A BRIEF HISTORY OF SMALL-GAUGE MAGNETIC STRIPED FILMS

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Intro: The Magnetic Solution to Sound Film – Technological Determinism

To better understand the emergence of magnetic sound on film it would be useful to do so from the perspective of technical developments in the form of "improvements" to the existing practice of optical sound. Briefly stated, a magnetic recording offers a higher degree of *fidelity* than its optical counterpart and is therefore more superior.[1] The rationale operating behind this kind of thinking is based on the ongoing technical mastery over the phenomenon of "noise" in recording/playback equipment and the desire, not only of engineers but among audiences as well, towards its reduction, if not altogether disappearance. Film theorist Mary Ann Doane writes: "In an industry whose major standard, in terms of production value, might be summarized as 'the less perceivable a technique, the more successful it is', the invisibility of the work on sound is a measure of the strength of the sound-track." [2]

Audio engineer Edward W. Kellogg's characterization of magnetic recording as signaling "freedom from noise" announces the technological promise of the new possibilities in sound film. [3] A freedom, moreover, that would potentially eclipse developments in

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[1] "Magnetic tracks may also have higher fidelity sound (greater frequency response and better signal-to-noise ratio)." Eastman Kodak Company, *Eastman Professional Motion Picture Films,* Rochester, New York: 63

[2] Doane, Mary Ann, "Ideology and the Practice of Sound Editing and Mixing", in Teresa de Lauretis and Stephen Heath's *The Cinematic Apparatus,* New York, St. Martin's Press, 1980: 48.

[3] Kellogg, Edward W., "History of Sound Motion Pictures", in Raymond Fielding, ed., *A Technological History of Motion Pictures and Television*, University of California, 1983: 215. (The original source appeared in a 1955 issue of *SMPTE Journal.*) Doane distinguishes *noise* ("the random sounds of the machinery – these lack meaning") from *sound* ("audible vibrations of air which have communication purpose") – differences recognized and maintained as standard definitions by film sound engineers. (Ibid., 55.)

optical sound. As early as 1946, magnetic sound pioneer Marvin Camras observes that with the "advent of fine grain films and ultraviolet optics," the optical sound film had reached its "theoretical limits of perfection" and that no "revolutionary changes" could be expected of it in the future.[4] Camras continues: "On the other hand, we have by no means reached the ultimate in magnetic recording heads or media."[5]

Origins: Magnetic Stripe Sound

The use of magnetic sound on film begins with the push by the audio industry in the marketing of its new researches into the magnetic field of sound. In 1947 the first taped radio broadcast of Bing Crosby not only demonstrates that the quality of a recording can compete with a live broadcast but also demonstrates the facility, not to mention economy, of the recording and editing process. The ease with which the magnetic elements can be organized, re-organized, recorded, erased, re-recorded – in short, the infinite plasticity of the medium – is enthusiastically received by the film industry:

> The compactness and portability of the magnetic-tape equipment, its freedom from dependence on laboratories, the immediate playback, the small storage space required, the relatively small cost of recording stock, plus the ability or reuse tape when the recorded sound on it is no longer wanted, the ability to work in daylight, and finally the excellent sound quality and dynamic range, combined to make the magnetic system a great advance from both the economic and performance standpoints. [6]

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[4] Camras, Marvin, "Magnetic Sound for Motion Pictures", in Marvin Camras, ed., *Magnetic Tape Recording,* New York, Van Nostrand Reinhold Company Inc., 1985: 385. (The original source was presented in 1946 at an SMPE Convention in Hollywood, and appeared in a 1947 issue of *SMPE Journal*.)
[5] Ibid., 385.
[6] Kellogg, 215-216.

Initially magnetic sound was only applied to 35mm but then moved to cover the small gauge formats. Each of these magnetic applications has its own technical history. This survey will focus on 16mm and Super-8.

