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Aqueous Alkaline Cleaners: A Better Alternative

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Metal-finishing operations employ a variety of organic solvents for degreasing metal parts. Common solvents used in degreasing operations include trichloroethylene, 1,1,1-trichloroethane (TCA), and Stoddard solvent (referred to as PD-680 at military installations). Wastes generated by these solvents are listed by the U.S. Environmental Protection Agency as hazardous and are subject to current land-disposal restrictions. Long-term costs associated with disposal make continual use of organic solvents not economically feasible. The replacement of chlorinated and petroleum-based solvents with an environmentally safe cleaner would greatly relieve the financial burden of waste disposal.

An alternative to organic solvents is aqueous alkaline cleaners. Alkaline cleaning is an age-old technology, which has been employed extensively throughout industry. Recently, the use of alkaline cleaners has increased due to the growing awareness of environmental and personnel safety concerns associated with chlorinated and petroleum-based solvents. The properties associated with alkaline cleaners (nontoxic, nonvolatile, noncombustible, and biodegradable) make them environmentally acceptable alternatives for use in metal parts cleaning at many installations.

Is the replacement of organic solvents with alkaline cleaners a feasible solution for degreasing operations? This study analyzes this question by examining characteristics of alkaline cleaners to determine the economical and environmental benefits. Based on previous case studies, an economic analysis, and current literature concerning alkaline cleaners, conclusions will be drawn regarding the use of alkaline cleaners in metal cleaning processes.

CHEMICAL PROPERTIES

Alkaline cleaners vary depending on the cleaning application, type, and relative concentration of their constituents. Generally, alkaline cleaners are composed of builders and surfactants. Builders are alkalis that provide the alkaline reserves and dispersion properties that assist in neutralizing acidic soils and soil removal. Surfactants provide the wetting and emulsification properties that lower surface and interfacial tension and prevent soil redeposition.[1]

Common builders used in alkaline cleaners are sodium hydroxide and potassium hydroxide. These builders produce high-alkaline solutions with pH values ranging from 13 to 14. The cleaning ability of these alkalis is poor for nonsaponifiable soils. Saponification is the reaction of any free alkali with animal or vegetable fats or with fatty acids, which can be obtained by hydrolysis of fats.[2] The resulting product is commonly known as soap. These alkalis should, therefore, be used when saponifiable compounds in the grease film are high. This leads to a fast reaction with the contaminant, creating a high concentration of soap and improving the cleaning and soil carrying capacity of the cleaner. Strong alkaline cleaners are commonly used for iron/steel. Metals such as zinc, aluminum, copper, and brass are corroded by strong alkalis and usually are cleaned with a milder alkaline solution.

Silicate builders are also used in alkaline cleaning solutions. Typical species of silicates used in cleaners are sodium orthosilicate and sodium metasilicate. These silicates develop alkalinity through hydrolysis. Hydrolysis is a process of "decomposition" in which products react with water to produce a weak acid and a weak base. In this case, the silicates decompose to form silicic acid and free alkali. The silicic acid in a colloidal state possesses excellent solid-soil dispersion and emulsification properties.[1] The free alkali creates an alkaline reserve, which acts as a buffer for the solution. During the cleaning process, silicates can adsorb onto certain metals (e.g., aluminum, zinc, and steel), forming a thin film. The protective coating inhibits corrosion from occurring in the alkaline solution.

Phosphates are typically used in cleaners in the form of pyrophosphate, orthophosphate, or polyphosphates. The addition of phosphates in a cleaner is not to provide alkalinity. Instead, phosphates are added to increase the sequestering properties of the solution. In addition, phosphates have the ability to soften water in the solution and to partly remove metal oxides and hydroxides from the substrate surface.[2]

Carbonates are alkaline builders that can be found in milder alkaline products. Carbonates possess good buffering qualities, which help stabilize the pH of the solution as it is cleaning; however, carbonates do not provide the same detergent qualities found in other builders (i.e., dispersion and prevention of soil redeposition).

Surfactants are typically synthetic detergents that are combined with alkalis to lower surface and interfacial tensions and to increase cleaning efficiency. There are three major classes of synthetic detergents: anionic, cationic, and nonionic.[1,3,4] Anionic surfactants possess a negative charge on the surface-active ion. The charge is localized to the hydrophilic functional group, which may be of the sulfonate, sulfate, carboxylate, or phosphate group bonded to the hydrophobe. Nonionic surfactants carry no charge on the surface-active species. The water-soluble parts of the molecule are usually polyalkylether chains with a high affinity for water. Such chains are introduced to the molecule by condensation of ethylene oxide with a reactive

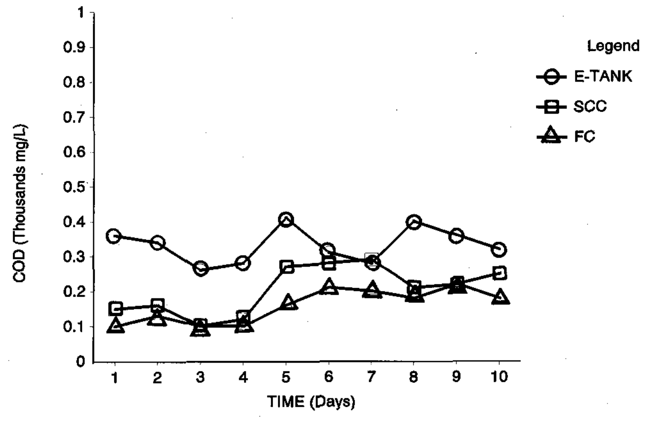

Figure 1. COD concentrations during Cleaner A pilot plant study (24-hr average).

end group on the hydrophobe. Nonionics have solubilities that increase and decrease with temperature and that can be raised by mixing with an anionic surfactant. Cationic surfactants possess a positive charge on the active species. Generally, this class of surfactant is not used in metal cleaning due to high cost, incompatibility with anionic surfactants, and the ability to strongly adsorb to metal surfaces. The last property has detrimental effects on process results.

