Studio Site

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Analog Tape Recorder Maintenance

TIME	EVENT	SOURCE
1:25 p.m.	News feature (delayed from satellite feed)	Tape 1
1:29 p.m.	Spot	Cart 1
1:30 p.m.	Newscast (live with actualities)	Newsroom
1:33 p.m.	Spot	Cart 2
1:34 p.m.	Weather (recorded from weather service)	Cart 3
1:35 p.m.	Newscast sponsor close	Cart 1
1:36 p.m.	Return to music programming	Various

This segment of a typical program schedule shows how important analog tape is to the average radio station. In only ten minutes this station used at least four analog tape machines. In all probability the newscast contained actualities that were on carts and may have been taken from either a news service or recorded by the station's own news staff on cassette recorders. That being the case, this station probably used seven or eight analog tape machines in the preparation and presentation of this program segment.

Analog tape recorders play a major role in most modern radio stations. Some stations play almost all local programming from analog tape. Analog tape recorders include many familiar formats, such as reel-to-reel, cassette, and the very familiar NAB cart. While these formats are all considerably different, and not even compatible with one another, they all share the same principles of operation and problems. The procedures used for maintaining one are applicable, with slight modification, for another.

While a discussion of the principles of operation for analog tape is very interesting, we are going to concentrate on the maintenance of analog tape equipment in this article. For convenience in this discussion, we will use the word "tape" for any analog tape, completely ignoring the fact that digital tape exists. If we wish to differentiate between cassette, reel-to-reel, and cart, we will use those terms.

When discussing tape recorder problems and maintenance, we must look at the entire tape system. A machine in perfect working order will not seem to work properly if the tape is defective. You can find new tape that is bad as well as old tape. Some of the problems you may encounter with tape are bad slitting, oxide shedding, edge damage, and bad reels (reel-to-reel) or housings (cassette and carts). Before attempting to find a problem with a machine, make sure the tape you are using is good. On the other hand, using perfect tape on an improperly maintained recorder will not give satisfactory results, and the tape may be damaged by the machine.

Problems with tape machines may show up in a number of ways. Audio frequency response degradation may be caused on both the record and playback sides of the system by

(continued on page-21)

Studio Site

Continued . . .

dirty heads, incorrect azimuth, worn heads, poor tape guidance, and improper adjustment of the electronics. On the record side, simply using a tape type for which the machine is not adjusted can cause the same sort of problems.

Distortion of the audio signal can take a number of forms. The amount of total harmonic distortion (THD), the type of distortion most frequently measured in audio, may give you an idea that something is not right, especially if you know what the typical value of THD is for that type of machine. However, it is more useful to know the specific nature of the distortion. A high content of *even* harmonics (2, 4, 6, 8, etc. times the fundamental frequency) indicates a very different set of problems from a high content of odd harmonics (3, 5, 7, 9, etc. times the fundamental frequency).

However, harmonic distortion is difficult to measure on any tape machine without an analyzer capable of both automatic nulling and automatic level adjustment. The normal variations in the tape and its movement through the machine will tend to invalidate any manually adjusted harmonic distortion measurements. An audio spectrum analyzer, while not usually found at a radio station, can be another useful tool for such analysis.

Inter-modulation distortion (IMD) can also tell you a lot about the condition of your tape and machine. High values of IMD show excessive non-linearities in the tape system. This can indicate that the bias is not properly adjusted, but it can also be an indication of bad tape. Different types of tape can yield different amounts of IMD, so knowing typical performance is once again useful.

Another symptom frequently encountered is wow and flutter. Wow and flutter are variations in the speed of the tape over the heads. Wow is usually the term used for very low frequency (below about 50 Hz) variations, such as what you would have if you put your finger on the reel momentarily. Flutter refers to higher frequency (about 50 to 200 Hz) variations in the tape speed. Another type of flutter, commonly known as scrape flutter, is caused by the vibrations of the tape as it passes over a stationary or non-rotating element in the tape path. These variations are usually in the 2 to 3 kHz range.

