ATR MAGNETICS

A detailed discussion of the Alignment and Calibration of your Reel to Reel Tape Deck

CONTENTS

1 ANALOG OVERVIEW ALIGNMENT AND CALIBRATION

All events that occur in nature are by definition analog. Recording and reproducing these events accurately is a very difficult endeavor. Musical performances remain some of the most difficult, and there is much debate as to what method is best. We believe that all forms of recording have their strengths and weaknesses. Analog recording, like any technology, requires a specific skill set to utilize it to its full potential.

1.1 WHAT BENEFITS ARE DERIVED FROM LINEAR ANALOG RECORDING?

Analog recording technology captures the original performance in a similar fashion that it was played. This may be the reason that most people attribute "realness" and emotional impact with analog recording.

Analog technology is mature. With maturity comes stability both in reproduction and archiving properties. Generally, once an investment is in a quality analog recording device, there is no need to upgrade in the future.

Since the beginning of biased analog tape-recording technology there have been relatively few recording formats. This stability, along with accepted industry standards in operating level and equalization, provide a high level of compatibility between studios over time.

Recording is an art as well as a science. A successful recording is often judged primarily on the quality of sound as art, and we obviously cannot guarantee that. A company that makes paint and brushes for artists cannot say that the paintings made with their products will be well received critically. The art is the province of the artist.

Your skill as a technician and your abilities as an artist will be significant factors in the results you achieve.

2 TAPE WIDTHS AND TRACK CONFIGURATIONS

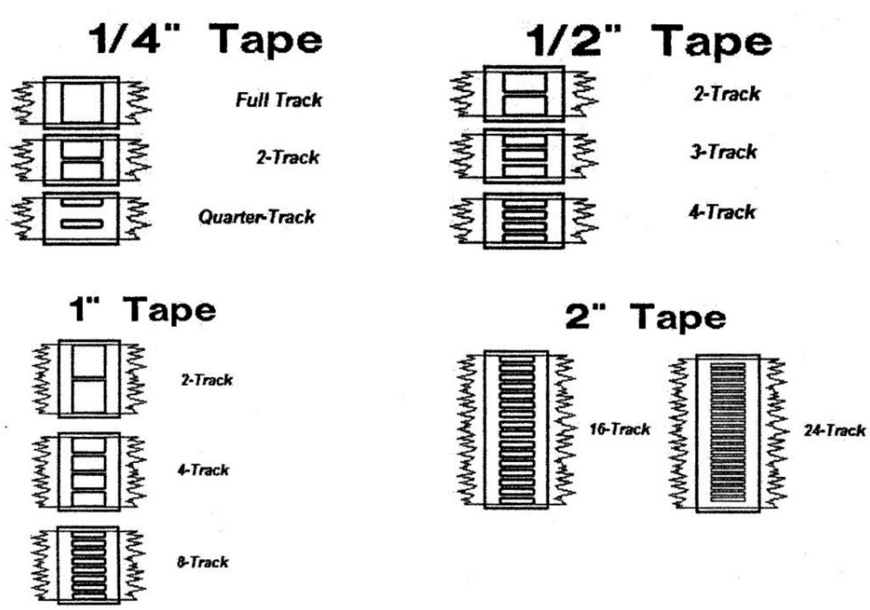
2.1 PROFESSIONAL AUDIO RECORDING TRACK FORMATS:

¼” Formats:	Track Width	Tape Width – 246 mils
Mono – “Full Track	234 mils	
2-Track NAB Stereo – “Half-Track”	75 mils	
2-Track DIN Stereo	110 mils	
Bidirectional Stereo – “Quarter Track”	43 mils	

½” Formats:	Track Width	Tape Width – 496 mils
2-Track Stereo	200 mils	
3-Track – “Left, Right, Center”	130 mils	
4-Track – “Quadraphonic”	70 mils	

1” Formats:	Track Width	Tape Width – 996 mils
2-Track Stereo	480 mils	
4-Track	200 mils	
8-Track	70 mils	

2” Formats:	Track Width	Tape Width – 1.996 inch
16-Track	70 mils	
24-Track	43 mils	



2.2 SPEED AND EQUALIZATION STANDARDS

Inches Per Second "IPS"	Centimeters per Second (cm/s)	Equalization Standards
30	76.2	AES
15	38.1	NAB or IEC
7.5	19	NAB or IEC
3.77 – 3 ¾	9.5	NAB/IEC
1.875 – 1 7/8	4.8	--

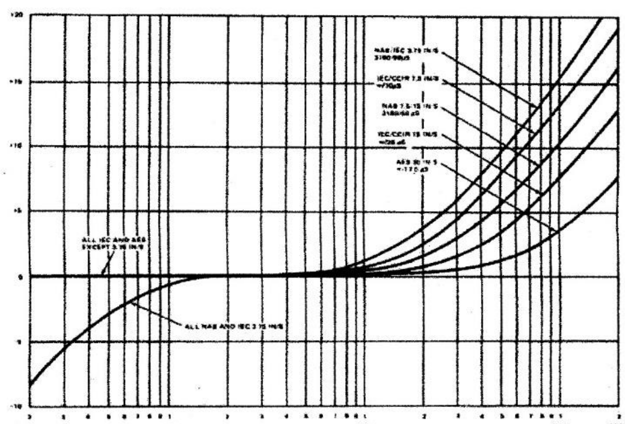
2.2.1 Abbreviations:

- AES – Audio Engineering Society
- NAB - National Association of Broadcasters
- IEC - International Electronic Commission
- CCIR - International Radio Consultative Committee
- DIN - Deutsche lndustrie-Norm
- EIA- Electronic Industries Alliance

For 30 IPS operation, there is only one equalization standard, so you don't have to worry about choosing one - it is called AES.

For 15 IPS and slower speeds, you have a choice between NAB [1965] or IEC [1968] equalizations. "NAB" may also be referred to as "IEC-2". "IEC" was previously known as "CCIR" and is officially referred to as "IEC-1". The primary difference between the two equalization standards is the presence or absence of low frequency record boost. This is compensated by a reduction of low- frequency content during playback.