The main function of surfactants is to improve the detergency of the alkaline cleaning solution. The mixture of surfactant and alkali used depends on the type of cleaning required.

Complexing agents represent another class of compounds that are added to alkaline cleaners. The agents are added to avoid undesired precipitation of scale-producing substances, to eliminate staining, activate metal surfaces during the cleaning operation, and to soften water.[2] Typical classes of complexing agents consist of alkanolamines, gluconates, polycarboxylic acids, and phosphonates.

BIODEGRADABILITY

In general, manufacturers of alkaline cleaners claim their products are biodegradable and can be discharged to storm sewers or receiving waters after the cleaning solution has been neutralized at a wastewater treatment facility. Numerous agencies have performed case studies on alkaline cleaners to verify manufacturers' claims. Recently, a study was conducted at Tinker Air Force Base by Idaho National Engineering Laboratory to find a suitable biodegradable cleaner to replace halogenated and nonhalogenated solvents currently used by the Air Force.[5] Preliminary testing narrowed the field to four cleaners, two of which were alkaline. Extended tests were then performed on the four solvents to ensure they met the proper performance specifications.

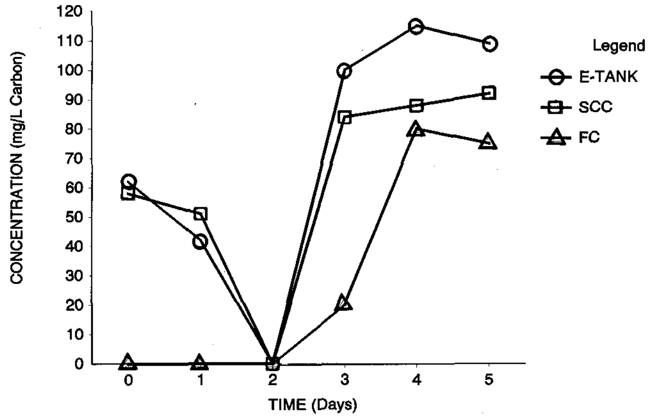

Figure 2. TOC concentrations during Cleaner A pilot plant study (24-hr average).

To determine if these cleaners were biodegradable, biological acclimation tests were performed to examine the effect of the cleaners on an activated sludge wastewater treatment facility. The biological analysis was divided into two phases. The first phase involved performing a series of 8-day acclimation tests to determine if microorganisms would adjust and degrade the cleaners. The second phase was a pilot scale study at a wastewater treatment plant to observe the effects the cleaners have on the system. The results are discussed below.

Cleaner A is a typical example of a mild alkaline degreaser available in the market today. During the 8-day acclimation tests, the microorganisms were able to degrade the solvent adequately. This was evident by the observed reduction in the chemical oxygen demand (COD) and the total organic carbon (TOC); however, during the pilot plant study, Cleaner A did biodegrade. A gas chromatography analysis performed on the effluent clearly detected cleaner coming out of the final clarifier. The COD concentrations showed no significant increases or decreases in the system (see Fig. 1).[5] The TOC concentrations fluctuated widely, but some reductions were observed between the equalization tank (E-tank), solid contact clarifier (SCC), and final clarifier (FC) (see Fig. 2).[5]

The presence of phenol in the waste stream prevented the biodegradation of the cleaner. Microorganisms in the activated sludge were selectively feeding on the phenol and ignoring the cleaner as a food supply. As a result, while phenol was present in the waste stream, the microorganisms would not be able to acclimate and degrade the alkaline cleaner. A possible solution to this problem would be to remove the phenol from the waste stream and provide a continuous feed of cleaner to the system, allowing the organisms a chance to acclimate. Also, neutralization of the cleaner before entering the

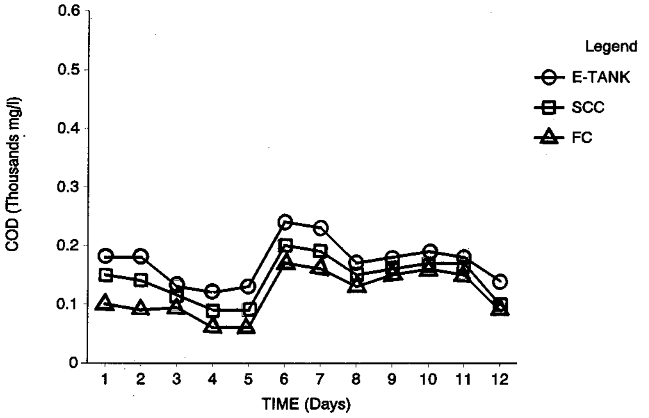

Figure 3. COD concentrations during Cleaner B pilot plant study (24-hr average).

wastewater stream would make handling the solvent more convenient and cost effective.

A second problem that occurred during biodegradation was flotation of the activated sludge in the clarifiers. To prevent this phenomenon, small amounts of ferric chloride were added to the treatment plant process stream. The estimated cost for the addition of 50 mg/L of ferric chloride would be $391 per million gallons of water treated for the chemicals alone.[5] The use of an iron-bearing polymer could help reduce the costs; however, verification of this was not presented in the study.

