Carmel Curtis
October 17, 2013
Moving Image and Sound: Basic Issues and Training
Ann Harris
Research Project

ULTRASONIC FILM SPLICERS: WELDING TOGETHER A HISTORY

Introduction

The history of moving images is a history that is connected not just to the visual images, but to the technology that helps produce the moving images. As Leo Enticknap writes in the Introduction to *Moving Image Technology*, "Images don't move on their own. They have to be made to move – or appear to move – by technology, invented and developed by human beings with the purpose of tricking the human brain into thinking that it sees a continuously moving two-dimensional picture." [1] The development of moving images is closely paralleled to the development of technologies that make it possible to create and view these images. This reciprocal relationship leads moving images to be "both shaped and [have] been shaped by the industry and culture."[2] This paper will focus on a specific piece of technology – the ultrasonic film splicer. The ultrasonic film splicer is a piece of technology that uses ultrasonic waves to weld together polyester based film. This paper aims to create a comprehensive picture of the origins of the ultrasonic film splicer, contextualizing its placement in the development of the synthetic plastics industry and the culture of cinema. Additionally, this paper will analyze the relevancy, functionality, and practicality of ultrasonic splicers today.

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[1] Enticknap, Leo. *Moving Image Technology: From Zeotrope to Digital*. New York: Wallflower Press, 2005. 1. Print.
[2] Enticknap, 44.

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Plastics: A Brief History of Plastic and a Background in the Basics of Film Bases

Before we explore the specifics of the ultrasonic splicer, it is important to gain a broader picture of how it entered the picture. As the ultrasonic film splicer is a device used specifically for polyester plastic based film, it is appropriate to start in the world of plastics. This history of organic plastics dates as far back as to Mesoamericans using natural rubber in 1600 BC.[3] However, it was not until World War II that researched improvements and mass production of synthetic plastics began to develop commercially in America.[4] Throughout the 1940s and 1950s, plastics became a common everyday item. [5] In the home (i.e. Tupperware[6]), in the workplace (i.e. ballpoint pens[7]) and in leisure (i.e. Long Playing (LP) vinyl records[8]), plastics were being used more ubiquitously. "Plastics are incredibly versatile materials; they are inexpensive, lightweight, strong, durable, corrosion-resistant, with high thermal and electrical

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3 Andrady, Anthony L., and Mike A. Neal "Applications and Societal Benefits of Plastics." *Philosophical Transactions of the Royal Society: Biological Sciences.* 364.1526 (2009): 1977-1984. JSTOR. Web. 16 Nov. 2013.

4 "History of Plastics." *Plastics Industry*. The Plastics Industry Trade Association, 1995. Web. 15 Nov. 2013.

5 Thompson, Richard C., Shanna H. Swan, Charles J. Moore, and Frederick S. vom Saal "Introduction: Our Plastic Age." *Philosophical Transactions of the Royal Society: Biological Sciences.* 364.1526 (2009): 1973-1976. JSTOR. Web. 15 Nov. 2013.

6 For more information on the impact of polyethelene and Tupperware see Chapter Three "Poly-T: Material of the Future"- A Gift of Modernity" pg. 56-77 in : Clarke, Alison J. *Tupperware: The Promise of Plastic in 1950s America*. Washington, DC: Smithsonian Institution Press, 1999. Print.

7 See Part 3-The Battle of the Ballpoint Pens in: Bellis, Mary. "A Brief History of Writing Instruments." *About.com*, About.com, N.d. Web. 19 Nov. 2013.

8 See - Columbia (Label) in: Hoffmann, Frank. Ed. *Encyclopedia of Recorded Sound*. New York: Routledge, 2005. Print

insulation properties."[9] It is because of these traits that plastic was so widely used across multiple production disciplines.

With the rise in production of synthetic plastics in the 1940s to 50s, it is not surprising that experiments were conducted to see if this material could be used in moving images. The usage of the plastic polymer, polyester as a film base began in 1955; however, it did not become popularized until the 1980s when it became an industry standard. For much of motion picture celluloid history, materials much less flexible, durable, and transparent than polyester were used. In the 1800s experiments on paper, leather, canvas, glass, and copper were conducted as a base to film (8). Around 1845-46, cellulose nitrate was developed as an acceptable, reproducible, base. By 1889, Eastman Kodak patented a formula for a nitrate based film. Its "simplicity, reliability, and low cost manufacturing…coupled with its high tensile strength made it an almost ideal medium for originating, distributing, and projecting moving images" (11). However, the nitrate base was also extremely flammable. Once ignited, it burns continuously and is unable to be extinguished – the nitrate base is autocatalytic and in the combustion process generates its own oxygen, further feeding and fueling the fire (18). This created a significant cause for concern in terms of health and safety when projecting, transporting, and storing the film (11). Nonetheless, nitrate remained the standard film base until 1948-50 (10). At that point, acetate took over the market as the standard base. Prior to 1948, there were fragile, unstable generations of acetate based film that existed since the early

