Economical and Efficient
Vapor Degreasing
with Chlorinated Solvents
from Dow
Contents

ECONOMICAL AND EFFICIENT VAPOR DEGREASING .......................... 1

Uses of Degreasing .................................................. 1

Degreasing Methods .................................................. 1

Vapor ................................................................. 2

Vapor plus Distillate Flush or Spray ................................ 2

Vapor plus Immersion — Single Dip ................................ 3

Vapor plus Immersion — Multiple Dip ............................. 3

Missile and Large Tank Cleaning ................................... 4

Ultrasonic Cleaning .................................................... 4

Economics of Degreasing .............................................. 4

Selection of Heat Source ............................................. 4

Selection of Water Source .......................................... 4

Degreasing Equipment ................................................. 5

Design Assistance .................................................... 5

Design Factors ....................................................... 5

Work Opening ......................................................... 5

Heat Requirements ................................................... 6

Heat Sources .......................................................... 6

Heat Safety Controls ................................................ 7

Freeboard ............................................................... 7

Vapor Control ......................................................... 8

Freeboard Cooler or Water Jacket ................................. 8

Refrigerated Freeboard Chiller ..................................... 8

Water Separator ....................................................... 8

Storage Tank .......................................................... 9

Provisions for Cleanout ............................................. 9

Materials of Construction .......................................... 9

Material Handling .................................................... 10

Manual or Open-Top Units ........................................ 10

Conveyorized Units ................................................ 10

Degreaser Installation ................................................ 12

Location ............................................................. 12

Space Requirements ............................................... 12

Room Size ........................................................... 12

Pits ................................................................. 12

Location of Gas-Heated Degreasers ................................. 12

Avoidance of Heat and Flames ..................................... 12

Avoidance of Drafts ................................................ 12

Heat Information .................................................... 12

Water Piping Requirements ........................................ 13

DEGREASER OPERATION ................................................ 14

Starting Procedure .................................................. 14

Cleaning the Work .................................................. 14

Size of Work Load .................................................. 14

Proper Positioning of Work ........................................ 14

Rate of Entry and Removal ......................................... 14

Vapor Contact Time ................................................ 14

Transfer of Work .................................................... 14

Spraying ............................................................... 14

Solvent Level in Heating Chamber ................................ 14

Solvent Contamination .............................................. 15

Shutdown Procedure ................................................ 15

Operation of External Still ........................................ 15

Common Degreaser Problems ....................................... 16

Pronounced Vapor Odors .......................................... 16

Causes and Remedies ............................................... 16

Excessive Solvent Consumption ................................... 17

Corrosion .............................................................. 17

Stained Work ........................................................ 18

Degreaser Maintenance .............................................. 19

Cleaning Procedures ............................................... 19

Restoration of Acid Degreasers ................................... 20

Solvent Reclamation ................................................ 21

Degreaser Boil-Down ................................................. 21

In-House Distillation .............................................. 21

Continuous ............................................................ 21

Batch ................................................................. 21

Commercial Recycling ............................................ 21

Instructions for Boil-Down ........................................ 22

Solvent Recovery with Activated Carbon ......................... 23

TOXICITY, HANDLING PRECAUTIONS, FIRST AID .................. 24

HOW TO SELECT A VAPOR DEGREASING SOLVENT ................. 24

Solvent Performance .................................................. 24

Properties of Vapor Degreasing Solvents ......................... 26

General Properties .................................................. 26

High Solvent Power ............................................... 26

