# RESTORING A "REEL" RECORDER

*This month we look at the final steps in bringing your vintage open-reel recorder back to its original glory.*

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Now that all of the preliminary steps described last month have been satisfactorily completed, you should have a "functioning" tape recorder. This month, we'll find out just how well your tape recorder is functioning. Assuming you find it is not entirely up to factory specs, you will need to determine whether the reasons for this are simply a matter of adjustment, or require component replacement. Finally, we'll describe critical alignment steps needed to bring out the best possible performance from your vintage audio recorder.

We're going to start with the tape recorder's mechanical section. We already know the basic electronic functions are at least working at some minimum performance level, and that will be adequate for the "ultimate" mechanical test—wow and flutter (W/F). Conversely, however, if the mechanical adjustments and alignments are not all "up to snuff", you cannot accurately perform the electronic specification checks and adjustments.

Okay, let's begin. Now you could jump ahead to the W/F spec measurement and try to get a "bottom-line" idea about the mechanical section before (or presumably in lieu of) performing the following tests, but I don't recommend it. These tests will give you an excellent portrait of the condition of your machine. Remember we're doing a restoration here, not a repair. Further, they will alert you to wear or misadjustment conditions that may be masked during the W/F test, but nonetheless are crying for attention.

**Tensions.** First, let's check the take-up and supply reel tensions. Please recognize that we can only provide general guidelines here, with "ballpark" specs. The actual specs are those originally provided by the manufacturer of your machine. Regarding those tensions, however, the ballpark numbers will probably suffice for your model as well. Remember how we did a crude form of this test with our finger during the preliminary test. Well, now we'll actually measure the tensions.

To do this, you will need an empty reel, some string, and a spring tension gauge capable of reading up to 10 or 15 ounces. Fasten one end of the string to the hub of the reel and place it on the take-up turntable. Now manually wind the string onto the reel clockwise a couple of revolutions. Fasten the other end of the string to the gauge. Now, with the recorder in play mode, and with the motor shutoff defeated (as in the preliminary test), allow the string to continue winding onto the reel while ensuring that the string is not binding against either reel flange and that the spring gauge is held parallel to the string. Read the tension as the string is slowly winding; it should be about three to five ounces.

If it's much less than three ounces, it could cause the tape to wind too "loosely" onto the reel; that could cause "bunching up" on the reel when it is subjected to the high tension encountered during the start of rewind mode. It can also result in a sudden jerking of the tape a second or two after the start of play mode if tape slack is formed as play is initiated. On the other hand, if the take-up tension exceeds about seven or eight ounces, that could cause the tape to be "yanked" (how's that for a technical term!) through the capstan/pinch-roller area, resulting in uneven tape speed, high W/F, and perhaps even tape stretching.

A similar test should be performed on the supply side (except, of course, winding the string counter-clockwise instead of clockwise). Supply-reel play-mode tension is often somewhat less than on the take-up side, with normal readings at about two to four ounces.

The adjustment for play-mode reel tension is either rather easy, or rather difficult, depending on whether this is a three-motor or a single-motor machine. If it's a three-motor machine, an adjustment can usually be made via slide rings on large power resistors connected to the supply and take-up motors. Hopefully, you have located a schematic diagram of your recorder, or at least an adjustment pictorial, to help find the appropriate resistor(s). If not, you might be able to visually (or through the use of an ohmmeter) trace down to the proper component.

If you have a single-motor ma-

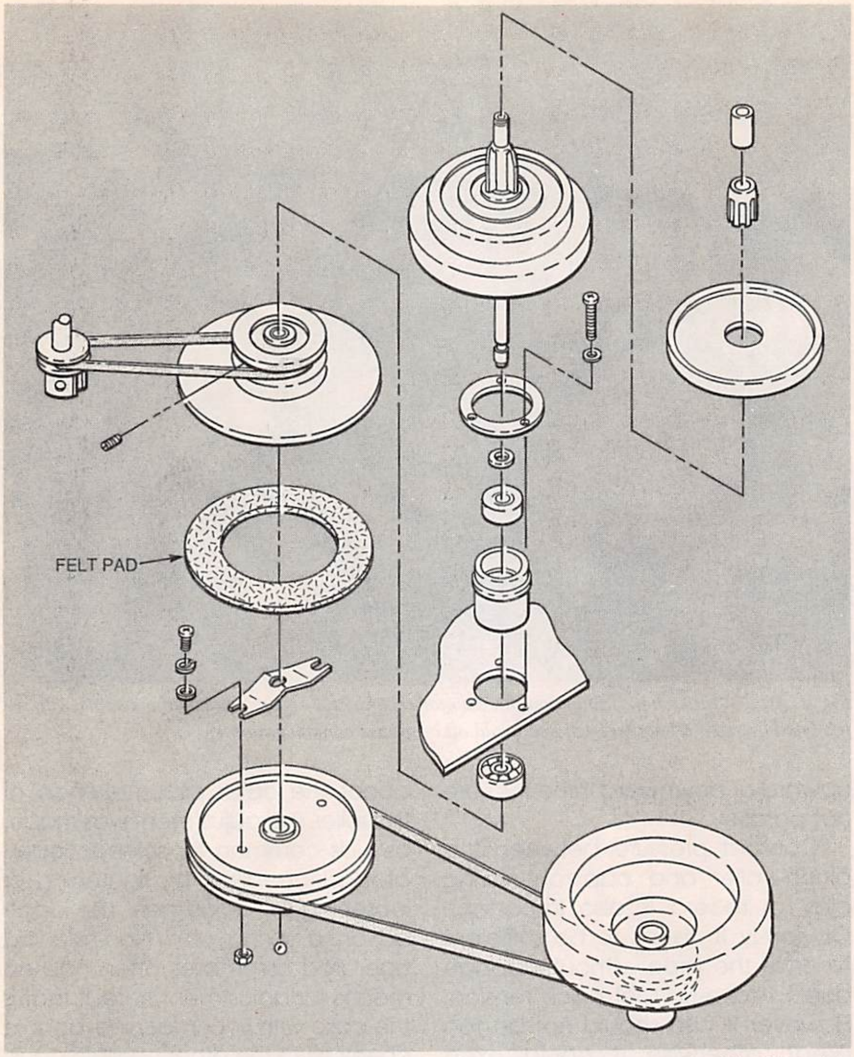

*Fig. 1. A typical take-up turntable-clutch assembly from a single-motor recorder. The felt pad is used as a "slip clutch," transferring rotational force on an as-needed basis to ensure smooth winding of tape onto the take-up reel. Great care must be used to avoid oil or grease contamination of either the felt or its mating surface.*

