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Moving Image and Sound: Basic Issues and Training
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Variable Density Sound-on-Film

*The Jazz Singer*appeared in 1927 and marked the first massive commercial success of synchronized sound in motion pictures. This event signaled the beginning of the most rapid industry-wide conversion process in film history. By 1932 this process had finished globally and silent film had become a thing of the past.[1] At the outset five competing systems of sound synchronization were vying for success. These can be divided into two main categories,sound-on-disc and sound-on-film. *The Jazz Singer* was an example of the Vitaphone sound-on-disc method, which relied on a phonograph record being played in synchronization with the film's projection. The other was sound-on-film, which utilized a photographic record of the soundtrack placed on one side of the filmstrip itself. By the early thirties the sound-on-disc methods, the most notable of which was marketed by Warner Brothers under the trade name Vitaphone, began to be eclipsed by the optical sound methods.[2] Sound-on-film came in two distinct flavors, variable area and variable density. It is the object of this paper to explore the historical development and significance of the variable density method.

A variable density soundtrack is produced through exposing a static width of film to an intensity of light that varies in direct proportion to the changes in voltage created by the recording microphone's reaction to the original changes in sound pressure. This differs from the variable area process, also known as variable width, which uses a

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[1] Leo Enticknap, *Moving Image Technology: From Zoetrope to Digital* (London and New York: Wallflower Press, 2005), 98-9.
[2]Ibid, 114.

constant amount of light but varies the width of the exposure in direct proportion to the above-mentioned changes in voltage.[3] While both processes are fairly similar in conception, they each had their advantages and disadvantages. When these processes first arrived the variable density displayed certain technical advantages over variable area. However, as time went on, the issues with variable area were more successfully overcome than those with variable density. The specifics of these issues will be detailed more fully below, but what ultimately became the main difference is that variable area was more easily reproduced and more easily read by the photoelectric cell that translated the photographic image back into an electrical current during projection. This is due to the fact that the constant amount of light resulted in an image that was either black or white, in contrast to the density process that yielded strips of black, white, and all the shades of grey in between. These more subtle differences required greater effort in processing labs to recreate faithfully, and so were more susceptible to generational loss.

[3] Edward W. Kellogg, "The ABC of Photographic Sound Recording," *Journal of the Society of Motion Picture Engineers*, Vol. 44, No. 3 (March, 1945), 152-3.

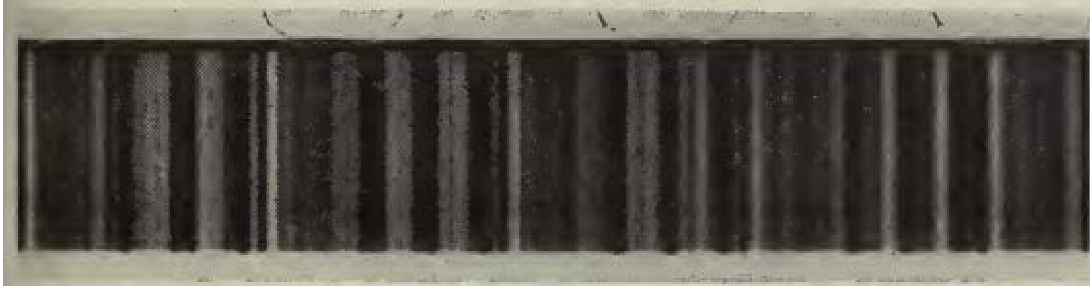

FIG. 2. Variable-density sound track.

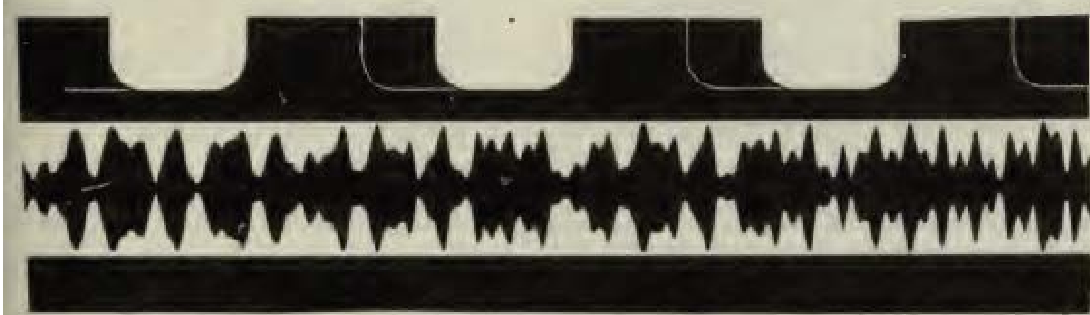

FIG. 3. Variable-area sound track.

[4]

Despite this drawback, Western Electric's variable density system remained the dominating sound synchronization method in Hollywood through the end of the 1940's, which saw the advent of magnetic recording.[5] This domination despite a recognized technical deficiency reflects a significant aspect of the motion picture industry. The reliance on controlled markets, rights to patents, and contractual relationships that reach from the moment of production through to the moment of exhibition enabled the system to remain in place much longer than it arguably should have. The domestic market dominance of the Western Electric variable density soundtrack is therefore not due to it

[4]Ibid, 153.
[5]Enticknap, 122.

being the best system but rather that Western Electric was in aposition to make the most advantageous use of the commercial opportunities.

