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Moving Image: Sound and Basic Training

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Final Paper

Cleaning with Sound: A History of Ultrasonic Film Cleaning

Films get dirty. This is an inherent fact associated with the everyday use, storage, and movement of moving images. Since the initial development of motion pictures a wide variety of cleaning techniques have been developed to combat the gathering of dust, mold, oil, and other foreign particles on film. Early cleaning machines from the early 1900s were simple hand cranksystems designed for the film to run through a tank of solvent before running between a pair of pads covered with soft cloths that would wipe away the particles.[1]Overtime however, the physical film form became a valuable artifact that requires safe handling and good care in order to last. The goal of the processes became to remove the foreign materials with as little damage to the film's content and form as possible. Unfortunately, despite these early inventions and subsequent versions, the cleaning of motion picture film has remained a problem in the industry.Processes continually developed, including every method from cleaning by hand with cloths to machine cleaning with vacuums and brushes. It was not until ultrasonic technology began to develop that a new method appeared, and in 1958 Lipsner Smith introduced its first

[1]Teitel, Albert. 1921. "Film Cleaning Apparatus". U.S. Patent No. 1, 389, 082, filed September 27, 1919, and issued August 30, 1921.

ultrasonic cleaning machine.[2] This revolutionary machine introduced a way to safely clean film with minimal damage to the material. This paper traces the ultrasonic cleaning process through its continuing development and the current concerns surrounding it.

Ultrasonic Cleaning

The first continuous ultrasonic cleaner was developed by Robert Gutterman for Lipsner Smith, and was issued a patent in 1961.[3]Gutterman's invention introduced the idea of utilizing current ultrasonic technology to provide a safe and effective method of cleaning film. His patent further introduced a non-evaporative method of drying the film using air squeegees (or air knives) in order to economize the solvent usage.[4]Since launching this technology in 1958, "Lipsner Smith has been the leader in providing motion picture film cleaning systems to the world's film laboratories and telecine operations."[5]Gutterman's invention removed the danger of further damaging a film by cleaning it with a wet cloth, and instead utilized the developing ultrasonic cavitation technology to clean film in the safest and most efficient way possible.

Ultrasonic cleaning is a full immersion process. Machines pass film "through a solvent bath where high frequency vibrations dislodge all but the most entrenched dirt."[6]The system works by transports a film from the feed reel on a series of rollers, through a tank of slightly heated solvent, through a rinse tank/chamber, into the drying

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[2]Research Technology International. *About RTI.* http://www.rtico.com/lipsner/.
[3]Gutterman, R.P. 1961. "Ultrasonic Process and Apparatus." U.S. Patent No. 2, 967, 119, filed September 8, 1958, and issued January 3, 1961.
[4] Gutterman
[5] Research Technology International
[6]National Film Preservation Foundation. *The Film Preservation Guide: The Basics For Archives, Libraries, and Museums.* San Fransisco: National Film Preservation Foundation, 2004. 51.

chamber, and onto the receiving reel. Ultrasonic cleaning occurs when transducers fitted to the outside of the tank convert electronic sound waves into sound pressure. The transducers emit sound waves between 20 kHz – 60 kHz through the tank, causing the liquid inside to come to a "cold boil" as a result of the increase of negative pressure built in the tank.[7] The "cold boil," also known as cavitation, results in bubbles developing in the liquid. These bubbles continue to grow until they reach an unstable size at which point they collapse and implode violently.[8] Shock waves created by these implosions churnthe cleaning solvent around the tank, forcing a continuous supply of solvent to attack the dirt and remove it through a powerful "scrubbing" action[9]. Forcing the solvent against the film surface, increasing the ability of the solvent to reach and clean all areas of the work. Ultrasonic cleaners are most efficient at removing minimal levels of dirt, oil, grease, and other foreign particles;[10] however ultrasonic cavitation has also been used to remove the dirt from film base scratches that alternative cleaning methods would leave behind.Ultrasonic cleaning gained favor in the industry because this process eliminates the risk of further damage to the film base that could result by cleaning the film by hand with a cloth, where a certain amount of rubbing would be required.

After the film passes through the solvent tank it moves between spray jet nozzles that pressure rinse the dirty solvent off with clean solvent. The nozzles are positioned at an angle so that the film runs towards them, effectively stripping any remaining

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[7] Gutterman
[8] The National Film and Sound Archive of Australia. Ultrasonic Cleaning. http://www.nfsa.gov.au/preservation/handbook/conservation-treatments/ultrasonic-cleaning/.
[9] Haig, R.N. "Film Care in the Telecine Age." *Image Technology* 71, no. 5 (May 1989): 186.
[10] The National Film and Sound Archive of Australia.

contaminants off before drying.[11] The drying chamber is the machine's one last effort to remove all remnants of the solvent and contaminants from the film. As a result of the solvents used in this process being prone to evaporation, it is crucial that the film not be allowed to air dry. If the film is left to air dry, the chemicals will evaporate and foreign particles will remain on the film, therefore the film must travel through a drying chamber where in which the liquid is blown off of the film. In most machines this is achieved through the use of another set of jet nozzles, also known as air knives. The "pair of air knives…will strip the liquid off the film surfaces in the form of a spray."[12] Air knives connect to a central air compressor that allows for the knives to blow a continuous stream of air on either side of the film in an angular direction opposite the movement of the film. As the solvent is ripped off the film surface in the form of a liquid spray, an exhaust vacuum in the drying chamber dispels the contaminated liquid from the area.[13]

