Evaluation of Alternative Cleaning Solvents, Methods, and Vapor Degreasing Emission Reduction Options

MnTAP Intern Project Report
Thomas Engineering Company
Brooklyn Park, MN

Rimma Krakhmalnikov
Edits and additions made by Karl DeWahl
November 2005

Table of Contents

Abstract

The primary vapor degreaser (T-16), using trichloroethylene (TCE) costs roughly $40,090/yr to operate, with the three largest cost components: labor = $25,000; solvent = $5900; electricity = $4100. There is also concern about potential liability in using TCE. This project attempted to evaluate alternatives to vapor degreasing with TCE, but did not reach a point where recommendations can be fully justified. Information on a range options is described in this report, including a significant evaluation of n-propyl bromide (nPB). Findings include:

- The actual cost and time of degreasing bears little relation to the standard estimates used to quote jobs, and actual costs are generally lower, because less than standard times are used to process jobs. However cleaning quality appears adequate based on visual examination and no customer complaints.
- The TCE consumption rate was cut in half in the first 5 months of 2005 (3600lb annualized) compared to 2003 (8900lb) and 2004 (7800lb). This is probably due to changes in jobs processed.
- There are a number of ways to reduce TCE emissions through improvements to procedures and equipment changes, but the amount of likely reduction was not quantified.
- Immersion cleaning with TCE leaves parts surfaces with 1/10th the surface residue compared to cleaning by vapor rinsing alone. Cleaning by immersion is important for Thomas Engineering Company's type of parts..
- In terms of vapor rinsing, nPB is a slightly weaker cleaner than TCE – immersion cleaning with nPB was not evaluated.
- nPB has heath risks comparable to TCE.

In terms future paths for Thomas Engineering Company's cleaning process, the analysis focused on the following options:

1. Staying with the current vapor degreaser will be the lowest cost option, but automation of parts handling through the degreaser, costing $33,500, is likely to save $7,500/yr in operating labor and should have a positive (but not quantified) effect on solvent emissions and liability.
2. nPB can eliminate Toxic Release Inventory (TRI) reporting and air permitting on the T-16 degreaser, but a new $70-100,000 vapor degreaser would likely be required to meet exposure limits. Air permitting on the portable degreasers would be unaffected, and in the long run it is unlikely that liability associated with an accidental release of nPB would be less than that for an equal release of TCE. A new degreaser would decrease the nPB emissions significantly (70-90%), solvent costs would remain the roughly same, and a new degreaser should lower labor costs by about $7,500/yr.
3. Outsourcing does not look like a reasonable option – based on a single set of quotes with a current subcontractor, outsourcing all cleaning would annually cost around $142,000 more than current degreasing costs. This method would considerably reduce the current flexibility in meeting order due dates. Outsourcing might still have a useful role if combined with aqueous cleaning if outsourcing can be limited to a relatively small number of jobs that are either difficult to handle with aqueous cleaning, or jobs where Production Part Approval Process (PPAP) resubmissions would be needed.
4. Aqueous Cleaning has a relatively expensive first cost ($40-100,000) to handle most of the loose, bulk parts load. Evaluation of this option was only started – many questions remain. The capacity of these cleaning systems should be larger than the vapor degreaser and have comparable operating costs.

One factor not included in this analysis of options is potential future risk and liability in the continued use of solvent cleaners – attaching a value/cost to this factor will make a significant difference in determining whether pursuing one of the more expensive options is worth while.

Summary of Options:

Option	Reduction / Benefit	Savings	Cost	status
Switch to nPB				
Vapor Degreaser retrofitting: automation	Some reduction in solvent releases	$7500 labor	$30,400	Not recommended
New vapor degreaser	70% ?reduction in solvent emissions	$7500 labor	$70-100,000	Consider
Stay with TCE				
Improved operating procedure	Some TCE emission reduction	Some?	$1000??	Recommended provisionally
Vapor Degreaser retrofitting -				
Automation w basket tilting	Some TCE emission reduction	$7500 labor	$26,000	Recommended
Freeboard extension	Small TCE emission reduction	Small?	$3700	Not recommended
Working mode cover	Some TCE emission reduction	Some?	$4400	Consider
New vapor degreaser -	Reduces TCE releases, exposure and liability 5500lb/yr?	$4500/yr? TCE $7500 labor	$70-100,000	Consider as alternative to retrofitting
Outsourcing Parts Cleaning	Eliminates 8170lb/yr of TCE (2004) and environmental liability	$40,000/yr	$185,000/yr	Not recommended Net cost > $100,000/yr
Switch to Aqueous cleaning entirely -	Eliminates 7800lb/yr of TCE (2004) and environmental liability	$4-10,000/yr?	$40-100,000 PPAP resubmittals?	Not recommended
Combinations with aqueous cleaning				
with some TCE Vapor degreasing	Reduces TCE releases, exposure and liability	$2-7500/yr?	$40-100,000	Consider – needs more information
with some Subcontracted cleaning	Eliminates 7800lb/yr of TCE (2004) and environmental liability	???	???	Consider – needs more information

A. Background

A1. Company Description

Thomas Engineering Company is a contract manufacturer founded in 1962 in Minneapolis, MN. They are a leader in micro-miniature, miniature and medium size metal stampings. Their parts are used throughout the United States and in many parts of the world. Parts range in size from about 1/8th of an inch to a few inches in various shapes and forms and can be stamped as a continuous strip or bulk. Their tooling and equipment are capable of producing millions of parts every month. Quality is an extremely important issue for Thomas Engineering Company and their customers, tolerances less than ±0.0005" are common. TEC is known for ingenuity and originality in precision metal stamping. They are the leader in thin-slotting, and regularly pierce slots that are less than ½ the material thickness. Employees strive to exceed customer expectations and ensure top quality parts with just-in-time delivery. The company also offers rapid prototypes, producing samples of parts for customer evaluation within days upon receipt of the part specifications.

The stamped parts are used by a wide variety of companies in industries such as electronics, appliances, telecommunications, automotive, medical and defense. To highlight the significance of the variety of parts produced, note that Thomas Engineering Company played an instrumental role in the design of the patented, single use, INSORB/20 Subcuticular Skin Stapler and is the sole source vendor for the metal stamped parts that make up the unit. Incisive Surgical won the 2005 Medical Design Excellence Award for their INSORB/20 Subcuticular Skin Stapler.

Thomas Engineering Company also offers secondary operations for the convenience of their customers to ensure that the parts will be incorporated into the process without additional operations. Degreasing is one process performed on site to either ensure that the clients receive clean parts that are ready for further operations or assembly, or to prepare the parts for the next process. The main production facility is in Brooklyn Park, Minnesota and a smaller facility is located in Santa Theresa, New Mexico. Both have similar degreasing operations and issues.

A2. Objective and Incentives for Change

Trichloroethylene (TCE) is used to clean oils from metal parts in the vapor degreasing process. Thomas Engineering Company wanted to find a substitute for TCE, and specifically to determine if EnSolv, (n-propyl bromide (nPB)) is a viable substitute. To this end, a first project objective was to determine if nPB cleans as well as TCE. Because nPB is more expensive ($2.40/lb for EnSolv compared to $0.75/lb for TCE), a second objective was to identify ways to reduce nPB emissions to at least 1/3 of current TCE emissions. A third objective was to verify nPB was a safe alternative to TCE. And a fourth objective, time permitting was to take a look at aqueous cleaning and outsourcing cleaning operations as other alternatives to in-house cleaning with TCE. Rimma Krakhmalnikov, a Chemical Engineering major at the University of Minnesota conducted the project work.

The reasons for looking at alternatives to TCE include:

- Cleaning with TCE is regulated requiring an air quality permit and compliance activities including equipment monitoring, record keeping, and reporting. Additional effort and resources are needed for Toxic Release Inventory (TRI) reporting, third-party consultation, and the implementation and maintenance of a pollution prevention plan.
- Although work exposure to TCE is monitored and remains within exposure guidelines, TCE has health effects. Eliminating all exposure would improve the working environment.
- Business is projected to increase, which will increase the number of parts to be degreased which may require equipment changes to stay in compliance.
- Accidental spills and releases of TCE are an on-going possibility as long as the solvent is used. Where these releases have occurred at other facilities, there have frequently been costly site

evaluations, monitoring and remediation spread over years, to mitigate potential effects on human health and the environment.

Thomas Engineering Company would like to decrease its potential impact on the environment as well as lessen and ultimately eliminate the reporting, permitting and other resources associated with compliance.

A3. TCE Health Hazards and Regulation

TCE is a hazardous chemical. Low exposure from breathing in TCE can cause headaches, dizziness, poor coordination and concentration, skin and lung irritation. High exposure can cause impaired heart function, unconsciousness, even death. Extended exposure might cause liver, kidney and nerve damage. The maximum allowed average worker exposure is set at 50ppm for an 8-hour time weighted average (TWA).

TCE is present in many underground and surface water sources because of its wide use throughout several industries. Drinking water with low concentration of TCE for an extended period of time may cause liver and kidney damage, impaired immune system function, and impaired fetal development in pregnant women. Drinking water with high concentrations of TCE may cause nausea, liver damage, unconsciousness, impaired heart function, or death *(Agency for Toxic Substances and Disease Registry, ToxFAQs for Trichloroethylene)*. Underground water contamination is a growing concern for regulatory agencies and the maximum water contamination level for TCE was recently lowered from 30ppb to 5ppb along with increased fines and serious consequences.

TCE is considered a volatile organic compound (VOC) and a hazardous air pollutant (HAP). This requires Thomas Engineering Company to obtain an air quality permit, perform record keeping and submit reports for emissions and solvent usage. As a TRI reportable chemical, an annual report for public disclosure and the maintenance of a pollution prevention plan for the state of Minnesota are required.

Currently, TCE is considered a likely human carcinogen by the National Toxicology Program [reasonably anticipated], NIOSH [potential occupational], EPA [possible to probable, currently under review], the State of California, and the International Agency for Research on Cancer (IARC) [group 2A (probable)]. On the other hand, TCE is not one of the 36 chemicals specifically identified and regulated, with specific action items by OSHA, as carcinogens. The American Congress of Governmental and Industrial Hygienists (ACGIH) lists TCE as "not suspected as a human carcinogen". The difference in opinion appears to be because there is definitive information that TCE causes cancer in some types of animals but not in other types. Those evaluating the issue for the ACGIH concluded cancer is caused by the metabolites of TCE - not by TCE directly, and since cancer does not appear in exposed animal species with metabolisms most like humans, cancer in humans should not be expected to result from human exposure to TCE. ACGIH is reputable in their analysis and recommendations – many times they recommend stricter exposure limits for chemicals than the regulators, since they can respond to new information more quickly. Their recommendations are prudent to follow – but they have no regulatory authority. In many cases, the ACGIH recommendation predicts the direction of future regulatory decisions, but this is not assured and the time lags can be long.

A4. Current Process Description

The shaping of sheet metal into parts and assemblies is the primary function of Thomas Engineering Company. Stamping presses process a variety of sheet and coil stock to cut and form metal into the specified shape and dimensional requirements. Many of the stamped parts need additional processing, such as deburring, plating, heat treating, or assembly. Depending on the process these can be done in-house, outsourced, or completed by the customers. Before processing parts further or shipping them to the customers, many of the parts need to have oils removed that were applied during the stamping operation. Thomas Engineering Company uses vapor degreasing to remove the oils from the parts. Vanishing oils are used on some parts to eliminate degreasing. However, a visible film of oil remains on the parts and the parts may need to be degreased depending on application.

Three vapor degreasers are used to remove oils: a primary degreaser, designated as T-16, (roughly 29 3/8"x45"), used nearly every day, for cleaning the vast majority of parts processed; and two smaller degreasers, designated as T19 and T-23 that are used less frequently for dedicated jobs where they are placed in-line with a stamping press processing strip stock. There are also two in-line aqueous cleaning units that are used in a similar fashion to the small degreasers for dedicated jobs. This project dealt exclusively with the large T-16 degreaser.

Vapor Degreasing

Vapor degreasing is a solvent cleaning process that boils (distills) solvent to produce a continuous supply of pure solvent for cleaning. The degreasing can be achieved in two ways: 1) vapor can be condensed on cold parts to function as a vapor rinse; or 2) parts can be immersed in the boiling sump followed by immersion in the clean sump. The vapor rinse has the potential to produce cleaner parts, but this method can be rendered ineffective by deep recesses (e.g. nested parts) and overwhelmed by heavy soil loading. At Thomas Engineering Company immersion cleaning is needed. This project found that parts cleaned by immersion had less than 1/10th the remaining carbon (from oil) as parts cleaned with a vapor rinse alone (see Table 2 on page 9). These results are based on 2 trials.

Solvent can be lost by four mechanisms:

- Drag-out - Is solvent leaving the degreaser as a liquid film on parts. This is generally the largest source of solvent loss. This can be caused by inadequate drainage or dwell in the vapor zone (see Figure 1), and by inadequate drying in the freeboard zone. Parts with recesses, cupped shapes or blind holes tend to increase drag-out – complex parts are typically tilted, rotated or shaken to reduce it.
- Vapor-Air Interface (VAI) Disturbance - Testing conducted by the EPA and industry, show loads should not move faster then 11 feet per minute (fpm) in order to limit solvent losses. Thomas Engineering Company staff consistently measures the basket speed to be 8 to 9 fpm. Faster load movement causes drafts inside the degreaser, opening the VAI and increasing vapors loss into the air. Unsteady or jerky basket or chain movements can cause the same effect. Room drafts also can push higher concentration vapors out of the degreaser.
- Diffusion - Although vapor zone ends at the VAI (vapor-air interface), vapor molecules tend to diffuse into the air above vapors eventually leaving the degreaser.
- Spills and leaks. This is the most variable, but also controllable solvent loss. Preventive maintenance and primary/secondary containment reduce the environmental effect from these events.

Solvent losses impact operating cost, worker exposure (health effects and cost), and environmental conditions, like smog formation, and in extreme cases soil or water contamination.

Figure 1. is a cross-section of a typical, open-top vapor degreaser. Solvent in the "boiling" sump is heated to its boiling temperature, creating vapors above the liquid solvent. Cooling coils condense the vapors and creates a vapor-air interface (VAI), which defines the end of the vapor zone located near the middle of the cooling coils. The area from the middle of cooling coils to the top of the degreaser is called the freeboard area.

The degreasing process at Thomas Engineering Company is as follows: 1) Parts are loaded into perforated stainless steel baskets. 2) Using an overhead hoist, the basket is lowered into the degreaser and submerged into the boiling sump. 3) The basket is rocked back and forth to ensure that solvent contacts all surfaces. 4) The baskets are raised out of the boiling sump into the vapor zone, manually transferred horizontally across to the "clean" sump side.

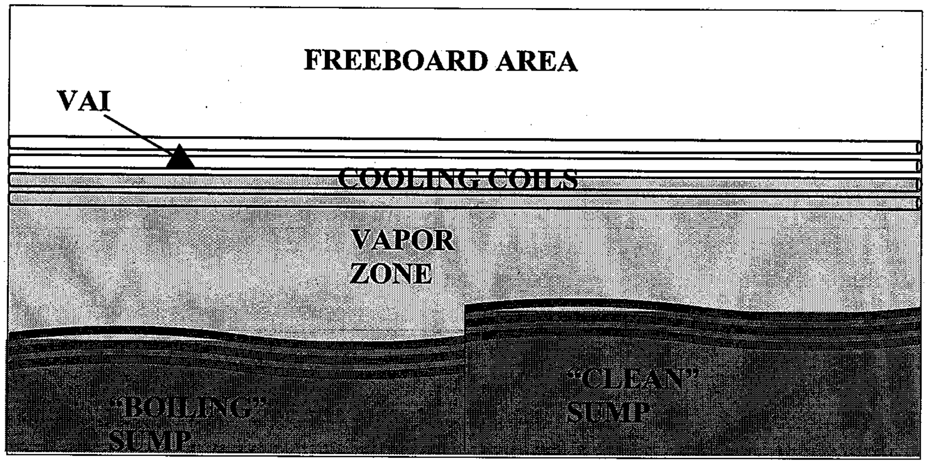


Figure 1

5) The basket is lowered to submerge parts in the "clean" sump. 6) The baskets are raised through the vapor zone, into the freeboard area above the cooling coils. 7) The baskets are tipped and wedged at an angle between the degreaser walls until the parts are completely dry. The whole process takes at least 5 minutes, depending on the type and amount of oil and the shape of the parts. The boiling sump is heated by an electrical immersion heater.

The boiling sump accumulates any oil and dirt removed from the parts. Vapor (distilled solvent) condenses on the cooling coil, runs through a water separator to remove any water introduced on the parts, and then drains into the clean sump. Solvent in the clean sump overflows into the boiling sump to complete the purification cycle for the solvent. There is a still connected to the degreaser that takes solvent out of the boiling sump, and runs it through a parallel cycle, returning condensed distillate to the degreaser's clean sump, in order to remove oils and soils from the boiling sump.

A5. Vapor degreaser regulation

The Halogenated Solvent Cleaning NESHAP (National Emission Standard for Hazardous Air Pollutants) sets the requirements for controlling emissions from vapor degreasers using traditional chlorinated solvents. This rule has three methods of compliance:

- An idling emission test;
- Control equipment; or
- The alternative standard (solvent consumption cap)

Only one of these methods is required for compliance. All three Thomas Engineering Company vapor degreasers (T-16, T-19, T-23) use the idling emission test as the compliance method. The idling emission test is one of the least costly methods of compliance but also may have the least impact of emissions reduction depending on degreaser design. A single test is required that never needs to be repeated as long as there is demonstration that emissions can be maintained at compliance levels. This means that facility conditions that could affect idling emissions have been identified and are controlled within ranges that keep idling emission below the compliance level. Conditions that can affect idling emissions include: whether a cover was used; the cover seal condition; drafts (caused by fans or open doors); leaks; condenser temperature; etc.

For both the idling test and control equipment methods, there are additional compliance requirements:

- Facilities have a choice of either using an idling mode cover whenever parts are not in the degreaser being cleaned, or limit drafts and air movement across the degreaser opening to less than 50 feet per minute (fpm).

- There are 5 equipment design features required that apply to Thomas Engineering Company, most notably the requirement have, and use exclusively, a parts transport system (hoist) that can move no faster than 11 fpm.
- There are 12 work practice requirements, notably requirements to hold parts in the degreaser until dripping stops, tip or rotate parts if needed for drainage, and follow specific start-up and shut-down sequences.

A more complete summary of these requirements is included in Appndix J

Under the control equipment standard there are a number of equipment combinations allowed – see the list in appendix J. Control equipment in the combinations include:

- Superheated Vapor Zone - a system of additional elements that heat the solvent vapor to at least 10°F above its boiling temperature. With proper hold time in the vapor zone parts will dry and eliminate drag-out. This is generally the single most effective method of emission reduction.
- Freeboard Refrigeration Device (FRD) - is intended to cool the air in the freeboard zone. A FRD is typically a set of secondary cooling coils, placed just below the lip of the degreaser, which needs to keep the air temperature in the center of the freeboard zone less than 55°F for TCE.
- Dwell - a hold time for parts loads in the freeboard zone that is no less than 35% of the time required for those parts, starting at room temperature, to stop dripping in the vapor zone of the degreaser.
- Freeboard Ratio – a ratio equal to 1 would be a degreaser wall height above the condenser equal to the degreaser's shortest internal dimension.
- Working Mode Cover - a cover that can be, and is, closed while part loads are in the degreaser, resulting in equipment that is closed almost all the time. It would be open only when parts are transported in or out.
- Carbon Absorber – an emission capture device that, by design, tends to increase solvent consumption, they simply don't release solvent to the environment. Carbon absorbers are relatively expensive to operate.

The alternative standard limits actual emissions from a degreaser, based on a 3 month rolling average, but it does not place any restrictions on how the degreaser can be configured or operated. This compliance method provides the greatest operational flexibility, but can be the most difficult to meet. Solvent consumption logs are kept for the portable degreasers (T-19 and T-23, each with a 4.4ft^2 vapor-air interface area), and this consumption has been consistently below the 136lb/month volume allowed by the alternative standard. These two degreasers have been meeting the alternative standard, although that is not the compliance method chosen for them. The large degreaser (T-16) has a vapor-air interface of about 9 ft^2, for which the alternative standard would require a solvent consumption cap 275 lb/month. The alternative standard cap translates to an annual solvent consumption of 3307 lb/yr for the T-16 degreaser. This compares to a consumption of 8880lb in 2003, 7870lb in 2004 and an extrapolated consumption estimate of 3650lb in 2005 for the T-16 degreaser. Based on 2004 consumption, a 42% reduction in TCE consumption would be needed to meet the alternative standard – and more to have a reasonable margin of safety.

A6. Cost of using TCE

Table 1 lists estimates of the costs components for the T-16 degreaser. Operating labor and the cost of solvent lost to the air are the two largest components of vapor degreaser operating cost. Liability is a cost component that was not estimated (left blank), and there is uncertainty in the labor and solvent costs.

Solvent use in 2003 was 8880lb, 7870 lb in 2004, and extrapolates to 3650 lb in 2005 based on use during the first 5 months of the year. This is a 50% drop in solvent consumption rate in the first half of this year. A big part of this reduction is thought to have been caused by the subcontracting of the production of one high-volume product. In addition, the mix of part designs cleaning will increase or decrease solvent consumption depending on how much solvent a design will drag-out. The 2004 consumption was used in Table 1 as an estimate of long-term solvent consumption.

Table 1. Operating cost for the T-16 vapor degreaser

Cleaning Labor	$25,000
Solvent purchase 2004 @ $0.75/lb	5900
Degreaser electricity[1]	2730
Still electricity[2]	1360
Regulatory fees[3]	2600
TRI reporting	840
TPPA plans and progress reports	175
Hazardous waste compliance	350
Purchasing, storage and handling_	500
Acid test kits	300
Waste handling and disposal	150
Worker exposure monitoring [4]	190
Liability	??
Total	$40,095 /yr

[1] 10kW heater; condenser refrigeration for a 10kW heat load operating at a COP of 3; $0.07/kWhr; 3000hr/yr

[2] 5kW heater; condenser refrigeration for a 5kW heat load operating at a COP of 3;

[3] Air Permit; Air emission fee; P2,TPPA; HW

[4] The purchase of a PID meter for measuring TCE concentrations may decrease or eliminate future exposure badge costs.

B. Evaluation of methods to reduce or eliminate TCE use

Project plan

Initially this project intended to demonstrate whether n-Propyl Bromide (nPB) was a viable substitute for TCE in terms of its ability to clean, any differences in how nPB would be used, and future regulation. The solvent nPB was the only seriously considered alternative to TCE. Other alternatives include:

- Hydrochlorofluorocarbons (HCFC) will be phased out of production by the year 2015 due to their ozone depletion potential. AKK-225 is the only HCFC finding use in vapor degreasing applications and it is more expensive than nPB ($11.65/lb compared to $2.40/lb for nPB).
- Hydrofluoroethers (HFE, a 3M product) and hydrofluorocarbons (HFCs, a DuPont product). HFE products seem to be the best fit for vapor degreasing. They have ozone-depletion potential of 0, no flash point, high solvency, and high exposure limits. But they have high global warming potential (ranging from 43 to 650 compared to 0.31 for nPB, <9 for TCE, and 1 for carbon dioxide) suggesting possible future regulation. These products are much more expensive then either nPB or TCE – about $20/lb for HFE7100.
- Ignitable solvents clean well, but have fire hazards. Many have exposure and regulatory compliance issues that vary with the solvent but can be roughly comparable to TCE for the stronger solvents. It is also more difficult to set up a system to maintain clean solvent in order to assure consistent cleaning effectiveness. Vapor degreasing equipment for flammable solvents is available but it is more expensive than comparable equipment for halogenated solvents due to the need for additional safety features.

The evaluation of nPB included testing cleaning effectiveness, a review of health and regulatory information, and a look at ways to reduce losses, since nPB is 3 time more expensive to purchase ($2.40/lb compared to $0.80/lb for TCE). Time permitting, we would attempt to collect information about aqueous cleaning and outsourcing of the entire cleaning operation as an alternative to on-site TCE degreasing.

Options and Recommendations

1. Switch to nPB	
Equipment retrofitting -	not recommended
New vapor degreaser -	consider
2. Stay with TCE	
Improved operating procedure	recommended provisionally
Equipment retrofitting -	
Automation w basket tilting	recommended
Freeboard extension	not recommended
Working mode cover	consider
New vapor degreaser -	consider as alternative to retrofitting
3. Subcontracting –	not recommended
4. Switch to Aqueous cleaning entirely	not recommended
5. Combinations with aqueous cleaning	
with TCE Vapor degreasing	consider – needs more information*
with Subcontracting -	consider – needs more information*

*See the Next Steps section on page 23.

B1. nPB as an alternative to TCE

The solvent n-Propyl Bromide cleans nearly as well as TCE and should work as a functional substitute when used in an immersion cleaning cycle. In the near term the only regulation affecting the use of nPB is likely to be a worker exposure limit. It is unlikely this exposure limit can be met with the current T-16 degreaser, which combined with the high cost of nPB probably requires the purchase of a new degreaser ($70,000-100,000) with superheat, automated load handling and an enclosure. The portables T-19 & T-23 may have less difficulty since their operation is largely unattended. Although, nPB is not currently regulated, research points to its possible regulation in the future. For the long term, while there are no current efforts to further regulate this solvent in the United States at the Federal level there are a few state initiatives and I suspect this solvent will be regulated similarly to TCE.

Evaluation of nPB cleaning effectiveness

Some of Thomas Engineering Company's customers follow a Production Part Approval Process (PPAP) for part submission and approval. Once approved, the materials and process operations are locked in and cannot be changed without prior notification, sample submission, and final customer approval. Since process changes usually affect customers further down-stream there is an expense and delays for process change submissions. Some submissions may cost upwards of $20,000. In Minneapolis there are 14 products approved under PPAP, with another 11 at the Santa Teresa location.

Typically, the PPAP process identifies only the operation for degreasing and not the solvent used. If the nPB cleans as effectively as TCE there is little concern of a part performance issue. However, there is valid concern if cleaning effectiveness between solvents is different; would customers notice a change in

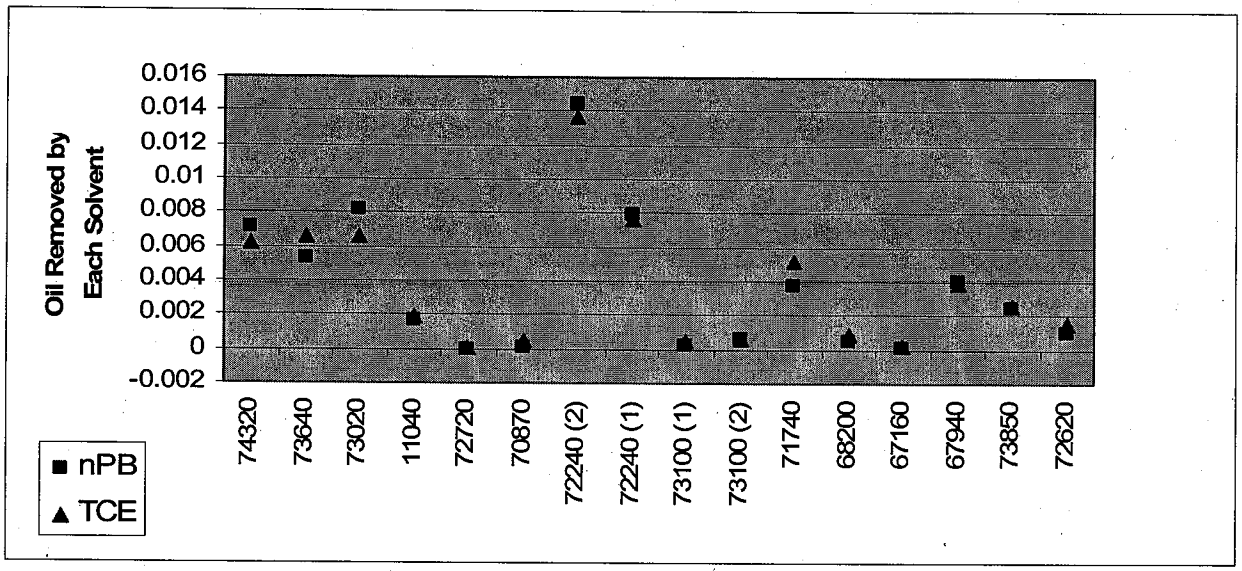


Figure 2. Comparison of the weight of oil removed by nPB and TCE for various parts

part performance? A decline in performance would result in a reject or non-conformance, requiring a corrective action. The identification of the root cause would expose the change in process. However, each customer tends to have their own interpretation defining a process change.

Cleaning test procedure

To compare the cleanliness effectiveness between TCE and nPB, parts were selected to test a variety of metal substrates, oils, complexity of shape features, and difficulty of cleaning. Parts were arranged in a way to test the worst possible scenario with cups and cavities facing upward. Two flat parts (items 72240 and 73100) were tested both individually (indicated on the chart by (1)), and stacked, pairs of parts one on top of the other (identified by (2)). The stacked trial represents what occurs when parts are cleaned in bulk and are nested or stuck together, which represents a more difficult cleaning situation.

During the experiments, the parts were held in the vapor zone for 5 minutes. There was no submersion or agitation to ensure that only the cleaning capability of the solvent was tested and not the additional physical influences. Parts that Thomas Engineering Company produces are very small, many have complex geometries with different angles, curvatures and formed cavities. The gravimetric method, weighing parts, was used to test the cleanliness because this test was not surface and geometry specific. A batch of 10 oily parts of each item were weighed, cleaned in TCE and re-weighted. A second batch of 10 oily parts of the items were weighed, cleaned in nPB and reweighed. The weight difference between oily and clean parts identified the amount of oil removed. Figure 2 was compiled to illustrate the relationship between the amounts of oil removed by each solvent for each part.

