods or fighting fire has resulted in a few simple rules that have provided over 99% recovery of the tapes that were wet.

1. Isolate tapes that are wet from the remainder of the library.

    While Mylar is humidity stable, it is also hygroscopic, that is it absorbs water. In selecting those tapes that have been water damaged, either move them away from the dry tapes, or, if the whole library is wet, then move the dry tapes out until the library is dry again.

2. Don't Force-Dry the Tapes with heat.

    The combination of water and heat may partially disolve the tape's binder causing the layers to adhere to each other. This will effectively ruin the tape for further usage.

3. Don't run wet tapes on a tape drive.

    The moisture will cause the tape to intermittantly stick to the walls of the vacuum column or to the capstan. The former cause will probably break the tape and the latter may break the drive by causing the tape to wind around the capstan.

4. Do spread the wet reels apart using 4 rubber grommets or equivalent to permit air flow past the wet tapes.

    This procedure will insure that the tapes will not stick to the reel side when drying and speed up drying by allowing evaporation of the water in the tape pack.

5. Don't worry about mud or dirt on the wet reels.

    When it's dry it can easily be cleaned from the tape on an off-line Computer-Link tape cleaner and the empty reels washed with detergent and water. If the muddy tapes are cleaned or run on a drive when wet — a big mess!

6. When they are dry, clean the tapes until they are clean or 5 times.

    As a rule of thumb, a tape should be cleaned once for each year of usage when beginning a tape maintenance program. Tapes that have been wet are no exception. If a tape still is leaving oxide residue after five round-trips on a Computer-Link cleaner/rewinder, its binder system has broken down and it should be replaced. This may be due to old age, mishandling, water or faulty manufacture, but the result is the same — the tape will continue to shed and will cause excessive dropouts each time it is used and leave dirt particles in the drive to contaminate other tapes.

    Computer-Link has a multi-cycle cleaning feature available that can simplify the task of cleaning old or dirty tapes by automatically programming the cleaner for 1–5 round-trips without requiring reloading. Call or write the factory for information.

7. Fireproof data safes aren't always waterproof.

    In a number of cases, water got into a fireproof safe and caused far greater damage by soaking the tapes rather than draining away rapidly. Fireproof storage is necessary — but don't locate your safe in the basement floor or other location where water may collect and cause flooding of the safe.

8. In a fire, the water normally comes from the ceiling, cover your tapes and disc packs too.

    Both tape and disc pack storage media and equipment damage caused by water used to fight a fire can be minimized by having plastic covers available in the event of a fire threat. Rolls of plastic used for covers are compact and can be spread quickly over machines and tapes and packs if there is a fire threat.

9. Be certain tape reels don't have water trapped inside after the tape is dry.

    Some styles of plastic tape reels with metal hubs can trap water which will pour out when the reel is rotated. When cleaning up tapes that have dried after being wet, be certain that all the water is also out of the center hub of the reel.

10. Beware of older tape cleaners that appear to be working satisfactorily.

    a. In testing a group of tapes that have been partially wet, we conducted a series of before and after tests to determine if the tapes had suffered any permanent damage. Our conclusion was that the tapes were OK but the customer's tape cleaner was cheating them of proper results.

        When a batch of tapes were tested and then cleaned on their 3 year old machine, there was only a 20% reduction in the average error count (61 dropout errors per tape before, 49 dropout errors after cleaning). When the tapes were then cleaned one time on the Computer-Link Model 101 the dropout error count dropped to 11 errors per tape — an 80% + improvement. These tapes had been kept on a regular tape cleaning program but the older cleaner simply wasn't doing its job. The better blades and tension control in the Computer-Link Model 101 really makes a difference. Since then we have duplicated this test in a number of data centers — maybe you had better check out your cleaner.

    b. At a data center in New York State, we were called in to help identify the cause of over 700 tapes that were ruined because of extreme cinching. It turned out that the cause of the tape damage was an older cleaner used by the customer to clean a batch of tapes which then were used on the 200 ips tape drives. The cinching occured because the winding tension on the cleaner was only about 5–6 oz. instead of 8–9 oz. Seems like a small difference but the tape wasn't wound tight enough and the tape pack cinched on the high speed drive. You can't see improper tension on a tape cleaner, but Computer-Link can check it for you. Call us if we can be of service.

ENVIRONMENTAL PROBLEMS

Temperature

Temperature ranges within the operating specifications have little effect on performance of magnetic tape. However, extremely high temperatures during storage along with heavy winding tension tend to aggravate oxide voiding when contamination is present.

Humidity

High humidity within reason seems to have little effect on tape

performance. However, low humidity has two pertinent effects.
1. Low humidity causes the backing to become stiff and the coating less flexible. Thus, wear particles build up faster.
2. Static charges build up faster at low humidity. Applications which see-saw over short sections of tape (several feet) are very sensitive in a low humidity environment. A combination of static charges and the smoothness of the tape causes clinging in the transport (idlers and head). This results in poor tape motion and, if severe, complete failure.

Contamination

Prolonged or unnecessary exposure of tape to dust and dirt can contaminate the tape surface and result in signal loss and errors. The following basic rules will help minimize the risk of tape contamination.
1. Maintain recommended temperature and humidity conditions in areas where tape is used and stored.
2. Thoroughly clean the entire floor area daily using a damp mop. Sweeping, dry mopping, or dusting in areas where tape is used or stored must be avaoided.
3. Floor waxing should be kept to a minimum. When necessary, the floor should be machine buffed to remove excess wax, damp mopped with cold water to harden the surface, then machine buffed again when dry. Steel wool or other metal abrasives should never be used for buffing.
4. Periodically inspect and clean tape drives to remove particles accumulated during normal tape use.