Ultrasonic cleaning is widely used by institutions and labs to clean large quantities of film, in particular original negative or archival material in either 16mm or 35mm format.[14]

Development

Shortly after the patent was issued to Robert Gutterman for his ultrasonic splicer, a company in London called Colour Film Services Ltd. developed an ultrasonic cleaner of

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[11]Gley, P.R. "Ultrasonic Cleaning Machine." U.S. Patent No. 3,052,244, filed October 9, 1961, and issued September 4, 1962.
[12]Haig, R.N. 186.
[13] Gutterman.
[14]McMullon, Mark. "Film Cleaning - Beyond the Motnreal Protocol." *Image Technology*, October 1996: 20.

their own due to the high demand for a safe method in film cleaning.[15]Their machine featured the now typical cabinet design with glass front for keeping watch on the film. Film moved through the system with minimal contact due to spring loaded rollers guiding the film by the sprockets.[16] The speed of the machine ranged 80 – 120 ft. per minute in order to allow for the use of the machine in conjuncture with more fragile negatives. Colour Film Services sought to capitalize on this low cost and economical machine, as repeated tests proved it to be effective and easy to operate.[17]

Back in the United States, Paul Gley filed a patentin 1961 under the assignee National Ultrasonic Corporation. A goal of his invention was to introducer the ability to adjust the transducers on the tank, thereby allowing for operators to clean "delicate tape-like objects" through a fine regulation of cleaning intensity.[18] This patent further brought Gley's objects of an alternative to air-drying, convenient threading, and increased ease of handling and maximum efficiency. Descriptions of the machine demonstrate improvements made on Gutterman's original design, however no further record remains of this cleaning system or of the National Ultrasonic Corporation's work with motion picture cleaning.

In 1969 the first patent filed by Howard Ott and Jerry Carmen contained the method of and apparatus for cleaning a web of film. Differing from previous ultrasonic systems, this invention proposed cleaning using ultrasonic vibrations through the application of a

[15]Haig, R.N. "The 'Ultramatic' Film Cleaning Machine." *British Kinematography*, July 1961: 22.
[16] Haig. 22.
[17] Haig. 24.
[18]Gley.

spray as the film travelled on a vibrating circular channel.[19]Ultrasonic cleaning is accomplished by the film passing over a horn, or circular device thatis held between two "shoulders" that impart the vibrations required for cleaning. The design chose to forego the immersion of film in a solvent in an effort to avoid any harm that may come from the submersion of materials in the volatile liquids typically used in cleaning tanks. Ott and Carmen claimed that the efficiency of the cleaning would also be improved as their machine wets the dirt particles on film, increasing their mass and making them easier to shakeoff. Suitable liquids for this system include the main cleaning solvent of the time (trichloroethane), as well as several others including trichloroethylene, perchloroethylene, and carbon tetrachloride. Their second patent issued in 1972 included a design for an ultrasonic cleaning system that could clean film either by use of the solvent spray and the horn, or through a solvent pool.[20]Once again this technology failed to make it into the public market. For unknown reasons it appears that Kodak failed to follow up with their improved ultrasonic cleaning system patents.

In the mid-1970's Lipsner Smith became a subsidiary of the newly started business RTI (Research Technology International), keeping offices in both the United States and the United Kingdom. In 1973, "Lipsner-Smith Corp… produce[d] the CF-2 Ultrasonic Film Cleaner that works without mechanical scrubbing or contact. An Academy Award for

[19]Ott, Howard F., and Carmen, Jerry. "Method and Apparatus for Ultrasonically Cleaning a Web of Film." U.S. Patent No. 3, 615, 814, filed November 25, 1969, and issued October 26, 1971.

[20]Ott, Howard F., and Carmen, Jerry. "Ultrasonic Cleaning of a Web." U.S. Patent No. 3, 635, 762, filed September 21, 1970, and issued January 18, 1972.

scientific achievement was awarded to the firm for the… equipment."[21]The Academy Award displayed to the movie industry how successful and trusted ultrasonic cleaning technology was, and still is. Lipsner Smith has won Academy Awards in subsequent years for scientific achievement for their developments in the ultrasonic cleaning field.[22]

In the late 1970's there were two major kinds of film cleaning machine devices: one with moving cleaning strips pressed against the film strip, and the second containing a fluid bath through which the film strip passes and receives ultrasonic cleaning. In February 1979 David Digel and David Henderson received a patent for an "Ultrasonic Film Cleaning Apparatus" that is a cross between these two devices. In this apparatus a film strip is moved at high speeds between a two cleaning strips moving in opposite directions. Cleaning fluid flows to a pair of beds between which the cleaning strips and film strip are sandwiched. An ultrasonic device in the beds activates the cleaning fluid to increase the cleaning power of the cleaning strips.[23]The patent is filed with the assignee named as: Research Technology Inc., the parent company of Lipsner Smith. The same year Richard Hughes filed a patent for another RTI cleaning system that combines ultrasonic immersion cleaning and high pressure spray solvent cleaning.[24]These patents were both granted in 1981. These machines that offer two different modes of cleaning were innovative, and would soon prove to be part of the main design of most machines.

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[21] SMPTE. "SMPTE Committees, Reports and Information for Members." Journal of the SMPTE 83 (1973): 639.

