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Ultrasonic Cleaning of Rotogravure Cylinders

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ULTRASONIC CLEANING OF ROTOGRAVURE CYLINDERS

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PREFACE

This project was funded by EPA's Control Technology Center (CTC). The CTC was established by EPA's Office of Research and Development (ORD) and Office of Air Quality Planning and standards (OAQPS) to provide technical assistance to State and local air pollution control agencies. Three levels of assistance can be accessed through the CTC. First, a CTC Hotline has been established to provide telephone assistance on matters relating to air pollution control technology. Second, more in-depth engineering assistance can be provided when appropriate. Third, the CTC can provide technical guidance through publication of technical guidance documents, development of personal computer software, and presentation of workshops on control technology matters.

The technical guidance projects, such as this one, focus on topics of national or regional interest that are identified through contact with State and local agencies. In this case, the CTC became interested in a rotogravure printing facility which had reduced their use of organic solvents in cylinder cleaning by the application of ultrasonic cleaning combined with an aqueous cleaning solution. This document discusses the general applicability of aqueous ultrasonic cleaning to the rotogravure printing process and other graphic arts process. It also identifies benefits and costs of ultrasonic cleaning.

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1.0 INTRODUCTION

This report evaluates the potential application of a new method for cleaning cylinders used in rotogravure printing. This method, ultrasonic cleaning, has the potential to reduce organic solvent use, volatile organic compound emissions, and solvent waste generation.

The ultrasonic cleaning method is based on the scrubbing action created by the passage of ultrasonic waves through a liquid cleaning medium. This method is now used in other industries to clean a wide variety of parts, assemblies, and finished goods. Among the benefits of ultrasonic cleaning are the speed of cleaning and the high level of cleanliness achieved. In addition, when an aqueous rather than solvent-based cleaning liquid is used, emissions of volatile organic compounds (VOC) from cylinder cleaning are eliminated and hazardous waste handling problems are reduced.

The rotogravure printing process is typically used only for printing where high quality is required because rotogravure cylinders are very expensive to produce. Due to their high cost, cylinders are frequently reused as long as possible. However, cylinders must be thoroughly cleaned between runs or prior to storage in order to maintain high print quality.

In a typical rotogravure process, the printing cylinders are manually or mechanically cleaned using an organic solvent. However, at least one facility is now using aqueous ultrasonics to clean rotogravure printing cylinders. Aqueous ultrasonic cleaning may be applicable to all rotogravure printing operations which reuse cylinders such as the flexible packaging industry, vinyl printing, wallpaper printing and other decorative printing operations. It may also be applicable to other types of printing operations as well. The benefits of the increased application of ultrasonic cleaning would be a reduction in solvent use and VOC emissions from graphic arts processes.

This report presents findings of a study on the aqueous ultrasonic cleaning of rotogravure printing cylinders. Section 2.0 presents a short review of ultrasonic cleaning. Section 3.0 describes the rotogravure printing process and the potential application of aqueous ultrasonic cleaning for cylinder cleanup. Section 4.0 discusses the potential application of ultrasonic cleaning to other graphic arts processes.

2.0 DESCRIPTION OF ULTRASONIC CLEANING

2.1 INTRODUCTION

Ultrasonic cleaning can be used to clean parts, assemblies, and finished goods. It is primarily used to meet precision cleaning requirements during product manufacture or equipment maintenance. Industries which have successfully applied ultrasonics include the medical, optics, electronics, electroplating, graphic arts, transportation, textile, plastics, glass, instrument, communications, automotive, aircraft, jewelry, paper, sporting goods, and metal cleaning industries. Ultrasonic cleaning is used on parts as small as rings and switch contacts to as large as 21 foot printing rolls, and jet engine and other aircraft parts. Ultrasonic cleaning equipment is available from industrial equipment manufactures and vendors of cleaning solutions.

2.2 PROCESS DESCRIPTION

The ultrasonic cleaning method is based on the use of ultrasonic waves (sound waves whose frequency is over 18 kHz) in a liquid medium. During ultrasonic cleaning, alternating zones of high and low pressure are generated when ultrasonic waves pass through the cleaning solution. In areas of low pressure, microscopic bubbles of vapor form because the pressure has dropped below the vapor pressure of the liquid. These areas of low pressure become high pressure areas a half-cycle later. Under high pressure, the vapor bubbles implode, generating a localized, but highly intense shock wave. This process of alternating high and low pressure formation is called cavitation. It is the cavitation that produces the scrubbing action in an ultrasonic cleaning system.

A simplified ultrasonic cleaning system is shown in Figure 2-1. All ultrasonic cleaning systems contain three basic elements: a generator, a transducer, and a tank containing the cleaning liquid. The generator produces high frequency electrical current. The electric current is