TAPE HANDLING

There are only two places that can be considered proper for a tape reel . . . in use on the tape drive or in storage in its container. Adequate procedures should be established to protect magnetic tape from contamination resulting in decreased machine performance. Some of the common violations of "good housekeeping" to be avoided are:
1. Never leave tape reels or containers exposed. In addition to the possibility of damage, dust in the air can accumulate on the tape or in the container and eventually contaminate tape.
2. Don't use the top of a tape unit as a working area. Placing tape reels or containers on top of the drive exposes them to heat and dust from the blowers and interferes with the cooling of the tape unit.
3. Erasing the reel identification label is a primary source of contamination. Select a label with an adhesive backing that does not leave a residue and that can be easily applied and removed.
4. Never allow a loose end of tape to trail on the floor, even though the end of the tape may not contain data. Dirt picked up can be deposited on the transport areas of the drive and be passed on to other sections of the tape.
5. Smoking should not be permitted in areas where tape is in use. Ashes are a source of contamination. Live ashes can produce permanent tape damage if they contact the tape surface.
6. When a reel is improperly seated on the tape drive hub, the tape edge receives undue wear and becomes burred. This burred edge winds to a larger diameter than the undamaged edge. Eventually, the center of the tape collapses and the burred edge of the tape is permanently stretched.
7. Improper handling while loading and unloading tape on drive causes tape damage. Any physical contact to the exposed tape through the reel openings or excessive pressure exerted on the reel flanges will compress the tape and damage the edges. Tape reels should always be handled by the hub.
8. Use extreme care while removing the file protect ring. Never remove the ring while tape is in the columns.

Tape Storage

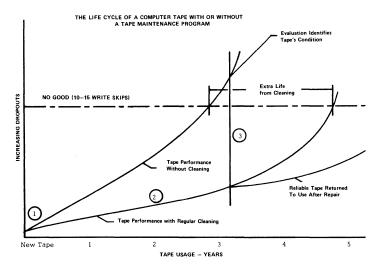To prevent tape contamination and damage during storage, follow these procedures:
1. Before a tape is stored, sponge rubber grommets or tape end retainers should always be placed on the reel to prevent free end of tape from unwinding in the storage device.
2. Always store tape in an upright position. Never store tapes flat or in stacks; accidental damage or reel warp can result.
3. Store tapes in a cabinet or shelf elevated from the floor and away from sources of paper and card dust. This minimizes the transfer of dust from the outside of the container to the reel during loading and unloading operations.

Tape Performance Versus Age

Figure 22 illustrated the increasing count of dropouts as a function of tape age. This assumes normal usage of 20–30 uses per year. Starting with substantially no permanent or transient errors, the tape gains dropouts as a result of normal wear producing dirt particles which cause head-to-tape separation.

A regular tape cleaning program scheduled by tape usage will increase the useful life of a tape by about 2½ years. The effect of tape evaluation and repair are also illustrated in Figure 22.

Figure 22.

The conclusion from this graph must be that a regular tape cleaning or cleaning/evaluation program is the secret to assuring continuing reliable tape performance. A regular tape cleaning program is easily scheduled by use of the computer's software or a tape reliability control label system as shown in the Tape Library Management section of this booklet.

WHAT IS THE EFFECT OF THE LATEST OS SOFTWARE CHANGES ON TAPE MAINTENANCE COSTS?

Since we introduced our first tape evaluator/cleaner 3 years ago, we've learned that the number and location of temporary write errors (TWE) and marginal errors (edge damage) doesn't always tell the whole story about a tape. Particularly with the IBM 370 and OS software, there are error conditions that may cause catastrophic failure on the computer, yet show up only as another TWE on an ordinary evaluator.

Permanent Write Error Detection

Older computer tape drives were programed to stop, back up and retry temporary errors up to 10 or more times before giving up and calling such an error a permanent write error (PWE). After such an error was found, the tape drive skipped ahead and began writing again. Graphically, this looked as follows:
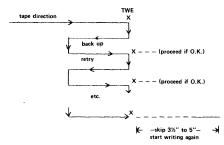
tape direction →

TWE
X

back up

X – – – (proceed if O.K.)

retry

X – – – (proceed if O.K.)

etc.

→ X – – – – – – – –

|← —skip 3½" to 5"— →|
start writing again

Figure 23 A.

Since this software was developed, there have been big changes in the costs of tape, computer time, and priorities as controlled by multiprocessing. As a result, it made good sense to reduce the time (and cost) of TWE's yet set a cutoff for a tape that is continuously bad.
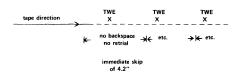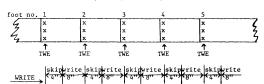
The new (OS) software works like this:

tape direction →

TWE   TWE   TWE
X   X   X

|← no backspace →|← etc. →|← etc.
no retrial

immediate skip
of 4.2"

Figure 23 B.

When a temporary write error is detected, the tape immediately skips and tries to write again about 4 inches down the tape. BUT, if there are 15 consecutive TWE-skips, that's called a PWE and the tape may be aborted — on a write pass. No limit on TWE on a tape unless they are consecutively located on the tape.

Because the I/O software under OS doesn't back space and retry temporary write errors, this had reduced the cost (time loss) of TWE's. But when there are 15 consecutive temporary write errors, this is classified as a permanent write error and that volume may be rejected causing a job abort and rerun. As a result, while one can generally classify a tape's performance and condition by the number and location of TWE's we believe that it is very important to simultaneously look for PWE conditions on a tape to avoid this very expensive failure. As a result, we have added this third type of error detection to our evaluator/cleaner (in addition to TWE and marginal/edge damage error detectors).

The two diagrams below show why this is important:

CASE 1.   Tape with one TWE caused by one defective byte in each of 5 consecutive feet.

foot no.   1   2   3   4   5

x   x   x   x   x
x   x   x   x   x
x   x   x   x   x
↑   ↑   ↑   ↑   ↑
TWE   TWE   TWE   TWE   TWE

|skip|write|skip|write|skip|write|skip|write|skip|write
WRITE → |←4"→|←8"→|←4"→|←8"→|←4"→|←8"→|←4"→|←8"→|←4"→|←8"→

CONCLUSION: *Tape has 5 TWE; this is "good" tape. Retain.*

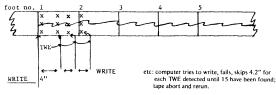CASE 2.   Tape with continuous errors (scratch, wrinkle, edge stretch, etc.) for 5 feet.

foot no. 1   2   3   4   5

x x x x
x x x x
x x x x
TWE

←→ ←→ ←→ WRITE   etc: computer tries to write, fails, skips 4.2" for
WRITE 4"   each TWE detected until 15 have been found;
                             tape abort and rerun.