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9 Thompson, Richard C., Shanna H. Swan, Charles J. Moore, and Frederick S. vom Saal "Introduction: Our Plastic Age." *Philosophical Transactions of the Royal Society: Biological Sciences.* 364.1526 (2009): 1973-1976. JSTOR. Web. 15 Nov. 2013.

1900s (19). Acetate started to take on in 1948 when Kodak released its new cellulose triacetate base that was "almost as strong as nitrate" but significantly more safe (22). Acetate became a standard industry base despite its inherent vices. Acetate base is prone to "vinegar syndrome," which if not stored under proper conditions, causes the film to decay. [10] [11]

The introduction of polyester based film was an attempt to address the issue of decay fundamental in acetate based film. The first polyester based film was introduced by Du Pont in 1955 under the trade name Mylar (22). Polyester (polyethylene teraphalate (PET)) was used not only because of its strength and versatility, but also because it is an inorganic polymer and "is not liable to dimensional change according to its varying moisture content" (22). The development of polyester film seemed like an enticing alternative to nitrate and acetate; however, like its film base predecessors, it had intrinsic difficulties that had to be overcome. One of these hurdles was the fact that polyester cannot be spliced using film cement. The polyester base does not adhere with cement.[12] With previous film bases of nitrate and acetate, there were a number of manufacturing variations of splicers fitting into two main classification types – tape splicers and cement splicers. Tape splicers joins two pieces of disconnected film with adhesive tape applied to

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[10] See Chapter 2 - Understanding Film and How it Decays in: *The Film Preservation Guide: The Basics for Archives, Libraries, and Museums.* San Francisco: National Film Preservation Foundation, 2003. National Film Preservation Foundation. Web. 10 Nov. 2013.

[11] All page number citations in this paragraph come from the first chapter of Leo. Enticknap's *Moving Image Technology: From Zeotrope to Digital*. For a more detailed history on the physical properties of film, see Chapter One in this text.

[12] Brown, Harold. Film Joins (Splices): Comments on Cement and Tape Splices. *Technical Manual, FIAF Preservation Commission* (1985). PDF File. 18 Nov. 2013.

both the emulsion and base sides of the film. Cement splicers scrape off a thin layer of emulsion on one piece of film and an adhesive glue or "cement" is then applied. With pressure (and often heat), the two pieces of film are joined. Since the cement does not adhere to polyester, tape splicing was the only option for polyester based film. Technological developments had to be made to catch up to the advancements in film composition. The next section of this paper will examine how new equipment was invented to address these growing needs.[13]

The Equipment- Introducing the Ultrasonic Splicer

Along with the rise of plastics came the rise of technologies to create, manipulate, and manufacture the material. One of the most influential pieces of equipment came in the early/mid 1960s when a test engineer at Branson Ultrasonics in Danbury, Connecticut accidently welded shut a polystyrene coin box.[14] This accident led to the development of ultrasonic welding – a process that "optimize[d] design and productivity in a race of industries. The repeatability, quality, and speed of the process…transformed plastics assembly into a more reliable and highly efficient operation."[15] This is still today a common piece of equipment in the assembly of

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[13] All page number citations in this paragraph come from the first chapter of Leo. Enticknap's *Moving Image Technology: From Zeotrope to Digital*. For a more detailed history on the physical properties of film, see Chapter One in this text.

[14] "Top 50 Innovations." *Plastics Technology*. 51.10 (2005): 83. *ProQuest*. Web. 16 Oct. 2013.

There is actually conflicting citations on the object that was accidently welded shut.