Figure 2 shows there is little difference between the amount of oil removed by TCE and nPB for a single item. There is substantial variability in the weight of oil removed per part, between items. This is largely due to variations in the amount of oil initially on parts, which is a function of parts size, the oil used and the amount applied – part size / surface area is likely the largest contributor. Visually, parts that were cleaned in TCE and nPB were very similar in appearance, except for item 71740. This part appeared to be clean and dry after being vapor cleaned by TCE, but was still oily after vapor rinsing in nPB. This item is a pre-tin plated beryllium copper part formed using an evaporating oil. This part was retested with orientation to promote drainage and resulted in clean dry parts. In this case orientation requirements would be too costly to implement. However, this implies that a switch to nPB may require either part orientation, smaller load sizes, or other processing techniques for some parts. On the other hand immersion cleaning in nPB may compensate for any vapor rinsing differences.

The gravimetric method measures the amount of oil remaining on parts. The method was quick, inexpensive and could be done on-site. The expectation was that both solvents would remove most of the oil, so we questioned whether small differences could be observed. In addition, the more important criteria is how much oil would remain on part surfaces after cleaning. Therefore, a subset of the tested parts were sent to UIC, Inc., for comparison testing using Surface Carbon Analysis. This test measures amount of carbon atoms on the surface. Since oils are hydrocarbons that contain carbon, the method determines the amount of oil remaining on the parts. Table 2 contains the results analysis by UIC, Inc. for five items cleaned with TCE and nPB. Sample parts 3 and 5, labeled "Current", measured remaining oil on parts taken from the regular degreasing process. These parts were cleaned in large loads run through the T-16 degreaser, immersing in both the boiling and clean sumps. The data show first that there is a slight difference in cleaning effectiveness of a vapor rinse between the two solvents. TCE left generally half the oil on the surface compared to nPB and in one case left only one tenth as much. This layer is very thin and the difference in weight was undetectable by the balance, which had an accuracy of 0.00005 grams/part. A second important observation is that the parts cleaned with immersion ("current" process) were much cleaner than the vapor rinsed parts. Immersion cleaned parts had less than one tenth the amount of residual oil on the surface as parts vapor rinsed in TCE. This indicates the importance of immersion and agitation as crucial components in the degreasing process at Thomas Engineering Company.

Table 2.
Results of Surface Carbon Testing – the amount of carbon remaining after cleaning

Sample Name	**No. of Pieces**	**ugC/piece (590 deg. C)**
1-TCE	5	14.86
1-nPB	5	24.40
2-TCE	5	10.29
2-nPB	5	103.34
3-TCE	5	**198.33**
3-nPB	5	**770.07**
3-Current	4	**17.48**
4-TCE	5	6.27
4-nPB	5	13.05
5-TCE	5	**858.69**
5-nPB	5	**1626.91**
5-Current	5	**65.84**

Note that these test results allow no conclusion on whether parts cleaned by immersion in nPB would have more residual surface oils than parts cleaned by immersion in TCE. Agitation or physical movement of parts through liquid solvent may make up for any differences the solubility of oils in the two solvents.

It is unlikely nPB will clean better than TCE, using immersion, for any of the oils tested, but it is possible the cleaning effectiveness of the two solvents would be equal. If nPB is a weaker solvent under immersion cleaning conditions also, there would be PPAP implications. This should be verified before committing to nPB as a replacement for TCE.

nPB Safety and Regulatory Outlook

Health Hazards

The solvent nPB is advertised as an unregulated alternative to the common vapor degreasing solvents. This leaves the impression that it is safer then TCE in terms of worker's health and environmental effects. However, research showed nPB has significant health concerns.

Low exposure can cause eye, nose, throat and skin irritation as well as headaches and dizziness, symptoms very similar to those of trichloroethylene at low concentrations. However, higher exposure to n-Propyl Bromide, as low as 100ppm to 200ppm, has caused adverse reproductive effects, and nervous system effects at 400ppm. Liver damage can also be observed, although at higher concentrations. There is some suspicion nPB might be a carcinogen because other related chemicals are carcinogens, but no conclusive tests have been published to date. All health effect studies have used animal test subjects – nPB is not yet in wide enough use to have epidemiological studies on human populations.

nPB Regulatory Information

Currently nPB is regulated only by the Community Right-to-Know Act requiring an MSDS be made available to workers using it, but further regulation is expected. Much of the developing regulation will not immediately require actions by industrial users of nPB in Minnesota, but they do indicate a trend. EPA has proposed a permissible exposure limit (PEL) for nPB of 25ppm time-weighted average (TWA) for an eight-hour work day [see the Significant New Alternatives Policy (SNAP) Program proposed rule in the appendix]. Margaret Sheppard, EPA (SNAP Program), said EPA is currently discussing whether to decrease the PEL to perhaps as low as 10ppm in the final rule – this will affect all users in the United States within 6-12 months. The American Conference of Governmental Industrial Hygienists (ACGIH) currently recommends a 10ppm exposure level. ACGIH is a reputable advisory organization, which while it has no regulatory authority is generally recognized as publishing prudent advice on chemical exposure. California is proposing 1ppm and European countries "proposed adding n-PB to the list of dangerous chemicals that can cause cancer, have mutagenic properties or are toxic to reproduction," *(May 2005 TEAP Progress Report, p. 95).*

For the time being, nPB is not considered a HAP (Hazardous Air Pollutant), is not TRI reportable, has no OSHA rules identifying nPB for specific actions, and is not a listed hazardous waste. However it would be prudent to dispose of waste nPB through the same disposal mechanism as are currently used for waste TCE. No current efforts were identified which would add nPB to any of these regulations, so it is unlikely there will be further regulations soon. There are two possible reasons for US regulators having relatively low interest in looking more closely at nPB. First, the body of evidence on nPB health effects is much smaller than for traditional solvent (there is less certainty in its effects). Second, the production volume of nPB is still relatively low so the exposed population is relatively small. But the nPB hazards identified are similar to the hazards of the heavily regulated traditional vapor degreasing solvents so there is no reason to think nPB will not be regulated in a similar fashion in the long run.

Too little is known about the behavior of nPB in underground water and soil to determine its effects on the environment and human health. It is not now identified as a drinking water contaminant. However, given the chemical similarity with other halogenated solvents that are water contaminants of concern, it is difficult to imagine there would not be liability if nPB were identified in a water supply.

Two recently identified articles provided additional insights into the likely regulatory future of nPB. The first article stated that Atofina Corporation, a European producer of nPB, refuses to sell its product to companies without a fully enclosed system. *(Refer to bottom of page 15, http://www.ssec.wisc.edu/icds/reports/Drill_Fluid.pdf).*

Another article stated that two legislators proposed for TCE to be phased out and the legislator from California proposed for nPB to be included with other hazardous halogenated solvents. This information was obtained in the last section of the article at http://www.hsia.org/updates/apr-may%202005.htm. It is unknown whether these proposals will pass or not, and it is hard to tell if this should be considered seriously at this point.

Evaluation of nPB emission reduction

The cost of nPB is roughly $2.40/lb, or three time that cost of TCE. All things being equal this could translate into a $13,000/per year increase in degreasing operating costs. Further, nPB has a lower boiling point which might double diffusion losses from the degreaser (drag-out losses should not be affected). It also appears nPB will have a more strict worker exposure limit. These three factors increase the importance of further control of degreaser emissions.

A current supplier of Thomas Engineering Company, made the substitution to EnSolv without making any process or equipment changes, and found the change was expensive. They have since switched back to using methylene chloride. (Note methylene chloride has additional OSHA requirements that all of the employees on the floor have to wear face masks and take urinary tests regularly, this tends to be time consuming, not to mention costly.)

The supplier of Ensolv has exposure data from a number of European facilities demonstrating it is possible to achieve exposures below the likely PEL of 25ppm. However there are only 4 examples for larger open-top degreasers like the T-16 degreaser, and there is no information about degreaser configuration, age, how automated, or how heavily used they are.

Recent TCE exposure monitoring for the operator of the T-16 degreaser measured exposures in the area of 45ppm. To meet the proposed 25ppm exposure limit, emissions would need to be reduced by at least 45%, and to have a 50% margin of safety in exposure, the reduction would need to be at least an 80% reduction. Methods of reducing emissions through retrofits of the current degreaser are discussed further under the heading of Retrofits for Solvent Loss Reduction, but this magnitude of reduction would likely be difficult to achieve through retrofits. To use nPB safely, a vapor degreaser with a full enclosure, superheat and cycle automation should be purchased. The cost for a new degreaser of this design is in the area of $70-100,000. Finding a used degreaser of modern design is possible, but they are not common. Potential savings are perhaps $7500/yr in operating labor, and perhaps $3400/yr in avoided regulatory costs, at least initially.

B2. Stay with TCE - Evaluation of the Current Degreasing Practice for Decreasing Solvent Loss

Staying with the current vapor degreaser will be the lowest cost option. Overall, the direct cost of regulatory compliance is small. Any potential risk from the use of TCE is an unknown cost.

Provisionally, the first recommendation is for an improved degreasing operating procedure to minimize drag-out, to reduce solvent losses, and reduce worker exposure. The recommendation is provisional because it is yet to be proved that solvent dripping can be stopped with a reasonable vapor dwell time given the current degreaser design and basket/load processing. Further, it is unclear how large the benefit would be if achieved.

The second recommendation is to retrofit the T-16 degreaser to add automation of parts handling through the degreaser, including basket tilting, costing about $26,000. Automation is likely to save $7500/yr in operating labor as well as having a positive but un-quantified (probably small) effect on solvent emissions and liability reduction.

Purchasing a new vapor degreaser could be considered as an alternative to retrofitting the T-16. A degreaser designed with load handling automation, superheat and a full enclosure will cost $70,000-100,000, and should cut operating labor in half ($7500/yr) and perhaps cut TCE loss by 70% ($4500/yr). Compliance with the vapor degreaser NESHAP would be very clear – control equipment would be the method on compliance, and potential liability would be incrementally reduced.

A working-mode cover (cost = $4400) could be considered as an additional retrofit of the T-16 degreaser. While a retrofit to extend the freeboard (cost = $3700) is not recommended. Both would cost about the same amount, but the working cover would be expected to reduce solvent losses by a greater amount. The amount of solvent use reduction and the cost savings were not quantified.

The recommendation to retrofit automated parts handling, and the provisional recommendation for an improved procedure apply to the Santa Therese, NM location also. If Thomas Engineering Company purchases a new degreaser for Minneapolis, then the current stationary degreaser could be retrofitted and moved there.

Recommended vapor degreaser procedure to minimize solvent losses:

1. Step parts into the vapor zone to prevent vapor zone collapse – see George Gawrys' calculator
2. Immerse in the boiling sump for a time determined by individual cleaning needs of that part, (rock the basket in the solvent if parts are cupped or have recesses that could hold small volumes of air).
3. Raise the basket out of the boiling sump, hold for 15 seconds to allow oily solvent to drain off parts (preventing contamination of the clean sump), (if parts are cupped or have recesses that could hold small volumes of liquid, rock the basket gently but tilt the basket as steep as possible without losing parts).

4a. If the clean sump is cold (within 90 minutes of startup, assuming that loads are being processed steadily during this time),

Transfer the basket into the clean sump, stepping the load into the clean sump to slow the overflow of cold solvent into the boiling sump and thus prevent vapor collapse, (rock the basket in the solvent if parts are cupped or have recesses that could hold small volumes of air), step the basket out of the sump to avoid vapor collapse, then hold for 60 seconds, oriented for load drainage, (rock the basket gently if parts are cupped or have recesses that could hold small volumes of liquid).

[Note: 90 minute is a guess at the time required for the clean sump to warm up to the point that parts coming out of the sump do not collapse the vapor zone].

4b. If the clean sump is hot,

Transfer the basket into the clean sump, raise the basket out of the sump, then hold for 40 seconds, oriented for load drainage, (rock the basket gently if parts are cupped or have recesses that could hold small volumes of liquid).

5. Raise the parts basket just above the condensing coil, orient the basket for drainage [determine if this is needed] and hold for 30 seconds to dry parts
6. Remove the basket from the degreaser and unload parts

Procedure background - Location of holds for drag-out reduction

In ideal vapor degreasing practice, part baskets are held in the vapor zone until dripping becomes very slow or stops, then the load would be positioned in the freeboard zone where the remaining solvent film on parts will flash off. Since TCE vapor is heavier than air, much of it will sink down and re-join the vapor zone. Currently parts go directly to a freeboard hold. The disadvantage of adding a vapor hold is that it increases cleaning time or lowers cleaning operation capacity.

A difficulty discovered late in the project was that it is hard to hold the basket in the vapor zone in a way that dripping stops. The standard drainage method, wedging the basket diagonally and at an angle, left a corner of the basket extended well out of the vapor zone, and resulted in dripping as long as the configuration was held. Taking care to keep the basket entirely within the vapor zone resulted in slower dripping, but not as slow as expected. Possible explanations are:

the vapor zone in the T-16 degreaser is very short (12" to the condenser trough);
the basket does not drain freely;
inability to tilt the load for drainage;
the basket hanger rods cool the basket.

Dave Blackstone of Finishing Equipment, George Gawrys of Thomas Engineering Company, Karl DeWahl of MnTAP, and Rimma Krakhmalnikov were involved with these observations and tests. We lowered the end of a 1/2" diameter aluminum rod into the vapor zone to both test the theory that condensation should stop after a vapor hold and to look at the effect of materials extending out of the vapor zone. Condensation started immediately when the end entered the vapor zone, then dripping slowed and then stopped within 30 seconds. This suggests that the vapor quickly heats up metal extending through the air-vapor interface to the point that this metal would not cause continuous dripping. To definitively determine whether the basket hanger rods draw heat out fast enough to contribute to the observed continuous dripping, repeat this test with a heavy steel rod.

Possible ways to improve drainage in a vapor hold include:

a) install support tabs on one wall to support a edge of the basket while the other side is lowered. This would work well with load cycle automation.
b) re-design the basket to either:
  i. open up the sides and bottom for better drainage; or
  ii. bow out or crease the current basket bottom to create a low spot for drainage.
c) shorten the basket in either width or length to allow tilting on the short axis – this might affect throughput, and there would need to be a new way to accomplish tilting – using support tabs would be one way;
d) consider enlarging the vapor zone if there will be a significant retrofit of the degreaser (e.g. superheat);

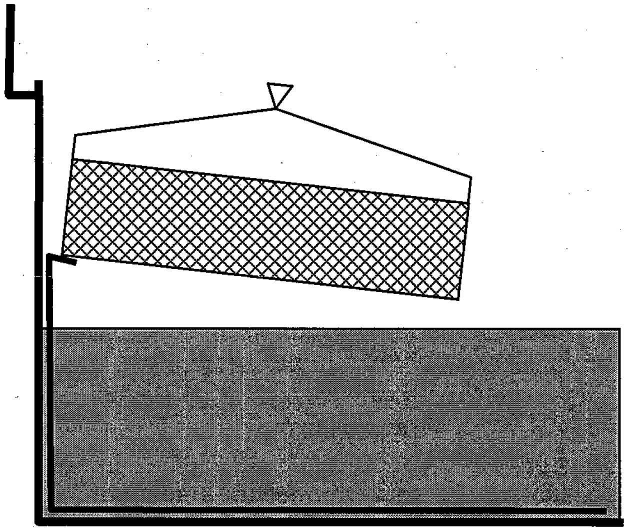


Figure 3. Load support tabs.

Vapor Collapse

Dave Blackstone observed that as cold parts were lowered into the vapor, the vapor zone collapsed – the cold parts condensed all of the vapor so air filled the volume down to the solvent surfaces. It took 2 minutes for the vapor zone to re-establish itself. Dave indicated vapor collapse is an undesirable event that increases solvent loss – with each vapor collapse a mixture of solvent vapor and air is pushed upward and much of it is lost. Dave indicated each vapor collapse is similar to removing a load of parts from the degreaser. As a solution, Dave suggested introducing the loads with starts and stops to prevent vapor collapse. George and Karl constructed a calculator to estimate hold times for various load sizes and materials. Stepping in parts will likely increase cycle time. The power of the boiling sump heating element will influence the boiling rate and thus the hold time calculator. There is conflicting information about the size of this heater - documentation onsite indicates a heater rated at 5kW, but a representative of the manufacturer indicated in a phone conversation that this degreaser generally has 10kW of heating capacity. Calculations looking at vaporization rate and load size suggest the heater should be larger than 5kW.

Load Movements
Industry tests have shown that load speeds higher than 11fpm create induced drafts that result in significant solvent losses. The hoist controls only the speed of up and down movements. To move the basket horizontally, the operator has to pull the chain in that direction. Even if they try to move slowly, their movements would still be, at least occasionally, faster then the required speed of the basket. Currently, operators also shake baskets to aid drainage.

Basket weight
The load tested weighed 42lb and the basket weighed 10lb. For a load of steel parts, the basket constitutes 20% of the thermal load. This is another reason to consider basket re-design. The best design change would have more open walls and bottom and be made of lighter material if possible. Constructing an aluminum basket to replace the current steel basket would have advantages in terms of the thermal load introduced into the degreaser, however aluminum is a reactive metal that promotes the hydrolysis of halogenated solvents leading to degreaser acidification. As long as the solvent stabilizer package is intact, this should not be a problem, but the benefits do not out weigh the risks of continuously exposing the solvent constantly to aluminum.

Retrofits for Solvent Loss Reduction

Process and equipment changes can reduce solvent losses, emissions, worker exposure. Eliminating human variables provide a consistent and repeatable process. Changes in the process and equipment also have to be made to remain within any possible exposure limits if Thomas Engineering Company decides to switch to nPB. Process changes should include lengthening hold times for drainage and drying. Vapor degreaser retrofitting options include:

1. Superheat
2. Secondary (freeboard) cooling coils
3. Automation
4. Basket tilting or rotating basket
5. Freeboard extension (at least 100%)
6. Working-mode cover

This project did not determine the amount of reduction possible at Thomas Engineering Company through direct measurement or simulation. Reduction estimates exist based on experiences at other facilities. One of the difficulties in extrapolating results from other facilities to the T-16 degreaser is that any change affects only one or two of the three main emission mechanisms, not all of them. A typical facility might lose 50% of their solvent losses to drag-out, 30% to drafts and 20% to diffusion, but these estimates are highly dependent on equipment configuration and operating practices. No estimate was made of the magnitude for these loss mechanisms on the T-16 degreaser. There are improvements that can be made but ultimately it is not clear how large a reduction will result. With the photo-ionization detector (PID meter) now owned by Thomas Engineering Company, quantitative estimates of emission reductions are possible by comparing solvent concentrations in the high freeboard zone for standard operating practices with those from simulated, improved practices. Itemized labor and material costs for retrofits are included in the appendix.

Superheat & Secondary Coils

Superheat can eliminate drag-out on parts by heating them above the boiling temperature of solvent. Superheat as a retrofit to the T-16 degreaser will cost at least $15,000 and may not be possible if the stainless steel of the degreaser has been embrittled – testing would be needed to determine if welding can be done on the equipment. Superheat modifications would need to be done by an external contractor, probably Finishing Equipment, and the degreaser would not be available for use during reconstruction, so alternative cleaning arrangements would be needed. Adding superheat would enlarge the degreaser footprint by 30-50%. The primary containment pan most likely would have to be replaced. Superheat is the single most effective way to reduce emissions, but is probably best accomplished through new equipment designed to function with this feature. A new degreaser would cost $70,000-100,000. Secondary coils, can reduce diffusion losses by cooling the air blanket in the freeboard zone, but this would cost over $10,000.

Automation

Automation eliminates human variables and improves consistency and safety. With automation an operator would only load the parts, start automation process, and then return to unload the parts when the process is finished. Automation can reduce drag-out losses and the creation of drafts by load movements. About 50% of degreasing time is spent on loading, unloading and packaging, and the rest of the time is spent on actually degreasing the parts, including moving hoist and tilting loads for drainage. If automation is incorporated, operators can do other tasks, such as deburring while the degreasing takes place. Therefore, labor costs should decrease by about 50% or perhaps $10,000/yr in labor costs, assuming there are other activities to productively use this labor or hours can be cut. We will use an estimate of $7500/yr for the value of saved labor to account for the likely inefficiency in utilizing these hours for other productive purposes.

Automating the Z-axis (vertical travel) will cost about $7300 in materials and labor, with work done internally. This accomplishes most of the emission reduction, but does not reduce operating labor much - rocking baskets for drainage would be still be done by hand. Automating the X-axis (horizontal travel) will cost an additional $12,500 in labor and materials, for a total of $19,800 for both axes, and $26,000 including the capability to tilt baskets.

Where necessary cleaning cycle time can be lengthened to reduce solvent losses through longer holds and tilting times, but with automation, these times do not require attendance. There are indications that some current loads are left in the degreaser longer than required when operators are busy with other tasks. Automated parts handling will ensure the correct process is performed consistently. The time for loading, unloading and packaging will be the same. Even though the degreasing time lengthened, the time will not be lost because other tasks can be accomplished. This implies that even with the longer process time, degreasing can still be completed as planned.

Basket tilting

Due to different shapes, angles, blind holes and formed cavities, one of the important issues in the degreasing process is the drainage of solvent. All of the solvent should be drained before lifting the part out of the degreaser. Solvent that remains on the part will completely evaporate into the air. This is called the drag out and is the major cause for solvent loss and higher levels of exposure. Currently, baskets are tilted manually. The operators hold the chain moving it toward and away from them causing the basket to rock and shake. This process promotes drainage but causes disturbances in the vapor blanket, opening the

VAI and producing a "chimney" effect where solvent escapes through the opening into the air. Some rapid movements also cause splashing of the solvent which is a different but related type of loss. Movements faster then 11fpm disturb VAI and cause larger solvent losses. Slow and uniform tilting of the basket will add some process time, but reduces solvent loss.

Rotating baskets drain complex parts the best, but they are expensive and mainly used in aqueous cleaning. Rotating baskets typically have smaller load capacity.

Freeboard Extension

Extending freeboard to at least 100%, by adding at least 8 inches to the current freeboard, will decrease the solvent lost through diffusion and draft mechanisms. Solvent vapors diffuse into the air. Therefore, air is very concentrated with the solvent directly above the VAI but vapor concentration in air decreases as the distance from the vapor zone increases. If the freeboard height increased, then the air leaving the degreaser and the air above and around the degreaser will be less concentrated with vapors. Extension of the freeboard involves adding a sheet of stainless steel to the top of the degreaser. Estimated cost is $3700 for materials and labor.

Working-mode cover

Working-mode covers reduce the area through which solvent can escape, reducing solvent losses and exposure. They keep the degreaser covered, except when loads are traveling into or out of the degreaser. With covers closed solvent vapor will concentrate below the covers because diffusion continues until equilibrium is reached. Since less vapor escapes, there is less depletion of the solvent at the degreaser mouth. As a result, air escaping through openings (cracks or opened cover) carries more solvent with it, but since solvent is heavier than air, as it becomes more concentrated, there is also a greater tendency for vapors mixed with air to rejoin the solvent vapor zone. A working-mode cover will also reduce solvent losses due to room drafts. The cost of adding working covers to the existing degreaser would be about $4400 in material and labor.

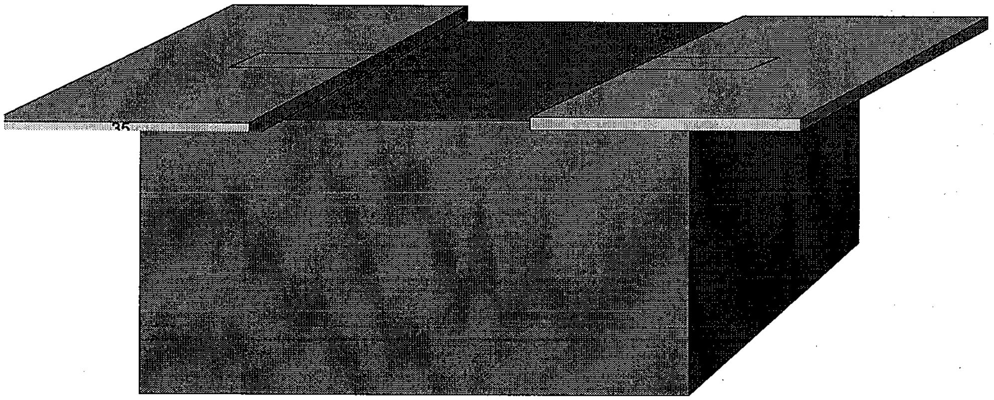
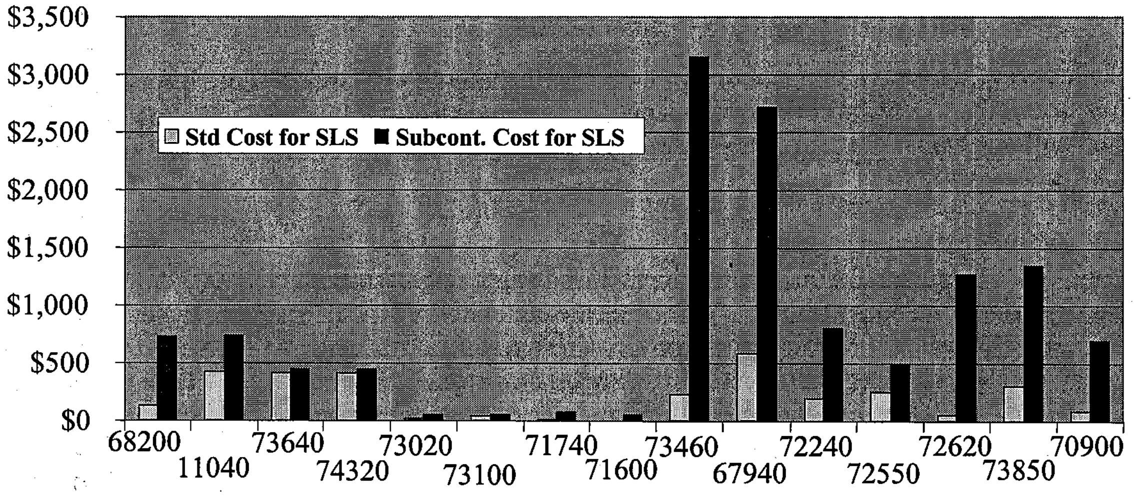


Figure 4. Working mode covers

B3. Subcontracting/Outsourcing

Complete outsourcing of degreasing is not recommended, because of the added expense and the increase order turn-around time. Costs of degreasing in-house or subcontracting were compared for the fifteen parts tested for cleaning effectiveness. The cost of subcontracting a regular lot size of each of those fifteen parts was about $10,000 higher than standard costs for degreasing, and standard degreasing costs are thought to be higher than actual costs because of operators degreasing. Figure 5 shows the subcontract costs of cleaning 15 parts lots quoted by a current supplier of Thomas Engineering Company, compared to standard costs at Thomas Engineering Company. Tested parts account for only 7% of the total production. This means it would cost about $143,000 of subcontract all parts cleaning each year.

Figure 5. Subcontracting versus In-house Costs



Thomas Engineering Company prides itself on delivering parts when the customer needs them. However, this will be more difficult if a third party is involved. Travel time and time for packaging parts for travel is not required for parts cleaned in house. If delays occur the pressure is on everyone to get the parts to the customer. Even though this job would be a high priority for Thomas Engineering Company, it might not be a high priority for their subcontractor. Table 3 shows some of the extra process steps inherent in outsourced operations.

Table 3. A comparison of processing before or after degreasing

In-house cleaning	Outsourcing cleaning
Stamping parts	Stamping parts
	Packaging parts
Move parts to the degreasing area	Move parts to the shipping area
	Processing shipment paperwork
	Delivering the parts to the subcontractor
	Parts received and papers are processed
	Parts taken to the degreasing area
Cleaning the parts	Cleaning the parts
Packaging parts	Packaging parts again
Move parts to the shipment area,	Move parts to shipment area,
Processing shipment paperwork	Processing shipment paperwork
Delivering parts to the customer	Delivering parts back to TEC or to the customer

B4. Aqueous Cleaning

Aqueous cleaning is unlikely to replace vapor degreasing at Thomas Engineering Company in the short run. There are too many questions about whether aqueous cleaning can clean all parts adequately – this will require significant amounts of testing to demonstrate what the limitations are. Dealing with PPAP resubmission would be another disadvantage of switching entirely to Aqueous cleaning.

Aqueous cleaning would work best in a transitional role where it would reduce reliance on vapor degreasing and be available for evaluating new parts and submitting initial PPAPs. The current need would be to clean a variety of bulk parts in baskets. If aqueous cleaning is used in combination with vapor degreasing, the vapor degreaser would be used to clean parts that will not be cleaned or processed well with an aqueous system, parts that have existing PPAP requirements, or critical part. Critical parts might include particularly delicate parts, or parts that might be corroded or damaged by water contact.

Aqueous cleaning and subcontracting would allow the elimination of vapor degreasing. It would work best if the majority of parts can be cleaned in an aqueous system, leaving a small number of parts to be subcontracted with the higher cost and time allowances involved. This would also be a possible solution for the Santa Teresa location.

Background and choices

Aqueous cleaning is a common alternative to solvent-based vapor degreasing. This project did not test the cleaning effectiveness of aqueous cleaning. While oils are generally relatively easy to clean and most metal can be cleaned in water, it remains to be proven whether aqueous cleaning will remove the oils used at Thomas Engineering Company or how many part design or materials are compatible. Testing should be conducted if aqueous cleaning is pursued. The main plant currently has two aqueous cleaning modules that are used to clean stamped parts on strips. A list of drying methods is included in the appendix I. Drying costs can be minimized by designing a process that mechanically removes much of the water film without evaporating it. There is a limited space on the manufacturing floor.