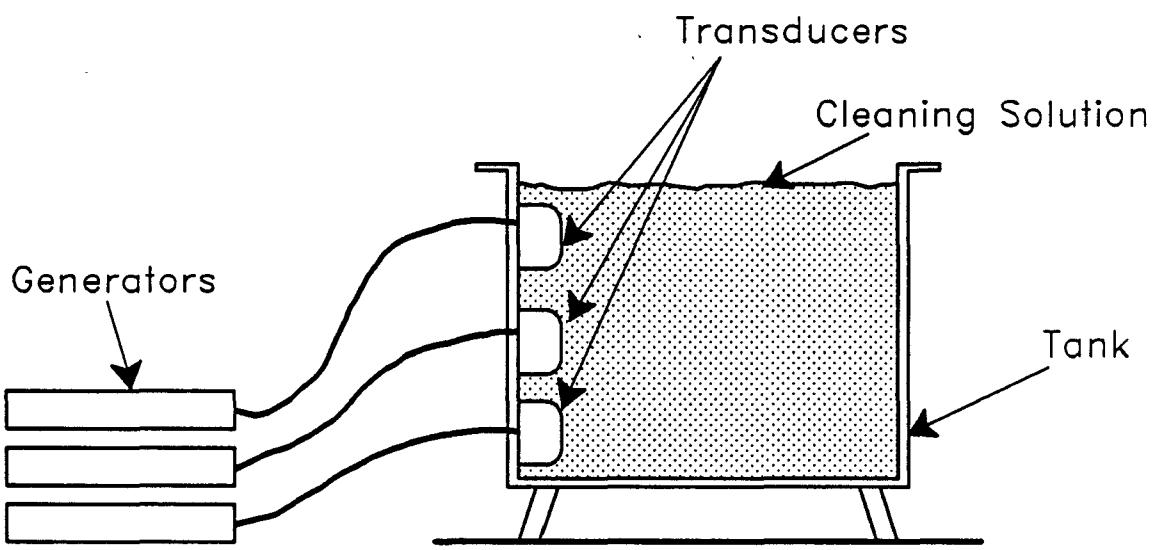

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Figure 2-1. Simplified ultrasonic cleaning system

converted into mechanical vibrations by the transducer. Transducers are usually placed on the bottom or sides of the tank. They can be bonded to the tank exterior or sealed in an immersible stainless steel container and attached to the tank interior. Figure 2-1 shows the immersible type of transducer.

There are two basic types of transducers used for ultrasonic cleaning: magnetostrictive and piezoelectric. The selection of transducer type is based on vendor preference. For industrial cleaning purposes, transducers generally operate at ultrasonic frequencies of less than 60 kHz (60,000 cycles per second).[1] Frequencies of about 20 to 40 kHz are common.

In its simplest form, an ultrasonic cleaning system includes a single ultrasonic tank (Figure 2-1). More complex systems incorporate other stages of cleaning as well. For example, conveyorized systems are available that automatically move parts through various cleaning stages such as rinsing, cleaning, and drying.[2] Another type of system, called a carousel, moves parts through multiple cleaning stages in rotating baskets. The parts are placed in baskets suspended from arms extending from a central column. As the arms rotate around the central column, the baskets move from one cleaning stage to another.[2] Systems are also available to clean continuous strip materials. In these systems, the material to be cleaned runs from a feed spool to a take up spool. It passes through a tank with opposed transducers at different frequencies that are approximately 1/2 to 3 inches apart. The opposed transducers create an intense ultrasonic field which allows the part to be cleaned during the short time period that the part is actually submerged in the tank.

2.3 FACTORS AFFECTING PERFORMANCE

Numerous factors affect the successful application of an ultrasonic system. One important factor is the ultrasonic power. At any specific frequency, it requires a certain power input to the transducer(s) in order to reach point at which cavitation begins. The power input beyond that required to initiate cavitation is the power available for cleaning.[3]

The greater the power input, the shorter the cleaning time. However, too much power may damage the parts to be cleaned. Determination of the optimum power levels is typically done by the equipment or cleaning solution vendors based on testing using specimens of the actual parts which will be cleaned. When delicate parts are being cleaned, variacs should be designed into the system to allow for the appropriate power level to be set. It is always advisable to conduct actual tests on the items to be cleaned prior to purchasing equipment.

A second factor is the ultrasonic frequency. At a constant power level, the cavitation intensity decreases as the ultrasonic frequency increases. Higher frequencies can provide less intense cavitation and, therefore, gentler and more penetrating cleaning. To achieve the same cavitation intensity when the frequency is increased, more power must be supplied.[4] The optimum frequency may also be affected by the cleaning solution because different cleaning solutions have different cavitation thresholds.[5]

A third factor is temperature. In general, cleaning solutions are more effective as the temperature increases. However, as temperature increases the vapor pressure of the cleaning solution increases, causing the bubbles to have a higher vapor concentration. Vapor present in the bubbles reduces cavitation intensity. Therefore, increasing the temperature of the cleaning solution reduces cavitation. In practice there is a temperature where the combination of cleaning solution effectiveness and cavitation intensity are optimized. This is usually no higher than $30^{o}F$ below the boiling point of the cleaning solution.[5]

The presence of dissolved gas in the cleaning solution will reduce the performance of ultrasonic cleaning. For this reason, the solution should be degassed prior to its first use. This can be accomplished by heating the solution, operating the ultrasonic system to drive off the gas, or adding a degassing agent.[3]

Other factors influencing the performance of an ultrasonic system include: the design and composition of baskets, the placement and design of parts to be cleaned, the position of transducers, the duration of part exposure, and the modulation of the sonic field. For example, parts with blind holes must be rotated to remove all air from the holes, otherwise the

cleaning solution will not contact the entire surface and any portion of the part not contacted by the cleaning solution will not be cleaned. Ultrasonic sound will not pass from liquid into or through gas.[3] However, as long as all the part surface contacts the solution, ultrasonic cleaning is especially effective compared to hand scrubbing for parts that have intricate designs, engraving, or small nooks and crannies.

As shown in Table 2-1, ultrasonic cleaning is applicable to a wide variety of soils and types of parts. The materials which can be cleaned include metals, plastics, and rubber. However, plastic and rubber tend to attenuate sound which may reduce the effectiveness of ultrasonic cleaning.[3] As previously discussed, testing of the actual materials to be cleaned should always be performed prior to applying ultrasonic cleaning. The soils which are removable include oils, dust, various particulates, buffing and polishing compounds, and mold release agents.