chine, chances are the supply and take-up tensions are created through the use of a "slip/clutch" contraption, usually formed by a cotton/felt pad slipping on a smooth nylon plate or plastic film washer. Figure 1 shows a typical take-up turntable clutch assembly. Driving force is transferred to this assembly from the motor via a belt or rubber idler. Therefore, the cause of tension problems can be from any or all of the above items. Belts should be soft and supple, and still possess sufficient tension to adequately drive all associated pulleys. If cloth belts were used, check for excessive fraying, or general decomposition, as well as tensioning and free rolling of the spring-tensioning pulley. Idler rubber must be soft enough, and free of flat spots or gouges, to evenly and reliably drive their associated pulleys.

Perhaps the most likely culprit in single-motor tensioning problems, however, is the slip clutches themselves. Occasionally, reconditioning is possible; but the majority of cases require the replacement of both the felt material and the nylon/plastic surface. In any event, the entire turntable assembly must be disassembled to gain access to those parts. That is often a difficult task for the uninitiated; so, if you don't feel up to it, this may be the time to call for professional help. If you do attempt this repair, be sure to take careful note of all the little washers, clips, and other hardware that will need to be removed along the way. Also note the sequence of removal, as that will need to be precisely reversed when re-assembling.

Once you have gotten to the slip clutch, inspect it for obvious damage. Usually, you will find that the felt has compressed somewhat because of the tension against it for many years. If it is not shiny, however, and if the compression has not resulted in a loss of reel height (as would be evidenced by the tape scraping on the upper reel flange), then it may still be serviceable. Now look at the nylon/plastic surface. It must not have any abrasions, deposits, or any other surface roughness of any kind. If it does, ordinarily it should be immediately replaced. Unfortunately, that is often not possible; in that case your next line of attack is to attempt refinishing via very light scraping and/or polishing of the surface. That will sometimes work; unfortunately, the only way to find out is to completely re-assemble the turntable assembly and see what happens. That can be one of the more frustrating aspects of the restoration process; but hang in there, eventually you will get it right!

Though of somewhat less concern, the other reel tensions to consider are the brake tensions. We can't get as specific here because of the wide variance in the brake methods used over the years, as well as the means of measurement and adjustment. The good news is that as long as the tape is not being unduly stressed or slackened, after the brakes are applied, and as long as you are satisfied with the amount of time it takes for the reels to stop (once again, specs vary widely here), then you are okay. After all, the brakes are totally out of the picture during play or record (actually, even here there are a few exceptions).

If you have access to the original factory specs, or if tape damage could occur if something isn't done, go ahead and check out and/or make some adjustments. If you have a three-motor machine, the most common adjustment is at one end of the brake band. A typical brake band configuration for three-motor designs is shown in Fig. 2. Sometimes the adjustment takes the form of moving to a different spring stop along a tab at the end of the band; other times it's a matter of bending the tab slightly, relative to a stop post. In single-motor machines, perhaps it's a heavier tension applied to the same slip clutch used to create play-mode back tension. If that is the case, the repair you performed to correct play-mode problems might also take care of the brake issue.

Note that there are two different brake specs for each turntable; one for each direction of travel. The tension spec for one direction will be perhaps as much as double that of the other direction. To give you at least some point of reference, the three-motor Ampex Model 350 has specs of 7 and 14 ounces at each turntable, using the string measurement method described above (this time with the transport in stop mode), but based on a 10½-inch reel instead of a 7-inch reel. It's important to note the type of reel used in conjunction with the specification, since different reel sizes will have different hub diameters.

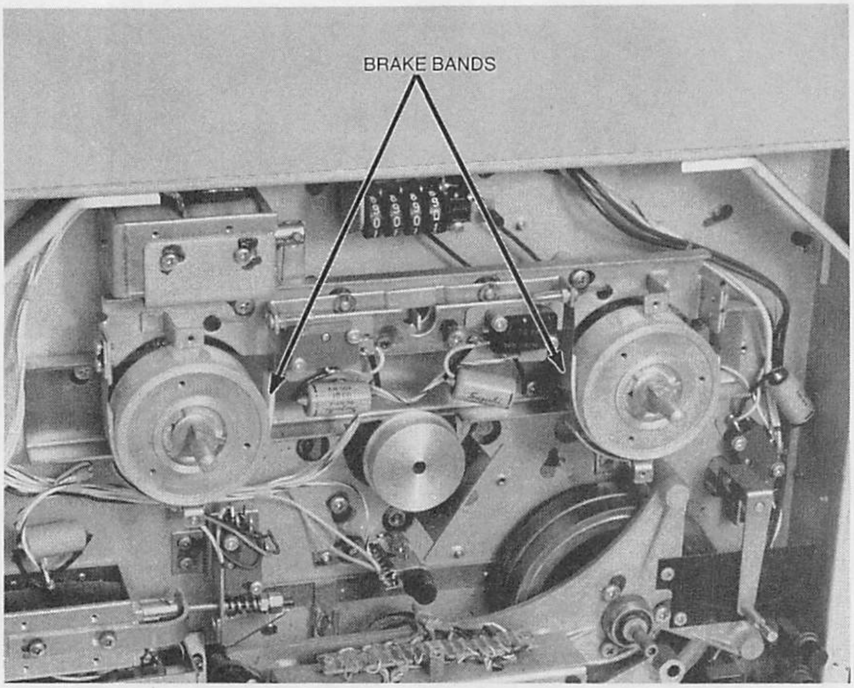

*Fig. 2. Typical brake bands found on three motor recorders. The same precautions apply with the felt band linings—do not moisten and avoid oil or grease contamination.*

