

# An Aqueous-Based Motion-Picture Film Cleaner — Final Report

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*This article presents the developmental work on an environmentally safe aqueous-based motion-picture film cleaner. This work has been performed under the aegis of the Technology Council of the Motion Picture/Television Industry, more commonly referred to as the Tech Council. The Tech Council was formed about four years ago by a group of scientists and engineers from the motion-picture, broadcasting, and allied industries. They volunteer their time and talents for the goal of identifying and resolving technology problems — safety and environmental issues that are too large or complex for individual companies to tackle alone.*

The concept of a technology council goes back to a time in the history of film and television engineering when the entire industry rallied together to support technological research because it was recognized that the advances made would benefit the industry as a whole. The first industry-supported organization was called the Research Council of the Academy of Motion Picture Arts and Science and was formed in 1934.

The current Tech Council was formed in late 1989 to fill the need for a centralized, nonbiased forum for the development of new technology and the exchange of technological resources. It is a nonprofit, public-benefit corporation dedicated to advancing all disciplines of the technological base that supports our industry.

Volunteers have staffed project committees and have initiated more than a half-dozen projects, of which the aqueous-based film cleaner is only one. These projects demonstrate the Tech Council's mandate to provide nonbiased development of

new technologies to support our industry.

Soon after the Tech Council's inception, John Baptista met with some Eastman Kodak Co. engineers and asked if they could identify any chemicals that would be environmentally safe, gentle on film, but tough on dirt. Their answer was a probable yes, but they would have to do some searching and testing. The goal was to eliminate the need for 1,1,1-trichloroethane, the cleaning solvent currently in use worldwide as a film cleaner. Various governmental agencies had declared this chlorinated hydrocarbon solvent as an ozone-depletion chemical as well as a toxic substance. The motion-picture/television industry is not a large user of this chemical, but trichlor does play an important part in the production of clean images for viewing, and the ability to effectively clean film is important to the viability of film itself. In anticipation of a worldwide ban on the production and use of trichlor, the Tech Council became involved in this project.

John Baptista, Consolidated Film Industries (CFI), and Frank Ricotta, Technicolor, Inc., as concerned laboratory executives, volunteered to head a project team to develop an aqueous-based cleaner. Their team consists of representatives of the major Hollywood laboratories and

representatives of the three worldwide motion-picture film manufacturers. A consultant was hired to develop a proposal and to coordinate the project development. A proposal was prepared and, after thorough discussion by the project team, the project was specified and funding obtained. Agfa-Gavaert Corp., Eastman Kodak Co., and Fuji Photo Film U.S.A. provided the funding for the project, and work began.

The specifications for the proposed system were that it should:

- Be as efficient in cleaning film as current chlorinated solvent systems
- Utilize no toxic chemicals
- Use existing EPA-approved chemicals and technology
- Have a throughput of 100 ft/min or more
- Be as simple to install, operate, and maintain as current systems
- Have no short- or long-term physical or sensitometric effects on the film emulsion, image dyes, masking dyes, or film support
- Not require significantly more floor space than existing cleaners
- Require no inventions or technological breakthroughs

With these specifications as a guide the project was divided into three parts: the cleaning solution, the film transport, and the drying system.

## The Cleaning Solution

After a thorough search by the Motion Picture Research and Development Group of the Eastman Kodak Co. of cationic and anionic surfactants, combinations of various wetting agents, and even commercially available cleaners and detergents, one chemical was selected for significant testing — Renex. Some

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other compounds were interesting, but Renex is currently used and accepted worldwide as a wetting agent in film processing, so no complex testing or government studies would be required. It has also been shown to have no deleterious effects on film emulsions or supports as supplied by any of the manufacturers. Renex in water as the cleaning solution is nontoxic, environmentally acceptable, and efficient for cleaning film.

The optimization of the wet-cleaning section of the machine will be left to the equipment manufacturers. The project team did have a wet-test device designed and built so that tests could be run to evaluate the cleaning ability of the solution and to supply the film manufacturers with film for their storage evaluations. The test device was tied into a negative-processing machine at CFI to provide the film transport, after which the film was passed through the dry section of the processor for drying.