Inertness to Metals and Plastics .................................. 26

Nonflammability ...................................................... 26

Low Toxicity ........................................................ 26

Low Latent Heat ...................................................... 27

High Density Vapor ................................................ 27

Chemical Stability .................................................. 27

Boiling Point ......................................................... 27

Vapor Pressure ....................................................... 27

CHLOROTHENE SM Solvent .......................................... 28

Advantages .......................................................... 28

Disadvantages ....................................................... 28

NEU-TRI Solvent ..................................................... 30

Advantages .......................................................... 30

Disadvantages ....................................................... 30

Dow Perchloroethylene SVG ........................................ 32

Advantages .......................................................... 32

Disadvantages ....................................................... 32

Dow Methylene Chloride, Vapor Degreasing Grade ............ 34

Advantages .......................................................... 34

Disadvantages ....................................................... 34

Economics of Dow Chlorinated Solvents ......................... 36

Which Solvent to Choose? ........................................... 37

Technical Assistance ............................................... 38

We’re Ready to Help ................................................ 38

Equipment Suppliers ................................................ 39
Economical and Efficient Vapor Degreasing with Chlorinated Solvents from Dow

This publication offers suggestions on the selection and use of vapor degreasing equipment and solvents. It also lists typical properties of Dow's vapor degreasing solvents. Dow also has a metal-cleaning technical service staff at its Midland, Michigan headquarters, prepared to answer any customer or user questions not covered in this publication.

The Dow Chemical Company is the world's largest, most experienced producer of chlorinated solvents and the only manufacturer of all four of the major chlorinated solvents used in vapor degreasing. This means that users can rely on Dow for objective guidance in the selection of solvents for vapor degreasing.

Dow offers the following selection of vapor degreasing solvents:

**CHLOROTHENE**® SM
Inhibited 1,1,1-Trichloroethane for Vapor Degreasing

**DOW** Methylene Chloride, Vapor Degreasing Grade

**NEU-TRI**® Brand Trichloroethylene

**DOW** Perchloroethylene SVG

*Trademark of The Dow Chemical Company

**Uses of Degreasing**

Degreasing is an essential part of the modern production process, particularly in industries fabricating or assembling metal parts — aircraft, appliance, automotive, electronics, railroad. It is widely used to remove oils and oil-borne soils, such as chips, metal fines, and fluxes, from objects that have been stamped, machined, welded, soldered, molded, die-cast, etc. Tiny transistor parts, printed-circuit assemblies, precision surgical equipment, diesel motors, aircraft components, automotive parts, spacecraft assemblies, — all can be safely, completely and quickly cleaned with modern vapor degreasing techniques, in most cases more effectively than with aqueous or fluorocarbon solvent cleaning, particularly if oil or grease is an element of the soil.

Although aluminum equipment is not recommended for use with chlorinated solvents, aluminum metal cleaning and aluminum electronic component cleaning are highly efficient, corrosion-free applications for these solvents.

**Degreasing Methods**

This section serves as a guide to help users select the right degreasing method for the size, mass, gauge, shape, specific heat, and design intricacy of the work to be cleaned and the type and amount of soil to be removed.

**Observe regulations** — Conduct small-scale experiments to determine the method best suited to the job. The shortest cleaning cycle that gives the required standard of cleanliness within environmental standards is best.
We recommend that you read the Dow publication entitled “Safety, Health, Environmental Aspects and Bulk Handling of Dow Chlorinated Solvents,” form no. 100-6171-86, and consult form no. 100-6170-86 for toxicity information.

In addition, users of chlorinated solvents should be aware of and observe all laws and regulations governing their use.

Dow strongly recommends that aluminum not be used as a material of construction for any of the equipment used in handling, storing or processing chlorinated solvents.

Vapor
Vapor degreasing is an effective and economical process for cleaning production or service parts prior to assembly, packaging or other applications requiring grease- and dirt-free parts. Sufficient heat is applied to a powerful cleaning solvent to vaporize it. The vapor is heavier than air and thus containable in an open-top tank into which the dirty parts are lowered.

On contact with the cold parts (called “the work”), the vapor condenses into pure liquid solvent which dissolves the grease and carries off the soil as it drains from the parts into the heating sump or reservoir below. The cleaning process continues until the work reaches the temperature of the vapor. At that point, condensation will cease. The work can then be lifted out of the vapor, clean and dry.