**Pinch Roller.** Let's spend a few moments discussing the pinch roller and its contact with the capstan shaft. First, having gone through all the preliminary cleaning and lubrication, the pinch roller should spin free, exhibiting no sluggishness. If it is sluggish, remove it from its shaft and clean both the shaft and the inside of the pinch-roller wheel again. Then apply a couple drops of oil and re-assemble. Now, with the recorder power off, push the roller very lightly against the capstan shaft (depending on the mechanics, you might have to move the operating lever into play mode in order to do this—as is the case with the Tandberg 3000X shown in Fig. 3). With your head at capstan level and one eye closed, sight down the area at which the pinch roller is making contact with the capstan. With just very light pressure, ensure that the edge of the pinch roller is perfectly parallel to the capstan. As you ease the pressure on the pinch roller, check that the amount of clearance between the two as the pinch roller is moved away is identical top and bottom. That is important as the tape will tend to skew upward or downward if the two are not parallel.

Contact pressure between the pinch roller and capstan during play or record is also important. Obviously, it needs to be sufficient to drive the tape without slippage due to take-up-reel back tension. However, it also should not be too great, otherwise it could exert undue strain on the upper capstan bearing. Unfortunately, most manufacturers do not have a spec on this; so you are left to your own judgment as to whether the force you observe and feel is sufficient, but not excessive. Another factor in the amount of contact pressure required is whether the pinch roller has hardened, or whether the capstan shaft has become too smooth as a result of wear. (You will note that the capstan shaft usually has a satiny finish when it comes from the factory. I have seen capstan shafts with lots of wear that have mirror finishes over the ¼-inch tape-contact area.)

Just to provide a ballpark number here, the Crown SX822 (a three-motor machine with a solenoid-actuated pinch roller) calls for a 10- to 12-pound pressure, measured by pulling straight down on the bar to which the pinch roller is mounted. The end of the bar is located at about the outer circumference of the roller. The adjustment was made, as was common for solenoid-operated pinch rollers, by tightening or loosening an adjustment nut located on a spring arm. Non-solenoid operated assemblies often had no means for adjustment here. If that is the case with your machine, double check all of the other possible causes of slippage mentioned above; if that still doesn't do it, then consider replacing the spring that holds the pinch roller against the capstan.

Before proceeding with the W/F measurement, take a final look at any roller-style tape guides. Those rollers (many of which have ball-bearing race assemblies) should spin freely, with no visible signs of embedded dirt still lurking in the corners or edges. It's a good idea to just disassemble these roller guides, clean them thoroughly, and lubricate as you put it all back together.

**Wow/Flutter Measurement.** Finally, let's go ahead and perform the W/F measurement. By this time, you should have taken care of all major mechanical subsystems, so I would expect decent results. However, don't be surprised if it doesn't quite meet spec the first time. While there are many factors that we have already checked, there are proba-

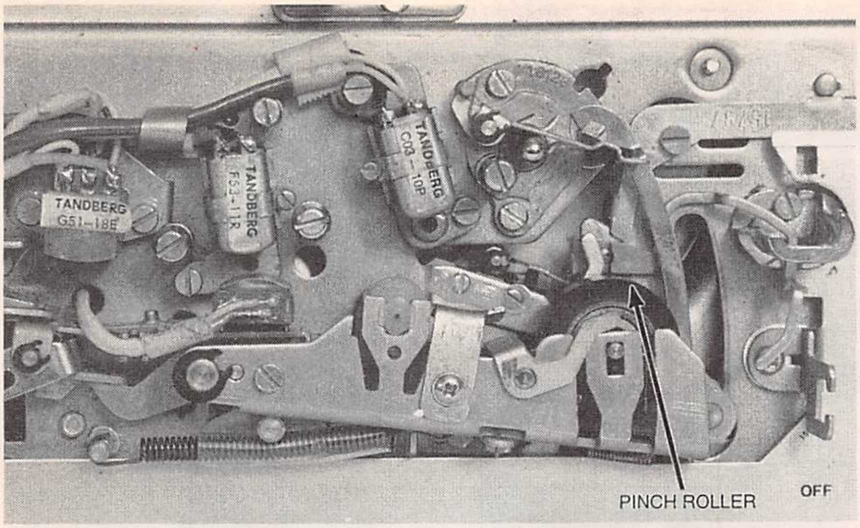


*Fig. 3. On some machines, such as this Tandberg Model 3000X, the transport function lever must be moved toward the play position in order to check that the tape-contact surface of the pinch roller is perfectly parallel to the capstan shaft.*

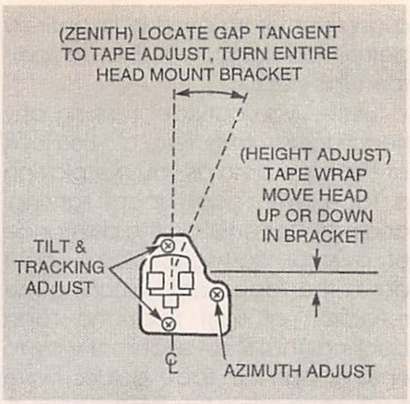


*Fig. 4. The various adjustments needed to bring tape heads into proper alignment.*

bly as many others that we haven't; many of which really can't be checked, from a practical standpoint, without replacing suspected components and comparing the results.

If you have a pre-recorded W/F tape, thread it up, set the appropriate tape speed, connect the recorder's playback pre-amp output to your W/F meter, and "let 'er rip." If you don't have a prerecorded W/F tape, don't worry about it. You can record the flutter test frequency directly onto the machine you're restoring (unless, of course, it's a "play-only" machine) and then simply play it back. The latter method does, technically, allow errors to creep in due to alternate reinforcement and canceling of the flutter components upon subsequent playback. However, the results obtained using this technique will be close enough.

Just take the time to record a sufficient length of tape, and then study the meter when playing back. Look at the dips and peaks for about a minute. This should allow you to observe the "usual" peak and average levels, as opposed to the "occasional" peaks and averages. The reading of W/F is always somewhat subjective; not using a prerecorded tape simply makes it a bit more subjective. Some W/F-meter manufacturers recommend making several test recordings, and use the "average of the peaks" as the "official" W/F number.