2.2.2 Reproduce Curves



3 ALIGNMENT AND CALIBRATION

Order of Operations

1. Inspection
2. Demagnetization
3. Cleaning
4. Electrical Alignment

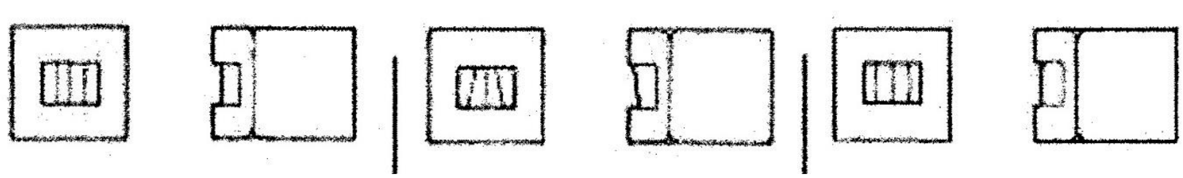
3.1 INSPECTION:

Tools:

- Magnifying Glass
- "Work Tape"
- Piece of Paper
- Grease Pen or Felt-tip Pen

Perform a close mechanical inspection of the entire tape path. Repeat the inspection with a magnifying glass, this time paying special attention to the non-rolling components of the transport: Tape Heads, Guide Posts and Lifter Arms.

Check record and reproduce tape heads for wear (flat spots) across the face of the heads. A small flat spot is normal but a large or uneven spot indicates badly worn or improperly adjusted heads. Hold a piece of paper at the base of the head to turn its mirror-finished face into one more easily observed.



Properly Aligned Misaligned Zenith Over-Tension

Spin all rolling guides and motors by hand. Listen and feel for any interruptions in each part's rotation. All items should spin smooth and quietly. Stiffness or a once-around "knock" typically indicates the need for lubrication or bearing replacement.

Thread up your "work tape" and run the machine in all modes: Play, Fast Forward, Rewind and Stop.

Make sure that tape does not touch (rotationally scrape) the tape reel flanges on the supply or take-up reels. If it does, the turntable height usually needs to be adjusted or shimmed. Use a piece of paper to help your eye focus on how the tape packs onto the hub.

The machine should handle tape gently. Violent or sluggish tape handling usually indicates the need for transport alignment. Consult your user's manual on the specific method of transport alignment.

3.2 DEMAGNETIZATION

Tools:

- Degausser – Han-D-Mag™

Why is it necessary to demagnetize?

The tape path components of a professional recorder are made of stainless steel or other ferrous alloys. Alloys with low concentrations of iron, such as those found in tape head cores, are still subject to magnetization even though they are considered "non-magnetic" materials. Tape path components become magnetized through use or accidental exposure to external magnetic fields.

Effects of magnetized transport components:

- Partial erasure of high-frequencies
- Low-frequency noise (rumbling and popping)
- High-frequency noise (hiss)
- High second harmonic distortion during recordings

The general rules of demagnetizing are:

- Stereo Recorders - 10 to 15 hours
- Multitrack Recorders - 20 to 50 hours

How do you demagnetize?

First make sure the recorder is OFF! (Very important) Also make sure that any tapes within a few feet of the demagnetizer are moved prior to plugging it in.

We recommend the Hand-D-Mag™ (HDM) degausser because it has a strong enough field to truly make a performance difference.

Plug-in the HDM at a distance of at least 4 feet from the recorder.

Slowly bring the HDM towards the machine, aiming for the head or guide you wish to de-mag. Bring the HDM as close to the head or guide as you can without touching it. Travel the length of the part then slowly pull the HDM away. A distance of about 6 to 10 inches is appropriate before moving on to the next component.

The actual demagnetization is accomplished as the tip of the HOM is pulled AWAY from the head.

When the HDM is slowly pulled at least four feet from the machine, unplug it.

Never unplug the HDM while it is close to the machine!

3.3 TAPE PATH CLEANING:

Tools:

- Isopropyl Alcohol (99%)
- Cotton Swabs

We recommend cleaning the entire tape path with Q-tip brand cotton swabs moistened with anhydrous (99%) isopropyl alcohol. Clean the tape heads in a horizontal motion (direction of tape travel). Do not clean the heads with an "up and down" motion and no not use excessive pressure while cleaning.

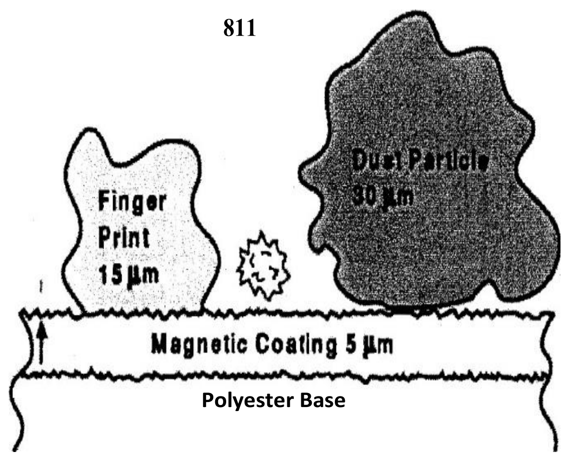
Be sure that all tape guides and rollers are clean as well.

99% isopropyl alcohol is recommended because it is effective, evaporates quickly and is safe for all parts on the machine - including rubber and urethane.

**Rubber Rejuvenators by TechSpray and the like are recommended for parts containing their original elastomers. New rubber or urethane are strongly encouraged.

Make sure no cotton swab lint is left on any of the heads or tape path parts.

Debris on **stationary** tape path components can result in damage to the tape edges or coated surface resulting in short-wavelength degradation. At the tape heads it can also result in a reduction in short- wavelength response due to spacing loss - separation between the head and tape.



Debris on **rotational** components can create changes in instantaneous tape speed, known as flutter.

3.4 ELECTRICAL ALIGNMENT:

3.4.1 Calibration Tapes:

Reproduce (playback) calibration requires the use of a pre-recorded set of tones on a specially produced tape called a "calibration tape", "reference tape" or "MRL Tape". MRL stands for Magnetic Reference Laboratory, which continues to- produce new reference tapes today.

Calibration Tape Deciding Factors

- Tape Width
- Tape Speed
- Equalization Standard - "EQ"
- Reference Fluxivity - "Operating Level"
- Program or Tone Set
- Tape Duration

3.4.2 Operating Levels:

Calibration tapes usually have many tones on them, but they always have a 1 kHz reference tone. This tone is used for establishing the operating level of your machine.

3.4.2.1 Common Operating Levels:

- 185 nWb/m - "0 dB" level - "Ampex Operating Level"
- 250 nWb/m - "+3 dB" (over the 185 level)
- 355 nWb/m - "+6 dB" (over the 185 level)
- 540 nWb/m - "+9 dB" (over the 185 level)

Note: Operating Levels in bold print are available from MRL.

We recommend purchasing a 250 nWb/m calibration tape. This is an operating level in the middle of the fluxivity range that allows for easy conversion to both higher and lower operating levels if you wish to experiment.