FIGURE 1 — Typical Open-Top Degreaser

Vapor plus Distillate Flush or Spray
This degreasing/cleaning method is especially recommended for removing insoluble abrasives and metal fines held on the work by oils remaining after completion of buffing or polishing operations. A straight vapor cycle may remove the lubricants and leave behind the insolubles. This method is also recommended for small parts that can be stacked in baskets. Nozzles can be arranged to break air pockets and to spray into enclosed areas. This method is used frequently for large casting and sheet stock as well as for high-volume production cleaning of small objects.

Unit — This unit is similar to the one previously described but has, in addition, a spray lance (see Figure 2) or fixed nozzles, a pump, and a storage tank for continuously collecting clean solvent.

Cleaning Cycle — The part is suspended in the vapor zone for initial cleaning. To dislodge remaining oils and insoluble contaminants from recesses and crevices, the work is flushed with clean, cool solvent. This lowers its surface temperature and permits further vapor condensation. The nozzle of the spray lance or fixed nozzles should be kept as low as possible in the vapor zone to minimize vapor disturbance. This cleaning method, adaptable to both hand-operated and conveyorized equipment, is preferred for heavily contaminated parts that cannot be cleaned by straight vapor condensation.
Vapor plus Immersion — Single Dip
(Vapor/Warm Liquid Wash/Vapor Rinse) — This method is used when the amount of soil is heavy, the contour of the work is intricate, or bulk quantities of small parts are covered with a light film of oil or grease. Both tumbling and agitation are practical means of minimizing solvent dragout but should be used only when the parts will not be damaged.

Unit — Generally, a two-compartment unit is used, one being a boiling-solvent sump and the other a warm-liquid chamber.

Cleaning Cycle — Work is lowered through the vapor zone, rotated or agitated in the warm liquid, then raised into the vapor zone for final rinsing.

Vapor plus Immersion — Multiple Dip
(Vapor/Boiling Liquid Wash/Warm Liquid Rinse/Vapor) This is one of the most efficient cleaning methods for removal of stubborn soils such as heavy oil deposits and insoluble particles.

Unit — This unit may be either a two- or three-compartment design with one or two boiling-liquid chambers and a warm-liquid rinse compartment (see Figure 3).
Cleaning Cycle — Vapor contacts the work as it is lowered into the boiling-liquid compartment, where boiling solvent adds mechanical agitation to solvent action to remove heavy oils and insoluble contaminants. The work is transferred to the warm-liquid rinse compartment, where clean solvent continues the cleaning action and cools the work to permit further vapor condensation. The warm-liquid compartment is continuously replenished with clean, condensing solvent and overflows into the boiling compartment.

Missile and Large Tank Cleaning
The interiors of enclosed vessels or tanks, such as tank transports, storage tanks, and processing tanks, can be cleaned and dried by spraying with solvent distillate and vapor degreasing with vapors produced in a separate generator. Recycling of solvent between generator and tank is continued until the cleaning is complete.

Ultrasonic Cleaning
Motion of either the cleaning solution or the part to be cleaned improves and speeds cleaning. Ultrasonic cleaning is industry’s most advanced application of this simple principle.

When ultrasonic energy is transmitted to a solution, it produces cavitation — the rapid buildup and collapse of thousands of tiny bubbles. Cavitation imparts a scrubbing action to the surface of soiled parts, and this scrubbing, teamed with the action of a solvent, results in highly effective cleaning.

Ultrasonic cleaning helps remove heavy oil deposits and solids that adhere to metal surfaces and are insoluble in solvents. It is also very effective for removing fluxes on printed circuit boards as well as micrometer-sized contaminants on precision electronic components.

Soils that are slowly soluble in a given solvent respond well to an ultrasonic bath. Ultrasonic cleaning can be especially effective in loosening contaminants from parts with hard-to-reach recesses.

Cycles — To limit solvent contamination and reduce cleaning time, pre-cleaning cycles often precede ultrasonic immersion, and a distillate rinse and a vapor rinse often follow the ultrasonic bath. A typical cycle employing ultrasonic would be: (1) vapor cleaning, (2) immersion in an ultrasonic-activated liquid chamber, (3) spraying, and (4) vapor cleaning.

