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# A REPLACEMENT SOLVENT CLEANER/DEGREASER STUDY AT DUFFY ELECTRIC AND MACHINE COMPANY


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## INTRODUCTION

Duffy Electric & Machine Company repairs and rebuilds electric motors. The company overhauls large electric motors (AC and DC with greater than 15 hp output). The company also overhauls small electric motors. The process involves gross cleaning of electromechanical devices to achieve a level of cleanliness that facilitates inspection, repair, and testing.

The cleaning system used in this study is comprised of a cleaning unit and a rinse unit. The cleaning unit is the IBR Series 400 parts washer, made by Inter Basic Resources, Inc., of Grass Lake, Michigan. The unit features an 11-inch-diameter impeller blade with 100-rpm rotation mounted at the inside bottom of an immersion tank. Cleaning fluid is circulated through a 50-µm filter at 5 gallons per minute, at 1 foot of head pressure to create turbulence in the cleaning fluid. Parts are cleaned as the fluid impinges on them. A 100-VAC electric motor powers the unit. The motor turns the impeller blade and runs the pump that circulates the fluid. The immersion well is 16 in x 19 in x 11.5 in and it holds approximately 14.5 gallons. Safety switches shut off the air motors if the loading door is open. The cleaning tank contains an insertion heater. The ester bath is heated to approximately 130° F. Light scrubbing is used to dislodge heavy grease and other difficult-to-remove contaminants.

The IBR alcohol rinser consists of a chamber that encloses a manifold sprayer. The tube-shape manifold is fitted with an array of nozzles to spray isopropyl alcohol (IPA) onto the parts from a variety of angles; the nozzles project a flat spray. Pneumatic pumps power the unit. The power supply is a high-pressure air line (110 to 120 psig) connected to the shop's air compressor. Alcohol drawn from a 5-gallon drum by an internal pump is sprayed inward toward the center of the manifold, which moves up and down at about 4 cycles per minute while spraying to better reach all of the part surfaces. While IPA is being delivered, runoff is caught by a pan at the bottom of the unit, flows to a drain, and is pumped by a smaller air motor back into the 5-gallon drum. When the IPA spray is deactivated after 5 minutes, the drain pump operates for another minute. Cabinet air is then purged by forcing air into the chamber through a venturi and exhausting through a hose to the outside of the building. The IPA rinser operates at ambient temperature.

The cleaner used in this study, Petroferm BIOACT™ 285, was selected because it is representative of its class of material. BIOACT™ is a mixture of high molecular-weight aliphatic esters and can be categorized as a semi-aqueous fluid. The cleaner is meant to be used without dilution and must be rinsed with alcohol, such as IPA, rather than with water. The alcohol is a technical grade that is at least 98% IPA, with the remainder being water. The IPA rinse is completely miscible with the ester solvent. The IPA evaporates rapidly due to its high vapor pressure ( 3 mm Hg @ 68°F).

## METHODOLOGY

The product quality evaluation involved analytical testing to ensure that the new technology provides an acceptably cleaned product. Cleaning effectiveness was evaluated to show whether the new process cleans electric motor parts to an acceptable level of cleanliness (judged visually by an experienced technician at Duffy).

A more quantitative approach also was used to monitor cleaning effectiveness. Two similar motors were selected from the shop's inventory, each was disassembled and a rotor, housing with stator, and end cover were saved. The two sets of motor parts were contaminated with an oil/carbon mixture, representative of the soils found on actual motor parts. The soiled parts were heated in a 105°C oven for 16 to 24 hours (MIL-C-85570B) and then cleaned at regular intervals using the cleaning system. Cleaning performance was determined by measuring residual soluble surface material on the parts being cleaned in the cleaning system.

The parts were cleaned using the IBR cleaning system, then visually inspected by a Battelle technician and by Duffy staff. Then the parts were cleaned by agitation in a 1-L bath of hexane. Parts were classified as Set A or Set B. Afterward, the hexane was evaporated onto platinum weigh dishes to determine nonvolatile matter according to ASTM D 1353, i.e., the amount of residue remaining after cleaning.

Certain parameters for monitoring the condition of the cleaner and alcohol also were checked, including appearance, color, nonvolatile matter (alcohol only), specific gravity, and pH of a water extract of the ester cleaner.

One of the product quality parameters was designed to show possible adverse effects of the cleaner and IPA on wire insulation materials. Tests were conducted to evaluate whether the elastomers are compatible with BIOACT™ 285. Swell ratio (by weight and thickness change, ASTM method D 2765) was measured in small (approximately 2-inch-square) coupons of the elastomers Buna-N, Hypalon M, silicone, and neoprene. These materials are used for electrical insulation on the wire leads of older electric motors.

Waste volume was determined by measuring the volumes of spent cleaner and IPA after completion of testing. After cleaning about 108 parts over a twelve week period, the testing was terminated and the cleaner and alcohol were disposed of.

The economic evaluation compared the costs of the new cleaning system with what is currently used in the shop. A return on investment and payback period for installation of a new ester cleaning system were not calculated because at this shop the ester-based cleaning system cost more to use on an annual basis.