Mag Track: On the Flexibility and Immediacy of Gauges – Exhibition Determinism

The major difference in the use of magnetic sound between the standard 35mm theatrical gauge and the smaller non-theatrical small-gauge formats can be understood from the perspective of exhibition practice. Whereas the film industry was quick to employ the magnetic solution to redefine and improve recording and mixing techniques, the prospect of a final release print with a magnetic stripe was not to be had due to the unwillingness of film exhibitors to renovate their current audio systems with costly magnetic playback equipment. Thus the final magnetic master had to be transferred to an optical track. Rather than seeing this as a compromise or failure, it became clear that high-fidelity deficiencies in the optical recording could be anticipated and even "improved" at the stage of the magnetic mix. The practice of sound on film, beginning as early as 1948, was a hybrid operation between the magnetic recording and its ensuing migration to an optical track. This was to be the dominant practice in the Hollywood film industry.[7]

More flexible practices for sound are characteristic of the non-theatrical small-gauge formats. Variations of pre-striped, post-striped, and a hybrid of mag-to-optical, and even mag-on-optical (as we will see) give a sense of the degree of magnetic flexibility in 16mm film. With Super-8 it is only the pre-striped and post-striped process, and even the possible combination of striped and non-striped (silent) passages in an edited work.[8] In a way, the magnetic stripe process in film had flourished as a distinctive audio feature in

[7] It is worth noting here that there were some exceptions like the multi-channel magnetically stripped 35mm and 70mm widescreen formats such as Cinerama, CinemaScope, and Todd-AO.

[8] Experimental Super-8 films by Saul Levine, Anne Robertson, and Scott Stark alternate between sound/silent footage, sometimes projecting the original reversal material.

the Super-8 format, at least in North America[9]; by the early 70's Super-8 sound film was synonymous with magnetically striped film.[10] Not so with 16mm sound film as the option between using an optical or magnetic track was a difference in choosing between a number of variables, including: 1.) higher fidelity requirements, 2.) single-system "sound-synch" filmmaking, and 3.) affordability.

The single-system 16mm optical sound camera, such as the Auricon, underwent modification to accommodate magnetic heads for the synchronous recording of sound and image on magnetically striped film. Similarly, 16mm film projectors were modified so as to playback both optical and magnetic tracks.[11] The single-system sound-synch unit was integral to the professional fields of news reportage and the emerging documentary practices of cinema-verite in the 60's. The use of magnetic in the single-system was well-suited towards capturing a sense of real life "immediacy" and even risk (as in war footage) that was necessary to convey the documentary moment or event. The instantaneity of recording/playback capabilities linked with economical viability (as magnetic was significantly cheaper than optical, especially at the post-production phase) contributed to the success of 16mm magnetically striped film in the area of low-budget productions.

Flexibility, immediacy, and portability are perhaps the most basic features of Super-8 sound film – features that effortlessly consolidated the format as an essential domestic apparatus: the so-called home-movie. The popularity of Super-8 sound was first unleashed with Kodak's Ektasound in 1973 which recorded sound-synch instantly onto the film's magnetic stripe.[12] One had the option of recording sound-synch or leaving the track blank so as to record after processing the film by operating the recording feature

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[9] Magnetic stripe for 16mm was just as prominent a feature of sound films in Europe.
[10] An exception is the short-lived feature length Super-8 optical sound film – a specialty format geared for the airline industry equipped with special loop projectors.
[11] Camras: "Ordinary sound-on-film amplifiers can be modified readily for magnetic sound." Ibid., 391. The emphasis is on "modification" *not* just as a technical procedure but as the language used by inventors in the industry to address the relatively low costs.
[12] Whereas Kodak discontinued its production of Super-8 sound cameras in 1979 (due to the emergence of video), Super-8 sound film continued through 1997.

built into the sound projector. Or, one could record sound-synch and later mix additional sound by recording onto the balance stripe. This was designed to counterbalance the main stripe and so prevent the film plane from resting unevenly in the camera and projector gate.[13] Projector manufacturers took advantage of the additional stripe to record a second track. It was usually advised to record a voice-over on this narrower magnetic portion. By leaving both tracks empty during the filming process one could record left-and-right channels, panning back-and-forth, and experimenting with spatial effects. Super-8 sound film successfully brought together the already advanced practices of home movies and hi-fidelity home recording as a unique opportunity for audio-visual creativity.