[15] *Ibid.*

thermoplastics. As of 2005, the global market of ultrasonic welding equipment was placed at about $500 million according to the journal, *Plastics Technology*.[16]

How does ultrasonic welding actually work? It is important to have a grasp on the science of this piece of equipment before we move forward to inspect its specific usage in film. Ultrasonic welding can be used on many different materials; however, this paper will focus on ultrasonic *plastic* welding. In its most basic form, ultrasonic plastic welding works by using a high frequency sound wave ($\geq$ 20kHz) to vibrate the two soon to be joined materials at an extremely fast rate. In the case of plastics, the perpendicular vibrations cause the materials to melt together.[17] The electrical energy from the power supply of the equipment is converted via a transducer into sonic energy. This energy is sent through the horn (or sonotrode), which then directs or localizes the energy (in the form of ultrasound vibrations) to the materials that are to be joined.[18] [19] The ultrasound vibrations create frictional heat, which coupled with the localized pressure applied from the horn, cause a molecular bond to be formed between the two materials. As the materials quickly cool, they are bonded together within seconds.[20] Figs. 1 and 2 illustrates this process. Ultrasonic plastic splicers were used in a number of different

[16] *Ibid.*
[17] Mistry, Kalpana. "Tutorial Plastics Welding Technology for Industry." *Assembly Automation* 17.3 (1997): 196. *ProQuest.* Web. 16 Oct. 2013.
[18] *Ibid.*
[19] Enticknap, 23
[20] Knights, Mikell. "Graphical Analysis Helps Find and Fix Ultrasonic Welding Problems." *Plastic Technology* . 51.9 (2005): 51-53. *ProQuest.* Web. 18 Nov. 2013.

applications. From toys to sneakers, ultrasonic splicers became a common piece of equipment in mass-market productions.[21]

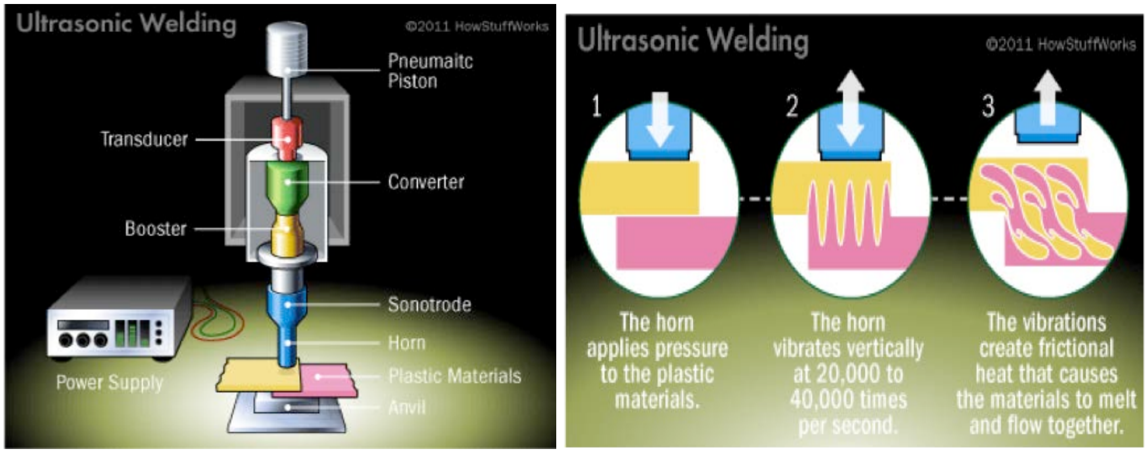

Fig 1 & 2 Diagram of Ultrasonic Welding[22]

When plastic welding was patented in the mid 1960s, it was soon after that this technology was adapted to fit the needs of motion picture film. Within the history of cinema, it is difficult to pinpoint an exact date when the ultrasonic welding process was introduced to film. Looking through patents from the early to mid 1970s, stress the increased popularity and attempted perfection of creating the ultrasonic film splicer occurred from the early to mid 1970s. [23] There is limited compiled documentation on the

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21 "Top 50 Innovations"
22 "How Ultrasonic Welding Works." *HowStuffWorks*. N.p., n.d. Web. 16 Oct. 2013.
23 Refer to United States Patent #s: 3,574,037; 3,661,667; 3,700,532; 3,728,183; 3,867,232; 3,904,474; and 4,029,538.