Equipment — New degreasing equipment is not necessary for ultrasonic cleaning if present equipment is made of stainless steel. Transducers can be installed on the bottom or sides of most degreasers. Completely sealed transducers should be specified if the immersible type is to be used. Transducers, particularly the piezoelectric type, are rated for a maximum temperature exposure and may be adversely affected if used at temperatures higher than rated. Generally, the optimum frequency range for effective chlorinated solvent cavitation is 20-50 kHz (kilohertz). Ultrasonic vibration should take place in the clean-solvent immersion chamber, not in the boiling compartment of the degreaser.

Operating temperatures of 25-40°F below the boiling point of the solvent are optimum. These lower temperatures will cool hot parts, permitting a final rinse with pure condensing vapors.

Economics of Degreasing
Vapor degreasing is low in cost compared to other production cleaning operations. Investment and utility costs are low, and floor-space needs are small. Work of excellent quality is achieved with a minimum of operator control.

Factors to be considered in comparing the costs of various types of degreasing operations include the following:
- Cost of chemicals or solvents
- Services available with the chemicals/solvents
- Cost of utilities
- Labor cost
- Cost of waste disposal
- Maintenance costs
- Initial capital investment
- Building space
- Depreciation

Selection of Heat Source
Heat-source costs vary from one locale to another and within individual plants. Although steam is the safest and preferred heat source, economic or other factors may preclude its use and necessitate using alternate methods.

Selection of Water Source
City water can be expensive if it is passed through a system only once. However, process water, or city water cooled in water towers and recycled, is more economical. To conserve water and lower costs, water can be routed from the degreasers to other industrial plant processes.
Degreasing Equipment

Vapor degreasing equipment is designed not only to vaporize solvent for cleansing and drying parts, but also to confine and recycle the solvent and solvent vapor to maintain a healthful environment and keep cleaning costs low. Vapor degreasing equipment must provide for:

1. Cleaning to remove soluble and particulate soil.
2. Recovery of solvent by distillation for repeated use.
3. Concentration of soils.

These requirements are met by the basic degreasing unit shown in Figure 1, which is an open rectangular tank with a pool of solvent in the bottom. The solvent is heated in the boiling sump and vaporized into a dense, heavier-than-air vapor layer that lies above the liquid and constitutes the vapor cleaning zone. The condensing coils, which are installed high on the inside periphery of the tank, condense the vapor reaching that level. The solvent condensate is returned to the solvent boiling sump via the condensate trough and water separator.

The freeboard, a very important vertical extension of the degreaser wall, provides a stationary air zone above the vapor level. The freeboard shields the normal vapor zone from moderate drafts which could carry the vapors into the work environment. In addition, a very thin solvent film evaporates from the work as it is slowly withdrawn from the vapor zone, and the freeboard area confines these vapors.

Design Assistance

Dow's metal cleaning technical service staff can assist in the selection of the right equipment for the job. Standard units for a variety of work capacities as well as custom-built units for specific needs or processes are available.

Design Factors

Factors influencing design are:

- Size, shape, mass, specific heat, composition and gauge of part to be cleaned
- Volume of work per unit of time
- Amount and nature of contaminants
- Cleaning cycle
- Method of work suspension and materials handling
- Space allotted for installation
- Government regulations
- Available utilities at degreaser site

Work Opening

The degreaser work opening must be adequate to handle the work dimensions and cleaning cycle, but should be kept to a minimum to maintain economical operation and acceptable working conditions. Even when vapor loss is controlled and no work is passed through, every square foot of exposed surface permits loss of a given amount of solvent related to the equipment design and the solvent used.

Table I shows the relative loss ratio of the various degreasing solvents in a typical open-top (58 x 24 in) degreaser.

In designing a unit, the equipment manufacturer should provide for minimum solvent loss by cutting down vapor disturbance.

Since vapor in the center of the tank passes to the walls for condensation, extending the tank width increases turbulence, which causes entrainment of air resulting in vapor loss. As narrow a tank as feasible is recommended.

