The History, Invention, and Early Development of Wet-Gate and Liquid-Gate Preservation Processes from 1934-1973

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This paper will explore the history of wet and liquid-gate preservation processes from their invention in 1934 until they became the new standard for scratch reduction within film laboratories roughly three and a half decades later. Liquid or wet-gate printing—a laboratory technique used in optical printing to reduce the appearance of scratches in the base of the original film element—is a process that has been in regular use since the mid 1950s. Although the technical specifications of the wet and liquid-gate processes differ slightly[1], the principal behind them, which will be explained at great length below, is the same: a non-aqueous volatile chemical that possessing a nearly identical refractive index to the film base—usually perchlorethylene, which is universally regarded as the most appropriate liquid for use in a wet-gate—coats the film element and temporarily "fills in" the scratches during optical printing so that the new film element appears free of defects.

The technique has a lengthy pre-history. Film wear has been a problem within the film industry since the medium began to take off in the early decades of the 20th century. Many different methods, including the use of lacquers, diffusion printing, and polishing the film base, have been developed over the years to ameliorate the appearance of scratches on the film base. The basics of wet-gate technology had first been described in the early 1930s by an Eastman Kodak engineer, however it was not developed further because the market conditions were not favorable to this product at that time. With the advent of Technicolor and widescreen as well as the market saturation of television during the 1950s, demand grew for a more effective method of scratch reduction. The burgeoning need for blemish-free prints ignited new research and development into wet-gate technology, which was developed and refined by several companies simultaneously throughout the late 1950s and 1960s. By the end of the decade the wet-gate

[1] In wet-gate printing, the original film element is coated with a liquid either at the moment of or just before it is exposed to the raw film element. In liquid-gate printing, both film elements are enclosed in a glass-walled cell that is filled with liquid at the time of exposure.

process had become widely accepted as the leading scratch reduction technology in its field. Although the process did not come without drawbacks, the technique made a significant impact on the film industry and remains in use to this day.

Scratches and Other Surface Defects

Scratched and otherwise damaged film prints have been a problem from the earliest days of cinema. It is relatively easy to scratch or damage the surface of a film. Film is relatively delicate, and may become scratched in a variety of ways during routine handling, printing, projection, and storage processes. Scratches are so common, in fact, that as Paul Read and Mark-Paul Meyer observe, "there is an entire vocabulary to describe different types of scratches. Intermittent diagonal scratches are known as rain, continuous parallel scratches are known as tramlines, short fine cross scratches are called cinch marks and so on."[2]

Film—particularly reversal originals—may become scratched simply as it runs through cameras and projectors.[3] Additionally, if film is not wound properly before it is stored, it may develop digs, abrasions, or cinch marks on its surface. The latter may also occur as a result of particles of dirt accumulating upon the film's surface. According to John G. Stott, George E. Cummins, and Henri E. Breton, three Eastman Kodak engineers who were pioneers of the wet-gate process, "as the films are wound and re-wound, the dirt particles trapped between convolutions of film scratch the emulsion and support if any motion occurs between the adjacent convolutions."[4] Stott, Cummins, and Breton go on to state that damage to film may be further

[2] Read, Paul, and Mark-Paul Meyer. *Restoration of Motion Picture Film*. Oxford: Butterworth-Heinemann, 2000. Print. p. 88
[3] National Film Preservation Foundation. *The Film Preservation Guide: The Basics for Archives, Libraries, and Museums*, National Film Preservation Foundation: San Francisco, 2004. p. 49.
[4] Stott, John G., George E. Cummins, and Henri E. Breton. "Printing Motion-Picture Liquid Films Immersed in a Liquid Part I: Contact Printing." *Journal of the SMPTE* 66.10 (1957): 607-12. Print. p. 607

caused as film negatives travel through a printer, “passing over rollers and stationary printing apertures” as it is duplicated and resulting in the signature longitudinal scratches that yield a distinctive ‘rainy’ effect to a film print.[5] Finally, they state that, “many scratches come from film cleaning and rewinding where careless handling, failure to change cleaning cloths frequently, and failure to keep equipment in good repair can damage the negative out of all proportion to the number of prints made.”[6]

If a scratched film is copied, the scratches will print through to the new film element and will register as defects in the printed image. This is due to the way in which light behaves as it hits a scratch in the film base. Stott, Cummins, and Breton explain it thusly: “Light from the printer passes essentially in straight lines through the undamaged portion of the support and emulsion of the negative to the positive emulsion. When light strikes the scratch, however, it is scattered and displaced from the straight line path casting a shadow on the positive emulsion.”[7] Therefore, a scratch in the base of a negative film will appear as a white line on the positive film. In fact, not only will the scratch appear in positive film, but because the specular (highly directional) light sources used in optical printing function to accentuate the appearance of scratches in the finished print.[8] This is because the scratches that print through will generally be of a lower density than the surrounding image material, causing them to stand out.[9]

Conversely, in reversal printing a scratch on the base of the original film element will appear as a black line on the print and will tend to blend in slightly better with the image around it.[10] Scratches on the emulsion of a film, however, are different matter entirely: If the emulsion of a

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[5] Ibid. p. 607
[6] Ibid. p. 607
[7] Ibid. p. 607
[8] Turner, John R., Philip A. Ripson, Jr., Frederick J. Kolb, Jr., and Eric A. Yavitz. “Liquid Gate for Projection of Motion-Picture Film.” *Journal of the SMPTE* 71.2 (1962): 100-05. Print. p. 612
[9] Eastman Kodak. *Use of Perchloroethylene in Motion Picture Wet-Gate Printing*, Eastman Kodak Company: Rochester, 2006. p. 2.
[10] Ibid. p. 2.

film has been scratched information contained within the image has been removed, no photochemical process can replace it.