The Magnetic Striping of Small-Gauge Formats

Magnetic stripe processes are two in kind: either it is applied as a liquid solution or it is applied as a laminating adhesive. In general, the bulk of the magnetic material is applied opposite the film perforations. For 16mm the width of the magnetic track is 100 mil (0.100"); for Super-8 it is 30 mil (0.03") wide. The balance stripe for Super-8 is adjacent to the film perforations and measures a mere 12 mil (0.012"). Both the liquid and laminating striping processes are composed of a magnetic mixture of ferric oxide. The composition of the materials is the same as used for magnetic audio tape – i.e., a thin flexible polyester or triacetate ribbon coated with a thin granular layer that has been chemically treated, dissolved into a powdery crystal, and suspended in a binder.

One of the first and largest producers of magnetic tape that was to become the industry standard, as early as 1946, was the 3M Company (formerly the Minnesota Mining & Manufacturing Co.). 3M also manufactured mechanical striping units for the film industry, such as Model 16CB Laminator for 16mm. This machine ensured that the laminated adhesive would "permanently" stick to the film, regardless of whether the material was applied on the emulsion side or base side. The transport system fed the film

[13] The balance stripe also allowed the film to be evenly spooled during storage.

through various mechanisms beginning with: 1.) a pre-coater that would prepare the surface and rid it of dirt and waxes, followed by 2.) the laminating adhesive with a protective backing, then 3.) a slitter for the desired track width, then 4.) a heating and pressure roller device to make the laminate adhere properly, and finally 5.) a humidity chamber that softened the plastic tape backing for easy removal.

Another mechanical striping unit was the Reeves Soundcraft Corporation's Magna-Striper Model Z 16-mm which used a direct application of the ferric oxide in liquid form through a small nozzle. This model, as is also the case with the above 16CB Laminator, offers three separate widths by which to apply the magnetic solution – all to the right side of the film strip: 1.) 25 mil for double-perforated silent film (30 mil in the case of the 16CB Laminator), 2.) 50 mil for single-perforated photographic and magnetic (or photo-magnetic) sound, and 3.) 100 mil for single-perforated silent film (or what is called the "all-magnetic soundtrack").

What is interesting about the different magnetic orientations of these striping units is the attempt by the industry to add sound to all varieties of 16mm films, including double-perforation and optical sound films. Thus the amateur home movie filmmaker could get his or her silent films magnetically striped and turn them into sound films, regardless of shooting on single- or double-perforated stocks; or an optical sound film with variable-density or variable-area tracks could be partially covered with a magnetic stripe while maintaining the original (optical) track. But it is the third of the magnetic solutions – the all-magnetic soundtrack – that became the predominant striping method for 16mm film

The striping units were generally available on a commercial franchise basis and small business. For instance, an advertisement for Magna-Striper Model Z 16-mm in a special *SMPTE Journal* issue on sound film[14] promotes the unit as "the answer to the demand for local striping service to provide true hi-fidelity 16mm magnetic sound". The emphasis here is on the *local* to provide a high quality service. Writing for *Super 8 Filmaker,* film columnist and reviewer Lenny Lipton gives an account of small business "basement"

[14] Vol. 64, No. 7, July 1955: 401.

striping services as reaching "first-rate quality."[15] These were typically one-person operations, offering multiple striping services for Super-8 film, such as single stripe and/or balance stripe on base and/or emulsion side. In general, Lipton discourages the use of the do-it-yourself striping kits as these presented far too many obstacles for the average home user – i.e., the precision in applying the laminate was too cumbersome, often resulting in the stripe pulling away from the film. Instead he recommends the local basement striping services which usually began as do-it-yourself operations and, through repeated experience, became "do-it-for-others" businesses.

