Petroleum solvents and production changes replace chlorinated cleaning solvents

Windings, Inc., New Ulm, Minnesota, manufactures electric motor stators for inustrial control, medical and avionics applications, and power generation.

Prior to the change:

- Parts cleaned using 1,1,1-trichloroethane (TCA) and CFC-113*

Changes Made:

- Converted two vapor degreasers to cold solvent dip tanks
- Constructed two stands for drying parts
- Changed operating procedures eliminating the final stator cleaning step on 85% of the units made

Cost:

- $1,000 one-time equipment cost

Savings:

- Solvent purchases reduced by $11,000 annually.

* Although the production of both of these prodcuts was banned in 1995, the process changes apply to other cholirnated solvents.

Background

Windings, Inc. manufactures electric motor stators, the stationary part of a motor within which a rotor turns,for industrial control, medical and avionics applications, and power generation. Motors constructed from Windings' components provide precise control of motor shaft position. Order volumes for stators range from a few prototypes to a few thousand units per order. Stator sizes range from 2 inch- to 12-inch diameters. Motor stator stacks are constructed of laminated steel stampings. Before the process change, these laminations were cleaned in a vapor degreaser containing 1,1,1-trichloroethane (TCA) to remove process oils before they were stacked. After the laminations were stacked and sanded, they were again cleaned in the TCA-containing vapor degreaser before applying the insulation coating (epoxy). Further machining was then performed and the assembly was cleaned in CFC-113. Next, coils of wire were inserted into the slots and the inside diameter of the stator stack was honed to close tolerances.

During the honing operation, the windings became saturated with oil that was removed in the second vapor degreaser using CFC-113. Oil in the windings must be removed because it is a potential overheating or fire hazard during motor operation. The oil also may cause grinding fines to adhere to the wires, which would increase the likelihood of electrical shorts. In the final production step, varnish was applied to the wires.

Reason for Change

Both TCA and CFC-113 are Class I ozone-depleting chemicals. In 1994, when Windings was considering the change, federal excise taxes were levied on both solvents to discourage their use by making them expensive,particularly CFC-113. At the time Windings began its search for alternatives, product labeling rules were on the horizon that would increase production costs and possibly reduce the demand for motors made with ozone-depleting chemicals.

Pollution Prevention Technique

Selecting an Alternative Cleaner

Windings staff evaluated a number of alternative cleaners including aqueous cleaners, petroleum solvents and other chlorinated solvents. For the evaluation, two selection criteria were used. First, the cleaning chemical had to clean the deep recesses in the wire coils—the most difficult cleaning task. To evaluate cleaning effectiveness, scrap stators were cut open and the wire bundle cross-sections were visually inspected for residual oil. Second, the cleaning chemical had to clean effectively without attacking and degrading the varnish or other materials of construction. Based on cleaning effectiveness and cost considerations, Exxon Actrel 3338L solvent was selected as the replacement. This solvent is comprised of blended aliphatic hydrocarbons with a flash point of 104^{o}F.

Modifying Equipment and Cleaning Process

To use the Actrel solvent, Windings converted its two existing vapor degreasers to two-stage dip tanks by disconnecting the sump heaters and increasing the height of the divider between sumps. A pre-clean step was added to remove water-based machine coolants or any gross oil contamination after machining. Pre-cleaning also was used to remove gross oil contamination in the final cleaning of assembled stacks after honing. The pre-clean step, using petroleum naphtha provided under a service contract with Safety-Kleen, eliminates water build-up in the Actrel sump and the corresponding risk of recontaminating parts with water. It also slowed the build-up of oils in the Actrel solvent.

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New Cleaning Cycle

A new cleaning cycle for assembled stators was developed, including these steps:

- pre-clean in naphtha
- soak two minutes in the dirty Actrel sump, and hand agitate
- drain and transfer to the clean Actrel sump
- soak in the clean sump for 10 minutes with ultrasonics
- transfer to a drying table for manual blow-off with compressed air to remove and recover excess solvent
- one hour of forced-air drying

With the exception of the drying steps, the old vapor degreaser cycle time was similar to the new cleaning cycle. Other cleaning cycles at Windings also were similar, although two of the three other cleaning operations did not use a preclean step (cleaning laminations before stacking and also after sanding).

Optimizing Cleaning Procedures

After devising an acceptable cleaning process, Windings staff looked for ways to simplify and optimize its procedures. The most effective change involved eliminating the need for a final stator cleaning by not contaminating the wire winding. This was accomplished by modifying manufacturing procedures to do machining steps, such as sizing the inside and outside stack dimensions, before the windings were installed in the stack. It also required operators to take more care when applying varnish to the installed windings. As a result, 85% of the production volume no longer needs the last and most difficult cleaning step. Only stators with the tightest mechanical tolerances required machining after the windings are installed, and need cleaning after assembly.