Although aqueous cleaning will eliminate air quality concerns and regulations if vapor degreasing is entirely eliminated, there will be increased water usage and related disposal, and water quality regulation costs. Water quality concerns that might involve treatment include:

pH – Neutralization can be avoided if it is possible to select a modern, mildly alkaline or neutral detergent;
Suspended solids (TSS) – can be controlled with filtration that can also help extend detergent life;
BOD/COD – is related to the surfactant content of the detergent and the amount of oil removed from parts and only applies to wash tank dumps. Strength charges can be minimized with good oil separation, and long lived detergents that minimize wash dumps.
Oil – can be an issue in rinses but good oil separation in the wash and drag-out control can minimize the issue.

Water volume and costs can be minimized by the use of cascaded rinsing. Separated oil has to be disposed of, but unlike still bottoms from a vapor degreaser, oils separated from aqueous cleaning can be disposed of as used oil, which is lightly regulated as long as the oil is recycled – a concern would be the water content of the waste oil. Metal chips, can be recycled as scrap metal, although if the cleaning system were designed to clean a variety of bulk parts, the collected chips would be mixed and have low value. Any sludge or filter waste would need to be evaluated to determine if they are hazardous, although given the metals processed at the Brooklyn Park plant, it is fairly likely this waste would be a non-hazardous industrial waste.

Thomas Engineering Company faces a variety of choices in aqueous cleaning.

- Centralized or cellular cleaning. Centralized cleaning appears to fit current needs for cleaning a variety of parts with different order volumes and durations. One system will cost less than a number of dedicated in line systems, but when they can be justified, cellular cleaning is more efficient in terms of labor and parts handling, and can be optimized for a specific job.

- Clean all parts or a majority – The vapor degreaser is a robust cleaning machine that can handle a very wide variety of parts well. Aqueous cleaning is somewhat more specialized. Finding a system that can do everything is much more difficult than finding a system that can do 80%. This requires a way to clean the remaining 20%.
- Fast transition or slow – would aqueous cleaning be for new products only to avoid PPAP resubmission, or be implemented quickly and completely to simplify operations.
- Type of system, ultrasonic, agitated immersion, centrifugal. Aqueous cleaning relies much more on the application of physical forces to remove soils than solvent cleaning. Ultrasonics create the most powerful forces but is the most expensive to purchase. Ultrasonic agitation is more susceptible to setup and operating problems – higher temperatures and strong solution movement can interfere with ultrasonic bubble formation and collapse, and newer systems use sweep frequencies and higher frequencies to minimize unevenness in effects. Pumped agitation has been the workhorse for many years and works well for discrete parts, while lift agitation is frequently used for bulk parts in baskets because it tends to force solution through the part mass. Centrifugal cleaning is newer in development and typically uses either solution sprayed through the spinning parts, or the chamber is filled with solution and agitated like a laundry washer. Ramp-up speed control is important for delicate parts, starts and stops may be needed to re-orient complex parts. Centrifugal washers are similar to the spin driers Thomas Engineering Company currently uses.
- Type of cleaner (emulsifying, oil separating, bioremediated) Strongly alkaline, emulsifying cleaners were the traditional choice, they cleaned well but had a short life and could attack some metals if inhibitors were not maintained. Ten years ago mildly alkaline to neutral cleaners were developed that would displace oil off surfaces, but would allow the oil to float to the surface when agitation was stopped for a time or temperatures are changed. A number of newer cleaners have been developed that operate at ambient to low temperatures, which lower operating costs, or bioremediated cleaners which use enzymes to breakdown oils removed from surfaces in order to keep the cleaner fresh. Bioremediated cleaners work best with a relatively steady load of oil – periods of low cleaning use can stress the cleaner.
- Degree of automation – aqueous cleaning systems can be operated manually, but automation would be desirable for Thomas Engineering Company's operation both for consistency in cleaning, and to improve system capacity. Each tank of aqueous cleaning system can contain a basket of parts, for example, three baskets can be cleaned at one time in the Stoelting aqueous system, while the vapor degreaser will be processing one basket (aqueous cleaning cycles are generally longer so there would not be a 3:1 capacity improvement. Rotating baskets will promote washing, rinsing and drying of the parts but cost more.
- Water quality – De-ionized water is more costly, but can eliminate spotting caused by the deposition of dissolved solids as water evaporates. The City of Brooklyn Park water supply is typically 30 grains of hardness, it should be softened before cleaning at least and de-ionized rinses should be considered and evaluated. Counter current, cascaded rinses decrease the volume of water needed to contact parts , with a given level of contaminants, at the end of the process. As a rule the volume declines by a factor of ten with each rinse added – two or three are typical. Softened waster would be the minimum required for cleaning.
- Type of drying – energy costs can be reduced by mechanically removing bulk water films by blow-offs of gentle shaking or rotation. This also reduces the chance for spotting.
- System capacity – the additional cost for a system large enough to clean the full load and probable future growth is small compared to the cost of the system. Possibly higher operating costs would the downside.

Equipment systems and Costs

Table 4 compares attributes of aqueous systems from Stoelting, Branson, Infinity and Nobles Manufacturing based on rough specifications for a system for Thomas Engineering Company. The specification used, were developed by the vendors individually based on a look at a few parts, with load size and throughput supplied by Rimma. But the systems probably do not accomplish identical tasks. They are not interchangeable or directly comparable. Karl DeWahl estimated operating costs, based on limited information – they are order of magnitude only. Detergent cost assumes: a detergent price of $10/gal, used at 5% concentration, a 3 month cleaning bath life, and that during the wash life an equal volume of cleaner will be consumed as makeup. Water and sewer costs are based on current Brooklyn Park rates of $1.40/1000 gal for water and $2.15/1000 gal for sewer. The MCES has a one time SAC charge for new or increased water use by industrial customers. The charge is $1500/unit, and a SAC unit is 274 gallons/day. John Watson of the City of Brooklyn Park indicated they only have a WAC charge ($1500/unit, same volume as SAC) for increased water used related to a building permit (new construction or expansion) but not for increased water use from existing facilities. De-ionized water costs depend on the hardness of the water source and whether it is needed to achieve cleaning goals. $0.05/gal was used for these estimates. The MCES has strength charges for TSS and BOD/COD – a first assumption is that those charges will not apply to this cleaning application. Labor is assumed to be the same as for the current loading and unloading of the vapor degreaser. Energy costs are based on equipment rating gleaned from supplier quotes and literature, and applying a load factor of about 50% (75% for Branson [ultrasonics] and Nobles Mfg[centrifugation and transfers]). Electric demand charges were not specifically estimated, but should be approximated in an energy charge of $0.075/kWh. All costs are based on 3000 hours per year of operation and 500 hours of operating labor.

The Stoelting unit is appears sturdy and reliable, but with significantly higher operating costs for energy and water due to its large size and single rinse (the 300 gph water consumption estimate comes from Karl DeWahl extrapolating from rinse theory), and labor costs are underestimated for this system in table 4. Because of the large tank and load capacity and the absence of a cascaded rinse, all of which increase water use, this system is expensive to operate, especially in terms of DI water, if that is needed. Operating costs are estimated at 50% higher than the degreaser. The cost of DI water accounted for 70% of the operating cost of this system – determining whether DI water is needed, determining its actual cost at this facility, and considering methods of reducing DI demand will be critical for the economics of this system and for aqueous systems generally although to a lesser extent. This system may run for shorter period because of its larger capacity. The one-time SAC charge for the Stoelting system would also be significant and would add about $16,000 to the effective purchase price. Operating costs and SAC could be lowered by considering adding a second rinse for a cascade, and a system with somewhat smaller tanks. This system uses pumped agitation which may limit the range of part designs that can be cleaned. All three tanks have capability to rotate parts, but with this design, operators would need to move baskets, between tanks, by hand. Automating this task might cost $30-40,000. No accessories were included in the system cost. Listed accessories include alarms for notifying operators of status, filters and more sophisticated oil separation that may keep the detergent cleaner and extend its life.

The Branson system uses ultrasonic agitation, which was recommended because many of the parts nest and some are delicate, according to Hawkins representative Marc Oprean. These are features that are hard to deal with via other types of agitation. Close fitting or nested parts create deep recesses. Specifically the disc parts stacked on a wire, Mr Oprean thought, would be difficult to clean by other methods. A bioremediated cleaner was specifically excluded from this quote because it does not degas well – an important feature of ultrasonic cleaners to prevent ultrasonic energy from being absorbed by non-condensable gasses. The bioremediated cleaner would work well in a pre-cleaning step for heavily oiled parts, according to Mr. Oprean. A rinse between the pre-clean bath and the first ultrasonic tank would be needed to keep the bio cleaner out of the ultrasonic tank, if a pre-clean tank was added. This system is relatively frugal with water and energy, but the Branson system relies on flash drying which may be an optimistic prediction for the drying needs of light sheet metal parts cleaned in bulk. The operating costs appear to be about half that of the degreaser, SAC costs approach trivial. Branson offers two types of load rotation: one integrated into individual tanks; and the other integrated into the transport. Transport integrated rotation becomes relatively less expensive as the number of tanks increase, but this option limits the possibility of the wash system to process multiple loads simultaneously when rotation is required. Multiple loads can be cleaned simultaneously without rotation with the standard transport, and the transport head can be quickly changed to accommodate loads requiring rotation, (system capacity goes down while rotated loads are processed). Niles Platt, Tech Line Sales Company, indicated the rotation mode is not field retrofitable, so how rotation will be accomplished needs to be determined up front based on capacity considerations. This estimate is based on rotation in the three wash and rinse tanks in order to increase system capacity.

The Infinity system is designed for precision cleaning and seems very expensive for current needs. The only indication of water flow is the rating for the system's ability to heat water, which seems high for the tank size and for a 3-tank rinse cascade. From rinse theory, the rinse flow was extrapolated to 30gph from the recommended Branson flow. The operating costs appear to be about 30% that of the degreaser, SAC costs approach trivial.

The Nobles Manufacturing equipment is a centrifugal washer/rinse and drier combination. Estimates are based on equipment literature and a phone conversation with a sales representative rather than a quote. No one from the company has seen the parts to be cleaned. This system has a lower initial cost, and has a single process vessel - wash and rinse solutions are sequenced and recirculated from remote reservoirs. Washing and rinsing can be done either with parts submerged with the basket agitating, or with the parts sprayed while the basket spins. The operating costs appear to be about half that of the degreaser, SAC costs approach trivial. Soft starts control forces on parts during startup and shut down, cleaning cycles typically take 12-15 minutes. Loads can be stopped and started to re-orient parts. Cleaning tightly nested parts like the disks stacked on a wire might be difficult and needs to be tested. Work has been done in Europe to limit damage to delicate parts in centrifugal washers, but this manufacturer's only effort in this area appears to haves been to include soft starts. Note that most parts at Thomas Engineering Company are poured into and out of baskets and boxes, indicating considerable resistance to damage generally, and that the plant currently owns two spin driers which are similar in operation.

Another manufacturer, Bruderer, makes aqueous cleaning systems ($85-105K) for use in-line with a press to streamline the process - literature is included in the Appendix. They also have a Strip Lubrication System ($12K) which claims to deposit a thin, uniform film of oil and to prevent spills. They claim the Lubrication System pays for itself within 6 months of purchase because it applies lubricant precisely in lower volume and can recover and reuse overspray. When parts will be cleaned with the aqueous system, oil will be separated, filtered and recycled back into Strip Lubrication System.

Table 4 Comparison of Aqueous Cleaning Systems

Manufacturer	Stoelting	Branson	Infinity	Nobels Mfg
Distributor	Ron Peterson & Assoc.	Techline/Hawkins		
Model	RTW-236	Flex2024		T-88 centrifugal washer
Cost	$58,700	$83,000	$177,000	$34,000
Accessories	Alarms 550 Filters 5200 Oil sep 4100 $9900	TDR* ext 2000 TDR rotation 9900 (*2D robot) Std bask. 500ea Preclean tank 13600		2nd rinse
Power	460V/ 3ph		480V/3ph	
Washer heat	21kw	3kW?		4kW
Washer circulation	3hp	NA		5hp
ultrasonics	NA	3kW		
Basket rot.	1/8 hp x 3	?		
Hoist	?	?		
Rinse heat		3kW x 2		
Rinse circulation	NA?	NA		
Drier heat	10 kW	Flash dry		
Drier circulation	3hp	NA		
Comp.Air	Oil sep pump	NA		
Total [op]/capacity	[15kW]/35.5kW	[9kW]/12kW		[6kW]/ 8kW
tank	120gal	60gal	35gal	40 gal
Basket	20"x13"x6"	17"x21"	22"x14"x7"	18"D x 18"h
load	100lb	?	50lb	100lb
rotating speed	0-4rpm	?	?	NA
rinse flow	[300gph est]	30gph, 2 cascade	60gph (heatg. cap.)	[30gph est, 2 cascade]
water use	3000gpd/1MMgpy	300gpd/90kgpy	? (3 cascade)	300gpd/90kgpy
drier flow	600cfm	NA		?
drier T	250F	NA	250F	?
Footprint	4' x 11'	3' x 8'?	3' x 9'?	3' x 7'

Estimated operating costs

Mfr	Stoelting	Branson	Infinity	Nobels Mfg
Detergent ($/y)	500	250	150	250
Water & Sewer ($/y)	3500	300	50	300
DI water ($/y)	50,000	4500	150	4500
strength charge? ($/y)	?	?	?	?
Water treatment ($/y)	?	?	?	?
Energy cost ($/y)	3400	2025		1350
Labor	12,500	12,500	12,500	12,500
Total ($/yr)	69,900+	19,600+	12,550++	18,900+
One-time charge				
SAC ($)	16,000	1600	450	1600
WAC [new construction only]	0	0	0	0

Assumptions:
Wash dump 1/gtr
Detergent $10/gal; 1:20
Double for makeup
W&S = $3.50/1000gal
DI = $0.05/gal
SAC = $1500/274gpd
kWh = $0.075
3000hr/yr operation
500hr/yr labor

C. Next steps:

1. Evaluating nPB (if changing solvents is the selected path).

Send difficult parts for cleanliness testing using an immersion cleaning cycle to determine whether, by any reasonable cleaning procedure, nPB will be weaker or equal to TCE. This question will bear on whether existing PPAP might be at risk if the solvent is switched.

Decide whether a new degreaser can be justified.

If not, determine if retrofits and improved operating procedures will reduce emissions (operating cost) and exposure sufficiently. 2. below will provide a partial answer.

2. Evaluate the 'improved degreasing procedure' – determine whether vapor holds should be added to the standard procedure. (these questions should be answerable with 8-20 hours of observations and testing on the T-16 degreaser).

- Determine if dripping can be stopped with a vapor hold to reduce drag-out
  - Is heat transfer / load cooling the cause of continued dripping?
    - Test steel rods in vapor zone – does condensation stop? How long does it take?
    - Test small baskets or simulated loads to determine conditions when dripping stops
  - Is basket drainage extending drip time?
    - Can basket be tilted below the condenser?
    - Does the existing basket fit in the vapor zone when tilted adequately for drainage?
      - Does a shortened basket (width or length) improve drainage?
      - What is the effect on throughput?
    - Can basket modifications improve drainage? Simulate changes:
      - i. open up the sides and bottom for better drainage; or
      - ii. bow out or crease the current basket bottom to create a low spot for drainage.
    - Do basket supports aid drainage? Increase drainage consistency?
- Does an adequate vapor hold reduce drag-out?
  - Are vapor concentrations at the degreaser mouth lower? PID measurements
  - Do bagged parts yield a lower PID measurement?
- Does an adequate vapor hold decrease worker exposure?
- What is the effect of vapor holds on cycle time?
- How much greater loss is there with 2 holds vs just a Freeboard hold? Is it worth the costs?
- Does placing loads in a cold, clean sump cause vapor collapse?
- Does basket shaking increase solvent loss? How much? Is drag-out reduced?
- Can gentle rocking match drainage and reduce emissions?
- Do fast horizontal movements increase solvent losses? How much? What is the effect of slower movements on throughput?
- What is the impact of the recommended cleaning procedure on cleaning costs?

3. Decide on vapor degreaser equipment improvements

How does automation affect solvent losses? 2. above will answer this – automation will ensure consistency.

How does basket tilting or rocking affect solvent loss? Is drag-out reduced? Will it pay for itself?

How does a working cover affect solvent losses? Will it pay for itself?

Decide whether or not to purchase a new degreaser.

4. Determine whether to pursue aqueous cleaning

Decide whether to explore aqueous cleaning further.
Narrow the choices on system configurations – what systems will be evaluated?
Arrange tests on cleaning effectiveness:
    Select parts to be tested and comparison controls, observe the cleaning tests. Test production-sized loads, observe how equipment operates, determine operating conditions, determine the cleaning cycle and throughput.
Decide on agitation, rinsing, detergent, whether DI water is needed, and operating conditions.
Obtain quotes on detailed specification.
Estimate implementation and operating costs.
Verify waste water discharge permit requirements and cost impacts.
Decide whether and what to implement.

APPENDIX A

nPB SNAP proposed rule preamble (health effects excerpt) ["..." denoted sections not included]

Federal Register: February 18, 1999 (Volume 64, Number 32)]
[Proposed Rules] [Page 8043-8048]

Protection of Stratospheric Ozone; Listing of Substitutes for Ozone-Depleting Substances
AGENCY: Environmental Protection Agency.
ACTION: Request for data and advance notice of proposed rulemaking.

IV. What Did EPA Consider for Today's Acceptability Decision?

...

Based on all information now available, EPA is proposing to find nPB acceptable subject to use conditions. The Agency is concerned that excessive exposure to nPB can pose risks of adverse health effects and is recommending a workplace exposure guideline that we believe will protect workers who are exposed to this chemical. EPA is basing this recommendation on several factors, including a review of the toxicological literature and a subsequent risk evaluation conducted according to EPA guidelines (adjusted to represent workplace exposure), and consideration of risk management principles. EPA finds that it is possible to reduce workplace exposure to nPB to acceptable levels with commonly available control equipment or ventilation equipment. Thus, the Agency has concluded that it is appropriate to list nPB as acceptable because there is evidence that it can be used in a way that does not present greater risk than other substitutes.

...

Today's proposed decision to find nPB acceptable under the SNAP program is based in part on its relatively low ozone depletion potential when emitted within the continental United States. However, the ODP of nPB varies with latitude; therefore, this decision should not guide decisions of other countries. For example, nPB emitted closer to the equator has a significantly higher ozone depleting potential than nPB emitted from the middle and northern latitudes, which include the continental United States (for a further discussion, see section IV.B. below on Ozone Depletion Potential). EPA recommends that any decisions on the use of nPB outside the U.S. should be based on latitude-specific ODPs and volumes of the chemical projected to be used in those regions.

A. Toxicity

A primary concern regarding nPB use in the United States is its potential adverse health effects to exposed workers. Since EPA recommended a preliminary exposure guideline in 1999, additional studies have been conducted on the toxicity of nPB and its isomer, iPB. EPA has reviewed available toxicity data in order to develop a contamination limit for iPB and an Acceptable Exposure Limit (AEL)\4\ for occupational exposure to nPB that are protective of human health. EPA has also reviewed workplace exposure measurements from several facilities where nPB has been used.

1. What Acceptable Exposure Limit Is EPA Recommending for n-Propyl Bromide, and Why?

Today, EPA is recommending an AEL for nPB of 25 ppm as an eight-hour time-weighted average. Based upon currently available data, EPA believes that workers can be exposed to an average nPB concentration of 25 ppm without appreciable risk of adverse health effects. In addition, like many halogenated solvents, nPB has the potential to be absorbed through the skin, so we recommend avoiding skin exposure to nPB by wearing protective clothing and flexible laminated gloves. The discussion below describes the derivation of the recommended AEL of 25 ppm for workplace exposure.

a. Summary of toxicity studies. EPA reviewed all the studies listed in docket numbers A-2001-07 and A-91-42 and the studies cited as references in Section XI at the end of this preamble. The epidemiological data on nPB are limited. An anecdotal report by Sclar described neurotoxic effects seen in one patient who used an nPB-based solvent (Sclar, 1999). Another recently published paper describes three women exhibiting signs of peripheral and central nervous system toxicity, such as stumbling, numbness, urinary incontinence, diarrhea, nausea, difficulty in concentrating, dizziness, and headaches which was attributed to nPB exposure (Ichihara, 2002a). Because detailed exposure data are not available in either of these papers, it is difficult to use this information in a risk assessment. Vibration sense deficits, decreased nerve conduction, and reduced scores on neurological functional tests were reported in female workers in China exposed to nPB between <1 ppm and 49 ppm (Ichihara et al., 2002b). The study authors concluded that their findings suggest that exposure to nPB at levels below or around 50 ppm may affect peripheral and central nervous system function. However, because only an abstract of the study was available to EPA, it was not possible to determine if the exposures and effects were well-characterized or if the sample was large enough to draw reliable conclusions. As discussed below in section IV.A.1.e, ``Feasibility of meeting the AEL for nPB in each industrial sector," NIOSH has performed a number of health hazard evaluations with measured workplace exposures to nPB. However, only one of these studies attempted to assess health effects (NIOSH, 2002). In this study, NIOSH

\4\ An AEL is the SNAP program's generic term for an eight-hour time-weighted average occupational exposure limit.

conducted a voluntary medical survey and performed a complete blood count on those workers who chose to participate (43 out of 70 workers participated). The medical survey included questions on whether workers had headaches at least once per week, and whether workers had difficulty having children. No exposure-response relationship could be identified from these data. The survey was not designed to fully characterize effects on the reproductive system, nor did the study employ a control group (a group of workers who were not exposed to nPB), further limiting the utility of this data for risk assessment.

The **acute toxicity** of nPB has been studied in Sprague-Dawley rats for inhalation (Elf Atochem, 1997), oral (Elf Atochem, 1993), and dermal (Elf Atochem, 1995b) routes of exposure. The 4-hour LC50 (lethal concentration for 50% of the test animals) for inhalation of nPB was 35,000 mg/m3 (Elf Atochem, 1997), with death resulting from pulmonary edema. The LD50 (lethal dose for 50% of the test animals) for gavage dosing of nPB was greater than 2,000 mg/kg (Elf Atochem, 1993).

Animals receiving 2,000 mg/kg nPB dermally (with occlusion of the exposure area) showed no cutaneous reactions and no evidence of toxicity (Elf Atochem, 1995b). A skin sensitization test in Guinea pigs was also negative (Elf Atochem, 1995c).

Key chronic and subchronic toxicological studies on nPB include a 28-day inhalation study (ClinTrials, 1997a), a 90-day inhalation study (ClinTrials, 1997b), a two-generation reproductive toxicity study (WIL, 2001), and various papers and abstracts published in peer-reviewed scientific journals (Ichihara, 1998, 1999, 2000a, 2000b; Kim, 1999; Wang, 1999; Yu, 2001; Ichihara 2002a, 2002b). The results of these studies consistently show that sensitive health endpoints \5\ (i.e., the biological effects occurring at the lowest levels of nPB exposure) include effects on the liver (centrilobular vacuolation--cellular changes in the central area of the liver) and on the male reproductive system (decreases in absolute and relative seminal vesicle weights, and reduced sperm count, motility and maturation, and effects on sperm shape).

\5\ An endpoint is an observable or measurable biological event or chemical concentration (e.g., metabolite concentration in a target tissue) used as an index of an effect of a chemical exposure.

The ClinTrials 90-day inhalation study showed liver effects at exposures of 400 ppm and above, which is consistent with the effects seen by Kim et al. (1999). Effects of nPB on the central and peripheral nervous system have also been reported, including peripheral nerve degeneration and axonal swelling in the spinal cord at 1000 ppm (Yu, 2001), degeneration of the myelin of peripheral nerves at 800 ppm (Ichihara, 1999), and significantly decreased hind limb grip strength (a measure of motor nerve function) at 400 ppm (Ichihara, 2000b).

Concerns over potential reproductive toxicity associated with nPB were initially raised because exposure to iPB, a structural analog of nPB, was associated with significant reproductive effects in both male and female workers (Kim, 1996; Park, 1997; Ichihara, 1997). In animal studies, iPB has been shown to induce estrous cycle alterations, decreases in accessory sex gland weights (e.g, seminal vesicle, prostate), reductions in sperm counts and sperm motility, and changes in sperm morphology (Yu, 1997; Ichihara, 1997; Kamijima, 1997). Results presented by Ichihara and colleagues indicated that nPB exerts some level of reproductive toxicity in rats (Ichihara et al., 1998, 1999; Wang, 1999).

More recently, two studies have reported effects of nPB on the female reproductive system in rats. In the first study, female rats were dosed at 0, 200, 400, and 800 ppm for eight hours a day for 7 weeks. Tests of vaginal smears showed a significant increase in the number of irregular estrous cycles with extended diestrus \6\ in the 400 and 800 ppm dose groups, and dose dependent reduction of the number of normal antral follicles in the 400 ppm group (Yamada, 2003). In the second study, female rats were exposed to 1000 ppm nPB for 7 days per week for three weeks. The ratio of the number of estrous cycles of 6 days or longer to the total number of estrous cycles was calculated for the 1000 ppm exposure group and the control group. This ratio was two times higher in the exposed animals than controls, however, this difference was not statistically significant (Sekiguchi, 2002).

\6\ Diestrus is a period of sexual inactivity during the estrous cycle.

In 1999, the Brominated Solvents Consortium (BSOC), a group of several nPB manufacturers, initiated a two-generation study (WIL, 2001) designed to investigate thoroughly the reproductive toxicity of nPB, as well as to provide additional information on other toxic endpoints of concern, including liver effects, and effects on the central nervous system (CNS). In this study, groups of 25 male and female rats were exposed to nPB via whole-body inhalation. The F0, or first generation, animals were exposed to target air concentrations of 0, 100, 250, 500, or 750 parts per million (ppm) of nPB for 6 hours/day, 7 days/week for at least 70 days prior to mating. The F1, or second generation, animals were exposed to 0, 100, 250, or 500 ppm nPB (infertility in the F0 750 ppm group precluded having an F1 750 ppm group). Exposure of male animals in both generations continued throughout mating to the day prior to study termination. Exposure for female animals in both generations continued throughout mating and gestation through gestation day 20. After birth of the pups, the females' exposure continued on lactation day 5 through the day prior to study termination.

In this study, **fertility** was compromised significantly at 500 ppm, and no live offspring were produced at 750 ppm. There was strong evidence of dose-response in both the parent (F0) and offspring (F1) generations for a constellation of reproductive effects in both males and females, including decreases in sperm motility and changes in sperm morphology, reduced numbers of implantation sites and changes in estrous cycles, and reduced litter size. There were slight decreases (only some of which were statistically significant) at 250 ppm, and even 100 ppm for some reproductive endpoints. Statistically significant effects were observed at 250 ppm for reduced prostate weight in F0 males and increased estrous cycle length F1 females. Sperm motility in the 250 ppm group of F1 males was slightly reduced (84.8%) compared to the control group (88.9%). The difference was statistically significant ($p<0.05$). The study authors noted, however, that the sperm motility percentage for F1 males was slightly higher than the mean value in the WIL Research Laboratories historical control data (83.2%). Therefore, the authors did not attribute the reduction in sperm motility to exposure to nPB at 250 ppm. Male reproductive effects were consistent with those identified in the Japanese studies previously cited (Ichihara et al., 1998, 1999, 2000a; Wang, 1999).

Liver effects similar to those reported in the ClinTrials (1997b) 90-day inhalation study were observed in males and females in both generations. Increases in liver weights occurred in both sexes following exposure to 500 ppm; corresponding increases in the incidence of minimal to mild hepatocellular vacuolation were observed at 250 ppm in males and 500 ppm in females. The adverse effects on the central and peripheral nervous system reported by Yu (2001) and Ichihara (1999, 2000b) occurred at higher doses than those associated with reproductive and liver effects in the two-generation study.

Carcinogenicity/Mutagenicity. Limited in vitro screening assays testing for mutagenicity and potential carcinogenicity have been conducted on nPB. Two studies have been performed investigating the potential mutagenicity of nPB in bacterial strains. Barber et al. (1981) exposed five S. typhimurium strains (TA98, TA100, TA1535, TA1537 and TA1538) to five different vapor concentrations of nPB ranging from 1.1 to 20.3 [mu]mol/plate (135-2497 [mu]g/plate). Exposures were performed in a closed incubation system in the presence and absence of liver S9 fraction (from Arochlor-induced rats). Increases in revertants were observed in only strains TA100 and TA1535 in both the absence and presence of S9; increases were not reported in the other strains. Elf Atochem (1994) exposed the same bacterial strains to nPB concentrations of 100 to 100,000 [mu]g/plate in both the absence and presence of liver S9 (from male Sprague-Dawley rats induced with Arochlor 1254). This protocol also used a closed system (closed stainless-steel vessels). The highest concentration was slightly cytotoxic; however, this assay did test up to the limit dose (5,000 [mu]g/plate) recommended for bacterial reversion assays. Appropriate positive and negative controls were used to determine spontaneous background revertant frequency. No increases in revertants were reported in any strain or condition. Given these conflicting studies, the current data regarding mutagenicity of nPB in bacterial strains are equivocal. Unpublished studies of in vivo micronucleus formation (Elf Atochem 1995a) indicate that nPB is not clastogenic, and a published dominant lethal assay with NPB was negative (Saito-Suzuki et al. 1982).

In a cell death bioassay using cultured human liver cells (HepG2 hepatoma), the cytotoxicity of nPB was evaluated at concentrations <=500 ppm (SLR 2001a). Results of the bioassay indicated that nPB was cytotoxic (measured as decreased cell viability) at the highest concentration tested (500 ppm). There were no positive responses reported at any concentration for tests that evaluated enzyme function, DNA damage, or DNA damage and repair when tested at concentrations up to 500 ppm. A closely related compound, ethyl bromide, is weakly carcinogenic in rodents (Haseman and Lockhart 1994), and iPB has been shown to induce reverse mutations in bacteria (Maeng and Yu 1997). Results from these screening assays for short-term genotoxicity do not suggest significant concerns regarding nPB's potential carcinogenicity, although more data are needed.