The attempt to produce photographic representations of sound began well before the attempt to synchronize sound with moving images. As such discussion of the technologies leading up to the sound-on-film systems requires some mention of these efforts. Recording sound with light was considered a preferable theoretical starting point by many who were wary of the difficulties in creating mechanical systems capable of vibrating at the high frequencies sound recording requires. Therefore efforts to photographically record sound begin with efforts such as the pre-telephone experiments by Alexander Graham Bell using manometric flames to capture voice recordings.[6]Another example is Professor E. W. Blake who performed experiments recording vocal sounds using a moving photographic plate and a vibrating mirror.[7]

For effective use with motion picture projection, the ability to accurately create a photographic analog of sound was not the only necessary component. There is also a need to transform this information into an electrical signal that can be amplified for the benefit of the larger audiences which film exhibition garnered. In 1873 Willoughby Smith discovered that Selenium Cells were photoconductive, or would output electrical energy based on exposure to light. Experiments with photoelectric cells were carried out towards the end of the 19th Century, beginning in 1887 with Heinrich Hertz.[8] There were issues with both the selenium and photocells in reproducing electrical currents based on light, as Kellogg describes:

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[6] Kellogg, "History of Sound Motion Pictures" in *A Technological History of Motion Pictures and Television*, ed. Raymond Fielding (Berkeley and Los Angeles: University of California Press, 1967), 175.
[7] Ibid.
[8]Ibid, 176.

> The response of a selenium cell to changes in illumination is sluggish, making it a very imperfect tool for sound reproduction, whereas the photoemissive effect on which photocells depend is practically instantaneous, but the electrical output from a selenium cell is very much greater.[9]

In short, one needed both a quickly reacting photocell for faithful sound representation and a strong enough electrical current for sufficiently audible playback. At the time of these experiments the latter was certainly lacking.

The problem with electrical current strength began to be solved in 1907 with Lee de Forest's invention of the Audion tube. For sound this event "marked the beginning of the electronic era."[10] This device amplified an electric current in a filament within an evacuated glass tube. While many improvements were necessary before adequate effects were generated, the amplification tube created by de Forest was an essential starting point for all applications of transmitting sounds, from film sound to telegraphy, telephony,and radio.

In addition to the inventions relating to the transduction of sound energy into electrical energy, electrical energy into light energy, and then back again into sound energy, some important mechanisms were necessary for the film transport system in both recording and reproduction. In Germany a company named Tri-Ergon began developing a variable density system in 1918. Between 1919 and 1923 the company secured a number of important patents. As Sponable notes, "Some of these patents – such as the printing patent, the flywheel patent, and the photoelectric cell patent – were so basic that they later were the cause of extensive litigation and nearly became controlling factors in sound

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[9] Ibid.
[10] Ibid.

recording and reproduction."[11] The flywheel mechanism is of special importance in the film transport system. The intermittent movement of the film frames that allows the illusion of movement to take place would make simultaneous sound playback untenable to the ear. As a result sound recording and playback occur in an expansion of the film transport path where the movement of the film is continuous. Ultimately the construction involved the film passing through a sound gate in which the light source and photoelectric cell were placed. Speed is kept continuous through the use of a flywheel and damping, or a very heavy flywheel and tight coupling to the projector's motor causing the necessary mechanical impedance.[12]

In 1922, Professor Joseph T. Tykociner demonstrated an early variable density system that used a mercury arc lamp as a light source and a photocell for reproduction. Issues with the system included that the placement of the soundtrack was not ideal[13] and that "the light from the mercury arc [was] potent photographically, but [was] sluggish in following the input modulation, which [resulted] in some loss of higher audio frequencies."[14]

Theodore W. Case worked in conjunction with Lee de Forest in the development of a variable density system that came to be known as Phonofilm beginning in 1918.A major development supplied by Case's research was the Aeolight, or a hydrogen filled light with a filament coated with alkaline earth oxides which was a marked improvement over other light sources designed to vary intensity in response to electrical current.[15]This

[11]E. I. Sponable, "Historical Development of Sound Films," *Journal of the Society of Motion Picture Engineers*, Vol. 48, No. 4 (April 1947), 282.
[12] Kellogg, "History," 190.
[13]Joseph E. Aiken, "Technical Notes and Reminiscences on the Presentation of Tykociner's Sound Picture Contributions," in Fielding op. cit., 222.
[14] Kellogg, "History," 177.
[15]Sponable, 285, 288.

was combined with de Forest's amplification technology and first demonstrated in New York in 1923.[16] Case had also previously developed a photocell more reactive than Selenium cells using thallium oxy-sulfide and dubbed it the Thalofide Cell. It was used in Naval communications during the First World War.[17]