[22]Research Technology International. "Academy of Television Arts & Sciences Engineering Award Presented to Lipsner-Smith and CFI for Development of New Film Cleaning System." RTI Research Technology International. http://www.rtico.com/emmy.html.

[23] Digel, David B., and Henderson, David. 1979. "Ultrasonic Film Cleaning Apparatus". U.S. Patent No. 4,138,757, filed March 20, 1978, and issued February 13, 1979

[24] Hughes, Richard J., and Bowen, Howards. "Method and Apparatus for Cleaning Film." U.S. Patent No. 4,244,078, filed April 26, 1979, and issued January 13, 1981.

Up until the late 1980's the main chemical used in cleaning machines was 1, 1, 1trichloroethane. It was produced industrially in large quantities as a solvent for a variety of things including film cleaning. In 1989 LipsnerSmith and the moving image community were thrown for a loop with the initiation of the Montreal Protocol and its subsequent amendments over the following years. Backed by 46 signatories, the Montreal Protocol agreed to in 1987 called for industries all over the world to begin phasing out specified chemicals that are believed to be contributors to the depletion of the ozone layer.[25]This agreement radically affected cleaning processes because films cannot be cleaned with just any cleaning solvent, precautions are taken to ensure that cleaning solvents utilized will have minimal to no effect on the emulsion and film base, and the machines are specially designed to work with the solvents utilized. After the Montreal Protocol (aka the 'green charter') and its amendment enacted in 1995 major changes in film cleaning became necessary.

On January 1, 1995 the Montreal Protocol banned the production of one of the most toxic and most effective cleaning chemicals, 1,1,1 trichloroethane. The problem that companies and institutions face now is finding a suitable replacement for 1,1,1 trichloroethane that will be both clean the film and be much safer for operators and the environment. This new protocol believed that without the production and use of these chemical products that the ozone layer will recover by 2050. Part of the protocol focused on phasing out chemicals containing bromine and/or chlorine. As stated in the *Toxicological Profile for 1, 1, 1 - Trichloroethane*,

[25]Ozone Secretariat. *Handbook for the Monntreal Protocol on Substances that Deplete the Ozone Layer.* Ninth Edition. Nairobi: UNEP, 2012. Xi.

> No 1,1,1-trichloroethane is supposed to be manufactured for domestic use in the United States after January 1, 2002, because it affects the ozone layer. However, until 2005, limited amounts were still allowed to be produced for essential purposes, and until 2012, production of 1, 1, 1-trichloroethane is allowed for export.[26]

Controlling the production and consumption of many chemicals, such as the widely utilized 1, 1, 1trichloroethane, was key for the protocol to work.

With the beginning of the phase out of 1, 1, 1, trichloroethane in 1993 (for some countries) and a completion of the phase out by all by 2015, with few exceptions.[27]Oddly enough 1, 1, 1 trichloroethane was initially developed as a safer solvent to replace other dangerous solvents. It became the standard film cleaner because it neither damaged the emulsion on the film nor left behind a residue that would affect the projection of the film later on.[28] It also effectively removed residue let from glue or tape after splicing. The main hazards to operators include irritation of the upper respiratory tract and sever eye irritation and swelling. The Agency for Toxic Substances and Disease Registry recorded reportings of fatalities and illness in the 1980s were linked to the inhalation of the solvent.[29]Despite struggles to find a perfect replacement for 1, 1, 1 trichloroethane as supplies depleted, the closest replacement found was perchloroethylene.

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[26]Agency for Toxic Substances and Disease Registry. *Toxicological Profile for 1,1,1 - Trichloroethane.* Atlanta: Agency for Toxic Substances and Disease Registry, 2006. http://www.atsdr.cdc.gov/toxprofiles/tp70.pdf. 2.

[27]Ozone Secretariat. *The Montreal Protocol: Summary of control measures under the Montreal Protocol.* 2001. http://ozone.unep.org/new_site/en/Treaties/treaties_decisions-hb.php?sec_id=6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24.

[28]Agency for Toxic Substances and Disease Registry.

[29]Agency for Toxic Substances and Disease Registry. 23.

Perchloroethylene demonstrated a low evaporation rate and because it was already used as a wet gate solvent it moved into being the new cleaning solvent.[30]

Soon after labs had begun using perchloroethylene for cleaning new restrictions were introduced by the South Coast Air Quality Management District (SCAQMD).[31]

> In film cleaning, the capture and recycling of perchloroethylene had become essential in the design of cleaning machines, with earlier models now unable to meet current regulations. Lipsner-Smith introduced the model CF-7200 film cleaning machine with self-contained solvent recycling using highly-efficient carbon adsorption and a continuous solvent distillation option, allowing simultaneous film cleaning for uninterrupted 24-hr operation. The French company CTM (formerly Debrie) introduced the Ultraclean 2000 solvent-based cleaning machine with an optional external vapor recovery system.[32]

The increase in environmental concerns in 1999 brought in a whole new line of ultrasonic cleaners specially designed to have the ability of operating with an environmentally friendly cleaning solvent, HFE.