Figure 24.

CONCLUSION:

a) Computer: PWE condition detected; tape abort and job rerun
b) Conventional tape evaluator: 5 errors reported for 5 feet on the tape. "Good" tape — retain???
c) Computer-Link PWE detector has detected 15 consecutive TWE on the tape; stops drive for immediate analysis and repairs. Tape is positively rejected.

VII   TAPE LIBRARY MANAGEMENT

Introduction

Today's new computing equipment utilizing faster operating speeds and more sophisticated recording densities require magnetic tape libraries to be the highest quality available. Many of today's installations have magnetic tape libraries that have been operated on 2nd and 3rd generation systems. Today's systems have moved from strictly tape-oriented systems to a combination tape and disk-oriented system. Magnetic tape once used for regular operational work now becomes the media for storage of summary or back-up data that is very costly to recreate.

Maximizing A Tape's Useful Life

Part of a library management system is the grading of the library into quality levels.

1. Acceptable for unlimited use.
2. Marginal acceptable for limited use but not for archival storage.
3. Rejected — To be replaced because of damage or excessive errors.

Magnetic tapes may be managed so that they are able to perform the work for which they are assigned. Certain tapes may be made acceptable through cleaning or cutting so that excessive damaged areas are removed. Tapes that are not used fully may be reversed to have even distribution of work. Cracked reels may be replaced reducing the chance of edge damage to the tape. These and many others are some of the facets of operation installed with Computer-Link's Library Management System.

Contamination

How does a Computer Environment become contaminated?

Causes are many, in fact too numerous to mention all here but some of the major causes are:

Poor filtering systems
Dirt carried in on shoes
Smoking and Eating in Computer Sites
Janitorial Services
Lint from Clothing
Loose Hair

All of the above are contaminants that will pollute the computer environment not to mention the self contamination of the magnetic storage media.

How A Tape Becomes Contaminated

Previously we have seen how a computer environment becomes polluted. This contamination can be reduced by the installation of corrective measures to guard against these causes. However, they cannot be eliminated completely.

Magnetic tape operating on the tape drive will generate static electricity. This static electricity will attract the debris in the air and in the drive and it will adhere to the magnetic tape. The tape itself will cause further debris by oxide shedding or scratching. This debris will then be attracted to the tape and held by the static electricity. Because the tape is wound under great pressure, debris will become imbedded in the tape itself. Although some installations control certain activities in house, tapes coming in from other outside sources may carry in other contamination that could grow in your library.

Other causes of tape damage and contamination may come from malfunctioning tape drives and operator mishandling of tapes.

Computer-Link's magnetic tape library system does include corrective measures to the above listed problems.

Corrective Measures

Fundamentally the process must start at the computer drives themselves. Drives must be cleaned properly and regularly to remove foreign debris that may be contaminant. Good housekeeping programs must be installed in order to prevent a build up of contaminants in the area.
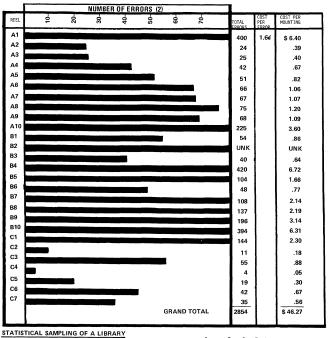
The magnetic tape itself must be cleaned. Since the contaminants are attracted by static electricity continued use of the tape will not clean off the particles not imbedded but rather move them from location to location thus reducing the reliability level of the media. Cleaning of the magnetic tape is the only way to remove the debris. A systematic cleaning program should be instituted so that a tape would be cleaned after every eight (8) times removed from library. Magnetic tape stored in long-term storage should be cleaned and rewound at least every six months. Debris wound into reel under such high pressure could change a transient error into a permanent one causing damage to several layers of tape up or down from the location of the contaminant.

In an article printed in COMPUTERWORLD, it showed that an average reel of tape after being used just once would have the following errors and grow in the amount of errors with usage.

New	3 Months Old	6 Months Old	1 Year Old
5	28	75	120

How Are Errors Determined

A program can be applied to your operating system; however, this will tell you how many errors are on the tape but not the location of these errors. Even this information is available only after the fact. The cost has already occured and data may be recorded on an unreliable tape. This, of course, is not consistent with a good library management system. An example would be if you knew that a tape had 75 errors and that sixty percent were located in the first six hundred feet, then the six hundred feet could be cut off leaving an acceptable tape.

REEL	NUMBER OF ERRORS (2)	TOTAL ERRORS	COST PER ERROR	COST PER MOUNTING
A1		400	1.6¢	$ 6.40
A2		24		.39
A3		25		.40
A4		42		.67
A5		51		.82
A6		66		1.06
A7		67		1.07
A8		75		1.20
A9		68		1.09
A10		225		3.60
B1		54		.86
B2		UNK		UNK
B3		40		.64
B4		420		6.72
B5		104		1.66
B6		48		.77
B7		108		2.14
B8		137		2.19
B9		196		3.14
B10		394		6.31
C1		144		2.30
C2		11		.18
C3		55		.88
C4		4		.05
C5		19		.30
C6		42		.67
C7		35		.56
GRAND TOTAL		2854		$ 46.27

STATISTICAL SAMPLING OF A LIBRARY

Number of Reels Examined	Total Errors	Average No. Errors Per Reel	Cost of Errors	Average Cost One Reel			
				1 Transport Mount	10 Transport Mount	25 Transport Mount	50 Transport Mount
26	2854	109	1.6¢	$ 1.74	$ 17.44	$ 43.50	$ 87.00

Figure 25.

12

It was determined at this installation that each write error would cost 1.6¢. No attempt was made to determine cost because of read errors.

Also it was determined that this installation uses 150 reels of tape per day. Using the average of 109 errors per tape this amounted to 16350 write errors per day. The number of errors times an average cost of 1.6¢ amounts to $251.60 in lost computer time per day.