Cleaner A did not adversely affect the microorganisms in the activated sludge during the testing. This was evident from the nitrogen, ammonia, and phosphorus concentrations in the effluent remaining constant during the analyses. Any increase in concentrations would indicate a problem with the system. Also, chromium and zinc levels in the effluent were unaffected by the addition of the ferric chloride; however, the iron concentration did increase in the effluent.

Cleaner B was the second alkaline cleaner tested at the wastewater treatment plant. This type of alkaline cleaner had a different chemical formulation than Cleaner A. Cleaner B was composed mostly of sodium metasilicate and did not contain any organic constituents. The Air Force requested this cleaner because it was already being used in spray washers for cleaning fuel assemblies. Due to the late entry, the 8-day acclimation test was not performed. Only the pilot plant analysis was conducted for this cleaner.

The results of the study indicated that the microorganisms were unable to degrade the cleaner because it was mostly inorganic sodium metasilicate; however, effluent concentrations of sodium metasilicate were not regulated under the treatment plant's National Pollution Discharge Elimination Standard (NPDES) permit and are not required to be biodegradable. Cleaner B did not cause the sludge to float and required no addition of ferric chloride. After the cleaner was added to the influent wastewater stream, the effluent became turbid and it took several days for the SCC to settle out the particles. Effluent ammonia, nitrogen, and phosphorus concentrations did not increase during testing, indicating no adverse effects on the microorganisms from exposure to the cleaner. COD concentrations remained constant and were unaffected by the addition of the cleaner (see Fig. 3).[5] The TOC concentrations fluctuated, but a consistent drop could be observed between the E-tank, SCC, and FC (see Fig. 4).[5] Increases in chromium and iron were detected; however, this was due to a change in the influent stream not attributed to the cleaner. Zinc concentrations remained constant during the testing.

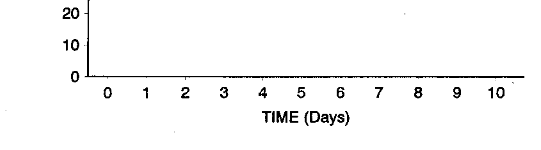

Figure 4. TOC concentrations during Cleaner B pilot plant study (24-hr average).

CLEANING EFFICIENCIES

Stoddard solvent and TCA have been used for many years as degreasing solvents in metal parts cleaning. These solvents have proven high cleaning efficiencies and provide protection of bare metal surfaces from corrosion during the cleaning process.

In order to compete with organic solvents, alkaline cleaners must possess comparable cleaning efficiencies without promoting corrosion. Studies have been conducted, which examined cleaning times, corrosivity, and cleaning enhancements to determine the cleaning efficiencies of these water-based detergents. The results are discussed below.

The research facility at the Paducah Gaseous Diffusion Plant was involved in cleanliness and corrosion testing of a number of alternative degreasing solvents.[6] One of the first goals of this project was to devise a method of measuring the cleaning ability of the solvents tested. It was determined that measurements of the surface energy, before and after cleaning, would pro-

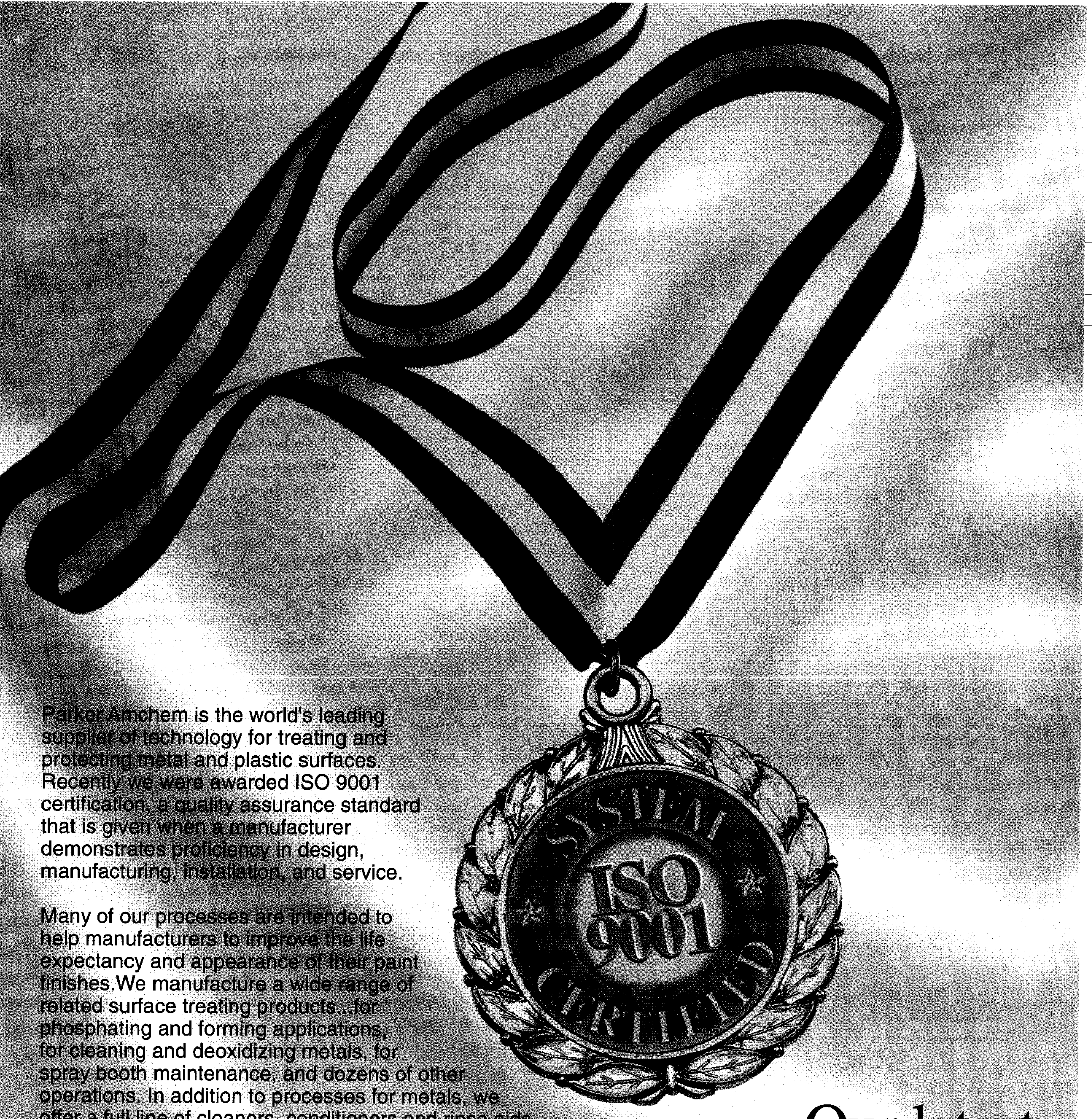
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Table I. Cleaning Times for Paducah Gaseous Diffusion Plant Study

