Why well-transferred magnetic masters still sound wrong

The secret world of 35mm mag frequency standards in Hollywood before the 1980s

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It is a fairly common problem in film sound preservation/restoration to find that a master mag sounds "wrong" and does not match a reference release print. Occasionally this is due to deterioration issues not being dealt with properly, but even when deterioration is carefully dealt with in transfer, a master mag can still often sound unpleasing and incorrect. The reason for this is almost always due to the element being transferred with the modern SMPTE playback equalization curve even though most Hollywood mags before the 1980s were not recorded that way.

Although SMPTE did standardize other audio-related elements in the film industry, they failed to standardize the recording curve of 35mm magnetic elements until the early 1980s. As a result, the first 30 years of magnetic film recording in Hollywood were completely unstandardized and varied wildly among the studios. This paper will briefly look at the origins of the equalization standardization problem and provide recommendations on how to deal with the issue in preservation and restoration today.

What typically occurs now in sound preservation is that these old standards are unknown or ignored during transfer. Then the wrong-sounding equalization is later adjusted subjectively to taste during the restoration mix. Although this does get to a usable result in the end, the curves applied in restoration rarely match the exact curves in the analog domain. The closer one can get to the original specifications in the transfer, the better the sound quality will be due to reduced phase distortion and more accurate frequency response.

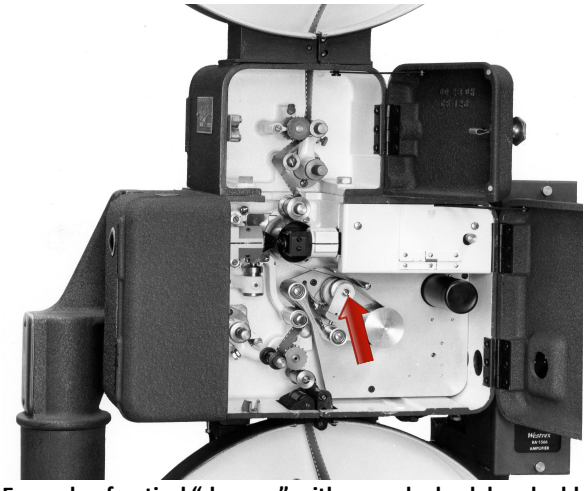
The beginning of magnetic film in Hollywood

When magnetic recording technology became viable for professional use shortly after World War II, it was adopted quickly by both broadcast studios and music studios. This is not surprising because it solved numerous problems encountered with the previous direct-to-disc approach used. Not only were magnetic tape machines settled on quickly, but magnetic tape standards were also quickly adopted since recorded reels were constantly moving around between studios and needed to be able to be played back in the same way they were recorded. The original NAB magnetic tape standards from the early 1950s are still being used by musicians recording on tape today.

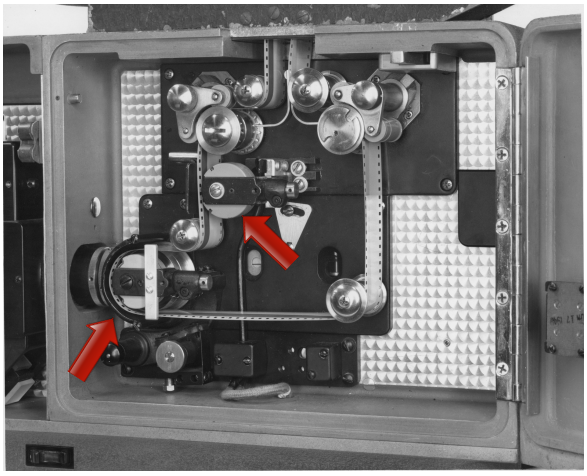
The film industry had a much different reception to magnetic recording. Although magnetic recording offered a significant reduction in noise and distortion compared to optical sound, it was a step backwards in other ways. The three main complications with mag film were found in editing, integration with other sound equipment, and sound libraries.