My most successful attempt in researching past ultrasonic film splicers has been through investigating patent documents. There is still much work to be done to understand the full history and scope of ultrasonic film splicers. The author of this paper suggests that for those who are interested in the technological differences in the history of film splicers look into the patents of the equipment.

variations of models in different companies. However, looking at these patents we see that while there were a number of different ultrasonic film splicers, there were three main manufacturing companies: Hollywood Film, Metro/Kalvar Corporations (Metric), and Solar Imaging Systems. Different models working with varying gauges of film were released from each of these companies. Though there were (and are) competing manufacturers of ultrasonic film splicers, they all serve a similar purpose. As stated in patent number 4,029,538 in 1976 from Metro/Kalvar, "ultrasonic bonding offers many distinct advantages and improvements, especially for splicing photographic films employing certain types of base materials, such as polyesters which are finding increased professional use, over older known splicing techniques such as by taping and the like."[24] Each of the ultrasonic film splicers created address this point – the growing professional use of ultrasonic splicing. There are slight differences between models in size and speed of parts, but for the most part, they were each created to fill technological need to splicing polyester film. All ultrasonic film splicers function based on the same scientific principles of ultrasonic plastic welding. Ultrasonic sound waves are used to fuse the two pieces of film together. However, plastic is not the only component of film. Polyester is only part of the structure of film. Film is composed to three basic parts: emulsion, base, and backing. See Fig. 3. When using an ultrasonic film splicer, there is no scraping of the emulsion layer (as with a cement splicer), so what happens to the emulsion? The

[24] Vance, Wallace I., Jr. "Ultrasonic Film Splicer." Metro/Kalvar Corporation (Darien, CT), assignee. Patent 4,029,538. 13 July 1976.

sonotode focuses the ultrasound waves, which easily softens the pliable emulsion and it, along with the backing, becomes part of the weld.[25]

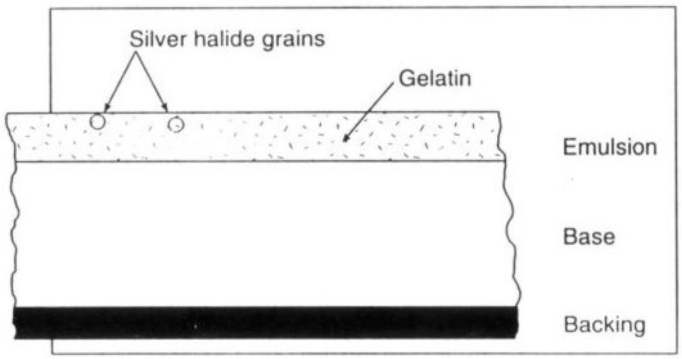

Fig. 3[26]

The operational step-by-step process of making an ultrasonic film splice is (for the most part) very similar across varying models. While Hollywood splicers are not identical to Metro splicers are not identical to Solar splicers, there are significant overlapping features that enable a discussion of instructions on *general* ultrasonic splicing that can be slightly adjusted and applied to each particular model. There are three basic steps that each ultrasonic splicer follows: Step 1: Trim; Step 2 Align; and Step 3: Splice. While this is an extremely oversimplified breakdown of how to operate an

25 "Kodak Vision Color Print Film / 2383/3383: Splicing." *Kodak Cinema and Television*. Eastman Kodak Company, 1998. Web 16 Oct 2013.

Although this is product information for a specific print stock, the information on splicing gave a comprehensive account of ultrasonic splicing.

26 Hemphill, Jeffry J. "Films & Filters." *UC Santa Barbara Department of Geography*. University of California, Santa Barbara. 9 April 2005. Web. 20 Nov. 2013.

ultrasonic film splicer, it is still accurate. Ultrasonic film splicers were designed to be easy to use.[27] If everything is working properly, operators should simply be able to just press a button, flip a switch, or lower a latch. The equipment is electrical and once turned on and engaged, the process is automated. This is one of the major advantages of using an ultrasonic film splicer. The next section of the paper will further examine benefits of using an ultrasonic film splicer.

Advantages of the Ultrasonic Film Splicer[28]

There are many benefits on the operator/owner of an ultrasonic film splicer. Easy of use is extremely important. Users do not need extensive training on how to apply tape without having air bubbles. No practice is needed to learn how to scrape just the right micrometer of emulsion off before cement is applied. This expands the scope of who can splice film and opens employment possibilities for those without extensive training in film handling. It also opens up employment possibilities to differently abled people who may have vast knowledge of film but might not have vision or motor skills required for tape and cement splicing. It also decreases training time that supervisors will have to carve out of their own schedules when teaching new employees. Ultrasonic film splicers also save time in its speed of splicing. It is a process that takes seconds as opposed to the

[27] See descriptions for ultrasonic film splicers on the websites for each of these three companies: metricsplicer.com, hollywoodfilmco.com, worldmicrographics.com
[28] Many of the benefits of the ultrasonic film splicer described in this section are based on the author's personal experiences splicing negative at Deluxe Archive Solutions and NYU's Barbara Goldsmith Preservation and Conservation Department.

minutes required of tape and cement splicing. Additionally, as manufacturing companies in the film industry at large are shifting and potentially discontinuing products, the lack of other products needed is an attractive feature. No tape rolls, replacement scraping blades, or film cement needs to be purchased or replenished. Another benefit to the user is health benefits. The toxicity of prolonged inhalation to film cement is still being realized.[29] Not having to be exposed the chemicals in the splicing process is a major benefit of this piece of technology.