Soil	*Cleaner C Immersion (sec)*	*Cleaner C Ultrasonic (sec)*	*TCA (sec)*
Fingerprints/Dust			
Monel	15	15	90
Steel	15	15	60
Copper	30	15	90
Aluminum	15	15	20
Phosphor bronze	15	15	150
Lube Oil			
Monel	30	30	460
Steel	30	30	1,200
Copper	120	60	900
Aluminum	30	30	1,200
Phosphor bronze	60	60	420
Water-Soluble Oil			
Monel	15	15	120
Steel	15	15	120
Copper	15	15	120
Aluminum	15	15	120
Phosphor bronze	15	15	120
Petroleum Grease			
Monel	16,200	540	21,600
Steel	16,200	540	21,600
Copper	16,200	540	21,600
Aluminum	16,200	540	21,600
Phosphor bronze	8,100	60	21,600
Silicone Grease			
Monel	9,000	1,320	21,600
Steel	9,000	1,320	21,600
Copper	9,000	1,920	21,600
Aluminum	9,000	960	21,600
Phosphor bronze	9,000	1,440	21,600

vide the information needed to define the cleanliness of the metal. The procedure for this analysis involved preparing 11 solutions with varying specific gravities ranging from 0.85 to 1.53. Each solution was then numbered from 1 to 11, in order of increasing surface tension. A cleaned test specimen would be immersed in the solution and observations noted. A clean surface would have a high surface energy, causing liquid to spread out when dipped into the solution. Conversely, a dirty surface would have a low surface energy, causing liquid to bead. Based on this procedure, the cleanest surface is one that has a surface energy greater than solution 11.

Cleaner C was tested in an immersion tank and in an ultrasonic tank. In the immersion tank, the dilution and temperature during testing were 20:1 and 145°F, respectively. In the ultrasonic tank, the concentration and temperature were 20:1 and 76°F, respectively. The cleaning times are shown in Table I[6] and are based on specimens with cleanliness ratings greater than 11. Other observations noted during testing were that Cleaner C rinsed freely from metal surfaces and no breakdown products were found in the spent solution.

Corrosion tests were also performed at Paducah to determine the corrosion rates and pitting tendencies of the cleaners on certain metals. The results from the analysis found that alkaline Cleaner C had the lowest corrosion rate of all the cleaners tested (see Table II).[6] Other data retrieved from the investigation revealed that pitting is possible; however, the time to initiate the pitting is typically longer than the contact time in a degreasing operation.

During Phase II of the study performed at Tinker Air Force Base, extensive cleaning efficiency tests on alkaline cleaners were conducted in addition to the biodegradation tests.[5] The main objective of the analysis was to determine the cleaning ability of the solvents for soils commonly encountered on aircraft parts (hydraulic fluid, molybdenum disulfide grease, etc.). Cleanliness of the parts was determined by the "white glove test," which means if a residue can be wiped from the part, it is not considered clean. In addition, a fluorescent penetrant oil was employed to help in the cleanliness testing. Residue from a cleaner tends to interfere with the fluorescent oil, simplifying the detection of flaws.

Table II. Corrosion Rates for Paducah Gaseous Diffusion Plant Study

Metal	*Cleaner*	*Corrosion Rate (mil/yr) (at 77°F)*	*Corrosion Rate (mil/yr) (at 140°F)*
Monel	A	0.05	0.11
	E	0.08	0.15
	F	0.07	0.11
Steel	A	0.08	0.17
	E	0.08	0.35
	F	0.07	0.08
Copper	A	0.38	1.31
	E	0.48	4.64
	F	1.60	3.91
Aluminum	A	0.10	0.16
	E	0.25	1.15
	F	0.18	0.25
Phosphor bronze	A	0.21	1.19
	E	0.50	4.35
	F	1.74	5.61

Table III. Cleaning Efficiencies[a] for Cleaner A

	Soil			
	Hydraulic Fluid		*Molybdenum Disulfide Grease*	
Process enhancements	*Temperature (°F)*	*% Removed*	*Temperature (°F)*	*% Removed*
No agitation	120	95	140	99
	140	97		
Mixer agitation at 500 rpm	100	98	100	92
	120	99	120	97
	140	99	140	100
Mixer agitation at 650 rpm	77	95	77	58
	100	97	100	95
Ultrasonic at 300 W	77	95	77	99

[a] These results are for a 10-min cleaning period.