Several methods have been used by manufacturers to express their W/F specs. Sometimes they will not state whether the published number is "peak" or "rms;" other times they will state "average peak" or "average rms;" still other times they will not stipulate whether the number is "weighted" or "unweighted". But, at least by now you will know the W/F of your machine; and, if you happen to own more than one, it can be a point of relative comparison between them.

If your reading is obviously out of spec, then I would recommend the following sequence: First, double check all of the mechanical work you have done thus far. Next, review your log of this machine, looking back to the very first cleaning-related observations. Are there any clues there that might lead to a cause for this condition? If neither of those steps help, then you will need to explore new ground.

It is always possible that a bad bearing somewhere is causing the problem. Listen very carefully to the sounds emanating from the mechanics as you play a tape. Are there any grinding, or raspy sounds? Sometimes, with the W/F meter still connected, you can simultaneously see and hear abnormal fluctuations in sight and sound, synchronized so as to point out the source. You might try replacing the capstan-motor capacitor (often somewhere between 2 and 4 mF, at about 350 volts).

If any of the above doesn't resolve the problem, at this point tracking down its source becomes more difficult. At the factory, or at a field service center, the technician would most likely start swapping out major parts, like capstan motors, to try to isolate the source. Obviously, that is even more difficult today, owing to a lack of replacement parts. If you happen to own two identical machines, then this is the time to drag out the other one and swap parts, one at a time. It's not pretty, but eventually you will find the problem this way; unless, of course, the second machine has the same problem. This does happen, when you consider that high wear items—or really any weaknesses—can easily be the same for identical model machines.

Now that we've gotten the mechanics "beaten into shape," let's move on to the electronics.

**Tape Path Alignment.** First, we're going to tackle tape-path and head alignment. If things here are not perfectly aligned, the electronic performance of your recorder will suffer. During a restoration, proper alignment should be assured before making any other electronic adjustments. That alignment includes vertical height, wrap, tilt, zenith, and azimuth.

A primary issue here might be wear: if the tape path is well worn (*e.g.*, substantial grooves worn into the head faces), then it might be best not to attempt any tape-path alignments. If that is the situation with your machine, then be especially careful to read the following alignment information in its entirety before deciding whether to perform this step.

Before you consider making any head adjustments, take a close look at the tape path as you are playing a tape. With good room lighting, and perhaps enlisting the assistance of a small flashlight, closely sight down the tape path, watching the reflection of light from the tape backing. That is an excellent way to ensure that the tape guides have not become bent or misadjusted. If, for example, you see one edge of the tape crimped against a particular guide, that could be an indication of trouble. However, be extremely careful before adjusting anything. Take careful notes of all abnormalities; and, if you do make any adjustments, be sure to note the extent of the adjustment. It might subsequently turn out that that was not the source of the problem. If so, you will want to return the adjustment to its original setting.

Make sure that alignment tools to be used in the head area are all demagnetized or non-metallic before you begin. Also, take a look at Fig. 4, which will familiarize you with the various head-adjustment parameters along with the common adjustment-screw locations. Note that these adjustments may or may not be located just as shown; and in some cases, not all of these adjustments may be present.

Figure 5 shows the proper track spacing for most ¼-inch open-reel tape standards. While track spacing relative to the tape edge is obviously very important, it's not something you can do much about during a restoration process, unless, of course, you need to replace a head. The reason is that many "used" machines have developed a wear groove across their front face as a result of tape friction. If, for some reason, vertical head positioning has gotten out of alignment (it's unlikely this happened at the factory), the odds are that the wear groove reflects that condition. If so, and if you were to readjust the vertical position to conform with Fig. 5, it would create an "overlap" condition over one edge of the groove. That would most likely mean the creation of an air gap between the head and the tape at one side. The result of this could be vertical tape skew, increased tape wear, poor high-frequency response, and reduced S/N on the track(s) closest to the air gap. The bottom line here is that it's not a good idea to mess with the vertical head alignment on used machines whenever a wear groove is present.

If you have a four-track machine, and do not hear any crosstalk (from alternate tracks) when playing commercial prerecorded tapes, then the odds are that your play head is in proper vertical alignment. With a two-track machine, you will have to rely on careful visual observation.