The benefits of ultrasonic film splicers are visible not only to its users/owners, but also in the quality of the splices themselves. A huge advantage of the ultrasonic film splicer is the consistency of its splices. Since the process is automated, as long as nothing is adjusted, each splice should be the same. There is no fluctuation in splice density or durability. The strength of the splice is a major draw of ultrasonic film splicers. Since the molecules are welded together, the bond is significantly stronger than adhesives. This is an important feature for archival preservation. Often tape splices and cement splicers will weaken over time and will need to be replaced. Splices made with an ultrasonic splicer are hailed as being extremely robust.[30] However, all of these benefits are valid only when the splicer is working. What happens when something goes wrong? The next section of the paper will look at some of the disadvantages of using an ultrasonic film splicer.

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[29] "Film Conservation Hazards." *National Film & Sound Archive*. The National Film and Sound Archive of Australia, N.d. Web. 18 Nov. 2013.

[30] Refer to several conversations on the Film-Tech Forums. Informal, conversational postings between various film related professionals and enthusiasts review ultrasonic splices as being extremely sturdy.

Disadvantages of the Ultrasonic Film Splicer[31]

Ultrasonic film splicers may seem like the most user-friendly development in the history of film handling – that is, until something goes wrong. While the equipment is designed to make fast, consistent, sturdy splices, what happens if there is a malfunction? If there is an imperfect splice, how does one identify what part of the equipment is causing the problem? One cause of an imperfect splice is the strength of the splice. "Research has proven that the consistency of the melting rate has a direct influence on bond strength. The more linear the joining velocity profile, the steadier the melting rate, the more homogeneous the molecular structure of the melt, and the stronger the weld."[32] If there is an error in the durability of the splice, repairs may need to be made to ensure that the amplitude and force of the sonotrode at the location of the splice as linear as possible. [33] While repairs can be attempted by splicer operators, it would not be surprising for troubleshooting to be out of the realm of expertise of the person splicing. Finding technicians with the expertise needed to fix an ultrasonic splicer can be a challenging and expensive task. [34]

It is particularly expensive when added on to the price of the equipment. Ultrasonic splicers are an extremely expensive piece of equipment. As of November 2013,

[31] Many of the disadvantages of the ultrasonic film splicer described in this section are based on the author's personal experiences splicing negative at Deluxe Archive Solutions and NYU's Barbara Goldsmith Preservation and Conservation Department.
[32] Knights, 51-53.
[33] *Ibid*.
[34] Based on several conversations on the Film-Tech Forums. Informal, conversational postings between various film related professionals and enthusiasts asking for assistance with ultrasonic film splicer repairs.

new splicers run an as much as $7,565.[35] This is an exuberant amount of money considering this does not include replacements parts or repairs. The cost of ultrasonic film splicers is a major obstacle in their penetrability across the film industry. The high cost excludes this from being an option for most individuals and smaller institutions. "Ultrasonic splicers are a lot more expensive than tape or cement splicers, which is why they are usually only found in laboratories, archives or in the post-production departments of major studios." [36] However, as labs continue to close down,[37] who is left with the financial capabilities needed to purchase and maintain this equipment? This is an especially poignant question when it is also addressed that an ultrasonic film splicer is not the appropriate machine for all film splicing. It *only* works on polyester based film. Different splicers are needed for nitrate and acetate based films. Additionally, it is only functional for making splices along frame lines, as opposed to repairing a tear or rip across multiple frames of film.

Most research has been focused on ultrasonic film splicers in America. Is it practical to expect that this equipment can be used in institutions throughout the world? While this is a relatively portable device, it still requires an electrical outlet. If it can't be plugged in, it can't work. The hesitations around cost and the access to repairs must be stressed even further for institutions in developing countries.