Scratches on a film's base, however, are far more common than scratches on a film's negative[11], and pose a significant problem to both film exhibitors and distributors alike. They are a problem for the former since a scratched film print will not be well received by audiences. As J.A. Norling and Albert P. Rippenbein, inventors of an early scratch reduction technique, note:

> When a film becomes scratched during the first run … subsequent use of the film will make these original scratches more and more apparent. In addition, new scratches will be added constantly, and by the time the print arrives in the smaller theaters, it has acquired the 'rainy' appearance which has been a source of much perturbation to conscientious projectionists throughout the country.[12]

The unattractive prints are not the only problem, however. Scratched film is also a problem for film distributors since scratches contribute actively to a film's deterioration. Once a film becomes scratched, the scratches become, as Norling and Rippenbein put it, "receptacles for dirt."[13] This gradually results in a print that must be replaced with a new one.

Early Methods of Scratch Reduction

As mentioned above, film is a vulnerable media and there have been many attempts throughout the history of the cinema to improve print quality by reducing the appearance of scratches on the film. One of the earliest improvements was the discovery that if film is printed using a highly diffuse (as opposed to a specular) light source, the beams will scatter and the effect of the scratch

[11] DeMoulin, Raymond H., Philip A. Ripson, Jr., and Stanley L. Scudder. "Application of a Liquid Layer on Negative Films to Eliminate Surface Defects in Optical Printing." *Journal of the SMPTE* 68.6 (1959): 415-16. Print. p. 415.
[12] Norling, J.A. and Albert P. Rippenbein. "Treatment for Rejuvenating and Preserving Motion Picture Film." *Journal of the SMPTE* 26.6 (1931) p. 766-772. Print. p. 766
[13] Ibid. p. 766.

will be somewhat minimized. Stott, Cummins, and Breton explain this effect by stating that, "since the light reaching the support of the negative film is scattered to begin with, a scratch on the support of the negative is of less consequence."[14]

Diffusion printing, however, is far from being an ideal solution. Because diffusion printing produces leads to a significant loss of definition and decreased sharpness in the resulting print,[15] lab technicians found this process to be increasingly "undesirable" given the trend toward wider screens during the 1950s.[16] Although the technique addressed to a certain extent the problem of scratches on the film base and was used regularly in film laboratories until the advent of wet-gate technology superseded it,[17] diffusion printing was ultimately a process that was doomed to failure.

Polishing the film base is another technique used to reduce the appearance of scratches. During polishing, the film base is softened by applying a solvent to it before the film is pulled, under significant tension, over a polished roller. Contact is brief—between four and six seconds—but during this time the softened film will harden against the roller, while "the scratches will be filled in with the softened substrate, and [will be] invisible once the new base surface has formed."[18] After the film is polished it may also be matted. This entails passing the film over an additional roller that is made from finely ground glass, which gives the film surface a matt texture and serves to fill in major scratches in the film base.[19]

Despite being used somewhat regularly since the 1930s both in the U.S. and abroad, polishing has significant downsides. It can put a substantial strain on the film, which may shorten

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[14] Stott, John G., George E. Cummins, and Henri E. Breton. p. 607.

[15] Gracy, Karen F. *Film Preservation: Competing Definitions of Value, Use, and Practice*, Society of American Archivists: Chicago, 2007. p. 126.

[16] Imus, Henry O., and Joseph W. Schmit. "Optical Printing of Liquid-Coated Negatives at Technicolor." *Journal of the SMPTE* 69.8 (1960): 545-47. Print. p. 545.

[17] Diffusion printing is still used in some film laboratories today, albeit in select circumstances.

[18] Read, Paul, and Mark-Paul Meyer. p. 89.

[19] Ibid. p. 89.

a film's lifespan or lead to an increase in damage. Additionally, film polishing leads to a loss of print definition. If matting is used the print quality may be so greatly deteriorated that optical printing of the film becomes impossible.[20] Moreover, it is an irreversible process that, "if… done badly, or dust [is] allowed to be incorporated the results could be worse than the untreated film."[21]

Another method of reducing the appearance of scratches that was common before the advent of wet-gate was to apply a coating of varnish or lacquer to the film. This method, used from at least the early 1930s onwards,[22] was always intended to be a reversible process that would temporarily protect films from scratches. "Wood varnishes, copal, or yacht varnishes were used because they were flexible and strong. The varnish was applied many ways: by brushes, rollers, sponges, and total immersion."[23] Sometimes the varnish was applied to both sides of the film, and other times only to the film base.

The logic behind applying the varnish was twofold. The varnish was meant to refract light appropriately, of which more below. The varnish was also intended to provide a protective coating for the film that would, "becom[e] scratched just as the film surfaces would have been scratched."[24] Lacquers and varnishes were intended to be easily removable, and when they became too scratched, the intent was they would be removed with a solvent and re-lacquered. Film that was coated with lacquer or varnish was no more resistant to scratches than uncoated

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[20] *Technical Glossary*. *Technical Glossary of Common Audio Visual Terms*. The National Film and Sound Archive of Australia. Web. 29 Nov. 2011. <http://www.nfsa.gov.au/preservation/glossary/>.
[21] Read, Paul, and Mark-Paul Meyer. p. 89.
[22] Although Paul Read and Mark-Paul Meyer state in *Restoration of Motion Picture Film* that, "lacquers were applied from the mid 1930s on" Norling and Rippenbein report in their 1931 article in the *Journal of the SMPTE* that already, "many processes have been used which involve the use of lacquers and varnishes," indicating an earlier usage of the process.
[23] Read, Paul, and Mark-Paul Meyer. p. 88.
[24] Talbot, R. H. "A New Treatment for the Prevention of Film Abrasion and Oil Mottle." *Journal of the SMPTE* 36.2 (1941): 191-198. Print. p. 191.

film, however the perceived advantage was that, in theory, "on removal and renewal of the lacquer, the film is found to be in as good condition as when new."[25]

The varnishes used in film laboratories were chosen because they possessed similar refractive indices to the film base they were being used to coat. The refractive index is the ratio of the velocity of light in a vacuum to its velocity in a specified medium. Put simply, it is a measure of the rate at which a given material bends light. If film is coated in a material with an identical (or nearly identical) refractive index, then light will fail to scatter when it strikes a scratch on the film because the light will bend at the same rate as the light passing through the image area surrounding the scratch. As Dominic Case explains,