The selection of the proper cleaning solution is of primary importance for the successful application of ultrasonic cleaning. The cleaning solution must be able to remove the soil of concern and must not react with the surface to be cleaned. In addition, the solution must be easily removable from the cleaning surface. As shown in Table 2-1, both aqueous- and solvent-based solutions are used for ultrasonic cleaning. For some applications, only aqueous solutions clean effectively, whereas for some other applications, only solvent systems clean effectively. In many cases, however, both aqueous and solvent systems are available for use. For example, Table 2-1 shows that atmospheric soils can be removed from plastic parts using either the solvent trichlorotrifluoroethane or an aqueous solution of mild alkaline detergent. The selection of solvent-based solutions is less desirable because of the potential for emissions of volatile organic compounds and the adverse environmental impacts of solvent disposal. Also, use of some organic solvents may be banned due to the Montreal accords.[3] However, even if a solvent solution is required for a particular application, using ultrasonics allows the cleaning vessel to remain closed and offers an alternative to the labor intensive methods such as hand scrubbing.

Once the proper cleaning solution is selected, other properties of the cleaning solution must be considered in selecting the design parameters of the ultrasonic system. These properties of importance include the solution

TABLE 2-1. POTENTIAL APPLICATIONS FOR SELECTED CLEANING SOLUTIONS[a]

Cleaning assignment	Soils	Cleaning method	Solvent/solution
Brass parts	Atmospheric soils	Ultrasonic immersion; immersion rinse; dry	Mild acidic detergent; tap water
		Vapor rinse; ultrasonic immersion; solvent spray rinse; vapor rinse	Methylene chloride
Aluminum parts	Grease, oils, particulate	Vapor rinse; ultrasonic immersion; solvent spray rinse; vapor rinse	Stabilized blend of trichlorotrifluoroethane and methanol
Nickel parts	Forming and cutting lubricants particulates	Vapor rinse, ultrasonic immersion; solvent spray rinse; vapor rinse	Perchloroethylene, methylene chloride or 1,1,1-trichloroethane
		Ultrasonic immersion; immersion rinse; dry	Strong, chelated alkaline detergent; tap water
Steel, mild	Grease, oils, particulates	Vapor rinse; ultrasonic immersion; solvent spray rinse; vapor rinse	Methylene chloride, azeotrope of trichlorotrifluoroethane and methylene chloride or 1,1,1-trichloroethane
Steel, stainless	Buffing and polishing compounds	Ultrasonic immersion; immersion rinse; dry	Soap-free alkaline cleaner; tap water
		Ultrasonic immersion; solvent spray rinse; vapor rinse	1,1,1-trichloroethane, or stabilized blend of trichlorotrifluoroethane and methanol
Titanium	Machining oils, particulates	Ultrasonic immersion; immersion rinse; dry	Alkaline cleaner; chloride-free rinse water
Plastic parts, miscellaneous	Atmospheric soils	Ultrasonic immersion; rinse; dry	Mild alkaline detergent; tap water
		Vapor rinse; ultrasonic immersion; solvent spray rinse; vapor rinse	Trichlorotrifluoroethane
Polypropylene	Mold release agents	Vapor rinse; ultrasonic immersion; solvent spray rinse; vapor rinse	Trichlorotrifluoroethane
Rubber, neoprene	Mold release agents	Vapor rinse; ultrasonic immersion; solvent spray rinse; vapor rinse	Stabilized blend of trichlorotrifluoroethane and methanol
Rubber molds	Carbonized rubber residues, release agents	Presoak; ultrasonic immersion; spray rinse; dry	Strong alkaline detergent and tap water; or specialized strippers
Bearings	Oil, dust, lint	Ultrasonic immersion; boiling immersion; ultrasonic immersion; solvent spray-rinse; vapor rinse	Blend of trichlorotrifluoroethane and surfactant/water emulsion; trichlorotrifluoroethane

Source: Reference 1.

[a]Note that some of the organic solvents shown in this table may soon be banned due to the Montreal Accords.

surface tension, viscosity, vapor pressure, density, and dissolved gas content. Determination of the optimum system frequency, power levels, temperature and other parameters depends on the cleaning solution properties and is usually based on actual testing performed by the vendors.

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3.0 ROTOGRAVURE PRINTING AND AQUEOUS ULTRASONIC CLEANING

3.1 ROTOGRAVURE PRINTING PROCESS

Gravure is distinguished from other printing methods by the nature of the image surface. The method is often referred to as the "intaglio" process. The surface of the gravure printing cylinder is etched or engraved with many tiny recesses (cells). The depth of each cell determines the amount of ink that will be applied to the substrate at that point.[1]

Rotogravure is the most widely used gravure printing process. A six color (unit) rotogravure printing press is illustrated in Figure 3-1. In rotogravure, or web-fed gravure, a continuous web of paper is fed from a roll and passed over the image surface of a revolving printing cylinder. A web-fed rotogravure printing press typically consists of 5 to 8 printing units.[2] All units of a press must be of the same size and width. In addition, all the units must simultaneously operate at the same press speed. Each unit handles an individual color of ink and prints on only one side of the web.[1]

An expanded diagram showing an end view of an individual printing unit is presented in Figure 3-2. The web is woven through a series of rollers which precisely adjust its path through the press. The rollers also help regulate the paper tension and maintain constant speed. The web is guided between the revolving gravure printing cylinder and a rubber roller. The substrate is pressed against the image surface of the gravure cylinder by the rubber roller, which serves as a backing. Pressure is applied to the rubber roller by a pressure cylinder. The point of contact between the web and the gravure cylinder is called the "nip" area.[1]