In 2000 3M developed a chemical called 3M Novec 8200 Engineered Fluid (HFE). This fluid was created with the intention of eliminating the use of both 1,1,1 trichloroethane and perchloroethylene.[33] In conjuncture with the Montreal Protocol, this solvent is reported to have zero ozone depletion and low impact on global warming. Major strengths of HFE are its higher boiling point, which means that there are lower losses due to evaporation, and its reported nonflammability. Unfortunately tests showed that in order to utilize HFE to the best of its ability it requires a specially designed cleaner or retrofit

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[30] McMullon, Mark. "Film Cleaning - Beyond the Montreal Protocol." Image Technology 78, no. 9 (October 1996): 20.
[31] Masson, Alan. "Motion Pictures." SMPTE Journal 108 (February 1999): 78.
[32] Masson. 78.
[33] 3M. "3M Novec 8200 Engineered Fluid." *Product Information.* September 2009. http://multimedia.3m.com/mws/mediawebserver?mwsId=66666UF6EVsSyXTtlxf_NXTXEVtQEVs6EVs6EVs6E666666--&fn=prodinfo_nvc8200.pdf.

package for old systems. Both Lipsner Smith and Debrie Technologies responded to this by designing new machines that can operate with perchloroethylene, HFE, or both.

In 2000 RTI introduced the CF-8200 film cleaner, a machine made for the use of HFE instead of perchloroethylene. HFE is a non-chlorinated cleaning solvent created by 3M. The machine itself introduced Lipsner Smith's cleaning tank containing higher powered ultrasonics for improved cleaning.[34] This new technology amplifies the process that is already enormously successful.Lipsner Smith also designed a new machine, the CF-9200, and retrofit packages for a few of its other machines that have brought about cleaning results comparable to those of perchloroethylene and 1,1,1 trichloroethane.[35] With its awareness and careful creation of having minimal effect on the environment, HFE stands as one of the few, if not only, solvent on the market that has no large risk of consequences. Toxicology testing revealed it to have low toxicology as well, only becoming mildly irritating to users after 28 days.[36] The cost to buy new machines or to retrofit old ones may be the only detrimental element to this new solvent.

Debrie Technologies, located in France, developed their current series of ultrasonic cleaners: the Ultraclean-2000 and the Ultraclean-4200. The Ultraclean-2000 is designed to clean both 16mm and 35mm film at a speed of up to 100 ft./min with either perchloroethylene or HFE.

> Other benefits include the machine's high-speed operation (CTM notes that the Ultraclean can typically clean 50-100 percent more film per hour than conventional ultrasonic cleaners using the same solvent), efficient recovery system, Plexiglas

[34]RTI. "Ultrasonic Film Cleaning Without Clorinated Solvents." *Image Technology* 82, no. 1 (February 2000): 5.
[35] 3M.
[36]3M.

> partition isolating clean and dirty areas, triple-drying system, capstan drive (with no sprockets, making the Ultraclean suitable for archive materials), low solvent consumption and no water contamination from solvents.[37]

The Ultraclean machine available today cleans with a combination system of buffers and ultrasonic systems.[38]Film is wound around the four buffers fully immersed in the perchloroethylene as the ultrasonic cavitation begins. This combined cleaning technique removes all surface particles as well as stubborn grease, oil, and dirt spots.Utilizing the multi-method system process opens a wider market for Debrie Technologies.

Lipsner Smith currently offers five different models of film cleaners. The three ultrasonic cleaning machines currently on the market are: LS 9220-PLC, CF 9200, and CF 8200P.[39] According to RTI's website, CF 8200P is currently the leading film cleaner. Specially designed for the use of perchloroethylene, CF 8200P can also be factory modified to use 3M Novec 8200 Engineer Fluid. The CF 9200 is one of the most recent cleaning machines, and is designed specifically for the use of HFE. It operates at a higher ultrasonic frequency of 40 kHz, and is designed with enhanced solvent recovery in order to reduce waste and increase output.[40] From the first patent in 1961 to the continued developments today, Lipsner Smith continually proves that it deserves it place as a leader in film cleaning development.

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[37] The American Society of Cinematographers. (2009, August). New Products & Services. Retrieved from The American Society of Cinematographers: http://www.theasc.com/magazine/new_products/main.html

[38]Debrie Technologies. "Cleaning Machine: Ultraclean Series." *Debrie.* 2010. http://www.debrie.fr/images/stories/ULTRACLEAN_ANG.pdf.

[39]Research Technology International. "Professional Film Cleaning Equipment." *RTI Research Technology International.*http://www.rtico.com/lipsner/

[40] Research Technology International. "Model CF 9200 Ultrasonic Film Cleaner." RTI Research Technology International. http://www.rtico.com/lipsner/cf9200.html

Preservation Concerns

Despite ultrasonic cleaning being the preferred method for cleaning negative film and archival film, many concerns still arise. The minimal contact involved with the process greatly reduced the risk of further damage being done to the film surfaces. A drawback of ultrasonic cleaning is that it weakens tape splices.[41] Primarily seen with older films where the tape splices have begun to alter, leaving a residue on the film surface. As the ultrasonic cleaning takes place, the cleaning solvent forced against the film attacks any foreign residue it can remove, in this case the tape adhesive. The cleaning solvent begins, or enhances, the deterioration of the tape that holds the splice together. Another drawback of this process is its inability to remove heavily entrenched particles that even rubbing may not get.