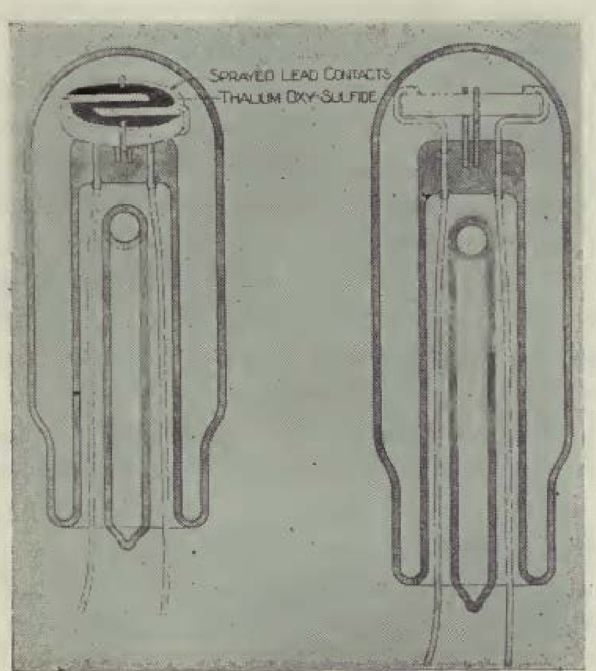

FIG. 3. Thalofide Cell, high vacuum, helium, or hydrogen filled. Case Research Laboratory, Inc., Auburn, N. Y.
[18]

Before beginning on the advent and heyday of commercial variable density recording and sound-on-film recording in general, a brief description of how optical sound quickly outshone the competing sound-on-disc method seems advantageous. Sound-on-disc reproduction required records with a playing time long enough to accommodate at the least a 1000 foot reel, or about 11 minutes, and this requirement was

[16]Ibid, 289.
[17]Ibid, 285.
[18] Ibid.

met by using 16 inch records recorded at $33^{1}/_{3}$ rpm. Additionally required were "a synchronous drive, and… electrical reproduction in order that, with the help of amplifiers, adequate sound output could be had."[19] Recording and reproduction required that both the camera and record motors be attached to achieve synchronization, and this led to cumbersome equipment requirements as well as technical difficulties in achieving a regular speed.[20]The limited playing time of the disc was also a serious drawback.

Despite these drawbacks, Warner Bros. decided to develop the system anyway, due to engineers' relative inexperience with optical recording and consumers' familiarity with disc recording.[21]The success of Warner Bros.' Vitaphone system with *The Jazz Singer* in 1927 rapidly convinced the industry and the public that talking pictures were the future. Yet this success did not change the fact that sound-on-disc was already largely incompatible with prevailing stylistic practices of Hollywood studios. The limited running time of the records was one issue. Another is that sound editing and mixing had to be done live, and once the master disc had been recorded there was no opportunity for further editing.[22]The setups for re-recording a film with the sound-on-disc method would involve anywhere from 1 to 100 different records being recorded on or from.[23]Sound-on-film therefore provided improvements in all the areas that caused issues with sound-on-disc. Sound-on-film would last as long as the longest reel of film as it was printed onto the film itself, it could be more easily edited in post-production, and the additions to the recording and exhibition systems were far less cumbersome.[24]

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[19] Kellogg, "History," 180.
[20] Ibid.
[21] Ibid.
[22]Enticknap, 111-2.
[23] Lea Jacobs, "The Innovation of Re-Recording in the Hollywood Studios," *Film History: An International Journal*, Vol. 24, No. 1 (2012), 11.
[24]Ibid, 112.

By 1932 Vitaphone and sound-on-disc recording had ceased to be a production medium, but the studios still continued to release Vitaphone records for exhibition for another 2-3 years due to the large investment many theatres had expended to incorporate the playback systems in the wake of its initial success.[25] Another system that died around this time was the Fox-Case system, into which Phonofilm had transformed after business disputes between de Forest and Case dissolved that partnership in 1925.[26]Case then signed over his patents to the Fox Corporation in 1926.[27] The variable system designed was used for newsreels and location work where a single system was adequate in Fox's Movietone newsreels. A single system incorporated the sound and image recording into one machine, which made portability easier but hindered the ability to edit since the two records were attached from the beginning to the same piece of film. Another issue with the Fox-Case system was the Aeolight described above. The RCA and Western Electric systems achieved light modulation more effectively, and by the early 1930s "the Aeolight system was not able to match the technical improvements made in the other systems."[28]The Fox-Case system largely disappeared around the time that Vitaphone vanished. In North America this left two systems, both of which were sound-on-film. One was the RCA variable area system. The other was Western Electric's improvement on the variable density system.

The RCA Photophone variable area system was the result of a threefold arrangement between General Electric, Westinghouse, and RCA. "RCA was the sales outlet for all radio and kindred equipment. Manufacturing was divided between General

[25]Ibid, 114.
[26]Sponable, 294.
[27]Ibid, 302.
[28] Barry Salt, *Film Style and Technology: History and Analysis* (London: Starword, 1983), 280.

Electric and Westinghouse. Research and development continued to be carried on at both manufacturing companies."[29] Additionally, "in 1928 RCA bought the theater chain interests of B. F. Keith and of Orpheum, and of the film producing company Film Booking Office… and organized Radio Keith Orpheum, or RKO."[30] By 1936 studios using this system included Disney, Warner Bros. and Columbia.[31] It is through this process that RCA Photophone had acquired a share of the production and exhibition market. However, this share was substantially less than that obtained by Electrical Research Products, Inc., the vendor for Western Electric's system. For instance in 1930 ERPI had equipped 4000 theatres domestically, whereas RCA had equipped 1200.[32] And by 1928, the five major studios in Hollywood had agreed to use Western Electric's improved variable density system using a light valve.[33]