> The amount by which light is refracted as it passes from one medium to another depends upon the angle at which it strikes the surface, and the refractive index of the two media. When both media have exactly the same refracted index, there is no refraction at any angle, and light passes straight through any scratches or other surface imperfections.[26]

The application of lacquers and varnishes is a direct forerunner of wet-gate technology in this regard, and they were applied to film for the better part of three decades before its advent. Although to a certain extent it did function to reduce the appearance of scratches, it was an untenable process. This was due in part to the fact that the refractive indices of the lacquers and varnishes were less accurate than those of the liquids that would later be used in wet-gate technology, meaning that only some scratches could be completely removed. It also fell out of favor because the lacquers and varnishes often proved difficult to remove. Despite the claims of their manufacturers, it often took several washes to completely remove it from the film.

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[25] Ibid.
[26] Case, Dominic. *Motion Picture Film Processing*, Focal Press: London and Boston, 1985. p. 132.

Necessary Preconditions for the Development of Wet-Gate Processes

There were a number of essential preconditions that had to fall in place before wet-gate technology could be developed—namely, the existence of the requisite optical printing technology, an understanding of the scientific principal of refractive indices, and the existence of chemicals that possessed similar refractive indices to acetate and nitrate film bases (as well as the means to test them). Optical printing technology had been developed in the 1910s, and by the 1920s use of the technology had become widespread in the film industry.[27]

A nuanced understanding of the principals of light refraction and a method to calculate the refractive index of given material, however, can be traced back much farther. Picking up on work done originally by Ptolemy, Willebrord Snellius, a 17th century Dutch astronomer, was the first to combine an accurate description the principal of light refraction with an equation for measuring the refractive index of a given substance.[28] The equation, which would come to be known as Snell's Law, was originally published by René Descartes in his 1637 book, *Dioptric*, eleven years after Snellius' death.[29]

As for chemicals possessing refractive indices approaching those of acetate and nitrate film bases, this paper will only address perchlorethylene, which was first synthesized by British chemist Michael Faraday in 1821.[30] Although the technology, chemistry, and scientific principals behind wet-gate technology had been in place for several decades, the process could not be developed until a final criterion was met: A sufficient market for improved scratch reduction technology to make the development of such a process commercially viable.

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[27] Enticknap, Leo. *Moving Image Technology: From Zoetrope to Digital*, Wallflower Press: London, 2005. p. 15.
[28] Sabra, A. I. *Theories of Light from Descartes to Newton*. Cambridge: Cambridge UP, 1981. Print. p. 98.
[29] For more on the controversy surrounding the publication of *Dioptrics* and the scholarly debate about to whom the discovery of Snell's Law should be attributed, please see Sabra, A. I. "Descartes' Explanation of Refraction. Fermat's 'Refutations.'" *Theories of Light from Descartes to Newton*. Cambridge: Cambridge UP, 1981. Print. 93-135.
[30] Cantor, Geoffrey, David Gooding, and Frank A. J. L. James. *Michael Faraday*. Atlantic Highlands, NJ: Humanities, 1996. Print. p. 47.

This process fits firmly within a pattern identified by film historian Leo Enticknap that has recurred throughout the history of film. Namely, "a significant technical advance … tends to happen in two stages: the research and development which makes the process technically viable, and the changes to economic and industrial practice which enables its widespread commercial use."[31] In the case of wet-gate technology, the research and development had in fact initially taken place (as will be discussed below) during the 1930s. It was not until the advent of several new technologies, all of which became enormously popular during the 1950s, that market conditions allowed for the wet-gate process to be a commercially viable process for film laboratories to explore.

One of the largest factors in this process was the increasing popularity of television. By 1955 half of all U.S. homes owned a television, and the need for content to air on television had never been greater.[32] Hollywood studios, which had been battling decreasing cinema attendance figures since 1946, began to sell or lease older films for television broadcast.[33] As film historian Douglas Gomery explains, "through the mid-1950s all the major Hollywood companies released their pre-1948 titles to television," and feature film presentations on television quickly become, "one of television's dominant programming forms."[34]

The only problem with this model, however, was that many of the studios' old prints were badly damaged and could not be used for television broadcast. In a 1959 article about their development of a cost-effective wet-gate process in the *Journal of the SMPTE*, three Eastman Kodak technicians claim, "The growing need for both 16mm and 35mm release prints for

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[31] Enticknap, Leo. p. 16.
[32] Gomery, Douglas. *Shared Pleasures: A History of Movie Presentation in the United States*. Madison, WI: University of Wisconsin, 1992. Print. p. 85.
[33] Sklar, Robert. "The Disappearing Audience and the Television Crisis." *Movie-Made America: A Social History of American Movies*. New York: Random House, 1975. 269-85. Print. p. 276.
[34] Gomery, Douglas. "Movies on Television." Museum of Broadcasting Communications. Web. 29 Nov. 2011.

television … warrants a special method for utilizing badly scratched negatives to make high quality prints. Several motion-picture laboratories have indicated their desire to have a simple method for this purpose….”[35] The statement made by these technicians clearly indicates the financial incentive for a viable method of cheaply “removing” scratches from damaged prints where one did not exist before.

Additionally, the advent of both Technicolor and widescreen should also be noted as significant contributors to the emergence of a market for an improved scratch reduction technology. Scratches on the base of a Technicolor print are highly visible to audiences because they will appear as white lines on the image, which will contrast with the colorful images surrounding it to a greater extent than it will on a black-and-white print. Moreover, during the 1950s many Technicolor films were also filmed in a widescreen format. Wider screens meant a larger image size, which frequently meant bigger auditoriums with considerable throws. In such cinemas, a scratch on a film’s base will be magnified considerably during projection and will register onscreen as a large white gap in the image. Therefore, finding a solution that would eliminate these scratches became a priority for the laboratory engineers at Technicolor.