Each printing unit has its own ink handling system. In a mixing tank (ink reservoir), the raw ink is diluted with additional solvent or extender to achieve the desired viscosity. The mixture is then continuously circulated through the ink fountain and back to the mixing tank. This circulation prevents the ink pigments from settling out of the mixture. Solvent is periodically added to the ink fountain to replace fugitive losses.[1]

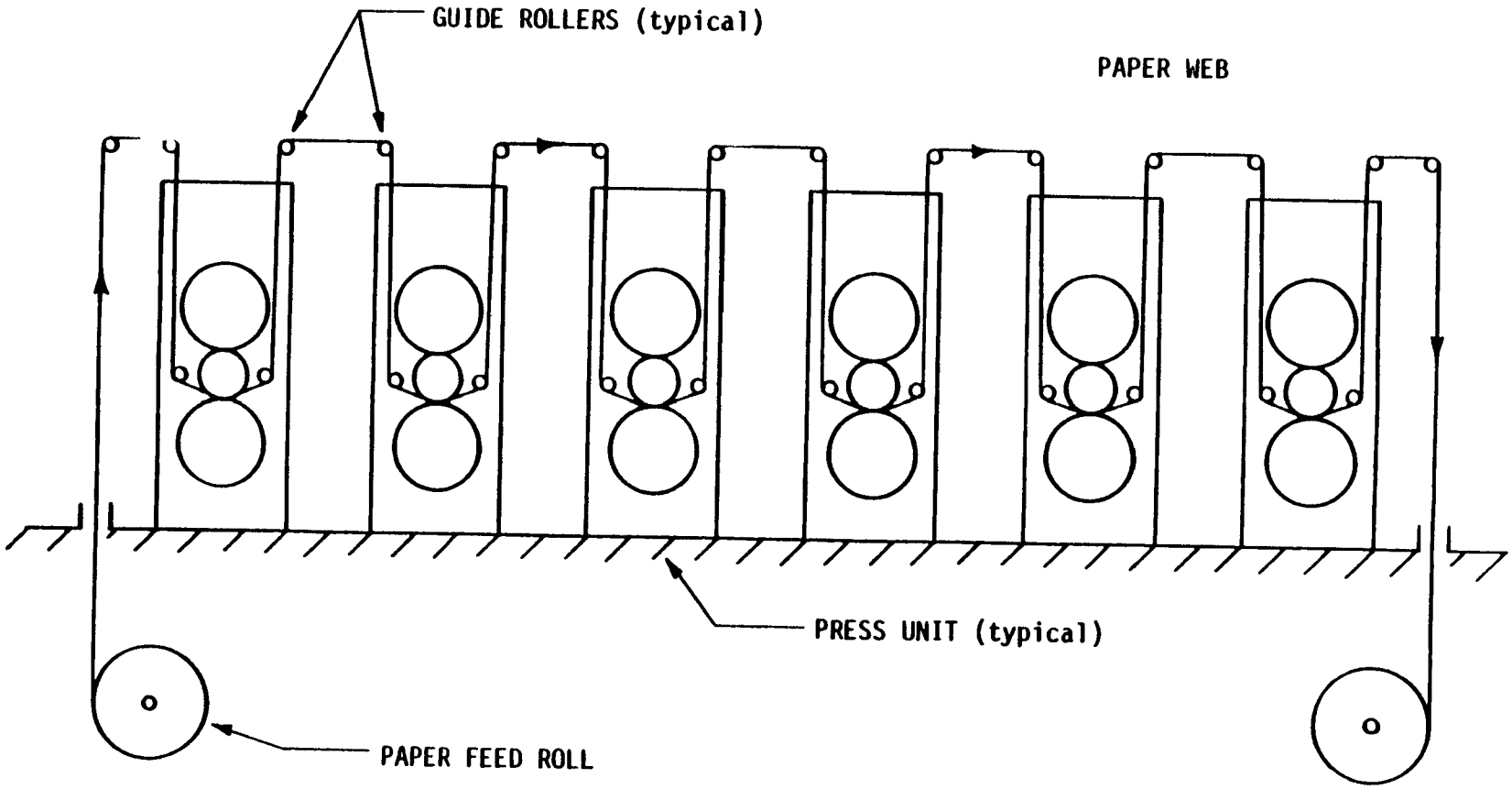

Figure 3-1. Six color rotogravure printing press

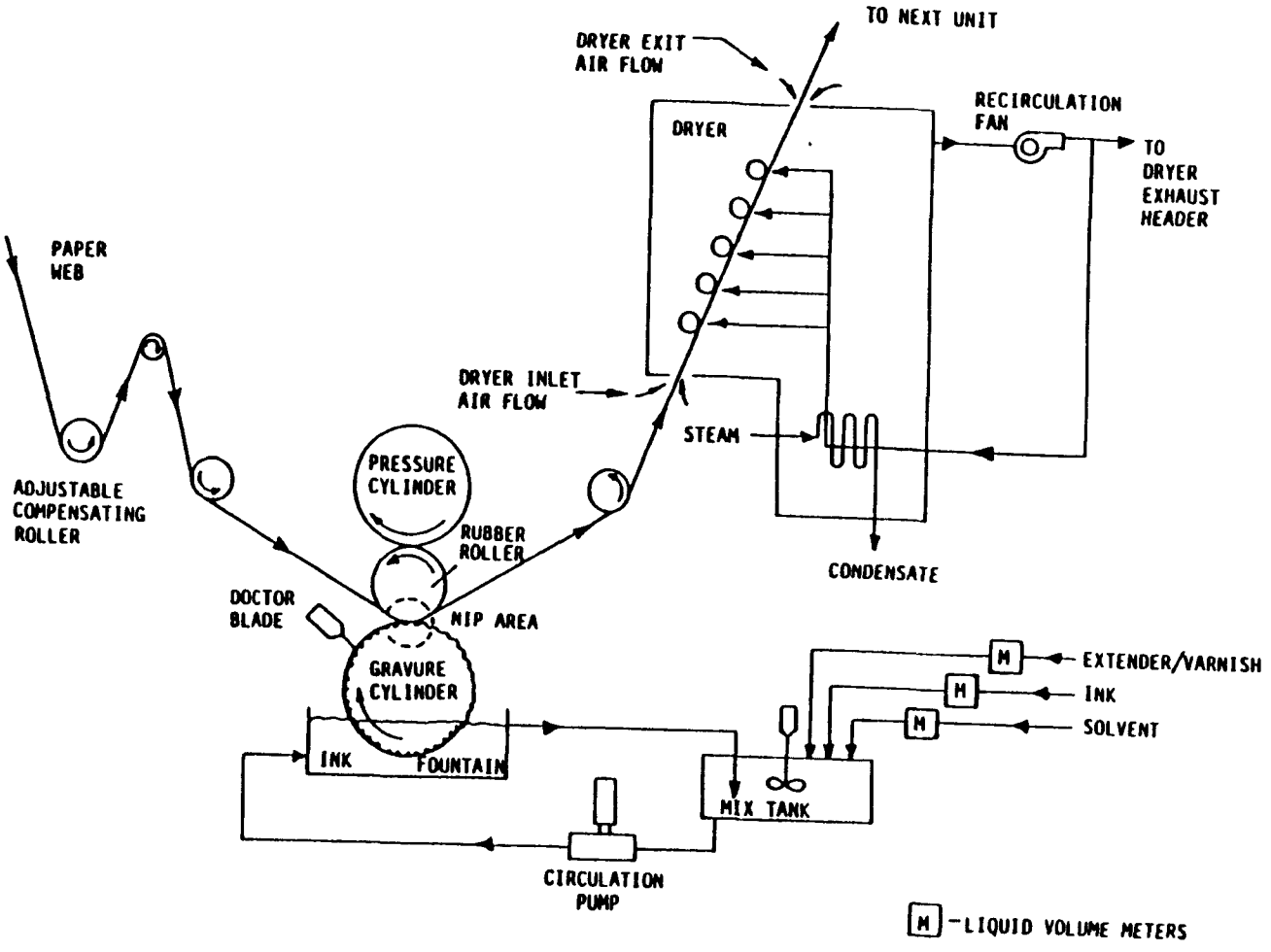

Figure 3-2. Diagram of a rotogravure printing unit

The gravure cylinder, on which the image surface has been etched, is about one-fourth submerged in a trough of ink called the ink fountain. Before a portion of the gravure cylinder contacts the substrate, it picks up ink from the ink fountain and is then scraped by a flexible "doctor blade". This blade removes ink from the smooth non-image surface, but leaves ink in the cells. These ink laden cells contact the substrate to form the image.[1]

After ink has been transferred to the substrate, the substrate travels up through an enclosed dryer where jets of heated air evaporate the volatile solvent. The web exits the top of the dryer and is guided along rollers to the next printing unit. In a typically controlled facility, the exhaust from all the dryers are gathered in a header, and directed to a carbon adsorption system or an incinerator. In an uncontrolled plant, the dryer exhaust is vented to the atmosphere.[1]

3.2 CONVENTIONAL CLEANING METHODS

After a job has been completed (or at least when the ink color is changed), all parts that come in contact with the ink must be thoroughly cleaned. These parts include the ink pans, ink reservoirs, pumps, doctor blades, and printing cylinders. Depending on the facility, parts may be left on the press or removed from the press for cleaning. At facilities leaving parts on the press for cleanup, rollers, pumps and ink pans are generally washed down with