Great care must be taken when using this system to clean damaged film. As mentioned above cleaning solvents can have adverse effects on tape splices resulting in required re-repair of a film and possible re-cleaning; even well repaired film risks further damage when entering a machine if film edges get caught on buffers. In the case of fragile film "most specialist laboratories have a cleaner without the buffers."[42]Ultrasonic cleaning machines need to be maintained and cleaned every so often to avoid bringing further damage and filth to the films by way of dirt left on the air squeegee, un-cleaned rollers, or residue left in the solvent bath.

Beyond the physical damage that can incur from machine use, there are also chemical dangers to be aware of. Overtime chemicals can have a variety of effects on the materials they interact with. While nearly all chemicals used will evaporate off of the film if

[41]National Film Preservation Foundation. 28.
[42]Read, Paul, and Mark-Paul Meyer, . *Restoration of Motion Picture Film.* Oxford: Butterworth Heinemann, 2000. 104.

not removed in the drying process, minute remnants of chemicals can be left behind. This is why most ultrasonic systems utilize air knives in the drying chamber to try and remove all remaining solvent without leaving streaks that will compromise the film's content and/or physical make up. One of the major reasons that HFE is gaining popularity is because it is a "non-flammable" solvent. Unlike perchloroethylene and isopropyl alcohol, HFE is barely toxic and has no flash point.[43] One of the major fears with the use of ultrasonic cleaners and nitrate film has been the high boiling point of the chemicals and low ignition point of the film material. Operators would have to slow the speed of the machine in order to maintain a safe area. 3M's HFE eliminates the need to clean nitrate films differently than normal films.[44] With every concern that arrives with this process, the manufacturers and engineers are quick to offer a solution.

Alternative/Competing Processes

Due to the high costs involved in owning and operating an ultrasonic cleaning machine, companies continued to develop alternative cleaning processes. Many films that require cleaning are not in need of a deep "scrubbing" of every inch of the film and therefore can be cleaned with alternative methods. Aside from the wide variety of hand cleaning options, the two leading alternative processes competing with ultrasonic cleaning are: adhesive cleaner and non-immersion cleaning systems.

[43]Banks, Jonathon A. "Developments in film Cleaning Technologies to Provide a Practical Alternative to the Use of Chlorinated Solvents." SMPTE. Pasadena, 2000. 1.
[44]Research Technology International. "3M Novec Engineered Fluids for Film Cleaning." RTI Research Technology International. 2001. http://www.rtico.com/manuals/3mnovecbro.pdf.

Adhesive cleaners provide a cleaning alternative that does not require large machines or toxic chemicals. There are a variety of adhesive cleaners on the market, but the most notable is Particle Transfer Rollers (PTRs). PTRs were first developed and manufactured by Eastman Kodak in 1990. Designed to easily and effectively remove dirt from the surface of a film, PTRs minimize the risk of further scratching the film by eliminating the rubbing action required in most other cleaning processes. These rollers contain a soft polyurethane material to clean surface dirt and particles off of film. PTRs can be made in varying degrees of tackiness depending on the choice of elastomer they are made with. Kodak engineer Fernando Ramos, designed the PTRs so that they would be soft enough to be tacky, hard enough to be durable, and just smooth enough that it adhere to the dirt on the film without adhering to the film itself.[45] Possible the best feature of PTRs is that when they get too loaded with dirt to work properly, they can simply by washed with water to remove the accumulated particles. As a result of their easy use and maintenance, PTRs are frequently used in projectors and processors to clean film of loose particles that would normally come off in the machines and cause build up.[46]While this does reduce the use of ultrasonic cleaners, PTRs can never completely replace them because they incapable of providing optimum archival cleaning.Any film where there is deep set dirt, oily residue, or more engrained particles, such as mold, will require liquid cleaning.[47]The possible use of

[45]Pytlak, John P, and Morrison, Dale R. "Particle Transfer Roller (PTR) Film Cleaning Experience." *Image Technology*, October 1991: 402.
[46] Read, and Meyer. 104.
[47]Read, and Meyer. 104.

PTRs in ultrasonic cleaning machines has been experimented with, and engineers found that PTRs removed the majority of loose surface dirt on films.[48]

Another alternative cleaning method on the rise is non-immersion cleaning. Competing with its own ultrasonic technology, Lipsner Smith offers non-immersion cleaning systems. The major producer of these machines is Lipsner Smith, who is currently manufacturing two non-immersion machines: the Excel 1100 and the Excel 2000. With non-immersion cleaning film is cleaned by first moving through a series of PTRs and then through a number of rotary buffers that have been wetted with cleaning solvents such as isopropanol and naphtha.[49]The solvent flow can be adjusted for varying degrees of dirt levels so films can quickly and effectively be returned to prime condition.[50] After cleaning the film passes through a drying chamber or over heated buffers for complete drying. Designed for use in film labs, archives, and transfer facilities, non-immersion cleaning is for use where ultrasonic cleaning may not be require.[51] Non-immersion machines offer a low cost alternative to other cleaning systems, thus appealing to smaller companies and facilities that still require high quality film cleaning. Protecting the film from any harmful side effects that may occur down the road due to chemical remnants left on the film or in the solvent tanks.There are a few instances associated with certain negative film stocks where particular contaminants, usually the result of careless negative cutting, are difficult to remove without some mechanical assistance. In such cases, buffing rollers immersed in

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[48]Pytlak, and Morrison. 403.
[49] Lipsner Smith. "EXCEL 2000." RTI: Research Technology International. 2001. http://www.rtico.com/manuals/xl2000lit.pdf.
[50]Lipsner Smith. "EXCEL 1100." *RTI: Research Technology International.* n.d. http://www.rtico.com/manuals/XL1100lit.pdf.
[51] Lipsner Smith. "EXCEL 2000."

the cleaning tank are effective, but this is in addition to, and not in the place of ultrasonic energy."[52]

Despite the troubles and controversy facing ultrasonic cleaning around the cleaning solvents utilized in the process, it remains the most efficient process in the industry. The speed and quality at which an ultrasonic cleaner can clean film is unmatched by even the competing solvent systems. In years to come it will be interesting to see the developments that come out of this area as a result of chemical restrictions, new chemical developments, and the evolution of a market dominated by Lipsner Smith.