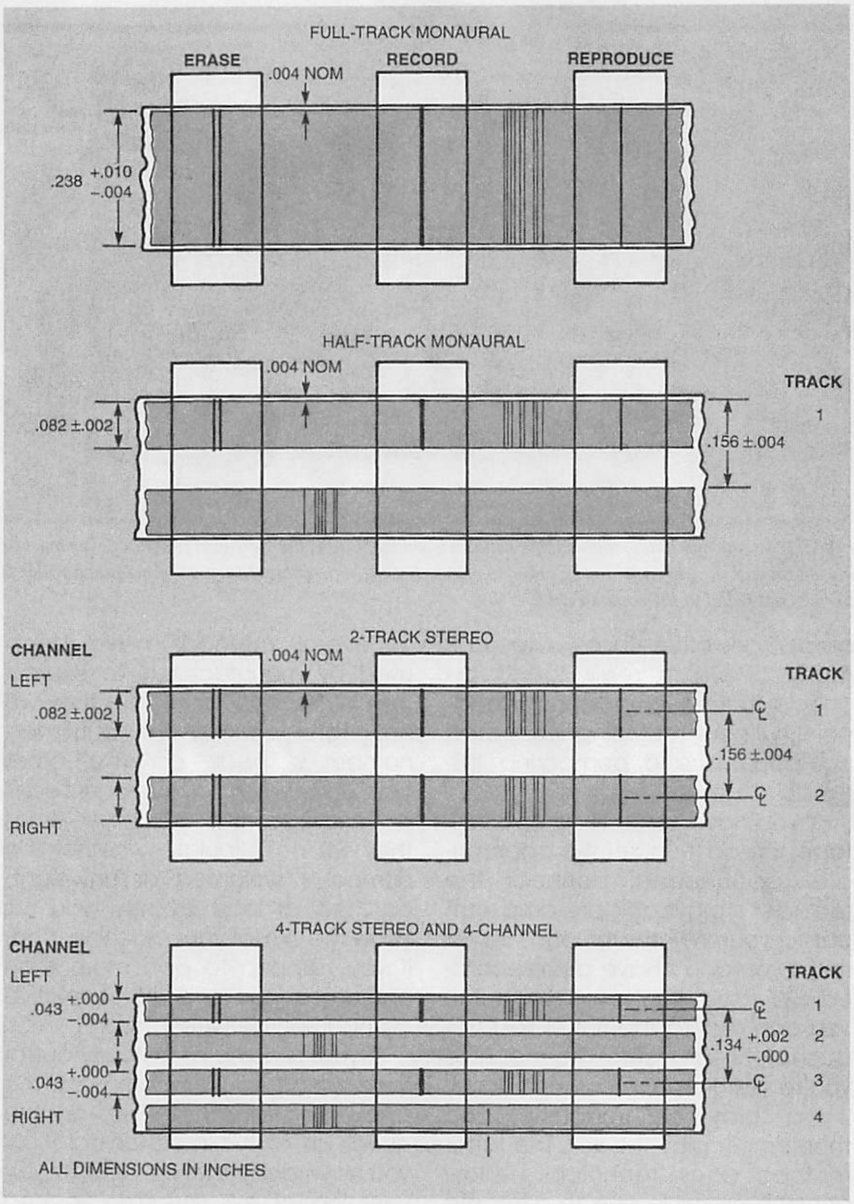


*Fig. 5. Track spacing standards for popular ¼-inch tape audio recorders.*

The erase-head gap is typically slightly longer than that of the record head, so erase-head height is usually not an issue. However, that can be easily verified, and you don't even need instruments to read the result. Simply record a 1-kHz peak signal; then rewind and place the machine in record again, this time with no input signal, and while monitoring the output by ear. If you don't hear any trace of the 1-kHz tone, the erase-head height is okay. Note, however, that even if you do still hear the tone faintly, it doesn't necessarily mean that erase-head height is to blame. It could also be inadequate current flowing to the erase head, perhaps due to weak

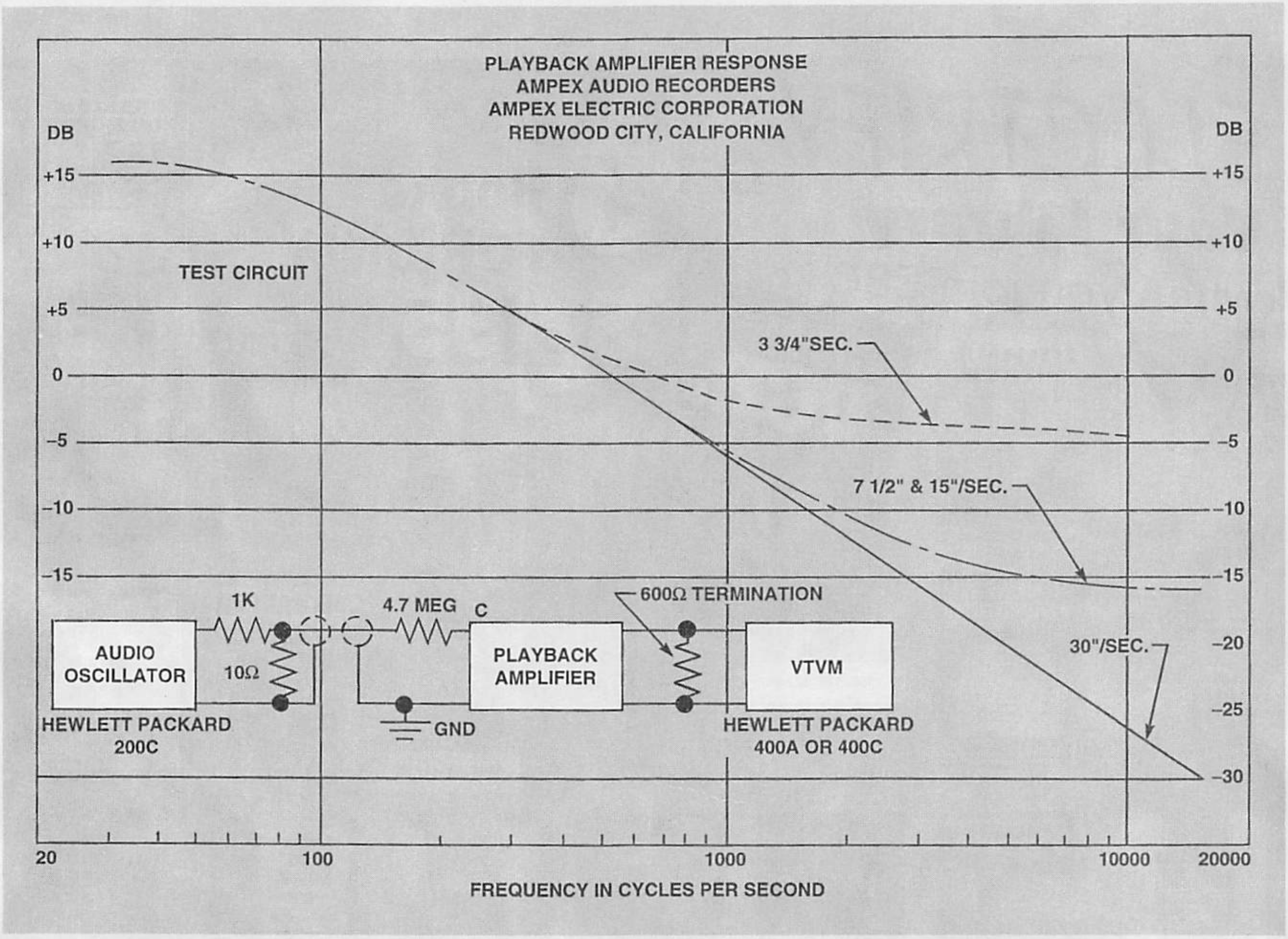


*Fig. 6. Typical playback-amplifier equalization curves.*

emission of the bias/erase oscillator tube, or a leaky oscillator capacitor. If you have a schematic diagram of the electronics, check to see if a current or voltage specification is given for the erase signal.