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35 "Ultrasonic Film Splicer." *World Micrographics & Imaging*. World Micrographics Inc., 2013. Web. 18 Nov. 2013.

List price for Solar Imaging Ultrasonic splicer is $7,565.00

36 Enticknap, 23.

37 Salemi, Michelle. "As Film Labs Wind Down Prints Business, Job of Preservation Falling to Archivists." *Variety*. 17 April 2013. Variety.com. Web. 16 Nov. 2013.

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To Use or Not to Use

Presently, there is limited research on ultrasonic film splicers. There is limited documentation on the production and sale of ultrasonic splicers. There are limited listings of institutions that own ultrasonic splicers. There are limited resources on how to properly use and repair ultrasonic splicers. With material as unforgiving as film, there are numerous standards and guides to instruct and guide with film handling. Why is there an obvious lack of information on ultrasonic film splicers? One possible answer could be time. It is clear that ultrasonic splicers were a technological answer to the question of how to deal with polyester film. As polyester film became more prevalent in the 1970s, the ultrasonic film splicer was the industry's response to how to splice this material. Ultrasonic splicers are still relatively new. Many questions about the prolonged durability of its splices have yet to be tested. It has also been the case through film history that it takes time for advances to become standardized. Polyester film was invented in 1955 but was not popularized until about three decades later.[38] Perhaps ultrasonic splicers are still ramping up. Or perhaps not. As we look back through cinematic history, one of the reasons why film lasted is because the equipment used to create and view film has remained relatively consistent with its original form. "The key reason film has survived so long lies in the interface between the software and hardware used to create and reproduce film-based moving images. The essential functions of a camera, printer and

[38] Enticknap, 22-23.

projector remain unchanged from those of the 1890s."[39] Of course there have been improvements to all of these technologies, but their basic properties have remained unchanged. The question to be asked is: is the ultrasonic film splicer an improvement to splicers or a change to the basic properties of splicers? If we view the ultrasonic splicer as an improvement, then it may be the case that with more time, it will become more universal. However, if we view ultrasonic splicers not as an improvement, but as a change, then their future is most likely grim.

As of now, ultrasonic film splicers are not an outdated or obsolete piece of equipment. They are still available. But they are not widely used. Their inherent limitations to only polyester film and their restrictive prices prohibit the equipment from gaining a solid foothold across film handling disciplines. Looking to the history and use of ultrasonic plastic splicers in general, a larger, longer existing technological industry, they are used mostly for mass production. General Motors and Nike use ultrasonic welding.[40] [41] What are the film handling equivalents to these corporations? Perhaps the reason the ultrasonic film splicer never became standard in film technologies is because it never had a place.

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[39] Enticknap, 25.
[40] Sizeland, Alex. "Ultrasonic Welding Gives Your Would-Be Cadillac ELR An 8yr/100k Battery Warranty." *GM Authority Blog.* 5 Aug. 2013. Web. 20 Nov. 2013
[41] Chase, Adam. "Innovations in Shoes" *Runner's World.* 26 July 2013. Web. 20 Nov. 2013

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Andrady, Anthony L., and Mike A. Neal "Applications and Societal Benefits of Plastics." *Philosophical Transactions of the Royal Society: Biological Sciences.* 364.1526 (2009): 1977-1984. JSTOR. Web. 16 Nov. 2013.

> This article gave a clear history of the plastic from 1600 to 2008. While it was an informative article, I ended up not using much of it in my paper. It was helpful for me to gain a larger general understanding of the creation and use of plastics.

Bellis, Mary. "A Brief History of Writing Instruments." *About.com*, About.com, N.d. Web. 19 Nov. 2013.

> Part 3-The Battle of the Ballpoint Pens was exactly the amount of information I was looking for. I was searching for the increased usage of plastic within the arena of work and thought to look into plastics in ballpoint pens. This article coherently explained that plastic ballpoint pens were created and popularized in the late 1940s-50s. Along with other applications of plastics after World War II, ballpoint pens were another application for synthetic plastics.

Brown, Harold. Film Joins (Splices): Comments on Cement and Tape Splices. *Technical Manual, FIAF Preservation Commission* (1985). PDF File. 18 Nov. 2013.

> This guide served multiple purposes for this paper. It explained the techniques used when tape and cement splicing. It serves as a reference manual for traditional splicing. There was a brief mention of ultrasonic film splicing simply to explain that it is an alternative form of splicing for polyester film on which cement does not work. This short mention of ultrasonic splicers highlighted how much of a side note it is in comparison to other splicing technologies. It is mentioned in one sentence. While this is a paper on cement and tape splices issued by FIAF, there is no paper issued by FIAF (that I am aware of) on ultrasonic splicers.