[52]Haig, R.N. 187.

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3M. "3M Novec 8200 Engineered Fluid." *Product Information.* September 2009. http://multimedia.3m.com/mws/mediawebserver?mwsId=66666UF6EVsSyXTtlxf_NXTXEVtQEVs6EVs6EVs6E666666--&fn=prodinfo_nvc8200.pdf.

A guide to all the properties, policies, and important information related to 3M Novec 8200 Engineered Fluid. As the new and environmentally friendly cleaning solvent, this information was important in understanding the relation between this solvent and perchloroethylene. Information in this document provided insight into why cleaning machines and solvents are headed in this direction.

Agency for Toxic Substances and Disease Registry. *Toxicological Profile for 1,1,1 – Trichloroethane.* Atlanta: Agency for Toxic Substances and Disease Registry, 2006. http://www.atsdr.cdc.gov/toxprofiles/tp70.pdf

A toxicology profile on 1,1,1 – trichloroethane provides an inside look as to why this solvent is being phased out by the Montreal Protocol. It also provides information on the affects that it would have on users, as well as a context for how powerful the chemical is by stating its other uses.

The American Society of Cinematographers. (2009, August). *New Products & Services*. Retrieved from The American Society of Cinematographers: http://www.theasc.com/magazine/new_products/main.html

A list of new products in 2006 that are relevant to the work done by cinematographers. One of the items on the list is the CTM Debrie Ultraclean machine. The article included key details regarding the operations of the machine that are helpful in comparing it to other systems.

Banks, Jonathon A. "Developments in film Cleaning Technologies to Provide a Practical Alternative to the Use of Chlorinated Solvents." SMPTE. Pasadena, 2000. 1-4.

This is a paper presenting technological updates on film cleaning at a SMPTE conference. The paper is presented by Jonathon Banks, an employee of Lipsner Smith, and discusses the advances that have been made in finding an alternative cleaning solvent after the Montreal Protocol.

Debrie Technologies. “History and Culture.” *Debrie*. 2010. http://www.debrie.fr/index.php?option=com_content&task=view&id=98&Itemid=156

Debrie Technologies has been in business since 1898, when it was known as Debrie. This site provides background history on the other major ultrasonic manufacturer aside from Lipsner Smith. Seeing the background of how this company came to be what it is today is very interesting, as the information on the page display changes in company focus.

Debrie Technologies. "Cleaning Machine: Ultraclean Series." *Debrie.* 2010. http://www.debrie.fr/images/stories/ULTRACLEAN_ANG.pdf.

Debrie Technologies released a product information sheet detailing minute information about the two cleaning machines currently available. Details included the solvents used, film sizes they can clean, speed of cleaning, size of the machine, and information on the operations of the machines.

Digel, David B., and Henderson, David. 1979. “Ultrasonic Film Cleaning Apparatus.” U.S. Patent No. 4,138,757, filed March 20, 1978, and issued February 13, 1979.

A patent issued to David Henderson and David Digel with the assignee Research Technology Inc. (RTI) whom is the parent company of Lipsner Smith. This patent provides information on the machines that have helped to make RTI the leader in film cleaning machines for over 50 years. This patent helps to build the historical timeline of the ultrasonic film cleaning machines that are so popular today.

Fassett, D. W., F. J. Kolb, JR., and E. M. Weigel. "Practical Film Cleaning for Safety and Effectiveness." *Society of Motion Picture and Television Engineers* 67, no. 9 (September 1958): 572-589.

A look into the problems of film cleaning in 1958, including the hazards to users, flammable qualities, and cleaning efficiency. The use of water as an effective cleaning method is acknowledged. The technique and practice of safe cleaning practices when using solvents is also discussed. This article helps to establish a basis of why film cleaning is important.

Gley, P.R. “Ultrasonic Cleaning Machine.” U.S. Patent No. 3,052,244, filed October 9, 1961, and issued September 4, 1962.

One of the earliest patents for an ultrasonic cleaning machine. Gley’s machine offers a regulation of the cleaning intensity for all tape-like objects, not just motion picture films. This patent includes a fill image of the form he desired for the machine. The cleaning intensity is controlled by a set of movable transducers. Information detailed on this

patent helps to establish the early stages of the development of the ultrasonic cleaning machines.

Gutterman, R.P. 1961. “Ultrasonic Process and Apparatus.” U.S. Patent No. 2, 967, 119, filed September 8, 1958, and issued January 3, 1961.

The first patented invention of an ultrasonic cleaning machine in the United States. Gutterman worked for Lipsner Smith who was, and still is, the leading manufacturer of motion picture film cleaners. This patent marks a beginning for the historical timeline and development of the ultrasonic film cleaner.