In an article published in August of 1960, Technicolor engineers Henry O. Imus and Joseph W. Schmit write, “As the three-strip color camera was gradually superseded during 1953 and 1954 by single strip cameras … the magnitude of the dirt and grain problem introduced by the new types of color negative became apparent, particularly in optical printing.” The article proceeds to provide an account of their experiments in wet-gate printing over a five-year period of time beginning in 1955, and concludes by offering a resounding, enthusiastic endorsement of the technology.

[35] DeMoulin, Raymond H., Philip A. Ripson, Jr., and Stanley L. Scudder. p. 415.

Development and Refinement of Wet-Gate Technology

What came to be known as the wet-gate process was pioneered by Otto Sandvik, an Eastman Kodak engineer, during the early 1930s. Sandvik had been assigned the task of reducing "parasitic" background noise caused by blemishes on the optical soundtrack of a film, and on April 17, 1934, he filed a patent on behalf of the Eastman Kodak Company for the "Method and Apparatus" that he had invented for this purpose. His patent, ultimately granted on March 9, 1937, describes a process whereby,

> Film is immersed in a liquid before and during the passage of film past the sound aperture at which the record is translated into modulated light. This liquid will not only tend to free the film of oil and other foreign matter, but will in effect render the surfaces of the film optically smooth if its refractive index approaches closely that of either the gelatine [sic] carrying the record or the transparent support.[36]

The method of optically printing the film while it is totally immersed in a liquid with a similar refractive index to the film base are the defining features of wet-gate technology. Although modifications to and improvements on this method would eventually be offered, Sandvik's patent describes all of the hallmarks of wet-gate as it is still known to this day.

Precisely why the Eastman Kodak Company did not pursue Sandvik's wet-gate system as a viable method for the removal of scratches on film is somewhat unclear. One reason may be that use of film lacquer—also manufactured and sold by Kodak—had only just started to be used for scratch removal, and Kodak did not wish to market competing products. Another, more probable answer may be that, as discussed earlier, there did not yet exist enough commercial viability for a wet-gate process to justify the costs of research and development. In either case,

[36] Sandvik, Otto. Method and Apparatus for Reproducing Sound. Eastman Kodak Company, assignee. Patent 2,073,287. 9 Mar. 1937. Print.

Eastman Kodak did not pursue Sandvik's invention, and did not elect to capitalize on it for another two decades.

The next significant development in wet-gate technology did not occur in the realm of moving images, but rather still photography. On September 24, 1954, Chauncey G. Suits, the Vice President and Director of Research at General Electric, filed a patent for a "Photographic Printing Method and Apparatus" whose object is to, "reduce substantially, or eliminate entirely, the magnification in the enlarged picture or photographic print of imperfections, such as scratches, dust, or dirt."[37] His patent, ultimately granted on June 16, 1959, describes a system of bathing or wetting the film while it is in the negative holder with, "a particular class of clear, colorless, transparent liquids of low viscosity which have a refractive index approximating that of the film base and emulsion of the negative."[38]

Suits' design consisted of a light source, projection screen, and a negative holder, over which one could pour the chemical directly onto the film. Whereas Sandvik's invention had incorporated the wet-gate component so completely into the design of the machine at large that the functions of his invention could not be compartmentalized, Suits' design, although not marketed or sold as independent parts, made clear the importance of a design that would be compatible with and detachable from existing optical printers rather than inventing new optical printers from scratch.

Two years later, on May 31, 1956, Richard Sassenberg, a Long Island-based inventor, files a patent that describes an "Apparatus for Treating Motion Picture Film."[39] Sassenberg's patent utilizes the principal of applying a liquid to the film in order to eliminate the appearance

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[37] Suits, Chauncey G. Photographic Printing Method and Apparatus. General Electric Company, assignee. Patent 2,890,621. 16 June 1959. Print.
[38] Suits, Chauncey G.
[39] Sassenberg, Richard. Apparatus for Treating Motion Picture Film. Patent 2,987,955. 13 June 1961. Print.

of scratches, but unlike other patents, his is the first to propose that this be done during the projection process rather than in the service of creating a new print. This patent is particularly interesting because Sassenberg discusses its potential for use within television, stating, "Scratching and marring of the film … has been particularly evident in television since many of the old films have been used for this purpose."[40] In addition to directly acknowledging the role television played in creating a market for scratch-free film reproductions, Sassenberg's patent is intriguing because it provides an interesting glimpse at a use of the wet-gate process that never managed to take off, despite the appeals of a small but vocal minority of lab technicians within the film industry.[41]

The publication in the *Journal of the SMPTE* of a major two-part article about wet-gate in October 1957 marks a watershed moment in the history of the process. Written by six engineers from the Eastman Kodak Company, the two-part article, entitled, "Printing Motion-Picture Films Immersed in a Liquid," describes in great detail their designs for a step contact liquid-immersion printer, a continuous contact liquid-immersion printer, and an optical step liquid-gate printer. It includes schematic diagrams and photographs of the machines, which were based on a Model D Bell & Howell Printer and altered for the addition of a liquid-gate. The article is the first to be published in the *Journal of the SMPTE* that describes this process, and as such signifies the arrival of wet-gate to the film industry.

The first part of the article concludes with a final remark to readers that, "the particular printers described in this paper should not be considered as production models."[42] The article concludes by suggesting that, "using the basic principles outlined by these studies, laboratories

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[40] Sassenberg, Richard.
[41] For more on the potential use of wet-gate technology in film projection, please see Turner, John R., Philip A. Ripson, Jr., Frederick J. Kolb, Jr., and Eric A. Yavitz. "Liquid Gate for Projection of Motion-Picture Film." *Journal of the SMPTE* 71.2 (1962): 100-05. Print.
[42] Stott, John G., George E. Cummins, and Henri E. Breton. p. 611.

or printer manufacturers should be able to build liquid immersion printers which fit specific laboratory operational requirements."[43] This remark underscores the fact that this technology was still so new that there did not yet exist a prototype for a commercially available wet-gate printer. (Incidentally, nor would there be for another thirteen years). In the years that follow the publication of this article an explosion of research and development would take place surrounding wet-gate processes.