Example: When the 250 nWb/m, 1 kHz tone is played from the calibration tape and you adjust the Reproduce Gain pot on your machine to read "O VU" on the machine's VU meter, the playback is calibrated for a 250 nWb/m reference level.

Notice that the operating levels are in 3 dB intervals. This means that the difference between operating levels will correspond to 3 dB increments on your machine's VU meters. If you have a 250 nWb/m calibration tape and wish to operate at 355 nWb/m or "+6 dB" then you must play back the tape and adjust the machine's VU meter for a reading of -3 dB/VU. This will yield a 355 nWb/m level from a 250 nWb/m tape.

Why do you set playback -3 VU down to move to a higher operating level?

When you decrease the playback gain, you must in turn increase the record gain to get back to a standard output level. This means that you are actually recording "hotter" when you decrease playback level.

Operating levels are best described as a function of how hard the record stage is working.

This is the key to understanding operating levels.

*Tape operating level is not to be confused with the standard +4 dBu operating level used in most studio equipment. +4 dBu level is a standard reference for Input/Output level when calibrating your console, outboard gear, etc. Tape operating level is only relevant "inside" the tape machine.

**Input and output calibrations are usually available on tape machines and must be checked prior to alignment to ensure proper operation. Consult your machine's service manual for information on calibration of inputs and outputs.

3.4.3 Equalization Standards:

Choosing an equalization standard is a "personal taste" decision and there is no right or wrong choice.

Be sure to pay attention to the capability of the machine you are working with. Certain track formats and model of recorder can only accommodate a single EQ standard.

3.4.4 Tape Speed:

Most professional tape machines operate at either 15 or 30 IPS (Inches Per Second).

The speed you choose is one of the biggest factors in the overall sound of your recording.

This is also a "personal taste" decision and we will discuss the advantages and disadvantages of different speeds in the seminar. Please be aware that calibration tapes are speed specific.

3.4.5 Audio Alignment Procedure

*This calibration procedure is for 15 **OR** 30 IPS. Most machines have different trim pots for different speeds, so be aware of what speed you are calibrating. Make sure you are using the correct trim pots, and use the appropriate speed calibration tape.

3.4.5.1 Reproduce Calibration

Please understand that the playback section of the recorder must **always** be done first.

> You cannot know where you are going(record) if you don't know where you are (playback).

Start by placing your calibration tape on the take-up side of your machine. MRL calibration tapes are supplied "tails out" which requires you to rewind to the supply reel before each use. A slow-pack or library wind is preferred, if available.

'Tails Out" results in an ideal play-pack state of the tape on the reel before storage.

Fast winding of calibration and master tapes is never advised because it will tend to damage the edges of the tape.

3.4.5.2 Azimuth Adjustment

*Note - some machines, such as the Ampex MM-1200, do not have any azimuth adjustments. If your machine has a fixed azimuth, skip this step.

Find the 10 kHz tone on your calibration tape. Refer to your machine's manual and locate the adjustment for the Reproduce Head azimuth. This is a *mechanical adjustment* that "tilts" the head side to side to optimize the head gaps to be perpendicular to the edge of the tape.

The azimuth adjustment will result in a phase match between the left and right channels.

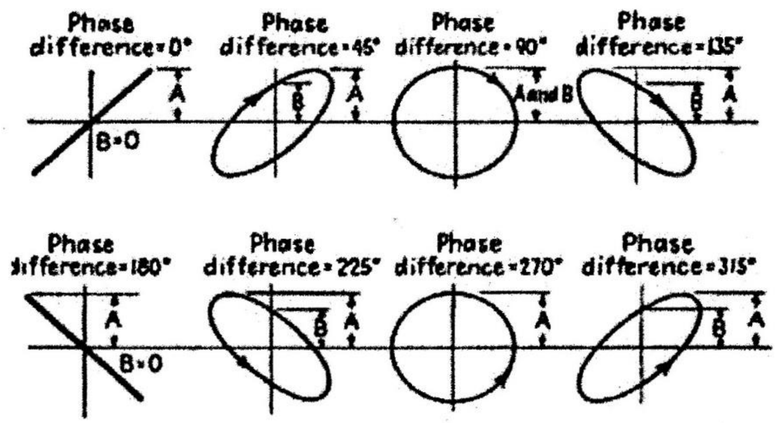
There are several methods for determining optimum azimuth that we will discuss.

3.4.5.3 Azimuth Adjustment Methods

- Oscilloscope in X-Y Mode
- Oscilloscope in Dual Trace Mode
- VU Meter Peak Level
- Electrical Summing

3.4.5.3.1 X-Y Mode

One of the most common methods for setting the azimuth adjustment is the use of a dual trace oscilloscope set for **X-Y**. Connect the outputs of your tape recorder to the two inputs of the oscilloscope. In X-Y mode the output is displayed in what are called "Lissajous Curves". During playback of pure tones the desired result is a straight line extending from the lower left quadrant to the upper right, representing a phase difference of O degrees.



Equal amplitudes and carrying phase differences

3.4.5.3.2 Dual Trace Mode

Alternatively, one can simply monitor the output of each channel on a dual trace oscilloscope. When azimuth is adjusted, you'll see a phase shift of one signal relative to the other. For example, channel 2 will move from leading to lagging as the azimuth adjustment is moved through its entire range.

3.4.5.3.3 VU Meter Peak Level

While reproducing a 1O kHz tone and adjusting the azimuth one will observe the overall output level of the tone rising and falling. An acceptable field adjustment is to simply set for peak output level.

3.4.5.3.4 Electrical Summing

Bar meters, as found on many consoles, are useful for summing the output of both or all channels to observe proper azimuth alignment. The peak reading of the summed channel indicates proper azimuth alignment.

3.4.6 Record Calibration

A good audio sine wave generator is essential for any record alignment. We will use the Sound Technology 1510A for our demonstration, today there are inexpensive generators that will do a fine job. As long as the output level is known and the output is flat from 20 Hz to 20 kHz it can be used.

*DAW based generators (plug-ins for Pro Tools, etc.) are also useful if you can verify the output by the time it gets to your tape machine. Just because the plug- in says it is producing +4 dBu signal does not mean that it is accurate after D/A conversion, etc.

Once you have selected a generator, distribute its output to feed all inputs/tracks of your tape machine. If you do not have the ability to "mult" the signal, you can calibrate each channel one at a time. Now set the generator to produce a 1 kHz sine wave and adjust the generator output gain until the machine's meter read 0 VU in Input mode. If your machines' input/output calibration is correct, this will be a "+4 dBm" level (again, this is a standard input/output electrical level that usually corresponds to 0 VU and has nothing to do with the tape operating level).