The test device consisted of four tanks. The first was used as a prewet tank and contained the standard stabilizer solution, 0.14 ml/l Renex. The next was a buffer tank, where the buffers were wetted with a solution of 20 ml/l Renex and both emulsion and base were scrubbed. The third tank held a fresh-water rinse, and the last tank contained the standard stabilizer solution, to be repeated. Overall the time in this wet-test bed was 33 seconds. Many experiments have been done since that indicate that the total time in the wet section can probably be 10 seconds or less.

Various concentrations of Renex in water were evaluated to determine an effective, yet economical, cleaning solution. Concentrations of from 0.1 to 5.0% were tested, and 2.0% was found to be totally satisfactory for cleaning while having no effect on the physical or sensitometric characteristics of the films. The effects of various concentrations were also tested by running the films through the wet-test system ten times. Incidentally, the 10X figure was agreed upon by the project team as a practical number of passes through a cleaner.

Agfa, Eastman, and Fuji were asked to supply film test strips that

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would be run through the test device once and then ten times. These test strips were then given back to the manufacturers to evaluate in any way deemed necessary to prove or disprove the viability of the wet part of the system.

The team members from the laboratories were also given the opportunity to evaluate the cleaning effectiveness of the product for their operations. Sample rolls of artificially dirtied negative film were transferred to video, cleaned on the test device, then transferred again to video. Check rolls were also cleaned with the current solvent-type cleaners and transferred to video. The videos were then evaluated by experts to determine the effectiveness of the aqueous cleaner.

The film manufacturers reported that they were satisfied, by their own testing, that the Renox cleaning solution had no deleterious effects on their films. The experts who viewed the videos agreed that the effectiveness of the cleaners was comparable and that fewer surface disturbances or scratches were observed on the films cleaned with the water solution.

It should be noted that this water-based cleaning system may not remove some of the greasy types of dirt as efficiently as the chlorinated solvent cleaners. However, it will remove embedded particles better and more easily, much like the rewash procedure.

### **The Film Transport**

The film-transport system, for our testing purposes, made use of current technology. There are any number of suppliers of excellent film-transport systems that treat the film gently and safely. The project team has not expended any developmental efforts or money in this area.

### **The Drying System**

With the cleaning solution identified and with no concern for a transport system, the main efforts of the project were directed to the difficult task of drying film safely in a very short time. This phase of the project provided the greatest challenge. Consider for a moment that cleaning film with 1,1,1-trichloroethane is a surface phenomenon. The organic solvent does not penetrate the emulsion or support to any great extent. It has a relatively low boiling point and can be removed from the surface of the film by a very short section of a warm air squeegee. The solvent vaporizes readily and the vapors are easily exhausted in only a few seconds.

When film is exposed to a water solution, the moisture is immediately absorbed and causes the gelatin emulsion to swell and take on even more. Even the cellulose triacetate support will absorb some moisture. Polyester-type supports take on water but at a significantly slower rate. Therefore, cleaning film with a

water solution will result in a film with a significant excess of unwanted moisture in both the emulsion and the support. It is desirable to have as short as possible exposure of the film to the water solution, but about 3 seconds are required for uniform wetting, which is necessary for uniform drying.

Most of the excess water must be removed in about 10 to 12 seconds, or less, to have a machine of reasonable size. Large dry boxes on processing machines require anywhere from 4 to 7 minutes to remove the water from a saturated strand of 35mm film. This gives some idea of the challenge that we faced. High-efficiency air-impingement dryers were considered but were not seriously pursued because of the potentially large space and energy requirements and also the lack of encouragement from the various experts who were contacted.