Possibly the greatest complication for film studios converting to magnetic sound was with sound editing. Magnetic tape provided broadcast studios and music studios with their first opportunity to edit sound since they had previously used disc recording, but the films studios had been editing sound on optical tracks for over 20 years. Additionally, optical sound modulations were visible to the eye so editing could be done quickly and precisely. When using magnetic film, this simplicity was lost and editing became slower. Editors had to find an exact splice point by "scrubbing" the mag back and forth over a playback head rather than by sight. A few systems were developed early on to "draw" the waveform on the mag for easier editing, but these were phased out as soon as editors became more comfortable just using their ears. Visible waveforms would not be used again for film sound editing until digital workstations were adopted nearly 45 years later.

The second problem with the adoption of magnetic sound in the film industry was due to the cost and logistical complications of making the transition. Unlike the broadcast and music industries where a ¼" tape deck or two could be wheeled into a studio and quickly patched in for recording, the film industry required many sound machines interlocked together for synchronization and mixing ability. Due to the cost and complexity of changing a hundred or so machines across a major studio, the initial conversion to magnetic sound was done incrementally by adding magnetic heads to the already installed optical sound machines. Playback "dummies" would get a magnetic playback head, while optical recording machines would get a recording head. In the early years of mag film use, the basic infrastructure of the machine room was unchanged and would look almost identical after converting to magnetic sound. By simply converting optical machines, it also allowed the equipment to be used for either optical or mag through the early years.



Example of optical "dummy" with mag playback head added. Optical playback ability maintained for library effects.



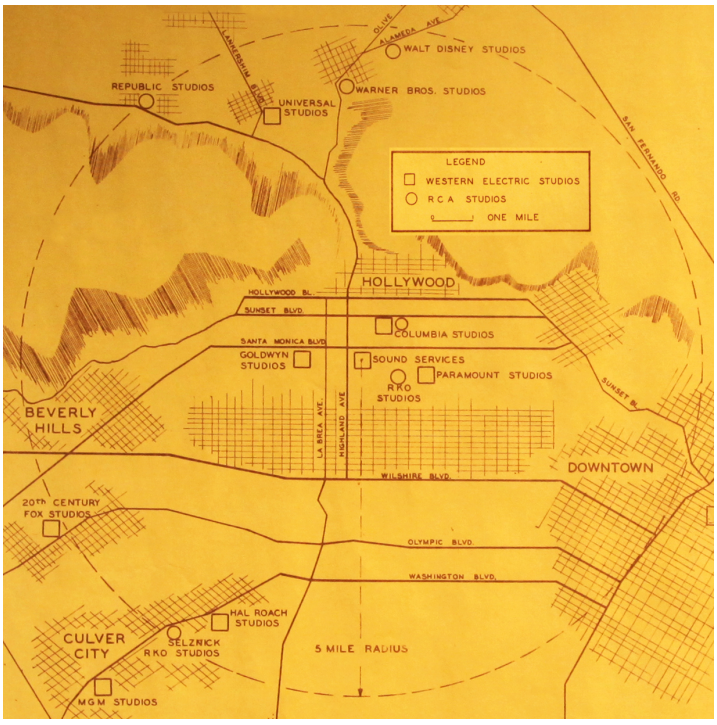
Example of optical recorder with mag record and playback heads added. Heads slide backwards for optical recording.

The third problem was the studios required many library effects for editing and mixing a film. Entire rooms of sound effects were comprised entirely of optical sound tracks in the 1940s and would require significant time and effort to re-record to mag or to create new library sounds on

mag. Some optical effects continued to be used directly on optical machines alongside the newer mag effects, while other optical-era effects were copied over to magnetic film and continued to be used that way. It is common to hear optical sound effects used in films well into the 1960s.

The desire to hold onto optical sound technology, especially for editing, can be seen in films like GENTLEMEN PREFER BLONDES (1953). The sound for this film was recorded and edited with optical sound even as THE ROBE (1953) was being recorded at the same studio with an entirely magnetic workflow. However, 1953 was roughly the last year that any major films used an optical sound workflow.