Haig, R.N. "Film Care in the Telecine Age." *Image Technology* 71, no. 5 (May 1989): 184-188.

Haig’s articles presents an overall look at recommended practices for good film care. The article stresses the importance of preserving not only the most current media format (video) but also original films on film stock. Topics in this article cover handling, rewinding, cleaning, Inspection, Storing, and Lubrication.

Haig, Ronald N. "Film Cleaning By Ultrasonic Liquid Cavitation and Acceptable Solvents." *Society of Motion Picture and Television Engineers* 89 (April 1980).

SMPTE journal article exploring the effective menas of cleaning film without touching the film surface. The article prociedes an indepth look at how this system operates, the solvents used, and how the film is dried after cleaning. This article will help me to understand and explain the phenomenon of ultrasonic cleaning and its place in the archiving and preservation world.

Haig, R.N. "The 'Ultramatic' Film Cleaning Machine." *British Kinematography*, July 1961: 21 - 26.

An early article from around the same time as the first U.S. patent, talking about an ultrasonic film cleaner developed by Colour Film Services Ltd. The article discusses the pros and cons of the machine, as well as future expectations based on the results of the operations tests. Haig writes another piece that helps to build and fill in the story of the ultrasonic cleaner. This is especially helpful due to the great detail it goes into about the interworkings of the machine.

Hill, George P. 1975. “Movie Film Cleaning System.” U.S. Patent No. 3,882,568*,* filed August 20, 1973, and issued May 13, 1975.

In 1973 George Hill filed this patent for a Movie Film Cleaning System that cleans film through the use of electrostatic attraction. This patent provides a look at a one of the competing processes to the popular ultrasonic process.

Hughes, Richard J., and Bowen, Howards. “Method and Apparatus for Cleaning Film.” U.S. Patent No. 4,244,078, filed April 26, 1979, and issued January 13, 1981.

A patent for a method of cleaning film by using an apparatus that can both clean ultrasonically and through pressureized solvent jets. This is an important evolution of the ultrassonic cleaning design. This machine is multifunctional and therefore more useful than a standard single method machine. Eventually these systems would become mainstream.

Le Vantine, Allan D. 1994. “Control Device for Film Cleaners that Remove Dust, Lint, and Static Charge from Film.” U.S. Patent No. 5,359,750, filed May 7, 1993, and issued November 1, 1994.

Le Vantine introduced another piece in the film cleaning machine timeline. In this case the machine offfers a cleaning process much like that of the hand cleaning process utilizing compressed air, making for an interesting comparisson with the ultrasonic cleaners. This technology also added to future designs of many cleaning devices beyond air compression machines.

Lipsner Smith. "EXCEL 1100." *RTI: Research Technology International.* n.d. http://www.rtico.com/manuals/XL1100lit.pdf.
“EXCEL 1100” is an information sheet released by Lipsner Smith on one of their non-immersion systems. This system stands as competition to ultrasonic cleaners due to its alternative cleaning style.

Lipsner Smith. "EXCEL 2000." *RTI: Research Technology International.* 2001. http://www.rtico.com/manuals/xl2000lit.pdf.
“EXCEL 2000” is the digital brochure on the second Lipsner Smith non-immersion cleaning machine. This brochure supplies detailed information on the technical specifications of the machine, easily displaying the differences between this and the other cleaning machines available.

Masson, Alan. "Motion Pictures." SMPTE Journal 108 (February 1999): 75-78.

SMPTE produced a progress report detailing product developments taking place in the industry. The main interest is the section on environmental concerns about the solvents used to clean films. The report discusses the benefical feature of solvent recycling within a system. Meaning that less solvent is lost due to evaporation and contamination.

McMullon, Mark. "Film Cleaning - Beyond the Motnreal Protocol." *Image Technology* 78, no. 9 (October 1996): 20.

A ½ page article written by an operations at Lipsner Smith, Mark McMullon, in an effort to keep readers informed on the current developments in the search for a new cleaning solvent. This article provides a chart depicting the basic information of ten different cleaning solvents. With this information I can discuss further the effects that the Montreal Protocol has on film cleaning.

National Film Preservation Foundation. *The Film Preservation Guide: The Basics For Archives, Libraries, and Museums.* San Fransisco: National Film Preservation Foundation, 2004.

A small book dedicated to instructing readers on preservation. Small sections in the book mention recommended practices regarding film cleaning. These bits are helpful in considering the relationship between how something is cleaned and the effect that will have on the preservation of an item.

The National Film and Sound Archive of Australia. *Ultrasonic Cleaning.*http://www.nfsa.gov.au/preservation/handbook/conservation-treatments/ultrasonic-cleaning/.

A basic explanation of how ultrasonic cleaning works provided through an online glossary of terms put together by The National Film and Sound Archive. This explanation helps me to understand and explain to others how ultrasonic cleaning machines work. By utilizing basic terminology, this site provides an easily accessible and understood library of terms.

Ott, Howard F., and Carmen, Jerry. “Method and Apparatus for Ultrasonically Cleaning a Web of Film.” U.S. Patent No. 3, 615, 814, filed November 25, 1969, and issued October 26, 1971.

A patent for an ultrasonic cleaning system during the early years of the process’ development for Eastman Kodak. This system proposed the use of an ultrasonic horn, rather than transducers, to clean film as it runs throught a machine. There is not evidence that this machine ever went into manufacturing, howver it is interesting to see that this esign may have been tempted.

