RESEARCH TRIANGLE INSTITUTE

REPLACING SOLVENT CLEANING WITH AQUEOUS CLEANING

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SECTION 1

INTRODUCTION

Several factors now strongly favor industrial cleaning of metal surfaces based on chemicals other than chlorinated solvents:

1. The Copenhagen amendments to the Montreal Protocol have established January 1, 1996 as the deadline for 100% phaseout of Class I substances*, such as 1,2,2,-2,2,1-trichlorotrifluoroethane CFC-113; methyl chloroform (1,1,1-trichloroethane, abbreviated TCA), and carbon tetrachloride.

2. EPA has required that all products manufactured with TCA or other Class I substances after May 15, 1993 must display a label announcing that fact along with the warning that these solvents are destructive to the ozone layer [Federal Register, Vol. 58, No. 27, p. 8162, Thursday, February 11, 1993].

3. The costs of these chemicals have skyrocketed, and the costs of most other chlorinated solvents are expected to follow the same pattern.

What are the options available to a manufacturer now using cleaning solvents and facing these realities? Many industrial leaders have already responded to this crisis and found acceptable answers. This report describes one such set of solutions carried out by Robert Bosch Corporation in Charleston, SC who have completely eliminated their use of CFC-113 (554,000 lbs in 1988) and have reduced their consumption of trichloroethylene (TCE) from 133,000 lbs in 1988 to 43,000 lbs in 1992. Their goal now is to eliminate all TCE-based operations by the end of 1993 and thus achieve a chlorinated solvent-free operation, even though TCE is not now a Class I substance.

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*A Class I substance is a substance listed in Section 602(a) of the 1990 Clean Air Act Amendments plus any subsequent additions. Typically it includes substances having ozone depletion potentials of 0.2 or greater.

The objective of this report is to provide the details of how these goals have been and are being achieved so that others can learn from these experiences. What has proven successful at Bosch may transfer directly to other sites both in the same industrial category and to other industries with similar metal or part cleaning problems.

SECTION 2

SITE/ORGANIZATION DESCRIPTION

The Robert Bosch Corporation, with corporate offices in Broadview, IL, is a US subsidiary of Robert Bosch GMBH, Stuttgart, Germany. The parent company is a large, worldwide conglomerate with annual sales on the order of 20 billion dollars and employees numbering about 180,000. Sales of the US subsidiary are a little over one billion dollars per year. It employs over 5,000 people spread among eight business segments. Robert Bosch, Charleston, is a manufacturing plant in the Automotive Group which is the largest subdivision of the Robert Bosch Corporation.

The Charleston plant has been operating since 1973. At present, it operates with about 600,000 ft^2 of manufacturing space and employs approximately 1,800 people, 350 of whom are support personnel and engineers. The plant has a heavy engineering emphasis in support of its assembly and test functions.

The primary products produced at Robert Bosch, Charleston, are gasoline fuel injectors, antilock brake systems, and diesel fuel pumps sold to manufacturers such as Ford and GM. This activity falls under Standard Industrial Code 3714, motor vehicle parts. Nationwide, this SIC is one of the top three in terms of total TCA emissions and is probably number one in terms of the number of facilities emitting TCA. Robert Bosch, Charleston, however, does not and has not used TCA. The metal parts have been cleaned here with CFC-113 and trichloroethylene (TCE). Since all CFC-113 use has now been eliminated, its parts do not require a Class I substance label. Nonetheless, the organization has made the decision to phaseout the use of all chlorinated solvents including TCE by the end of 1993. This decision is based partly on being a good community citizen and supporting EPA's 33/50 program* but also on the improved cleaning efficiency and product performance the replacement cleaning technologies have spawned. Eliminating chlorinated solvents has been good for both Charleston's environment and the company's bottom line.

The primary Robert Bosch contacts in the preparation of this report were Roland De'ssaure, Manufacturing Engineer ([803] 760-7637) and Wolfgang Hasper, Unit Manager, Industrial Engineering ([803] 760-7659) who contributed most of the information reported here. The details and data summaries originated with them and their coworkers who are justifiably proud of their success in solving their cleaning problems and are willing to share their experiences with others facing similar problems.

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*EPA's 33/50 program is a voluntary pollution prevention initiative to reduce national pollution releases and off-site transfers of 17 toxic chemicals by 33 percent by the end of 1992 and by 50 percent by the end of 1995. TCE is one of the 17 target chemicals on the 33/50 list. Bosch, Charleston, has already met its 1995 TCE goal under this program.

SECTION 3

SPECIFIC CLEANING OPERATIONS

PARTS BEING CLEANED

Most of the parts cleaned at Bosch, Charleston, are used in two assemblies: a fuel injector and an antilock brake system. The cleaning processes associated with the fuel injector are representative of all Bosch cleaning processes and will be discussed here.

The fuel injector assembly, hereafter called F.I. (Fuel Injector), consists of various component parts, some of which are cleaned more than once before final assembly. The F.I. manufacturing process includes over 30 separate cleaning operations. Component materials to be cleaned consist of mild steel, stainless steel, plastic, and rubber.

SECTION 4

SOLVENT CLEANING

PREVIOUS CLEANING TECHNOLOGY

In 1988, all cleaning operations for the F.I. manufacturing were performed using either CFC-113 or trichloroethylene (TCE). Typically these cleaning steps were carried out in large central degreasers. Eight units used TCE; seven, CFC-113. The TCE degreasers were manufactured by Zurich Technochemie Ag. in Switzerland (Figure 1). CFC-113 cleaning was carried out in several different units including those manufactured by Detrex Corporation, Quadrex Corporation, and Zurich Technochemie Ag. All were obtained as off-the-shelf, commercially available units, and all included some form of solvent recovery. The units used combinations of sprays and ultrasonics to dislodge the contaminants, as well as vapor degreasing.

Both the TCE and the CFC units were used as general purpose cleaning stations for the various cleaning steps required in the F.I. manufacturing. Parts passed through the cleaning stations in their order of arrival. Throughput time for baskets containing 60-100 lbs of parts was typically on the order of 40 minutes.

In this operating mode, solvent consumption in 1988 was 544,000 lbs of CFC-113 and 133,000 lbs of TCE.

COSTS OF PREVIOUS TECHNOLOGY

Costs of cleaning using CFC-113 and TCE fall into five categories: capital, solvent, operating expenses, maintenance, and waste disposal. Waste disposal depends on site location, as do labor and energy costs. Capital equipment and chemicals, while less site specific, change with time--quite rapidly over the last few years.

Figure 1. TCE Degreaser (Not Yet Available)

The capital cost of a single Zurich Technochemie Ag. central vapor degreaser of the size pictured in Figure 1 averaged $250,000/unit over the time period they were acquired by Robert Bosch, Charleston. When replacing these units, Bosch chose not to resell them as operating used equipment but to scrap them, preferring to retire them permanently as sources of solvent emissions.