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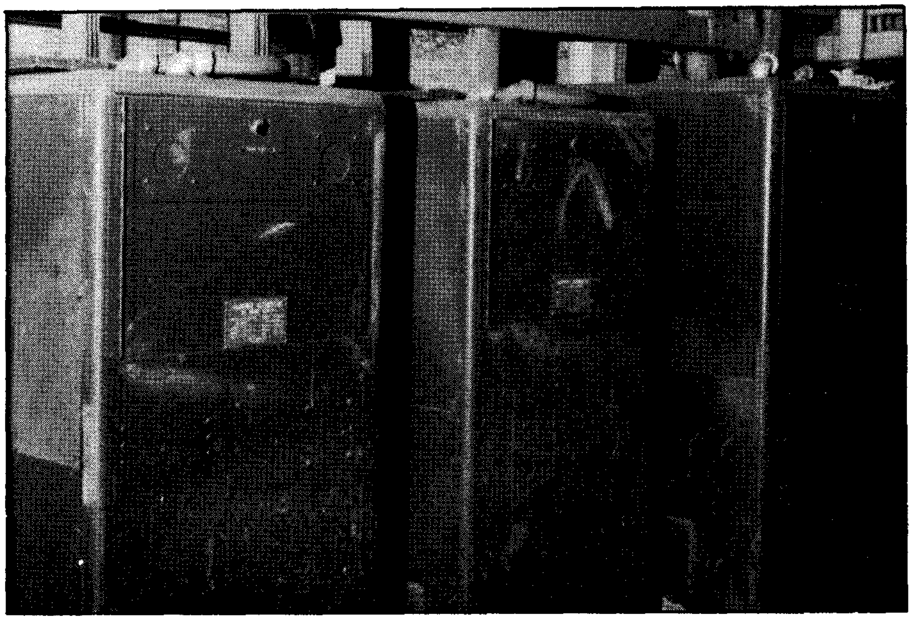

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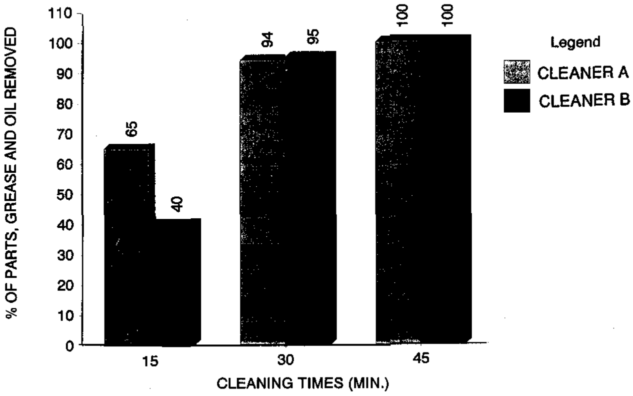

Figure 5. Oil and grease removal during the 100-gal test.

Table V. NADEP Cost-Benefit Analysis

Annual Costs	*Spray Washer*	*Vapor Degreaser*
Material usage		
Makeups, gal/yr	100	16,000
Additions, oz/yr	4,800	0
Material cost, $	795	61,440
Steam usage, lb/yr	13,728	4,529,408
Energy cost, $	109.82	36,235.26
Water usage, gal/yr	0	570,000
Rinse water cost, $	0	256.50
Production labor, hr/yr	1,040	2,080
Labor cost, $	16,848	33,696
Maintenance labor, hr/yr	50	100
Labor cost, $	1,220	2,440
Engineering labor, hr/yr	0	12
Labor cost, $	0	342
Rejected parts, no./yr	0	0
Rejection cost, $	0	0
Solid waste, lb/yr	3,500	48,000
Waste disposal cost	1,750	58,800
Total overall cost, $	20,722.82	193,209.76
Total waste savings, lb/yr	44,500	
Total cost savings, $	172,486.94	

Three types of cleaning processes were tested in this study, including immersion with no agitation, immersion with agitation, and ultrasonics. The ultrasonic unit was tested at three different settings—300, 600, and 900 Watts. Ultrasonics at the 900-W setting tended to increase the temperature of the water above normal operating ranges; therefore, it was decided that all ultrasonic tests be operated to maintain a water temperature below 140°F to ensure maximum cleaner performance.

The only alkaline cleaner tested during Phase II was Cleaner A. Results of the cleaner's performance are shown in Table III.[5] Rinsing tests were observed to be satisfactory. A 99.9% removal efficiency was achieved for the hydraulic fluid and a 97% removal efficiency was achieved for the molybdenum disulfide grease. Cleaner A also passed the drying tests with 93% of the cleaner being evaporated in 5 min, and 99% of the cleaner being evaporated in 20 min.