Tape wrap has to do with the extent of tape contact across the head, and is a function both of the shape of the front of the head (which, obviously, you can't control—but remember this if you replace a head with a non-identical substitute), and the "penetration" the head makes into the line of the tape path. Penetration is sometimes adjustable, usually by moving the platform onto which the head is mounted forward or backward. Excessive penetration might be, for example, where the head pushes the tape far enough forward to where it is lifted from the adjacent guides, or another head. Insufficient penetration would be where the head barely touches the tape. There's no mathematical precision here; just look at how the heads are situated relative to the penetration issue. For example, often the record and play heads have similar geometry, and so one might expect a similar tape wrap. Another clue is to look very closely at the groove worn into the head face. If the tape wrap is such that it's not covering a portion of the wear area, that could be an indication that tape wrap is now insufficient.

A related adjustment (called "zenith") ensures that the head gap is centered within the portion of the tape that is in contact with the head. If a significant wear groove is present, however, it might be better to leave this adjustment alone.

The "tilt" alignment ensures that the "front-to-back" angle of the heads is correct with respect to the tape. If it is off, the tape will have more head contact on one side than on the other. One way to observe that is to look at the wear pattern on the head. If it is in the shape of a trapezoid instead of a rectangle, you likely have a poor tilt adjustment. As with head height, it's not a real good idea to go making changes if this situation has been around long enough to create a significant trapezoidal groove. However, if the tape wrap is fairly extensive, it might be okay to make a small correction here. You might be best off to just note the problem, and then see how successful the rest of the electrical spec checks and adjustments are before changing the tilt settings. If all else comes back to spec, and the "dropout" level (instability in playback level) is tolerable, then leave it alone.

Next, we'll tackle azimuth adjustments, which will ensure that the record- and play-head gaps are perpendicular to the length of the tape. The first check should be made on the play head, and you will need a standard alignment tape to accomplish this. Typically these tapes will have a number of recorded passages, often with a voice lead-in to identify the next passage. (If you have need for an

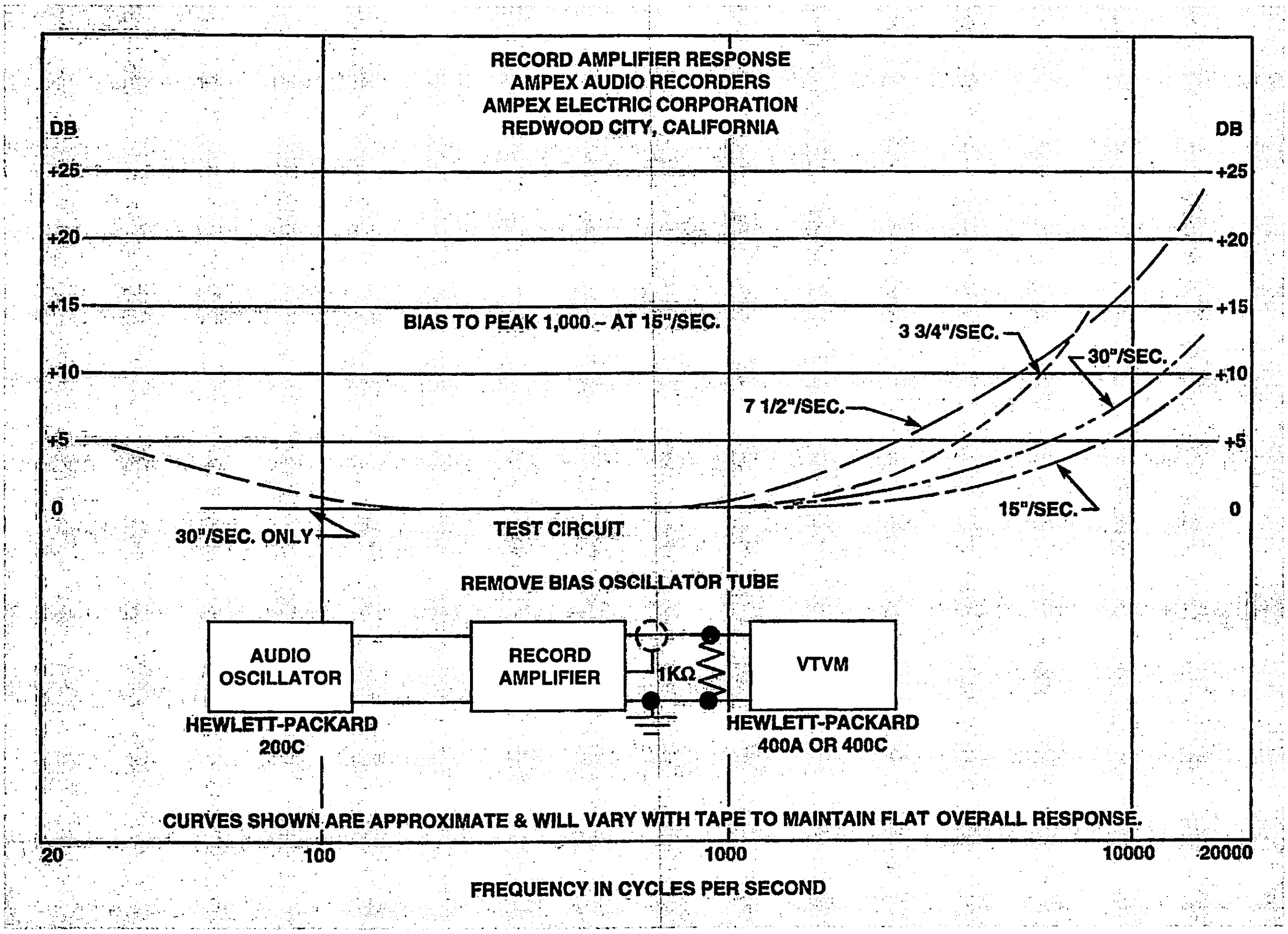


*Fig. 7. Typical record-amplifier equalization curves.*

alignment tape, you may contact the author c/o EC Designs at the address given in the "For More Information" box for suggestions.) The passage of interest here is a high frequency tone (often 10 kHz). Before playing it, identify which screw on the play-head platform influences the azimuth angle, and clean off any locking paint as necessary. Adjust for a peak level while watching an output meter, then take careful note of the extent of adjustment (just in case you need to reset it later).