At $1.10/lb, the 1988 cost for CFC-113 solvent was $600,000; for TCE, $133,000. Costs of power for operating all the cleaners was estimated, by prorating plant power costs, to be $100,000/yr. Operating labor requirements averaged 1 man/cleaner/shift or $75,000 per year per cleaner in the three-shift operation.

Maintenance costs were relatively minor on the central cleaners. The equipment had relatively little time down for either scheduled or unscheduled maintenance.

Waste disposal costs were also minimal for the CFC-113 central cleaners, most of the losses being dragout and vapor losses to the atmosphere. The TCE degreasers also had some atmospheric losses, but about 92% of the vapor was recovered for reuse.

SECTION 5

AQUEOUS CLEANING

SELECTION OF AQUEOUS REPLACEMENTS

The most desirable option considered by Bosch, Charleston, in replacing chlorinated solvent cleaning, was the "no clean" option. For the "no clean" option, the cleaning step is examined to determine if it is absolutely necessary. Sometimes it can be bypassed with only minor changes, or no changes, in the rest of the manufacturing process. The cleaning step is simply omitted. Successful replacement of a chlorinated solvent clean with a "no clean" is a relatively rare event, but it has large benefits in reduced costs and cycle time.

An example of this type of process change involved the replacement of solvent cleaning of a part between two machining steps. In the "no clean" replacement process, the oil-based lubricant is centrifuged off the parts, eliminating the wash and rinse cycles formerly used. (This "no clean" action followed from a shop floor suggestion by manufacturing personnel.)

For all those operations for which "no clean" was not feasible, Bosch, Charleston, decided to bypass any interim alternatives, such as the hydrochlorofluorocarbons. They also decided not to revert to the hydrocarbon cleaners of earlier years (although the polyamide coil discussed in Section 6 temporarily remains an exception). The Bosch decision was to immediately address the long-term environmental issues associated with cleaning and develop cleaning methods that would be as permanent as could be conceived under present knowledge and regulations. The interim solutions were abandoned as "not buying time but wasting time."

The next option to be considered then was aqueous cleaning. Aqueous cleaning with deionized water has proven very effective, especially when customized for one specific cleaning step on a specific part. It was determined that parts cleaning could best be done with small custom cleaners dedicated to one or a small number of cleaning steps--a major switch from the large central cleaners of 1988. This eliminated any any possibility of cross contamination, shortened cycle times, and allowed better matching of each cleaning process to the specific part and contaminants. This fresh approach of introducing single function washers for critical cleaning tasks required careful analyses of a large number of cleaning steps. While this process was lengthy and demanding and continues even today, the improvements in product yield and quality that accompanied the early efforts have convinced Bosch that this approach is the best approach for them.

CLEANING PROCESS SELECTION

All but one replacement solution adapted to date has consisted of deionized water alone or deionized water containing an alkaline cleaner. The specific additives and surfactants used in the cleaning steps were selected to be compatible with the part being cleaned, the soil being removed, and the cleaning equipment used. These decisions involved experimenting with various proprietary products* such as MI Clean 8™, Rustcote 805™, BB100™, Quik Dri™ to confirm lack of part corrosion and satisfactory soil removal.

Some parts have corners or pockets that trap particles making them difficult to remove. A high-pressure spray (water at 2000 psi) directed at these recessed areas flushes the particles from such parts effectively.

Drying following wash and rinse was a particularly sensitive issue for Bosch. Functional requirements typically require that all water be removed before the next operation. Removal of water by heating the parts often produced unacceptable spotting. Centrifuging at room temperature after aqueous cleaning has now become

*Appendix A contains Material Safety Data Sheets for these products.

the part drying technique almost universally adopted by Bosch. The centrifuges used provide the option of warm air circulation during the spinning, but this drying assistance has not often been necessary.

Oil-based lubricants were deliberately chosen for the machining of the parts. The reason for this decision was that oil-based lubricants are easier to separate from the aqueous cleaning liquid than water-based lubricants. This extends the life of the cleaning baths. This approach is probably controversial but has been effective at Bosch. The oil is removed in most operations by skimming or gravity separation in holding tanks and subsequently shipped offsite in sealed containers for disposal.

HARDWARE SELECTION

To rapidly zero in on suitable aqueous cleaning hardware, Bosch first investigated off-the-shelf washing stations. If off-the-shelf units proved ineffective or were not available, Bosch engineered custom units of their own design. In one application, they converted a low-pressure Hapa spray washer to high pressure; in another, a high-pressure Quadrex unit was modified to use water instead of CFC-113. A Bowden turbo washer has also proved very successful in aqueous cleaning of certain parts, but no single piece of hardware solved all cleaning problems.

None of the aqueous cleaning systems employed or designed by Bosch, Charleston, have been "closed loop" in the sense of having zero discharge. However, the replacement washers typically feature recirculation of the wash solution through filters (ultrafiltration is planned on some units) which has lengthened bath replacement times to 1 to 2 weeks. Bath changes between scheduled periods of preventive maintenance are determined by the particle counts in the bath.

Complete regeneration of the wash solution in the Charleston plant is a future project. Bosch GMBH has several sites in Germany that have been operating with a closed-loop aqueous system since 1989. Bosch, Charleston, plans to implement some closed-loop systems by the year end 1993.

SECTION 6

CONVERSION PLANS AND PERFORMANCE OF FOUR CLEANING STEPS

This section reviews the details of the conversion of four TCE- or CFC-113-based cleaning steps to aqueous cleaning. The four parts selected are described in Table 1 and are representative of Bosch cleaning operations that have been switched out of CFC or TCE cleaning. These four cleaning steps were chosen because they show the wide variety of options available and results possible when ingenuity is applied to solvent replacement. Each of these parts is discussed separately in the following sections, describing the replacement of a chlorinated cleaning operation by an aqueous process. These sections summarize the steps taken in selecting a specific aqueous replacement process and compare before and after cleaning performance and operating costs.

PART A, VALVE BODY

Figure 2 shows two process flows in which the valve body is cleaned, one being the 1988 process based on TCE and CFC-113, and the other, the 1992 aqueous process which was developed to replace the 1988 chlorinated solvent process.

The process flow consists of two stages, one before an annealing heat treatment--the "soft" stage of the process flow--and a "hard" stage following the heat treatment. This machine and anneal sequence typifies many of the Bosch processed parts.