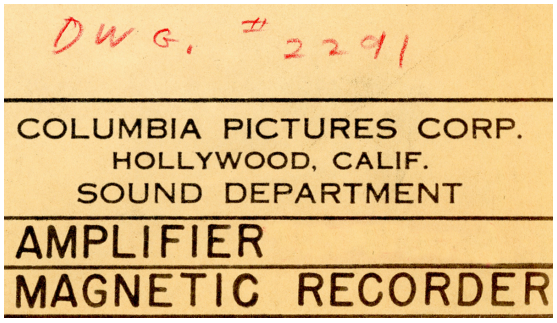
Because of these three complications, the slow adoption of magnetic recording at the major studios was done piecemeal and handled differently at each studio. At the time magnetic recording became available, all recording equipment at the major studios was leased equipment supplied by either Western Electric (Westrex) or RCA. See map below. These two companies provided different magnetic recording systems with differing perspective on best recording practices. Additionally, all studios had their own engineering departments with their own ideas on how to maximize the quality of magnetic recording systems.



Modified copy of Westrex document ASR-80263 from 1951 showing which companies were licensing which sound equipment. These designations were fairly stable, but Universal did switch to mostly RCA equipment in later years. Todd-AO ended up where the Sound Services building was, and Ryder Sound was located between Sound Services and RKO on the map.

Some studios used Westrex or RCA equipment almost as-is, some used modified systems, and some studios, like Columbia, built their own mag recording electronics entirely from scratch (shown below). Other manufacturers such as Magna-Tech Electronics and Stancil-Hoffman

eventually entered the industry, and these machines were used alongside the earlier Westrex and RCA equipment at many studios.



Example of entirely custom mag record and playback electronics used by Columbia Studios from the early 1950s until they left the Gower lot around 1972. It was designed with plug-in modules so the same basic amplifier could be used for multiple applications depending on what plug-in modules are inserted.

It is important to note that SMPTE did get slightly involved in mag recording standards in the early 1950s. However, they only dealt with more clear-cut specifications like 35mm azimuth test films (PH22.99) and magnetic track widths (PH22.86). SMPTE presumably stayed away from equalization standards because of disagreements between manufacturers and studios about what was the correct approach. By 1965, SMPTE did offer a multifrequency magnetic test film in their test film catalog, but it was not made to a published standard and did not conform to any major studio at the time. It was simply defined in the SMPTE sales literature as “high frequency response identical to the CinemaScope 4-track Multi-Frequency Test Film” (SMPTE document 7/65/3M).

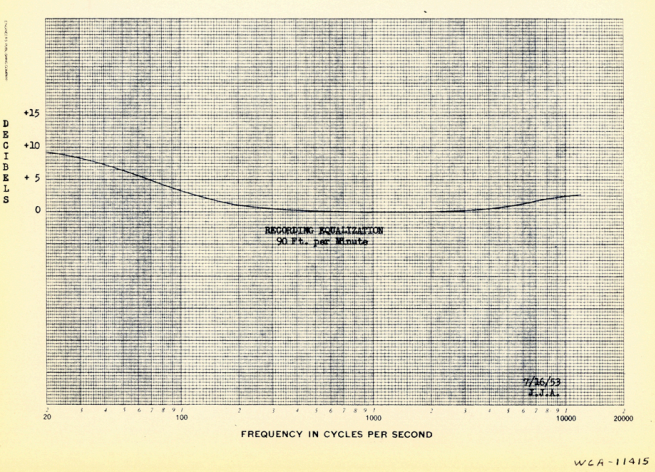
Magnetic recording curves and why they were used

When recording magnetic sound on 35mm film, the linear speed is fairly fast (18 inches per second), so it is not mandatory to modify the equalization significantly for a good recording. However, the reason additional equalization is added in recording is to help reduce noise in playback. Many tracks had to be mixed together in film sound, and each track would increase the noise level. By boosting the low frequency response in recording, it is possible to reduce hum and low-frequency electronics noise by reducing the low frequencies in playback the same amount as the recording boost. Similarly, it is possible to reduce tape hiss by boosting high frequencies in recording and then cut a similar amount in playback. There is also a natural loss of high frequencies in recording due to magnetic coating thickness, which needs to be corrected through high frequency equalization.

The problem with boosting equalization during recording is that it limits headroom and can add distortion. This is why there were different opinions as to what an ideal recording curve should

be. Overall recording level is also a variable, and the less recording EQ used, the higher the recording level can be. Studios using less recording equalization could record at a higher overall level to minimize noise in a different way.