The National Institute of Environmental Health Sciences' National Toxicology Program (NTP) is planning to conduct carcinogenicity studies in both sexes of rats and mice, which will allow for more definitive conclusions. To date, the NTP has not initiated new experimental studies on nPB, and the data will not be available for several years.

b. Derivation of an AEL for nPB.

...

Dermal Exposure. EPA believes that workers should use good workplace practices and proper handling procedures to avoid unnecessary dermal exposure to all industrial solvents, including nPB. Similar to other halogenated solvents, nPB may defat the skin and may cause local irritation due to this characteristic. A skin notation is applied to those chemicals where ``dermal absorption contributes substantially to the overall systemic toxicity" (skin notation documentation for methyl chloride; ACGIH, 1991). As described previously, the available acute dermal toxicity study in rats (Elf Atochem, 1995) indicates that acute dermal exposure to nPB does not result in systemic toxicity. Because significant dermal absorption of nPB was not demonstrated in this study, EPA is not including a skin notation for nPB along with our recommended AEL in the comments section of the regulatory text. The database regarding dermal toxicity for nPB is not as conclusive as the data for chemicals that have a skin notation, (e.g., methyl chloride, dichlorvos). To apply a skin notation to nPB would imply that the dermal toxicity of this compound is similar to that of these other compounds. It is also noteworthy that there is no skin notation for other halogenated solvents such as methylene chloride or perchloroethylene, and there is no evidence that absorption through the skin is greater for nPB than for the other halogenated compounds. Thus, in EPA's judgement the database currently does not support the need for a skin notation for nPB.

However, we note that the acute dermal study did not provide information regarding chronic dermal absorption.

Further, NIOSH evaluated the potential of nPB to permeate skin and promote chronic, systemic toxicity using a mathematical model and the log octanol::water coefficient for nPB, which is approximately 2. This evaluation found that nPB dermal exposure may be an additional source of exposure to workers if the unprotected skin of both hands is exposed (NIOSH, 2003). Given the above information, EPA specifically requests comment on whether to add a skin notation to our recommended AEL in the final rule if there are data that support this change.

c. Overview of the Evaluation of Risks to Human Reproduction ...

The conclusions of the March 2002 Expert Panel Report on nPB were as follows:

- Available human data are insufficient to draw conclusions on the potential for reproductive or developmental toxicity.
- Available toxicological data were sufficient to conclude that nPB exposure can induce developmental and reproductive toxicity in rats. In evaluating the potential effects on human reproduction, the rat data are assumed to be relevant for humans.
- The mechanisms that lead to reproductive or developmental toxicity are unknown.
- There are no relevant kinetic or metabolism data for nPB to compare human and animal exposure levels.

The Expert Panel identified LOAELs from the body of animal data as follows:

- A LOAEL for male reproductive effects of 200 ppm based on decreases in absolute and relative seminal vesicle weight reported in Ichihara (2000b). A NOAEL of 100 ppm was identified based on decreases in prostate weight observed at 250 ppm in WIL (2001).
- A LOAEL of 250 ppm, and a NOAEL of 100 ppm for female reproduction based on increased estrous cycle length in WIL (2001).
- A LOAEL of 250 ppm and a NOAEL of 100 ppm for mineralization of the kidney pelvis in both F0 and F1 generations, based on WIL (2001).

...

Reduced seminal vesicle weight. EPA did not conduct BMD analysis for reduced seminal vesicle weight observed in the Ichihara (2000b) study because there is no consistency of effect across available studies for this endpoint. Reduced seminal vesicle weight was not found to be a sensitive endpoint in WIL (2001). In fact, a statistically significant reduction in seminal vesicle weight was only seen in the 750 ppm group in the F0 generation, and there were no statistically significant effects on seminal vesicle weight in the F1 generation. Because there were other endpoints that were more sensitive in the WIL study, we regard those endpoints to be of greater toxicological importance. Further, EPA believes that because the Ichihara study was not performed according to GLP guidelines, and there were conflicting reports regarding the exposure regime and the number of animals used, it is not appropriate to use this study in quantitative risk assessment.

Reduced absolute prostate weight. Based on the WIL study, the CERHR Expert Panel identified a NOAEL of 100 (with a LOAEL of 250) for reduced absolute prostate weight in the F0 males. The toxicological relevance of absolute prostate weight reduction is questionable since this endpoint may be associated with reduction in overall weight gain. To assess the significance of this particular endpoint, EPA calculated the mean relative prostate weights for exposed dose groups from the WIL (2001) study. Relative prostate weights (organ weight/body weight) in F0 males were 0.0040, 0.0039, 0.0036, 0.0035, and 0.0035 at 0, 100, 250, 500, and 750 ppm respectively, revealing that relative prostate weight at exposures greater than or equal to 250 ppm decreased only 10% relative to controls. Because the dose-response relationship in other endpoints was more pronounced, EPA did not conduct BMD modeling on this endpoint.

Increased estrous cycle length. The Expert Panel identified 250 ppm as a LOAEL for females based on increased estrous cycle length in the F1 generation of the WIL (2001) study. EPA agrees that the slight increase in estrous cycle length may be a result of nPB exposure. However, because the estrous cycle length of 4.9 days at 250 ppm is within the range of historical controls, the effect cannot be conclusively attributed to exposure without statistical analysis. The study report also notes lack of cycling in some females, which may have caused difficulty in accurately determining the average estrous cycle length for each affected group. Because these data are lacking, this endpoint should not be used for developing the AEL.

Mineralization of the kidney pelvis. The Expert Panel concluded that mineralization of the pelvis of the kidneys at 250 ppm was an adverse effect. EPA notes that mineralization of the kidney was not consistently associated with nPB exposure across different studies, and that in WIL (2001) the severity of mineralization did not increase above a category of minimal except at 750 ppm where it was mild. Therefore, EPA did not consider using this endpoint as useful for developing the AEL.

Sperm Motility. The Expert Panel identified 500 ppm as the LOAEL for reduced sperm motility. The Panel agreed with the WIL (2001) study authors that the slight but statistically significant reduction in the percentage of motile sperm in the F1 males at 250 ppm (85% vs. 89% in concurrent control animals) could not be attributed to nPB exposure since the percentage of motile sperm in this dose group slightly exceeded that of historic controls (83%). The data indicate that the small changes observed at 250 ppm are consistent with larger changes in sperm motility observed at 500 and 750 ppm. Thus, results for sperm motility in F0 and F1 males exhibited dose-related trends, and conformed to other principles for the selection of endpoints for BMD analysis (See earlier discussion in section IV.A.1.b.). Thus, regardless of whether a LOAEL of 500 ppm or 250 ppm is assigned to this particular endpoint, the Agency determined that reduction in the percentage of motile sperm in the F1 males is a good candidate for BMD analysis. In addition, it is important to note that the Panel did not have access to either the ICF or SLR International benchmark dose analyses. As discussed in section IV.A.1.b, benchmark dose modeling overcomes the issue of drawing a ``bright line" in the form of a LOAEL or NOAEL and instead uses the full set of data across all exposure levels (ICF, Inc., 2002a; SLR International, 2001b). Using the results of benchmark dose modeling, it becomes clear that sperm motility is a sensitive effect, and is an appropriate effect upon which to base an AEL.

...

e. Feasibility of meeting the AEL for nPB in each industrial sector. Each of the three sectors EPA is considering in today's proposal could potentially expose workers to nPB in different ways. Therefore, we considered separately whether it is feasible to meet the AEL in each of the three sectors. If EPA becomes aware of further information showing that nPB use is likely to pose unacceptable risks to human health in particular applications or end uses, we will find nPB unacceptable in those applications or end uses.

Solvents cleaning. When using industrial cleaning equipment, workers are likely to be exposed to solvent vapors continually over the course of a workday. However, users can control nPB emissions from vapor degreasers by changes to the equipment, as well as changes in operating practice. For example, a user can install an additional set of condensation coils to prevent vapor from leaving the vapor degreaser or defluxer. An operator can tilt pieces to be cleaned to allow the solvent to drain off inside the vapor degreaser instead of evaporating outside of the degreaser where workers will breathe the vapors.

Exposure data on nPB used in vapor degreasers indicate that it is possible to maintain exposure levels from 2 to 24 ppm over an 8-hour average, as measured using personal samplers (Albemarle, 1997). In 1998, Albemarle Corporation also collected workplace monitoring data from metal cleaning operations. Many, although not all, of the samples collected showed concentrations that, extrapolated to an 8-hour period, would remain under 25 ppm. In addition, another manufacturer and distributor of nPB-based solvents stated that, ``For a properly designed, installed, operated, and maintained traditional open-top vapor degreaser, experience has shown that eight-hour time weighted operator exposure levels will be < 20 ppm. For enclosed and automated degreasers, lower exposures can be achieved" (Amity UK Ltd, 2001).

EPA has only one set of direct exposure data for equipment that cleans using nPB below its boiling point (``cold cleaning"). These data are from a NIOSH Health Hazard Evaluation for a company that produces instrumentation and components for radio and microwave frequency communications. In this study, NIOSH measured exposures to nPB from a cold batch cleaner that was in a special enclosed room with a local exhaust ventilation system. The highest exposure level was 8.4 ppm (NIOSH, 2000b). However, the type of enclosure and ventilation used at this site is not typical of most facilities using cold cleaning equipment.

In general, it is expected that it will be more difficult to control emissions from cold cleaning equipment than from vapor degreasers. The design of vapor degreasers reduces emissions from the equipment by boiling the solvent and then causing it to condense, rather than allowing solvent vapors to be emitted. Because cold cleaning equipment may expose workers to high levels of nPB, we recommend that nPB not be used in cold cleaning equipment unless additional engineering controls are instituted to keep worker exposure to levels below the recommended AEL of 25 ppm.

The limited data available on manual cleaning indicate that it may be difficult to attain exposures less than 50 ppm when wiping with nPB by hand (Albemarle, 2001). The SNAP program currently does not regulate manual cleaning with solvents. However, we recommend that nPB not be used for manual cleaning because of the likelihood of high exposures.

Aerosol Solvents. ...

Adhesives. ...

...

3. Is the General Population Exposed To Too Much nPB?

...

4. What Limit Is EPA Proposing on Isopropyl Bromide Contamination of nPB as a Condition of Acceptability, and Why?

Isopropyl bromide (iPB or 2-bromopropane), an isomer of nPB (1-bromopropane), is a contaminant that is created to different degrees in the manufacture of some nPB formulations. In reviewing the toxicological risks of iPB, EPA initially was concerned that its molecular structure was similar to chemicals that are potent reproductive toxins and carcinogens. This concern focused on the position of the halogen atom within the compound. There are toxicological data that indicate that when the halogen atom is located on the second carbon, there may be increased potential for the compound to cause cancer when compared to the compound with the halogen atom on carbon number 1. One example of this is the differential toxicity of 1-nitropropane and 2-nitropropane. Inhalation exposure to 2-nitropropane has been linked to liver toxicity in humans and has resulted in liver, and to a lesser extent, lung toxicity in male and female Sprague-Dawley rats (US EPA, 1991); it has also been shown to induce liver cancer in both Sprague-Dawley (IARC, 1992) and Fischer rats (Fiala, 1995). 1-Nitropropane has shown no carcinogenic potential to date.

Direct data on the carcinogenic potential of iPB are limited, although it has been shown to induce reverse mutations in bacteria (Maeng and Yu, 1997). Further, iPB was shown to be more cytotoxic and genotoxic to human liver cells than nPB and other toxins, including methylene chloride and trichloroethylene (SLR, 2001a). The combination of the position of the bromine atom in iPB (and its relationship to the carcinogenic potential of the compound) and the genotoxicity of the compound in bacterial and human cells indicate that caution is necessary when recommending an acceptable exposure concentration for iPB.

In the limited animal testing data available, iPB has been shown to be inherently more toxic than nPB on reproductive and hematopoietic endpoints. In two separate studies, significant disruptions in the estrous cycles and abnormal growth in uterine cells were reported in female rats exposed to iPB daily for 9 weeks (Kamijima, 1997a, 1997b; Yu, 2001). Daily exposure of male rats to iPB at 300, 1000, and 3000 ppm was associated with effects ranging from reduced body and organ (e.g., kidneys, liver, testis) weight, reduced sperm counts and sperm motility, abnormal sperm, reduced red blood cell and platelet counts, and hemoglobin volume (Ichihara, 1997). A recent study has been published (Sekiguchi, 2002) in which the effects of iPB exposure on the reproductive physiology of female F344 rats were investigated. The rats were exposed to air (in the control group, the number of animals, n, is 7) or 50 (n=6), 200 (n=7), or 1000 (n=9) ppm of iPB via whole-body inhalation for 8 hours/day for 21-24 days (exact number of days not specified in the article). A larger number of females at the high concentration exhibited an estrous cycle of <ls-thn-eq>6 days (7 of 9 animals) than those at the control, low- and mid-concentration (4, 2, and 3, respectively) which corresponded to the greater number of estrous cycles lasting <ls-thn-eq>6 days (9 of 34 animals) in the high-concentration group as compared to the other groups (4 of 31, 4 of 30, 3 of 30). A dose-dependent increase in the number of days/cycle was observed in rats at 200 and 1000 ppm. These increases did not reach statistical significance, however. A smaller number of females per group was analyzed for uterine and ovary weights because only rats showing the estrous stage upon vaginal smear test were chosen for autopsy (5, 5, 5, and 7, respectively in the low-, mid-, and high-
concentration groups). No changes were noted in the weights of ovaries or uterus, or in the number of ovulated ova among any of the female groups (exposed or controls). Although this study indicates that iPB was not a strong reproductive toxin in the female rat, the small number of animals exposed is a significant limitation to the study. The dose dependent increase in estrous cycles observed at 200 and 1000 ppm suggest the potential for reproductive failure from exposure to this compound. These results also indicate the need for additional studies using greater numbers of exposed animals.

Both male and female workers occupationally exposed to iPB have been found to exhibit some of the same effects reported in animal toxicological studies. Ichihara (1999) reported low sperm motility, low semen volume, abnormal sperm cells, and decreased blood cell count, hemoglobin and hematocrit in otherwise healthy Chinese male workers exposed to a wide range of iPB concentrations (2.5-111 ppm). Abnormal or an absence of menstruation was associated with iPB exposure in several female workers, as well as reduced blood cell count, hemoglobin, and hematocrit. Employees of an electronics factory in South Korea showed similar effects following exposure to iPB (Kim, 1996). In female workers, disrupted or absent menstruation, abnormal hormone levels, hot flashes, and abnormal bone marrow were found, while male workers exhibited significantly reduced sperm counts and sperm motility.

CERHR convened an Expert Panel to consider existing toxicological studies on effects of both nPB and iPB. (See section IV.A.1.c. for a discussion of CERHR review process and the Expert Panel Report.) The CERHR Expert Panel came to the following conclusions on the existing studies on iPB (CERHR, 2002b, p. 44):

- Available human and animal data are insufficient to draw conclusions on the potential for developmental toxicity due to iPB.
- There is sufficient evidence that iPB is a reproductive hazard in men and women, particularly based upon the epidemiological data from Korea.
- At low levels (less than 0.004 ppm), there is minimal concern for human reproduction. At higher levels up to 1.35 ppm, there is some concern.
- For reproductive data from male rats, the panel identified a NOAEL of 100 ppm.

The toxicological studies on male reproductive endpoints for iPB have limitations which (e.g., small number of dose groups) make them inappropriate for use in quantitative risk assessment. Although the occupational exposure studies also are limited, given the mutagenicity of the compound and that human exposures have resulted in significant health effects consistent with those reported in the available animal studies, the Agency considers it appropriate to limit the amount of iPB exposure resulting from nPB use to the maximum extent feasible.

Today's action proposes to limit SNAP acceptability of nPB to those formulations of nPB that contain concentrations less than 0.05% iPB by weight before adding stabilizers or other chemicals. The current American Society for Testing and Materials (ASTM) standard for vapor degreasing grade and general grade nPB specifies that unstabilized nPB must have less than 0.1% of iPB as a contaminant. EPA believes that this level should be reduced to 0.05% given the toxicity of iPB, and the fact that achieving a level of 0.05% is technologically feasible and would not cause significant economic impacts (US EPA, 2003). The Agency also requests comment on the appropriateness of alternative concentration limits for iPB in nPB, including 0.1%. If this provision is finalized, the iPB concentration limit would be a condition that all users in the U.S. must observe in all sectors and end uses where nPB is listed as acceptable.

In order to show compliance with the use condition, end users would need to keep records to demonstrate that the nPB used in the product contains no more than 0.05% iPB by weight before adding stabilizers or other chemicals. Documentation could involve, for example, keeping a certificate of analysis or purity provided by the manufacturer or formulator for two years from the date of creation of that record. Such records are customary business information that chemical companies provide to their customers, so we do not expect that this requirement will impose an additional paperwork burden.

B. Ozone Depletion Potential

The ozone depletion potential (ODP) of a chemical compound provides a measure of its impact on stratospheric ozone levels relative to the impact of an equal mass emission of CFC-11. The Parties to the Montreal Protocol have used the ODP benchmark index as a means of characterizing the relative risks associated with the various ozone-depleting compounds subject to the requirements of the Protocol and to calculate the total allowable production and consumption of different classes of ozone depleting substances. Every four years the World Meteorological Organization publishes the Scientific Assessment of Ozone Depletion. These assessments are authored by leading experts in the fields of atmospheric science and atmospheric chemistry, and include the most current research findings relevant to the science of ozone depletion. These assessments, along with other studies in the field of atmospheric chemistry, have traditionally focused on compounds with relatively long atmospheric lifetimes (in excess of 3 months).

Two-dimensional (2-D) models that base calculations on latitude and altitude are sufficient for calculating the ODP of long-lived chemicals. However, 2-D models cannot simulate the complex atmospheric transport pathways that are necessary to determine the ODP of short-lived compounds like nPB (Wuebbles, 2000). nPB is estimated to remain in the atmosphere for only 11 to 20 days after emission.\12\ The short lifetime of nPB complicates the calculation of its ODP because it is not valid to make the standard simplifying assumption that concentrations are ``well mixed" in the troposphere. Thus, a meaningful comparison can be made between the ODP of nPB and the longer-lived compounds already controlled under the Montreal Protocol only by using the results from a 3-D model that bases calculations on longitude, latitude, and altitude to augment the ODP calculation using a 2-D model.

\12\ Wuebbles et al., 1998; Wuebbles et al., 2000.

Generally, a compound emitted in the troposphere travels toward the equator and into the tropics before rising convectively into the stratosphere. As a result, a compound emitted at high latitudes, such as the northern United States or the southern tip of Brazil, will take longer to reach the stratosphere than one emitted in the tropics. For a long-lived chemical, this difference in travel time is insignificant. But for a short-lived compound such as nPB, which is subject to degradation in the troposphere, the latitude of emission can have a significant impact on the amount of ozone-destroying bromine that is delivered to the stratosphere.

Using a combination of 2-D and 3-D models, Wuebbles et al. (2001) estimated the ODP to be between 0.016 and 0.019 for nPB emissions over the United States. In the tropical latitudes, over India, Southeast Asia and Indonesia, nPB emissions have a larger ODP of 0.087 to 0.105. A more recent paper by Wuebbles found that the ODP of nPB emissions from the United States would be closer to 0.013-0.018, while nPB emissions in the tropics would have an ODP of 0.071 to 0.100 (Wuebbles, 2002).

In proposing to list nPB as an acceptable substitute for CFC-113, methyl chloroform and HCFC-141b, EPA has considered that the ODP for nPB at the latitude of the continental U.S. is substantially less than the ODPs for the chemicals it would replace (0.8 for CFC-113, 0.1 for methyl chloroform, and 0.11 for HCFC-141b). Given that fact, we do not believe that nPB's ODP is a compelling reason to list it as an unacceptable substitute for CFC-113, methyl chloroform, and HCFC-141b for use in the U.S.

While advances in modeling are producing more specific methods to better estimate nPB's ODP, the value will never be pinpointed to a single number that may be applied to all latitudes. EPA notes that if the ODP were as high in the U.S. as it is in the tropics (0.071 to 0.100), we would have found it unacceptable as a substitute. When making regulatory determinations, governments or users in other latitudes should consider the ODP at their latitude as well as the toxicity of other solvents available for use. For example, users in other counties may find nPB preferable to carbon tetrachloride, which has a high ODP (1.1) and is highly toxic. On the other hand, users in the tropics should realize that nPB at their latitude has an ODP comparable to substances controlled by the Montreal Protocol (methyl chloroform or HCFC-141b). EPA also recommends that any decisions on the use of nPB outside the U.S. should be based on latitude-specific ODPs and volumes of the chemical projected to be used in those regions.

Few commenters on the ANPRM discussed the ODP of nPB. However, the Agency agrees with two commenters who stated that nPB's low ODP should be balanced against the much longer atmospheric lifetime of other choices.

We have attempted to gather and assess all available information from the full range of experts on nPB's ODP. EPA continues to be interested in receiving from the public any other information pertaining to the atmospheric effects and ODP of short-lived atmospheric chemicals, especially nPB. In the event that data become available after final rulemaking that are contrary to the current scientific understanding, section 612 of the CAA allows the Agency to reconsider our decision under the SNAP program.

C. Global Warming Potential

The global warming potential (GWP) index is a means of quantifying the potential integrated climate forcing of various greenhouse gases relative to carbon dioxide. Thus, the GWP of carbon dioxide is, by definition, equal to one. Since GWP is a measure of the climate forcing integrated over time, the value of the index depends on the choice of time horizon. The standard GWP used for making climate-related policy decisions is based on a 100-year time horizon (called the 100yr GWP).\13\

\13\ The 100yr GWP is the index recommended by the Intergovernmental Panel on Climate Change (IPCC) for comparing the climate impacts of various global warming gases. The United States employs the standard 100yr GWP index for making climate policy decisions and reporting of greenhouse gases.

The 100yr GWP of nPB is 0.31 (Atmospheric and Environmental Research, Inc., 1995). This is a relatively low GWP, representing a climate forcing approximately one third that of carbon dioxide, by weight. Estimations of the net climate impact must take into consideration the amount of the compound expected to be emitted. As will be discussed in section V.B. below, nPB will most likely be emitted in small enough quantities worldwide that there should not be a concern about its causing climate change. Additionally, the GWP of nPB is considerably lower than that of the chemicals it potentially replaces. (100yr GWP values are 6000 for CFC-113, 140 for methyl chloroform and 700 for HCFC-141b.) \14\ Therefore, we conclude that the use of nPB as a substitute for CFC-113, HCFC-141b, or methyl chloroform should not be restricted based on its GWP.

\14\ All GWPs (other than that of nPB) discussed in this NPRM are taken from the Scientific Assessment of Ozone Depletion: 1998 (WMO, 1999).

D. Flammability

nPB forms flammable mixtures in air within only a narrow range. All estimates that EPA reviewed fall somewhere within the range of 3.5%-9%. Most, but not all, of the material safety data sheets we reviewed state that nPB has no flashpoint. The 1998 Report of the United Nations Environment Programme's Solvents, Coatings and Adhesives Technical Option Committee stated that ``under certain test conditions, using standard flash point testing apparatus, pure nPB has demonstrated a flash point at -10[deg]C * * * [O]ther ASTM test methods have resulted in no observed flash point'' (UNEP, 1999). In response to information requests in the nPB ANPRM, various commenters asserted that nPB has a flashpoint of 10[deg]C, 14[deg]C, and 21[deg]C-25[deg]C, 70[deg]F (21[deg]C), and 70[deg]C. These data are inconclusive about the flashpoint of nPB and whether nPB is likely to be flammable under normal use conditions.

In addition, we are aware that many manufacturers of foam cushions use adhesives containing nPB because it is essentially non-flammable compared to many other solvents used in adhesives, such as acetone or heptane. Also, one company has submitted a fire suppressant containing nPB as the active ingredient for review by the SNAP program. (We are not addressing this incomplete submission in today's proposed rule.) It is not surprising that nPB would have little or no flammability, given that many organic compounds containing bromine have little or no flammability, such as halons or hydrobromofluorocarbons.

Based on the full range of available information, we do not currently believe that the use of nPB as a substitute for CFC-113, methyl chloroform, or HCFC-141b should be restricted because of flammability. EPA, however, invites commenters to submit more specific information concerning the flashpoint of pure nPB. We are aware that nPB blends may have flashpoint characteristics different from that of pure nPB, depending on the nature of the additives or stabilizers. In this rulemaking, EPA is evaluating only pure nPB as a substitute for CFC-113 and methyl chloroform. We therefore are not interested in receiving information concerning the flashpoints of blends that contain nPB. Commenters providing information on nPB's flashpoint should refer to the specific test methodology and apparatus used to determine the flashpoint, such as ISO 1523, American Society of Testing Materials (ASTM) E-681, D92, D93-85--Pensky-Martens closed cup, or D56-96--Tag closed cup. EPA also invites readers to submit information concerning any potential fire or explosion hazards that may result from the use in solvent cleaning of compounds that have flashpoints within the range of normal atmospheric pressures and temperatures.

E. Other Environmental Concerns

Because nPB breaks down in the atmosphere within 21 days, and is not particularly soluble in water, it is unlikely that ``rain out'' from nPB released into the atmosphere could cause contamination of water supplies. However, as with all chemicals, significant contamination of soil and water can result when directly introduced into water or onto the ground. Thus, EPA expects that users will dispose of nPB in accordance with relevant regulations under the Resource Conservation and Recovery Act, and with applicable state and local regulations. Compliance with these regulations will mitigate the possibility that nPB might enter water supplies or top soil.

nPB is a volatile organic compound (VOC). VOCs are associated with the formation of ground-level ozone, a respiratory irritant. Therefore, nPB use currently is controlled under state and local regulations implementing Federal clean air requirements at 40 CFR part 51. These regulations are intended to bring areas into compliance with the National Ambient Air Quality Standards for ground-level ozone. Users located in ozone non-attainment areas may need to consider using other alternatives for cleaning that are not VOCs or control emissions.

F. Comparison of nPB to Other Solvents

. . .

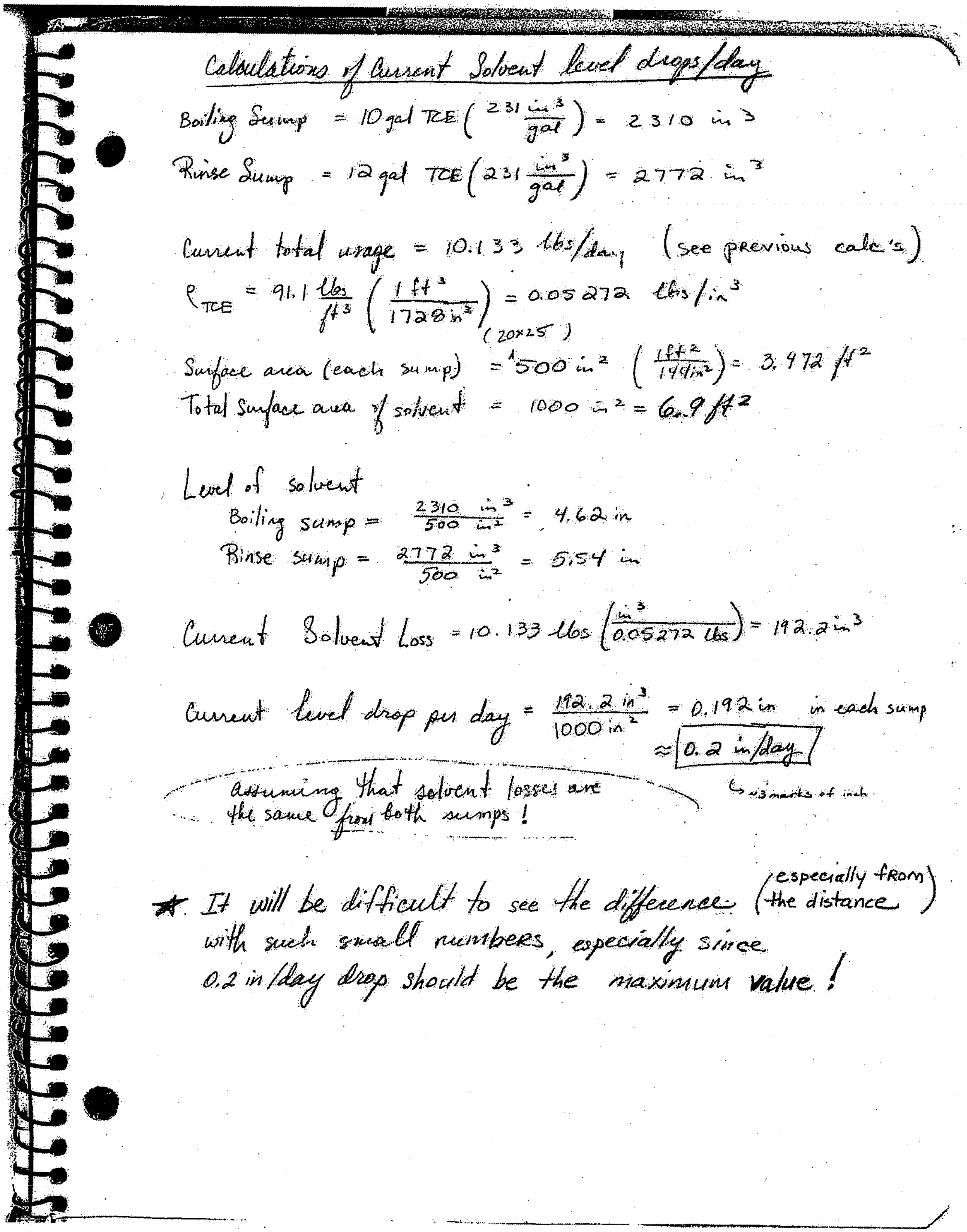
nPB has an ODP of 0.013 to 0.018 at the latitudes of the continental U.S. Thus, nPB reduces risk compared to CFC-113, methyl chloroform, and HCFC-141b, the ODSs it replaces, which have ODPs of 0.8, 0.1, and 0.11, respectively. HCFC-225ca/cb has an ODP of approximately 0.03. HCFC-225ca/cb is acceptable in metals cleaning and aerosol solvents, and acceptable subject to use conditions in precision cleaning and electronics cleaning. Although HCFC-141b has been phased out of production in the U.S., its use is currently acceptable in aerosol solvents; HCFC-141b has a higher ODP than nPB. HCFC-123 has an ODP of 0.0124, which is comparable to that of nPB. HCFC-123 is acceptable in precision cleaning. There are other acceptable cleaners that essentially have no ODP (aqueous cleaners, hydrofluoroethers (HFEs), hydrofluorocarbon (HFC)-4310mee, HFC-365mfc, HFC-245fa, hydrocarbons, volatile methyl siloxanes (VMSs), methylene chloride, trichloroethylene (TCE), perchloroethylene (PERC), and parachlorobenzotrifluoride (PCBTF).

nPB has a GWP of only 0.31, which is lower than or comparable to that of the lowest GWP solvents. Acceptable HCFC, HFC and HFE solvents all have GWPs that are two to four orders of magnitude higher than that of nPB (55 to 1700 on a 100 year time horizon compared to CO₂).

nPB is a volatile organic compound for purposes of EPA regulations, although there are petitions with EPA requesting its exemption. Thus, nPB currently is subject to regulations for ground-level ozone and local air quality. nPB is not currently regulated as a hazardous air pollutant and is not listed as a hazardous waste under RCRA.