During the Phase III testing at Tinker Air Force Base, additional cleaning efficiency analyses were performed, including a 100-gal test, a cabinet spray washer test, and a full-scale analysis. Both alkaline cleaners, Cleaner A and Cleaner B, were evaluated during this phase of the study. The 100-gal test was designed to determine how the cleaners would perform at a demonstration scale. The system was equipped with a turbowasher designed to create vigorous agitation within the cleaning tank. Both cleaners performed satisfactorily, removing 94% of the oil and grease from aircraft components within a 30-min time period (see Fig. 5).[5] It was also observed that the water-based solvents removed a higher percentage of carbon from parts than did the organic-based solvents. The cabinet spray washer test was only conducted with Cleaner A because Cleaner B was already being utilized by the Air Force in spray washing. The results of the testing showed that at a 20:1 dilution, Cleaner A effectively removed all the oils and greases within 10 min. Carbon removal proved more difficult, but after 30 min, only light deposits were observed on the parts. During full-scale testing, a 300-gal tank was employed, equipped with a 7.5-hp electric pump, which created intense agitation. Both alkaline cleaners achieved excellent cleaning efficiencies during this analysis. Within a 15-min cleaning period, 100% of the oil and grease, plus a high percentage of the carbon, had been removed from the parts. The increased performance in the full-scale test, compared with the 100-gal test, was primarily due to more intense agitation achieved by the use of a larger pump.

Corrosion of metals during cleaning

Table IV. Corrosion Rates[a] for Tinker Air Force Base Study

Metal	*Cleaner A[b]*	*Cleaner B*
Copper	0.35	0.0
Nickel	0.47	0.03
Aluminum	61.8	0.11
Stainless steel	0.37	0.0
Monel	0.22	0.02
Waspaloy alloy	0.04	0.01
Magnesium	727	0.0

[a] Corrosion rates in mils per year.

[b] Cleaner A was at a 3:1 dilution at 77°F; Cleaner B was at a concentration of 6 oz/gal a 140°F.

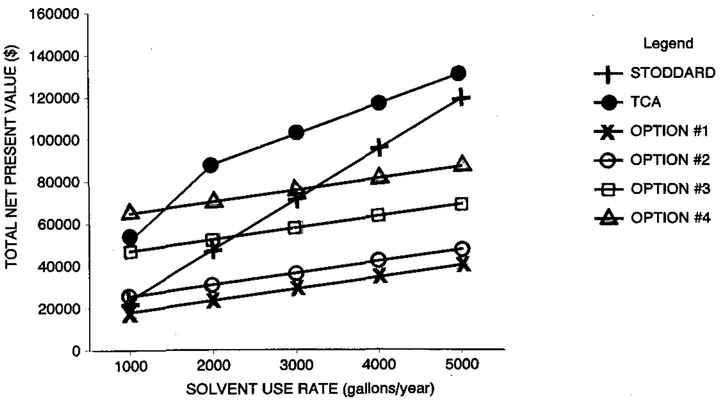

Figure 6. Alkaline cleaner comparison at 10:1 dilution with generation of nonhazardous waste.

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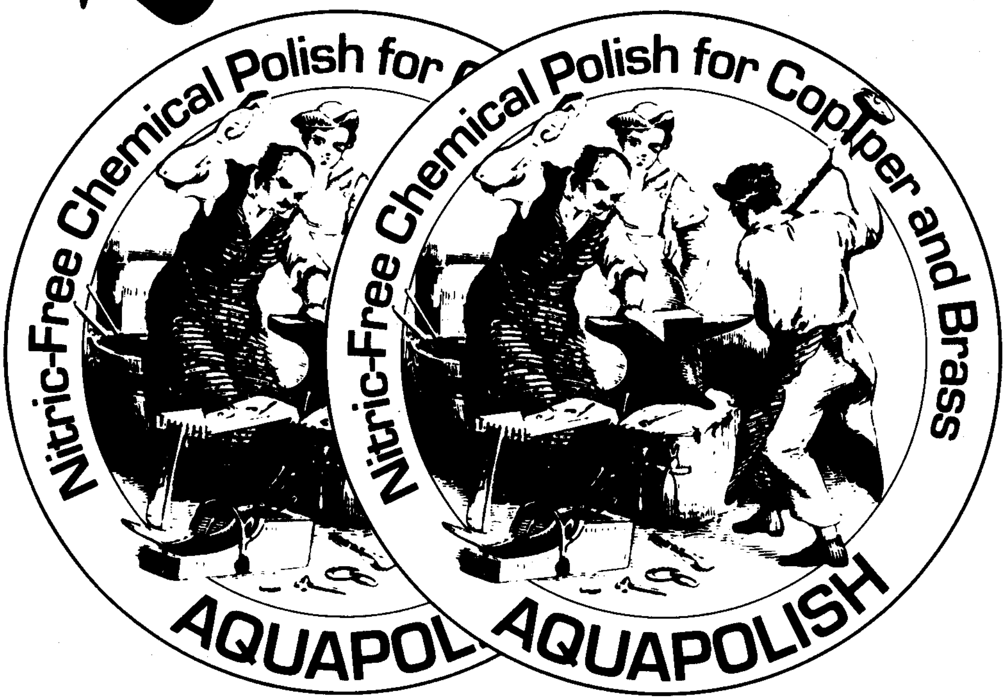

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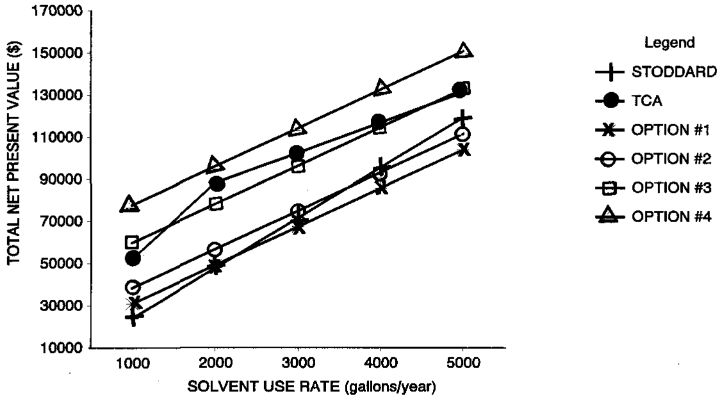

Figure 7. Alkaline cleaner comparison at 3:1 dilution with generation of nonhazardous waste.