Ott, Howard F., and Carmen, Jerry. “Ultrasonic Cleaning of a Web.” U.S. Patent No. 3, 635, 762, filed September 21, 1970, and issued January 18, 1972.

Eastman Kodak employees filed a new patent that outlined two different ways in which to utilize ultrasonics to clean: in a pool, or by spraying the film and send ultrasonics through a circular channel in the air. The pool design resembles the popular solvent tank seen on other machines. The non-immersion design would have been interesting to see in practice just to find out how succesfull it would be.

Ozone Secretarait. *Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer.* Ninth Edition. Nairobi: UNEP, 2012.

A conclusive record of the Montreal Protocol implemented actions, reasoning, decisions, and general information. The handbook includes the full treaty, as well as an updated list of decisions made by the participating parties.

Ozone Secretariat. *The Montreal Protocol: Summary of control measures under the Montreal Protocol.* 2001. http://ozone.unep.org/new_site/en/Treaties/treaties_decisions-hb.php?sec_id=6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24.

This website is a recorded summary of the control measures set forth by the Montreal Protocol and its amendments. Information is provided on the expected start and end dates of chemical phase-outs as well as the differentiated timelines as determined by the countries annual consumption of the substances. This information helps to explain the sudden need for companies to find alternative cleaning agents that are both effective and environmentally **friendly**.

Pytlak, John P, and Morrison, Dale R. "Particle Transfer Roller (PTR) Film Cleaning Experience." *Image Technology*, October 1991: 402-404.

A paper detailing Kodak's PTR invention that still stands as a competitive alternative process to ultrasonic cleaning. Instead of immersing the film in liquid, PTRs rely on their "naturally" sticky surface to remove particles from film. The article discusses cleaning with PTRs and how they compare to current cleaning processes being that they are easier to maintain and utilize.

Read, Paul, and Mark-Paul Meyer, . *Restoration of Motion Picture Film.* Oxford: Butterworth Heinemann, 2000.

Chapter 11, section 8 is entirely devoted to exploring different film cleaning methods. Read and Meyer go beyond simply discussing the methods and discuss the importance

of cleaning film throughout the restoration process. The chapter includes sections on cleaning solvents, safety precautions, hand cleaning, cleaning machines, and PTRs.

Research Technology International. "3M Novec Engineered Fluids for Film Cleaning." *RTI Research Technology International*.2001. http://www.rtico.com/manuals/3mnovecbro.pdf.

RTI published this information about the growing popularity of 3M Novec, and how to clean film using it. RTI predicts that one day 3M Novec fluids will make perchloroethylene obsolete. This paper provides all information desired to learn about this up and coming chemical and how it will affect the future of film cleaning.

Research Technology International. *About RTI.* http://www.rtico.com/lipsner/.

Research Technology International is the corporation that owns Lipsner Smith amongst many other companies. The website provides a brief history of these companies as well as a list of past and present products. Along with images of film cleaning machines, the website also offers manuals for the various cleaning machines. Manuals about the machines will help in the explanation of how these machines operate.

Research Technology International. "Academy of Television Arts & Sciences Engineering Award Presented to Lipsner-Smith and CFI for Development of New Film Cleaning System." *RTI Research Technology International*. http://www.rtico.com/emmy.html.

This is a short article about the Academy Award that Lipsner Smith and CFI won for their development of an ultrasonic cleaning machine that can successfully operate utilize 3M's Novec 8200 Engineered Fluid. Novec 8200 is the environmentally friendly and non-toxic cleaning solvent on the market. In order for it to be used successfully machines had to be specially made or altered, which is what the CF-8200 cleaning machine was made for.

Research Technology International. "Professional Film Cleaning Equipment." *RTI Research Technology International* . http://www.rtico.com/lipsner/

This provides a look at the cleaning machine products currently available from Lipsner Smith. Multiple cleaners, both ultrasonic and not, are available. Thus demonstrating that while ultrasonic cleaning is a favorite within the industry, it is by no means considered the only way to clean film and thus other options are available.

SMPTE. "New Products." SMPTE Journal 99 (April 1990): 340-344.

A collection of advertisements and recommendations of new products in the industry, including the CF3000 by Lipsner Smith. This article boasts the CF3000's solvent recycling system, and minimal solvent use in the process.

SMPTE. "SMPTE Committees, Reports and Information for Members." Journal of the SMPTE 83 (1973): 607-648.

Listing of companies that are sustaining members of SMPTE. This list includes Lipsner Smith, mentioning their production of ultrasonic cleaners and the Academy Award for scientific achievement they received for their work.

Teitel, Albert. 1921. “Film Cleaning Apparatus.” U.S. Patent No. 1, 389, 082, filed September 27, 1919, and issued August 30, 1921.

This is a patent for a film cleaning apparatus patented in 1921. It contains diagrams of the machine, as well as a detailed description of how this invention operates.

Westfall, R., and E.V. Knutsen. "Factors Affecting the Cleanliness of Motion-Picture FIlm." *Society of Morion Picture and Television Engineers* 85 (November 1976): 853-859.

An article resulting from a study made on the sources of dirt and ways in which to reduce the amoutn of dirt collected onto film during production and post production. Westfall and Knutsen provide a complete look at environmental, human, and equipment factors.