This information used in library management system would significantly reduce operating costs.

Computer-Link manufactures a magnetic tape evaluator/cleaner capable of operating off-line. The evaluator will clean in a forward pass and evaluate in the return pass. The evaluation is accomplished by writing on all channels and then reading back. If the signal cannot be read the machine will print the error and its location. The machine will also check for edge damage and so record this information. Tapes that are determined to have excessive errors or edge damage are marked for replacement. Tapes with a marginal amount of errors will be recleaned and re-evaluated for acceptance or rejection.

ANALYZING YOUR TAPE COSTS

a. Write Check Costs

First use the table of time loss per write check to determine your lown loss per write check and complete the rest of the data required.

For example:

Tapes used/day	= 200
Errors/tape	= 8
Computer Cost/hour	= $160.00
Time loss/error	= 1 sec.
Cost of errors per year (3 shift) operation, 6 day	$22,100.00

b. Read Error Costs

First analyze the computer operations log to determine the average rerun time per month over a several month period.

For example:

8 hours per month lost due to rerun or 96 hours per year at $160.00/hour = $15,360.00/year.

c. Data Re-Creation Costs

For each hour of data loss not recovered by cleaning tapes with read failures, estimate the number of hours and cost to reproduce the data in order to begin the rerun.

_____hours at $_____/hour = $_____/yr.

d. Extra Purchases of Tape

Buying new tape to replace defective tapes is a major cost savings. Extra purchases of tape without removing the cause of the problem only continues the loss of money due to defective tape failure. Assume 15% of library replaced each year because of tape problems. Assume tape library size 2500 reels or 375 tapes purchased at $12.00/reel = $4,500.00.

The total cost of your tape library is the sum of these losses:

Tape write error cost	$_____/yr.
Tape read error cost	$_____/yr.
Data re-creation cost	$_____/yr.
Extra tape purchase	$_____/yr.
TOTAL TAPE FAILURE COST	$_____/yr.

JUSTIFYING A TAPE LIBRARY MANAGEMENT PROGRAM

The cost savings derived from a tape library maintenance program will far exceed the cost of the equipment and personnel required. These savings are calculated as follows:

a. Savings from Decreased Write Checks

Installation of a regular tape cleaning program will typically reduce write checks by 75–80%. For our example let's assume the following:

Assume cleaning program saves only 5 minutes per shift or 77 hours per year. 77 hours x $160.00/hour = $12,320.00 — savings due to tape cleaning program reduction of write checks.

b. Savings from Decreased Read Errors

Tapes that fail during a read only operation typically have dirt adhered over previously written data. Cleaning these tapes after the fact will allow recovery of the data. Evaluation of tapes will weed out defective or unreliable tapes from file retention applications.

Let's assume the recovery rate of live tapes by cleaning to remove the cause of the read failure.

For example 50% success level in failure recovery equals 4 hours per month or 48 hours/year.

Net computer time loss_____ hours at $_____/hour
In our example 48 hours at $160.00/hour = $7,860.00/year not including maintenance time loss to determine error cause.

c. Savings from Elimination of Data Re-Creation

Obviously if we don't have read errors, we won't have to re-create the data from historical files.

When these savings are totaled, they represent a major cost reduction program with the added benefit of improved reliability and greater efficiency of computer operations.
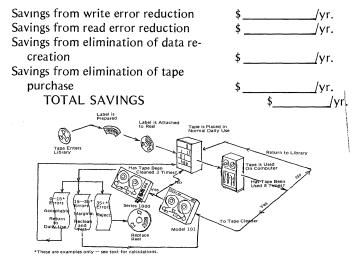
d. Savings in Extra Purchase of Tapes

We want to replace defective tape with new tape whenever the replacement cost will be lower than the failure cost. A tape library management program will also reduce the extra purchase of new tapes by recovering usable tapes through cleaning and repairing.

Now assume that the tape purchase is reduced 50% by cleaning and stripping defective areas of tapes. Only 187 tapes are required or $2,250.

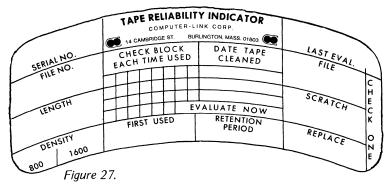## ESTIMATED SAVINGS FROM TAPE LIBRARY MAINTENANCE PROGRAM

These calculations are made as shown above.

Savings from write error reduction $_____/yr.
Savings from read error reduction $_____/yr.
Savings from elimination of data re-creation $_____/yr.
Savings from elimination of tape purchase $_____/yr.
TOTAL SAVINGS $_____/yr.

*These are examples only — see text for calculations.

The Computer-Link Tape Library Management System
Figure 26.

ESTABLISHING A TAPE LIBRARY MANAGEMENT SYSTEM

a. Identify and Control Tapes Usage and Reliability

Computer-Link Corporation Tape Reliability Indicator Label

Figure 27.

Label Preparation

Serial No.	List serial number assigned to reel. Record in tape history log book.
File No.	Assign file numbers to reel. Record in tape history log book.
Length:	Record original length.
Density:	800 bpi — check block (If seven track mark 7 instead of check) 1600 bpi/3200 fci — check block Other list in space provided.
First Use:	List data tape is first entered in library.

Label Use

Blocks:	As each reel is issued from library check ( ) or (x) in next open box. Use horizontally. Left to right.
Date Cleaned:	After eight (8) uses ( ) or (x). Clean on C-LC Model 101 cleaner/rewinder. Record data in date column. Record in tape history log book. Return to library.

Sub Routine

If notification from computer operations that a particular tape causes trouble.

After cleaning, put tape on C-LC Model 1000 Series for evaluation. Record date of evaluation in upper right hand corner of label.

Record results of evaluation on reliability level chart.

File:	Tape is acceptable for unlimited use. 0–errors.
Scratch:	Tape is acceptable for daily work but not for storage. ____ to ____ errors. Evidence of edge damage.
Replace:	Excessive dropouts — damaged tape — edge damage, not acceptable for use.