solvent. In addition, the printing cylinder may be manually scrubbed with a brush. At facilities removing parts from the press for cleanup, parts are generally placed in a tank, immersed in solvent, and soaked or manually scrubbed. Cylinders frequently require scrubbing with a brush. Some facilities do a combination of on-press and off-press cleaning. For example, the printing cylinder may be cleaned off the press and all other parts may be cleaned on the press; or, the cylinder may be wiped first while still on the press and then removed from the press for additional cleaning. Alternate cleaning methods, such as aqueous detergent solutions, agitated caustic baths, and solvent degreasers are also used at some rotogravure printing facilities. The prevalence of these methods within the rotogravure industry is unknown.

3.3 AQUEOUS ULTRASONIC CLEANING OF ROTOGRAVURE PRINTING CYLINDERS

3.3.1 Process Description

Ultrasonic cleaning with an aqueous solution is one potential alternative to conventional solvent-based cleaning methods used for rotogravure printing cylinders. In this method, the dirty cylinder is removed from the press and placed in a tank containing an aqueous detergent solution. The solution is then sonicated for a brief period (usually a few minutes). For more difficult cleaning jobs, the sonication period may be extended or repeated. Because the cylinder must be cleaned over its entire surface, the cylinder must be rotated during cleaning. The simplest and cheapest tanks allow the cylinder to be manually rotated on its support. More sophisticated tanks are equipped with an automatic mechanism to slowly rotate the cylinder. After cleaning, the cylinder is moved to a rinsing tank, where it is rinsed with clean water. After rinsing, the cylinder is dried using air drying or some other method such as compressed air or hand drying with towels. The cylinders are usually hot when they come out of the cleaning bath; when rinsed with hot water (and sometimes with cold water), they tend to dry quickly.