The differences between liquid and lamination processes are several in kind and we will briefly mention two. One pressing difference which is of particular concern today in the field of preservation, is in the strength and durability of the binding agent. In general, the lamination process was the most secure. This had to do with the high quality and consistent production standards of the manufacturer which supplied the magnetic stripe in bulk quantities of 2400ft. Consistencies in magnetic dispersion in the binder achieved optimal density before solidifying into its final laminated form. The liquid process, on the other hand, suffered from irregularities in the solution and the application itself. The solution was available in one-gallon cans and its maximum shelf life was three months. The liquid had to be manually agitated in order to ensure optimal magnetic dispersion. This was not always achieved. Furthermore, over time and through repeated projection use, the solidified solution could flake-off, chip, or peel.

However, the main source of contention between both forms of magnetic stripe applicators was during their initial appearance on the market in the early-mid 50's: the quality of the sound reproduced. The auditory (and even visible) difference was in the overall uniformity of the product. As the magnetic tape laminate adhering to film was of similar stock currently used for ¼" magnetic recording tape (such as 3M's "Scotch" brand) the results were of a significantly higher standard than the conventional liquid-

[15] Lipton, Lenny, "King of the Basement Stripers", *Lipton on Filmmaking,* New York, Simon and Schuster, 1979: 164-168. (Previously printed in *Super 8 Filmaker* as "Finding the Best Sound Stripe", Vol. 6, No. 1, January/February 1978.)

coated product. This is measured in db (decibels), with the former producing anywhere between 5 to 14 db more output than the latter.

Mag Projection: Recording/Playback

The nature of the sound recording relies upon several factors, including the width of the magnetic stripe and the speed of the recording/playback system. The wider the stripe and the faster the carrier, the better the sound. So that 16mm magnetic stripe is superior in that it is wider (at the standard width of 100 mil) and travels at a higher rate than the Super-8 magnetic stripe. As we have seen, the quality is also contingent in the uniformity of the magnetic product. But the high level of standardization in the manufacture of the magnetic product is not always met in the manufacture of the recording/playback system, the magnetic sound projector. Different projector makes and models offer a wide variety of recording/playback options all with equally varying levels of auditory fidelity. Thus 16mm sound projectors were available with both magnetic and optical track capability. Super-8 sound projectors were only available to play magnetic stripe[16], but the option was in the single- or double-channel capability. For both 16mm and Super-8, the recording feature was offered only in the higher-end models.

As mentioned earlier, the recording could be achieved through the single-system sound-synch method in which the camera synchronized picture and sound, and/or carried out through the "post-production" audio recorder feature built into the film projector. Simple recordings could be made while the film was running in the projector in the "record" mode with a regular microphone. This method was crude at best as extraneous projector noise also made its way into the recording. Auxiliary inputs and recording levels featuring VU-Meters for the monitoring of audio allowed for more sophisticated recording modes. Thus a prerecorded mix tape from a reel-to-reel player could be fed directly into the projector and recorded onto the magnetic stripe. This method had the

[16] The Japanese Fuji Film "Fujicascope Sound" is a Super-8 Sound projector with the dual "mag-opt" feature; the recording feature on this projector was for magnetic only.

advantage of achieving a hi-fidelity recording, thereby eschewing unwanted noise. Sophisticated amateur, experimental, and low-budget films could be produced by the double-system method of shooting silent film (single- or double-perforation, negative or reversal film) while recording audio on a separate source, like the reel-to-reel Nagra. After editing picture and sound the lab would post-stripe and synchronize the edited audio to the final film print.

Magnetic Stripe Users

The television industry was one of the major users of magnetic stripe 16mm film. As with Bing Crosby's recognition of the plastic powers of the emerging magnetic media, television quickly caught on. Absolute control over the recording and mixing – quick, easy, and economical – was unprecedented. Television employed all varieties of the magnetic stripe process, including shooting single-system sound-synch newsreel footage. Rapid turnaround facilitated the massive demands for continuous television programming. Today one can find a collection of such films, like "The KTLA Collection" (1955-1981) and "The TV News Collection" (1973 – 1975), housed at the UCLA film archives.