RCA mag machines tended to suffer more from hum than Westrex mag machines, so RCA used significantly more low-frequency emphasis in recording to achieve an acceptable noise figure in playback. As a result, those studios using RCA equipment were more likely to use low-frequency emphasis in recording. However, the degree of low-frequency boost would vary with a particular studio, as shown in the next section.



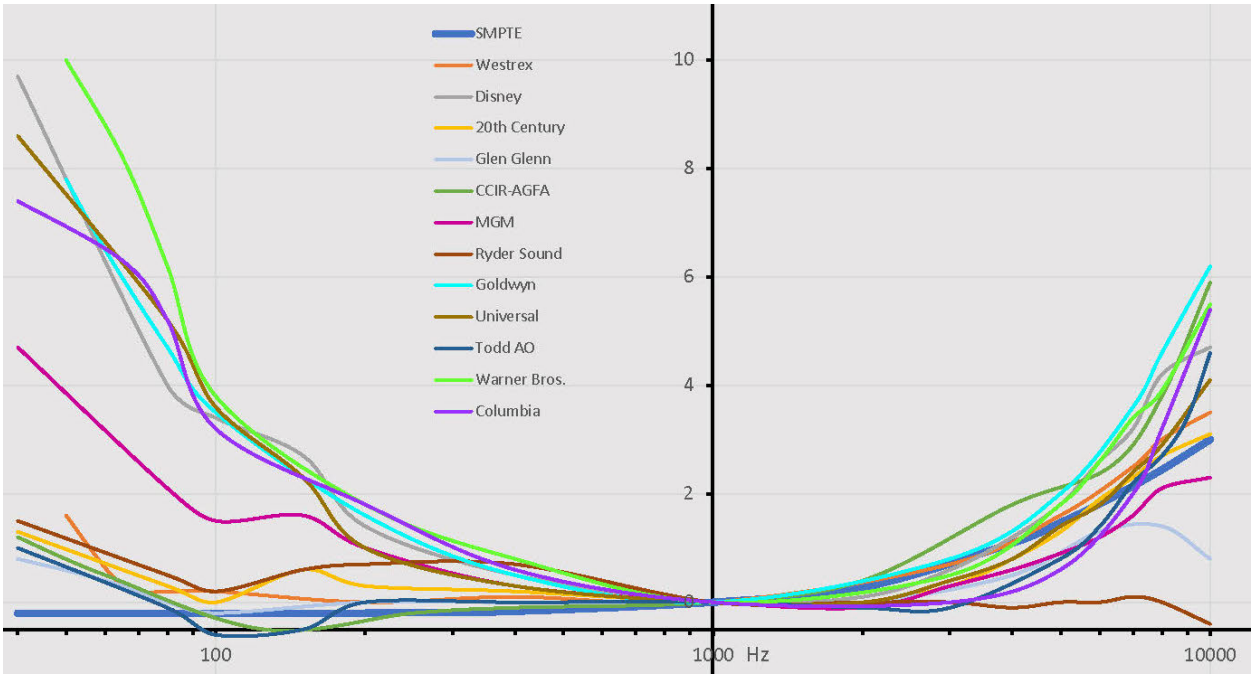
Original 1953 RCA drawing showing the RCA mag recording curve with low-frequency boost

Documenting early mag film recording standards

Unfortunately, not only was little done to standardize 35mm mag recording curves, but also there was very little documentation about the curves being used at studio. Original technical documents on the stock equipment from Westrex and RCA exist as shown above, but these curves were typically modified by the major studios so they only give a rough picture of what was going on. Although some studio blueprints of internal recording standards survive, they do not cover all of the studios, and the way each studio defined the recording curve was not always the same.

The most comprehensive study of legacy recording curves was undertaken around 1970 by Glen Glenn studios with the help of Robert Morrison at Standard Tape Laboratory. The exact date of the work is unknown. This was internal research that was not shared widely and was not published. Since Glen Glenn was an independent studio receiving mag elements from other larger studios, they wanted to understand how to properly adjust for these varying standards. The data is not from the theoretic blueprint curves at the studios, but rather an analysis of actual test tone films from each studio. Although there can be errors in this approach, at least three sets of the Glen Glenn data were cross-referenced to original blueprint curves going back to the 1950s, and they match within +/- 1dB.