It was suggested that microwave ovens were very efficient in heating and drying, but that radio-frequency (RF) waves might be more applicable. It is known that it is difficult to selectively apply the microwave energy to the thin layer of gel containing the moisture. An electrical field applied parallel to the gelatin layer increases the rate of energy transfer, making the RF heating more applicable. Manufacturers of both types of apparatus were contacted and told of the project and the requirements for careful, safe handling of film. Although none of the companies were familiar with film handling, several of them expressed interest in the project, and samples of 35mm film were sent for their initial testing. Only a few of these wanted to go deeply into testing and evaluation, and these companies used RF energy. It was decided not to pursue the microwave approach when two manufacturers commented that the microwaves were probably too difficult to control and focus on the film for consistent drying.

The Council has recently been contacted by a company that designs and builds specialized microwave systems for various drying tasks. Some of their preliminary experiments have been encouraging, but it is too early to decide on feasibility of this application, and with restricted funds another development

approach would not be practical at this time.

When it was decided to evaluate further the use of RF waves, the Council signed a development agreement with a company that built and tested a device that proved this approach was feasible. Further discussions with that company and one other provided more ideas and many more experiments that needed to be run. It was decided to continue with only one company. Nemeth Engineering Associates, Inc., was chosen to design and build a prototype dryer that could be attached to a wet-cleaning device and would dry 35mm film transported through the dryer at approximately 150 ft/min. Drying would be accomplished using RF waves.

RF-wave heating or drying falls into the general category of dielectric heating. The frequencies are in the range of 1 to 100 MHz, and these frequencies are also used in broadcasting and communications. Microwaves also fall under dielectric-type heating, but their frequencies are in the 300 to 30,000 MHz range.

In the last 40 years RF heating, or dielectric heating, has been applied to many products as manufacturers look to increase heating rate, reduce costs, and improve product quality in the heating and drying operations for nonconductive materials. Our product, film, is a nonconductive material, but the water is polar so that coupling of the RF energy to the water molecules is relatively efficient.

Much like the motion-picture and television technologies, dielectric heating technology has a language of its own. There are two terms that help us to understand what follows. The first term is "applicator." To those experienced in film processing, an applicator is used to apply the sound-track developer, but in dielectric terms it is the place where the RF energy is applied to the product. For our purposes, it will ultimately be called the dry box. This is the unit where the RF waves are applied to the wet film and where the removal of moisture or drying takes place. The applicator contains a specific array of electrodes for application of the waves to the film.

The other term is "loss factor."

The RF industry's recommended definition is that loss factor is a measure of the ease with which the material can be heated. It can also be looked at as the coupling efficiency of the waves with the material to be dried. In this case water is the material to be heated and dried or removed from the film, and water has a very high loss factor. This makes the RF technique particularly applicable to moisture removal. As moisture is removed, the loss factor decreases and the material will absorb less RF energy. This represents a great advantage in preventing overheating or overdrying of the film when RF heating is used, making the process easier to control. This self-controlled feature makes the RF application even more appealing. By controlling field strength at the end of the heating cycle the amount of moisture remaining in the film can be consistently regulated.

The most important parameters that determine the application of the RF energy to any particular material is the configuration of the RF applicator, in particular the electrode system. The electrodes that apply the electric field are generally flat parallel plates separated so that the work, or in this case the film, can be placed between them without touching. One plate is operated at ground potential, with the other acting as a high-voltage electrode. The strength of the electric field is determined by the RF voltage applied to the hot electrode, which in most cases can be in the range of 1.0 to 10.0 kV, with frequencies up to 100 MHz. The operating frequency of the unit is also critical, depending upon the specific material involved. Currents involved are relatively small. The object is to remove water, a high loss-factor material, so frequency normally would not be critical for us. The selection of the operating frequency became an important factor, since the water is mostly contained in a very thin layer of gelatin. RF fields at higher frequencies, having shorter wavelengths, will couple better to thinner materials.

Another electrode system consists of an array of parallel rods alternately arranged at high voltage and ground potential on the same side of the material to be heated. This sets

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up an electrostatic field between the electrodes that is usually known as a stray or fringe field. The material to be dried is run through the stray field.