The amateur home movie market was the major motivating force behind the production of Super-8 sound film. Although Super-8 sound features on magnetic film were available such as "Star Wars" (1977) and television episodes such as "Battlestar Gallactica" (1978 – 1980), the format was primarily geared towards appealing to a mass consumer audience – that is, in their concerted efforts to obtain precious and invaluable audio-visual moments of everyday life. Even the features and television episodes, as well as a vast catalogue of diverse genres, were primarily for home consumption. The portability of Super-8 sound equipment allowed the user to take his or her audio-visual apparatus anywhere and everywhere.

Experimental filmmakers in the US experimented with Super-8 magnetic sound film. Saul Levine's "Notes after a Long Silence" (1989) is a fifteen minute Super-8 film that takes advantage of the 18-frame separation between film gate and magnetic sound head, with each shot sometimes cut at exactly 18 frames. Because sound is located before the image, the sound of one shot appears to be "synched" to the image of the following shot, thereby achieving a radical audio-visual discontinuity. In an earlier film "Notes of an Early Fall" (1976), a thirty-three minute Super-8 film, the film was shot at 24fps and is projected at 18fps to slow down both image and sound; a repeating image of a skipping phonograph player with warped vinyl calls attention to the sound. Another filmmaker that shoots Super-8 sound at 24fps and projects at 18fps is Bay Area filmmaker Steve Polta who creates an assemblage of unedited three-minute camera rolls producing atmospheric drones and soundscapes, in films such as "1977A (Arrival)" and "1997B (Departure)".

Anne Robertson, Peggy Ahwesh, and Jennifer Montgomery have all worked with Super-8 sound in the experimental film diary mode. Anne Robertson's "Apologies" (1990) consists of the filmmaker addressing the camera and speaking into the microphone, expressing repeatedly for seventeen minutes and in a range of dramatic moods: "I'm sorry," "I'm really sorry," "I said I was sorry," "Will you forgive me?" etc.; at one point she apologizes for not returning the overdue camera to the film rental facility. In Peggy Ahwesh's twenty-minute *Martina's Playhouse* (1989) a young girl takes the microphone and breaths heavily into it with babbling baby talk, causing overmodulation in the recording; in another scene the filmmaker forces her friend – filmmaker Jennifer Montgomery – to speak into the microphone and tell her a story of secrets. Low-tech aesthetics materialize Mary Ann Doane's hint of a sound that "would signal the existence of the apparatus."[17]

[17] Ibid., 55.

Magnetic Fields: A Snapshot Pre-History of Magnetic Stripe Film

- In 1927 Austrian chemist Fritz Pfleumer develops a paper tape coated with powdered magnetic particles. In 1928 he builds a magnetic recorder that uses a paper strip with steel particles as its recording medium. The device is a simplified mechanism for moving the lightweight tape across a new type of magnetic head.

- In 1935 the "Magnetophon" is developed by the German electric company AEG, shortly after purchasing all of Pfleumer's patents. AEG collaborates with the chemical company I. G. Farben (known today as BASF) to investigate other magnetic particles. Iron oxide coated on plastic tape offers the best result, which leads into the invention of the Magnetophon – the first tape recorder.

- At the end of the war, American serviceman Jack Mullin dismantles and confiscates the Magnetophon to study it back in the US. Mullin demonstrates the device to Bing Crosby in 1947. Crosby embraces the possibilities of the medium to circumvent the constraints of live radio broadcast. His show becomes the first major radio program in the US to be aired from magnetic recordings.

- In 1948 Ampex Corporation produces an improved version of the Magnetophon. Other manufacturers begin to market competing products. 3M develops better tapes.

- American engineer Marvin Camras, of Armour Research Foundation, promotes magnetic recording for the soundtracks of motion pictures. By 1951 the majority of Hollywood films are edited and mixed magnetically. Just prior to this, in 1949, television was already using more film than Hollywood, much of which used the magnetic stripe process.