The optimum frequency, power levels, cleaning time and other parameters of the ultrasonic system are usually based on actual testing performed by the vendors on the parts to be cleaned. An ultrasonic system must be properly designed to prevent damage to the cylinder being cleaned. If power levels are too high, for example, the cylinder surface may be damaged due to cavitational erosion. Well designed systems will include a variac to allow a reduction from full power when delicate parts are being cleaned. Rotogravure cylinders engraved using photoresist acid etch tend to be more delicate than mechanically engraved cylinders.[5]

The general applicability of an aqueous system for rotogravure cylinders must also be considered. Two factors are of primary concern: (1) whether rotogravure cylinders are damaged by water immersion, and (2) whether the cylinders are difficult to dry (i.e., would require thorough drying at high cost). Neither of these factors appears to be a problem for rotogravure cylinders.

3.3.2 Benefits

Conversion to aqueous ultrasonics offers many benefits (Table 3-1). For example, potential environmental hazards associated with the use of solvents are avoided. Use of the aqueous solution reduces solvent emissions from the plant and worker exposure to solvent. Lack of solvent reduces fire hazards in the cleanup area. In addition, many detergent solutions are available that are biodegradable and nonhazardous. Use of these solutions not only ensures worker safety, but minimizes waste disposal problems. When the printing inks used do not contain metals or other hazardous ingredients, these solutions can generally be flushed directly to the sewer. In contrast, spent solvent used for cleanup always produces a hazardous waste.

Another major benefit is that cylinder cleanup is faster and less labor intensive.[3,4] This not only reduces time and labor spent on cleanup after a job has been completed, but can reduce downtime during a printing run. For example, if a problem occurs at the beginning or during a run due to a dirty cylinder, the cylinder can be quickly cleaned and the press returned to service in minimal time.

Improved product quality can also result from the more effective cleaning achieved by the ultrasonic system. For example, ultrasonic systems effectively remove waterborne inks, which are characteristically difficult to clean. Because cleaning is more uniform and thorough, problems of poor print quality due to ink buildup can be reduced. In addition, cylinder cleaning performed on the press can be less thorough or even eliminated. The rotogravure facility mentioned in the introduction switched to ultrasonic cleaning mainly to improve product quality.[3]

3.3.3 Costs

The disadvantage of an ultrasonic system is its capital cost relative to using simple tanks. Based on discussions with equipment vendors, an ultrasonic system could cost from roughly $10,000 to $150,000, depending largely on the tank size required as well as on other design features of the system. In some cases, it may be beneficial to lease the equipment.[6]

TABLE 3-1. POTENTIAL BENEFITS AND DISADVANTAGES OF AQUEOUS ULTRASONIC CLEANING OF ROTOGRAVURE PRINTING CYLINDERS

Benefits	Disadvantages
Reduces solvent use	High capital cost relative to other cleaning methods
Reduces solvent emissions	
Reduces worker exposure to solvent	Waste disposal costs per gallon of waste may increase if ink residues or detergent produce a hazardous waste.
Minimizes solvent waste disposal problems	
Detergent solutions that are biodegradable and non-hazardous and inks that do not contain metals or other hazardous ingredients can be directly sewered.	
Reduces time and labor spent on cylinder cleanup	
Reduces downtime during printing run	
Cleans more effectively	
Reduces problem of poor print quality due to ink buildup on cylinders	

Because the cost of purchasing an ultrasonic system is potentially high, the use of ultrasonics would be less beneficial at facilities where cylinders are not reused or are cleaned infrequently due to long printing runs. In rotogravure publishing, for example, installation of an ultrasonic system would be less beneficial because printing cylinders are rarely reused.

The primary operating cost of an aqueous ultrasonic system is the cost of chemicals purchased for the cleaning solution. This cost is influenced by the volume of parts to be cleaned and by how often the solution needs to be changed. Because the dirt cleaned from each part remains in the tank, each part cleaned enters a dirtier tank than the part cleaned previously. Consequently, one factor influencing the frequency of cleaning solution changes is the amount of dirt on each part and how clean the parts need to be. In addition, the tank may need to be cleaned periodically due to a buildup of ink solids on the transducers if they are on the bottom of the tank. Locating the transducers on the sides of the tank will reduce solids buildup on transducer surfaces.

After the installation of an aqueous ultrasonic system, operating costs for cylinder cleanup would be expected to decrease. A facility would no longer need to purchase solvent for cylinder cleanup. Instead, the facility would purchase aqueous detergent solution. The detergent solution would probably cost much less annually than the solvent previously purchased. Thus, the operating costs would be expected to decrease. The magnitude of the cost reduction, however, would be facility-specific.

The effect of an aqueous ultrasonic system on the costs of waste disposal also varies from plant to plant. The cost for disposal of the spent aqueous solution depends on the type of waste treatment required. It is important to note that both the nature of the cleaning solution and the soil being removed must be considered. A solution that contains biodegradable detergent, no hazardous ink residues, and is nearly neutral in pH, generally requires no treatment and can be flushed directly to the sewer. A solution that contains non-biodegradable detergent or hazardous ink residues (such as certain metallic pigments) must be sent to an appropriate treatment facility. Solvent wastes, in contrast, must always be treated as hazardous wastes.