A good flutter meter is the best way to identify these variations. (For a more thorough discussion of flutter, I would suggest a paper by Dale Manquen of Altair Electronics, 1694 Calle Zocalo, Thousand Oaks, CA, 91360, entitled

(continued on page-22)

"A Wideband Tape and Transport Diagnostic System." This paper was presented in the 66th Convention of the Audio Engineering Society. Copies should be available from the AES or from Altair Electronics.) High wow or flutter is usually an indication of some sort of mechanical problem. However, a bad tape reel or housing can also cause wow or flutter. Anything that prevents the tape from moving freely over the heads will cause wow or flutter, so the possibilities are broad. Depending on the specific machine, wow and flutter can also be caused by electronic problems. If the capstan motor is electronically controlled, as is the case with most modern machines, any problems in the electronics may cause irregularities with the tape speed.

Audio is recorded by applying a magnetic field to the tape. The tape acquires this field and stores it so it can be reproduced at a later time. Any stray magnetic fields around the tape or the tape machines may cause problems. If the magnetic field is strong enough to change the magnetism on the tape, the recorded signal will be affected. If any elements of the tape recorder that come near the tape become magnetized, the performance will be degraded. Magnetization of something in the tape path (heads, guides, capstan) is usually indicated by either self-erasure of the tape (every pass of the tape through the machine further erases the signal on the tape) or by a high amount of second harmonic distortion or noise during recording.

Magnetization is generally not a problem in professional equipment manufactured within the last ten to twenty years, but it can occur if there is an electronic problem such as a leaky capacitor between one of the heads and the electronics. Routine demagnetization of your recorders is not recommended, since it is possible to do more harm than good if you are not careful. Errors in the demagnetization process can leave more magnetism on the recorder than you had when you started. Unless you strongly suspect a magnetization problem, don't try to fix a non-existent problem. If you would like more information on this subject, a good discussion is available from Magnetic Reference Laboratory, 229 Polaris Ave, Suite 4, Mountain View, CA, 94043. Their phone number is (415) 965-8187.

Frequency	What To Do
Daily*	Clean heads and tape path
Weekly	Clean heads and tape path Clean outside of machine Replace burned out lamps Check for signs of wear
Monthly	Do all weekly checks plus: Check for tight & rough bearings Check for excessive mechanical noise Check for proper operating level calibration Check for proper head azimuth*
Quarterly	Do all monthly checks plus: Check for proper record/play freq. response Check for proper flutter Check for proper signal-to-noise ratio

Items marked with (*) may have to be done more frequently depending upon usage and machine

Figure-1

In addition to the various problems already discussed, there are a few things that can be very elusive when trying to find them. For instance, the switches on the recorder can make poor contact, causing anything from poor frequency response to incorrect levels. Cassettes (and sometimes carts) may appear to need a new head alignment each time you use them. The lubricant on the tape in a cart may begin to dry out, causing any number of speed and stability related problems. The more completely you understand the tape recording process and your machines, the easier it will be to locate these problems.

Now that we know what some of the problems are that we may encounter with our tape machines, let's see what we can do to make them work better. Since tape machines are both electronic and mechanical devices, the best way to keep them in good working order is with a routine preventative maintenance program. The check list in **figure-1** can serve as a handy reminder of what to do and when to do it.

Keeping a tape machine clean is the simplest, yet most effective thing you can do to assure proper performance. The heads and tape path tend to get dirty rapidly due to the slight abrasion of the tape on the heads and guides. Small amounts of dirt and oxide from the tape will be left on all of these surfaces. These deposits may cause erratic movement of the tape over the heads. They may also clog the gaps on the heads or lift the tape slightly from the heads, causing very poor frequency response. Depending on the tape used, it may be necessary to clean this area each time the machine is used. For any critical work, such as a master recording, the heads should be cleaned before each tape pass. Do not rely on the deposits being visible before cleaning the heads. I have seen many cases of "clean" heads not working properly until they have been cleaned.