Now you are ready to thread up you "work reel". The work reel should be the same type of tape that you will be using during your session. It is important because **different tape formulations require different record settings.**

3.4.6.1 Azimuth Adjustment

Once you have threaded your work reel, ready all of the channels on your machine. Refer to your machine's manual and locate the adjustment for Record Azimuth. Set you generator for 10 kHz and engage record on all channels of your machine. As with reproduce azimuth earlier, we're looking for a zero degree phase relationship or peak level while adjusting the **Record Head** azimuth screw.

3.4.6.1.1 Bias

What is bias?

Bias is a high-frequency AC current distributed through the record head. Its purpose is to linearize the transfer characteristics of the tape and recording system. In addition, the AC bias also increases the sensitivity of the tape. By adjusting bias, you are creating the best "compromise" of frequency response, modulation noise, third harmonic distortion and signal-to-noise ratio.

Bias needs to be adjusted after record azimuth and before any other record alignment can take place.

When you set bias, you are going to be "over-biasing" by a certain amount of dB. This amount varies for each machine and tape formula combination.

The size of the gap in your record head, tape speed, and the type of tape you are using are the biggest factors in determining how much bias is required.

Refer to your machine's manual and to bias charts provided.by tape manufacturers for figures.

Once you have determined your required amount of over-bias, you are ready to set your bias adjustment.

Bias is most commonly set by recording a 10 kHz tone, adjusting the bias control until a peak level is shown on the VU meter, then increasing the bias adjustment (typically clockwise rotation) until the VU meter falls by the specified amount.

Example: You want to over-bias by 3.0 dB. While recording 10 kHz, turn the **Bias** trim pot counter-clockwise until you find a peak, in this case it happens to be at "+2" on the VU meter. Next tum the **Bias** trim pot clockwise until the VU meter reads -1 dB, giving you an over-bias of 3.0 dB from your peak at +2 dB on the meter.

3.4.6.1.2 Notes on Bias

The peak bias level may be different on every channel and is not important, it is just a reference to use for determining how much you have over-biased. In some cases, the meter will "peg" before you get to the peak. If this happens, turn the **Record Gain** pot counter-clockwise on that channel until the meter comes back into a useful range.

Bias is frequency dependent. 10 kHz is a standard reference frequency, but it is also common practice to use higher frequencies, and therefore different bias figures. We will discuss bias/frequency relationships in the seminar.

3.4.6.2 Record Level Adjustment

Now you will set the record level on your machine. Set your generator to 1 kHz, engage record on your machine and adjust the **Record Gain** trim pot to read 0 VU on all channels while monitoring reproduce output.

3.4.6.2.1 High Frequency Equalization Adjustment

To set the high frequency equalization in record, generate a 10 kHz tone into your machine, engage record and adjust the **Record HF EQ** pot for +0.3 dB/VU while monitoring reproduce output.

[Why +0.3 dB? See the discussion pages section about self-erasure.]

Since the **Record HF EQ** adjustment and the **Record Gain** adjustments are interactive, go back and recheck **Record Gain** with a 1 kHz tone. If record gain has changed, then readjust for 0 VU as needed. Check back and forth between the two tones until you are satisfied that they are both correct.

3.4.6.2.2 Low Frequency Reproduce Equalization Adjustment

Low frequency playback equalization is part of the record calibration procedure, but it is done using the **Reproduce** **LF EQ** pots. Set your generator to 50 Hz. While in record and monitoring reproduce, adjust the **Reproduce** **LF EQ** pots on all channels to read about 0 VU. If your oscillator can sweep it is very handy to know what the whole bass response looks like. Sweep from 20 Hz to 200 Hz and adjust the **Reproduce** **LF EQ** for flattest overall low end response. We will cover this thoroughly in the seminar.

3.5 FINAL CHECK

As a final test, put your machine in record and check the frequency response from 20 Hz to 30 kHz (or as high as your generator will go). The channels should match and the midrange response (800 Hz to 8 kHz) should be flat to within +/- 0.3 dB/VU. Midrange errors are very easy for the ear to pick-up, so very flat midrange is necessary for most applications. If your machine does not match well between channels, recheck your calibration. If you still have discrepancies, you may have faulty electronics, faulty mechanical alignment, or badly worn heads.

3.6 DISCUSSION PAGES

3.6.1 Track Stability

Track stability is easily determined by placing your machine in record on all channels and observing how much the VU meter needles waiver as the tape is running. On a well adjusted ½" mix-down recorder, using well slit tape at 30 IPS, there will be very little shake even at 20 kHz. The same is true for 1" and ¼" 2- track formats. When you switch to lower tape speeds like 15 IPS then the 10 kHz stability will be good and there will be some wobble at higher frequencies. Tape slitting will greatly affect the stability. If you see instability, try a completely different brand or batch of tape. If the problem continues carefully inspect the tape transport for any edge grooves or oxide build-up.

3.6.2 Choosing the Best Record Level and Equalization for a Project

Standard record (operating or fluxivity) levels are:

- 185 nWb/m – “0 dB" level - "Ampex Operating Level"
- 250 nWb/m – “+3 dB" (over the 185 level)
- 355 nWb/m – “+6 dB" (over the 185 level)
- 540 nWb/m – “+9 dB" (over the 185 level)

These operating levels are used as a reference to define the average tape level and do not take into account things like high frequency tape compression, headroom and distortion.

For example, let's say you set up a recorder for a +6 (over 185 nWb/m) operating level but during the actual recording you see the VU meter needles pegged most of the time. Well, that is not actually an average track level of +6. In fact with banging VU meters the level could be as much as +10 or +12 (over 185 nWb/m).

It is wise to choose an operating level that is true to what you really intend to do. If you want +12, set your machine up for +12. It may not look as impressive to your clients, but it gives you a more accurate picture of what's going on and will also save expensive VU meter movements.

Basically, the rule for choosing operating level is based on how much headroom you wish to maintain for peaks, particularly high frequency peaks, which will compress first.

"+9 dB" (over the 185 level) - Dirty sound with restricted dynamics

"+6 dB" (over the 185 level) - Solid sound with just a hint of compression

"+3 dB" (over the 185 level) - Open and airy sound

See: 3M- Choosing the Right Operating Level: To Change or Not to Change

3.6.3 **Self-Erasure:**

All tape oxide formulas are subject to a small amount of self-erasure soon after recording. This phenomenon occurs because some of the fine particles in the influence of a stronger field from the other oxide particles will neutralize.