Appendix B

Rimma's calculations



Calculations of Current Solvent level drops/day

Boiling Sump $= 10 \text{ gal TCE} \left(231 \frac{\text{in}^3}{\text{gal}}\right) = 2310 \text{ in}^3$

Rinse Sump $= 12 \text{ gal TCE} \left(231 \frac{\text{in}^3}{\text{gal}}\right) = 2772 \text{ in}^3$

Current total usage $= 10.133$ lbs/day (see previous calc's)

$\rho_{TCE} = 91.1 \frac{\text{lbs}}{\text{ft}^3} \left(\frac{1 \text{ ft}^3}{1728 \text{ in}^3}\right) = 0.05272 \text{ lbs/in}^3$

(20×25)

Surface area (each sump) $= 500 \text{ in}^2 \left(\frac{1 \text{ ft}^2}{144 \text{ in}^2}\right) = 3.472 \text{ ft}^2$

Total Surface area of solvent $= 1000 \text{ in}^2 = 6.9 \text{ ft}^2$

Level of solvent

Boiling sump $= \frac{2310 \text{ in}^3}{500 \text{ in}^2} = 4.62 \text{ in}$

Rinse sump $= \frac{2772 \text{ in}^3}{500 \text{ in}^2} = 5.54 \text{ in}$

Current Solvent Loss $= 10.133 \text{ lbs} \left(\frac{\text{in}^3}{0.05272 \text{ lbs}}\right) = 192.2 \text{ in}^3$

Current level drop per day $= \frac{192.2 \text{ in}^3}{1000 \text{ in}^2} = 0.192 \text{ in}$ in each sump

$\approx \boxed{0.2 \text{ in/day}}$

↳ ≈3 marks of inch

assuming that solvent losses are the same from both sumps!

★ It will be difficult to see the difference (especially from the distance) with such small numbers, especially since 0.2 in/day drop should be the maximum value!

Appendix B
Rimma's calculations

7/14/05 Solvent loss Calculations (for Main Degreaser) ①

* all calculations per year

$\rho_{TCE} = 91.1$ lbs/ft³

$\rho_{nPB} = 82.99$ lbs/ft³

Measured Exposure Level @TEC = 46ppm (can be higher)

0.57 = evaporation rate of TCE
0.96 = " Lenium

OR

3 = evaporation rate of TCE
4.5 = " EnSolv

$$(8 \text{ barrels})\left(670 \frac{\text{lbs}}{\text{barrel}}\right)\left(\frac{\text{ft}^3}{91.1 \text{ lbs}}\right)(0.787) = 46.3 \text{ ft}^3 = 4218 \text{ lbs}$$

← in previous calculations this value = 4221!

$$\frac{46.3 \text{ ft}^3}{0.57} = \frac{x \text{ ft}^3}{0.96} = 77.98 \text{ ft}^3 = 6471.56 \text{ lbs of Lenium lost}$$

$$\frac{46.3 \text{ ft}^3}{3} = \frac{x \text{ ft}^3}{4.5} = 69.45 \text{ ft}^3 - 5763.66 \text{ lbs of EnSolv lost}$$

$$\frac{46.3 \text{ ft}^3 \text{ TCE}}{46 \text{ ppm}} = \frac{77.98 \text{ ft}^3}{X \text{ ppm}} \rightarrow 77.5 \text{ ppm}$$

exposure (max!) of nPB solvent using same equipment & process

$$\frac{77.5-10}{77.5} \times 100\% = 87\%$$

→ need to decrease solvent loss by this ammount (target ~90% to be safe b/c TCE exposure can be higher)

$77.98 \text{ ft}^3 (1-.87) = 10.14 \text{ ft}^3 = 841.52$ lbs of Lenium solvent lost/yr if achieve 10ppm exposure

$69.45 \text{ ft}^3 (1-.87) = 9.03 \text{ ft}^3 = 749.40$ lbs of Ensolv lost "

Check: $(10.14 \text{ ft}^3)\left(82.99 \frac{\text{lbs}}{\text{ft}^3}\right)\left(\frac{\text{barrel}}{670 \text{ lbs}}\right) = 1.26$ barrels/yr if use same as for TCE (compared to original calculation)

↑ less by ~ 0.1 (could be round-off errors)

Cost Analysis

TCE: $\left(4218 \frac{\text{lbs}}{\text{yr}}\right)\left(\frac{\$0.7492}{\text{lb}}\right) = \$3160.13$ /yr spend on TCE

Lenium: $\left(841.52 \frac{\text{lbs}}{\text{yr}}\right)\left(\frac{\$2.75}{\text{lb}}\right) = \$2314.18$/yr might be spend on Lenium → will SAVE \$845.95 /yr

EnSolv: $\left(749.40 \frac{\text{lbs}}{\text{yr}}\right)\left(\frac{\$3.10}{\text{lb}}\right) = \$2323.14$/yr " EnSolv → will SAVE = \$836.99/yr

So, should save ~ \$800 /yr

Appendix B
Rimma's calculations

Solvent Loss Calculations

$8\ \frac{\text{barrels}}{\text{yr}}\left(670\ \frac{\text{lbs}}{\text{barrel}}\right)\left(\frac{1\text{ yr}}{12\text{ months}}\right) = 446.67\ \frac{\text{lbs}}{\text{month}}$ ⟹ assumed/expected estimate is a little high for current –

current: main degreaser

$\frac{1520\text{ lbs}}{5\text{ months}} = 304\ \frac{\text{lbs}}{\text{month}}$

portable degreasers:

$= 82.22\ \frac{\text{lbs}}{\text{month}}$

$\Big\} = 386.22$ lbs/month current total lb

$\frac{82.22}{386.22} = 0.213 = 21.3\%$ of TCE loss from portable degreasers vs. total TCE loss (curr

Then, TCE loss in the main vapor degreaser is 0.787 (78.7%) of the total loss.

Assume same ratio in the future, The TCE loss from the main degreaser $= 8\ \frac{\text{barrels}}{\text{yr}}(0.787) = 6.3\ \frac{\text{barrels}}{\text{yr}}$

$\frac{6.3\text{ barrels}}{0.57} = \frac{X\text{ barrels}}{0.96}$ ⟹ X = 10.61 barrels of Lenium will be used/lost in the main degreaser.

$\frac{6.3\text{ barrels}}{3} = \frac{X\text{ barrels}}{4.5}$ ⟹ X = 9.45 barrels of EnSolv will be used/lost in the main degreaser

Exposure of TCE measured at TEC was 46ppm (It might be higher at times)

$\frac{6.3\text{ barrels TCE}}{46\text{ppm TCE}} = \frac{10.6\text{ barrels nPB}}{X\text{ ppm nPB}}$ ⟹ X = 77.397 ppm exposure to nPB with current equipment/proc

69.0 ppm using ensolv

Target exposure limit = 10ppm.

$\frac{10\text{ ppm}}{77.4\text{ ppm}} \times 100\% = 12.9\%$ → So, will need to decrease exposure (and solvent loss) by $(100-12.9) = \boxed{87.1}$

14.5 85.5

$\frac{10.6\text{ barrels}}{77.4\text{ ppm}} = \frac{X\text{ barrels}}{10\text{ ppm}}$ ⟹ X = 1.37 barrels/yr of nPB will be used/lost if decrease exposure level to 10pp changing/improving process and equipment.

1.37

\# barrels will be used with current process and current exposure level

168%

★ 0.57 = evaporation rate of TCE
0.96 = " Lenium GX (nPB solvent)

when compared to TCA (TCA=1)

150%

3 = evaporation rate of TCE
4.5 = " EnSolv (nPB solvent)

when compared to nBA (nBA=1, TCA=4.6)

Appendix B
Rimma's calculations

Cost Analysis for main degreaser

EnSolv = \$3.10/lb
Linium GX = \$2 - 2.75/lb
TCE (current cost) = \$0.7492/lb

TCE (with current loss and exposure)

$$\left(6.3\,\frac{\text{barrels}}{\text{yr}}\right)\left(\frac{670\text{ lbs}}{\text{barrel}}\right)\left(\frac{\$0.7492}{\text{lb}}\right) = \$3,162.37/\text{yr}$$

12.18 lb/gal

nPB (with 10 ppm expossure level)

10.9 lb/gal   601 lb/drum

$$\left(1.37\,\frac{\text{barrels}}{\text{yr}}\right)\left(670\,\frac{\text{lbs}}{\text{barrel}}\right)\left(\frac{\$2.75}{\text{lb}}\right) = \$2,524.22/\text{yr} \quad = \text{max. cost for Lenium GX}$$

$$\left(1.37\,\frac{\text{barrels}}{\text{yr}}\right)\left(670\,\frac{\text{lbs}}{\text{barrel}}\right)\left(\frac{\$3.10}{\text{lb}}\right) = \$2,845.49/\text{yr} \quad = \text{cost of EnSolv}$$

With 10ppm exposure level (to be achieved!),
TEC will save at least \$638.15/yr with Lenium GX
and will save \$316.88/yr with En Solv.

Now need to consider costs for equipment upgrades and training to decrease solvent loss by at least 87%.

vs

compliance costs, time lost on reports/measurements/calculations, fees, insurance premiums, worker's compensation, possible improved quality (maybe)
also, if automating the system, then count for a time saved — operator can be doing other tasks while operating a vapor degreaser, and will eliminate discrepancies between reported amounts and hours compared to the values specified in the system and PAPS.

★ I need to be able to measure current and future exposure levels (should be able to determine solvent losses as well)

★ The following pages will have my ideas on how to improve the main degreaser and the process, as well as some calculations.

- basket rocking
- working covers
- automation

• at least some of it can be done by TEC (will drop costs!)

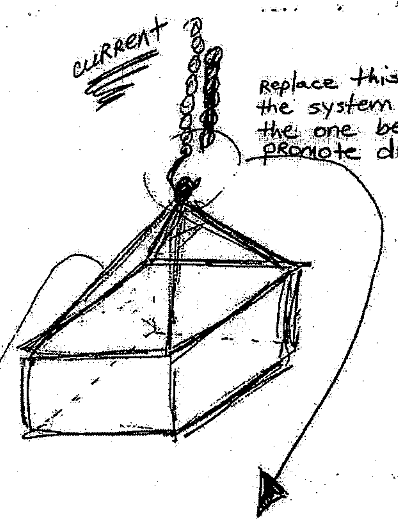
★ TEC definately needs a working cover (compliance)

.5 lb dragout

20 lb/day
@ 2% dragout
at 5000 lb TCE/yr
16 lb/day

Appendix C
Rimma's retrofit sketches

Technique ⇒ need to change!
Times
baskets/hr
• Think about sliding/working covers
• ~~Think al~~ automation
promote drainage (hoist/basket)



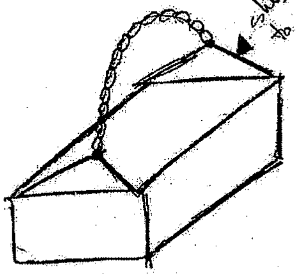
Replace this hook with the system similar to the one below to promote drainage.

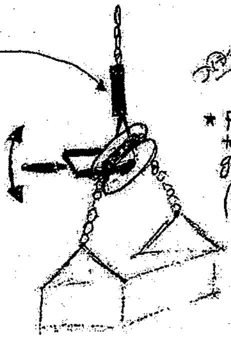
chain ring will go around each tooth to ensure that the chain moves as desired

Too expensive to outsource Rotating baskets)

So, either do manually OR automate ourselves.

shouldn't be too difficult to rewire/change here.

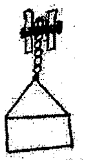




operator can hold metal Rod w/ one hand and mover lever up/down w/ another hand!

* place Rubber stoppers to prevent the basket from going too high & splashing.
(Rubber stoppers to limit the movement of the lever & to ensure no jerky movements)

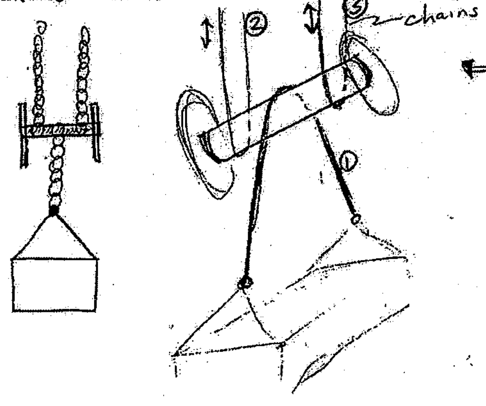
* Also, can place latches to lock the basket at a certain angle



The only problem, is that the chain will move when operating a lever. So, when automating & changing the system, will have to figure out how to keep it stationary to prevent Rocking.

How difficult will it be to keep the basket steady? What can be done to improve design? (mechanical/automation)

To eliminate the lever & automate it



⇐ Chain ① wraps around the Rod and connects to the basket

Chains ② and ③ wrap around the same Rod and go up to the hoist mechanism, which will be automated.

Slight movements of the chains ② and ③ will promote the Rocking of the basket.
(this shouldn't be hard to automate?)

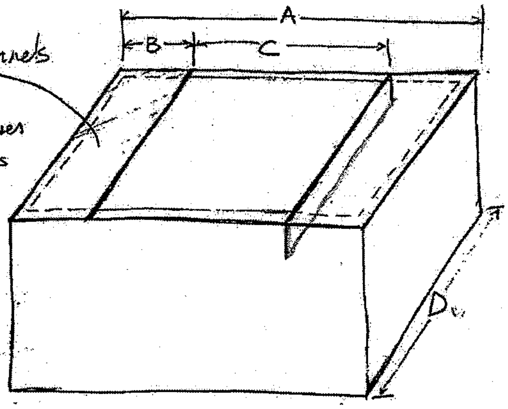
So, automation will move the basket up/down, left/right,
and will also more chains ② and ③ up/down slightly to make the
basket rock slightly and lock at a certain angle for a specific } ?

Appendix C
Rimma's retrofit sketches

Sliding/working covers! (incorporate into ~~automation~~ design!) if possible

hese two pannels ermanently velded on top of the degreaser

& sliding covers are right underneath them



aybe the permanent vers should have small rubber or astic line right der the edge that ill touch the iding cover to sure no gaps r solvent to escape | legradation ue to vapors ?)

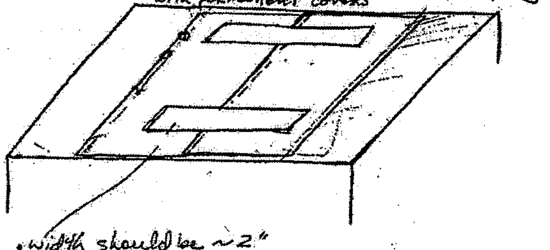
for the part to go in & out, can the basket go in/out in the middle of the degreaser?

width (D) of sliding covers should be as wide as width of the degreaser (touch the sides & slide side to side)

length of each sliding cover should be $(\frac{1}{2}C+1)$
(1" extra to ensure overlapping with the permanent cover and with another sliding cover)

Sliding Covers (closed)

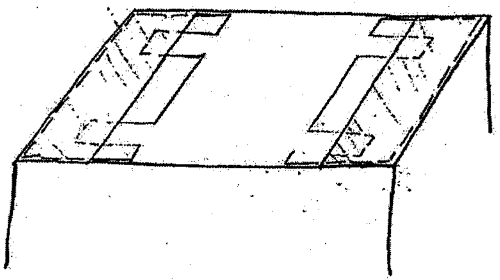
- Two sliding covers overlap a little to ensure no gaps
- Both sliding covers also overlap slightly with permanent covers



- width should be ~2" (enough for chain to fit w/o scratching sides)
- length should be just enough for the basket to move back 'n forth

Sliding Covers (open)

- allow enough space for basket to be lowered



open sliding covers, lower the basket

(★ Need working cover for possible audit)

automate this also

1) open the covers
2) lower the basket in the center
3) close the covers
4) start automation process
5) when prompted by the system, move lever up/down for drainage
6) continue w/ automation process
7) when cleaning & drying is finished, the basket should be in the center of the degreaser.
8) System will prompt the end of the cycle
9) Open (slide) covers
10) Lift the basket
11) close covers
12) Remove the basket

★ After all degreasing jobs are complete, slide in the manual (idling/downtime) covers!

★ Current Vapor-Air Interface Area =
= 45" × 29" = 1305 in² = 9.06 ft²

★ New Vapor-Air Interface Area =
= 23" × 2" = 46 in² = 0.32 ft²
×2
0.64

length of the slit

width of the slit

(assuming from center of boiling sump to center of rinse sump plus a little extra)
↳ should be about ½ of the length of the current vapor-Air Interface.

★ VAI will ↓ even more & only hold parts in the vapor zone w/o moving them back & forth btwn sumps.

★ VAI decreased by 28.3 to 28.4 times. (per slit)

★ Therefore, working losses should be decreased by the same amount — times when covers are open. Determine the fraction of time when covers are open vs. when they are closed to determine true change of working losses

Appendix C
Rimma's retrofit sketches

when closed ★ New VAI is $\frac{0.32\ ft^2}{9.06\ ft^2} = \frac{1}{28} = 0.0353 = 7.06\ \%$ of the old one
$\times 2$ slits

$\frac{9.06-(2\times 0.32)}{9.06} \times 100\% = 92.94\ \%$ change (drop) in the VAI.

★ when the covers are open, the opening should be slightly larger then the size of the basket

↳ assume opening is 19" x24" (but can make it slightly ~~smaller?~~ larger)

~~the VAI = 456 in² = 3.17 ft²~~

Then minimum VAI for open degreaser = 19" × 24" = 456 in² = 3.17 ft²
Maximum VAI " = 22" × 29" = 638 in² = 4.43 ft²

When open ★ New VAI is $\frac{4.43\ ft^2}{9.06\ ft^2} = 0.489 = 48.9\%$ of the old one.

$\frac{9.06-4.43}{9.06} \times 100\% = 51.1\%$ minimum change (drop) in the VAI

★ With this design, working losses should drop by ~~[illegible]~~ at least 2/3 !
(possibly ~ 1/4)

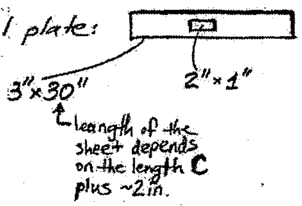
⟹ when will figure out the average fraction of time when covers are closed vs. open, then will know exact amount of losses!

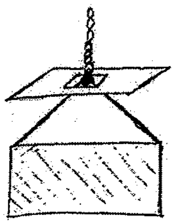
↳ need to measure current emissions & exposure levels → **evaporation** rat

---

*Can also add two small metal plates with the opening to hang on the chain, so that when the basket is lowered these metals plates are also lowered over the slits and move along with the chain, reducing the VAI even further.

↳ each metal plate:





This design should decrease VAI to 2 in² for each slit, then VAI (total) will be 4 in² (0.0278 ft², instead of 9.06 ft².

$\frac{9.06-0.0278}{9.06} = 0.997 = 99.7\%$.

VAI will decrease by ~ 99.7% and solvent losses should decrease accordingly.

There will also be some additional losses due to th small space between the metal sheets and cou

Appendix D

Late Developments Memo - regulatory findings on TCE and nPB, as well as degreaser operation

To: George Gawrys and Tim Aberwald October 5, 2005
From: Rimma Krakmalnikov and Karl DeWahl
Subject: **Late Developments in the Thomas Engineering Company Degreasing Intern Project**

In the 8/29/05 presentation for the n-propyl bromide (nPB) evaluation project questions were raised about the status of TCE as a carcinogen and on likely regulation of nPB. In addition, after the presentation, a number of people viewed the degreaser operation, and contrary to the description of the recommended procedure of holding parts in the vapor zone until dripping stops, the observation at Thomas Engineering Company was that dripping did not stop no matter how long parts remained in the vapor zone. This memo contains additional information on each of these issues.

Carcinogen status of TCE

Trichloroethylene (TCE) is currently considered a likely human carcinogen by the National Toxicology Program [reasonably anticipated], NIOSH [potential occupational], EPA [possible to probable, currently under review], the State of California, and the International Agency for Research on Cancer (IARC) [group 2A (probable)]. TCE is not one of the 36 chemicals specifically identified and regulated, with specific action items by OSHA, as carcinogens. On the other hand the American Congress of Governmental and Industrial Hygienists (ACGIH) lists TCE as "not suspected as a human carcinogen". The difference in opinion appears to be because there is definitive information that TCE causes cancer in some types of animals but not in others. Those evaluating the issue for the ACGIH concluded cancer is cause by the metabolites of TCE and not directly by TCE, and that since cancer does not appear in exposed animal species with metabolisms most like humans, cancer in humans should not be expected to result from human exposure to TCE. ACGIH is reputable in their analysis and recommendations – they many times recommend stricter exposure limits for chemicals than the regulators, because they can responde to new information more quickly. Their recommendations are prudent to follow – but they have no regulatory authority. In many cases, the ACGIH recommendation predicts the direction of future regulatory decisions, but this is not assured and the time lags can be long. Practically, the main effect to TCE's current classification is to increase liability in the case of an employee or neighbor developing cancer and claims that Thomas Engineering Company was the source of exposure – there is no specific action required related to TCE's carcinogen designation.

New nPB regulatory information

Two recently identified articles provided additional insights into the likely regulatory future of nPB. The first article stated that Atofina Corporation, a European producer of nPB, refuses to sell its product to companies without a fully enclosed system. This, in my opinion, is a proof that there are serious health concerns associated with nPB, since the company limited their own market and potential profits. Please refer to bottom of page 15, http://www.ssec.wisc.edu/icds/reports/Drill_Fluid.pdf.

Another article stated that two legislators proposed for TCE to be phased out and the legislator from California proposed for nPB to be included with other hazardous halogenated solvents. This information was obtained in the last section of the article at http://www.hsia.org/updates/apr-may%202005.htm. It is unknown whether these proposals will pass or not, and it is hard to tell if this should be considered seriously at this point. However, it is important to keep in mind that there is a possibility for further regulations.

Observations on degreaser operation – parts continuing to drip

This observation contradicts everything that I have learned about the vapor degreasing process. To ensure that I understood the process and knew exactly the right way to degrease the process, I reviewed the issue using the following resources:

manufacturers of vapor degreasing equipment,
producer vapor degreasing solvents,
manuals and training material from those companies.
EPA documents
and most importantly George and I gathered Dave Blackstone from Finishing Equipment, and Karl DeWahl from MnTAP to look at degreaser operation as a group.

Many degreasing descriptions indicated parts will stop condensing and come out dry after the hold in the vapor zone; others just stated that the condensation will stop in the vapor zone. All described the mechanism of vapor degreasing as follows. Parts and the basket submerged into the vapor degreaser are colder then the vapors, and vapor that comes into contact with the colder parts and the basket, condenses into the liquid droplets on the surface of the parts. These droplets then drip off the parts carrying dirt and oil into the boiling sump. The temperature of the parts increases due to contact with hot vapors and will eventually approach the temperature of the vapors. As parts heat up, fewer vapors condense on the parts and the condensation (dripping) rate decreases until the equilibrium is reached and condensation stops.

Dave Blackstone from Finishing Equipment, company that manufactured the current degreaser, worked with the T-16 vapor degreaser on numerous occasions, examining it, troubleshooting, etc. When he was told that the condensation "will never stop", he first said that the parts will never completely dry because the parts' temperature will get very close to the temperature of the vapors but it will never be exactly equal to the temperature of the vapors. But with further discussion he elaborated that dripping will decrease drastically, to a point that it will not be visible at all (there will be long periods between drips). He was very surprised to hear that we could clearly observe the condensation for very long periods.

A number of Thomas Engineering Company staff met with Dave Blackstone and Karl DeWahl on September 1 to discuss the observations and ways to improve the degreasing procedures and then George, Rimma, Kenny, Dave and Karl went out to observe the degreaser operation. The degreaser had recently been started up so the clean sump had a surface temperature of 110°F which is lower than in normal operation, but a condition present each day of operation for perhaps 1 hour. These are the observations made and their significance:

1 Dave observed that as cold parts were lowered into the vapor, the **vapor zone collapsed** – the cold parts condensed all of the vapor so air filled the volume down to the solvent surfaces. It took **2 minutes** for the vapor zone to re-establish itself. Dave indicated vapor collapse is an undesirable event that **increases solvent loss** – with each vapor collapse a mixture of solvent vapor and air is pushed upward and much of it is lost. Dave indicated each vapor collapse is similar to removing a load of parts from the degreaser.

As a solution, Dave suggested introducing the loads with **starts and stops** to prevent vapor collapse. George Gawrys and Karl DeWahl constructed a calculator to estimate hold times for various load sizes and materials. Stepping in parts will likely **increase cycle time.**

2 Kenny's standard procedure is to introduce parts into the boiling sump, quickly transfer them to the clean sump, and then withdraw the parts basket to the freeboard zone, above the condensing coils, and wedge the basket with a tilt for drainage and drying. During all transfers there was significant dripping of solvent indicating **excess solvent** on the parts. Once in the freeboard zone the hot parts **dried quickly** as expected. With the freeboard hold significant amounts of **solvent vapor mix with air** – some will sink down and rejoin the degreaser solvent and some will be carried out of the degreaser and lost by drafts and basket movement.

3 Attempts were made hold baskets in the vapor zone until dripping stopped. This turned out to be very difficult. It was impossible to wedge the basket for drainage entirely within vapor zone – a corner of the basket would always extend well out of the vapor zone. The **vapor zone in the T-16 degreaser is very short**, particularly above the clean sump (12" to the condenser trough). Under these conditions, dripping was fast and continuous, with no signs of stopping.

4 We also hung the basket in the vapor zone, close to the solvent surface and got **slower dripping** than the earlier trials, but we did not see it stop. Dripping was very difficult to observe given lighting, distance and sight lines. The lack of tilt on the basket may have allowed the solvent to pool and slow drainage, and there may have been splashing of the boiling solvent onto the basket. On the other hand, the heavy steel rods supporting the basket extend out of the vapor zone, and may cool the basket causing extended condensation.

Possible ways to improve drainage in a vapor hold include:

a) install support tabs on one wall to support a edge of the basket while the other side is lowered. This would work well with load cycle automation.

b) re-design the basket to either: i. open up the sides and bottom for better drainage; or
ii. bow out or crease the current basket bottom to create a low spot for drainage.

c) shorten the basket in either width or length to allow tilting – this might affect throughput, and there would need to be a new way to accomplish tilting, ;

d) enlarging the vapor zone if there will be a significant retrofit of the degreaser;

5 We lowered the end of a 1/2" diameter aluminum rod into the vapor zone to both test the theory that condensation should stop after a vapor hold and to look at the effect of materials extending out of the vapor zone. Condensation started immediately when the end entered the vapor zone, then **dripping slowed and then stopped** within 30 seconds. This suggests the possibility of **constructing an aluminum basket** to replace the current steel basket. A test of this option would be to repeat this test with a heavy steel rod. If it takes much longer for dripping to stop, aluminum would be a a good choice of materials.

6. The load tested weighed 42lb and the basket weighed 10lb. For a load of steel parts, the basket constitutes 20% of the thermal load. An aluminum basket of the same dimensions would weigh 3.4lb and constitute 12% of the thermal load of a load of steel parts and basket. An aluminum basket would allow shorter holds to avoid vapor collapse. Good basket design would also maximize the open of the sides and bottom, while still containing small parts.

Recommended vapor degreaser procedure for Thomas Engineering Company:

1. Step parts into the vapor zone to prevent vapor zone collapse – see George's calculator
2. Immerse in the boiling sump for a time determined by individual cleaning needs of that part.
3. Raise the basket out of the boiling sump, Hold for 15s to allow oily solvent to drain off parts (preventing contamination of the clean sump)

4a. If the clean sump is cold (with in 90minutes of startup, assuming that loads are being processed steadily during this time),
Transfer the basket into the clean sump, stepping the load into the clean sump to slow the overflow of cold solvent into the boiling sump and thus prevent vapor collapse, Step the basket out of the sump to avoid vapor collapse, then Hold for 60s, oriented for load drainage. [Note: 90 minute is a guess at the time required for the clean sump to warm up to the point that parts coming out of the sump do not collapse the vapor zone].

4b. If the clean sump is hot,
Transfer the basket into the clean sump, Raise the basket out of the sump, then Hold for 40s, oriented for load drainage.