ANNOTATED BIBLIOGRAPHY

Bate, Geoffrey, and John K. Alstad, "A Critical Review of Magnetic Recording Materials", in Marvin Camras, ed., *Magnetic Tape Recording,* New York, Van Nostrand Reinhold Company Inc., 1985: 262-280. Originally published in the *Institute of Electronic and Electronic Engineers, Inc.* (magazine)*,* 1969. The authors are with the IBM Systems Development Division Laboratory, Boulder, Co. This article was relevant to our study in understanding gamma ferric oxide recording surfaces. Particular attention is given to the reasons ferric oxide had gained dominance over other potential metal recording surfaces, covering chemical-magnetic properties with particular emphasis on economical explanations, i.e., "cheapness". The authors state that superior recording surfaces are not needed; the problem is not in introducing better quality metals but in addressing "dimensional instabilities" in the binders.

Camras, Marvin, "Magnetic Sound for Motion Pictures", in Marvin Camras, ed., *Magnetic Tape Recording,* New York, Van Nostrand Reinhold Company Inc., 1985: 384-394. Original published in *Society of Motion Pictures Engineers Journal,* 1947; presented October 22, 1946, at the SMPE Convention in Hollywood. The publications of Marvin Camras (1916-1995) of Armour Research Foundation were significant for garnering widespread interest in magnetic recording in the film industry. The article was relevant to our study in breaking down the pros and cons of optical sound vs. the pros and cons of magnetic sound. In this early article, Camras stresses the importance of the magnetic system as an "alternative to present photographic methods, and should be more flexible and economical." (394) The author concludes that "further improvements are probable." (394)

Case, Dominic, *Film Technology in Post Production,* London, Focal Press, 1997: 172. Significant section on "Soundtrack Quality" compares the differences in quality between optical and magnetic sound. Describes the technique of "compression" as the use of magnetic sound to compensate for the "limiting factors" of optical sound due to the latter's "far lower signal to noise ratio". The loss of sound level in the optical track,

particularly in quieter passages, is "boosted considerably in the magnetic print master or during optical sound transfer". A method of comparison for checking sound quality is described in which both magnetic and optical tracks are synchronized, thereby allowing one to switch back and forth between them. Ultimately revealing for our study, is the author's concluding remarks that "even the best optical track is inherently more limited in range and response than magnetic".

Daniel, E. Eric, "Tape Noise in Audio Recording", in Marvin Camras, ed., *Magnetic Tape Recording,* New York, Van Nostrand Reinhold Company Inc., 1985: 350-357. Originally published in *Audio Engineering Society Journal,* 1972. Paper by Memorex Corporation presented October 14, 1970, at the 39th Convention of the Audio Engineering Society, New York. This paper was relevant to our study in understanding tape noise occurring in audio recording systems, including noise produced in the magnetic particles of tape coatings and the playback equipment. Physical properties of the oxide particles and the coatings are described with particular reference to achieving high-fidelity performance. Includes an electron photomicrograph of gamma ferric oxide particles. The author states that the results of his study establish criteria for designing tape with improved signal-to-noise capability.

Doane, Mary Ann, "Ideology and the Practice of Sound Editing and Mixing", in Teresa de Lauretis and Stephen Heath's *The Cinematic Apparatus,* New York, St. Martin's Press, 1980: 47-60. This essay is significant to our study in providing a theoretical perspective in which to think through the ideological implications of sound film practice, in particular as these manifest themselves in the writings of sound engineers, primarily from the pages of *SMPTE Journal.* The ideological unveiling characteristic of Doane's acute prose is highly informative (if not formative): "The rhetoric of sound is the result of a technique whose ideological aim is to conceal the tremendous amount of work necessary to convey an effect of spontaneity and naturalness. What is repressed in this operation is the sound which would signal the existence of the apparatus." (55)

Dubbe, Richard F., "Recent Developments in Magnetic Striping by the Lamination Process", *SMPTE Journal,* Vol. 64, No. 7, July 1955: 378-379. This paper was originally presented on April 21, 1955 at the Society's Convention in Chicago. Edward Schmidt is a representative from the Minnesota Mining & Manufacturing Co., the company which manufactured the Model 16CB Laminator demonstrated in this paper. Significant to our study is an example of the laminate type striper. The striper's basic features and operation is described. "Performance of the Laminated Track" illustrates graphic representation of the laminate track's "uniformity of output and excellent high-frequency response".