RCA had at the outset, under C. A. Hoxie, experimented with both variable area and variable density systems. An important discovery during this time was that the width of the sound track did not dictate sound quality, and therefore sound and picture could exist on the same strip of film.[34] Variable-width was selected due to the influence of A. C. Hardy who saw inherent distortion issues in variable density systems not present in the variable area method. This was "due to the lack of linearity in the film characteristics, unless exposures and developments were held within very close tolerances."[35]A version of the Photophone system was reached in the mid-thirties that, according to Kellogg, an employee of RCA, had eliminated some of the concerns that variable density was the

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[29] Kellogg, "History," 183.
[30]Ibid, 187.
[31] Ibid.
[32] Ibid.
[33]Enticknap, 114.
[34]Kellogg, "A Comparison of Variable-Density and Variable-Width Systems," *Journal of the Society of Motion Picture Engineers*, Vol. 25, No. 3 (September, 1935), 204.
[35]Ibid, 205.

smarter choice to due to initial eases in avoiding certain types of distortion and certain types of problems in achieving proper exposures.[36] This involved a galvanometric mirror that caused the light spot to move transversely to the film, which required less work from the galvanometric mirror, allowing it to be moved closer and increase light intensity.

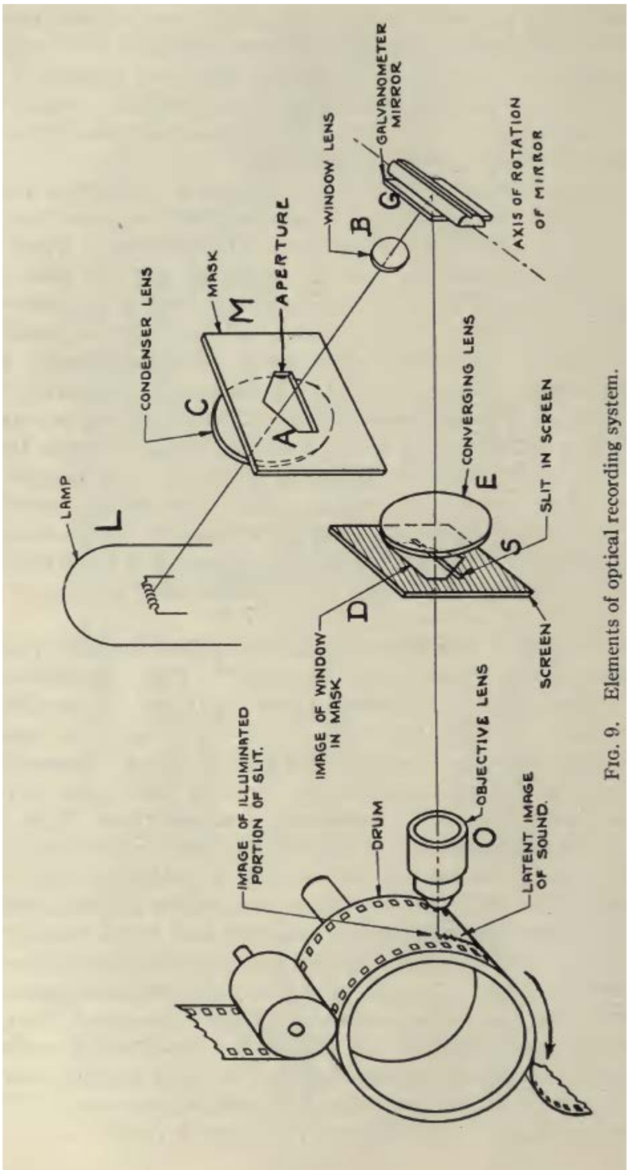

Fig. 9. Elements of optical recording system.

[37]

This allowed sufficient exposure and accuracy to create a sharp outline of the wave shape on which one side the film was uniformly clear and on the other side uniformly dark.

[36] Ibid, 207.
[37] Ibid, "ABC," 158.

Achieving sufficient light to create the exposure necessary for the clear side of the film had been an important reason why others initially chose variable density systems. Due to Photophone's demarcation of light and dark, the system lent itself to more advanced editing techniques, as distortion resulting from generational processing would be much less of a probability than with the variable density system. The types of distortion still possible with variable area were halation and image spread. Halation is a slight exposure creeping past the outer edge of the waveform. Image spread results from over or under exposure and results in an inaccurate tracing of the waveform. Scratches were also of concern, since the grays in variable density were thought to better hide these imperfections than the uniform nature of the variable area process.[38]However, various improvements were made which ultimately led to substantial reduction in noise and distortion, such as the use of push pull tracks. As Kellogg notes, "Several types of distortion are substantially reduced by applying a push-pull system."[39]

With these reductions in distortion area tracks significantly improved the possibilities of sound reproduction. There were a great number of various options.

[38]Ibid, "Comparison," 207.
[39]Ibid, "ABC," 161.