(continued on page-23)

The heads should be cleaned with a good quality head cleaner or with alcohol. Use isopropyl alcohol or a good grade denatured alcohol for cleaning heads if you do not use a commercial head cleaner. Do not use rubbing alcohol as this contains oils which will leave a deposit on the heads. Use a new cotton swab to clean the heads, and only dip it in the cleaning agent once. A second dip may transfer contaminants to the cleaning agent, rendering the whole container useless. Tape guides, idlers, and the capstan may also be cleaned with this alcohol.

Unless you know it is safe, do not use the head cleaning agent on the pinch roller. There are special cleaners available that will not dry out the rubber used on pinch rollers. When cleaning the head and tape path area, be sure not to leave any fuzz from the cotton swab. Also, try not to use so much cleaner that you can squeeze it out of the swab, especially in the area of the capstan. The swab should just be moist enough to do the job. You may need to use a flashlight to see what you are doing with some machines.

While it may not seem very apparent, cleaning the outside of the tape machine periodically serves two very useful purposes. First, it prevents build-ups of dirt that may eventually get into the machine and cause mechanical problems. Second, it signals your co-workers and management that you care about the equipment. If you keep the equipment clean, it will be treated with more respect by those who use it. Most machines can be cleaned with a mild solution of dish detergent and water. Use a paper towel or cloth dampened with this solution and wipe machine clean. More stubborn dirt can be removed with a stronger cleaning agent and some elbow grease. Many owner's manuals suggest ways of cleaning the equipment. Follow these suggestions whenever possible. Be especially careful of strong solvents, such as alcohol, when cleaning machines. They may attack the plastic parts used on the machine.

Replacing burned-out lamps on your tape machines (as well as other equipment) on a regular basis will prevent operator confusion, as well as letting your co-workers know you are doing your job. Check the equipment manuals for the proper lamps to use and the procedures to replace them. Many manufacturers offer special tools to assist in changing lamps on their machines. These tools can often mean the difference between doing the job efficiently and really messing up the machine.

(continued on page-24)

Studio Site

Continued . . .

While tape feels smooth on your fingers, it is really quite abrasive. As the tape moves over the heads and guides it acts like very fine sandpaper. Even though some tape types are more abrasive than others, all good tape should provide even wear. A quick visual inspection once a week of the heads and guides will let you know when a problem is brewing. If you see any signs of horizontal scoring, you have a problem that should be dealt with immediately. This usually indicates that you are using bad tape and may cause damage to any good tape you run over the machine. Whenever a head, guide, or idler becomes so worn that there is a groove in it, it should be replaced or otherwise repaired. A groove will cause the tape to be forced out of the proper path defined by the guides and may cause damage to the tape as well as degrade the recording. Many guides can be rotated to provide a fresh surface, thus prolonging their life. The heads can be quite a different problem.

Worn heads must be either replaced or relapped. Relapping is a process whereby the surface of the head is polished smooth. Over the years many people have suggested relapping your own heads. On most modern machines, especially those with more than one track, this is not a good idea. When the electronics of a tape machine are designed, they are matched to heads of a specific impedance. Remember that impedance includes both resistance and reactance, just like your antenna. If the head varies more than about 10% from this design specification, performance of the system will be degraded, perhaps significantly.

Any head that is to be relapped should be checked against the design impedance both before and after it is relapped. This *must* be done with an impedance bridge. (Do not use an ohmmeter to check a head at any time. This will almost certainly magnetize the head.) Not only must the impedance of the head be within the design specification, but all channels of the head should match fairly closely. If they do not it may be an indication of uneven wear on the head. When the head is relapped, it must be done in such a way that the surface is even and parallel with the original surface. This is almost impossible to do to tight tolerances, which are necessary for good channel matching on any multitrack (including stereo) head. Most people do not have the necessary equipment to do this job well, so it is best left for those who do. When a head is relapped or replaced, it must be properly aligned in the machine. We will discuss this a bit later.