Chase, Adam. "Innovations in Shoes" *Runner's World.* 26 July 2013. Web. 20 Nov. 2013

> Article that mentions use of ultrasonic welding in Nike's shoe designs.

Clarke, Alison J. *Tupperware: The Promise of Plastic in 1950s America*. Washington, DC: Smithsonian Institution Press, 1999. Print.

> Chapter Three: "Poly-T: Material of the Future"- A Gift of Modernity" pg. 56-77 detailed the impact of polyethelene within Tupperware. Several other basic overviews of plastics mentioned Tupperware. This text is exclusively on the impact of Tupperware. While this paper was not the appropriate

outlet for an extremely deep look into plastics, this text (especially chapter three) provided insight into how deep and widespread the impact of Tupperware was on the industry of plastic and its perception in America.

Enticknap, Leo. *Moving Image Technology: From Zeotrope to Digital*. New York: Wallflower Press, 2005. Print

This text served as a major reference point throughout this paper. It was heavily consulted when giving a history of film and various film compositions. It clearly explained the timeline of different film bases throughout cinematic history while providing contextualization these developments. While there was limited mention of ultrasonic film splicers, it ended up being the source I used with the most compiled information on ultrasonic film splicers. This speaks to the value of this text as a reference point and highlights the lack of other sources on ultrasonic splicers. I also used this text as the general support for the core statement of my paper – that motion picture developments are closely tied to the technology that enables them to move.

"Film Conservation Hazards." *National Film & Sound Archive*. The National Film and Sound Archive of Australia, N.d. Web. 18 Nov. 2013.

This website provided information on the potential health risks in working with film chemicals. While it is a good starting point for identifying hazardous materials and substances, it does not provide much research on prolonged affect of exposure to these hazards.

The Film Preservation Guide: The Basics for Archives, Libraries, and Museums. San Francisco: National Film Preservation Foundation, 2003. National Film Preservation Foundation. Web. 10 Nov. 2013.

Chapter 2 - Understanding Film and How it Decays gave a general overview of the different film bases. I used this guide mostly for its information on acetate film and the effects of vinegar syndrome. However, this guide also served as further evidence of the amount of detailed instructions on film and film handling that are available for nitrate and acetate film and tape and cement splicers. There was a very brief mention of ultrasonic film splicers in this guide highlighting the lack of focus on this piece of equipment.

Film-Tech Forums. Film-Tech Cinema Systems, 2013. Web. 20 Nov. 2013.

The Film-Tech forums are very convoluted and difficult to search through. However, there is a lot of very useful information on this website. Comments here and there on varying topics contributed to an overall understanding of the practicality and functionality of ultrasonic film splicers.

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Hemphill, Jeffry J. "Films & Filters." *UC Santa Barbara Department of Geography*. University of California, Santa Barbara. 9 April 2005. Web. 20 Nov. 2013.

This website was used for its simple, straight forward diagram of film layers.

"History of Plastics." *Plastics Industry*. The Plastics Industry Trade Association, 1995. Web. 15 Nov. 2013.

This article was not the most useful resource. It was simultaneously broad and specific. It did help point me in the right direction and look for further points to research.

Hoffmann, Frank. Ed. *Encyclopedia of Recorded Sound*. New York: Routledge, 2005. Print

The entry for Columbia (Label) gave a brief history of the Columbia Record label. It explained how the Long Playing record was released in 1948. This encyclopedia did not have much information on plastics but served as a good counterpoint to some other sources that mentioned vinyl (and specifically LPs) in their history on plastics.

"How Ultrasonic Welding Works." *HowStuffWorks*. N.p., n.d. Web. 16 Oct. 2013.

The text description on this website is basic but provided a very useful diagram to illustrate and support some of the more complicated scientific texts I've been using.

"Kodak Vision Color Print Film / 2383/3383: Splicing." *Kodak Cinema and Television*. Eastman Kodak Company, 1998. Web 16 Oct 2013.

Although this is product information for a specific print stock, the information on splicing gave a comprehensive account of ultrasonic splicing.