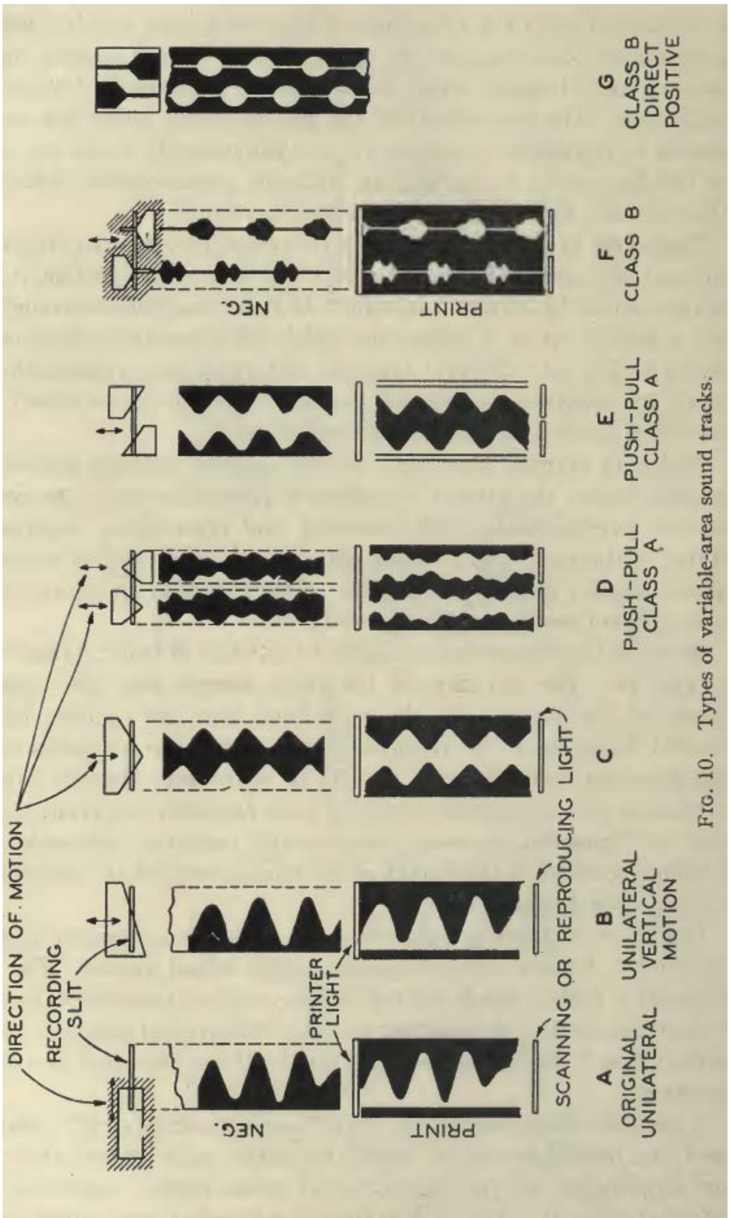

FIG. 10. Types of variable-area sound tracks.

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These advances helped to increase signal to noise ratios and greatly reduce certain types of distortion in a way that was unavailable to variable density systems by their very nature. However, the variable density system still dominated for quite awhile despite these innovations.

[40]Ibid, 162.

As mentioned, variable density soundtracks in the US came in two flavors at the beginning of sound films, Fox-Case and Western Electric. There are several reasons why Western Electric beat out its competitor. Not least of these, as mentioned above, is that the Case's Aeolight system was hindered compared to the light valve method used by Western Electric. Sargent notes how Western Electric's "system was better than the Case system from the get-go and had the potential to get much better. On the other hand, the Case system had nowhere to go."[41]It became clear to Case fairly early in the development of Photophone and Movietone that his Aeolight didn't generate a lot of exposure. To anticipate the effective levels of contrast, or gamma, film developers and engineers used an H and D, or sensitometric, curve to plot the resulting density of an ideal negative film as a result of a length of exposure.

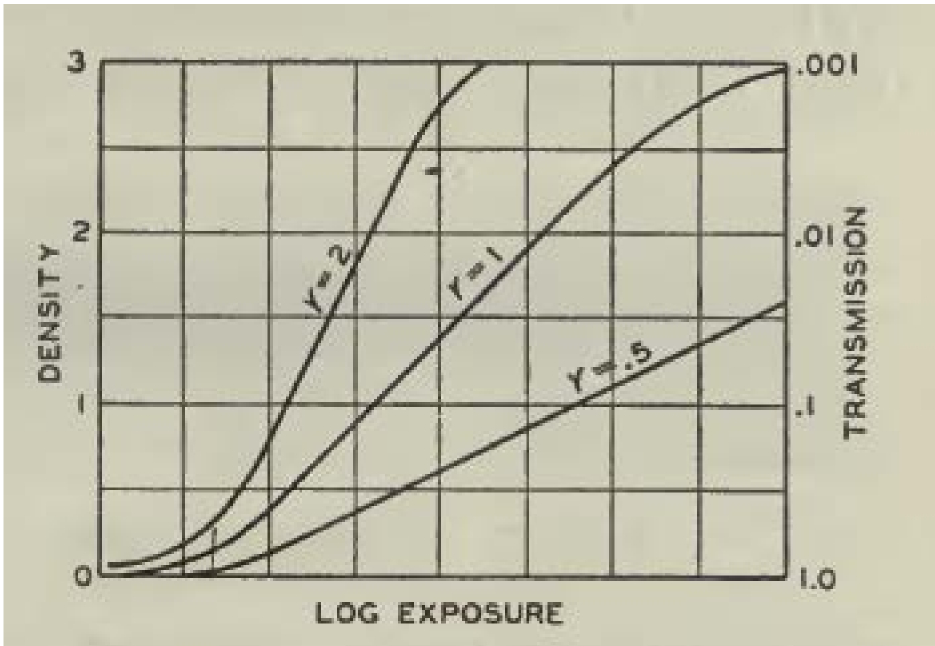

FIG. 16. H and D curves.[42]

[41] Ralph Sargent, "Legacy Analog Optical Recordings: Then and Now." *Association of Moving image Archivists Tech Review*, No. 2 (October, 2010), 8.
[42] Kellogg, "ABC," 169.