After installation of aqueous ultrasonics, waste disposal costs would be expected to decrease for facilities using biodegradable detergents and inks with nonhazardous ingredients. At facilities where the spent aqueous solution would require treatment, the change in waste disposal costs would depend on the relative amount of waste generated and the relative costs of waste disposal before and after the application of ultrasonics. Based on one facility now using aqueous ultrasonics, the volume of aqueous waste generated is expected to be less than the volume of solvent waste. However, the disposal of hazardous aqueous wastes can be more expensive per gallon than solvent wastes. Therefore, the cost of waste disposal may increase at some facilities.

3.4 HYPOTHETICAL CASES DEMONSTRATING IMPACTS OF APPLYING AQUEOUS ULTRASONIC CLEANING

Two examples were developed to illustrate the potential effect of aqueous ultrasonics on hypothetical rotogravure facilities. In Example 1, the presses have a 16 foot printing width. Production is characterized by short (less than 8 hours) production runs. In Example 2, the press print width is approximately 2 feet. Production runs are much longer than in Example 1, but because the facility has more presses, the same number of cylinders are cleaned each day.

Tables 3-2 and 3-3 present estimates of solvent emissions, waste generation, and costs for cylinder cleanup before and after the installation of an aqueous ultrasonic system for Examples 1 and 2, respectively. The parameters for Example 1 and Example 2 are based on phone conversations and two site visits. Neither example, however, is intended to represent any particular facility. Each example is described in more detail below.

3.4.1 Example 1

Example 1 has 2 rotogravure presses. Run lengths are generally less than 8 hours. The printing cylinders have a 16 foot etched surface and a total length of about 20 feet. The facility cleans about 48 of these cylinders/day.

TABLE 3-2. HYPOTHETICAL ROTOGRAVURE FLOOR COVERING FACILITY BEFORE AND AFTER THE INSTALLATION OF AN AQUEOUS ULTRASONIC SYSTEM FOR CLEANING PRINTING CYLINDERS

Parameter	Before	After
Plant Characteristics		
No. of presses	2	2
No. of stations	6	6
Run length (h)	<8	<8
Hours of operation (h/yr)	6,000	6,000
Cylinder length (ft)	20	20
No. cleanups/day/press	4	4
No. cylinders cleaned/day	48	48
Cleanup Solvent		
Use (gal/yr)	40,000	0
Atmospheric emissions (lb/yr)	130,000[a, b]	0
Waste generated (gal/yr)	20,000[b]	0
Aqueous Cleanup Solution		
Detergent use (gal/yr)	NA	700
Waste generated (gal/yr)	NA	5,400
Costs		
Capital cost of ultrasonic system ($)		80,000
For solvent purchase ($/yr)	110,000[a, c]	0
For aqueous detergent purchase ($/yr)	NA	5,600[e]
For solvent waste disposal ($/yr)	6,000[d]	0[f]
For aqueous solution disposal ($/yr)	NA	0
For cylinders saved per year ($/yr)	NA	(12,000)[g]

[a] Assume solvent = MEK.
[b] Estimated based on assumption that 50% of solvent used is emitted to atmosphere and 50% is disposed of as waste.
[c] Based on $0.40/lb for MEK in 1988.
[d] Assumes solvent disposal costs $0.3/gal solvent waste.
[e] Assumes concentrated detergent solution costs $8/gal.
[f] Assumes spent aqueous solution does not require treatment prior to disposal (i.e., can be flushed down sewer).
[g] Parentheses indicate cost savings. Assumes that cylinder dechroming/rechroming costs $1,200/cylinder, and that 10 cylinders/yr no longer need to be dechromed/rechromed.

TABLE 3-3. HYPOTHETICAL ROTOGRAVURE FLEXIBLE PACKAGING FACILITY BEFORE AND AFTER THE INSTALLATION OF AN AQUEOUS ULTRASONIC SYSTEM FOR CLEANING PRINTING CYLINDERS

Parameter	Before	After
Plant Characteristics		
No. of presses	4	4
No. of stations	6	6
Run length (h)	12	12
Hours of operation (h/yr)	6,000	6,000
Cylinder length (ft)	3	3
No. cleanups/day/press	2	2
No. cylinders cleaned/day	48	48
Cleanup Solvent		
Use (gal/yr)	8,000	0
Atmospheric emissions (lb/yr)	27,000[a, b]	0
Waste generated (gal/yr)	4,000[b]	0
Aqueous Cleanup Solution		
Detergent use (gal/yr)	NA	140
Waste generated (gal/yr)	NA	1,100
Costs		
Capital cost of ultrasonic system ($)		30,000
For solvent purchase ($/yr)	22,000[a, c]	0
For aqueous detergent purchase ($/yr)	NA	1,100[e]
For solvent waste disposal ($/yr)	1,200[d]	0
For aqueous solution disposal ($/yr)	NA	1,300[f]

[a] Assume solvent = MEK.
[b] Estimated based on assumption that 50% of solvent used is emitted to atmosphere and 50% is disposed of as waste.
[c] Based on $0.40/lb for MEK in 1988.
[d] Assumes solvent disposal costs $0.3/gal solvent waste.
[e] Assumes concentrated detergent solution costs $8/gal.
[f] Assumes spent aqueous solution is hazardous and four times as expensive to dispose of per gallon as solvent waste.

The capital cost of the aqueous ultrasonic system for this facility is estimated to be about $80,000. This is an order of magnitude cost estimate only, and is based on the average of cost estimates received from equipment vendors. The capital cost of an ultrasonic system for any particular facility would depend on that facility's specific needs.