## RESULTS

The data in Table 1 show that the residual soil levels on both sets of motor parts varied consistently over the course of the study. Except for the first measurement (day 8), residue measurements from day 37 to day 86 are within 1 to 2g per set of motor parts. The higher values on day 8 are believed to be due to removal of debris from the motors or to incomplete cleaning, because these results are not consistent with the remainder of the cleaning runs. Higher residue measurements at 71 and 79 days are believed to be caused by soil-loading of the ester cleaner.

The check of appearance and color was used to assess how soiled the cleaner and alcohol had become. By the 7th week of the study, or after washing 30 parts, the cleaner and rinse were very darkly colored. After 100 parts were cleaned, they appeared highly contaminated. Specific gravity is useful to track how much soil loading the cleaner and alcohol experience. Both solutions showed a small, monotonic increase in specific gravity over time. The main contaminants expected to be present in the cleaner are oils and suspended solids; in the alcohol, the main contaminant is dragout cleaner.

The pH of the cleaning solution was measured for solution acidity or alkalinity changes over time. This test was done to determine whether exposure to moisture over time caused any acid increase in the ester cleaner. Acidity was determined by extracting samples of the cleaner with water (ASTM D 2110). The pH dropped rapidly, reaching a steady state of about 5.04 in the seventh week. In all cases, the materials in the compatibility tests experienced a net decrease in weight and thickness, which is probably caused by removal of process oils, colorants, stabilizers, and other additives. The loss of these constituents could have a negative effect on the performance of the elastomers.

In evaluating waste reduction/pollution prevention potential, the new cleaner achieves waste reduction through the elimination of solvent air emissions and potential discharge of wastewater to the environment because it is a nonaqueous process. However, the spent liquid must be disposed of. Contaminants in the ester cleaner primarily are oil, grease, and shop dirt. Therefore, the cleaner itself is assumed to present little environmental or health hazard during use.

Annual solvent usages were calculated to be 51.4 gal of cleaner and 55.2 gal of IPA. These values represent a worst-case estimate for the cleaner because it was not fully spent at the time the study was concluded. However, the cleaning performance was determined to be degrading. The annual volumes of waste liquids were calculated to be 39.0 gal of cleaner and 39.1 gal of IPA.

The petroleum solvent formerly used by Duffy Electric Company had been supplied at a rate of 360 gal per year. Industry estimates indicate that about half of the amount of petroleum solvents supplied is recovered. The remainder is lost due to dragout, evaporation, and spillage during transfers. About 180 gal of spent solvent can be collected for distillation and later reuse, and another 180 gal is unrecoverable. In contrast, the alternative cleaning system generates 106.6 gal of solvent (total) per year, of which 16.1 gal of IPA is unrecoverable due to evaporation, and 78.1 gal of liquid waste is produced.

Table 2 gives the annual operating costs of both the existing petroleum solvent cleaner and the alternative ester-based cleaning system. The major operating cost of the new cleaning system is the cost of the ester cleaner and IPA rinse. If a heating element is used, energy usage also needs to be considered. Disposal costs may vary depending on the system currently in use. At this shop a contractor retrieves the used petroleum solvent for recycling and supplies the shop with a clean recycled product for use.

## CONCLUSIONS

The ester-based cleaner used at Duffy Electric performed adequately for cleaning parts when used in conjunction with a heater or with manual scrubbing for final touch-up cleaning. Soiled parts were cleaned in the ester system to determine the amount of residue remaining after cleaning to determine the life of the cleaner and to observe the rate of degradation. In general, parts removed from the alcohol rinse were visibly dry and residue-free upon removal.

The economics of the ester cleaner are not advantageous when compared to the recycled petroleum solvent used at Duffy Electric. Because the same contractor handles the supply and recovery of the petroleum solvent, its cost is relatively low. Currently, the ester cleaner is not recycled by a contractor, although the potential for recycling does exist. When the economics of the ester cleaning system are compared to those of other existing systems such as the use of chlorinated solvents, the results will differ. The ester cleaning system is likely to be less expensive than chlorinated solvent use.

The pollution prevention aspects of the ester-based cleaning system must be looked at on a case-by-case basis. In the shop that participated in this study, Safety-Kleen is contracted to provide a recycled petroleum solvent and to perform recycling on the spent product, so the solid waste generated is minimal. Currently, the ester cleaning waste and the alcohol rinse are sent to hazardous waste disposal sites, and therefore the pollution prevention benefits for this shop in using an ester cleaner are limited to reduced waste toxicity and decreased VOC emissions. With further commercialization of the product, recycling may become more common and the benefits more apparent. In shops that use chlorinated solvents, which are usually more regulated, the pollution prevention benefits of an ester cleaner become more obvious.