The 1988 Process

The 1988 clean-up sequence following the soft machining consisted of three separate operations, labelled with a "W" in Figure 2. The initial step was a pass

TABLE 1. REPRESENTATIVE COMPONENTS CLEANING IN THE FUEL INJECTOR ASSEMBLY

1. Part A (Valve Body)

   Composition: 440C steel
   Size and shape: Approximately 3/4" diameter, cylindrical, 3" long
   Special cleaning challenge: Square shoulders at base
   Contamination to be removed: Metal chips, grinding coolant, shop dirt, cleaning chemical residues, fibers, fingerprints
   Measurement of cleaning effectiveness: Visual inspection (100%); extraction testing for particles; statistical process control (SPC) charts

2. Part B (Metering Needle)

   Composition: 304 steel
   Size and shape: 3/4" pin, 1/16" diameter
   Contamination to be removed: Grinding coolant, shop dirt, cleaning chemical residues, fibers, fingerprints
   Measurement of cleaning effectiveness: Visual inspection (100%); extraction testing for particles; SPC

3. Part C (Coil)

   Composition: Polyamide 66
   Size and shape: 1 1/4" high, 1 3/4" diameter
   Contamination to be removed: Fingerprints, fibers, soldering splatter
   Measurement of cleaning effectiveness: Visual inspection (audit only); extraction testing for particles; SPC

4. Part D (O-Ring)

   Composition: Viton B
   Size and shape: 1/2" ring made of 1/32" stock
   Contamination to be removed: Metal fibers, filler material, plastic contamination
   Measurement of cleaning effectiveness: Extraction testing for particles; SPC

	1988	1992
Soft		
	● Soft Machine	● Soft Machine
	W Immersion US Cleaning TCE	**W** Turbo Wash Aqueous (Wash time: 15 min; drain time: 2 min); (5% BB 100™ detergent; 150 °F)
	W Solvent LP Spray	**W** Turbo Rinse DI Water (130 °F); rinse time: 15 min; drain time: 2 min
	W Vibratory Immersion CFC	**W** Spray Rinse/Air Blow-Off (0.2% MI Clean 8™)
	● Heat Treat	● Heat Treat
		Qty/Day: 42,000 Cycle Time, 2 Baskets (1300 pcs): 18 min (same for wash & rinse)
Hard		
	● Auto Deburr	● Auto Deburr
	W US Immersion TCE	**W** HP Spray Wash Aqueous (0.002% MI Clean 8™; 2000 psi; 4 min/tray)
		D Air Dry (6 min, 2 trays)
	● Visual Inspect/Extraction	● Visual Inspect/Extraction
		Qyt/Day: 42,000

● = Noncleaning
W = Wash
US = Ultrasonic
LP = Low Pressure
HP = High Pressure
D = Dry
DI = Deionized

Figure 2. Cleaning sequences for Part A, 440C steel valve body.

through a Zurich Technochemie Ag. 60 RK central degreaser (Figure 1). Four other parts were also cleaned in this degreaser. From the TCE degreaser, the valve bodies received a low-pressure (8-10 atmospheres) solvent spray of VISCOR™*, a petroleum distillate with a flash point of 104 °F. This spraying unit, made by Gluth in Germany, was dedicated to the processing of valve bodies; no other parts were cleaned in this sprayer. The final cleaning step prior to annealing was immersion in CFC-113 in a unit made by Detrex. The parts fed into the bath through a spiral chute and were lifted from the bath on a track that was mechanically vibrated to provide agitation and more complete cleaning.

After heat treatment and deburring, the valve bodies once again passed through the Zurich central degreaser. They then were subjected to 100% microscopic inspection for contamination. Lots were also audited by a 5-min ultrasonic extraction in VISCOR™. The particles released during the extraction were collected on a 4" filter with a 5 μm pore rating and weighed to assess cleanliness. Control charts plotting reject rates from both the visual inspection and the extraction test monitored the efficiency of the cleaning process.

The 1992 Process

The initial action taken to replace the chlorinated solvents consisted of sending dirty samples of the valve bodies to six vendors of aqueous cleaning equipment and evaluating the cleaned samples returned. This competition for cleaning the valve bodies produced a clear winner--the Bowden turbo washer using a Bowden proprietary surfactant, called BB100™. The criteria on which this judgment was based included not only the visual inspection and the extraction tests but also a "white glove" test in which the cleaned part was wiped with a clean white cloth. By all of these tests, the turbo washed valve bodies were superior, so the decision was made to further evaluate ultrasonic aqueous cleaning in the Bowden turbo washer.

*MSDS sheets are in Appendix A.

A series of in-house metallurgical and chemical laboratory tests confirmed that the turbo washed parts exhibited no dimensional or chemical changes. The valve body surfaces appeared to have retained the properties needed for operation in the fuel injector. No residue or altered texture could be detected.

With manufacturing compatibility seemingly established and rough cost estimates favoring the aqueous process, the decision was made to switch the valve body cleaning to the Bowden turbo washer.

Turbo washing implies turbulent washing in a vigorously stirred solution, the agitation being supplied by a high-speed impeller. The Bowden design incorporates a rotary disk skimmer to separate oils from the wash solution. This feature plus filtration of the wash solution means cleaning solution replacement occurs only once a week. The oils are collected in a container and sent out as waste for disposal; the wash water is treated and discharged to the city sewer system.

Two cycles--a wash cycle in the aqueous surfactant solution and a rinse cycle in deionized water alone--became part of the process adapted, as indicated in the 1992 flow sequence (Figure 2). In the initial manufacturing version, two separate units, each of 160 gal capacity, were used to carry out the wash and rinse cycles. Indeed, the initial process introduced actually included an insurance rinse, called the "spray rinse/air blow-off" in Figure 2. This additional step was carried out in apparatus built by Leimberger. It was readily available at Bosch and thus became part of the initial replacement sequence. Subsequent plans assume that all three "W" steps in the soft portion of the 1992 process can be compressed into one step in one apparatus.

The cleaning step in the "hard" portion of the valve body cleaning, previously an ultrasonic TCE bath, was replaced with a high-pressure (2,000 psi) wash in a modified Hapa washer followed by centrifugal drying in a New Holland dryer.
This custom modification was performed in-house by Bosch personnel and proved more effective in eliminating debris from the deburring operation than the ultrasonic immersion step it replaced. The alkaline aqueous cleaning solution used
MI Clean 8™ (0.2%).

Performance Comparisons

Visual inspection has been the primary criterion for assessing valve body cleanliness. All valve bodies are routinely 100% visually inspected for residue, rust, fibers, and dirt, in addition to machining defects and burrs. By this criterion, the present aqueous process clearly outperforms the 1988 chlorinated solvent process. Rejection rates from visual inspection have dropped to essentially zero from the 1988 rate of about 40 lots/month. This comparison, however, does not yet represent a full year's operation with the 1992 process. Historically, the high humidity months of June, July, and August have always correlated with high rejection rates at visual inspection because of obvious rust. This high incidence of rust disappears during winter. In 1993, this phenomenom has not reappeared. This observation suggests that the chlorinated cleaning solutions played a key role in the formation of this rust as well as the high humidity. The chemistry is not understood, however, and the high humidity season is not yet over, so the excellent performance record of the aqueous process is still preliminary.