When this facility installs aqueous ultrasonics, atmospheric emissions of solvent from cylinder cleanup are reduced by an estimated 130,000 lb/yr. This assumes total cleanup solvent use for cylinder cleaning is reduced by 100 percent, and that half of the solvent originally used for tank cleanup evaporated. In addition, the hazardous solvent waste generated by the facility is reduced by about 20,000 gal/yr. The spent aqueous waste generated by the facility is assumed to require no treatment and is dumped directly to the sewer.

The facility previously spent about $110,000/yr to purchase cleaning solvent and about $6,000/yr to dispose of waste solvent. The facility now spends about $5,600/yr to purchase cleaning solution and a negligible amount for solution disposal. Thus, the facility now saves about $110,000/yr in cleaning chemical purchasing and disposal costs. Because ultrasonic cleaning is more effective than the previous method, the problem of poor print quality resulting from ink buildup on the cylinder has been eliminated. Thus, the facility also saves $12,000/yr in cylinder dechroming/rechroming costs.

3.4.2 Example 2

Example 2 has 4 rotogravure presses. Run lengths are about 12 hours long. The total length of the printing cylinders is about 3 feet. The facility cleans about 48 of these cylinders/day. The capital cost of the aqueous ultrasonic system for this facility is estimated to be about $30,000. This is an order of magnitude estimate only and is based on the average of cost estimates received from equipment vendors. The capital cost of an ultrasonic system for any particular facility would depend on that facility's specific needs.

After installation of the aqueous ultrasonic system, atmospheric emissions of solvent from cylinder cleanup at the facility are reduced by an estimated 27,000 lb/yr. Solvent waste generated at the facility is reduced by

about 27,000 lb/yr, but aqueous waste is increased by 1,100 gal/yr. This facility is assumed to produce a hazardous aqueous waste that must be sent off-site for treatment and disposal.

The facility previously spent about $22,000/yr to purchase cleaning solvent and about $1,200/yr to dispose of waste cleaning solvent. The facility now spends about $1,100/yr to purchase the aqueous detergent and about $1,300/yr to dispose of the hazardous aqueous waste. Thus, the facility saves roughly $21,000/yr in cleaning chemical purchasing costs and spends roughly $100/yr more for waste disposal. This facility is assumed to not have a problem of poor print quality due to ink buildup, and thus, does not save any costs for cylinder dechroming/rechroming.

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4.0 ULTRASONIC CLEANING APPLIED TO OTHER GRAPHIC ARTS PROCESSES

4.1 INTRODUCTION

Aqueous ultrasonics may potentially be used in graphic art processes besides rotogravure depending on the nature of the process and the particular facility. This section discusses the potential application of aqueous ultrasonics in letterpress, lithography, flexography, and screen printing. Because of the limited data available, however, detailed examples were not developed.

4.2 APPLICABILITY OF AQUEOUS ULTRASONIC CLEANING

There are two questions which must be answered to determine whether aqueous ultrasonic cleaning is applicable to other graphic arts processes and what the benefits of ultrasonic cleaning would be. They are:

1) Are aqueous solutions combined with ultrasonic cleaning capable of removing the inks used without damaging the underlying materials?

2) Does the particular printing process being evaluated use a significant amount of solvent for cleanup and are the parts being cleaned removable from the press?

As long as sufficient care is taken to select an appropriate cleaning solution, it can be generally stated that aqueous ultrasonics should be able to remove inks used in all graphic arts processes. The exception to this may be a few specially formulated inks, such as caustic resistant inks used on kitchen wallpapers or detergent containers. To determine if a specific facility can use ultrasonic cleaning, tests should be performed using that facility's specific inks and cylinder or part materials. Because aqueous ultrasonic cleaning should be capable of removing most inks, the applicability and benefits of ultrasonic cleaning appear to be most dependent on the cleaning process itself.

In flexography, printing plates are generally not reused. However, other press parts are frequently cleaned and can be removed for cleaning.

Except for the rubber-faced fountain roll, aqueous ultrasonics could be used to clean these other press parts. For example, aqueous ultrasonics may be especially useful for the cleaning of engraved ink metering (or anilox) rolls. The major benefit of ultrasonics would be a reduction in cleanup time. The actual benefits realized would be facility-specific; the more cleanups required at a given facility (i.e., the shorter the run lengths), the more benefits from aqueous ultrasonics.

In addition, flexography is one sector of graphic arts which is moving fastest to replace solvent based inks.[1] Because ultrasonic cleaning appears to be ideally suited for waterborne inks, this factor would also tend to favor the use of ultrasonic cleaning in this sector of graphic arts.

Ultrasonic cleaning does not appear to be applicable to offset lithography. In this process, plates are generally not reused.[1,2] Other press parts are not dissembled for cleaning.

Detailed information on cleanup procedures for letterpress and screen printing was not obtained due to the fact that these processes make up a very small part of the total industry. Ultrasonic cleaning would appear to be applicable to letterpress since individual type letters are removed from the press and reused. Screens could also be cleaned using ultrasonics. However, the number of times screens are typically reused is likely to vary significantly from one facility to another.

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16. ABSTRACT

This report summarizes available information on the use of ultrasonic techniques (in an aqueous solution) for cleaning cylinders used in rotogravure printing processes Ultrasonic cleaning has the potential to reduce organic solvent use, volatile organic compound emissions, and solvent waste generation. The report briefly reviews the ultrasonic cleaning process, describes the rotogravure printing process and the potential application of aqueous ultrasonic cleanings for cylinders, reviews potential benefits and costs, and discusses the potential for application to other graphic arts processes.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
	Air Pollution Control Hazardous Air Pollutants Volatile Organic Compounds Flexographic Printing Ultrasonic Cleaning Rotogravure Printing Metal Cleaning Aqueous Cleaning	

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