Numerous patent applications and subsequent articles published in the *Journal of the SMPTE* bear this out. In the next decade three distinct patent applications were registered with the U.S. government for different wet or liquid-gate optical printers, and five distinct articles appear in the *Journal of the SMPTE* that either describe the authors' various designs for wet-gate systems of their own or their quests to produce methodically conducted research in regard to how their wet-gate system might be improved.

When taken together, these articles and patent applications provide insight into the rapid development and refinement of this technology during the late 1950s and 1960s, and bear witness to enthusiasm with which the industry embraced it. Furthermore, they provide a remarkable snapshot of the various angles from which this technology was approached. Among them is an article published in October 1958 that is entirely devoted to evaluating various liquids that might be used in a wet-gate, and provides detailed test results for 93 distinct liquid mixtures[44]; an article published in June 1959 by Eastman Kodak engineers describing, "a simple, inexpensive method for applying a liquid to the support side of the film to be printed on a modified Depue optical printer"[45]; an article published un August 1960 by Technicolor engineers

[43] Ibid. p. 611.
[44] Delwiche, Donald A., James D. Clifford, and William R. Weller. "Printing Motion-Picture Liquid Films Immersed in a Liquid Part III: Evaluation of Liquids." *Journal of the SMPTE*67.10 (1957): 678-86. Print. p. 684.
[45] DeMoulin, Raymond H., Philip A. Ripson, Jr., and Stanley L. Scudder.

describing their institution's experiments into and embrace of wet-gate technology[46]; and an article published by Howard F. Ott of the Eastman Kodak Company detailing his design a liquid-gate, "built for use in an Acme Optical Printer."[47]

The latter article is of particular significance to this discussion because it represents the first liquid-gate that was commercially available. The article begins by acknowledging the jerry-rigged arrangements in place at film laboratories around country due to the fact liquid immersion gates were unavailable for purchase. After listing eleven design considerations that Eastman Kodak had established as being essential to a successful liquid-gate, Ott describes the design that was ultimately chosen. This paper will now briefly consider that design, and will borrow from both the Ott article in the *Journal of the SMPTE* as well as Ott's patent application for the liquid-gate system to describe how it worked.

The liquid-gate was built for use in a 16mm Model 104 Acme Optical Printer. In this design, the negative film is threaded from its supply reel through the film advance mechanism and onto a take-up reel on the other side of the machine. The raw, positive film stock is threaded in an identical pattern. The positive and negative films advance simultaneously, reaching, as Ott describes it, "the optical axis of the printer."[48] Just before it enters the gate, the film is vacuumed to remove all of the loose dirt on its surface. Four pull-down pins pull the film through the optical gate, where both film stocks are immersed in perchlorethylene.

The perchlorethylene is brought to the gate via a tube under minimal pressure—Ott suggests perhaps .5 pounds per square inch. Before reaching the gate, however, the perchlorethylene flows past an immersed heater that raises its temperature to 85 degrees

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[46] Imus, Henry O., and Joseph W. Schmit.
[47] Ott, Howard F. "Liquid Gate for Optical Printing." *Journal of the SMPTE* 79.4 (1970): 333-37. Print.
[48] Ott, Howard F. Liquid Gate. Eastman Kodak Company, assignee. Patent 3,614,223. 19 Oct. 1971. Print.

Fahrenheit, “in order to prevent the possibility of condensation of water vapor at the gate.”[49] After it has been sufficiently heated, the perchlorethylene is pumped through the supply tube to a “jet orifice” which propels the liquid into the gate, where it coats the scratched film.[50] When film reaches the optical window another set of pins hold the film in place while an exposure is made.

As the light source from the optical printer strikes the negative, because the refractive indices of perchlorethyle and cellulose acetate are extremely close—1.49 and 1.50 respectively—the light will pass straight through the scratches and will project a blemish-free image onto the positive film stock, which will be exposed without any evidence of the base scratches appearing on the new print.

As the film leaves the optical gate, most of the perchlorethylene is vacuumed off of the film and returned to the supply tank, from which point it will be re-circulated. The films continue to advance through the printer, and are wound onto their respective take-up reels. The liquid-gate system could print up to 640 frames per minute and could also be used to print in reverse.

In the May of 1970—one month after Ott’s article about his new product first appeared in the *Journal of the SMPTE*—a notice is printed in the “New Products and Developments” section of the journal announcing, “A significant advance in the state of the art of ‘liquid gate’ or ‘wet gate’ printing was announced by Eastman Kodak resulting from the development of a 16mm liquid projection gate for use in an optical printer.”[51]

Just over a year later in the June 1971 issue, the *Journal of the SMPTE* announces a new and improved model of this design offered for sale by the a California company called Producers Services Corp. The notice says that, “Following the basic design of Howard F. Ott and manufactured under a patent license from Eastman Kodak Company, the system is known at the

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[49] Ott, Howard F. “Liquid Gate for Optical Printing.” p. 336.
[50] Ott, Howard F. Patent 3,614,223.
[51] “New Products and Developments: Printing Techniques.” *Journal of the SMPTE* 79.5 (1970): 418. Print.

PSC/Ott Liquid Gate."[52] This system boasted a liquid gate that was interchangeable from one optical printer to another, bubble traps, and an exhaust system. Prices ranged up to $14,000.

By the time this design was rolled out liquid-gate had already become a standard practice in the film industry. Competition began to emerge. One month later the Oxberry division of Richmark Camera debuted their own model and priced it at $8,700, or a little under half of what Kodak was charging for their model.[53] The ready commercial availability and competitive pricing of these systems only increased their popularity.

In 1973, Howard F. Ott of the Eastmak Kodak Company, William W. Valiant of PSC Technology Inc., and Gerry Diebold of Richmark Camera Service Inc. were jointly given a Science and Technology Academy Award for the development of a liquid-gate system for motion picture printers.