Extraction tests were also performed on an audit basis. By 1992, the filter used to collect extracted particles has been changed to a 2" diameter with a 3 μm pore rating. Particles on the filter are now counted optically on a Cambridge imaging system (rather than weighing). Thus, direct quantitative comparisons are not appropriate. Reject rates because of extraction audits have not changed substantially between the two processes; however, extraction tests continue to be a secondary criterion, depending as they do, on variables such as part orientation and fluid status.

Cost Comparisons

Two types of costs of cleaning the valve body are compared in Figure 3--prorated nondepreciated capital costs and annual labor costs of operation. The prorated nondepreciated capital costs represent the initial capital cost of the cleaning equipment divided among the number of different part types cleaned by that equipment. In 1988, a number of different parts were cleaned in the same equipment. The valve body capital costs in Figure 3 represent the valve bodies' fractional use of the equipment. Similarly, labor costs represent the costs of operator labor for cleaning just the valve bodies.

All of the cleaning equipment used in the 1992 process of Figure 2 is dedicated to valve body cleaning. No other parts are cleaned in this equipment.

Cost comparisons for solvent/chemical use, utility power maintenance, and waste treatment will not be broken down according to part but will be presented as total annual costs (Section 7).

The data in Figure 3 show the 1992 aqueous process to be less expensive in terms of both capital and operating labor costs. This conclusion plus the reduced reject rates of the 1992 aqueous process confirm that replacing chlorinated solvents in the cleaning of the valve body has been a smart business move for Bosch in addition to an environmentally responsible action.

PART B, 304 STAINLESS STEEL METERING NEEDLE

This metering needle is also a stainless steel part machined at Bosch. The processing sequence, depicted in Figure 4, is a post anneal cleaning sequence only. The cleaning steps associated with the soft machining steps have been omitted (they are similar to those of Part A). The 1988 cleaning sequence consisted of four steps and used both TCE and CFC-113. This cleaning sequence was virtually reject free.

Prorated, Nondepreciated Capital Costs,
No Price Index Adjustment

	1988		1992	
Soft				
	TCE immersion (Zurich):	$ 50,000	Turbo wash (Bowden):	$70,000
	LP solvent spray (Gluth):	140,000	Turbo rinse (Bowden):	
	Vibratory CFC (Detrex):	38,000	Spray rinse (Leimberger):	
Hard				
	TCE immersion (Zurich):	$ 50,000	HP spray (Hapa, modified):	$ 50,000
		278,000	Centrifugal Dry (New Holland):	10,000
				130,000

Prorated, Operating Labor Costs - 1992 dollars

Zurich	0.2 man year	Bowden	0.5 man year
Gluth	0.5 man year	Bowden	
Detrex	0.5 man year	Leimberger	
Zurich	0.2 man year	Hapa	0.5 man year
	1.4 man years ($105,000)		1 man year ($75,000)

Figure 3. Comparison of valve body cleaning costs.

1988	1992
● Auto Deburr	● Auto Deburr
W Immersion Agatiation VISCOR™	
W Immersion US Aqueous	
W Immersion US TCE	W HP Spray Aqueous (4 min/tray)
W HP Spray CFC	D Hot Air Dry (6 min for 2 trays)
● Visual Inspection	● Visual Inspection

W = Wash
VISCOR™ = Petroleum Hydrocarbon
HP = High Pressure
US = Ultrasonic
D = Dry

Qty/Day: 42,000
Parts/Tray: 300

Figure 4. Cleaning sequences for Part B, 304C stainless steel metering needle.

The primary driving force for change was the need to eliminate chlorinated solvents. As will be seen, the 1992 aqueous replacement process has matched the cleaning performance of the 1988 process and has done so at lower capital and operating costs for this critical part cleaning.

The 1988 Cleaning Sequence

The first of the four wash steps of the 1988 cleaning sequence was immersion and agitation in a dip tank of in-house design. The cleaning solvent for this step was VISCOR™. An aqueous ultrasonic bath followed. An ultrasonic clean in TCE in one of the central Zurich Technochemie Ag. units then followed and finally a high-pressure spray with CFC-113 in a Quadrex unit. This high-pressure cleaning step appeared critical to the success of the cleaning operation and high pressure became the focus of the replacement search.

The 1992 Cleaning Sequence

The 1992 cleaning sequence is a one-step exposure to high-pressure water containing 0.6% QUIK DRI®. This replacement for the preceding chlorinated cleaning sequence began with the assumption that a high-pressure spray of some sort would have to be part of the answer, since the high-pressure spray was known to be a crucial step of the 1988 process. Bosch engineers converted one of the Quadrex units to a high-pressure water sprayer and initiated a series of exploratory needle cleanings. Variables in the test matrix included type of cleaning agent, pressure, temperature, nozzle-to-part distance, and exposure time. From these test results, an acceptable cleaning receipe and sprayer design were developed using the in-house modified Quadrex unit.

For the construction of an automated production unit, Bosch hired Forward KLN to build a custom unit meeting the design specifications based on Bosch's in-house work. This arrangement proved highly successful as Forward KLN, primarily an automation company, used both the clean part specification, in terms of visual inspection and extraction tests, and the technical guidance provided by the Bosch prototype experiments. Preacceptance tests at Forward KLN's site led to initial minor modifications. Additional changes in chemical additives and cycle times were made on the production floor at Bosch.

Performance Comparison: Chlorinated Solvents vs High-Pressure Aqueous Spray

The cleaning performance of the 1992 high-pressure aqueous cleaning sequence has matched that of the 1988 chlorinated solvent cleaning sequence. The 1988 cleaning sequence performed very well with virtually no cleaning-related rejects by visual inspection. The 1992 process performs similarly.

Cost Comparison: Chlorinated Solvents vs High-Pressure Aqueous Spray

Figure 5 contains prorated nondepreciated costs of capital equipment for both the 1988 and the 1992 cleaning sequences for the metering needle. It also includes estimates of prorated annual labor costs for both sequences. As before, power and chemical solvent costs are estimated for all cleaning operations at Bosch in Section 7. No breakdown of these costs by part has been made.