There are three sections to this curve, which are known, from left to right, as the toe, the straight-line, and the shoulder. Due to the low levels of exposure, Case operated in a very small straight-line range in the toe region. Linearity is crucial in sound reproduction and as such the goal is to operate in the much longer linear portion of the curve.

A sound reproduction is linear if the stages of sound recording and reproduction do not introduce any unwanted characteristics. Another way to put it is that the amplified sound should have the exact same characteristics of the original signal apart from increased amplitude. In terms of the photographic stage of this process, Eade explains that "the fundamental for any form of photographic sound record is that the instantaneous change of the track transmission from point to point shall be directly proportional to the instantaneous change in the original sound pressure."[43]In the linear portion of the characteristic curve Case used, the available dynamic range was around 30dB.[44] Western Electric on the other hand aimed for the larger straight-line section that had a potential dynamic range of 60dB.[45] Additionally, Case's use of toe recordings required very rigorous development standards to create a usable print. On top of that the resulting prints were 'thinner' or of much smaller average density than the Western Electric counterparts. This led to increased susceptibility to damage and distortion resulting from the wear and tear of exhibition.[46]

Western Electric generated variable density tracks with a constant light source producing the highest amount of exposure required, and a light valve controlled the size of the penumbra or slit exposing the film to the light. This cut out a step from the Case

[43] S. R. Eade, "Photographic Technique for Variable Area Recording," *Journal of the British Kinematograph Society*, Vol. 8, No. 2 (1938),120.
[44]Ibid, 6.
[45]Ibid, 8.
[46]Ibid, 7.

system, which required that the current react with nitrobenzol creating a magnetic field which then would react with the gas in the Aeolight to create light modulation.[47]In the Western Electric system, instead of the intensity of the source varying, the size of the light spot varies, meaning that the differences of intensity are now created through a varying length of exposure.[48]

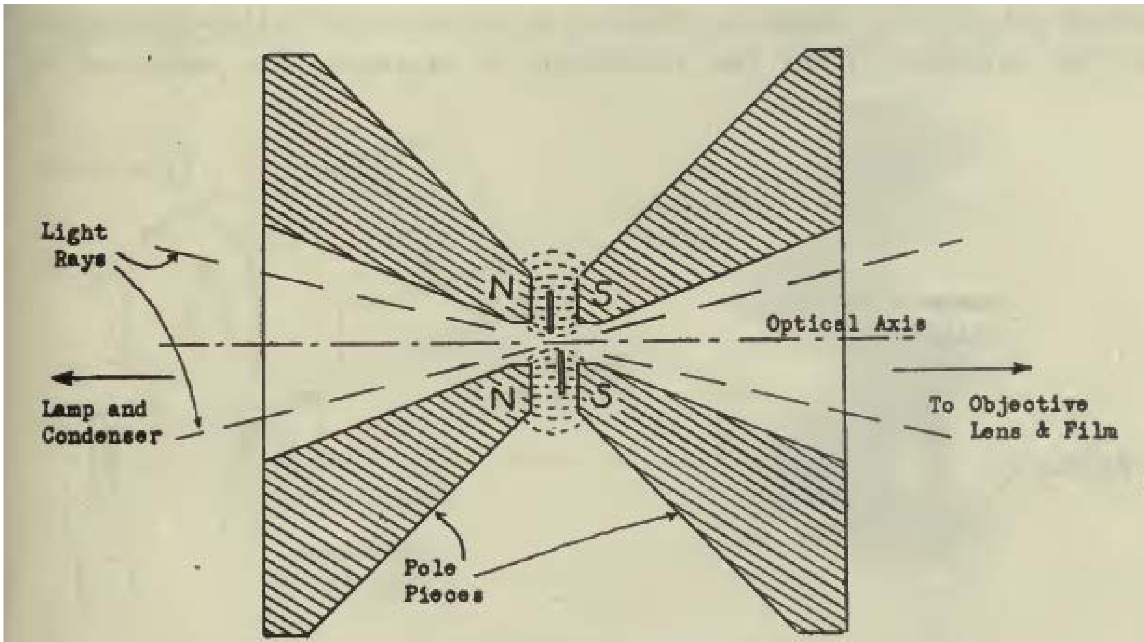

FIG. 5. Light-valve ribbon and pole piece arrangement—section at right angles to ribbons.

[49]

However, as mentioned above the issues with variable density are mostly in the development stage. Many tests had to be developed in order to monitor these resulting distortions, including for intermodulation, gamma and density, changes in decibel, rectification and harmonics.[50]Some of these tests would also benefit variable area distortion monitoring, but some experts could do basic reproduction quality control by

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[47] Ibid.
[48] Kellogg, "ABC," 156.
[49]Ibid, 155.
[50] R. J. Engler, "Variable Density Recording," *Journal of the British Kinematograph Society*, Vol. 8, No. 2 (1945), 39-41.

sight with the variable area setup given the clear demarcation of exposed and unexposed film.