Schedule for recleaning and re-evaluation. Same results — replace.

Record finding in tape history log.

Repeat cleaning procedure until reaching block label "Evaluate Now." After the tape has had 30 uses or has been declared as a scratch tape, it should go through the evaluation cycle.

Clean tape on C-LC Model 101 cleaner/rewinder or Series 1000 Evaluator/Cleaner.

Caution!

Tape to be evaluated must be released under one or all of the following conditions.

1. Data must be copied to another reel. (Evaluation will destroy data on reel except for header label).

2. Retention date expired. (No need to copy tape. Data not useful).

3. Scratch Tapes. (Tapes that are being assigned to new applications and contain no essential data).

Evaluation — put reel on C-LC 1000 Series Evaluator.

Record results on new label.
Series No. — copy from original label.
Serial No. — assign new number if available.

NOTE: Parameters established for file, scratch, replacement will vary from installation to installation depending on the sophistication of the hardware and the equipment.

b. **Establish Tape Replacement and Repair Points Based Upon Your Facility Error Costs**

The next step is to determine the point at which a tape should be discarded and replaced with a new tape. We believe that this point is clearly set by the cost of new tape.

For example:

$$\frac{\text{Cost per hour x Time in Seconds}}{60 \times 60} = \text{cost per error}$$

Assume cost per hour = $160.00
time per error = 1 second
cost per error = 4.5 cents
errors per tape = 8 average
average tape use per year

$$\frac{\text{tapes/day x days/year}}{\text{tape library size}} = \frac{200 \times 310}{2500} = 25/\text{year}$$

Therefore the errors/year for an average tape cost 8 x 25 x 4.5¢ = $9.00/year. Any tape with 11 errors or more will cost more per year than the purchase price $12.00 of a new tape.

This number of errors is the maximum acceptable for use on the computer. It is entered into the Series 1000 Evaluator classification counter and then built into the machine to insure proper grading of evaluated tapes.

From these calculations, limits are set for file tapes, scratch tapes, and replacement of tapes.

Example:

	Errors
File	0—5 in 2400'
Scratch	5—15 in 2400'
Reject — Replace	15 + in 2400'
or	
File	0—25 in 2400'
Scratch	25—50 in 2400'
Reject — Replace	50 + in 2400'

c. **Labeling or Relabeling Tested Tapes**

Date of evaluation should be filled in upper right corner of label.

Repetitive information should be transferred to new label.

Serial No.
File No.
Length
Density
First Used

After evaluation the following determination should be made.

1. Tape is good and may be used freely. 0—15 errors, file block should be checked.

2. Tape is marginal and should only be for non-critical use. Check scratch 15—35 errors.

3. Tape is not acceptable for use. Check replace 35 + errors.

The causes of detected errors should be reported to the proper people for corrective action:

Tape Coating Problems — Tape Vendor
Tape Mishandling Problems — Computer Operators
Tape Physical Damage — Customer Engineer

NOTE: Errors will be printed out on adding machine tape from EOT marker (the same as the reel is measured). D0123 will denote an error 123' from the EOT not the BOT. These error locations correspond to the engraved tape reel footage scale.

It is important to note that transient errors may move from one location to another. Tape must be cleaned prior to evaluation.

VIII TAPE MAINTENANCE EQUIPMENT

In the earlier sections of this booklet, we have discussed the basics of magnetic tape, its use with the computer, types of errors and some hints for more reliable performance from the tape library.

There are two basic techniques available for maintaining magnetic tapes; (1) cleaning and (2) evaluation or testing. In some applications, used tapes are also recertified in order to assure a level of perfect reliability. We have previously explained the results of a regular tape cleaning and evaluation program together with a format for justifying the cost of the equipment needed to establish the program.

1. Model 1011 Magnetic Tape Cleaner

The Model 1011 Magnetic Tape Cleaner/Rewinder has been specifically designed to maintain the high density tapes now coming into wide spread usage. Obviously it also is extremely effective in cleaning the larger particles that cause dropouts at lower tape recording densities. This is possible because of the unique dual capstan design of the Model 1011 which completely isolates the rewinding tension from the cleaning tension while maintaining precise independent control of each. In effect, the Model 1011 is two machines in one, relatively high tension magnetic tape cleaner and a relatively low tension magnetic tape rewinder. Previous machines have always represented a compromise between these two needs — the higher tensions need for effective tape cleaning and the lower tensions recommended by IBM and other computer manufacturers for the safe and reliable storage of magnetic tapes. We believe that this unique design offers you both effective tape cleaning and proper rewinding in a single machine.

The Model 1011 may be used not only for regular, preventive maintenance cleaning of scratch and file tapes, but also for cleaning defective areas of tapes that have been found with read failures. In addition the rewind capability of the Model 1011 may be used for retensioning tapes that are being held for long-term file application. The tape cleaner is also very important in assisting in easy tape conversion from 7 to 9 channels and/or low to high density usage.

SPECIFICATIONS

Reels —½" x 10-½"
Hubs — Quick release. IBM or NAB
Speed — 180 ips
Cleaning — 2 gemstone blades, 2 automatic advance tissue cartridges, complete 2-cycle cleaning.
Brakes — fail safe
Precision wind tension — dual capstans to insure constant tension forward & reverse
Physical — 24" wide, 19" high, 17-½" deep, 85 lbs.
Power — 115 VAC, 60 Hz, 230 VAC, 50 Hz, 285 Watts
Blade Life — 5000 tapes, unique indicator shows need to change
Controls — power, load, start, forward/reverse only.

OPTIONS:

Preset Footage Counter
dial the number of feet to be cut off for repairs or tape area inspection. Cleaner will automatically advance to selected location.
E — Z Load Adapter
Packaging Wheel

2. Series 1000 Tape Evaluator/Cleaner

A magnetic tape evaluator/cleaner makes sense for your tape library operations primarily because new tape is so reasonable in price compared with the costs of tape failure on the computer. But a really effective evaluator/cleaner must be more than just a cleaner and a tester if it is going to do the whole library maintenance job. We think that the following list represents the minimum requirements for a machine that will accomplish all of the tasks required for a complete tape maintenance program.