Table VI. Aero Precision Engineering Economic Evaluation

Vapor Degreaser Costs	*($/yr)*
Solvent (479 gal/yr)	2,700
Solvent disposal (150 gal/yr)	150
Electricity	335
Maintenance	1,500
Water	50
Total	4,735
Alkaline Cleaner Costs	
Detergent (1,200 gal/yr)	850
Electricity	583
Maintenance	1,050
Water (use under 1,000 gal/yr)	50
Total	2,533
Savings	2,202

was also a concern researched at Tinker Air Force Base. Extended testing was performed on different types of metals to observe their reaction when exposed to Cleaner A and Cleaner B (see Table IV).[5] Based on the results, using a 0.3 mil/yr limit, Cleaner A exhibited light corrosion on most of the metal tested, with excessive corrosion being noticed on aluminum and magnesium. Cleaner B was more effective in preventing corrosion, maintaining the required 0.3 mil/yr limit.

ECONOMICS

An economic analysis was performed with a program called CERL Economic Analysis for Minimizing Hazardous Waste (CEAMHW), which was developed by the U.S. Army Construction Engineering Research Laboratories (CERL).[7] This program allows a cost-benefit analysis of various waste minimization alternatives by comparing the life-cycle cost with the cost of current operating practices. The advantage of the program is that it provides installation managers with a tool to analyze multiple minimization alternatives in a short amount of time. Documentation of the analyses can be generated and used to help obtain funding for specific waste minimization projects.

With the aid of CEAMHW, an economic evaluation was conducted to investigate the feasibility of substituting an aqueous-based alkaline cleaner for solvents currently being used at metal cleaning facilities (Stoddard solvent and TCA). In this analysis, Stoddard solvent was purchased through an off-site, closed-loop recycling contract. This is a common practice at many installations due to the convenience of handling and disposal. In the TCA model, the solvent was recovered and reused with the help of a distillation unit. The advantage of these units is that most processes are highly automated and require only minimal operator attention. Cleaner D was evaluated in four different enhancement options with dilution rates varying from 3:1 to 10:1. The dilution rates were recommended by the manufacturer for cleaning heavy oils and light oils, respectively. The following is a description of the four options:

Option #1: The conversion of an existing vapor degreaser to an alkaline cleaner tank with air agitation and oil skimming. Typical cost $1,800.

Option #2: Installation of a new alkaline cleaning tank with air agitation and oil skimming. Typical cost, $6,000 (1,000-gal tank).

Option #3: Installation of a spray washing unit. Typical cost for a large capacity machine, $18,000.

Option #4: Installation of a new alkaline cleaning tank with ultrasonic cleaning. Typical cost, $28,000.

Also considered during the analysis on alkaline cleaners was the cost of disposing of the contaminants in the cleaner (e.g., oils, grease, etc.). The contaminants were classified into two groups: hazardous and nonhazardous waste. The reason for the distinction is the variance in state regulations on the classification of hazardous waste. The disposal of hazardous and nonhazardous contaminants is taken into account for all cases in the economic model. The results of the economic model are plotted in Figures 6 through 9.

Case Studies

Cost-benefit analyses have been performed by other agencies to determine the economic feasibility of substituting

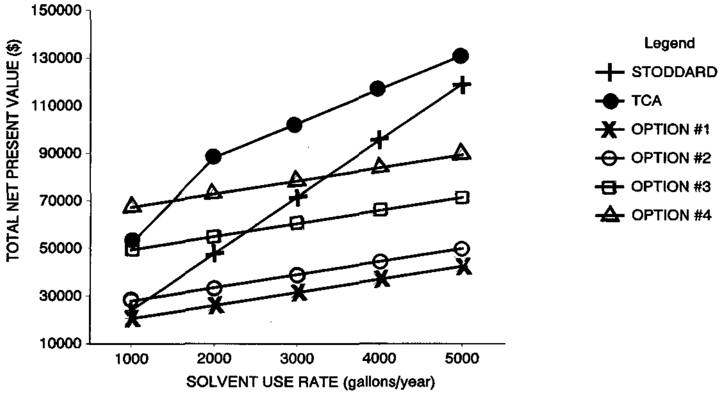

Figure 8. Alkaline cleaner comparison at 10:1 dilution with generation of hazardous waste.

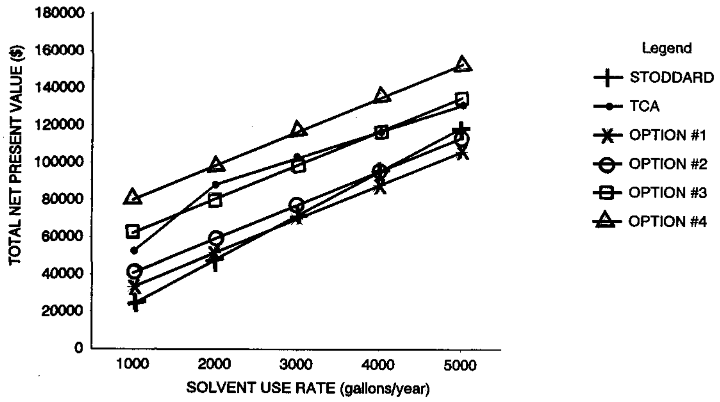

Figure 9. Alkaline cleaner comparison at 3:1 dilution with generation of hazardous waste.

alkaline-based cleaners for organic solvents currently used in cleaning operations. Empirical data derived during these studies are helpful in comparing the CEAMHW model to real-world situations. The following briefly summarizes the results.