It is very much a high frequency phenomenon and to understand this is crucial when doing recorder calibration. This loss of high frequency energy is only apparent after the first night of storage. After that first night the tape remains stable for years and years with very little deterioration of top end frequencies.

In order to counteract this problem, when doing your **Record HF EQ** adjustment at 10 kHz, always adjust it to be about 0.3 dB higher than the 1 kHz **Record Gain** adjustment. This ensures your mix will sound the same 6 months or 6 years down the road.

The effect is more pronounced at 15 IPS than 30 IPS because 30 IPS doubles the surface area of magnetized tape. However, both speeds are affected. Record level will also add to the equation. The higher the average record level the more high frequency self-erasure occurs. This applies regardless of track width.

3.6.4 **Track Width**

One of the beauties of analog recording is the ability to have control and personal input into the overall landscape of a recording. Track width is a big factor when deciding what sound you are going for. By doubling the track width from ¼" 2- track to ½" 2-track, for example, there is a 3 dB sign-to-noise ratio improvement. In addition, wider tracks also provide a more extended bass response because there is more tape oxide depth to print into.

What are the drawbacks of wide tracks? Wider tracks require greater tape path precision than narrow tracks to maintain good dynamic azimuth (stereo image solidity). In addition, not many tape recorders were designed to provide adequate signal electronics to drive wider format heads. A one-inch conversion on a recorder that can barely operate ½" heads sounds constricted and compressed, but with a lower noise floor.

Wide format heads provide an incredible sound that you can't get anywhere else, but so does ¼" 2-track. Think about how many great records were mixed on ¼".

There is something to gain for everyone in analog recording, and an enormous array of sonic possibilities are at your disposal if you know how to align and calibrate your tape machine.

Thanks for attending this seminar, we hope you enjoyed it and learned a lot about the art of analog recording!

4 DEMAGNETIZING A TAPE RECORDER[1] – MCKNIGHT

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The Talkback column of *db Magazine*, on page 2 of the 1987 March/April issue, published some answers to readers' questions about demagnetizing tape recorder heads. This brought a flood of comments and further questions to the Editor. So he asked me "is there any technical basis for a procedure for demagnetizing tape recorder heads?" Here is what we think we know.

4.1 WHAT GETS MAGNETIZED IN A TAPE RECORDER?

Anything that contains iron, nickel, or cobalt is probably ferromagnetic, which means that it can become magnetized.

But the magnetic field decreases rapidly with spacing, so our concern with magnetization can usually be limited to only those things which directly contact the tape - heads, guides, and the capstan shaft.

The materials used to make head cores and shields are very low remanence (that is, they would make terrible permanent magnets), but if they are subjected to a high magnetizing field they do retain enough magnetization to affect a tape recording.

The guides and capstan shaft are subject to the constant abrasive wear from the tape running over them, so they must be wear-resistant. What is non-magnetic and wear resistant? Ceramics are used and Pyrex glass is used, but most often guides and capstan shafts are made of "non-magnetic stainless steel." As with the head material, "non-magnetic" only means that you would not intentionally use the material to make a permanent magnet. It does not mean that it has no remanence at all!

Another source of unwanted magnetic field in a tape recorder could be current flowing in an electrical conductor. It takes a current of 300 A to make a field of 2.5 kA/m (10 % of the tape coercivity - the least that could affect a recording) at a distance of about 20 mm away from the conductor. Such currents are never found in a tape recorder, so we won't further consider the field from a conductor. Yet more sources could be solenoids and transformers. We have not measured their fields, but we do not believe that they produce large enough leakage fields to be a problem.

4.2 HOW DO HEADS AND GUIDES GET MAGNETIZED?

Certainly there is an obvious way to magnetize a head, guide, or capstan shaft - touch it with a permanent magnet, such as a magnetized screwdriver.

The capstan shaft runs down into the motor "works" which is a veritable hotbed of magnetic fields. But they are *alternating* fields in many studio recorders; and even in de motors, the magnetizing path through the capstan shaft would seem to be very inefficient. So I would not expect the motor to magnetize the capstan shaft.

You can also magnetize a head by passing direct current or a large unidirectional current pulse through it. How could this happen? Testing continuity with an ohmmeter is one way. But tape recorders in normal use do not have magnetized screwdrivers poked into them, and the heads are not continuity tested. Things *do* get magnetized, but how? That is one of the great mysteries of tape recording.

It may happen that an associated amplifier draws current through the head, either all of the time, or during power-up or power-down. We have had reproducing-head magnetization that seemed - as best we could find - to be caused by occasional current pulses from an integrated-circuit pre- amplifier on power-up or power-down (this was a homebuilt pre-amp, not a commercially-manufactured unit). This is difficult to analyze, because it happens only rarely. But once can be enough to magnetize the head.

If you find an answer, please tell me! Suffice it to say that I have observed "mysterious magnetization" and I'll bet that you have too.

4.2.1 SO WHO CARES ABOUT A LITTLE MAGNETIZATION?

We all do! Magnetization can produce high second harmonic distortion in your recordings. It can produce clicks at tape splices. It can produce low-frequency noise (rumblings and poppings), and high-frequency noise (hiss). It can partially erase the recorded signals – especially the short recorded wavelengths (that is, the high frequencies, especially at slower speeds).

4.2.2 HOW DO I KNOW IF I HAVE MAGNETIZATION?

If the magnetization is bad, you have already heard some or all of the effects just listed. But you really want to eliminate the magnetization *before* you ruin a recording session or an existing master tape, not afterward.

Finding out what is magnetized, how much it is magnetized, and why it is magnetized, will take much longer than the actual demagnetizing. So if you are the usual busy maintenance engineer, you will probably just demagnetize without worrying about scientific analysis. But, for the curious...

The list of magnetization effects can be broken in two categories - magnetization in recording, and magnetization in reproducing.

Magnetization in recording occurs because of unidirectional magnetization at a point where an alternating magnetic bias field is present. Such a point would be at the recording head, the erasing head, or both[2] This magnetization causes high second-harmonic distortion, high recorded background noise - mostly rumblings and poppings and clicks at splices.

Magnetization in reproduction occurs because of unidirectional magnetization at a point where there is no alternating bias field, such as the reproducing head, guides, and capstan shaft. It causes increased noise - mostly high-frequency noise, and erasure of signals mostly high- frequency signals.

These effects directly suggest the tests that you can perform.