5. Raise the parts basket just above the condensing coil, Orient the basket for drainage (determine if this is needed) and Hold for 30s to dry parts
6. Remove the basket from the degreaser and unload parts

Appendix E

Calculations for vapor hold times - by Karl DeWahl, on the parts temperature change due to condensation in the vapor degreaser at Thomas Engineering Company. (10/8/05)

Heat capacity of steel (Metals Handbook pp1-64)
T range 300-350K heat capacity ranges from 565-586 J/Kg-K for grades ANSI-SAE 1010 & 1078 respectively. Use 570J/kg-K = 0.136btu/lb-F

Heat of vaporization TCE = 57.2 cal/g 103 btu/lb() @ 85.7C (186F) Perry's Handbook 5ed, pp3-116

On 9/1/05 we collapsed the vapor blanket with a 53.4 lb load and it took 120 s for the vapor zone to be re-established. Parrts weighed 42.8 lb, the basket weighed 10.6 lb
For a 53.4lb load of steel increasing in temperature from 80F to 186F

$$\begin{array}{c|c|c} 53.4\text{lb} & .136\text{ btu} & 106\text{F} \\ \hline & \text{Lb}-\text{F} & \end{array} = 770\text{ btu} \qquad [617\text{ btu for the parts, } 153\text{ btu for the basket}]$$

TCE condensate needed for this increase

$$\begin{array}{c|c|c} 770\text{ btu} & \text{lb TCE} & \text{gal} \\ \hline & 103\text{ btu} & 12.2\text{ lb TCE} \end{array} = 0.61\text{ gal TCE}$$

Degreaser heating rate (vaporization rate)

$$\begin{array}{c|c|c} 770\text{ btu} & & 60\text{ min} \\ \hline & 2\text{min} & \text{hr} \end{array} = 23{,}100\text{ btu/hr} \qquad \begin{array}{c|c} 23{,}100\text{ btu} & 2.93\text{x}10\text{-}4\text{ kWh} \\ \hline & \text{btu} \end{array} = 6.8\text{kW}$$

The other heat load we observed was cold solvent overflowing into the boiling sump. Assuming the overflow is 1/32th inch thick, 18" wide and moving at 2 ft/s

$$\begin{array}{c|c|c|c|c|c|c|c|c|c} 1" & 18" & 2\text{ ft} & \text{ft2} & 7.48\text{gal} & 186\text{-}120\text{F} & 0.223\text{ btu} & 12.2\text{lb} & 2.93\text{x}10\text{-}4\text{ kWh} & 3600\text{s} \\ \hline 32 & & \text{s} & 144\text{ in2} & \text{ft3} & & \text{lb-F (TCE)} & \text{gal} & \text{btu} & \text{h} \end{array} = 11\text{kW}$$

This thermal load seems too large given that on 10/6/05 Dave Blackstone said the heat rating for this degreaser is 10kW. In any case even if the load is 3.2 kW this a very substantial drain on vaporization from the cold sump.
Also this heat load disappears when the vapor blanket collapses and condensation and flow through the water separator stop.
Total degreaser heating rate = 10kW
The degreaser costs $1.25/hr to heat the boiling sump, maybe $2.50/hr to run the degreaser & still & both condensers – assuming the still has half the heating rate of the degreaser and the refrigeration operates at a COP of 3. $7500/yr for 3000 hours of operation.

Holds to avoid vapor collapse
It took 2 minutes for the load to equilibriate going in to the degreaser – 24 seconds for the basket and 95 for 42. lb of parts. That is how long a hold would need to be to prevent collapse.

Appendix F
Vapor Degreaser Retrofitting Options

OPTION 1 (Economical) as proposed by Rimma K.

	Design/Eng. (hr)	**Labor (hr)**	**Labor ($)**	**Material Outcost**
Extend freeboard/Incorporate sliding covers	8	14	$1210	$2,500
Automate "Z" axis	14	6	$1100	$3,000
Tilt basket	We recommend manual with dwell on auto "Z"			
Interlock	2	6	$440	$220
Visual/Audio notification	2	6	$440	$100
Programming/Engineering	30		$1650	
Meeting time/concept development	12		$660	
Total:	68	32	$5500	$5,820

Total labor: 100 hours @ $55.00 = $5,500 + $5,820 out costs
Total for Option 1: $11,320

OPTION 2 (Semi-Automatic) as proposed by Rimma K

	Design/Eng.(hr)	**Labor(hr)**	**Labor ($)**	**Material Outcost**
Costs from option 1, plus the following:	68	32	$5500	$5820
Automate "X" Axis	40	10	$2750	$4500
Automatic tilt basket	48	30	$4290	$2000
Automatic sliding covers	20	32	$2860	$1500
Interlock/override		4	$220	$500
Programming/Engineering	40		$2200	
Meeting time/concept development	16		$880	
Additional automation expenses				$500
Total X-axis:	164	76	$13,200	$9000
Total X&Z-axis			$18,700	$14,820

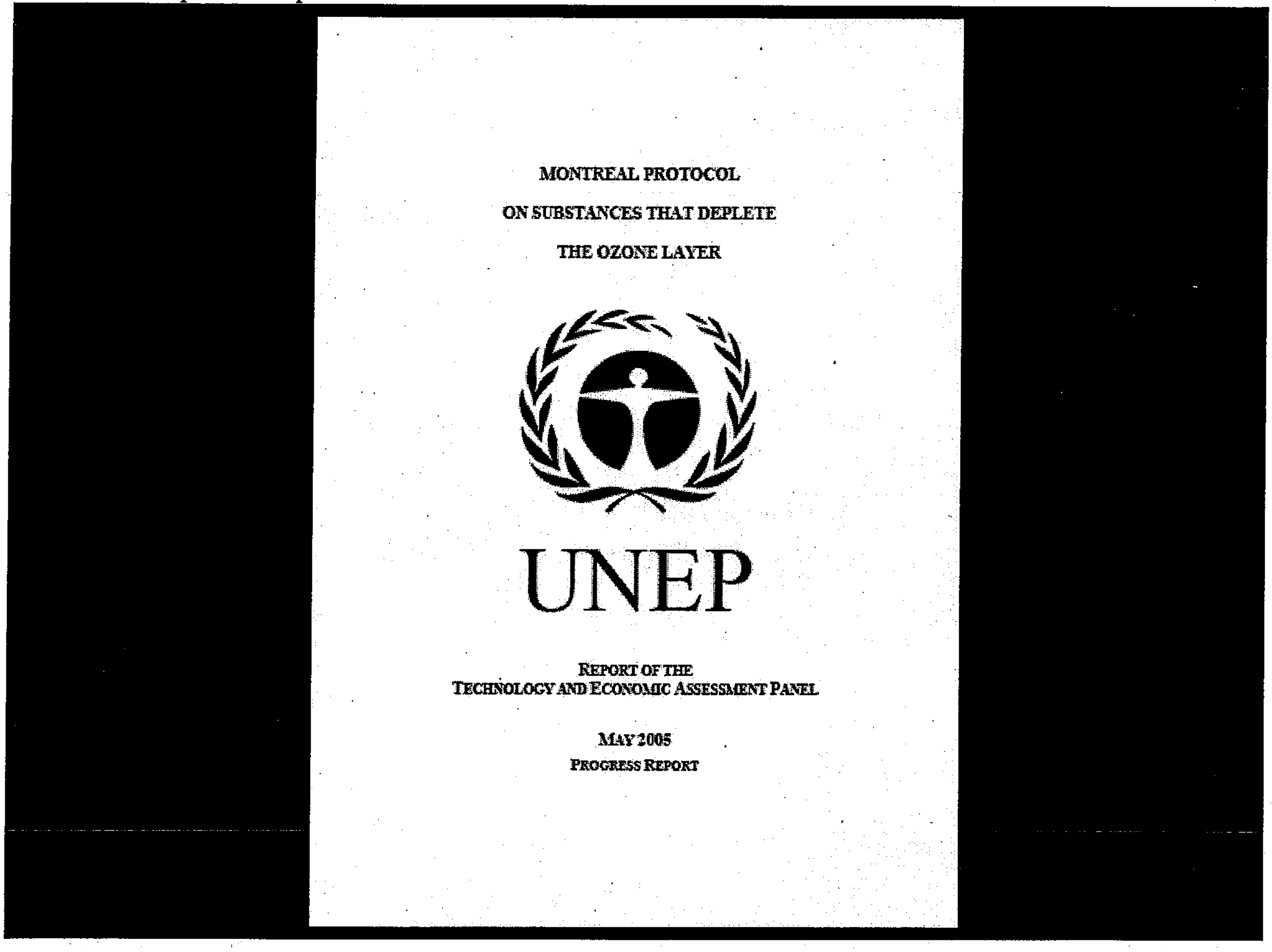
Total labor: 164 hours @ $55.00 = $9,020 + $9,000 out costs
Total additional costs for option 2: $22,020 + option 1: $11,320
Total for option 2: $33,340
Note: The above is a rough estimate based on retrofitting existing equipment.

Options as presented in the final report

	Design/Eng. (hr)	**Labor (hr)**	**Labor ($)**	**Material Outcost**	**Total**
Automate "Z" axis Interlock Visual/Audio notification Programming/Engineering Meeting time/concept development	60	18	$4290	$3000	$7290
Automate "X" Axis Automatic tilt basket Interlock/override Programming/Engineering Meeting time/concept development Additional automation expenses	144	44	$11 ,340	$7500	$18,840
Automatic sliding covers	20	32	$2860	$1500	$4360
Extend freeboard/Incorporate sliding covers	8	14	$1210	$2500	$3710

Appendix G

2005 TEAP report excerpt



MONTREAL PROTOCOL

ON SUBSTANCES THAT DEPLETE

THE OZONE LAYER

UNEP

REPORT OF THE
TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

MAY 2005
PROGRESS REPORT

area, the likelihood of these replacing solvents that have been used for critical cleaning applications appears small at this time.

Stockpiling of critical cleaning solvents was considered an option. Of course when the supply is depleted a critical situation again arises and stockpiling only delays reality.

The UNEP and country environmental protection agencies recognise that there are areas where there is no direct replacement of solvents for high technology projects. These projects were developed predicated on the benefits of the solvent. In these cases a mechanism of essential exemption exists. Proposals are made to continue the use of critical solvents until suitable replacements are found or the project terminates. This is a process that grants exemptions only in very few cases and is not intended to be a method of circumventing the need for continuing research and development. Summary: Since the last UNEP STOC report no new and novel alternatives have been developed. Further it is unlikely that there will be new solvent alternative breakthroughs. Major chemical companies are reluctant to embark on expensive research projects, the products of which are subject to extensive scrutiny by federal and state agencies. In addition the time frame is extremely long, in some cases many years. Thus far only the HFCs, HCFCs and HFEs are leading the field in halogenated solvent replacements, although they have a high purchase cost per unit weight. Aqueous and "no-clean" techniques are most widely used for replacement of OD solvents.

6.7.2 n-Propyl Bromide (n-PB) Update (Decision XIII/7)

Under Decision XIII/7, TEAP was requested to report annually on n-PB use and emissions.

6.7.2.1 Market Trends

Use of n-propyl bromide (n-PB) continues (in spite of toxicity concerns and pending proposals to reduce exposure guidelines) due to its good solvency and relatively low cost. Its current use estimates range from 2,200 MT to 9,100 MT per year. This substance has a very short atmospheric lifetime of 11 to 25 days, and its ODP for emissions in the tropics is greater than the ODP for emissions at northern latitudes. n-PB has an ODP that ranges from 0.013 to 0.1 depending on where it is emitted.

n-PB has been used as feedstock for the synthesis of pharmaceuticals and other organic compounds for a long time. In the last few years, its uses have grown as a solvent for industrial cleaning for degreasing, metal processing and finishing, electronic defluxing and other cleaning applications in aerospace and aviation. It has also successfully captured some applications in aerosol formulations and as a carrier solvent for adhesives, inks and coatings.

n-PB is also promoted by its vendors as a substitute for non-OD trichloroethylene, dichloromethane (meth ylene chloride) and perchloroethylene and ozone depleting chlorofluorocarbons (CFC) in many applications.

It is marketed as n-Propyl Bromide or Propyl Bromide as well as under many trade names such as Leksol, Ensolve, Solvon, Abzol, VDS-3000, Hypersolve, and Lenium. (This is not a complete list of all trade names under which n-PB and its blends are sold).

Guidelines from manufacturers suggest exposure limit of around 10-25 ppm. Only a few stay with 100 ppm.

6.7.2.2 Recent Toxicity Data and Proposed Regulatory Actions

Long term (chronic) testing of n-PB in animals has shown toxicity to the reproductive systems of both males and females. In males, it affects sperm counts and motility, testicles and prostate. In females it damages ovaries and results in sterilisation. Based on the reproductive toxicity data the Commission of the European Communities has proposed adding n-PB to the list of dangerous chemicals that can cause cancer, have mutagenic properties or are toxic to reproduction.

The Environmental Protection Agency (EPA) of the USA has suggested an exposure limit of 25 ppm.

n-PB also has significant neurotoxicity to animals and humans. The animal study showed significant neurological effects on animals at various dose levels. A recent case study involving five workers whose job was gluing foam cushion with glue containing the solvent n-PB, reports that they developed serious neurological symptoms, some of which appear to be permanent. Based on these recent findings and until more toxicological test data become available, the American Conference of Industrial Hygienists (ACGIH) has recommended an exposure limit for solvents containing n-PB of 10 ppm. Hazard Evaluation System and Information Services (HESIS) of California Department of Health Services have gone a step further and has suggested that worker exposure should be limited to about 1 ppm (a meeting has been called for May 2005, proposing the 1 ppm recommendation be made mandatory). Also the Office of Environmental Health Hazard Assessment (OEHHA) of California announced on Nov 8, 2004 its intention to add n-PB to the Proposition 65 list as a chemical known to the State to cause reproductive toxicity. So far only one of the n-PB vendors has reduced the recommended exposure limit to 10 ppm.

100 years 1905-2005

STOELTING
LEWIS TREK
A Polar Ware Company

Ms. Rimma Krakhmalnikov
Thomas Engineering Company
7024 Northland Drive North
Minneapolis, MN 55428

Dear Ms. Krakhmalnikov:

Per your request, enclosed please find a proposal for Stoelting RTW 236 parts washer.

If you have any questions or need further information after your review of this proposal, please feel free to call me at our office at 800-558-5807 or our qualified representative in your area Ron Peterson with Ron Peterson & Associates at 651-257-9505

Thank you for your interest in Stoelting products. We appreciate the opportunity to quote on your cleaning requirements.

Sincerely,

STOELTING/LEWIS/TREK
Industrial Products Division

Greg Farrell

Greg Farrell
Application Engineer

Enclosures

CC: Ron Peterson & Associates

ISO 9001:2000 Registered

Trek
Regional Offices
San Dimas, CA
Louisville, KY
Medord, NJ
www.trekindustries.com

Lewis Ultrasonics
Regional Office
766 Main Street South
Woodbury, CT 06798
203-266-0470
Fax 203-266-0473
www.lewissonics.com

Stoelting®
Corporate Office
502 Hwy 67
Kiel, WI 53042
920-894-2293
800-545-0661
Fax 920-894-7029
www.stoelting.com

100 years 1905-2005

STOELTING ® LEWIS ® TREK
A Pelar Ware Company

PROPOSAL NO: **4914-082605**
DATE: August 26, 2005

Ms. Rimma Krakhmalikov
Thomas Engineering Company
7024 Northland Drive North
Minneapolis, MN 55428

Tel: 763-531-4129
Fax: 763-533-8091
E-mail: rkrakhmalnikov@thomasengineering

PROPOSAL

STOELTING Model RTW-236 with recirculating wash stage recirculating rinse stage, and heated blow-off with controls; stainless steel construction; with electric immersion heater; oil skimmer; insulated tank; current sensing relay; 460 Volt; 3 Phase; 60 Hz.

PRICE	**$58,729.00**

<u>OPTIONS</u>:

Audible alarm..........each	**253.00**
Beacon alert...........each	**303.00**
HRS filter	**1,305.00**
Stainless steel filter	**3,940.00**
Oil coalescing unit (2 GPM with air diaphragm pump in lieu of oil skimmer)	**4,110.00**
High temp (above 150°F) air pump in lieu of standard - ADD $510 to base coalescer price	
Electric pump in lieu of air – ADD $1,960 to base coalescer price	
Baskets 18" x 12" x 6"	**TBD.**

<u>SHIPMENT</u> – Drawing for information will be furnished within 4 weeks* after receipt of purchase order. Completed machine will be shipped approximately 16 weeks* after receipt of purchase order at factory. (*) Depending on conditions at factory at time of order entry.

<u>RECOMMENDED METHOD OF PROCESSING</u>:

PARTS MUST BE ORIENTED TO PROVIDE FREE DRAINING AND ACCESS OF WASH AND/OR RINSE SOLUTION TO CONTAMINATED AREAS.

THE CLEANING PERFORMANCE TO BE EXPECTED IS BASED ON A FACTORY TEST. STOELTING CAN DEMONSTRATE, AT NO CHARGE, THE ABILITY OF THE QUOTED MACHINE TO MEET YOUR REQUIREMENTS PRIOR TO THE START OF ENGINEERING AND MANUFACTURE. IF THIS IS DESIRED, PLEASE SUBMIT PARTS WITH YOUR PURCHASE ORDER.

By Greg Farrell
Greg Farrell
STOELTING, LLC

ISO 9001:2000 Registered

Page 3

Trek
Regional Offices
San Dimas, CA
Louisville, KY
Medford, NJ
www.trekindustries.com

Lewis Ultrasonics
Regional Office
766 Main Street South
Waterbury, CT 06798
203-266-0470
Fax 203-266-0473
www.lewisonics.com

Stoelting®
Corporate Office
502 Hwy 67
Kiel, WI 53042
920-894-2293
800-545-0661
Fax 920-894-7029
www.stoelting.com

THIS PROPOSAL IS SUBJECT TO THE TERMS AND CONDITIONS OF SALE ON THE REVERSE SIDE.

51

THIS MACHINE IS MANUFACTURED TO STANDARD STOELTING MECHANICAL AND ELECTRICAL SPECIFICATIONS. (FINAL SPECIFICATION SUBJECT TO CHANGE)

CUSTOMER IS RESPONSIBLE FOR THE PROPER DISPOSAL OF ALL CLEANING SOLUTIONS USED IN THE MACHINE ACCORDING TO HIS LOCAL EPA REQUIREMENTS, INCLUDING THE CONTROL OF ANY FUMES FORM CHEMICALS ACCORDING TO OSHA AND N.F.P.A. REQUIREMENTS.

GENERAL CONDITIONS – Only new and proven quality components shall be used in the construction of your equipment. Components will be purchased from recognized name manufacturers and their standard warranties shall be extended to you.

As is Stoelting's policy, the entire unit will be assembled, wired, piped and tested prior to shipment. Stoelting welcomes your personnel to view and inspect the tests, if desired.

This proposal is based on current prices of materials from our stock and from vendors, as promised to us by them and also prevailing wage scale in our plant. Therefore, any prices quoted by us are for prompt consideration and will be subject to change beyond a period of 30 days from the date of this quotation. In the event an order is placed and accepted by us, prices shown on acknowledgement of order will be firm and not subject to change.

Prices quoted are F.O.B. factory. Unloading and installation of equipment will be the responsibility of the customer. Necessary drawings and written instructions for installation will be furnished by Stoelting.

SUPPORTING DATA: The following data is attached: Drawing # 6995758

RESPONSIBILITY:

By Purchaser:
Purchaser shall reassemble those components whose disassembly was required for shipment and provide all installation services.

By Stoelting:
Pre-shipment: Equipment shall be completely assembled and mechanically tested prior to shipment. Purchaser is invited to view testing and inspect machine.

Shipment: All machines will be shipped F.O.B. our plant. A carrier of our choice will be used unless otherwise specified.

Instructions: One (1) complete installation and operation manual will be furnished.

Installation and/or start-up service: Installation and start-up is the responsibility of the purchaser and is not included in the quoted price of the machine. If requested, we will furnish a trained field technician to assist in installation and/or inspect your installation and instruct your personnel on proper operating and maintenance procedures, at current per diem rates plus expenses.

WARRANTY: Our standard warranty statement is attached.

OSHA: Our standard statement of policy on OSHA requirements is attached.

TERMS: Net 30 days from date of invoice applies on sales up to $50,000. Orders above $50,000 – 30% with order, 60% at shipment, 10% net 30 days.

Interest is charged at the maximum legal rate per month on past due accounts.

ALL SALES AND TERMS SUBJECT TO CREDIT APPROVAL BY STOELTING IN WRITING PRIOR TO ACCEPTANCE OF ORDER.

STOELTING appreciates the opportunity to submit this proposal for your consideration. If questions or comments arise during your evaluation of the enclosed information, please feel free to contact us at 1-800-558-5807, or our qualified representative in your area:

Ron Peterson/Ron Peterson & Associates
651-257-9505

INDUSTRIAL PARTS WASHER
Design Specifications
RTW-236

MODEL NO.:	RTW-236
TYPE OF MACHINE:	Tank type – rotating below submergence/spray
MACHINE DIMENSIONS:	(see attached drawing)
UTILITY REQUIREMENTS:	460 Volt, 3 Phase, 60 HZ

MATERIALS OF CONSTRUCTION:

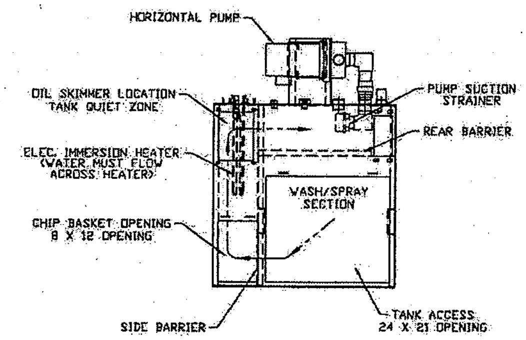
- Tanks: 12 Gauge 304 Stainless Steel
- Pumps: 304 Stainless Steel
- Piping: Stainless Steel, Bronze Drain Valve
- Spray Manifolds: Stainless Steel
- Chip Basket: 304 Stainless Steel
- Rotating Fixture: Stainless Steel
- Fixture Lid: 3 x 3 mesh (.270 opening)
- Electrical Power Panel: Carbon Steel, Painted gray

PRODUCT SIZE:

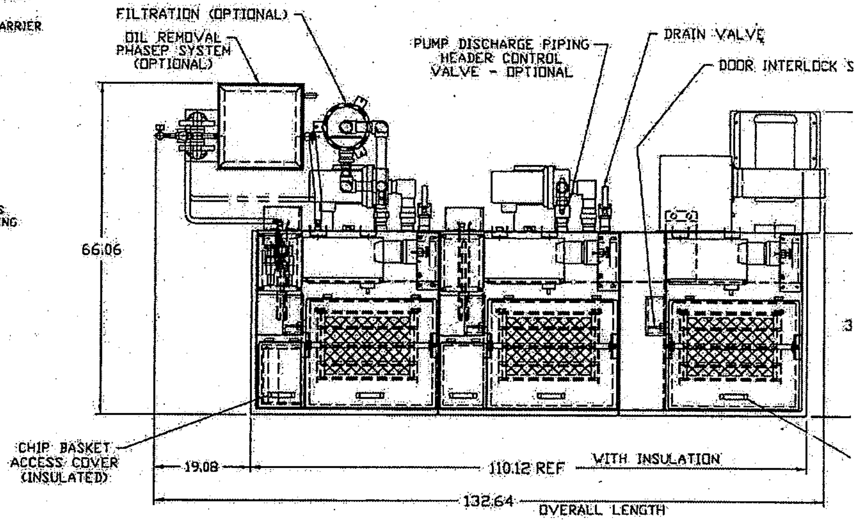
- Machine fixture is 19.75" wide x 12.75" deep x 6.25" high (maximum basket dimensions)
- Fixture will hold two (2) 18" wide x 12" deep x 6" high baskets (I.D. Dimensions), to be supplied by customer
- Hold up to 100 lbs./each maximum

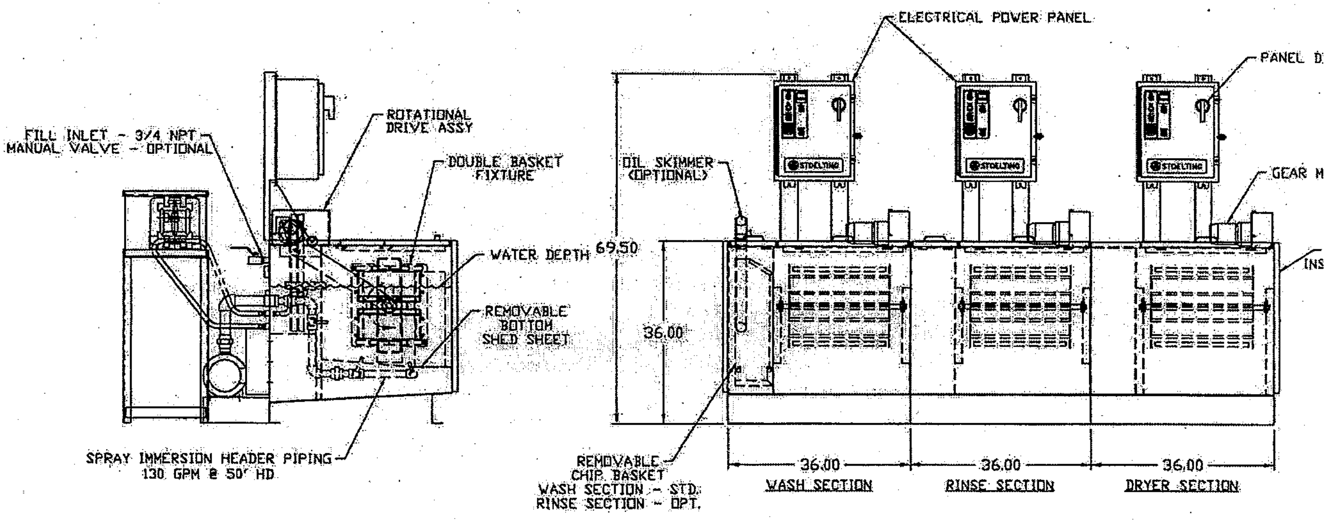
WASH TANK:

- All welded construction
- Holds approximately 120 gallons
- The rotating fixture is partially submerge in the liquid (0 – 4 RPM, 1/8 HP) (mesh lid only, sides open) (holds two (2) baskets)
- Automatic water level and fill controls
- Manual fill pushbutton for initial tank filling
- Using barriers and weirs, chip are directed to the chip basket (.062 diameter holes), while the oil is trapped in a quiet zone for easy removal
- At the end of the cycle, the water level in the tank returns to its static level, which is below the top of the weir. This feature traps the oil in the quiet zone, not allowing it to flow back on the clean parts
- Low level switch to automatically shut down pump and heat when level drops to unsafe level
- Stainless steel removable chip basket
- Insulation (high efficiency, ceramic fiber blanket) tank cover, front and exposed sides (not between tanks or back)
- Removable, hinged tank cover with safety interlock switch
- Recessed tank top – 1" high lip all around to contain dripping
- Fill pipe connection – 3/4" NPT
- Tank overflow connection – 1 1/2" NPT
- Removable shed sheet to allow access to all internal piping components and pump screen
- Sloped bottom for drainage – drain 1 1/2 NPT



WASH TANK PLAN VIEW
TANK CIRCULATION FLOW PATTERN





MATERIALS

TANK: 12 GA. STAINLESS STEEL
ROTATING FIXTURE: STAINLESS STEEL
CHIP BASKET: STAINLESS STEEL
BASKET MESH: PERFORATED - .062 DIA HOLES
PUMP: STAINLESS STEEL
PIPING: STAINLESS STEEL
HEADERS: STAINLESS STEEL
DRAIN VALVE: BRONZE

TANK INSULATION: 1" THICK INSULATION
VERTICAL SIDES ONLY
FRONT, TOP, & OUTER 2 SIDES ONLY

ROTATING FIXTURE: HOLDS 2 INNER BASKETS
NOMINAL BASKET SIZE: (I.D. DIMENSIONS)
18.00" WD X 12.00" DP X 6.00" HIGH
MAX. BASKET SIZE: (O.D. DIMENSION)
19.75" WD X 12.75" DP X 6.25" HIGH
FIXTURE CAPACITY: 100 LB MAX.