Eastman Kodak Company, *The Book of Film Care,* Rochester, New York, 1992: 68. Diagram illustrating 35mm frame separation difference between optical and magnetic sound films. 21-frame separation between the film gate and the optical sound head, with sound before the corresponding picture frame; 28-frame separation between the film gate and the magnetic sound head, with the sound "lagging" behind the corresponding picture frame.

Eastman Kodak Company, *Eastman Professional Motion Picture Films,* Rochester, New York: 63. Important comparison information and authoritative statements regarding surface protection and sound performance between optical and magnetic tracks. In comparison to optical tracks, "Magnetic tracks […] are less susceptible to dust and dirt distortion and are degraded very little by scratches […] The additional height of the magnetic stripe raises the emulsion (image) off the base side of the next convolution of film on a reel, protecting the picture area from frictional damage, emulsion-to-base sticking, etc. Magnetic tracks may also have higher fidelity sound (greater frequency response and better signal-to-noise ratio)." Also, noteworthy in this publication is the announcement that the Eastman Kodak Company does not manufacture post- or pre-striped film.

Eastman Kodak Company, *Film Notes for the Reel People,* Rochester, New York, 1984: 119-120. "Projectionist's Trouble Shooting Guide" has a section on magnetic sound.

Example: “Problem: Hissing sound (rain)”; “Probable Causes: Magnetic tracks partially erased or subjected to spurious magnetic sources”; “Remedy: Exchange print”. The probable causes are revealing for what can go wrong with magnetic tracks and where these are different (i.e., “oxide buildup on heads”) and/or share similarities (i.e., “insufficient film tension”) with optical tracks.

Enticknap, Leo, *Moving Image Technology: From Zoetrope to Digital,* London, Wallflower Press, 2006: 122-125, 149. Leo Enticknap is a curator and former projectionist. He has written on the ethics of archival film restoration. A chapter on sound, with the subheading “Magnetic Sound in the 1950’s” was useful in mapping a general timeline of events that lead to the use of magnetic sound in film. It offered significant clues and points of entry from which we were able to expand our research, such as the following passage by technical advisor Leslie Knopp quoted in the text: “It is now recognized that magnetically recorded sound is superior in quality to the optical soundtrack […]” (149) Enticknap does not go into the details as to why this is the case. For this we had to turn to Camras and Kellogg.

Glenn, George D., and Charles B. Scholz, *Super 8 Handbook,* Indianapolis, Indiana, Howard W. Sams & Co., Inc., 1974: 124-153. Chapter on sound offers a comprehensive overview of the various ways and methods to record sound on Super-8, including pre- and post-stripe films. For the purpose of our study, this handbook gave us a sense of the range of recording techniques that were possible, including the use of mixers and multiple-channel setups. Informative illustrations and diagrams demonstrate how far the Super-8 sound film progressed as a sophisticated audio-visual format.

Kellogg, Edward W., “History of Sound Motion Pictures”, in Raymond Fielding, ed., *A Technological History of Motion Pictures and Television*, University of California, 1983: 215-217. The complete three-part installment of articles from *SMPTE Journal* (June 1955; July 1955; August 1955). The series of articles was presented May 5, 1954 at SMPTE’s Convention in Washington, D.C. The biography for Kellogg in the facsimile of “First Installment” lists him as “Consulting Engineer”. He is recognized as inventor,

with Chester W. Rice, of the coil loudspeaker in 1925. The author introduces the article as an overview of sound technology and practices up to 1955, and expands on earlier attempts by authors of the Journal, namely Theisen (1941) and Sponable (1947). The article was suitable for our study in at least three areas: 1) Kellogg points out that most histories leave out of their descriptions detailed accounts of sound developments in 16mm film, typically assuming that what applies to 35mm also applies to the smaller gauge; Kellogg's history is a corrective to such a view; 2) The history ends with the latest developments of magnetic recording and striping units; 3) Up to 406 references, mostly from *SMPTE Journal,* cover many aspects of sound motion pictures up to 1955.