4.3 RECORDING TESTS WOULD BE AS FOLLOWS:

Distortion test: Record a mid-frequency test signal (any frequency in the 250 Hz to 1000 Hz range) having low distortion (less than 0.2 % second harmonic distortion) at normal recording level[3] using normal bias, and measure the second harmonic distortion of this recording. If the second harmonic distortion exceeds 0.5 %, then there is probably a magnetization problem. (You will need a sharply tuned filter such as a wave analyzer or at least a 1/3-octave spectrometer for this measurement. A Total Harmonic Distortion meter is completely useless here - its indication is derived mostly from third harmonic distortion, background noise, and bias leakage.)

Pop and thump test: Record a "blank" tape with normal bias. Increase the playback gain so you can clearly hear the noise. Listen to the playback of the noise. If you hear "popping and thumping". noises, you probably have a magnetization problem. This is not a very repeatable test because the "popping and thumping" are also very much a function of the blank tape itself. So a "bad" tape on a "good" recorder may sound rather like a "good" tape on a "bad" recorder. Therefore this test may be difficult to use. I have said "listen" rather than "measure with a voltmeter" for two reasons: First, not all studios own a voltmeter that will read levels down to the -50 dB to -80 dB range that we are measuring here. Second, your ear can tell the difference between hiss, rumble and thumps, bias leakage, etc., but a voltmeter can't tell the difference unless you filter the noise first, and have the right averaging time in the rectifier.

Splice click test: Take the recording mentioned just previously and splice a 10 mm length of non-magnetic (paper or plastic) leader into it. For best effect make a 90 ° (not 45 °) cut, and be sure the splicer is not magnetized. Play through this splice. If you hear distinct clicks when the splice passes the reproducing head, you have a magnetization problem. With a storage oscilloscope you could make quantitative measurements.

4.4 REPRODUCING TESTS:

Are easy enough if the magnetized element is "downstream" of the reproducing head, because reproduction *during recording* would give a reference condition (the tape has not passed the magnetized surface) but rewinding and reproducing again would give the measurement after the tape has passed the magnetized element.

Noise-increase test: Record a "blank tape" as above. Turn up the reproducer gain so you can hear the noise. First listen to the mid- and high-frequency hiss *as you make the recording*. Then rewind and play the tape several times. If the hiss increases with number of plays, then something is magnetized.

High-frequency erasure test: Record a high frequency (16 kHz at 7.5 in/sec, at about -10 dB), and (as above) play during recording, then rewind and play several times. See if the recorded level remains constant for all of these playbacks. It is not unusual to see the level at this wavelength drop a few tenths of a decibel on repeated playings (attributed to magnetostriction, and commonly called "bending loss"), but if the level of the recording drops more than about 0.5 dB with several plays, then magnetization is likely.

If, on the other hand, the reproducing head *is* magnetized, then even the first playback may be noisy and erased. In this case, you have to make a first recording that may already be noisy and erased. Then demagnetize the reproducing head, and make a second recording. Compare the noise level and high-frequency response of the first and second recordings. If they are the same, you didn't need to demagnetize the reproducing head. If the second recording has less noise and a higher level than the first, you did need to demagnetize the head.

Note that on a multi-channel recorder it is probable that the magnetization problems will be different on the different channels. So all tests have to be done on every channel that you care about. This may be a blessing in disguise, because you may find that some channels are not magnetized, and serve as reference for the magnetized channels.

4.5 MAGNETIZING AND DEMAGNETIZING

There are two concerns when using a demagnetizer: First, is the field from the demagnetizer strong enough to demagnetize the heads and guides? And second, when is it far enough away so that you can shut it off without re-magnetizing the heads and guides?

Demagnetizing: If the demagnetizer is to demagnetize the core laminations, then the field that it produces must be large enough to cause the induction (flux density) in the core to approach saturation. When saturation approaches, the head output voltage waveform becomes distorted. But by this time the output voltage level is about 50 dB greater than the maximum output from tape, and the playback head preamplifier will surely be completely overloaded. Thus to perform this test you must disconnect the head and connect it directly to an oscilloscope input, and look for distortion in the waveform.

Now another measurement complication arises: the head output voltage is the derivative of the core flux. The effect is that when the core flux is sinusoidal, the output voltage is also sinusoidal. But when the flux becomes a square wave, the head output voltage becomes a series of "spikes," and there's no way to tell just how near you are to core saturation. The "fix" for this is to build an integrating amplifier[4] When the head output voltage is fed through an integrator, the integrator output voltage has the same waveform as that of the core flux. Therefore the 'scope waveform will show a flat-topped wave when the core saturates.

For rough estimation purposes, you can look at the head output voltage directly on an oscilloscope. Turn the head demagnetizer on, and bring it to a point about 20 mm away from the head. You should see a sinusoidal wave on the 'scope. Then bring it closer, eventually touching the core with the demagnetizer pole tips. As you bring it closer, you should come to a point where the waveform on the 'scope begins to look distorted. The sinusoid will turn into more-or-less spikes. When you begin to see spikes, the core is saturating, and the head will be magnetized if you switch the demagnetizer off, or demagnetized if you move the demagnetizer away from the head before switching it off.

Remagnetizing: So... you ask "how far away from the head do I have to be before I turn off the demagnetizer?" The magnetics textbooks get pretty vague here. They tell us that a field that produces less than about 10 % of the saturation induction will not produce permanent magnetization. If you measure the actual head output voltage level at the onset of non-linearity, and compare it with the level from a test tape (at the same frequency), you will see that the level difference is about 60 dB, which corresponds to an induction not 10% of saturation, but just one-hundredth of that, which is 0.1 % of saturation. Put another way, it seems intuitive that the magnetization on ordinary recorded tapes will not permanently magnetize the heads, so the same field from a demagnetizer should not permanently magnetize the heads either.

Now this gets to be a measurement that you can easily do for yourself: Take a reproducer that is calibrated so that normal recording level of around 250 nWb/m gives a reference (0 dB) indication on the volume indicator of the reproducer. Turn on your head demagnetizer, and bring it closer to the heads, until the volume indicator reads around 0 dB. (With our particular demagnetizer and heads this condition corresponded to a demagnetizer-to-head spacing of about 70 mm. You will probably find a similar distance.) Now at this distance, nothing you do to turn off the demagnetizer or move it still farther away can possibly produce a high enough field to magnetize the heads.