Liquid-gate systems based on Ott's design are still in use to this day.

Drawbacks and Downsides

Although the liquid-gate system has been somewhat of a success story thus far, it is not a process without downsides. These include environmental restrictions and economic constraints that may govern usage, as well as restrictions on its use of wet-gate in specific instances.

Strict government regulations that govern the sale and use of perchlorethylene make the product a scarce commodity. Because it is scarce, the price of perchlorethylene increases, making wet-gate an expensive process. Nevertheless, perchlorethylene is non-combustible, has a relatively low toxicity, and, most importantly, has a refractive index that is nearly identical as

[52] "New Products and Developments: A Liquid Gate…." *Journal of the SMPTE* 80.6 (1971): 522-523. Print.
[53] "New Products and Developments: The Oxberry Liquid Gate System" *Journal of the SMPTE* 80.7 (1971): 601. Print.

that of film base. Therefore, perchorethylene remains the most viable option for wet-gate systems and the high cost of the chemical is passed on to the consumer.

Additionally, wet-gate systems may not be used in every case. Perchlorethylene is a powerful solvent that will dissolve many things, except those that are water-soluble. In *Recommended Procedures for Motion Picture and Video Laboratory Services*, the Association of Cinema and Video Laboratories has published a list of all of the rules must be followed on materials that should not be intended for wet printing. They are as follows:

> There must never be tape splices in wet printing materials. … If the film has been treated or coated, there could be a problem in wet printing. There must be no markings or coatings on the film to be wet printed. Magnetic striping may be susceptible to the liquid.[54]

Wet-gate technology has improved since those rules were first published in 1982. It is now possible, albeit perhaps undesirable, for a film meeting any of the above criteria to be successfully run through a wet-gate system.

Conclusion

Wet-gate technology was invented as a solution to improve the appearance of scratches on the film base. When first invented, however, there was no way for wet gate technology to take off; although a market for scratch reduction existed, there were other solutions available for consumers and Eastman Kodak, who owned the patent for the technology, did not put pursue its development. With the advent of widescreen, Technicolor, and the rapid increase in television ownership during the 1950s, a new need for scratch-free film prints was established and the

[54] Association of Cinema and Video Laboratories. *Handbook: Recommended Procedures for Motion Picture and Video Laboratory Services*, 4th ed. Association of Cinema and Video Laboratories: Bethesda, 1982. p. 7.

market for an improved method of scratch reduction technology steadily grew. Several companies including General Electric, Eastman Kodak, Movielab, and Technicolor Corp. began experimenting with wet-gate technology.

Eastman Kodak soon proved to be the leader in the field. The publication of an article written by several Kodak engineers in October 1957 detailing their research into this technology brought forth a flurry of interest in wet-gate. The diverse patent applications and articles that were authored about wet-gate over the course of the next decade are evidence of both how much interest this process generated, as well as how effective a technique wet-gate proved to be, and how quickly it caught on as a result. Technicolor, for instance, who began wet printing their material on an experimental basis in 1957, state, “20 million feet of imbibition prints from wet-printed matrices were released” during their first year. “As more matrix printers were converted to wet printing in 1958, the figure increased to 100 million feet. By 1959, practically all of the imbibition footage produced was from wet-printed matrices.”[55] The August 1960 article goes on to mention that its Technicolor-affiliated processing plants in both London and Rome are also equipped with wet-gate technology.

Although the process was widely embraced, due to the fact that no commercial prototype yet existed, companies were forced to pursue their own research into the process and build models of their own design. Kodak was the first to put a liquid-gate system on the market. PSC and Oxberry soon followed suit, and by the close of the decade wet-gate had been firmly established as the industry standard in scratch removal technology. Despite its drawbacks, including its expense and restrictions on the material that can pass through a wet-gate system, the technology has remained in continuous use since to this day.

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[55] Imus, Henry O., and Joseph W. Schmit. p. 545.

Why did wet-gate become—and remain—so successful? To a certain extent, the success of the process was due to timing. Without the urgent, multi-faceted need for scratch-free prints that arose in the 1950s, it is unclear whether there would have been a sufficient impetus for the development of the wet-gate technique at a later date. That its use remains widespread to this day, even after the urgent need for scratch-free prints subsided, to some degree, when television production began using video instead of film, is a testament to its superior quality. Despite its high cost, other technology in existence does as thorough or as excellent a job of allowing the original information on a negative to print through, scratch-free, to the positive.

The history of the wet-gate process is rich, and although it remains outside the scope of this paper, there is much research that remains to be done on the development of this process over the course of the last forty years. It is my hope that the research presented here will be used as a jumping off point for a lengthier discussion of the process and its impact on the medium.

Annotated Bibliography

Association of Cinema and Video Laboratories. *Handbook: Recommended Procedures for Motion Picture and Video Laboratory Services*, 4th ed. Association of Cinema and Video Laboratories: Bethesda, 1982.

This is a handbook designed to provide filmmakers with accurate information about the recommended procedures for the processing and duplication of both motion picture film and video. The book contains descriptive text as well as drawings to illustrate certain concepts.

With the new laboratory processes and technology that have been invented or updated since this book was first published, some of the information in this text has been outdated.

Cantor, Geoffrey, David Gooding, and Frank A. J. L. James. *Michael Faraday*. Atlantic Highlands, NJ: Humanities, 1996. Print.

This is book that considers the work of British scientist Michael Faraday in the context of his life at large. Combining descriptions of his experiments alongside excerpts from his diary, the authors of this book aim to reckon Faraday the Man with Faraday the Scientist and in s doing shed light on the singular life he led.

Case, Dominic. *Motion Picture Film Processing*, Focal Press: London and Boston, 1985.

As part of the Media Manuals series, this book aims to present information to an informed filmmaker about some of the more advanced concepts involved in motion picture processing. Like other books in the Media Manual series, this text combines informational text with drawings on the page directly opposite that provide a visual illustration of the concept discussed.