A third arrangement uses the same parallel rods but places the ground on one side of the material and the high-voltage rods on the other, again allowing for the field to penetrate the material. This system is known as a staggered stray field. In all cases the alternating electric field between the electrodes increases the internal energy of the polar molecules of the material by vibrating them at the operating frequency of the RF unit, producing heat inside the material.

The test results have indicated that the support plastics, cellulose triacetate and polyethyleneterephthalate, both have low loss factors, which means that no appreciable heat is developed because of the support. Only the high loss-factor water molecules are targeted by the RF and heated. Water is the major heat source of all the temperature increase.

The wet-test device was shipped from Hollywood to the Nemeth plant in Crestwood, Ky., for system-type testing. A source of controlled-wetness film was needed for the development of a dryer. A variable-speed drive was installed and experimental-design RF applicators were attached to dry the film. Nemeth engineers evaluated all three RF applicator designs previously described and also tested various frequencies and power levels.

It was concluded that the parallel-plate design was the most efficient, and an 80-MHz frequency was chosen. The prototype unit has a variable-voltage control and variable-

speed control to attain a continuum of power or drying levels within its 3-kW capacity. A final design could have pushbutton controls to simplify the selection of drying level to effectively accommodate various films with differing water loads. Operation of the RF applicator is simple and safe for all installations.

Negative, intermediate, and positive films have been successfully dried in the prototype RF applicator at times from 5 to 12 seconds. However, the applicator or dry-box film path is nearly twice as long as originally planned. While the film is in the energy field for the same length of time there has to be a relaxation time between wave sections so that the film is not overdried or damaged. This threading path would require perhaps 60 feet or more each of head and tail leader for batch operation. Such a length would mean major changes in the lab procedures and increased costs. A commercial unit could be run continuously using feed-on and take-off elevators, which would then not require any change in lab operations. Continuous feed would also provide for more effective utilization of the cleaner and increased throughput. A continuous cleaner running at 150 ft/min is equivalent to a batch-type cleaner that runs 250 ft/min at an estimated 60% effective operation.

#### **Acknowledgments**

The Tech Council is grateful for the financial support of Agfa-Gevaert Corp., Eastman Kodak Co., and Fuji Photo Film U.S.A.

#### **Conclusion**

The Tech Council owns, as part of the joint developmental effort with

Nemeth Engineering, a prototype RF-wave dryer that is attached to the wet-test device. It has demonstrated efficient cleaning and short-time drying at reasonable throughput speeds. All results have proven satisfactory for physical and sonometric evaluations in tests performed by Agfa, Eastman Kodak, and Fuji on their respective films. In addition the Tech Council, through CFI, cleaned films on both the sonic/solvent cleaner and the prototype aqueous cleaner, printed the films, and then optically projected the prints to evaluate sharpness. It was determined that all the films were equally sharp. Rolls containing both tape and cement splices have been run many times with no adverse effect due to water solution or RF drying.

It is our conclusion that the technology for an aqueous-based motion-picture film cleaner has been demonstrated. The Tech Council will provide all of the information and data available to any legitimately interested equipment manufacturer. Nemeth Engineering is equipped to supply RF applicators similar to the prototype, or with custom-designed modifications, to attach to the wet section.

There are still applications that cannot immediately apply aqueous cleaning, so some tests were performed using perchlorethylene, or "perc." This is the wet-printing solvent and, while it is, as are many commonly used chemicals, allegedly animal-carcinogenic, it is not yet banned environmentally. Its usage and handling can be made safe for the operators.

Our tests consisted of converting a current-design sonic cleaner to use perc and evaluating the results versus aqueous and trichlor/sonic cleaning. The machine conversion required the addition of squeegees, such as those used on the wet printers, and slowing the speed from 175 to 100 ft/min. This decrease in speed was necessary to ensure safe and streak-free drying. The cleaning results were comparable for all methods. While this was not part of the original project, it was deemed necessary to provide a potential interim solution to the cleaning-solvent problem until the aqueous-based system is commercially available.