1. Effective cleaning of the tape before testing.

The C-LC Series 1000 cleans each tape twice (2 blades) before evaluating to insure that all of the loose dirt particles are removed before testing. Without this, the evaluator will show more errors than actually should exist and good tapes will be thrown away unnecessarily.

2. Tape Testing sensitivity matched to both the tape and the drives used at your data center.

The C-LC has a unique dual calibration capability to allow the evaluator to be matched to the model tape drives and brand(s) of tape that you are using. Without this, there can be as much as ± 10% difference between the tape evaluator and the actual results on the computer.

3. Ability to detect temporary write errors and permanent write errors like the computer tape drives.

There have been major changes made to the IBM O.S. input-output software used with the IBM 3420 tape drives. As a result all of the evaluators on the market are not compatible with these changes, since they are still reporting tape errors as found with IBM 7000 series or IBM 360 with DOS software. C-LC has modified its error reporting procedures as follows:

a. Marginal Errors — not hard temporary write errors but likely to cause problems in reading on a different tape drive from the one that wrote the tape. These errors are only reported if there are no hard errors.

b. Temporary Write Errors (TWE) — these errors are reported for each foot of the tape in which they occur. Adjustment may be made for proper threshold to match local data center tape and drive types.

c. Permanent Write Errors (PWE) — under current O.S. software 15 consecutive skips for a TWE will result in a PWE and a job abort. There is no limit on the number of TWE on a tape — only 15 consecutive errors will cause an abort. The C-LC Series 1000 machine will signal such a permanent error and immediately stop to allow the defective tape to be stripped or rejected.

d. Gross Error Detection (GRE) — This feature is useful in detecting areas of the tape with large errors such as scraped oxide areas, diagonal creases, etc. A gross error condition (GRE) is indicated when the signal read, from any or all of the channels, falls below the testing threshold for a distance of approximately ¼ inch. The tape will then come to a stop, and the GRE indicator will light. The tape may be manually wound back 6 to 8 turns to view the defective area.

e. 3 Track Lateral Parity — This feature monitors all 9 tracks to determine if 3 or more tracks contain a dropout error at the same time. The errors do not have to occur exactly simultaneously but may occur within .18 inches (4.5 mm) of each other. The presence of a parity error is shown by an E symbol in the fifth column of the printed output.

4. Fail-safe capabilities.

a. Diagnostic test tape — an exclusive feature of the C-LC Series 1000 lets you know that the evaluator is working correctively. This avoids days or weeks of falsely accepting or rejecting tapes because the evaluator wasn't working properly.

b. File Project Ring Detector — prevents your operators from inadvertantly testing a live data tape. Without a write permit ring in the reel, the C-LC evaluator just dual pass cleans the tape.

c. Header Project — to prevent unnecessary initialization of all tested tapes.

5. Maximum Tested Tape Throughput

If the C-LC evaluator is used in parallel (each machine used for a half-pass) with your existing tape cleaner, 15 or 16 tapes per hour can be cleaned and evaluated. This gives you the ability to test batches of tapes for critical jobs, etc. This is 50% — 60% more tape testing throughput than available from other machines.

6. Ability to Repair Tested Tapes.

After a tape has been tested, there are four basic choices available to the operator: accept it as O.K., reject it, strip off a portion or attempt to re-clean a portion of the tape. Only the C-LC evaluator has automated the latter two functions.

a. Repair Location Counter — just dial the number of feet to be stripped, load the tape on the empty take-up hub and start the machine. No operator supervision is required.

b. Intensive Clean — this unique feature automatically re-cleans any 100 foot section of the tape — 6 times automatically. The tape may then be retested to see if it is acceptable.

7. Built-In Quality control capabilities.

a. Classification Counter — the maximum number of TWE (temporary write errors) is pre-selected. The machine will indicate to the operator when this number has been exceeded to show that the tape should not be returned to the library without repair or recleaning.

b. Blade Life Indicator — prevents tape damage by automatically indicating when cleaning blades are due for replacement.

c. Simplified Supplies Change — C-LC has selected low-cost supplies for tape cleaning and error reporting. There are no tissue cartridges to manually reload, the machine does not have to be disassembled to remove filter bags and no special tools are required for blade change.

8. An Experienced Vendor

C-LC has been supplying Series 1000 evaluators for 7 years. It is an experienced, field-proven design with very low downtime. A complete list of references will be furnished upon request.

GENERAL SPECIFICATIONS

Tape/Reels — ½" x 10-½" reels

Hubs — IBM standard, quick release, NAB optional.

Tape Tension — Precision controlled

Tape Format — 7 and 9 channel heads, both IBM and ASCII, 800, 1600 bpi and 6250 bpi.

Error Printer — A digital record of the exact footage and type of error (dropout and edge damage) is printed for each detected error. Printer paper capacity about 300 tapes. Total tape footage also printed at end of test.

Dropouts — Threshold adjustable from 0-100% with visual meter to confirm desired setting.

Edge Damage — Threshold factory preset for detection of marginal edge errors at 800, 1600 bpi and 6250 bpi.

Header Label Protect — standard. Test through header switch optional.

Diagnostical Calibration Tape — Provides a built-in "customer engineer" to insure system performance by testing write, read and error detection functions for all channels in a one minute test.

Computer Calibration Feature — The Series 1000 is calibrated during installation to match the facilities tape drives. This prevents false rejection or acceptance of tapes.

Classification Counter — A dual register preset error counter to insure that tapes are properly classified as acceptable or repairable or rejected for replacement.

Repair Location Counter — Automatically selects the length of tape to be stripped for repair. Machine operates unattended during the repair mode.

Intensive Cleaning Feature — After evaluation any selected area(s) of the tape may be locally cleaned automatically by using the Repair Location Counter to reach the desired area and depressing the Intensive Cleaning button. Approximately one minute of double pass cleaning is provided over a 100 foot area. The machine then automatically completes another evaluation of the tape to determine if the intensive cleaning has removed the cause of the excessive dropouts.