Perhaps someone will say, "Ah, but when you switch the field off suddenly, a spike is produced." It is true that the head output voltage will have a spike because the output voltage is the derivative (rate of change) of the magnetic field. But there is no spike in the magnetic field itself - it just falls to zero. You can confirm this for yourself. Connect a loudspeaker to the tape recorder output. Position the demagnetizer about 70 mm from the reproducing head. Switch it on and off, and listen for loud clicks. You won't hear any, and this means there are no large magnetizing pulses that could magnetize the head.

4.6 CONCLUSION ABOUT REMAGNETIZING:

Once the demagnetizer is around 70 mm away from the head, it doesn't matter how you move it around and turn it off.

PS It is possible for a ferrite erasing head to be permanently magnetized enough to record "de noise" onto the tape. The only solution in this case may be to replace the erasing head.

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1 This paper was originally published in db Magazine, Vol. 21, Nr. 4, pp 41...43 (1987-07/08). The present version is very slightly re-edited from the originally published version. Typo corrected and PS added 2005-02

2 Yet another source of unidirectional field in the recording and erasing process is an asymmetrical biasing or erasing current waveform. This may be a high harmonic (such as the 1O'h harmonic) "blip" on the wave.

3 Unlike the third harmonic distortion, which is a function of the square of the signal amplitude, the second harmonic distortion due to the unidirectional magnetization is essentially independent of the signal amplitude.

4 Contact MRL for information if you want to build such an integrating amplifier.

5 AMPEX – CARE AND STORAGE OF MAGNETIC TAPE

Your recording of valuable data is done under precise and closely controlled operating and ambient conditions to insure exact reproducibility. Every care is taken to provide optimum performance of the machine, tape and all components. It is equally important to provide the same care in the handling and storage of the tape to protect the valuable recorded data.

In order to understand more clearly the factors affecting magnetic tape storage, there are a few basic concepts to be understood. The magnetic ability of the oxide on a magnetic tape does not degenerate in other words, the magnetic particles will never get tired and allow the data they are holding to "leak off". The only thing that will cause the particles to change their orientation is the influence of an external field.

However, degeneration can occur in another fashion. Basically, magnetic tape consists of three constituents: base material, binder, and oxide. The oxide does not lose its magnetic potency with time, however the base materials may become brittle, distorted, and lose their intrinsic properties if not stored under proper conditions. The binder system also may degenerate which will result in complete loss of stored data if proper precautions are not taken.

Base Material. The main broad function of the base material is to provide a means to hold iron oxide and move past the heads of the recorder in a controlled fashion. It must also electrically insulate one layer of oxide coating from the other to prevent print through. Dimensional stability (resistance to physical change as a result of varying ambient conditions) is the keynote in good base material. It must also maintain resilience so that in this flexible state it may provide good tape to head contact. It is obvious that if they base material becomes brittle, work, or wavy, the tape will be useless regardless of how superior the oxide coating may be. Temperature and humidity extremes should be avoided to maintain the dimensional integrity of the base material.

Mylar* (or polyester) affords the best characteristics to meet the demands for magnetic tape ace material. Plastic acetate base does not possess the dynamic mental stability and durability required for instrumentation and computer tape requirements.

Binder. The function of a binder system is more complex and critical. Actually there are several distinct functions that a binder must perform the binder must provide even dispersion of the oxide particles confine them within a very thin layer it must maintain durable, frictionless surface possessing long wear characteristics all this must be accomplished while the buyer provides efficient bond (adhesion) of oxide coating to the backing material, and effective bond (cohesion) of the magnetic particles to each other. There must be no physical or chemical reaction between the binder and the tape packing or any material normally encountered in the tape handling mechanism. The life of the binder system is critically dependent upon the storage environment.

Ideal temperature and humidity conditions are shown in figure 1. In the case of long-term storage, it is imperative that these conditions be met to eliminate unnecessary and accelerated degradation of magnetic tapes.

Physical Damage. All tapes in storage must have proper protection from physical damage. The reels should be sealed in dust proof bags, replaced in original cartons and stored on adequate shells where they will not be moved or subjected to vibration. The storage area must be free from all external magnetic fields (See Part I: Effects of Stray Fields on Magnetic Tape.) The boxes of tape stored on is proper support to prevent them from falling.

The usual precautions of tape handling apply in the preparation of reels for storage tape should be used, handle, and packaged in dust free, controlled ambient. Nothing should come in contact with the tape edges exposed through the Flange windage holes. Tape should always be handled by the wheel in such a manner fingers never touch the tape reel should be handled by the hub. When handling a real by the flan just you may pinch the flame just together to the point where they assume permanent set and will not properly track on the transport. Final winding of the tape must be done as accurately as possible to minimize port tape pack, internal stress, pack slip, etc. the rewind mechanism should be checked frequently and must always meet the published specifications of the equipment manufacturer, particularly in regard to braking systems, holdback tensions, etc.

It is advisable that all tape in long-term storage be rewound once a year. This is done to relieve any internal stress that may have built up within the tape pack during storage.

Stored tape should be normalized before it is used. If the storage ambient is different from the operating ambient, the tape should be placed in its operating ambient at least 6 – 8 hours prior to its use to ensure the tape is reached thermal equilibrium.

For best results with medium or long-term tape storage, it is recommended that mylar based film tape be used. A 1.5 mil mylar back tape provides optimum strength and print through characteristics.

6 AMPEX – EFFECTS OF STRAY FIELDS ON MAGNETIC TAPE

A major vantage of magnetic tape is a storage medium is its ability to be erased and recorded over many times. Normally this is accomplished by one of two methods. One approach is to use a bulk eraser that is capable of erasing entire reels in seconds, which is done by slowly rotating and moving the real through a concentrated AC field. The second technique is the more familiar erase head incorporated in the tape transport. The erase head is energized during record mode to ensure that a new recording is never made over previously recorded information.

Virtually all equipment incorporating a race head contains a simple interlock to minimize unintentional erasure. The danger of unintentional erasing is recognized by most operators, and their attention to it minimizes the problem. However, a less understood phenomenon is the effect of stray fields on a tape during handling and storing.

An understanding of the relationship between gauss and oersted as applied to measurement of field strength will help to clarify the effects of stray fields on tape.

Bot the gauss and the oersted are units of magnetic measurement. The oersted is the measure of magnetizing force in the gauss is a measure of the resultant magnetic intensity. When measuring field strength in air the gauss and oersted are numerically equal. The relationship is altered in magnetic materials such as tape which have a greater permeability than air. In these materials of high permeability the oersted – gauss relationship is a function of the permeability.

Different types of stray fields affect tape in different ways the first field to consider is a steady DC field, such as that produced by permanent magnet. If a reel of tape remains within DC field, the resultant effect is that an extra signal is recorded on the tape. This will take the form of background noise, and will vary in strength in proportion to an exponential of the applied field and a proportional to the length of time the field is applied.