PART C, AN INDUCTION COIL OF VARIOUS COMPOSITIONS INCLUDING POLYAMIDE 66

This part differs from Parts A and B discussed earlier not only in composition but also in that it is a part fabricated outside of Bosch. The part as received is ready for assembly into the fuel injector without additional machining or other processing

Prorated, Nondepreciated Capital Costs,
No Price Index Adjustment

1988		1992	
VISCOR™ agitation (In house dip tank):	$ 0	High-pressure aqueous spray (Forward KLN):	$160,000
Ultrasonic immersion, aqueous (Klear-Flo):	50,000		160,000
Ultrasonic immersion, TCE (Zurich):	50,000		
High-pressure spray, CFC-113 (Quadrex):	100,000		
	200,000		

Prorated, Operating Labor Costs - 1992 Dollars

1988		1992	
Dip tank	0.25 man year	Forward KLN:	0.75 man year
Klear-Flo	0.25 man year		
Zurich	0.20 man year		
Quadrex	0.75 man year		
	1.45 man years ($109,000)		0.75 man year ($56,000)

Figure 5. Cleaning cost comparisons for the metering needle.

except cleaning. Cleaning of the coil is essential. Otherwise contaminants from the coil will interfere with the operation of the fuel injector.

The 1988 Cleaning Sequence for Coils

Figure 6 indicates the outside origin of the coil by the label "warehouse" prior to cleaning for assembly. The 1988 cleaning step was ultrasonic cleaning in CFC-113. This cleaning operation was carried out in a Technochemie Jura unit.

The 1992 Cleaning Sequence for Coils

The 1992 process differs from the 1988 process only in the substitution of the ultrasonic cleaning fluid and the apparatus in which the cleaning is carried out. The ultrasonic cleaning fluid in the 1992 process is VISCOR™, and the apparatus used is a dedicated Ramco ultrasonic bath modified to be compatible with VISCOR™ operation (the commercial Ramco unit is designed as an aqueous bath). A centrifugal drying step in New Holland's K90 has also been added in the 1992 process.

The choice of a VISCOR™ ultrasonic bath was based primarily on expediency and represents the only instance in which Bosch implemented an interim replacement solution prior to developing the long-term replacement. The reason for this action was to achieve the corporation goal of CFC-free operation by the end of 1992. Replacement of the CFC used to clean the coil was the final step in achieving that goal. VISCOR™ was known to be compatible with the coil and constituted an easy, sure-fire path to a CFC-free plant. Developing an aqueous cleaning process, while thought to be feasible and the likely long-term solution, was perceived as a more difficult, longer task because of drying and spotting problems.

Ultrasonic VISCOR™ did permit Bosch Charleston to meet their deadline for CFC-free operation. Developing a suitable aqueous or other nonVOC-based clean for the coil is now underway.

1988	1992
● Warehouse	● Warehouse
W Immersion US Cleaning CFC	**W** Immersion US Cleaning VISCOR™
	D Centrifugal Dry
● Assembly	● Assembly

W = Wash
US = Ultrasonic
D = Dry

Figure 6. Cleaning sequences for Part C, a purchased induction coil.

Performance Comparisons Between Coil Cleaning Sequences

Coil cleanliness is checked by visual inspection audits (1 tray out of 10-20 trays are visually inspected). The visual inspector looks for fibers, dirt, and other foreign matter on the cleaned parts. The primary measure of part cleanliness is the extraction test with VISCOR™ being the extracting fluid. Based on the extraction tests, the performance of the 1992 process is superior to that of the 1988 process. Virtually no rejects occur after the 1992 cleaning sequence. The same was not true for the 1988 cleaning sequence which occasionally did have cleaned parts rejected and returned for reclean prior to assembly.

Cost Comparisons of Coil Cleaning Sequences

Figure 7 summarizes costs for the two cleaning sequences. Labor costs are estimated to be similar, but the capital costs associated with half-time use of the Jura ultrasonic apparatus exceed those of full-time use of the modified Ramco. Six thousand dollars of the Ramco capital costs represent modifications to the off-the-shelf unit costs.

PART D, VITON B O-RING

Bosch's fully assembled fuel injector has five O-rings, all of which are obtained by outside purchase. The only Bosch processing of the O-rings is cleaning prior to assembly. Just one of the O-rings is in a sensitive location–the valve group O-ring. This O-ring is audited for cleanliness.

1988 Cleaning Sequence for O-Rings

The 1988 cleaning sequence for the O-rings (Figure 8) was identical to the 1988 cleaning sequence for the coils, Part C (Figure 6). These parts shared the same cleaning equipment in 1988, splitting the use of the Jura ultrasonic apparatus between them. CFC-113 was the solvent used during ultrasonic cleaning of both parts.

Prorated, Nondepreciated Capital Costs,
No Price Index Adjustment

1988		1992	
Ultrasonic CFC bath (Jura):	$100,000	Ultrasonic VISCOR™ (Modified Ramco):	$26,000
		Centrifugal Dry (New Holland K90):	$10,000
			$36,000

Prorated, Annual Operating Labor Costs - 1992 Dollars

Jura: 0.5 man year ($38,000)	Ramco: 0.5 man year ($38,000)

Figure 7. Comparisons of coil cleaning costs.

1988	1992
● Warehouse	● Warehouse
	W Turbo Wash DI Water (140 °F; 2 min)
W Immersion US Cleaning CFC	**W** Turbo Rinse DI Water (60 °F; 2 min)
	D Centrifuge Dry (room temp; 1 min)
● Assembly	● Assembly

W = Wash
D = Dry
US = Ultrasonic
DI = Deionized

Qty/Day: 42,000 each of 5 types of O-rings (210,000 total)
O-rings/basket: 1500

Figure 8. Cleaning sequences for Part D, Viton B O-rings.

1992 Cleaning Sequence for O-Rings

Early concern over ultrasonic CFC cleaning of O-rings arose because of suspected part degradation caused by the ultrasonic action. This fear of damage directed Bosch's replacement selection away from ultrasonics and high-pressure sprays and toward the lower intensity mechanical actions of the Bowden turbo washer. The cleaning sequence adopted, labelled 1992 in Figure 8, depicts a three-step wash operation consisting of a turbo wash (140 °F), a turbo rinse (60 °F), and a dry by centrifuging. In practice, the 1992 cleaning sequence has been found to perform better without any surfactant or proprietary cleaning agent in the wash solution. Thus, the wash step and the rinse step are, in effect, a rinse-rinse sequence, the first two steps of the three-step sequence now being identical. They both use the same cleaning solution (deionized water) although carried out in sequence in separate units at different temperatures.

These Bowden units are small, 15 gallon units dedicated to O-ring cleaning. The subsequent centrifuge dry is by a New Holland Spin Dryer. These low-cost units easily maintain adequate throughput for the F.I. assembly.