Now let's align the record-head azimuth. (If your machine has a combination record/play head, you're done; just go to the next adjustment.) Set up the machine to record a 10-kHz tone onto a blank tape, at a level of about -15 dB. While watching the simultaneous play-head output on a meter, adjust the record-head azimuth very slowly for a peak reading (note that there is a delay between the time you make the adjustment and the time that portion of the passage reaches the play head). Again, write down the amount of adjustment needed.

That completes the head-alignment process. Before we leave the subject of heads, and get into frequency response, it's probably worthwhile to spend a moment on head wear. While all tape heads wear out eventually, they do last a long time. Typical head life from an early 1970s machine, using premium tapes, could be 4,000 hours or more. There's no sudden, magic point where the heads become useless. Rather, the wear process is gradual, eventually affecting the electrical specifications. Further, different model heads have different head-gap depths and are composed of different materials with still different wear characteristics. What I'm saying here is to not rule out a set of heads just on the basis of the size of the wear groove. Check the electrical specs first. See what effect bias and level adjustments might have. You might discover that there are still hundreds of hours of life remaining!

On the other hand, improper cleaning of the tape path very often spells premature doom for the tape heads—if not in the form of poor frequency response, then perhaps in the form of excessive dropouts (maybe as a result of "craters" formed on a head face due to a glob of oxide stuck there for a long time). While it certainly pays to carefully note those issues when evaluating a machine for potential purchase, once again don't categorically rule it out on the basis of improper wear; just be cautious.

**General Adjustments.** Now that we've gotten the mechanics back to spec, and we're confident that the tape heads are aligned properly, what's left is a number of general electronic checks and adjustments. Please note that the following procedure is very general in nature. Tape recorder electronic designs vary widely; and, as such, you are always better off if you have the manufacturer's alignment instructions. If you do, then follow those instructions in lieu of the following. If you do not, then proceed with the following instructions, but bear in mind that this might not be the optimum way to set up your machine. While this procedure will work, a few things might get overlooked, and other things may have to be done twice due to interacting controls.

The approach we're going to take is to first make a few assumptions. If true, we can streamline the remaining electronics alignment. (If they are not true, we'll find that out anyway, in the process of the tests we perform.) These assumptions are based on the electronic alignment controls still appearing to be at (or near) their original factory settings, and on the overall condition of the electronics appearing to be excellent (and/or you have already replaced any "suspect" components—leaky wax/paper capacitors, weak tubes, etc.). If these assumptions are correct, then it's a good bet that the equalization and approximate record- and play-level calibrations are close to spec.

*Fig. 8. Magnecord Model 1024 deck. Another "big iron" machine from the 1960s.*

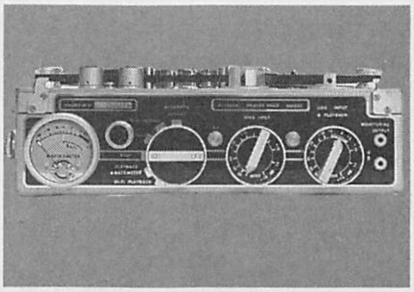

*Fig. 9. Nagra Model III recorder. This was a professional portable machine, popular with the motion-picture industry.*

**Frequency-Response/Bias Adjustment.** Let's take a look at the frequency response. To do this, connect your audio oscillator and THD analyzer (assuming that it also houses an audio voltmeter), and thread a blank tape of the formulation you will be using on this recorder. If the machine has separate record and play heads, this process will proceed much faster as that will allow simultaneous playback monitoring as you adjust the bias. (We'll assume this configuration for the following adjustments. If you do not have playback capability during record, you will have to alternately record, then play back several times to find the optimum settings.)

Initially, set the oscillator to 1 kHz and a level of 0 VU on the recorder meter. Now, reduce the oscillator level by 20 dB, and, while monitoring the source with the external voltmeter, set the voltmeter pointer (achievable if your instrument has a "set level" mode) to a 0 VU meter reading. Now place the machine into record mode (let's start at the fastest tape speed on your recorder), and switch the output to "playback" monitoring. The tape output level at this point might, or might not, be at 0 VU. Don't worry about that right now; just note the level relative to the 0 VU setting you had when looking at the record preamp.

Now switch the oscillator to 10 kHz (while maintaining the same oscillator level). Ideally, the 10-kHz output level should be at 0 VU, but a level within + 3 dB or so is often still within factory spec. If it's much higher than that, try increasing the bias-level control to bring the 10-kHz response into that range. Now, increase the oscillator frequency, and note the point where the response trails off to - 3 dB. If the frequency is less than the high-frequency-response spec, and if the 10-kHz response was identical to that at 1 kHz, then you might try going back to 10 kHz, decreasing the bias a bit to increase the 10-kHz level to, say + 2 dB, and then check the 3 dB drop-off point again.

If you are unable to achieve the factory frequency-response specs, something is obviously wrong. This could be due to worn heads, improper equalization (either record or play), or a faulty preamp component (again either record or play). The frequency-response portion of a standard alignment tape could be used to rule out the play head and play-preamp/-equalization circuitry. If that's okay, then the record circuitry should be considered suspect. If you have an oscilloscope, and are adept at such things, you might find a faulty component in a preamp section.

**Total Harmonic Distortion (THD).** If, on the other hand, the machine now meets the high-frequency spec, the next step is to measure the THD at 0 VU. Simply make a 1-kHz recording at 0 VU (on the recorder meter) for a couple of minutes; then, while playing it back, "set level" at 0 VU on the THD meter, then switch to "distortion" mode, and adjust frequency and balance for a null. If the THD is what you want it to be for a 0-VU recording level, then proceed to the S/N test, coming up next. If the distortion is greater than what you want it to be at 0 VU, then you can try to go back and increase the bias a bit more. While that will bring down the distortion, it will also decrease the high frequency response. So, if that is not to your liking, you can try the THD test again, this time at, say -3 dB.