Air emissions also need further study when evaluating the benefits of an ester- and alcohol based cleaning system. Industrial suppliers of petroleum solvents estimate that approximately 50% is unrecoverable. The petroleum distillate solvent contains an unknown amount of toluene, ethylbenzene, and other hazardous air pollutants. Certain chlorinated solvents result in evaporation of high percentages of these compounds. Many such compounds are included in the 33/50 Program list and are regulated as hazardous air pollutants (HAPs) under the Clean Air Act. The ester-based cleaner itself does not result in any significant evaporation. Although the alcohol rinse has a high evaporation rate, its constituents are not as hazardous as those found in petroleum solvents or chlorinated solvents.

Health hazards, although not specifically studied in this testing, are important to weigh when considering the ester-based cleaning system. The ester cleaner does not have the defatting properties common in other cleaners that lead to skin irritations and dermatitis.

TABLE 1. TOTAL SOLIDS RESIDUE ON PARTS

| | | | | Weight of Solids (g/part set) | | |
|---|---|---|---|---|---|---|
| Sample ID | Motor Part | Sample Date | Days of Study | Primary | Duplicate | Average |
| H2 | A | 6/17/93 | 8 | 3.22 | 3.27 | 3.25 |
| H3 | B | 6/17/93 | 8 | 3.05 | 3.29 | 3.17 |
| H4 | A | 7/16/93 | 37 | 1.99 | 1.76 | 1.87 |
| H5 | B | 7/16/93 | 37 | 1.44 | 1.24 | 1.34 |
| H6 | A | 7/27/93 | 48 | 1.83 | 2.06 | 1.94 |
| H7 | B | 7/27/93 | 48 | 1.33 | 1.55 | 1.44 |
| H8 | A | 8/6/93 | 58 | 1.24 | 1.01 | 1.13 |
| H9 | B | 8/6/93 | 58 | 1.62 | 1.66 | 1.64 |
| H10 | A | 8/19/93 | 71 | 2.60 | 1.98 | 2.29 |
| H11 | B | 8/19/93 | 71 | 1.50 | 1.30 | 1.40 |
| H12 | A | 8/27/93 | 79 | 2.79 | 3.42 | 3.11 |
| H13 | B | 8/27/93 | 79 | 2.73 | 2.81 | 2.77 |

TABLE 2. ANNUAL OPERATING COSTS

| | |
|---|---|
| **New Cleaning System** | |
| Ester: 51.4 gal @ $20.00 per gal | $1,028 |
| Isopropyl Alcohol: 55.2 gal @ $3.00 per gal | $166 |
| Disposal: 78.1 gal @ $2.50 per gal | $195 |
| Total[a] | $1,389 |
| **Existing Petroleum Solvent System** | |
| Solvent purchase and disposal | $1,070 |
| Total[b] | $1,070 |

[a] Total does not include labor, energy, and small maintenance costs.
[b] Total does not include cost of drying the parts, should faster drying be necessary.

# EVALUATION OF SUPERCRITICAL CARBON DIOXIDE SPRAY TECHNOLOGY TO REDUCE SOLVENTS IN A WOOD FINISHING PROCESS

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## INTRODUCTION

The purpose of this evaluation was to provide an objective evaluation of the use of supercritical carbon dioxide ($CO_2$) as an alternative technology for spray applied in wood finishing processes using reduced solvent formulations. Union Carbide has pioneered this technology under the UNICARB™ trademark. In the UNICARB™ process, the solvent-like properties of supercritical $CO_2$ are employed to replace a portion of the organic solvent in the conventional coating formulation. The supercritical $CO_2$ acts as a diluent solvent to thin the viscous coating just prior to application so that the coating can be atomized and applied with a modified spray gun. According to Union Carbide, 30 to 80 percent of the organic solvent in a coating formulation can be replaced with the supercritical fluid.

This evaluation addressed the issues of product quality, pollution prevention potential, and process economics. The testing was conducted at the Pennsylvania House Furniture Company in White Deer, PA. The White Deer facility produces cherry and oak chairs, stools, dining room tables, and four poster beds. At the time of the evaluation, the White Deer plant had been using the UNICARB™ process to apply nitrocellulose lacquer finish on their chair line for over a year with good results. Testing was done to quantify and qualify these results.

## METHODOLOGY

In this technology evaluation, three issues were examined:

- Product Quality: to show that a coating applied by this technology meets company standards for a quality finish.
- Pollution Prevention Potential: to demonstrate that use of spray application technology for solvent replacement in coatings reduces volatile organic compounds (VOCs) released during finishing operations.
- Economics: to document the cost to install and operate this pollution prevention technology on an existing spray coating finish line.

In the product quality evaluation, the objective was to determine whether nitrocellulose lacquer applied by the UNICARB™ process provided a wood finish of equal or better quality than does the conventional nitrocellulose formulation and spray technique previously used by Pennsylvania House. At Pennsylvania House, the appearance and quality of the final finish are judged through visual examination by inspectors on the coating line. Special attention is given to gloss, smoothness, and lack of surface defects such as blisters or pinholes. In this project, product quality was evaluated through independent evaluations performed by Pennsylvania House staff and coatings experts at Battelle. Nine chair-back splats(three sample sets) were prepared by Pennsylvania House staff on the chair finishing line. All panels were finished by the same production methods that typically are used on the chair line.