Performance Comparisons Between O-Ring Cleaning Sequences

The primary measure of cleaning effectiveness comes from the visual inspection audits. Plastic or metal fibers are the most common cause of lot rejection. By this measure, the 1992 cleaning sequence outperforms the 1988 cleaning sequence. Lot rejection runs about 1% now compared with 1988 lot rejection of approximately 5%.

Extraction tests yield nondiscriminating poor results for both cleaning sequences. Neither cleaning sequence performs well by this test. This observation supports the suspicion of part damage by ultrasonics. Indeed, prolonged exposure to ultrasonic agitation in the VISCOR™ used in the extraction tests results in O-ring disintegration and disappearance. The O-ring evidently is eroded away. Thus, even the 5-min exposure to ultrasonic VISCOR™ probably produces Viton B particles by erosion rather than foreign particles extracted off the surface. The extraction test is thus of dubious value as a measure of cleaning sequence efficiency for these Viton O-rings.

Cost Comparisons Between O-Ring Cleaning Sequences

Costs of the 1988 O-ring cleaning sequence are identical to those of the induction coil. The 1992 cleaning sequence, on the other hand, is carried out in relatively small units which reduce capital costs significantly (Figure 9). Even these modest capital costs could be reduced by eliminating the rinse step which at present is simply a repeat of the wash step.

Labor costs are estimated to be the same for the two cleaning sequences.

Prorated, Nondepreciated Capital Costs,
No Price Index Adjustment

1988		1992	
Ultrasonic CFC bath (Jura):	$100,000	Turbo wash (Bowden RB15):	$11,000
		Turbo rinse (Bowden RB15):	
		Centrifuge:	
			$11,000

Prorated, Annual Operating Labor Costs - 1992 Dollars

Jura:	0.5 man year ($38,000)	Bowden RB15:	0.5 man year ($38,000)
		Bowden RB15:	
		Centrifuge:	

Figure 9. Comparisons of O-ring cleaning costs.

SECTION 7

SUMMARY

The examples reviewed in Section 6 show that Bosch Charleston has succeeded in every instance in replacing a CFC-113 or TCE cleaning sequence with a sequence based on a nonchlorinated solvent. Furthermore, these replacement sequences have all performed as well or better than the chlorinated sequence and have done so with reduced capital costs and the same or reduced labor costs.

Costs of replacement solvents, operating power, and waste disposal were not broken down by part cleaning sequence. For the entire Charleston site, however, the 1988 costs, based on the CFC/TCE cleaning sequences of that year, greatly exceed those of the 1992 cleaning sequences (Table 2).

Comparative costs between 1988 and 1992 cleaning sequences do not include the engineering and other labor expended in developing and implementing the replacement strategies and tactics. These costs are substantial and continue to be incurred today as Bosch continues to upgrade and improve its parts cleaning operations. Many of the 1992 cleaning sequences described in this report will differ from the sequences actually in use in 1994. It is clear that Bosch is convinced that the time and resources already spent in converting from chlorinated solvents has been a good investment. This activity will continue until all TCE and hydrocarbon solvents have been replaced.

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TABLE 2. NONLABOR ANNUAL OPERATING COSTS, ALL CLEANING

	1 9 8 8			1 9 9 2		
	TCE	CFC	Total	TCE	H_2O/Additive	Total
Maintenance						
Waste Disposal						
Solvent Replacement	133,000	600,000	733,000			
Electric Power	53,000	47,000	100,000			

APPENDIX

Material Safety Data Sheets

AB 13524

46M000 zero

Material Safety Data Sheet

May be used to comply with
OSHA's Hazard Communication Standard,
29 CFR 1910.1200. Standard must be
consulted for specific requirements.

U.S. Department of Labor
Occupational Safety and Health Administration
(Non-Mandatory Form)
Form Approved
OMB No. 1218-0072

IDENTITY *(As Used on Label and List)* BB-100

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: Bowden Industries, Inc.	Emergency Telephone Number: (205) 533-3700
Address *(Number, Street, City, State, and ZIP Code)*: 1004 Oster Drive N.W.	Telephone Number for Information: (205) 533-3700
Huntsville, AL 35816	Date Prepared: August 25, 1990
	Signature of Preparer *(optional)*

Section II — Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% *(optional)*
<10% Non-Ionic Surfactant				
CAS# 9016-45-9				
<10% Sodium Metasilicate				
CAS# 6834-92-0				
<15% Sodium Xylene Sulfanate				
Balance - Deionized Water				

PH-11.0 (with 25% BB100 & 75% Water) PH=13 in Concentrated form

Section III — Physical/Chemical Characteristics

Boiling Point	212 deg.	Specific Gravity (H_2O = 1)	1.01
Vapor Pressure (mm Hg.)	N/A	Melting Point	94.0
Vapor Density (AIR = 1)	1.0	Evaporation Rate (Butyl Acetate = 1)	1.0

Solubility in Water
Completely

Appearance and Odor
Opaque Blue liquid; Mild Detergent Odor

Section IV — Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
None	N/A	N/A	N/A

Extinguishing Media
None

Special Fire Fighting Procedures
None

Unusual Fire and Explosion Hazards
None

MATERIAL SAFETY DATA SHEET

MITCHELL-BRADFORD DIVISION
HUBBARD-HALL INC.
563 SOUTH LEONARD STREET
WATERBURY, CT 06708

PHONE NUMBER: 203-756-5521
EMERGENCY: 1-800-424-9300

DATE: DECEMBER 12, 1991

PRODUCT CODE: KI2250108

TRADE NAME: MI-CLEAN 8
CHEMICAL NAME: NA
CHEMICAL FAMILY: ALKALINE LIQUID CLEANER
PROPRIETARY FORMULATION

NFPA DESIGNATION 704

HAZARD-RATING:
4 - EXTREME
3 - HIGH
2 - MODERATE
1 - SLIGHT

FIRE: 0
HEALTH: 1
0 REACTIVITY
0 SPECIFIC

SECTION II - HAZARDOUS INGREDIENTS

TETRASODIUM PYROPHOSPHATE (APPROX) 3%, CAS 7722-88-5, ACGIH (TLV): TWA = 5 MG/M3, REGULATED UNDER OSHA AIR CONTAMINANTS, ACGIH TLV CHEMICALS, CANADIAN IDL 1% CONC., MA SUBSTANCE LIST, NJ RIGHT-TO-KNOW HAZ SUBSTANCE LIST, PA HAZARDOUS SUBSTANCE LIST.

NO OTHER INGREDIENTS IN THIS MIXTURE ARE CONSIDERED TO BE HAZARDOUS ACCORDING TO ANY STATE OR FEDERAL REGULATIONS.