As we mentioned earlier, tight or rough bearings will lead to wow and flutter problems. Remember that all rotating idlers in a machine have bearings, even though you may not notice them. A general rule of thumb is that if it rotates, it should do so freely and smoothly. However, some idlers may seem tighter than others. Knowing your machine will help you know when you have a problem.

Any unusual noises in a tape machine indicate a problem. They will usually appear at first in fast forward or rewind modes. Knowing normal operation of your machine is important here. Excessive noise usually indicates some sort of mechanical problem, such as a bad bearing, and may give you some advance notice before it causes any audio problems. However, carts and cassettes frequently make strange noises in the fast modes, so make sure you are using a good one for this test.

Proper level calibration is very important in any tape machine. When properly adjusted the operating level will be set at a point that will give the best compromise between noise and

(continued on page-25)

overload with both the tape and the signal electronics. Tape users and manufacturers use a variety of standard operating levels, depending on the characteristics of the tape. This level has nothing to do with "0" level on the meters, but is instead a magnetic level (fluxivity) on the tape. Most broadcasters use 200 or 250 nanoWebers per meter (nWb/m) for their standard level for reel-to-reel tape. Cassettes and carts usually use 250 nWb/m and 160 nWb/m respectively for their reference levels. However, some users may wish to use a higher or lower level to give a lower noise floor or better headroom.

A calibrated reference level tape is necessary to set operating level for a recorder. The audio signal on this tape should be of a frequency that is not affected by the playback equalization. In this way errors in the equalization adjustment do not introduce errors in the level adjustment. If the reference tape available to you is not the same level you wish to use, **figure-2** on page-26 can be used to get to the right level.

Play the reference tape and adjust the reproduce level controls while looking at the output level with an audio level meter. For the moment, ignore the VU meters on the recorder. The level you are reading should be your desired output level (for instance, +4 dBu) with any necessary correction applied to compensate for differences in your tapes. For example, if your desired output level is +4 dBu and your desired tape reference fluxivity is 200 nWb/m and you are using a 250 nWb/m reference tape, you should adjust for a reading on the output of +6 dBu. Then adjust the VU meters on the recorder for the proper level. Using the same example, you would adjust the VU meters to read +2 VU.

After the reproduce level has been set, you can then set the record level calibration. Place a tape of the same type you normally use on the machine and feed a tone into the machine. This tone should be the same frequency as the tone on the level calibration tape, and should be at your system "0" level as measured before the tape machine. Adjust the record level controls (usually on the front panel) for a reading of "0" on the VU meters while looking at the input. Then adjust the record calibration controls (usually an internal adjustment) for a "0" reading on the VU meters while looking at playback. This procedure may take a bit longer if you can not look at playback while recording, but it is the same adjustment.

Head azimuth (perpendicularity relative to the tape) will affect many parts of the tape signal. Poor azimuth on either record or playback will result

(continued on page-26)

Studio Site

Continued . . .

in loss of high frequencies on both mono and multitrack machines, as well as poor mono compatibility on a multitrack machine. Perhaps you have heard a "swishy" sound when playing a stereo tape and listening to it in mono. The "swishiness" is not there when you listen in stereo. This is the result of poor azimuth adjustment on either the recording or reproducing machine. You are hearing the various frequencies of the signal as they cancel each other. Azimuth is easy to check, but you need a good alignment tape to do this. Most tapes have a section marked for azimuth adjustment but, if not, you can use any high frequency signal on the tape.

In order to check azimuth, you need a way to see the error. If you are setting a mono machine, you need only go after optimum high frequency response. If you are doing a multitrack machine, look at the two outer tracks, since this is where the error will be most noticeable. Depending on the type of test equipment you have available, you may have provision for looking at the relative phase of two input signals. If not, you can set up a scope to feed one signal into the vertical input and the other into the horizontal input. Another technique is to sum the two channels you are looking at, with the same gains out of phase, and look at this on a meter. Adjust the azimuth screw on the reproduce head (check the manual to see where this is) for minimum phase difference between the two channels.