It is important to note that the analysis done at this time was of the recording curve not the playback curve. The modern SMPTE curve is essentially a playback curve to help incorporate the variable high frequency loss that can occur with the thickness of mag coatings. The bold SMPTE curve shown in the graph is not part of the original Glen Glenn data set and has been approximated on the record side to provide a reference for the other curves. The low frequency section of the SMPTE has no low-frequency alteration so that section is obvious. The high frequency approximation is within +/- 1dB. Also note that since the graph (and original data) shows recording equalization. The playback correction for these curves is the inverse of these numbers.



Legacy mag *recording* curves compared to modern SMPTE curve. Data from ~1970 Glen Glenn research.

When transferring early mags now, the simplest way to achieve something close to the legacy equalization curves is by “un-calibrating” the SMPTE curve to an offset table. In other words, instead of adjusting a 100Hz SMPTE tone at 0, it can be adjusted to say -4dB to better match a particular legacy curve. This will get the transfer close to the original sound, but as shown in the graph above, there can also be odd bumps and dips in the legacy curves that do not follow standard 6dB/octave equalization. These can be from the use of inductors in the recording EQ or from interactions with the inductance of the mag head. The best way to get these exact curves is to use the original playback circuits, but the contours can also be compensated for after a close transfer by using parametric equalizers in a digital workstation. When performing a raw transfer with equalization different from SMPTE, it is useful to document the curve used by noting the deviation from SMPTE (like the table below). For example, a note such as “transferred with 100Hz down 3.5dB and 10kHz up 1dB compared to SMPTE ref” can be easily duplicated or changed in the future.

Frequency	Westrex	Disney	Fox	Glenn	MGM	Ryder	Goldwyn	Universal	Todd AO	WB	Columbia
100	-0.2	-3.4	0	0.2	-1.5	0	-3.5	-3.6	-0.6	-3.8	-3.2
1000	0	0	0	0	0	0	0	0	0	0	0
10000	-0.5	-1.7	-0.1	2.2	0.7	2.5	-3.2	-1.1	-1.6	-2.5	-2.4

Offsets from SMPTE *playback* test tones to achieve close approximation to legacy recoding curves. Even small changes in the low frequency curve can be significant since it is a long-tail curve. Note that Teccon playback heads typically have a 1dB dip at 100Hz, so when using Teccon heads, this should be considered.

It may seem confusing how it was even possible that each studio had such a wildly different recording standard when what ended up in the theaters had to be standardized. This was possible because the Hollywood studios were essentially self-contained islands during this time. The final optical track negatives were recorded in-house so the master mags did not typically ever leave the studio. As long as the release prints for the theaters were recorded in a standardized way, it was not critical that the steps before were standardized. Additionally, the optical sound used for release prints did not need pre/post equalization in the same way that magnetic recording requires it. M&E mags did leave the studios for the creation of foreign version, but they would typically be sent to an affiliated studio that would have matching test film.

It also may seem confusing why it took so long for mag standardization to occur. Along with still needing to deal with the shortcomings of specific equipment (such as the hum in RCA machines), the other likely reason for slow standardization was the heavy use of library sound effects. Once magnetic sound took over at the studios in the mid 1950s, the sound effects libraries at each studio were converted to mag as well. These mag libraries were recorded in-house on the specific studio curves decided on in the early 1950s. To impose a new industry-wide standard in say the late 1960s would mean that a studio would have a mix of differently equalized material under one-roof and would need to very carefully keep track of what was recorded each way. Maybe not so difficult with final master reels, but nearly impossible to deal with on loose effects that could be cut together on a single edited reel. Once the window for easy standardization in the early 1950s was lost, it became increasingly difficult to fix the problem.

Example of a non-SMPTE standard mag still being recorded in late 1981. Marked here as the generic "RCA EQ" curve with low frequency emphasis. In the late 1970s and early 1980s it was at least more common for alternate equalization to be identified.