Delwiche, Donald A., James D. Clifford, and William R. Weller. "Turner, John R., Duane E. Grant, and Henri E. Breton. "Printing Motion-Picture Liquid Films Immersed in a Liquid Part III: Evaluation of Liquids." *Journal of the SMPTE*67.10 (1957): 678-86. Print.

This article is entirely devoted to evaluating various liquids that might be used in a wet-gate system, and provides detailed test results for 93 distinct liquid mixtures. The liquids were rated in a number of different categories including their overall effect on the film, flammability, volatility, cost per pound, and their effects on the respiratory and ocular health of the lab technicians who handled them. Among the liquids assessed was perchlorethylene, which was found to be an outstanding chemical for use in a liquid-gate.

DeMoulin, Raymond H., Philip A. Ripson, Jr., and Stanley L. Scudder. "Application of a Liquid Layer on Negative Films to Eliminate Surface Defects in Optical Printing." *Journal of the SMPTE* 68.6 (1959): 415-16. Print.

This article details a cost-effective method geared toward copying film for reproduction on television. In this design, instead of immersing the film totally in a liquid, the liquid is applied via an applicator just before it enters the film gate. This reduces the overall cost of the process to roughly ten cents per thousand feet of 35mm negative film.

Eastman Kodak. *Use of Perchloroethylene in Motion Picture Wet-Gate Printing*, Eastman Kodak Company: Rochester, 2006.

This is an informational pamphlet published on Kodak's website to advise manager's of motion picture archives on all aspects of perchlorethylene. The publication provides an array of information including the safe handling, storage, and transportation of perchlorethylene, end-of-life practices, and an extensive list of country-specific regulatory information. In addition, this pamphlet also contains a very well written explanation of the role perchlorethylene plays in wet-gate processes.

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

This is an exhaustively researched technical history of the cinema. In addition to providing a painstakingly detailed history of the technological advances that have taken place in each area of film throughout its history, Enticknap's text also functions as an economic history of the cinema, providing insights into the relative successes and failures of various formats and processes based on their commercial viability.

Gracy, Karen F. *Film Preservation: Competing Definitions of Value, Use, and Practice*, Society of American Archivists: Chicago, 2007.

Gracy's book stems from her doctoral thesis and aims to provide a systematic assessment of the essence of what it means to preserve films. She attempts to define concepts that are sometimes nebulous, like the sometimes-competing notions of 'preservation' and 'restoration.'

Because her book was based on a series of interviews she conducted with leaders in the archival field, her book sometimes suffers from the assumptions made by her interviewees, and despite quoting what they say as fact, she does not offer any evidence whatsoever to back up many of the statements that they make with regard to the effectiveness of particular laboratory processes.

Gomery, Douglas. "Movies on Television." Museum of Broadcasting Communications. Web. 29 Nov. 2011. <http://www.museum.tv/eotvsection.php?entrycode=moviesontel>

Gomery's essay is a history of feature film showings on television. He contends that films shown on television has been one of the most reliable and successful forms of television programming since they began to be shown in the mid 1950s.

Gomery, Douglas. “New National Chains.” *Shared Pleasures: A History of Movie Presentation in the United States*. Madison, WI: University of Wisconsin, 1992. 83-102. Print.

This chapter in Gomery’s seminal text about film going focuses on the advents of the both drive-in movie theatres and multiplex theatres during the post-war era. Gomery discusses television at length, and conflates the myth that television alone was responsible for these changes.

Imus, Henry O., and Joseph W. Schmit. “Optical Printing of Liquid-Coated Negatives at Technicolor.” *Journal of the SMPTE* 69.8 (1960): 545-47. Print.

This article was describes the process by which the Technicolor Corp. began experimenting with wet-gate technology in 1955. The articles details five years of research and development of the process at Technicolor, and concludes by offering a resounding embrace of this technology.

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

This is a publication geared towards professional organizations or individuals that have moving images within their collections, but who may not have a significant amount of experience working with moving images. This text provides basic technical information about all aspects of film care, and provides reader with a series of useful charts, graphs, and photographs that they may consult. This book is a reference source for anyone involved in preserving moving images.

“New Products and Developments: Printing Techniques.” *Journal of the SMPTE* 79.5 (1970): 418. Print.

This notice announces the first commercially available wet-gate printing system. Howard F. Ott designed this printer, which featured a total immersion system that propelled perchlorethylene into the optical gate via jets. The perchlorethylene was then vacuumed off of the film as it exited.

“New Products and Developments: A Liquid Gate….” *Journal of the SMPTE* 80.6 (1971): 522-523. Print.

This is a notice for PSC’s liquid-gate system, the second commercially available liquid-gate to be advertised in the *Journal of the SMPTE.*

“New Products and Developments: The Oxberry Liquid Gate System” *Journal of the SMPTE* 80.7 (1971): 601. Print.

This is a notice for Oxberry’s liquid-gate system, the third commercially available liquid-gate system to be advertised in the *Journal of the SMPTE.*

Norling, J.A. and Albert P. Rippenbein. “Treatment for Rejuvenating and Preserving Motion Picture Film.” *Journal of the SMPTE* 26.6 (1931) p. 766-772. Print.

This article describes the Recono method for film rejuvenation, which is a process that would come to be known as re-wash. This process is used to anneal scratches in a film’s emulsion. The article provides a useful assessment of the problems that result from a scratched print. The article also describes common causes for these scratches.

Ott, Howard F. Liquid Gate. Eastman Kodak Company, assignee. Patent 3,614,223. 19 Oct. 1971. Print.

This is Howard F. Ott’s patent for the first commercially available liquid-gate systmem.

Ott, Howard F. “Liquid Gate for Optical Printing.” *Journal of the SMPTE* 79.4 (1970): 333-37. Print.

Ott’s article was published shortly after submitting the patent application for his liquid-gate system, which was the first to be available commercially.