If you are using the scope method, set the scope's gains for a line at 45 degrees with the same signal applied to both inputs. Then adjust the azimuth screw a nearly matching angle line. If you are using the summation method, adjust the azimuth screw for a null on the meter. Do not turn this screw far, especially if you are working on a previously adjusted machine. It is possible to adjust to a false point when only using a single frequency. After you have adjusted the azimuth, double check at other frequencies to make sure they all agree.

Desired Operating Level	Test Tape Reference Level	Meter Reading
185 nWb/m	185	0
	200	+1dB
	250	+3dB
	370	+6dB
200 nWb/m	185	-1dB
	200	0
	250	+2dB
	370	+5dB
250 nWb/m	185	-3dB
	200	-2dB
	250	0
	370	+3dB
370 nWb/m	185	-6dB
	200	-5dB
	250	-3dB
	370	0

Figure-2

After the reproduce azimuth is set, then feed a high frequency signal into the inputs of the machine. If you are using a speed lower than 15 IPS, reduce the level at least 10 dB from operating level. Record a tape with this tone, and then check the azimuth as above. If it is not correct, adjust the azimuth screw on the record head until you find the right point. This is easy to do with a machine that allows you to look at the reproduce signal while recording. Two head machines, like some cassette machines, will not need a record azimuth adjustment, since the same head is used for record and play.

If you are doing a complete check-out on a machine, the correct order of events is:

1. Check and adjust tape path mechanics and alignment

2. Check and adjust playback azimuth

3. Check and adjust playback frequency response

4. Check and adjust playback level

5. Check and adjust record azimuth

6. Check and adjust record bias

7. Check and adjust record frequency response

8. Check for proper flutter

9. Check for proper signal-to-noise ratio

(continued on page-27)

Normally the tape path mechanics will need no adjustment unless something has been changed in the tape path. Check your manual for the correct procedures. You may need some special equipment to perform this procedure, and do not attempt to do it without the proper tools and equipment as you may make things worse. Be sure to check that the tape is not rubbing on the edges of any guides or reels as it passes through the machine, as this will cause tape edge damage.

If you have changed or worked on the heads, they need to be checked for proper height, zenith (front to back tilt), azimuth (side to side tilt), and wrap or penetration of the tape. Depending on the machine and the way the heads are made, you may need a gauge to adjust the head height. You can come close with a length of tape with the oxide removed (if you can see the heads with the tape in place). Put the tape in play mode and make sure the head is centered vertically. Be sure to allow for special track positions if they are used on your machine.

To check the other parameters, find a head position that is as near as you can tell to correct. Paint the face of the heads with Magic Marker and run some old tape through the machine. The tape will wear off the marker and show you a wear pattern. This pattern should have parallel and vertical sides and the head gap should be centered in the wear pattern. Non-parallel sides indicates improper zenith and non-centering of the gap indicates improper wrap or head rotation. Adjust the head and repeat the process until it is correct. Then adjust the playback azimuth as we described above.

Playback frequency response must be checked using a frequency response alignment tape. Depending on the type of test equipment you have available, you may wish to use either a swept-frequency tape or a multi-frequency tape. The swept-frequency tape should be used if you have a plotter or other automatic device to record the frequency response. Otherwise, you will need to use a multi-frequency tape. Play the tape and record the level at each frequency. Do not rely of the VU meters on the machine (or any other VU meter) to give accurate indications at all frequencies. While some meters will give accurate readings, don't assume that yours will.

Also, if you are using a digital multimeter for measuring audio, be sure it is accurate over the entire frequency range. Many of these only are accurate to about 2 to 5 kHz. This is greatly simplified if you have a meter that has a relative dB mode. Simply set your reference for the frequency response reference tone and record the readings. Otherwise you will have to do some math to come up with relative levels. If you have a computer and the right program, you can enter the raw data into the computer and come out with a frequency response curve. A response curve is the most useful, since it shows you at a glance what the machine is doing.