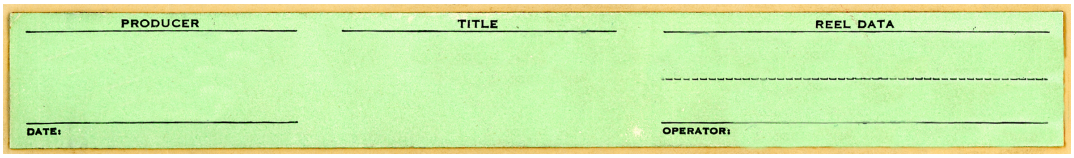
The studio who owns a film vs. the studio who recorded the film

In practice, films did move around occasionally between studios, which complicated things. This could occur when a film was mixed at another facility or when a film was purchased from an independent production company. For example, MY FAIR LADY (1964) was a major film for

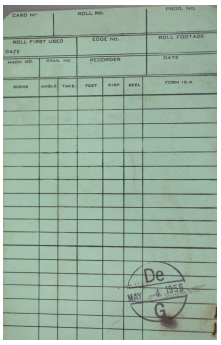
Warner Bros., but they did not have the equipment to mix a six-track audio master. As a result, the film was mixed at Todd-AO and all the final MY FAIR LADY mag masters are made with the Todd-AO mag equalization standard rather than the Warner Brothers equalization standard. Therefore, the mags for MY FAIR LADY are recorded significantly different than almost any other WB film from the same year. Todd-AO did occasional work for most major studios and many major films including SOUND OF MUSIC (1965) for Fox and SPARTICUS (1960) for Universal.

Today, just because a project is coming from a particular studio, does not mean it was actually recorded there even if a particular studio always owned the film. When possible, it is helpful to identify the actual studio where a mag was recorded so the mag curve can be more accurately determined. The problem is that only occasionally is there explicit information on the physical element listing where it was recorded. Many studios have re-canned their film in archival cans and the original boxes with this information have been discarded. Additionally, even when there are original labels, they often do not specify the studio. This may seem odd, but if an element was never intended to leave a studio, there was no need to identify the studio.

Even without explicit information on the film, there were only a handful of studios in Hollywood so it is often possible to recognize the studio where a mag was recorded by more subtle details. Details like the format of the label info, how the elements are named, or even the handwriting found on the element. For example, a mono DME marked as “ABC” is an MGM element, while Goldwyn typically used uppercase “DUBB MASTER” in the earlier years to label a master mix. Below are just a few examples of common labels that can be easily used to identify which studio actually recorded a mag. Although the studio name is not marked in these examples, they each have a distinctive style and demonstrate how labels and paperwork can used to accurately identify the studio.



Generic Todd-AO label used from late 1950s to 1970s. Later labels are similar but have Todd-AO included on the label. Various colors were used including yellow and pink. Todd AO was used by many studios and these labels can be found on mag elements from most major studios including Columbia, Fox, Warner Bros., etc.



Generic MGM Card used from 1950s to early 1980s, although later cards have “MGM” in lower left corner.

Generic card from 20th Century Fox transfer room. Late 1950s through 1980s.

Conclusion

The preservation of motion picture magnetic sound elements faces many challenges these days. Not only are there the well-known deterioration issues such as vinegar syndrome, but there are also the lesser-known issues such as the variable equalization standards discussed in this paper. There are also helpful features of mag elements that are important to recognize, though. Unlike master picture elements such as camera negatives where there is color correction from shot to shot, mags are essentially consistent from the beginning of a film to the end. If one takes the time to transfer a mag in a way that compensates for deterioration issues as well as correctly compensates for the recording EQ curve used, it is possible to hear a mag very close to how it was heard originally on the mix stage through the entire film. Only the theatrical playback curve needs to be added on top of the final raw transfer. Most often these days, raw audio transfers go directly to a digital restoration stage so the preservation or the original raw art object is not always considered as important. In other words, there is often a "fix it in post" mentality when dealing with equalization and deterioration. However, when a master mag is transferred carefully it can sound stunning and it is possible to hear (and preserve) a mix on its own terms before modern digital restoration and reformatting for commercial re-release.