Lipton, Lenny, *Independent Filmmaking,* San Francisco, Straight Arrow Books, 1973: 19, 23, 36-38, 43-45, 136, 300-303. Lenny Lipton has written many books on amateur filmmaking, including the definite book on 3-D filmmaking, *A Study in Depth: Foundations of the Stereoscopic Cinema*. He is also an independent filmmaker with films in the collection of the Pacific Film Archive. *Independent Filmmaking* is a technical and practical filmmaking guide. As well as being a 'how-to' manual it also offers insightful evaluations of the various options offered for16mm and Super-8 magnetic sound. For our purposes, a section on "Magnetic Stripe Film" was very useful in demonstrating a step-by-step method for preparing and recording the striped film. Informative observations regarding the overall quality of Super-8 sound recording and playback equipment. In general Lipton's filmmaking handbook tends to be written from the perspective of a 'consumer report'; in this way, the author teaches us how to be both creative and informative filmmakers.

Lipton, Lenny, *Lipton on Filmmaking,* New York, Simon and Schuster, 1979: 71-89, 143-147, 164-168. More so than his earlier *Independent Filmmaking,* this collection of reviews, initially published in the magazine *Super 8 Filmaker,* offers informative perspectives from a consumer report approach. Of particular interest for our study on magnetic sound were the articles "The 200-Foot Cameras – Four Times the Fun!", "The Clean Sound", and "King of the Basement Stripers".

Matzkin, Myron A., *The Super 8 Film Maker's Handbook,* London, Focal Press, 1976: 8-9, 225-234. Of significant use for our study for its comprehensive diagrams of striped possibilities in the small-gauge formats. Illustrates the various positions and widths of the magnetic stripe track on the surfaces of 16mm, Regular 8mm, and Super-8.

National Film Preservation Foundation, *The Film Preservation Guide: The Basics for Archives, Libraries, and Museums,* San Francisco, National Film Preservation Foundation, 12-13, 17, 60-61. Section on "Magnetic Track Deterioration" describes: "The magnetic coating can shed oxide, become sticky, or completely separate from the base." (17) Vinegar syndrome will ultimately destroy the magnetic stripe. The section ends with a recommendation to copy the sound before it decays. Also noteworthy is temperature storage recommendations for prints with magnetic sound track. Whereas freezing nitrate-, acetate-, and polyester-only film, films with the magnetic stripe may cause significant damage. It is therefore recommended to store the latter at a temperature range between 54°F (12°C) - 40°F (4°C). The guide states that more research needs to be carried out on magnetic track deterioration.

Schmidt, Edward, "Laboratory 16mm Striping Unit", *SMPTE Journal,* Vol. 64, No. 7, July 1955: 375-377, 401. This paper was originally presented on October 20, 1954 at the Society's Convention in Los Angeles. Edward Schmidt is a representative from the Reeves Soundcraft Corp., the company which manufactured the Model Z-16 Magna-Striper demonstrated in this paper. Significant to our study is an example of the liquid type striper. The striper's basic features and operation is described. Also of significance, is an advertisement for this unit with a photographic reproduction, marketing it as a "highly profitable business" franchise.

Vandetti, James, *The Theater Student: Filmmaking,* New York, Richards Rosen Press, Inc., 1978: 99-100. Although not the kind of book that would normally be referenced for a research paper of this kind, we include it here for its photographic reproduction of Kodak's 1973 Ektasound camera and projector system.