This will be similar to the effect that a magnetized recording head which was not properly degaussed will have on the tape during recording. This points up to the need and advisability of degaussing heads frequently. (Consult equipment operating guide for specific degaussing procedures.)

A different phenomenon occurs when tape is exposed to an AC field. If a tape is moved rapidly through an AC field, the effect is about the same as recording on the tape without using AC bias. A highly distorted time varying signal can be left on the tape. This noise is recorded in much the same manner is significant data coming through the record head in normal operation. With a stray AC, the possibility of erasure always exists, and degree of erasure is not with respect to the AC field strength. If the peak strength of the field is less than the coercivity of the tape, it is impossible to have a complete erasure regardless of how long the tape remains in the field. In AC fields greater than the tapes coercivity (usually 250 – 260 oersteds), the signal on the tape will be completely obliterated. Tape erasure in an AC field may be considered a time function. A brief exposure to a 700 – 1,000 oersted field will completely erase the signal on the tape, whereas longer exposure to weaker fields will be required for complete erasure.

Another effect suffered from exposure to stray fields is that of increased print through. This can occur at relative small field strengths. For instance, a five minute exposure to an RMS field of 20 oersteds will cause a print through increase of 10 db. The print through increases roughly at the rate of two DB for every additional five oersteds.

The effect on tape of the Earth's magnetic field of approximately 0.5 oersteds is negligible. Generally stated, a stray field of up to approximately 10 oersteds should have no detrimental effects on magnetic tape. When tape is exposed to more powerful fields, up to 100 oersteds, low-level short wavelength may be erased. As the field strengths of 700 oersteds or more will completely destroy all magnetic data previously recorded on the tape.

Although field strength increases significantly as we move away from the source, a safe storage space away from electric motors and other known sources of magnetic fields should be provided.

7 dB Definitions

dBm

The reference level is 1 milliwatt across an impedance of 600 ohms. The "m" stands for milliwatt. The 600 ohms came from standards in the telephone industry where maximizing power transfer by matching output and input impedances was an important consideration. Note that a 0 dBm signal in a circuit with an impedance of 600 ohms corresponds to 0.775 volts RMS. A signal change of -3 dBm is about a halving of the power.

dBV

The reference level is 1 volt RMS across any impedance. To convert dBV to dBu, add 2.2 dB. Consumer audio gear is designed for a normal input level of -10 dBV, which corresponds to 0.316 volts RMS. This voltage level arose because it was the optimal maximum level for a signal fed directly to an electron tube, which was a practice in consumer equipment.

dBv

The reference level is 0.775 volts RMS across any impedance. The 0.775 volts value comes from the definition of dBm, since it is the voltage when a 0 dBm sine wave is fed into 600 ohms. **This symbol was too easily confused with dBV, and so was renamed dBu.** Some writers do not observe the distinction between the upper and lower case V and treat both dBV and dBv as referenced to 1 volt rms.

dBu

New designation for dBv. The "u" stands for un-terminated. Professional audio equipment is designed for a normal input level ("line level") of +4 dBu, which corresponds to 1.23 volts RMS. A signal change of -6 dBu is about a halving of the voltage.

dBFS

The FS stands for "full scale." This unit is used in converting a signal between analog and digital formats. Full scale is the level at which the binary number describing the signal is a 1 in all places; it can't get any larger.

8 TAKING CARE OF YOUR TAPES

8.1 DIRT

- always store tape and a dustproof container when not in use. This protects the tape from dust particles, which can cause dropouts.
- Never touch the tape surface or tape pack. Even touching the back of the tape can transfer dirt to the adjacent layer. If touching the tape cannot be avoided, use lint free gloves.
- Avoid smoking or eating in the tape area. Smoke and food particles can contaminate the tape and ashes can cause damage.
- Loose tape and should not trail on or near the floor. Always use approved hold down tabs or reel bands, even when the tape is in its container.
- Clean the entire tape path after each pass, if possible, using a lint free cloth and approved solvent. Clean the path at least every eight hours.

8.2 PHYSICAL DAMAGE

- Handle tape reels only by the hub. Never squeeze the flanges. Bent flanges should be replaced to avoid tape edge damage.
- Rewind poorly packed tapes.
- Trim damage tape ends to avoid depositing debris on the tape transport and recording heads.
- Never stack tapes on top of one another. Store tapes vertically so they will be supported by the hub.
- Don't put tapes on top of equipment. This interferes with the equipment's cooling system also exposes the tape to heat and dust.

8.3 ENVIRONMENT

- the ideal operating and short-term storage environment should be 68°F (20°C) and 40% relative humidity.
- For best archival storage, rewind tapes everyone the five years to relieve stress is in the pack. (Refer to "Rewind Frequency Chart in the Addendum.)
- Allow a minimum of eight hours for tapes to condition themselves when brought from a different environment.
- Never expose tapes to direct sun, hot vehicles, etc.
- Always store and use tape in the cleanest environment possible away from magnetic fields.

8.4 TAPE DO'S AND DON'TS

DO

1. Do store tapes in dustproof containers or on transport.
2. Do trim damage tape ends.
3. Do clean tape path of machine as often as possible.
4. Do rewind poorly packed tapes.
5. Do store and use tape in comfortable controlled environment.
6. Do allow tape to acclimate itself to a new tape room environment before using.

DON'T

1. don't use top of equipment as a work area.
2. Don't let tape get close to the floor.
3. Don't smoke or eat in the tape room.
4. Don't handle reels by the flanges.
5. Don't stack tape reels horizontally.
6. Don't touch tape surface or tape pack without lint free gloves.

Observing his dues and don's will help you get the highest performance and longest life from your magnetic tape.

9 BIAS SETTINGS

ATR Tape is a +6 Tape

ATR Tapes is a low noise/High Output Tape – Button "LH"

ATR Tape is similar to the Ampex 456 & Scotch 206 Tape Formulas

	Switch Positions	
Pioneer/Revox	BIAS	EQ
909	2	2
707	"STD"	"LH"
RT-1020L	2	"LH2"
RT-1011L	2	LH
RT-901	2	2
Technics		
RT 10B218	2	2
1506	2	2
1500	2	2
RS-1700	2	2
TEAC		
A-4300SX	2	1
A-2300SD	1	2
3340S	1	EE – Pressed In
X-10R (Up Position)	1	1
X1000R	LH-1 – Tab Down	LH-2 – Tab Up