One improvement that was necessary for variable density but not variable area was the use of fine grain, low contrast positive stock. This helped to reduce distortions, particularly grain hiss and intermodulation, a problem particular to variable density.[51] Intermodulation sounds as though low frequencies are overtaking higher frequencies; bass notes influence and interrupt high notes.[52]Variable area on the other hand benefitted from the use of higher contrast stock.

The use of ultraviolet light improved both types of recordings for the same reasons. Exposure was more precise and so distortions were reduced. Also, given the light's shorter wavelengths, high frequency response improved as well. However this innovation helped both systems and did not bring one's quality over and above the other.[53] Ultimately, greater control over distortion and inherent noise developed for the variable area system than for the variable density system.

The Western Electric system that prevailed through the 1940s in Hollywood despite the arguments for variable area did so at the outset of sound-on-film because the density system provided simpler solutions than variable area in relation to the distortion and exposure considerations discussed above. However, this changed, as did the effectiveness of the area system. The lack of growth in variable area marketswith the major studios was not the result of a lack of innovation, or even of already embedded mechanical procedures. Some cameras could easily be modified to produce either type of track, and projectors could read either type of sound track since the photoelectric cell

[51]Ibid, 38-9.
[52]Sargent, 18.
[53] Kellogg, "ABC," 172-4.

reaction is based on the total amount of light absorbed.[54] The standardization of the sound-on-film systems, in terms of being able to playback any on the same cameras, occurred early on, specifically on December 30, 1928.[55]Once sound-on-film system producers standardized the width of the soundtrack, incompatibility was not an issue. Instead, the endurance of the Western Electric system should be attributed to the nature of the industry'seconomy; specifically how vertical arrangements beginning at production and ending with exhibition were especially rigid. So though improvements in variable area superseded those in variable density, these were not substantial enough to dissolve the economic structures in place. Variable density only exited once an entirelynew technology entered the stage.

As Enticknap states, "Western Electric maintained its dominating market share as Hollywood's principal sound system until the advent of magnetic recording in the late 1940s."[56] Advances in magnetic sound that occurred post-World War II led to a technology that captured a broader frequency range with less noise than any sound-on-film iteration. On top of this, editing with magnetic tape proved much less costly in terms of both money and time. As a result, magnetic tape formats replaced all sound-on-film formats for every stage of the filmmaking process save for exhibition.[57]Release prints continued to feature a variable area soundtrack. While the variable area track would eventually come to be supplemented with digital information placed around the sprocket holes as this technology developed, most release prints featured two variable area tracks on the side of the film that were read by the projector just as they had been beginning in

[54] Kellogg, "History," 208-9, and "ABC," 152-3.
[55] Brian Coe, *The History of Movie Photography* (New Jersey: Eastview Editions, 1981), 106.
[56]Enticknap, 122.
[57]Ibid, 123, 125.

the 1930s. This has been the case until recently as digital projection has become increasingly employed. For releases on film, a variable area soundtrack was the mainstay for commercial prints, and variable density became another obsolete technology.

As such, there are serious issues in the preservation of variable density. The delicate and precise development requirements of the format will naturally become forgotten as more time passes. This makesfilm-to-film migration of variable density films an issue. Sawyer notes how "one can understand why one ex-archive head insisted that all variable-density preserved sound should be turned into variable-area by re-recording.[58] Additionally, the preservationist may find many different types film stocks featuring variable density from a group ofmanufacturers that exceedsthe significant contenders discussed in the foregoing. Moreover, individual films can contain variable density as well as variable area segments, and different scenes in the same film may have been developed differently.[59] Film-to-film reproduction of optical soundtracks requires either re-recording or the use of continuous printers, each of which has its own dangers of which the preservationist must be conscious.[60] The already complicated development process can only become more complicated as the necessary knowledge of these practices grows more and more scarce. This poses an interesting problem peculiar to variable density in that the technology to play back a variable density film is still relatively abundant, but the knowledge to reproduce these films faithfully is disappearing. Preservation copies of variable density soundtracks and films are rare, and actual physical evidence of this format's existence may only be able to survive as long as the remaining

[58] Martin Sawyer, "The Sound of Nitrate," in *This Film is Dangerous: A Celebration of Nitrate Film*, eds. Roger Smither and Catherine A. Surowiec (Brussels: FIAF, 2002), 138.
[59] Sargent, 17-9.
[60] FIAF Preservation Committee, *Technical Manual* (Brussels: FIAF, 1993), 50.

film elements that feature it survive. As a significant stage in the history of moving images with sound, attention must be paid to the maintenance of those variable density elements that still exist.

Annotated Bibliography

-Aiken, Joseph E. "Technical Notes and Reminiscences on the Presentation of Tykociner's Sound Picture Contributions," in *A Technological History of Motion Pictures and* Television, edited by Raymond Fielding. Berkeley and Los Angeles: University of California Press, 1967.

This article provides insights into the first public demonstrations of Tykociner, creator of one of the first variable density systems. The article is short in length and scope, and so served the paper in its treatment of this figure alone.

-Coe, Brian. *The History of Movie Photography.* New Jersey: Eastview Editions, 1981.