SECTION III - PHYSICAL DATA

SPECIFIC GRAVITY: 1.04
VAPOR PRESSURE: NA
PERCENTAGE OF VOLATILITY BY VOLUME: NA
VAPOR DENSITY (AIR =1): NA
EVAPORATION RATE (ETHER =1): NA
SOLUBILITY IN WATER: INFINITE
APPEARANCE AND ODOR: CLEAR LIQUID
PH (CONC): 11<12

SECTION IV - FIRE AND EXPLOSION DATA

FLASH POINT (^{O}F): NONE
FLAMMABLE LIMITS: NA

EXTINGUISHING MEDIA: WILL NOT BURN OR SUPPORT COMBUSTION
SPECIAL FIRE FIGHTING MEDIA: NA
UNUSUAL FIRE AND EXPLOSION HAZARDS: NA

SECTION V - HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE (TLV): SEE SECTION II.
EFFECTS OF OVEREXPOSURE:
SKIN: MAY CAUSE IRRITATION.
EYES: MAY BURN OR EVEN CAUSE PERMANENT DAMAGE.
INGESTION: DAMAGE TO TISSUE.
ROUTES OF ENTRY AND EMERGENCY FIRST AID PROCEDURES:
SKIN/EYE CONTACT: IMMEDIATELY FLUSH EYES AND SKIN WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES. ALWAYS CONTACT A PHYSICIAN FOR EYE CONTACT.
INGESTION: DRINK WATER, DO NOT INDUCE VOMITING. IMMEDIATELY CONTACT HOSPITAL OR PHYSICIAN.

SECTION VI - REACTIVITY DATA

INSTABILITY: STABLE
INCOMPATIBILITY: OXIDIZING ACIDS
DECOMPOSITION: NA
POLYMERIZATION: WILL NOT OCCUR
CONDITIONS TO AVOID: NA

SECTION VII - SPILL OR LEAK PROCEDURES

SPILL, LEAK OR RELEASE: SOAK UP WITH ABSORBENT MATERIAL. THEN NEUTRALIZE REMAINING RESIDUAL WITH A DILUTE ACID AND FLUSH WITH WATER TO CHEMICAL SEWER OR TO DISPOSAL SYSTEM IN ACCORDANCE WITH LOCAL AND STATE REGULATIONS.
WASTE DISPOSAL: DISCHARGE TO A DISPOSAL SYSTEM. IN ORDER TO BE COMPLETELY INFORMED ON THE LATEST REGULATIONS FOR YOUR AREA, PLEASE CONTACT THE LOCAL AUTHORITIES.

SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: NIOSH/MESA - APPROVED DUST TYPE RESPIRATOR.
VENTILATION: LOCAL EXHAUST; AS NECESSARY TO ELIMINATE DUST.
SPECIAL: NA
OTHER: SAFETY SHOWER IN WORK AREA.
PROTECTIVE GLOVES: RUBBER, NEOPRENE OR VINYL
EYE PROTECTION: CHEMICAL SAFETY GOGGLES
OTHER PROTECTIVE EQUIPMENT: FACE SHIELDS, RUBBER APRONS OR

CLOTHING TO PREVENT SKIN CONTACT.

SECTION IX - SPECIAL PRECAUTIONS

HANDLING AND STORAGE: NA
OTHER PRECAUTIONS: NA

SECTION X - TRANSPORTATION REQUIREMENTS

PROPER SHIPPING NAME: NA
HAZARD CLASS: NA
ID NUMBER: NA
RQ: NA
OTHER: NA

WHILE THE INFORMATION AND RECOMMENDATIONS GIVEN ARE BELIEVED TO BE ACCURATE, HUBBARD-HALL INC. MAKES NO WARRANTY, EXPRESS OR IMPLIED, AND ASSUMES NO LIABILITY WITH RESPECT TO USE OF THIS INFORMATION.

M A T E R I A L   S A F E T Y   D A T A   S H E E T

HUBBARD-HALL INC.
563 SOUTH LEONARD STREET
WATERBURY, CT 06708

PHONE NUMBER: 203-756-5521
EMERGENCY: 1-800-424-9300

DATE: JANUARY 11, 1988

PRODUCT CODE: ZFG 8708

TRADE NAME: QUIK DRI
CHEMICAL NAME: NA
CHEMICAL FAMILY: WETTING AGENT MIXTURE
PROPRIETARY FORMULATION

NFPA DESIGNATION 704

HAZARD-RATING:
4 - EXTREME
3 - HIGH
2 - MODERATE
1 - SLIGHT

FIRE: 0
HEALTH: 0   0 REACTIVITY
0 SPECIFIC

SECTION II - HAZARDOUS INGREDIENTS

ETHYLENE GLYCOL ETHYL ETHER (APPROX) 10% CAS 7580-85-0 REGULATED UNDER DOT.

NO OTHER INGREDIENTS IN THIS MIXTURE ARE CONSIDERED TO BE HAZARDOUS ACCORDING TO ANY STATE OR FEDERAL REGULATIONS.

SECTION III - PHYSICAL DATA

SPECIFIC GRAVITY: 1.040
VAPOR PRESSURE: NA
PERCENTAGE OF VOLATILITY BY VOLUME: 10%
VAPOR DENSITY (AIR =1): NA
EVAPORATION RATE (ETHER =1): NA
SOLUBILITY IN WATER: INFINITE
APPEARANCE AND ODOR: WATER-WHITE TO OFF-WHITE LIQUID.

SECTION IV - FIRE AND EXPLOSION DATA

FLASH POINT (F): NA
FLAMMABLE LIMITS: NA
EXTINGUISHING MEDIA: ALCOHOL FOAM, CO2, DRY CHEMICAL.
SPECIAL FIRE FIGHTING MEDIA: NONE
UNUSUAL FIRE AND EXPLOSION HAZARDS: NONE

SECTION V - HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE (TLV): UNKNOWN. OVER 200 PPM.

EFFECTS OF OVEREXPOSURE: MILD IRRITATION OF SKIN UPON PROLONGED OR REPEATED EXPOSURE.
ROUTES OF ENTRY AND EMERGENCY FIRST AID PROCEDURES: IF ILLNESS OCCURS, KEEP PATIENT WARM AND GET MEDICAL ATTENTION. FOR SKIN AND EYES, FLUSH WITH PLENTY OF WATER. GET MEDICAL ATTENTION IF IRRITATION DEVELOPS. IF LARGE AMOUNTS ARE SWALLOWED, INDUCE VOMITING.

SECTION VI - REACTIVITY DATA

INSTABILITY: STABLE
INCOMPATIBILITY: NA
DECOMPOSITION: NA
POLYMERIZATION: WILL NOT OCCUR.
CONDITIONS TO AVOID: NA

SECTION VII - SPILL OR LEAK PROCEDURES

SPILL, LEAK OR RELEASE: RINSE AWAY WITH PLENTY OF WATER.
WASTE DISPOSAL: MAY BE RINSED TO SEWERS IF REGULATIONS PERMIT. ALWAYS CONSULT LOCAL AUTHORITIES.

SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: OVER TLV, USE FULL FACE MASK. CANISTER.
VENTILATION: LOCAL EXHAUST: WELL VENTILATED AREA.
SPECIAL: NA
OTHER: NA
PROTECTIVE GLOVES: RUBBER OR VINYL.
EYE PROTECTION: SAFETY GOGGLES.
OTHER PROTECTIVE EQUIPMENT: CLEAN, PROTECTIVE WORK OR OTHER.

SECTION IX - SPECIAL PRECAUTIONS

HANDLING AND STORAGE: STORE IN WELL-VENTILATED AREA. AVOID SKIN CONTACT AND INHALATION OF VAPORS.
OTHER PRECAUTIONS: NA

SECTION X - TRANSPORTATION REQUIREMENTS

PROPER SHIPPING NAME: NA
HAZARD CLASS: NA
ID NUMBER: NA
OTHER: NA

MATERIAL SAFETY DATA SHEET

HUBBARD-HALL INC.
563 SOUTH LEONARD STREET
WATERBURY, CT 06708

PHONE NUMBER: 203-756-5521
EMERGENCY: 1-800-424-9300

DATE: SEPTEMBER 20, 1991

PRODUCT CODE: ZFG 9845

TRADE NAME: RUSTCOTE 805
CHEMICAL NAME: RUST PREVENTATIVE
CHEMICAL FAMILY: SURFACE ACTIVE AGENTS
PROPRIETARY FORMULATION

NFPA DESIGNATION 704

HAZARD-RATING:
4 - EXTREME
3 - HIGH
2 - MODERATE
1 - SLIGHT

FIRE: 0
HEALTH: 1
0 REACTIVITY
0 SPECIFIC

SECTION II - HAZARDOUS INGREDIENTS

MIXTURE CONTAINS NO INGREDIENTS CONSIDERED TO BE HAZARDOUS ACCORDING TO ANY STATE OR FEDERAL REGULATIONS.

SECTION III - PHYSICAL DATA

SPECIFIC GRAVITY: 1.073
VAPOR PRESSURE: N.D.
PERCENTAGE OF VOLATILITY BY VOLUME: NEGLIGIBLE
VAPOR DENSITY (AIR =1): NON VOLATILE
EVAPORATION RATE (N-BUTYL ACETATE): NON VOLATILE
SOLUBILITY IN WATER: SOLUBLE
APPEARANCE AND ODOR: AMBER COLORED LIQUID
PH (CONC): 11.0

SECTION IV - FIRE AND EXPLOSION DATA

FLASH POINT (F): NONE
FLAMMABLE LIMITS: LEL = N.A. UEL = N.A.
EXTINGUISHING MEDIA: FOAM, DRY CHEMICAL, CO2 OR WATER FOG OR SPRAY.
SPECIAL FIRE FIGHTING MEDIA: NONE
UNUSUAL FIRE AND EXPLOSION HAZARDS: NONE

Inman, S.C. 29349
472-9031,
800-442-5573

SECTION V - HEALTH HAZARD DATA

UNDER NORMAL USE CONDITIONS: MAY CAUSE EYE AND SKIN IRRITATION.
EFFECTS OF OVEREXPOSURE:
EYES: CONTACT CAN CAUSE SEVERE IRRITATION, REDNESS, BLURRED VISION, SEVERE OR PERMANENT DAMAGE.
SKIN: PROLONGED CONTACT CAN CAUSE SEVERE IRRITATION. MIST MAY IRRITATE MUCOUS MEMBRANES.
TOXICITY DATA:
ORAL TOXICITY LD (50) - ND
EYE IRRITION - ND
DERMAL IRRITATION - ND
FIRST AID:
EYE CONTACT: IMMEDIATELY FLUSH WITH COPIOUS AMOUNTS OF WATER FOR AT LEAST 15 MINUTES. CONSULT PHYSICIAN.
SKIN CONTACT: IMMEDIATELY FLUSH WITH COPIOUS AMOUNTS OF SOAP AND WATER FOR AT LEAST 5 MINUTES. IF IRRITATION PERSISTS, CONTACT PHYSICIAN. LAUNDER CONTAMINATED CLOTHING BEFORE RE-USE.
INGESTION: <u>INDUCE VOMITING IMMEDIATELY. ADMINISTER 2 GLASSES</u> OF WATER AND STICK FINGER DOWN THROAT. NEVER GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON. CALL PHYSICIAN IMMEDIATELY.
INHALATION: REMOVE TO FRESH AIR. IF NECESSARY, GIVE OXYGEN, ARTIFICIAL RESPIRATION. CONTACT PHYSICIAN.

SECTION VI - REACTIVITY DATA

INSTABILITY: STABLE
INCOMPATIBILITY: STRONG OXIDANTS LIKE: LIQUID CHLORINE, CONCENTRATED OXYGEN, SODIUM OR CALCIUM HYPOCHLORITE...
HAZARDOUS DECOMPOSITION PRODUCTS: NONE KNOWN.
POLYMERIZATION: WILL NOT OCCUR.
CONDITIONS TO AVOID: EXTREMELY HIGH TEMPERATURES.

SECTION VII - SPILL OR LEAK PROCEDURES

SPILL, LEAK OR RELEASE: FOR LARGE SPILLS, SOAK UP WITH SAND OR SWEEPING COMPOUND AND DISPOSE OF AS SOLID WASTE. FOR SMALL SPILLS, FLUSH TO INDUSTRIAL SEWER.
WASTE DISPOSAL: IN ACCORDANCE WITH LOCAL, STATE AND FEDERAL REGULATIONS.

SECTION VIII - SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: NOT REQUIRED.
VENTILATION: N.A.
SPECIAL: NA
OTHER: NA
PROTECTIVE GLOVES: USE CHEMICAL RESISTANT GLOVES IF NEEDED TO AVOID PROLONGED SKIN CONTACT.
EYE PROTECTION: USE SPLASH GOGGLES OR FACE SHIELD WHEN EYE CONTACT MAY OCCUR.
OTHER PROTECTIVE EQUIPMENT: WEAR PROTECTIVE CLOTHING TO PREVENT SKIN CONTACT.

SECTION IX - SPECIAL PRECAUTIONS

HANDLING AND STORAGE: KEEP CONTAINERS CLOSED WHEN NOT IN USE.
OTHER PRECAUTIONS: SPILLED MATERIAL IS QUITE SLIPPERY.

SECTION X - TRANSPORTATION REQUIREMENTS

PROPER SHIPPING NAME: NA
HAZARD CLASS: NA
ID NUMBER: NA
OTHER: NA