File Protect — Clean Only — Protects against accidental tape erasure by requiring use of the write ring for evaluation. Permits dual pass blade-tissue cleaning instead of evaluation.

Test Only Switch — Selects clean-test operation or test only operation. Used in conjunction with separate cleaner to double throughput of evaluated tapes.

Shaped Gemstone Blades — Two blades (patented) are supplied to clean tape during forward and reverse tape passes. Blade life is more than 5000 tapes.

Blade Life Indicator — Automatically indicates when to change blade edges (2500 tapes) and when to replace worn blades after 5000 tapes have been cleaned.

Automatic Advance Tissue Cartridges — Quick change cartridge change after 200 passes without spool change. Tissue advance speed is constant.

Fail-Safe Controls/Brakes — All controls fully interlocked to prevent tape breakage or stretch. Brakes are fail-safe in the event of no tape or no power.

Tape Stacking — Precision tension controlled tape stacking without packing wheel to avoid contamination of cleaned tapes during final rewind.

IX BENEFITS GAINED FROM A COMPUTER-LINK TAPE LIBRARY MANAGEMENT PROGRAM

Prevention of computer downtime (downtime = money).

Reduction of re-runs due to tape read errors. (C-LC Series 1000 cleaning has average of 90% success level of cleaning errors causing tape read failure.)

Reduces new tape purchases.

Ensures maximum trouble free life from all tapes in library.

Tapes maintained at optimum operating level.

By eliminating oxide and error build-up reduces the amount of expensive computer time consumed by read/write attempts and skips.

Good tape always available for new or critical tape operations. (e.g., program testing).

Regular reversal evens out tape wear and ensures maximum tape life. (Most files use less than 50% of a reel).

Significantly reduces tape problem normally encountered when upgrading packing densities, either 7 to 9 track or 800 to 1600 bpi.

Precise retensioning eliminates the majority of tape errors caused by tape storage.

Uniform stacking reduces edge damage and skew errors.

Tape re-reeling can be accomplished off line, saving expensive computer time. Allows for replacement of damaged or contaminated reels.

Substantial increase in computer time available.

Fewer schedules or deadlines fail to be met.

Reduces the necessary safety percentage allowed for downtime in normal operating schedules.

Tapes can be cut to shorter lengths.

New tapes can be run-in to remove initial excess oxide prior to use on tape transports.

APPENDIX A
TAPE RELIABILITY AT 6250 BPI

Because of all of the confusion caused by the varying claims of tape vendors, computer manufacturers (and tape evaluator manufacturers), Computer-Link has prepared a brief review of the significant differences between data recording at 6250 bpi with Group Code Recording and tape recording at lower densities. We have also suggested the basic requirements for a reliable tape tester together with the reasons for our suggestions.

What About Data Reliability At 6250 BPI?

Unfortunately, there has been a lot of confusion generated by certain computer and tape vendors in an effort to sell their computer systems — or tapes. Such statements as "most existing tapes will run O.K. at 6250 bpi" or "equivalent performance on a byte for byte basis will be realized at 6250 bpi" are both misleading and partially untrue. The facts are as follows:

A.   There are many more tape errors at 6250 bpi:

The reason for this increase in tape errors may be seen in Figure 18. For example, 80% of the read-head signal is lost with head-to-tape separation of 40-50 microinches at 6250 bpi whereas it takes debris particles 3 times bigger — about 150 microinches — to cause an 80% signal loss at 1600 bpi. While the increased electronic signal correction capability of the GCR logic can correct most of these tape errors, the system reliability is reduced since the GCR system can only correct 2-track errors. In using tapes with many single track errors, smaller migratory errors will cause read failures and reruns. The problem facing the user is that the system software (e.g. IBM, SMF, or TMS) does not report single track errors and therefore provides no clue of the true condition — and progressive wear of the tapes — until disasters in the form of ABENDS and reruns occur.

B.   Certain kinds of tape errors are worse than others at 6250 bpi:

Single track errors that occur in the data groups can be electronically corrected. Single track errors that persist or occur in the control character area of the storage data will cause temporary write errors (TWE) and skips which waste computer time and money. Because the system software does not report all tape errors, an excessively good picture of true tape condition is obtained. A more comprehensive test prior to usage is required to measure true longer-term tape performance.

For example, referring to Figure 28, the data in the resync burst area must be perfect in order to resynchronize the electronic data correction logic. The data groups (up to 1580 bytes) can have up to 2 tracks defective and still operate in the read only mode. The interblock gap (0.3") can have data errors but not noise records without impairing tape performance.
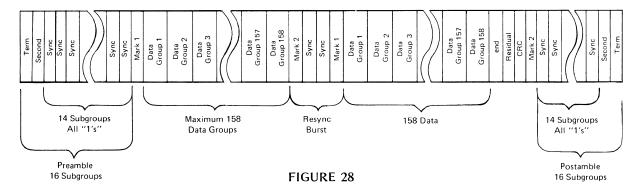
C.   Future reliable tape performance is not guaranteed by a successful read-after-write check on the computer:

Because the GCR format can correct single track errors electronically, but does not correct the actual bits on the tape, any migratory dirt can cause an increase in expensive read errors. A regular tape and drive cleaning program is more necessary at 6250 bpi to reduce loose (transient) debris particles on both tapes and drives.

The real problem here is that the operating system (OS, VS, etc.) does not collect and report error conditions that do not result in write skip conditions. As a result, the software input-output error reporting system is not nearly as good a mirror of tape performance and future reliability as it is at 1600 bpi.

D.   Commercially available software tape test programs do not reflect actual operating performance:

Conversely to the computer's operating system software, software-oriented tape test programs test the tape for single track errors without providing multiple track error correlation for given faults. This is a 1600 bpi tape test performed at 6250 bpi re-

FIGURE 28

cording density and not a true measure of the tape's performance at 6250 bpi — GCR. As we have shown in Figure 18, raw single track errors can be up to 3 times greater at 6250 bpi than at 1600 bpi. This will result in unnecessary rejection of tapes that would run reliably on the computer with its single track error correction logic.

What Are The Key Elements Of A 6250 BPI Tape Management Program?