Implementation Problems

Drying Time

The most significant problem encountered after changing to the Actrel cleaning solvent was an increase in production time due to longer drying times. When Windings used CFC-113, drying times were not significant. With Actrel 3338L, drying stators after cleaning initially took four hours. This drying time was reduced to one hour by using drying tables designed and constructed by Windings staff. The drying table consists of a wood structure with a blower that moves room-temperature air vertically through a screen mesh platform on which parts are placed. The one-hour drying time was still too long to complete motor assembly within an eight-hour shift, so Windings rescheduled initial assembly operations for each batch of stators to start the previous day.

Fire Hazard

When petroleum solvents replace nonflammable chlorinated solvents, increased fire hazard is generally a concern. Windings found that the ultrasonic sump raised the temperature of the solvent close to the flash point when the ultrasonics were in use. To solve this problem, Windings cooled the ultrasonic sump with a chiller coil that was part of the original vapor degreaser design. Since the volume of petroleum solvent needed to be open and in use was well below the 60-gallon limit in the national fire code for Class II liquids, no other equipment or facility changes were required to reduce fire hazards.

VOC Emissions

The effect of volatile organic compound (VOC) emissions from cleaning with petroleum solvents was considered. However, Windings found that a smaller amount of Actrel solvent was needed for cleaning than when using chlorinated solvents. They only needed to purchase four 55-gallon drums of Actrel annually, as compared to ten 55-gallon drums of chlorinated solvents. In addition, less than half of the Actrel solvent purchased,approximately 25%, was lost to evaporation, as compared to an estimated 80% of chlorinated solvents. The evaporative losses of petroleum to the air were well under the thresholds requiring an air quality permit.

Cost and Benefits

About $11,000 per year in net savings was expected from the solvent substitution. Savings in solvent purchases is the largest component. In 1992, six drums of CFC-113 and four drums of TCA were purchased for $11,400 and $1,980 respectively. In the first year of the new cleaning procedure, four drums of Actrel 3338L were purchased for $1,350. Eight changes per year of a 30-gallon Safety-Kleen washer cost about $1,420, including the cost of parts washer rental, solvent purchase and solvent recycling.

On the average, two drums per year of chlorinated solvent (CFC-113 and TCA) waste were disposed of at a cost of $400 per drum. Actrel waste was accumulated at the rate of two drums per year and cost about $275 per drum to dispose of as hazardous waste, saving approximately $250 per year.

Utility costs were not quantified. But, based on the comparison of required utilities, cost differences were thought to be small, with a slight advantage possibly going to the current operation. The new system uses two blowers running during the drying step (five hours per day), two compressed-air blow-offs operating for a few minutes each day, and an ultrasonic sump and a chiller used during the stator cleaning step. This compares to the old vapor degreaser operation where two sumps were heated, the vapor zones of two degreasers were chilled, and ultrasonics were used in one degreaser during the cleaning of all assembled stators.

The parts transfer to the drying table and manual blow-off was new and required a slight amount of additional labor. No new staff were required, so there was no additional labor cost. Further improvements are being considered to reduce staff time required for the new procedures.

Converting both vapor degreasers to dip tanks cost $600 in materials and labor, and constructing two drying tables cost $400, for a total of $1,000 in one-time costs.

Additional benefits of the new system include: eliminating the second cleaning step on 85% of the production volume; avoiding product labels required when using ozone depleting chemicals; avoiding possible production delays due to interruptions in solvent supplies (phase-outs); and avoiding equipment retrofit costs and paperwork requirements for the upcoming emission-control rule for halogenated solvent cleaners.

Application to Other Companies

Discovering ways to eliminate the need for cleaning has the greatest potential for cost savings, and for simplifying cleaning requirements so that conversion to less hazardous cleaning chemicals is easier.

Two-stage solvent cleaning is a broadly applicable technique to reduce solvent use, maximize cleaning effectiveness and minimize drying time. The initial or precleaning stage removes most dirt and oil from parts, but does not have to produce parts that meet the final cleaning specification. Therefore, the first stage can accumulate more dirt than would be allowed in a single dip tank. Typically, two-stage cleaning systems reduce solvent use by at least half. Because the final cleaning stage builds up contaminants more slowly, the solvent dries fast and parts come out more consistent.

Look at petroleum solvent as an alternative to chlorinated solvent, particularly if visual inspection is sufficient to judge cleanliness. Selection of a solvent for a specific application should be based on cleaning tests conducted under appropriate production conditions.

Additional Information

A large number of nonchlorinated solvent cleaners are available. For more information about these cleaners see the following publications on MnTAP's Web page: *Alternative Solvent Degreasers* [#27] and *Safer Stripping and Cleaning Chemicals for Coatings and Polymers* [#55].

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For More Information

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