SPECIFICATIONS

WETTED SECTION

(PER WETTED STAGE)
TANK CAPACITY: 120 GAL.
PUMP: 130 GPM @ 50'TDH - 3 HP
PUMP INLET STRAINER: 20 MESH
ROTATION: 0-4 RPM - 1/8 HP - 130 VDC
ELECTRIC HEAT: 140° - 21 KW
ELECTRIC HEAT: 180° - 31.5 KW (OPTIONAL)
TANK DRAIN: 1-1/2" NPT
OIL SKIMMER: DOUBLE BELT
OIL PICKUP RATE: 4 GALS/HR (STD)
OIL PICKUP RATE: 8 GALS/HR (OPTIONAL)

FILTRATION OPTION
BAG FILTER W/CANISTER
2" NPT CONNECTIONS
5 TO 100 MICRON FILTER BAGS AVAILABLE

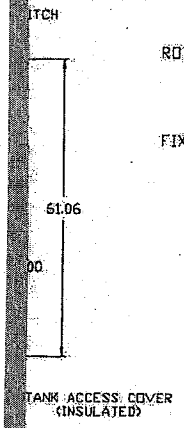
OIL COALESCING FILTER OPTION
PHASEP MINI SKIMMER, STAINLESS STEEL
W/PNEUMATIC PUMP, 1/2 GPM OIL PICKUP RATING

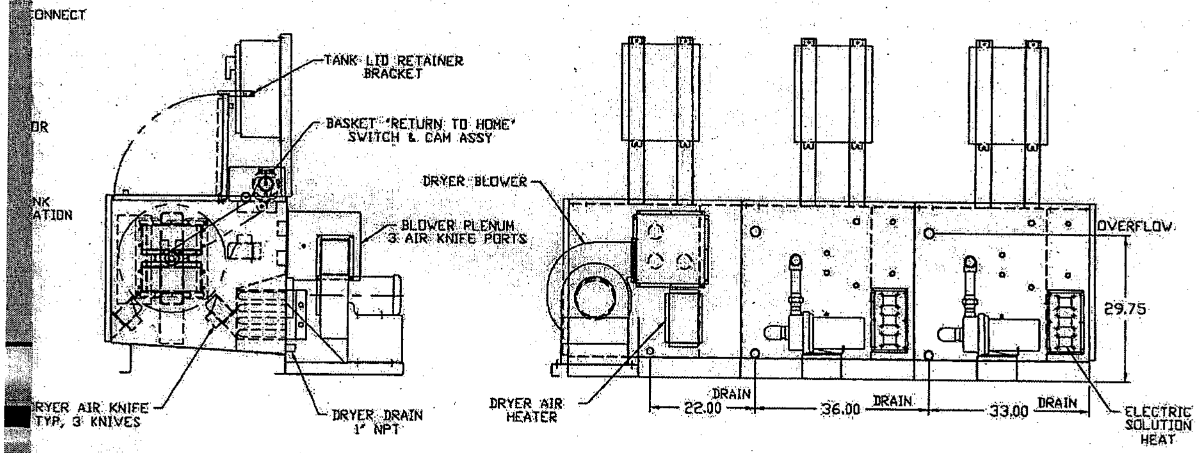
UTILITIES
REF. - SEE ELECTRICAL SCHEMATIC

HEATED BLOWOFF SECTION

TANK CAPACITY: 120 GAL.
BLOWER: 600 CFM @ 8.5" S.P. - 3 HP
ROTATION: 0-4 RPM - 1/8 HP - 130 VDC
ELECTRIC HEAT: 250° MAX. - 10 KW
TANK DRAIN: 1" NPT

UTILITIES
REF. - SEE ELECTRICAL SCHEMATIC





REV	REVISION DESCRIPTION	C.N.	BY	DATE	CK

NOTE:
DO NOT SCALE DRAWING
TOLERANCE UNLESS OTHERWISE NOTED.
X.X = ±.12
X.XX = ±.030
X.XXX = ±.010
ANGLES = ±1°

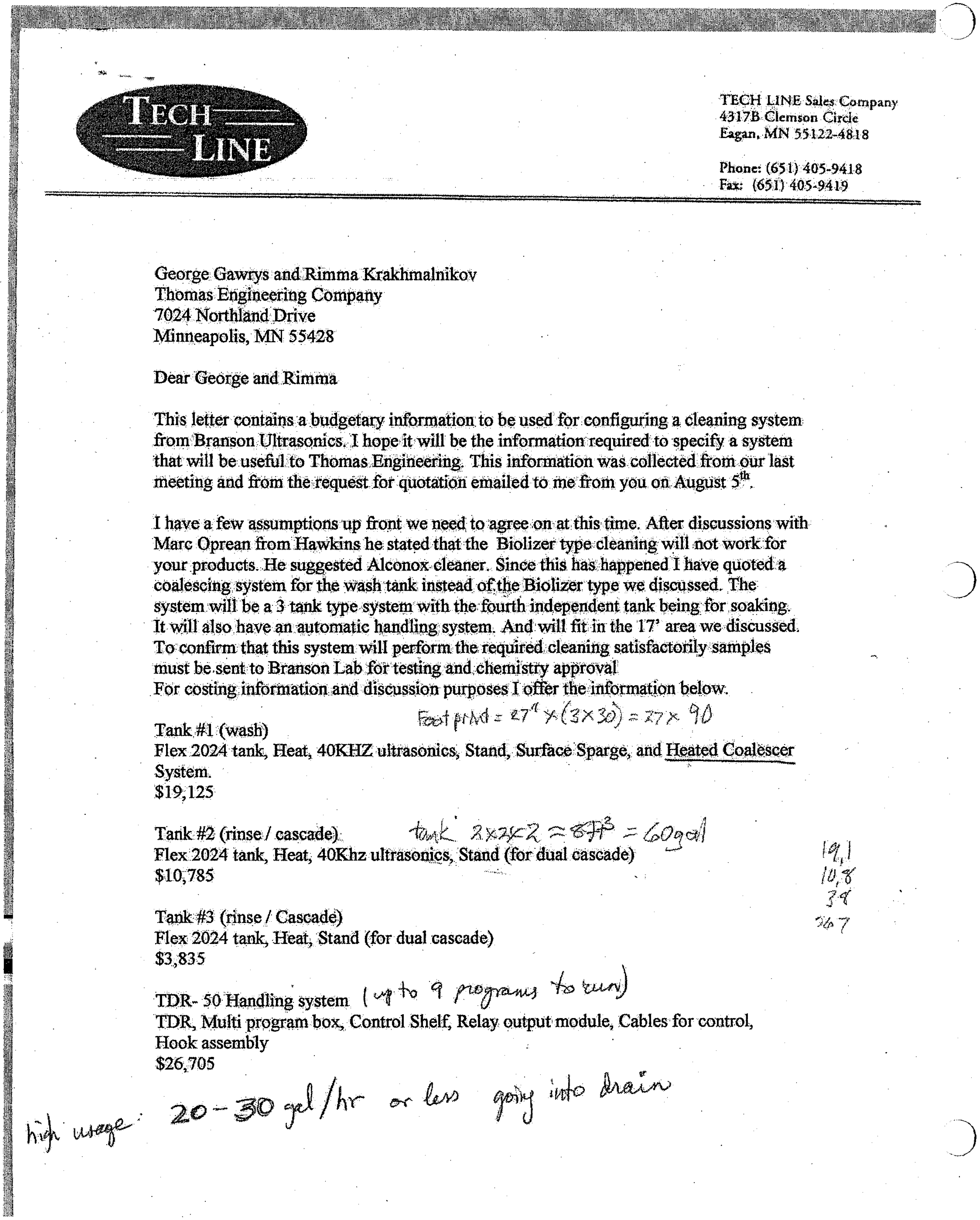
SUCCEEDING USAGE

SHEET 1 OF 1

THIS DRAWING AND PRINCIPLES OF DESIGN ARE NOT TO BE REPRODUCED, COPIED, OR LOANED IN PART OR WHOLE WITHOUT THE WRITTEN CONSENT OF:
STOELTING
KIEL, WISCONSIN 53042

TITLE FLOOR PLAN/PROPOSAL LAYOUT
RTW-236 W/DRYER
MATERIAL OR SOURCE
PRODUCT RTW36
AUTOCAD NO. 6995758
PRODUCT CODE 30
PART NO. 6995758
DATE 8-1-95
DWG BY JS
SCALE 1=16
CHK BY
DWG NO. 6995758
REV 0

Appendix H
Aqueous Cleaning Product Literature



TECH LINE

TECH LINE Sales Company
4317B Clemson Circle
Eagan, MN 55122-4818

Phone: (651) 405-9418
Fax: (651) 405-9419

George Gawrys and Rimma Krakhmalnikov
Thomas Engineering Company
7024 Northland Drive
Minneapolis, MN 55428

Dear George and Rimma

This letter contains a budgetary information to be used for configuring a cleaning system from Branson Ultrasonics. I hope it will be the information required to specify a system that will be useful to Thomas Engineering. This information was collected from our last meeting and from the request for quotation emailed to me from you on August 5th.

I have a few assumptions up front we need to agree on at this time. After discussions with Marc Oprean from Hawkins he stated that the Biolizer type cleaning will not work for your products. He suggested Alconox cleaner. Since this has happened I have quoted a coalescing system for the wash tank instead of the Biolizer type we discussed. The system will be a 3 tank type system with the fourth independent tank being for soaking. It will also have an automatic handling system. And will fit in the 17' area we discussed. To confirm that this system will perform the required cleaning satisfactorily samples must be sent to Branson Lab for testing and chemistry approval
For costing information and discussion purposes I offer the information below.

Foot print = 27" × (3×30) = 27 × 90

Tank #1 (wash)
Flex 2024 tank, Heat, 40KHZ ultrasonics, Stand, Surface Sparge, and Heated Coalescer System.
$19,125

Tank #2 (rinse / cascade) tank 2×2×2 ≈ 8ft³ = 60gal
Flex 2024 tank, Heat, 40Khz ultrasonics, Stand (for dual cascade)
$10,785

19,1
10,8
3,8
367

Tank #3 (rinse / Cascade)
Flex 2024 tank, Heat, Stand (for dual cascade)
$3,835

TDR- 50 Handling system (up to 9 programs to run)
TDR, Multi program box, Control Shelf, Relay output module, Cables for control, Hook assembly
$26,705

high usage: 20 - 30 gal/hr or less going into drain

$60,450

Preclean Soak tank
Flex 2024 tank, Heat, 40Khz ultrasonics, pump and filter, Stand.
$13,580

this would be intended for heavily oiled parts
& should not have ultrasonics

60,500
2,000
10,000
5,000
77,500

Options

Baskets for above system 17" x 21"	$500 each	
TDR Extension 5'	$2000	
Intank rotation per tank module including basket	$7500ea	x1
On TDR Rotation with basket	$9900	x1
Additional rotation baskets	$2500	x2

On Site Startup quoted separately.

for the soak tank (?)

9900
5000
2000
13,580
~~7500~~

Two Dimensional Robot

I hope this covers most of your questions.
Thank you for taking time to discuss your requirements with me
Nile Plapp

ArtCraft Baskets 408-377-2725 for smaller baskets
$100 - 250

Speed control for Rotary Baskets

Max 7rpm w/ ultrasonics, better 5rpm

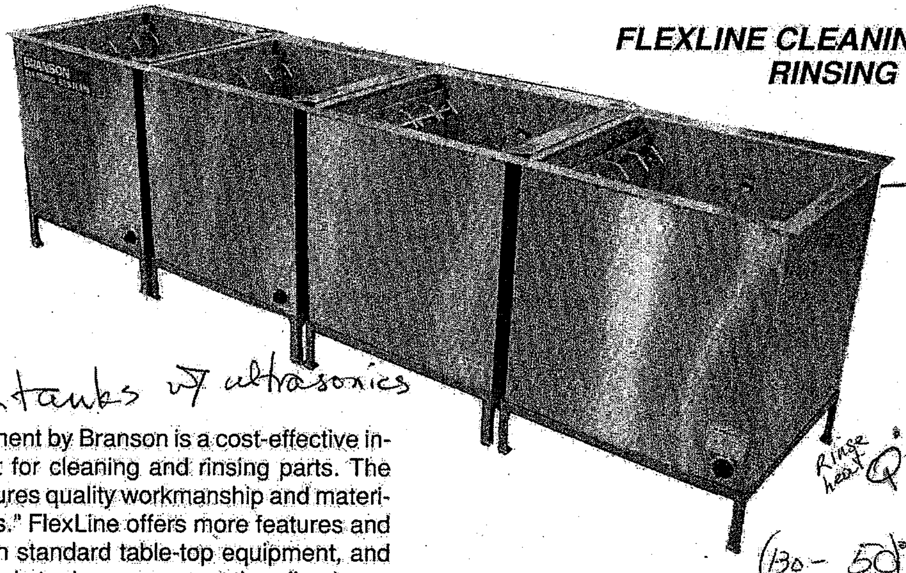
★ With everything (all possible expenses, hopefully) ≈ $100K!

BRANSON
Sound Ideas For Business

Bulletin S-1014

AQUEOUS ULTRASONIC CLEANING SYSTEM

FLEXLINE CLEANING AND RINSING TANKS



$60-75K
total
including
wash
2 rinse
1 prewash
Biolizer

2 tanks w/ ultrasonics

DRIER
NO unit
will rely on
heat
130°F
flash dry

Rinse heat $\dot{Q} = C_p \Delta T\, m$

$(130 - 50)°F \left(\frac{30\,gal}{hr}\right)$

FlexLine equipment by Branson is a cost-effective industrial product for cleaning and rinsing parts. The equipment features quality workmanship and materials without "frills." FlexLine offers more features and capabilities than standard table-top equipment, and greater flexibility in tank arrangement than fixed console systems.

The basic component of the FlexLine is a standard 304 stainless steel tank with protective skirting. This tank can be configured in a variety of ways for:

- Ultrasonic cleaning
- Spray under immersion
- Weir overflow
- Surface sparging
- Spray rinsing
- Overflow rinsing
- Cascade rinsing

Because the FlexLine system is based on standard components, quick delivery is assured. It also allows for a very flexible configuration of tanks that can easily be adapted should production requirements change.

FlexLine equipment is available in two tank sizes, 12 inches by 16 inches and 20 inches by 24 inches. All tanks are supplied with a stable painted steel support stand. This brings the system to a convenient 36-inch working height.

FEATURES & BENEFITS

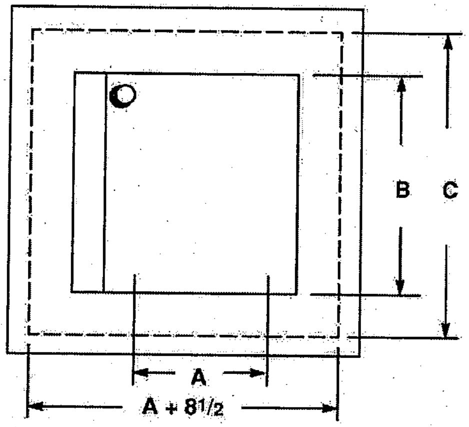
- 304 stainless steel construction
- Protective tank skirting
- Standard overflow weir
- Support stand
- Drip tray
- Stainless steel covers with handles
- Ease of maintenance
- Maximum flexibility
- Quickest delivery
- Cost-effective design

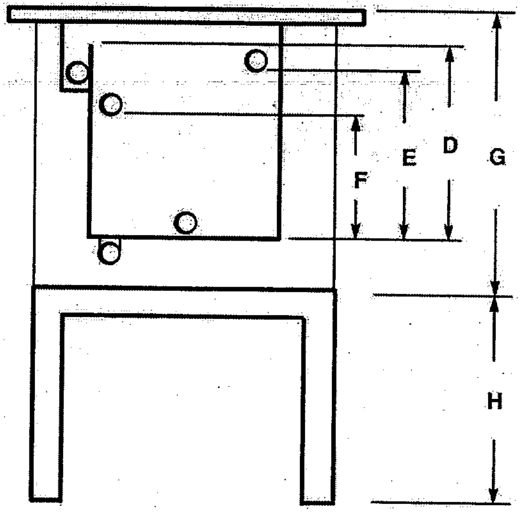
~~2000~~
30 gal/hR

CONFIGURING OPTIONS

- 20 kHz magnetostrictive ultrasonics
- 25 kHz or 40 kHz piezoelectric ultrasonics
- Single or double spray headers
- Sparger manifold
- Overflow rinse
- Cascade rinse, 2-3 tank arrangement
- Thermostatically-controlled heat
- Recirculating pump and filter
- Parts baskets

BASIC TANK





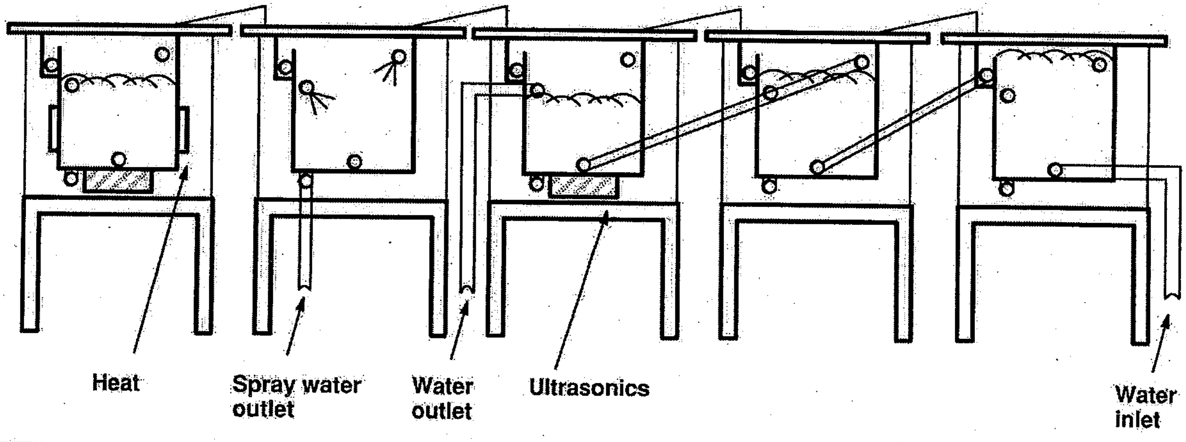
Model	A	B	C	D	E	F	G	H	Heat	Drain dia.	Inlet dia.	Spray/Sparger nozzles	Transducer elements
1216	12	16	19	15	13½	12	22	14	2000	1	½	6	18
2024	20	24	27	23	21½	20	30	6	3000	1	½	10	36

28½

NOTE:
- Dimensions are in inches.
- External dimensions do not include 1″ flange around tank.

TYPICAL CONFIGURATION OF CLEANING & RINSE TANKS

1 ultrasonic cleaning tank with heat; 1 spray rinse tank; 3 cascade rinse tanks; drip trays



BRANSON ULTRASONICS CORPORATION
41 Eagle Road, Danbury, CT 06813-1961 • (203)796-0400 • FAX (203)796-9813

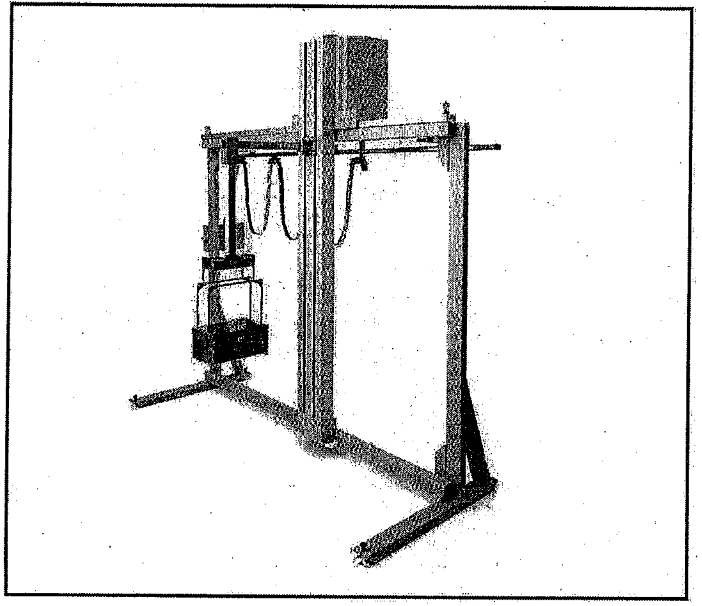
Branson Japan Tokyo, Japan	**Branson United Kingdom** London, England	**Branson Canada** Markham, Ontario
Branson Southeast Asia Hong Kong	**Branson Europe** Dietzenbach-Steinberg, Germany	

rotary basket $9K
in-tank rotation $2-3K

BRANSON

Bulletin S-994

TWO-DIMENSIONAL ROBOT
TDR-50



The Branson TDR-50 is a proven batch transport system. It includes a stable, ruggedly constructed gantry, mechanical winch, and a choice of three electronic control systems to form a reliable automation system. The standard control package is a specially-designed microprocessor-based system. PLC and PC control packages are also available. The unit is capable of handling up to 110 lbs. of parts.

PROGRAMMABILITY

The TDR-50 can be easily programmed in several ways, depending on the control system. A hand-held keypad/programmer can be used to "walk" through the process, and the steps stored by simply pressing the "save" button. This process can also be directly entered using XY coordinates and the keypad. The maximum number of steps available is 255, contained within 10 programs.

Optional PLC or PC-based controls offer the flexibility of open architecture and the ability to allow parallel processing of baskets with different programs. When programming this system, you manually move the system through the process using the joystick and noting the distances between each step. You then enter the process into the program via keypad.

All three control systems utilize optical encoders for positioning and are repeatable within +/- 3/8." They all include an operator interface to enter data and indicate system status, and self-diagnostics for troubleshooting.

EXPANDABILITY

A single TDR head can dramatically increase process throughput and repeatability. As your business grows, additional heads may be required to meet future demands. Up to two additional heads can be added to give a maximum of three heads in a system (two with PLC or PC controls). Each head in the system is programmed individually to effciently perform its task while continuously communicating with other heads. Inter-head communications guarantee coordinated, trouble-free operation of even the most complex processes.

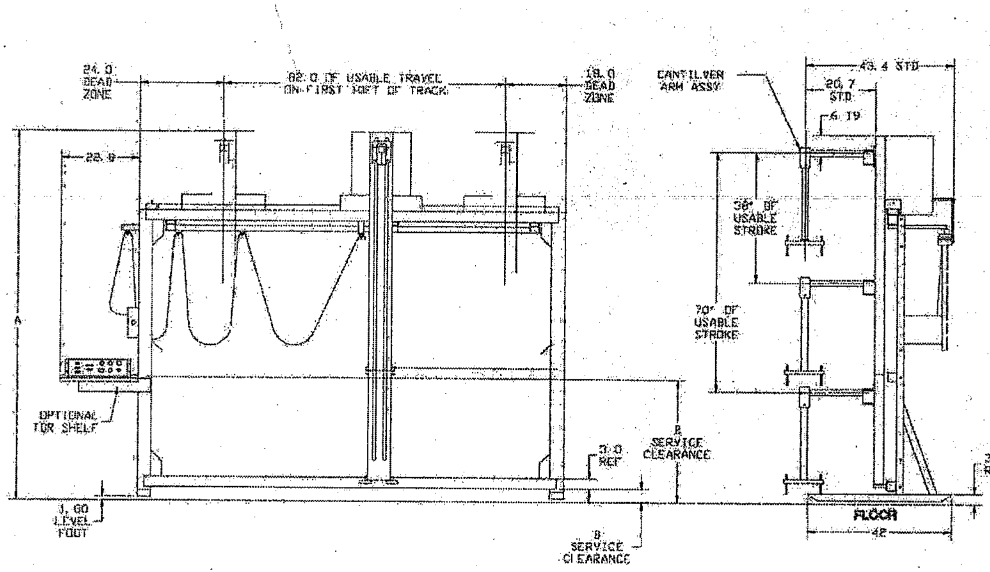
The standard TDR-50 comes with a basic track length of 10 feet. If a longer unit or additional heads are required, modularized increments of 5-foot sections of track and cabling can be added, up to a maximum of 40 feet.

PROCESS CONTROL

Increased productivity is gained by process control through automation with use of the TDR-50. The mircoprocessor system comes with eight 5-volt inputs and four 24-volt outputs (can be expanded to eight). These allow the automation to control the process variables utilized in cleaning, as well as allowing the system to interface with other parts of the manufacturing process.

The PLC and PC-based systems have an expanded number of I/Os available and can be interfaced with a manufacturing information or SPC system through an optional communication interface.

The ability to control automation speed can enhance process control, and, in the case of vapor degreasers, is required by law. The TDR can be programmed to change speeds to improve the throughput. Whatever speed the transport is moving, an electronically-controlled ramping and braking program ensures smooth acceleration and stopping. A four-point basket eliminates the need for balancing loads. The maximum horizontal speed is 60 fpm, and the maximum vertical speed is 23 fpm.



TDR-50 DIMENSIONS (inches)

Model	A Overall Height	B	
		38"	70"
91	91.5	19.3	N/A
108	108.0	35.8	3.9
126	126.0	N/A	21.9
150	150.0	N/A	45.9

Overall TDR length. Usable travel + 42" + 12".
Overall usable track = track length - 38".

Service clearance is area under bottom rail to floor

STANDARD FEATURES

- Load capacity of 110 lbs. (50 kg) & 22 lbs. (10 kg) fixturing
- Ten-foot track length.
- Four-point basket pickup for stability
- Cantilevered arm (no moving parts over process stations)
- Microprocessor-based controls
- 19" rack mounted control box
- LED readouts
- Connector for remote PC
- Keypad or keystroke programmabilty
- Ten-program memory
- Self-diagnostic electronics
- Four horizontal and four vertical speeds
- Ramping and electronic braking for smooth operation
- Eight internal outputs
- Four external outputs
- Communication capability with Branson and competitive products

OPTIONS

- Additional work heads
- Four additional external output controls
- PC interface cabling
- Additional track in 5-foot increments
- Alternate input voltages
- Multi-program selector box
- PLC and PC controls

SPECIFICATIONS

Electrical reqs.	120 VAC, 1 phase, 5 Amps
Max. track length	40 feet (non-PLC)
Max. horiz. travel distance	33 feet per head
Travel speeds (fpm)	
Horizontal	15, 30, 45, 60
Vertical	6, 11, 17, 23
Max. load	110lbs. (50 kg), parts 22lbs. (10 kg), fixturing
Max. number heads	Three (Two with PLC /PC)

Note: All specifications to change without notice.

BRANSON ULTRASONICS CORPORATION

41 Eagle Road, Danbury, CT 06813-1961 • (203) 796-0400 • FAX (203) 796-0320 • www.BransonCleaning.com

Branson SE Asia
Hong Kong

Branson Europe
Dietzenbach, Germany

Branson Japan
Tokyo, Japan

Branson Canada
Markham, Ontario

Branson de Mexico
Nuevo Laredo, Mexico

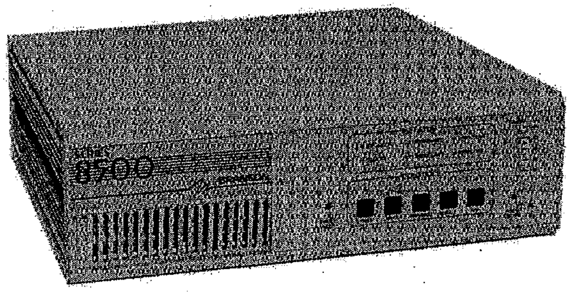
S-994 - Revised and Printed in U.S.A., 1/00

BRANSON
Sound Ideas For Business

Bulletin S-1044

ADVANCED ULTRASONIC CLEANING GENERATOR

SERIES 8500



Branson's *Series 8500 Advanced Ultrasonic Generator* offers a full range of features to meet any precision cleaning requirements. Used on a simple cleaning tank or in a fully integrated cleaning system, the *Series 8500* will deliver precise cleaning quickly, consistently, and cost effectively.

KEY FEATURES & BENEFITS

- **Line / load regulation** compensates for liquid level and temperature changes as well as line voltage and load variations. Changes are held to less than 3% for very consistent cleaning.
- **True variable power control** makes the cavitational intensity (not time) infinitely variable from 0% to 100% which allows matching the power to your application. A bright LED display indicates the selected level.
- **Selectable sweep frequency** permits the process engineer to select both band width and sweep rate to eliminate standing waves and improve ultrasonic activity distribution.
- **Auto tuning** maintains optimum operating frequency around *your* application. It allows the generator to dynamically adjust to changing bath conditions optimizing performance around parameters such as temperature, liquid level, and tank loading.
- **Power modulation mode** is a unique patented feature which produces four times the peak power in the bath. This is helpful for tenacious soils or for driving difficult to cavitate chemistries like semi-aqueous and hydrocarbon formulations.
- **Two input / output (I/O) interface** options permit remote control of operating parameters. One is for *on/off only*. The other enables *full remote control* of the generator for automation or the addition of a PLC to record statistical information on ultrasonic performance.

ADDITIONAL STANDARD FEATURES

- User-adjustable power and frequency controls.
- Indirect cabinet cooling - sensitive components are isolated from potentially dirty cooling air.
- 19 inch, 3 DIN rack mount cabinet.
- Status indicators on safety and fault alarms.
- Bright LED display for easy viewing.
- Two-year warranty period.

SPECIFICATIONS

Element configurations: 12, 18, 24, 36, 48
Input Voltage: 120V(12 ele only), 220V +/- 15%
Avg. output power: 40 watts per element ×36 = 1440
Output frequency: 25, 40, or 75 kHz
Regulatory Approvals: FCC and CSA or CE
Dimensions: 17.5"W, 16.8"D, 5.5"H
Weight: 30 lbs. (13.6kg)

36
40
1440

GENERATOR SPECIFICATIONS

Model	Frequency	Transducer Elements	Voltage Requirements	Average Output Power
S-8525-12 S-8540-12	25 kHz 40 kHz	12 12	120 V or 220 V +/-15% 50 / 60 Hz	500 Watts
S-8525-18 S-8540-18	25 kHz 40 kHz	18 18	220 V +/- 15% 50 / 60 Hz	750 Watts
S-8525-24 S-8540-24	25 kHz 40 kHz	24 24	220 V +/- 15% 50 / 60 Hz	1000 Watts
S-8525-36 S-8040-36	25 kHz 40 kHz	36 36	220 V +/- 15% 50 / 60 Hz	1500 Watts
S-8525-48 S-8540-48	25 kHz 40 kHz	48 48	220 V +/- 15% 50 / 60 Hz	2000 Watts
S-8575-21	75 kHz	21	220V +/-15% 50/ 60 Hz	750 Watts
S-8575-28	75 kHz	28	220V +/-15% 50/ 60 Hz	1000 Watts

NUMBERING SYSTEM

Each Series 8500 Ultrasonic generator has a model number which contains information useful for selecting other compatible components.

For example: S-8540-12. This model number, stamped on the generator nameplate, indicates the model (Series 8500), the operating frequency (40 kHz), and the total number of transducer elements the generator can drive (12 elements).

These may be on one cleaning tank or a combination of immersible transducer cans with a total of twelve elements.

REGULATORY APPROVALS

All Series 8500 ultrasonic generators meet FCC Rules and Regulations. They conform to the EN 60-204-1 standards and carry either the CSA or CE mark.