1.   The computer tape error software printout (TMS or SMF) is also not a reliable indicator of actual tape performance. Therefore a regular cleaning routine and a single track error test capability is important to determine true tape reliability.

2.   Areas of the tape that contain control characters must be perfect to avoid tape errors. Therefore a tape test program is needed to define those areas with errors that are likely to cause this type of failure.

3.   Areas of the tape with 3-track errors will cause both write and read failures and must be identified for remedial action. The computer cannot correct these errors.

4.   Areas of any tape with physical damage that is marginal in nature; e.g. wavy edge damage that tends to come and go or is not detected by every tape drive because of differences in tape tension and head wear must be detected and identified for remedial action.

5.   Tapes used with IBM DOS, OS or VS system software must also be tested for permanent write error (PWE) areas (equal to 15 consecutive TWE's) which extend for 5.25 or more feet along the tape. These areas cause tape write ABEND and must be eliminated from the system.

While such a variety of tests seems complex, the computer's system software is simply inadequate to provide an accurate prediction of tape performance — until it's too late and excessive read errors and reruns are encountered.

The Computer-Link Total Test For Reliable 6250 BPI Performance

The Computer-Link Model 1700 (6250 bpi) and Model 1800 (1600/6250 bpi) are the most comprehensive tape evaluator/cleaners on the market today. By double-cleaning each tape followed by the comprehensive tests, reliable tape performance can be assured.

1.   Marginal Errors — physical damage that is not severe enough to consistently result in a dropout.

2.   Single Track Errors — these are the non-software reported write failures on the computer that greatly inhibit the GCR read logic's ability to overcome tape faults.

3.   Three-Track Errors — these are hard failures on the computer resulting in write or read errors and must be identified by type and location for remedial action.

4.   Gross Errors — these are single or multiple track errors that extend into the control character area of the data group. Such defects also may result in false end-of-file marks or noise records and should be eliminated from the tape by stripping.

5.   Permanent Write Errors — these are a cause of tape ABENDS with an IBM operating system in which 5.25 feet of the tape have a continuous error condition. Such areas must be eliminated by stripping. (Optional feature)

Don't Settle For A Partial Test Program

It can be seen that tape testers that only test for single-track errors will not differentiate between marginal and hard computer errors. Similarly, testers with only 3-track error testing will not indicate the condition of the tape in terms of single track errors and in fact are little better than the computer's printout. Both types of errors plus those marginal and major errors found by the Computer-Link 6250 bpi testers are necessary to know that a tape will perform reliably on the computer.

Conclusions/Recommendations

Because an effective tape maintenance program can save thousands of dollars of computer time each year over the costs of implementing it, immediate approval should be sought to acquire the evaluator/cleaner.

An arrangement should be negotiated with one or more new tape vendors for a "trade-in" program to recover the maximum value from those rejected tapes that must be replaced.

New tapes, empty reels and labels should be stocked at the data center to facilitate replacement of defective tapes, broken reels with satisfactory tape and labeling of all tapes returned to service.

Any tape cleaners currently in use should be tested to determine if they meet current performance standards. Those that do not should be repaired or replaced to insure maximum effectiveness of upgrading all tapes.
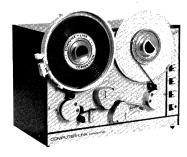
A serial numbering system for tapes should be selected that will avoid number duplication when any tape libraries are consolidated.

Computer-Link will be pleased to furnish additional information as well as presenting tape maintenance and care and handling seminars to assist in better tape handling procedures.
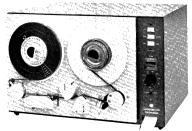
SERVICE REQUEST

Please send more information on:
Magnetic Tape Maintenance

☐ Model 1011 Magnetic Tape Cleaner/Rewinder
☐ Series 1000 Magnetic Tape Evaluator/Cleaner
☐ Tape Maintenance Program/Justification Information
We Have _____ Tapes Used At _____ bpi

Disc Pack/Cartridge Maintenance

☐ Series 600 disc pack inspector-cleaners
☐ Model 670 disc cartridge cleaner-inspector
☐ Disc pack maintenance program/justification information
We have _____ 3336; _____ 2316; _____ 1316 type packs. _____ 1315; _____ 5440 type cartridges. _____ Other.

Ribbon Maintenance

☐ Send information on the new Model 400 Computer Ribbon Re-Inker
☐ Send information on the new Model LC-IA Line Counter with presettable alarm.

We use _____ ribbons per month, type _____ printer.

NAME _____

TITLE _____

COMPANY _____

ADDRESS _____

CITY_____ STATE_____ZIP _____

TEL. (   ) _____ Ext._____
    Area Code

☐ Please add my name to your mail list.

☐ Please call me to set up appointment.

Computer-Link Products and Systems

Computer-Link Products and Systems

Model 1011
Tape Cleaner/Rewinder

A double-pass tape cleaner/rewinder with dual capstans for independent tension control of cleaning and winding.

Series 1000
Tape Evaluator/Cleaners

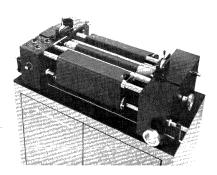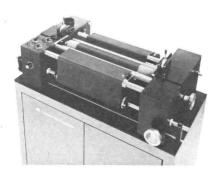A complete tape library management system that cleans, tests, classifiers, and repairs computer tapes.

Series 600
Disc Pack and Cartridge
Cleaner/Inspectors

☐ Head Replacement
☐ Time Loss — Maintenance
☐ Data Loss — Recreation

Model 400
Computer Ribbon Re-inker

Features

☐ 60% reduction in your ribbon budget
☐ NEW CAPILLARY flow ink system — actually puts more ink in the ribbon than when new — for longer life and better image.
☐ High Speed Operation — a 1000% inspection and re-ink in 3 minutes average time.
☐ EASY TO USE, a practical solution to high ribbon costs and availability.

NEW—MODEL LC-IA LINE COUNTER WITH PRESET ALARM FEATURE

NOTE: The Post Office no longer accepts cards without postage.

PLACE POSTAGE HERE

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