As its name suggests, the book is a general overview of motion picture history. Though this source did not provide very much information on the specifics of the variable density system, it did prove a helpful guide to the economic players and relationships. As such it did help to provide background and support for the thesis of the paper relating to the economic strengths of the density system.

-Eade, S. R. "Photographic Technique for Variable Area Recording." *Journal of the British Kinematograph Society*, Vol. 8, No. 2 (1938).

A technical description of issues with variable area recording that touches on several issues with photographing sound in general. The source provided useful background on variable area and sound photography with a more technical bent.

-Engler, R. J. "Variable Density Recording." *Journal of the British Kinematograph Society,* Vol. 8, No. 2 (1945).

The paper is a relatively brief yet technical description of the merits of variable density. That the author was an employee of Western Electric may perhaps have skewed his opinion on his preferences, but the technical side appears fairly objective. The finer points of most of the chemistry and physics described in the engineering journal papers would escape me, but it did not seem that his affiliation skewed his objective descriptions, just his preference. The paper was therefore useful in providing and confirming technical processes related to variable density.

-Enticknap, Leo. *Moving Image Technology: From Zoetrope to Digital*. London and New York: Wallflower Press, 2005.

The book is a thorough but more accessible history of the entire scope of moving image technology. In addition to a jumping off point for description of the technical processes behind photographic records of sound, the book also proved useful in framing the thesis through its historical account of industry shifts.

-FIAF Preservation Committee. *Technical Manual*. Brussels: FIAF, 1993.

The book is a collection of several manuals detailing best practices for the preservation of moving images on a wide variety of formats. It provided some basic information for some of the difficulties associated with preserving sound-on-film.

-Jacobs, Lea. "The Innovation of Re-Recording in the Hollywood Studios."*Film History: An International Journal* Vol. 24, No. 1, 2012.

The article is a description of changes in sound editing and re-recording, mostly focusing on the early decades of sound film. The article proved most useful in its discussions of re-recording and editing techniques for sound-on-disc and sound-on-film systems, and the relative merits and drawbacks thereof.

-Kellogg, Edward. “A Comparison of Variable-Density and Variable-Width Systems.” *Journal of the Society of Motion Picture Engineers*, Vol. 25, No. 3 (September, 1935).

I will start here by saying in general that Kellogg’s papers were perhaps the most useful resources. This paper in particular is an early account of the relative merits and drawbacks of the two systems. The language gets very technical as it is from an engineering journal, but the information proved invaluable to my own comparisons between the two. It should also be noted that Kellogg was part of RCA, and hence some of his preferences will obviously be skewed towards the RCA variable area system.

-------------------. “The ABC of Photographic Sound Recording.”*Journal of the Society of Motion Picture Engineers*,Vol. 44,No. 3, 1945.

Again, this proved an extremely useful resource. While this paper serves as another largely comparative piece, it is extremely useful in that it has some historical information. It also benefits from providing the viewpoint of Kellogg, still with RCA, ten years further down the road, just before sound-on-film production would be overtaken by magnetic sound. As such it addresses the advances made in both variable area and density in the ten years following the article above.

-------------------. “History of Sound Motion Pictures.”*Journal of the Society of Motion Picture and Television Engineers* Vol. 64 (June; July; August 1955).

As with the previous two papers, this was also extremely useful. In addition to being as technically robust as the first two mentioned, as a history this paper treats a much broader time period, tracing many important figures and their discoveries leading up to the ability

to create a sound-on-film system. By the mid 1950s, sound-on-film was already declining, and so again it is a great resource that provides the opinions of the same author a further ten years down. The greater historical breadth is of particular use in this article.

-Salt, Barry. *Film Style and Technology: History and Analysis*. London: Starword, 1983.

The book is an account of the history of film split up into chapters outlining significant eras and touching on relevant subheadings organized by important technologies and stylistic trends. Since the book is geared heavily towards the stylistic account, it proved most useful in providing a general historical account, as well as providing editing practices as they were influenced by the various early sound film methods.

-Sargent, Ralph. "Legacy Analog Optical Recordings: Then and Now." *Association of Moving image Archivists Tech Review*, No. 2 (October, 2010).

The article is a brief account of the differences between area and density systems and the challenges in preservation related to each. Though brief, the technical information regarding the two sound-film systems proved invaluable in bridging the gaps I had between the more general accounts of these technologies from Enticknap and Salt, and the heavily technical accounts of Kellogg, Eade, and Engler. Additionally, the article provided useful information regarding preservation concerns.

-Sawyer, Martin. "The Sound of Nitrate." In *This Film is Dangerous: A Celebration of Nitrate Film*, edited by Roger Smither and Catherine A. Surowiec (Brussels: FIAF, 2002).

The article is a very brief description of preservation concerns regarding sound films on nitrate. As such it provided only a little but still very useful information regarding the difficulties of preserving variable density film in particular.

-Sponable, E. I. "Historical Development of Sound Films." *Journal of the Society of Motion Picture Engineers*, Vol. 48, No. 4 (April 1947).

As a partner of Theodore Case, this account proved invaluable in not only outlining a general history of sound-on-film, but also in providing an extremely detailed account of Case's research with de Forest and Sponable himself. It goes from Case's studies at Yale in 1911 to the sale of the Case system to Fox. The paper is written as a chronological account.