If the THD is to your liking, the next step is to re-calibrate the record preamp "VU meter record level" to read 0 VU for that signal level going to the head. (This is another area where you must be careful if you do not have a schematic. Some recorder designs do not have a separate VU-meter calibration pot. Therefore, the only record-level adjust is sometimes an overall record level, acting on both the VU meter and the signal going to the head. If that is the case, it will be apparent when you try to adjust it; just be sure to watch for it.)

If your machine has separate bias controls for each speed, go ahead at this point and complete the bias adjustments, along with THD checks.

**Signal-to-Noise Ratio (S/N).** Assuming frequency response and THD is now acceptable, the next step is to measure S/N. If you wish to measure S/N relative to 0 VU, simply make another recording at 0 VU for about 20 seconds (otherwise, if measuring relative to 3 % THD, first determine the "head room," then set the VU level for that peak reading. You may need to use an external meter for this if the recorder meter is above full scale); then, while still in record, turn off the oscillator—or turn the record level control down to zero—and continue recording for another 30 seconds. Play back that same section of tape, quickly "setting level" on the audio meter to 0 VU and then, when the level drops, measure the decade drops and residual meter reading to determine the S/N. If it meets spec, congratulations! If it doesn't, then—once again—you've got some work to do.

Some common causes for poor S/N, beyond what we've already covered, are noisy transistors or tubes, faulty capacitors, and sometimes (although much less often) even resistors. This can be a very time-consuming investigative process. An oscilloscope may be very helpful here to spot the "corrupt creature."

It's worth mentioning again that we have really simplified the alignment process described above. It may, or may not, be totally adequate for your machine. If you have a "professional" machine, for example, then you should pay more attention to "standard" levels. Use the alignment tapes, along with the manufacturer's instructions, to set up your recorder.

**Equalization.** Finally, let's cover equalization. So far, we've been assuming that record and play equalization is probably okay. If you need to check it out, however (or, are simply curious), let's take a look at what's involved.

Figure 6 shows the playback equalization published by Ampex for their recorders back in 1953. These curves are similar to those for many other recorders, representing an approximate doubling in signal amplitude with a doubling of frequency (an increase of 6 dB per octave). This has to do with the physics of magnetic recording,

*Fig. 10. Acme Model 1500 recorder. A modest 3-inch reel machine, using "rim drive" and a swing-out permanent magnet to erase previous recordings when in the record mode.*

and, in theory at least, will be the same for all machines. This curve "levels off" at the higher frequencies due to natural losses.

If you have a standard alignment tape for this purpose, that would be the quickest means to check conformance with the curves at each speed on your recorder. If not, then a setup similar to the one shown in Fig. 6 can be used to directly inject the test frequencies. One frequency representing each of the low-, mid-, and high-frequency points should be adequate (*e.g.*, 30 Hz, 1 kHz, 10 kHz). Recorders differ as to the adjustments available: from none at all (fixed equalization), to a single control (usually influencing the high-end response), to multiple controls (high- and low-frequency adjustments, sometimes with one set for each machine speed).

Figure 7 shows some record-equalization curves, published for the early Ampex professional machines. Before checking or adjusting record equalization, be sure that play equalization has been set properly, as the measuring of record equalization uses the play preamp as well to ensure overall flat response. Unlike play equalization, record equalization may have to be reset for significantly different tape formulations; particularly, for example, if converting from a typical 1950s formulation (such as Scotch 150) to a premium 1970s low noise tape (such as Maxell UD35).

Note the test circuit shown in Fig. 7, which is to be used if you want to measure the actual signal being applied to the head. Also note the recommendation that the bias oscillator tube be removed during the measurements; that's done to eliminate any bias component from influencing the readings. If your recorder is transistorized, you would need to carefully select a test point at which to insert the VTVM; it should be after the equalization boost and before mixing with the bias signal (just before delivery to the record head). Then, make sure to check for presence of the bias signal, after you have set up your audio oscillator, by temporarily removing the audio frequency and ensuring that any bias component is minimal.

Perhaps a simpler method, however, is just to read the overall response throughout the recorder, exploiting the fact that we now know that the play equalization is correctly adjusted. We also know that the bias has already been optimized for the desired tape formulation. Therefore, if we simply connect an audio oscillator to the record input jacks, thread the desired tape, enter record mode, set the input level to -20 dB, and then monitor tape output with our trusty audio meter, we should be able to sweep through the frequency range and see a reasonably flat response (depending on the manufacturer's frequency response spec).

If the response is not flat, then carefully adjust the record equalization. Note, however, that you will then have to go back and reset bias, and also re-check THD. It shouldn't take more than two "equalization-bias" adjustment cycles to get a feel for the capabilities of your machine and thus choose an optimum setting. If the response will not smooth out, and you have confirmed proper operation in all of the previous steps, then you must suspect the equalization circuit components.

Believe it or not, if you have successfully made it through to this point, you should now have a tape recorder capable of virtually the same performance as when new. As a matter of fact, the existence of modern premium tapes could mean even better specs than when new if your machine is more than 25 years old.

**Completing the Restoration Process.** What remains in the restoration process is all the cosmetic stuff;

**FOR MORE INFORMATION**

This article is based on the new book *Evolution of the Audio Recorder* by the author, Phil Van Praag. It contains over 500 pages of history, evolution, restoration, photos, and a price guide. It's available at $39.95, postpaid, from EC Designs, P.O. Box 33, Genesee Depot, WI 53127.

everything from re-gluing and pinning cracked or broken cabinet joints, to buffing front panels, to restoring worn lettering, to replacing hardened rubber feet, and on and on. The list is long, but the additional work is necessary if the restoration is to be complete.

I sincerely wish you the best of luck in these pursuits. Whether your machine is a "big iron" Magnecord 1024 (Fig. 8), a professional Nagra III (Fig. 9), or a modest Acme 1500 (Fig. 10), it will be well worth the effort. If you 'stick it out' to a successful completion, I'm sure you'll derive much more satisfaction and enjoyment from the subsequent use of your "like new" tape recorder. Ω