Knights, Mikell. "Graphical Analysis Helps Find and Fix Ultrasonic Welding Problems." *Plastic Technology* . 51.9 (2005): 51-53. *ProQuest.* Web. 18 Nov. 2013

Plastic Technology was a very useful journal for this paper. Information on ultrasonic film splicers was limited, but information on ultrasonic plastic splicers was somewhat solid. This article used science that was mostly over my head and relevant to ultrasonic splicers connected to a computer system, but the general principles were applicable to my paper. They discussed what they identified as a common problem for ultrasonic splicers. While their methods of repairing the problem could not be used on ultrasonic film splicers, the problem of force and velocity are relevant.

Metric SplicerNet. Metric SplicerNet, n.d. Web. 21 Nov. 2013.

This is the whole website for Metric ultrasonic splicers. There was limited information on the different products available. I contacted them via email and phone requesting more information but never received a response.

Mistry, Kalpana. "Tutorial Plastics Welding Technology for Industry." *Assembly Automation* 17.3 (1997): 196. *ProQuest.* Web. 16 Oct. 2013.

This text explains different processes of welding. While it focuses on plastics, it also briefly touches on how these processes apply to other materials.

"New equipment." Ultrasonics 12.3 (May 1974): 95-99. *Science Direct*. Web. 16 Oct. 2013.

This journal gives a break down of equipment used across different trades that use ultrasonics. This source proved to be useful to leading to other areas of research.

Rozenberg, L.D., ed, *High-Intensity Ultrasonic Fields*. New York: Plenum Press, 1971. Pint.

Textbook of the science and math behind ultrasonic waves and its application in the world. This text has useful information but works more as a reference source.

Salemi, Michelle. "As Film Labs Wind Down Prints Business, Job of Preservation Falling to Archivists." *Variety*. 17 April 2013. Variety.com. Web. 16 Nov. 2013.

This article speaks to the number of film labs that are closing down. This article is current (from April 2013) and speaks to the decreasing number of film processing labs and the impact on this decline specifically in the preservation and archival communities.

Sizeland, Alex. "Ultrasonic Welding Gives Your Would-Be Cadillac ELR An 8yr/100k Battery Warranty." *GM Authority Blog.* 5 Aug. 2013. Web. 20 Nov. 2013

This is an article on the use of ultrasonic welding from a major corporation, General Motors.

Thompson, Richard C., Shanna H. Swan, Charles J. Moore, and Frederick S. vom Saal "Introduction: Our Plastic Age." *Philosophical Transactions of the Royal Society: Biological Sciences.* 364.1526 (2009): 1973-1976. JSTOR. Web. 15 Nov. 2013.

This article gave further information on a general history of plastics. It focused mostly on the impact of plastic in the Western world. The Philosophical Transactions of the Royal Society: Biological Sciences was a source that I was not previously familiar with. Searching through this journal, there were a number of articles that I consulted on the history of plastic before settling on the few that were actually used in this paper.

"Top 50 Innovations." *Plastics Technology*. 51.10 (2005): 83. *ProQuest*. Web. 16 Oct. 2013.

This article was a feature in the journal Plastics Technology celebrating the top 50 inventions in plastics. It led to further avenues for me to research. It also had specific information that was easy to understand on the history of the invention of ultrasonic splicers.

"Ultrasonic Film Splicer." *World Micrographics & Imaging*. World Micrographics Inc., 2013. Web. 18 Nov. 2013.

This is a website that sells Solar Imaging Ultrasonic splicers. I emailed and called for further information but never received a response.

"Ultrasonic Film Splicer: Splicing Instructions." *Hollywood Film Company*. Hollywood Film Company, 17 June 2005. Web. 21 Nov. 2013.

This is the web instructions for operating a Hollywood Film ultrasonic splicer. It proved to be a useful set of instructions to compare to other models. While this was the only instructional manual I could find for any ultrasonic splicer, I could compare this guide to my own experiences and other conversational comments.

Vance, Wallace I., Jr. "Ultrasonic Film Splicer." Metro/Kalvar Corporation (Darien, CT), assignee. Patent 4,029,538. 13 July 1976.

This patent helped to understand the physical make up of the ultrasonic film splicer. When compared to other patents it also showed how similar splicers were across different manufactures.

"Who Was First In Hot Runners, Ultrasonic Welding & PET?." *Plastics Technology* 51.12 (2005): 10-11. Applied Science & Technology Source. Web. 16 Oct. 2013.

Helpful but brief resources that did provide me with leads to many other sources and routes to research. The Journal *Plastic Technology* has proven to be a useful resource in looking into historical developments in the world of plastic.