Read, Paul, and Mark-Paul Meyer. *Restoration of Motion Picture Film*. Oxford: Butterworth-Heinemann, 2000. Print. Butterworth-Heinemann Ser. in Conservation and Museology.

This text is a reference for film archives and anyone involved in the preservation and restoration of moving images. This text discusses some of the laboratory processes that are no longer used anymore from the perspective of a film restorer who would need to understand how the film in their possession had originally been treated at the film lab.

Sabra, A. I. *Theories of Light from Descartes to Newton*. Cambridge: Cambridge UP, 1981. Print.

Sabra presents a very thoroughly researched account of the history of optical theory. His writing is heavily footnoted, and is are particularly useful source of information about the controversy surrounding the claims that Descartes plagiarized Snell’s Law.

Sandvik, Otto. Method and Apparatus for Reproducing Sound. Eastman Kodak Company, assignee. Patent 2,073,287. 9 Mar. 1937. Print.

This patent application marks the first mention of wet-gate technology in a patent application. Although this design would later be modified, Sandvik’s method of printing film while it was totally immersed in a liquid with a similar refractive index to that of the film base represents the invention of this process.

Sassenberg, Richard. Apparatus for Treating Motion Picture Film. Patent 2,987,955. 13 June 1961. Print.

Sklar, Robert. “The Disappearing Audience and the Television Crisis.” *Movie-Made America: A Social History of American Movies*. New York: Random House, 1975. 269-85. Print.

Sklar’s seminal text is a social history of the cinema. It is meticulously researched an provides an account of the history of moving images from a socio-cultural perspective. His chapter on the decline of Hollywood in the post-war era provides an interesting perspective on the role television played during this time period.

Stott, John G., George E. Cummins, and Henri E. Breton. “Printing Motion-Picture Liquid Films Immersed in a Liquid Part I: Contact Printing.” *Journal of the SMPTE* 66.10 (1957): 607-12. Print.

This article is the first in a two-part article that heralded the arrival of wet-gate to the film industry at large.

Suits, Chauncey G. Photographic Printing Method and Apparatus. General Electric Company, assignee. Patent 2,890,621. 16 June 1959. Print.

Suits patent application describes a liquid gate system that was designed to be used for the enlargement of still photographs. Suits’ design is clumsy and does not bear very much resemblance to the designs that would follow for motion pictures, but it does provide an early example of a wet-gate gate system.

Talbot, R. H. “A New Treatment for the Prevention of Film Abrasion and Oil Mottle.” *Journal of the SMPTE* 36.2 (1941): 191-198. Print.

Talbot’s article describes a process of film lacquering. His article is useful inasmuch as it provides an insight into precisely how this lacquer was applied, and to a certain extent pre-figures some of the design elements of the liquid-gate system that Ott would design several decades later.

Technical Glossary. *Technical Glossary of Common Audio Visual Terms*. The National Film and Sound Archive of Australia. Web. 29 Nov. 2011. <http://www.nfsa.gov.au/preservation/glossary/>.

This is a glossary of terms, phrases, and products that are commonly used in the preservation and restoration of film and audio elements. This glossary has a particularly useful and detailed entry on film polishing and provides descriptions of several different variations on the process that have were used during the first half of the 20th century.

Turner, John R., Philip A. Ripson, Jr., Frederick J. Kolb, Jr., and Eric A. Yavitz. "Liquid Gate for Projection of Motion-Picture Film." *Journal of the SMPTE* 71.2 (1962): 100-05. Print.

These Eastman Kodak engineers write a somewhat forceful article explaining at length the benefits of using liquid-gate technology during the projection of motion pictures. The article describes their design for a projector (based on a Model XL Simplex in this case) that has been modified to include a liquid gate. They argue that the liquid gate has huge potential for projection, claiming that in to greatly improving the print quality, it will prevent drift out of focus and will yield a sharper image onscreen.

Works Consulted

Hall, Henry J., and Arthur E. Rodda. Optical Gates. Newman & Guardia Limited, assignors. Patent 3,473,874. 21 Oct. 1969. Print.

This is a patent application submitted originally in Great Britain and a year later in the USA. It details a liquid-gate system similar to those already being developed in the United States, and provides an interesting series of detailed illustrations that describe its unique attributes.

Happé, Bernard L. *Your Film and the Lab*. London: Focal Press, 1974. Print.

As part of the Media Manuals series, this book aims to provide a informative descriptions of a variety of different film laboratory procedures. The layout of this book provides roughly one page of text for each process discussed, and often an image or images will be provided on the accompanying page. This book is geared towards amateur filmmakers who do not yet possess a complete knowledge of film laboratory processes.

Jeffee, Saul, and Pedro P. Weinschenk. Apparatus and Process for the Liquid Gate Printing of a Photographic Film. Movielab Inc., assignee. Patent 3,554,641. 12 Jan. 1971. Print.

This is a patent that was designed by engineers at Movielab in New York for a liquid-gate system that was not dissimilar to the Ott design that was produced by Kodak. This system uses an aquarium-gate—a variation on the design of the wet-gate where the film is entirely covered with liquid.

Turner, John R., Duane E. Grant, and Henri E. Breton. "Printing Motion-Picture Liquid Films Immersed in a Liquid Part II: Optical Printing." *Journal of the SMPTE* 66.10 (1957): 612-15. Print.

This is the second part of the watershed, two-part article published in the *Journal of the SMPTE* that functioned to herald the arrival of the wet-gate technique to the film industry. This article focuses on the use of wet-gate in an optical printer and provides a series of diagrams that explain how it works.

Wolbarst, John. “Magic Liquid Will Revolutionize Print Making.” *Modern Photography* 18.10 (1954): 72-75, 116, 117. Print.

Wolbarst’s article was published a month after Chauncey Suits filed a patent application for his wet-gate projection system. The article hails this process as revolutionary, and shows a series of “before” and “after” examples how effective this new technology is.

This articles provides readers with an understanding of how novel this technology was when it was first invented, and how impressive the effect was.