BRANSON ULTRASONICS CORPORATION
41 Eagle Road, Danbury, CT 06813-1961 • (203) 796-0400 • FAX (203) 796-0320
Branson Southeast Asia
Hong Kong
Branson United Kingdom
London, England
Branson Europe
Dietzenbach-Steinberg, Germany
Branson Canada
Markham, Ontario
Branson Japan
Tokyo, Japan
Branson de Mexico
Nuevo Laredo, Mexico

Printed in U.S.A., 1/97

Appendix H
Aqueous Cleaning Product Literature

INFINITY Precision Systems
7850 Park Drive • Chanhassen, MN 55317 • USA • (952) 401-4600 • Fax: (952) 380-9796 • www.infinityprecision.com

July 27, 2005
Infinity Proposal No. 8939-0

Ms. Rimma Krankhmalnikov
Thomas Engineering Co.
7024 Northland Dr...
Minneapolis, MN 55428

Phone: 763-533-1501
Fax: 763-533-8091

rkrakhmalnikov@thomasengineering.com

RE: QUOTATION FOR ONE INFINITY FIVE STATION PROCESSING SYSTEM WITH AUTOMATED PARTS HANDLING

Thank you for the opportunity to offer our quotation for the five stage aqueous cleaning system you discussed with our representative, Mr. Chuck Bangasser. The proposal below incorporates the automated basket transfer with basket rotation in each station, filtered high velocity spray under immersion agitation, and a triple cascade rinse for water conservation. The unit is design to process hexagonal baskets 22" long x 14" wide (7" per side) with loads up to 50 pounds.

Specific characteristics of the proposed system are as follows:

Tank #1 - Turbulent Agitated Wash Station
- Approximate usable tank size 16"L x 26"W x 19"D
- 12 gauge 316 stainless steel tank construction
- Forced eductor flow in the tank
- Electrical heating capable of 160°F.
- Initial heat-up time from ambient less than 2 hours
- Discrete level control system
- Bag style filtered recirculation with single-sided overflow weir in the tank, and with pump suctions in both the weir and the tank
- Integral basket rotation mechanism within the tank

30× (20×5) = 30× ll
359

Tank #2 – Turbulent Agitated DI Water Cascade Rinse
- Usable tank size 16"L x 26"W x 19"D
- ½" natural polypropylene tank construction
- Incoming cascade flow from the DI Rinse Tank #3
- Forced eductor flow in the tank with bag style filtered recirculation
- Electrical heating capable of maintaining 140°F at a one GPM flow incoming flow rate.
- Initial heat-up time from ambient less than 2 hours.
- Single-sided overflow weir
- Discrete level control system

Tank #3 - Turbulent Agitated DI Water Cascade Rinse
- Usable tank size 16"L x 26"W x 19"D
- ½" natural polypropylene tank construction
- Incoming cascade flow from DI Rinse tank #4
- Electrical heating capable of maintaining 140°F at a one GPM flow incoming flow rate.

- Initial heat-up time from ambient less than 2 hours.
- Single-sided overflow weir
- Discrete level control system
- Integral basket rotation mechanism within the tank

Tank #4 - DI Water Cascade Rinse

- Usable tank size 16"L x 26"W x 19"D
- ½" natural polypropylene tank construction
- Incoming cascade flow from the plant DI water supply
- Electrical heating capable of maintaining 140°F at a one GPM flow incoming flow rate.
- Initial heat-up time from ambient less than 2 hours.
- Single-sided overflow weir
- Discrete level control system
- Integral basket rotation mechanism within the tank

Station #5 - Heated Down-flow Dryer

- Nominal tank dimensions 16"L x 26"W x 27"
- 316 Stainless Steel construction
- Electrical heating capable of maintaining 250°F in the process area
- Pneumatically operated sliding cover, PLC interlocks to operate with the automated parts handling system
- HEPA filtered recirculation drying with variable speed blower
- Pressure switches to monitor airflow
- Temperature sensors with PID temperature controls
- Damper adjustable humid air exhaust
- Integral basket rotation mechanism within the tank

Automated parts handling system
Two-axis overhead hoist

- 75-lb lift capacity
- Load and unload stations with basket sensors
- The system is capable of processing more than one basket simultaneously. Actual basket throughput will be a function of exact process times
- 50-lb per station capacity

Programming and controls features

- Allen Bradley PLC controlled
- Text touch-screen operator interface
- Control panel with disconnect for single point electrical connection
- Intelligently engineered program to maximize flexibility, allow multiple process recipes, and allow process development

Required utilities

- 480 V 3 phase, 60 Hz, AC power
- Clean, dry air at 80 psi minimum
- City water and DI water supply at customer-specified purity

Price

The price for the system described above is $177,175.00.

- Initial heat-up time from ambient less than 2 hours.
- Single-sided overflow weir
- Discrete level control system
- Integral basket rotation mechanism within the tank

Tank #4 - DI Water Cascade Rinse
- Usable tank size 16"L x 26"W x 19"D
- ½" natural polypropylene tank construction
- Incoming cascade flow from the plant DI water supply
- Electrical heating capable of maintaining 140°F at a one GPM flow incoming flow rate.
- Initial heat-up time from ambient less than 2 hours.
- Single-sided overflow weir
- Discrete level control system
- Integral basket rotation mechanism within the tank

Station #5 - Heated Down-flow Dryer
- Nominal tank dimensions 16"L x 26"W x 27"
- 316 Stainless Steel construction
- Electrical heating capable of maintaining 250°F in the process area
- Pneumatically operated sliding cover, PLC interlocks to operate with the automated parts handling system
- HEPA filtered recirculation drying with variable speed blower
- Pressure switches to monitor airflow
- Temperature sensors with PID temperature controls
- Damper adjustable humid air exhaust
- Integral basket rotation mechanism within the tank

Automated parts handling system
Two-axis overhead hoist
- 75-lb lift capacity
- Load and unload stations with basket sensors
- The system is capable of processing more than one basket simultaneously. Actual basket throughput will be a function of exact process times
- 50-lb per station capacity

Programming and controls features
- Allen Bradley PLC controlled
- Text touch-screen operator interface
- Control panel with disconnect for single point electrical connection
- Intelligently engineered program to maximize flexibility, allow multiple process recipes, and allow process development

Required utilities
- 480 V 3 phase, 60 Hz, AC power
- Clean, dry air at 80 psi minimum
- City water and DI water supply at customer-specified purity

Price
The price for the system described above is $177,175.00.

Payment Terms
- First payment, thirty-five percent (35%), with purchase order.
- Second payment, sixty percent (60%), payable upon receipt of invoice and bill of lading copy for complete items that are shipped. In the event that Buyer is not ready to receive equipment or otherwise prevents Seller from shipping the equipment, this payment shall be due notwithstanding within thirty (30) days of date of invoice, which will be dated and mailed at the time materials are packed and ready for shipment.
- Final payment five (5%), after installation and start-up, but not later than sixty (60) days after receipt of the invoice for the second payment.

Delivery
The equipment will be ready for acceptance inspection at our facility approximately 8 weeks after Infinity receives signed approval drawings. The approval drawing package will be available for inspection within 4 weeks from date of order and receipt of down payment. Lead-times may vary depending upon exact time of order, exact scope of work, and backlog at the time of order.

Freight
At Buyer's option, the equipment will be shipped freight-collect or infinity will prepay the freight and bill actual freight costs plus a handling fee of five percent (5%) of freight costs to cover administrative effort and use of funds. A copy of the carrier's freight bill will be furnished as support.

General Terms and Conditions
All terms and conditions of this quotation shall be in accordance with "Infinity General Terms and Conditions of Sale for Quotations" unless otherwise stated in this quotation.

Validity
This quote shall remain valid for 30 days.

Thank you for the opportunity to offer our quotation. Please call me directly at (952) 401-4600, extension 209 if you have any questions or if we can be of assistance to you in any way. In any event, Chuck Bangasser, our representative, will contact you in the near future to offer his assistance.

Best Regards,

John D. Bloomgren
Infinity Precision Systems
7850 Park Drive
Chanhassen, MN 55317

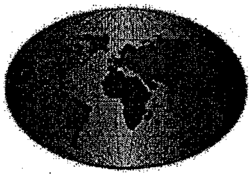
(952) 401-4600 x209
(952) 215-6604 (cell)

NOBLES Manufacturing, Inc.

HOME | ABOUT US | PRODUCT LITERATURE | CONTACT US

CENTRIFUGAL DRYERS
DEFENSE APPLICATIONS
PARTS WASHERS
AQUEOUS CLEANERS
Order Replacement Parts

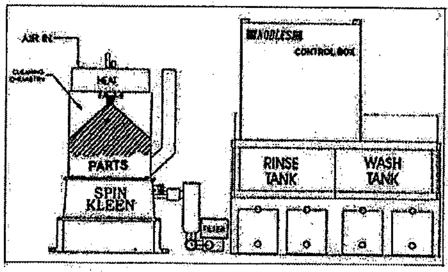
Please Contact us at
(715) 483-3079 or E-mail
jkusske@noblesmfg.com.



STATE-OF-THE-ART! CENTRIFUGAL TECHNOLOGY USING "BASKET AGITATION" IS THE FASTEST METHOD OF CLEANING BASKET HELD PARTS.

FEATURES:

- Stainless Steel Construction
- Maximum System Flexibility
- "Run Dry" Protected Pumps
- Wide Range of Options
- Digital Temperature Controllers
- Total Immersion for Hard to Clean Parts
- Single Step Process Control
- Single Point Electrical Hook Up
- Compact Design
- PLC Controlled
- Ease of Maintenance
- Advanced Spray System



TYPICAL APPLICATIONS:

- Removal of Chips in Hard to Reach Areas
- Oil and Grease Removal
- Fine Particulate Removal
- Chemical Residue Elimination
- Temperature Control Processes
- Application of Rust Inhibitors
- Batch Part Processing in a Cellular Environment

SPIN-KLEEN™ SPECIFICATIONS

MODEL	T-22	T-88	T-231
Chamber Size	12" x 12"	18" x 18"	23" x 18"
Foot Print	6' x 6' x 3'	7' x 7' x 3'	8' x 7' x 4'
Tank Size	40/40 gal.	40/40 gal.	80/80 gal.
Motor	2 HP	5 HP	10 HP
Spray Pressure	60 PSI	60 PSI	60 PSI
Chamber Heat	4 KW	4 KW	8 KW
Tank Heat	4 KW per Tank	4 KW per Tank	10 KW per Tank
Agitation	Included	Included	Included
Chamber RPM	750	650	350

Sheet No.: UniPrep CC-W
Revision: 01/20/05T-706
IMDS ID No.: Not Relevant

Technical Information

UniPrep CC-W

Bioremediation Cleaner Conditioner

INTRODUCTION

UniPrep CC-W is the first step in the UniPrep system, which is the latest technology in pretreatment prior to powder coating. This system eliminates many of the problems associated with conventional iron phosphate systems, especially the formation of scale and sludge, high operating temperatures and the high volumes of waste.

Bioremediation is a natural process that we live with every day. Naturally occurring microorganisms have the ability to convert organic molecules into less complex innocuous substances such as carbon dioxide and water.

The **UniPrep CC-W** cleaning system utilizes microorganism bioremediation combined with highly emulsifying surfactants to consume and metabolize a wide range of oils and other complex organics from the working cleaner. An economical, steady state, never-dump schedule is thus possible. **UniPrep CC-W** contains neither hard chelators nor alkyl phenol surfactants.

Features	**Benefits**
• Steady-state operation	Consistent process performance
• Closed-loop bioremediation system	Reduces waste treatment and disposal costs
• Low alkalinity	Can be used with all commonly coated metals
• Low temperature	Energy savings
• Liquid concentrates	Ease of handling and operation
• No sludge build-up	Reduces the time spent cleaning nozzles and removing sludge from process tanks

ATOTECH

Atotech USA Inc. 1750 Overview Drive, Rock Hill, SC 29730
Telephone: 803-817-3500 • Fax: 803-817-3666

From Marc Upkern <Marc. Upkern@ [illegible] .com>
8/15/05 @ 9:42am
w/ Nile Plapp

ALCONOX

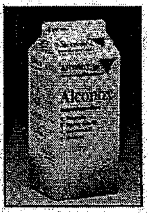
Critical-cleaning detergents for laboratory, healthcare and industrial applications

30 Glenn Street
White Plains NY 10603 USA
Tel.914.948.4040
Fax.914.948.4088

24 Hour Emergency Number
(CHEM-TEL) (800) 255-3924 in U.S.

(e-mail) cleaning@alconox.com

(URL) http://www.alconox.com
- distributors
- technical information
- free samples
- new developments



Alconox®

Powdered Precision Cleaner

- Concentrated to save you money
- Biodegradable and readily disposable
- Penetrating wetting power to save you time
- Replaces corrosive acids and hazardous solvents
- Free rinsing to give you reliable results and no interfering residues
- Use to pass your cleaning validation tests for lab accreditation and plant inspection approval

Used to clean: Healthcare instruments, laboratory ware, vacuum equipment, tissue culture ware, personal protective equipment, sampling apparatus, catheters, tubing, pipes, radioactive contaminated articles, optical parts, electronic components, pharmaceutical apparatus, cosmetics manufacturing equipment, metal castings, forgings and stampings, industrial parts, tanks and reactors. Authorized by USDA for use in federally inspected meat and poultry plants. Passes inhibitory residue test for water analysis. FDA certified.

Used to remove: Soil, grit, grime, buffing compound, slime, grease, oils, blood, tissue, salts, deposits, particulates, solvents, chemicals, radioisotopes, radioactive contaminations, silicon oils, mold release agents.

Surfaces cleaned: Corrosion inhibited formulation recommended for glass, metal, stainless steel, porcelain, ceramic, plastic, rubber and fiberglass. Can be used on soft metals such as copper, aluminum, zinc and magnesium if rinsed promptly. Corrosion testing may be advisable.

Cleaning method: Soak, brush, sponge, cloth, ultrasonic, flow through clean-in-place. Will foam—not for spray or machine use.

Directions: Make a fresh 1% solution (2 1/2 Tbsp. per gal., 1 1/4 oz. per gal. or 10 grams per liter) in cold, warm, or hot water. If available use warm water. Use cold water for blood stains. For difficult soils, raise water temperature and use more detergent. Clean by soak, circulate, wipe, or ultrasonic method. Not for spray machines, will foam. For nonabrasive scouring, make paste. Use 2% solution to soak frozen stopcocks. To remove silver tarnish, soak in 1% solution in aluminum container. RINSE THOROUGHLY—preferably with running water. For critical cleaning, do final or all rinsing in distilled, deionized, or purified water. For food contact surfaces, rinse with potable water. Used on a wide range of glass, ceramic, plastic, and metal surfaces. Corrosion testing may be advisable.

Convenient Sizes:	Alconox Cat. #
Case 9 x 4 lb. Boxes	1104
25 lb. Carton	1125
50 lb. Carton	1150
100 lb. Drum	1101
300 lb. Drum	1103
Case 12 Box 50 x 1/2 oz.	1112
1 lb. makes 13 gal. cleaning solution	

Alconox is available from leading laboratory, hospital, clinical and industrial suppliers. To find a distributor for Alconox, Inc. detergents, visit "Find Dealer" at the website. To request FREE samples visit our Sample Request at www.alcnox.com, write or call Alconox, Inc. today.

ALCONOX

Critical-cleaning detergents for laboratory, healthcare and industrial applications

30 Glenn Street
White Plains NY 10603 USA
Tel.914.948.4040
Fax.914.948.4088

24 Hour Emergency Number
(CHEM-TEL) (800) 255-3924 in U.S.

(e-mail) cleaning@alconox.com

(URL) http://www.alconox.com
- distributors
- technical information
- free samples
- new developments

PHYSICAL DATA	TYPICAL VALUE
pH of 1% solution	9.5
Flash Point (degrees F)	None
Phosphate Content (as Phosphorus)	7.3%
Organic Carbon (% calculated w/w)	11%
Fragrance Content	0%
Surface Tension 1% Sol'n (Dyne/cm)	32
Percent active ingredients	100%

Color: White and cream colored flakes
Form: Powder
Solubility in Water: To 10% (w/w) at ambient temperature
Hard Water Effectiveness: Highly Effective
Biodegradability: Biodegradable
Foam Tendency: High Foaming
Shelf Life: Two years from the date of manufacture

Chemical Description

Alconox consists primarily of a homogeneous blend of sodium linear alkylaryl sulfonate, alcohol sulfate, phosphates, carbonates. Alconox is anionic in nature.

Cleaning Validation Methods:

Test a parameter of rinse water before and after rinsing the cleaned surface. No significant change in the parameter indicates no detectable residue. Parameters measured include: pH, conductivity, UV, TOC, HPLC, sodium concentration, phosphorus concentration, anionic surfactant concentration using inexpensive detergent water testing kits, surface tension, and surface analysis. Pharmaceutical Cleaning Validation references are available in the tech info section of www.alconox.com.

Health Safety Information:

OSHA Hazardous Ingredients: None
RCRA Hazard Class: Non-hazardous
Flammability: Non-flammable
Latex Content: None in detergent, packaging materials or adhesives.
Oral Toxicity: (5 g per kg > 500 mg/kg)
No ingredient defined as an oral toxicant by OSHA
Eye Irritation: Mild to Moderate eye irritant if not rinsed
Inhalation Toxicity: Non-irritating solution, powder a potential irritant
VOC Content: 0%
Carcinogenicity:
NTP = No IARC = No OSHA = No
All ingredients in Alconox are listed in TSCA inventory.USDA NSF cat A1.

Precautions:

No special precautions other than good industrial hygiene and safety practices employed with any industrial chemical (see Directions). A Material Safety Data Sheet is available at www.alconox.com or by calling fax-on-demand at 914-948-4040 and following the prompts. Use fax document # 0311.

Contact Alconox, Inc. for purchase specifications. Typical data is not a specification.

While the information in this report should not be considered to be a product warranty, we urge you to investigate, test and verify the suitability of Alconox detergents for your specific application. We, of course, can not give permission to use, or recommend the use of, our detergents where they infringe patents. No representation or warranty is made as to the safety of products or materials mentioned under the Federal Food Additives Amendment of 1958.

Appendix I
DRYING OF METAL PARTS

Karl DeWahl, MnTAP
These notes are an expansion of an outline of a presentation made for a MnTAP workshop on
Alternatives to Vapor Degreasers and the Use of Chlorinated Solvents
December 17, 1991

A. The Value of Drying
  1. Minimize rusting and corrosion
  2. Minimize spotting
  3. Minimize recontamination
  4. Improve parts handling

B. Parts Drying Methods
  1. Displacement
    solvent emersion *
    oil emersion *
  2. Mechanical (Gross Water Removal)
    slow withdrawal rates *
    blow-offs *
    centrifugal *
  3. Evaporation
    hot forced air (or any inert gas like nitrogen)
    infrared
    hot wash or rinse
    vacuum
  4. Starred methods (*) tend to be simpler and lower cost methods.
  Most fill a drying niche, most don't work for all applications.

C. Displacement Drying - Water is pushed off parts by another liquid, then the water sinks or floats away from parts depending on the system used.
  1. Halogenated Solvents - CFC, TCA, HCFC, HFC, TCE, DCM
    Equipment is similar to vapor degreasers but boiling solvent is not needed.
    This method makes no sense as part of a switch from halogenated solvent cleaning to aqueous methods.
  2. Hydrocarbons
    Need parts fixturing or rotation to allow water to drain away.
    Need to control rust between cleaning and drying steps (may not be a problem).
    a. Light hydrocarbons - hexane, toluene, xylene, MEK
      These are flammable, and are not commonly used for this purpose.
    b. Medium hydrocarbons - mineral spirits (MS), 140° MS, MS plus 5% dipropylene glycol.
      The bath should last a long time.
      Drying is somewhat slow.
    c. Water displacing oils - rust proofing oil thinned with mineral spirits
      This method leaves an oil film
  3. Alcohols or water miscible solvents - isopropanol (IPA), methanol, acetone
    The use of IPA especially is relatively common.
    There is no need for fixturing, alcohol absorbs water.
    These solvents are flammable.
    They are hard to separate from water.
    You can distill as an azeotrope (12% H_2O for IPA) and reuse the water alcohol mixture or waste needs to be incinerated or recycled off-site.

D. Mechanical methods of water removal.

These are methods of gross water removal - some water will usually remain.

These methods can reduce dying time and energy costs, when used with evaporative methods.

1. Capillary action - withdraw parts slowly from a bath (~1fpm) using the surface tension of water to pull itself off the parts.
    - Parts must be oil-free (water break clean).
    - An automated hoist is needed to control withdrawal rates.
    - This method can work on moderately complex parts, but effectiveness falls off with part complexity.
2. Mechanical Methods
    - a. Air knives can compliment any drying method by physically blowing water droplets off parts this means less water has to be dealt with by other drying methods.
    - b. Compressed air blow-offs are labor intensive but can be a way to get water out of holes.
      For methods a. & b. make sure the air source is well filtered, especially for oils.
    - c. Gentle shaking of parts can also help get water out of holes as long as the holes open downward.
    - d. Centrifuges can also throw off excess water.
      Units designed as centrifugal driers will also have a source of hot forced air.

E. Evaporative drying

1. Heat capacity of metal parts

   Use a hot rinse (or wash) so that heat absorbed by the parts evaporates the water on part surface.

   Does not work on parts with low specific heat, e.g. plastics.

   Does not work on parts with large water hold-up relative to part mass,
   e.g. parts with a large surface area to volume ratio
   or lots of recesses or texture.

   May need to raise bath temperatures to make it work.

   Be careful using this method after the wash step, it may work, but it may cause the cleaner residue to dry on the part. Some residues are difficult to remove when dry.
2. Forced air (or gas drying)

   This is the most common method used in commercial systems. It has broad application to a wide variety of drying problems and can guarantee any level of drying.

   Its disadvantages can be: equipment and operating costs; cycle time; and space requirements.

   Air supplies should be filtered to avoid re-contamination with air-borne particulate.

   Energy can be conserved by recycling the air flow.
3. Infrared or any other radiant heating method.

   This method has the same potential advantages and disadvantages as forced air methods, but this method works best when the heating elements can be placed equa-distant from all surfaces requiring drying to avoid hot and cold spots.
4. Vacuum

   This method lowers the boiling point of liquids on parts by a change in pressure.

   Works well for parts that are heat sensitive.

   Must be carried out batch wise.

This is generally a slow method of drying, especially when dealing with water and its high latent heat of vaporization.

Appendix J

Halogenated Cleaner NESHAP Compliance Requirements for Existing, Small, Batch Vapor Degreasers

The final rule was published on December 2, 1994, and describes the operating requirements for facilities which use any of six chlorinated solvents for cleaning or drying operations, in any volume (where the chlorinated solvent concentration exceeds 5%). The rule is intended to reduce solvent emissions from an average, small vapor degreaser by 50%. The regulated solvents are: trichloroethylene; 1,1,1 trichloroethane; methylene chloride; perchloroethylene, carbon tetrachloride; and chloroform. The rule defines required emission control requirements for four types of equipment:

Small, batch vapor degreasers (air/solvent interface < 1.21 m^2 [13.0 ft^2])
Large, batch vapor degreasers (interface > 1.21 m^2)
All in-line (continuous) cold or vapor degreasers
All batch cold cleaners

Existing equipment must comply with the standards summarized below by December 2, 1997. New equipment is defined as any equipment construction or reconstruction beginning after November 29, 1993. New equipment must comply with these standards by December 2, 1994 or the date of start-up, which ever is later.

Finally switching to cleaning methods not using halogenated solvents removes those operations from coverage by these rules. Alternative cleaning methods include: non-halogenated solvents (e.g. mineral spirits or terpenes); aqueous cleaning methods; no-clean methods or manufacturing process changes that reduce soiling, eliminate soiling, or substitute a soil that is easier to clean.

Equipment/System Design and Operation - one of three emission compliance options must be chosen:

Option 1 - ensure emissions are capped at 150 kg/m^2-month (30.7 lb/ft^2-month), and maintain a log of solvent additions and withdrawals.

Option 2 - demonstrate and maintain an idling emission limit of 0.22 kilograms per hour per square meter of solvent/air interface area (0.045 lb/ft^2-hr) and maintain either a cover used during idling and downtime periods or maintain room drafts below 15.2 m/min (50 ft/min).

Options 3 involves operating one of the 20 combinations of emission control devices or procedures listed on the next page.

Degreasers complying with Options 2 or 3 must also comply with six design and 12 work practice requirements. The six design requirements are:

1. a freeboard ratio of at least 0.75.
2. an automated parts handling system with a maximum speed of 3.4 meters per minute (11 fpm);
3. a low liquid level shut-off/interlock for the hot sump;
4. a high vapor level shut-off/interlock just above the primary condenser.
5 a primary condenser;
6. a carbon adsorber if a lip exhaust is used.

The 12 required (if applicable) work and operational practices for options 2 or 3 are:

1. control air disturbances by:
   - a. close cover(s) during idling and downtime – times when parts are not in the degreaser being cleaned
   - b. control drafts directly above the degreaser to less than 50fpm
2. parts baskets or parts being cleaned must not occupy more than 50 percent of the solvent/air interface area, unless transport speeds are reduced to less than 0.9 meters per minute (3 fpm)
3. all spraying must be done in the vapor zone or in a section isolated from the ambient air.
4. keep parts in the cleaning machine until dripping has stopped.
5. orient parts so that the solvent drains freely. Parts having cavities or blind holes must be tipped or rotated before being removed from any solvent cleaning machine.
6. start up the primary condenser before the sump heater.
7. shut down the sump heater, and allow the solvent vapor layer to collapse before the primary condenser is turned off.
8. add, drain or transfer solvent using threaded or other leak-proof couplings, and keep the end of the pipe in the solvent sump beneath the liquid surface.
9. maintain equipment and associated controls as recommended by the manufacturers.
10. prepare each operator to complete and pass a test of operating procedures if requested during an inspection by a regulator.
11. collect and store solvent waste in closed containers;
12. cleaning of sponges, fabric, wood and paper products is prohibited.

Control alternatives for Option 3 (one alternative must be chosen):
(these alternatives are listed from least to highest probable capital costs)

1.	Superheated Vapor Zone	Freeboard Ratio = 1	Working Mode Cover
2.	Superheated Vapor Zone	Freeboard Refrigeration Device	
3.	Working Mode Cover	Freeboard Refrigeration Device	
4.	Superheated Vapor Zone	Reduced Room Draft	Freeboard Ratio = 1
5.	Reduced Room Draft	Freeboard Refrigeration Device	
6.	Freeboard Ratio = 1	Freeboard Refrigeration Device	
7.	Parts Dwell in the Freeboard	Freeboard Refrigeration Device	
8.	Reduced Room Draft	Freeboard Dwell	Freeboard Ratio = 1
9.	Carbon Absorber	Freeboard Refrigeration Device	
10.	Superheated Vapor Zone	Freeboard Ratio = 1	Carbon Absorber

Summary of Options: Thomas Engineering

Option	Reduction / Benefit	Savings	Cost	status
Switch to nPB				
Vapor Degreaser retrofitting: automation	Some reduction in solvent releases	$10,000 labor	$22,000	Not recommended
New vapor degreaser	70% ?reduction in solvent emissions	$10,000 labor	$70-100,000	Consider
Stay with TCE				
Improved operating procedure	Some TCE emission reduction	Some?	$1000??	Recommended provisionally
Vapor Degreaser retrofitting -				
Automation w basket tilting	Some TCE emission reduction	$10,000 labor	$22,000	Recommended
Freeboard extension	Small TCE emission reduction	Small?	$3700	Not recommended
Working mode cover	Some TCE emission reduction	Some?	$4400	Consider
New vapor degreaser -	Reduces TCE releases, exposure and liability 5500lb/yr?	$4500/yr? TCE $10,000 labor	$70-100,000	Consider as alternative to retrofitting
Outsourcing Parts Cleaning	Eliminates 8170lb/yr of TCE (2004) and environmental liability	$33,000/yr	$185,000/yr	Not recommended Net cost > $100,000/yr
Switch to Aqueous cleaning entirely -	Eliminates 7800lb/yr of TCE (2004) and environmental liability	$4-13,000/yr?	$40-100,000 PPAP resubmittals?	Not recommended
Combinations with aqueous cleaning				
with TCE Vapor degreasing	Reduces TCE releases, exposure and liability	$2-10,000/yr?	$40-100,000	Consider – needs more information
with Subcontracting	Eliminates 7800lb/yr of TCE (2004) and environmental liability	???	???	Consider – needs more information

adId	paymentAmount	netPrice	Difference
	67.40	67.40	
4,493,999	72.00	72.00	0.00
	72.00	72.00	
4,494,018	44.40	44.40	0.00
	44.40	44.40	
4,494,061	11.25	11.25	0.00
	11.25	11.25	
4,494,067	98.00	98.00	0.00
	98.00	98.00	
4,494,076	59.00	59.00	0.00
	59.00	59.00	
4,494,077	68.43	68.43	0.00
	68.43	68.43	
4,494,084	25.00	25.00	0.00
	25.00	25.00	
4,494,097	614.80	614.80	0.00
	614.80	614.80	
4,494,121	307.85	307.85	0.00
	307.85	307.85	
4,494,156	115.90	115.90	0.00
	115.90	115.90	
4,494,158	185.45	185.45	785.45
	185.45	185.45	785.45
	785.45	185.45	785.45
	-185.45	185.45	785.45
	970.90	185.45	
4,494,173	38.00	38.00	0.00
	38.00	38.00	
4,494,176	11.25	11.25	0.00
	11.25	11.25	
4,494,181	55.00	55.00	0.00
	55.00	55.00	
4,494,213	0.00	215.01	0.00
	215.01	215.01	0.00
	215.01	215.01	
4,494,218	191.22	191.22	0.00
	191.22	191.22	
4,494,228	59.00	59.00	0.00
	59.00	59.00	
4,494,232	120.00	120.00	0.00
	120.00	120.00	
4,494,265	203.00	203.00	0.00
	203.00	203.00	
4,494,268	60.80	60.80	0.00