The Naval Aviation Depot (NADEP) employs 18 solvent vapor degreasers at its facility for cleaning oils and oily contaminants from aircraft components. Recently, NADEP evaluated the feasibility of replacing the vapor degreasers with a high-pressure spray washer that uses a water-based alkaline cleaner.[8] When tested, the spray washer effectively degreased landing gear components and ordnance components. Ultraviolet light and water-break-free evaluations were also acceptable, and in many cases superior, to vapor degreasers. Based on the results from the comparison study and the economic analysis (see Table V),[8] it was determined that the incorporation of the spray washer system would benefit NADEP in the following ways: water consumption would be reduced annually, a savings would be incurred due to the decrease in costs for procurement/disposal and waste generation, a safer work environment would be created enhancing productivity, and fewer labor hours would be required to operate the process, making the system more efficient.

Aero Precision Engineering Corp. is a small company that produces precision parts for industry located in St. Paul Park, Minn.[9] In order to reduce hazardous waste generation, the company initiated a program to look at nonhazardous degreasers for its metal-cleaning operations. The following guidelines were used for the selection of an alternative cleaning method: (1) The method is safe for the employees and the environment. (2) The method is cost effective. (3) The method does not damage delicate parts and does not lead to rusting of steel parts. (4) The method meets current cleanliness specifications.

Based on this criteria, several cleaners were tested and Cleaner B was chosen as a replacement. Aero Precision decided to convert the existing degreaser to an aqueous system, which alleviated the need to purchase a new unit (see Table VI).[9]

Table VII. Cleaning Rates[a] Before and After Ultrafiltration

	Cleaner G		*Cleaner H*		*Cleaner I*	
Soil	*Before*	*After*	*Before*	*After*	*Before*	*After*
Houghton 431	1:00	2:00	0:45	0:45	1:00	1:00
Bees Wax	1:30	9:00	0:45	1:00	1:30	3:00
Petrolatum	0:15	0:30	0:15	0:30	0:15	0:15
Cimflo	0:15	0:30	0:15	0:15	0:15	0:15
Castor Oil	0:45	0:45	0:30	0:30	0:30	0:30
EP-2	3:30	>15:00	4:30	5:00	3:00	10:00
PF-400	2:00	4:00	1:00	2:00	3:00	3:00
K34/36	0:15	0:15	0:15	0:15	0:15	0:15
H-11	0:15	0:30	0:15	0:15	0:15	0:30

[a] Data expressed in minutes:seconds.

RECYCLING

Because of the biodegradable nature of alkaline cleaners, reclamation is not commonly practiced as part of the cleaning process. Typically, once the solution is contaminated the bath is neutralized, dumped, and a new batch of cleaning solution is prepared. Ultrafiltration of alkaline cleaners was recently investigated as a possible recycling method by General Dynamics.[10] During a study that examined the use of alkaline cleaners as an alternative solvent for vapor degreasing, General Dynamics performed an ultrafiltration pilot test to determine the viability of this process for recycling. Three types of commercial alkaline cleaners were tested. Each cleaner was fed through the filter at a constant rate and concentration to identify membrane fouling characteristics. Ranges for the rates and concentrations varied from 1 to 5% and 1 to 30%, respectively. Results of the tests showed that in most cases soil concentrations in the permeate were low (0.001–0.25%) and ~93% of the alkaline salts were recovered. The recovery of the surfactant constituents tended to be the limiting factor in the ultrafiltration analysis. The loss of surfactants in the alkaline solution would result in increased cleaning times (see Table VII).[10] Only one of the three cleaners maintained its surfactant constituents during filtration.

The use of ultrafiltration as a recycling method can lead to large savings in cleaner costs. The regeneration through ultrafiltration can greatly extend the life of an alkaline cleaning bath, thereby decreasing the frequency of replacement and raw material cost. Additionally, the membrane filter elements are regenerable and can be used indefinitely.

CONCLUSIONS

In a laboratory environment, alkaline cleaners are biodegradable, but in full-scale operation, biodegradation is dependent on site-specific operating conditions existing at a wastewater treatment plant. Operational modifications may be required to ensure complete degradation of the cleaner.

Alkaline cleaners are able to achieve cleaning efficiencies comparable to organic solvents. Cleaning enhancements, including agitating immersion, spray washing, and ultrasonics, can help improve cleaning efficiencies for removal of heavier oils and greases. In most cases, corrosion during the cleaning cycle was minimal. Because of the high pH of alkaline cleaners, aluminum and magnesium are prone to excessive corrosion; however, this problem is a function of the cleaner formulation and can be controlled.

The economic analysis comparing alkaline cleaners with Stoddard solvent and TCA shows that the alkaline cleaners are cost-effective alternatives. Implementing these alternatives can help accrue savings while reducing the liabilities associated with storage, handling, and transportation of waste solvents.

Generally, alkaline cleaners are not recyclable. Ultrafiltration can be used as a recycling option, but preliminary tests should be performed to ensure that the cleaner and filter membrane are compatible. Preliminary analysis will guarantee a proper systems design that will benefit the installation and the environment.

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