If the high frequency end of the range is not flat, adjust the reproduce equalization adjustments on the machine to compensate. Depending on the machine, this adjustment may or may not allow you to come up with a totally flat response. Remember that frequency response, especially for tape machines, is specified as a "plus or minus dB" term. Also, knowing your machine is important here. Don't try to make a machine ruler flat that is only capable of plus or minus 2 dB.

When you have adjusted all channels of the machine for proper playback frequency response, then set for proper playback level as described earlier. Then you can proceed to adjust record azimuth as well.

When record azimuth is set, you can set the bias. There are a number of techniques for setting bias that have appeared over the years, but the following one seems to be the most prevalent at the present time. Some machines, especially carts and cassettes which may not have great high frequency response, may suggest different techniques, so be sure to consult the manual. If no procedure is given, try the 10 kHz overbias technique. Depending on the machine's geometry, speed, and tape type, find the point

(continued on page-28)

at which a 10 kHz signal peaks. Be sure to reduce the level to -10 or lower if you are using speeds below 15 IPS. For cassettes, use -20.

Then increase the bias until the audio level decreases the desired amount. If you do not have any recommendations, try 3 dB at 15 IPS, 5 dB at 7 1/2 IPS, 10 dB at 3 3/4 IPS, and 12 dB for cassettes. If you only have one bias adjustment for all speeds, set the machine for the speed you most frequently use. Then check the record frequency response by recording tones and looking at the playback level. Adjust the record equalization control for the best match to the playback response curve. If you cannot get satisfactory results, adjust the bias slightly and try again. If your high end rolls off too much, reduce the bias. If you have too much high end, increase the bias.

Some machines will require compromises to be made between bias and equalization, depending on the design of the machine. The most common compromise is not to have a full set of adjustments for all speeds. Again, if this is the case, optimize the machine on the most commonly used speed and under the most common conditions, and check to make sure the rest is in the ball park. Another common compromise is found with the low frequency response, especially on machines with narrow tracks.

You may encounter a problem known as "head bump" where the extreme low end of the range has a peak. This peak may be as much as 6 dB above the frequency response reference level, but will probably be below the specified frequency response range. There is little you can do to correct such a discrepancy. At one time there was a special equalizer available to deal with this error, but I do not know if it is still available. A severe head bump may give you a problem if you are using noise reduction. The frequency response error it introduces can cause noise reduction mistracking, especially on low frequency material such as kick drum.

Checking a machine for flutter requires a flutter meter. There are a number of these devices commercially available, some as part of a larger test equipment package. However, I only know of two such devices that can measure scrape flutter. When comparing flutter measurements to specifications, be sure you are using the same setup. There are a number of standard weighting curves for flutter measurement, and each will yield different results. Record the flutter test signal on your tape, and then rewind it. Play back the tape while measuring the flutter. You may have to do this a few times and should take the highest reading. If you try to record and play back at the same time, the errors could cancel themselves for the measurements. By making a number of passes with the tape, you eliminate the probability of such an error occurring.

Signal-to-noise ratio is a final check that everything is okay with your machine. Some machines have shields on the playback head that should be in place. When measuring signal-to-noise ratio, be sure to use a filter for your measurement. Failure to do so will give higher than expected readings due to bias leakage on the playback. Check the manual for your machine as to the proper conditions for this test. Many machines are specified with a higher than normal reference level for this measurement and with a restricted bandpass. You should be able to duplicate this measurement with a few dB to spare.

When you have finished working on a machine, you have to return it to service to be useful. When you do so, check the interface cables for any problems and do a quick listening test with the machine in the system. Listen for any signs of hum or buzz that may indicate an improper ground. Make sure the system levels match the levels you have set the machine for, or you will have discrepancies in your meter readings. This is especially true if you are using any sort of noise reduction (dBx, Dolby, etc.) with your tape machines. Level matching is important to the proper operation of some of these devices.

This has been a quick trip through the world of analog tape recorder maintenance. There are no great tricks to tape recorder maintenance, but you do have to be aware of the principles involved.