### TABLE I — Solvent Consumption Comparison — Idling Vapor Degreaser

<table>
<thead>
<tr>
<th>Solvent Consumption†</th>
<th>% Increase from CHLOROTHENE SM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily†</td>
<td>Hourly‡</td>
</tr>
<tr>
<td>CHLOROTHENE 84</td>
<td>13.14</td>
</tr>
<tr>
<td>Methyl Chloroform</td>
<td>27.20</td>
</tr>
<tr>
<td>DOW Methylene Chloride</td>
<td>0.26</td>
</tr>
<tr>
<td>Typical Degreasing Solvent</td>
<td>0.29</td>
</tr>
</tbody>
</table>

1 Daily average for 7 days (16-hour)
2 Daily average for 24-hour period

In designing a unit, the equipment manufacturer should provide for minimum solvent loss by cutting down vapor disturbance.

Since vapor in the center of the tank passes to the walls for condensation, extending the tank width increases turbulence, which causes entrainment of air resulting in vapor loss. As narrow a tank as feasible is recommended.
Heat Requirements
The amount of heat required to operate a vapor degreaser can be computed on an hourly basis, and includes:

- Heat to raise the temperature of the work and work-carrier to the solvent boiling point
- Radiation losses from tank walls in contact with vapors or boiling solvent
- Solvent distillation for replenishment of spray pump reservoirs or dilution of immersion baths.

The heat requirement for the work and carrier depends on their weight, specific heat, and surface area. Since a constant vapor level is required for minimum vapor losses, sufficient heat (in the form of vapors) must be available to bring the work load surface temperature up to the vapor temperature in a minimum practical time. Heavy parts with a small surface area often cause less condensation and thus less vapor layer collapse than light, thin parts with a large surface. The degreaser walls should be insulated if radiation losses are high or if the degreaser requires a significant amount of heat. The radiation heat losses of a degreaser vary directly with the boiling points of the solvents employed.

The amount of heating surface required is determined by a heat transfer coefficient from this surface to the solvent when contaminated with approximately 25 percent oil or similar soluble soil. Heat densities that are too high will result in premature fouling of the surface as well as possible decomposition of the solvent. Inadequate vapor generation results in poor cleaning, collapse of the vapor zone, and excessive solvent losses.

Immersion heating elements are frequently protected by a metal grating above the element. These grates may also serve as work rests.

Heat Sources
Steam — Steam is the preferred heat source if it is available or can be generated economically. When steam pressure is controlled, the risk of excessively high temperatures and the resultant problems and recovery costs are eliminated. Usually, pipe coils are the preferred type of heating surface. Occasionally, steam-jacketed tank bottoms or steam panels are used.

Use of Pressure Regulators — When a plant steam supply provides pressures higher than recommended (see Table II), a pressure regulator is required. Possible superheating can be avoided by placing a pressure reducing valve at least 15 feet from the degreaser for 75 psig steam and at least 35 feet away for 150 psig steam. Care should be taken to ensure that the steam supply line and reducer are of the proper capacity for the required steam volume and pressure. A pressure gauge and pop-off or relief valve should be installed on the low pressure side.

Use of Steam Traps — A steam trap drains steam condensate from the equipment and vents air from the system while preventing the escape of live steam. For efficient operation, each steam outlet should be trapped individually to insure proper circulation and air elimination. The trap capacity must be adequate. This capacity is based on the differential pressure, not the operating pressure. Also, the height to which a trap can elevate condensate depends on the differential pressure; approximately two feet of height per pound (psig) of differential pressure is required. The more common types of traps are inverted-bucket, thermostatic, and ball-float. Traps should be selected to operate in the range of the solvent employed (see Table II). The steam coil must drain down into the trap.

Electricity — Electricity is another heat source for degreasers. Immersion-coil-type heaters with a heat density less than 22 watts per square inch are recommended. Strip or contact heaters clamped to the bottom of the boiling sump are used to heat small degreasers. Soil accumulation on the heating elements can cause "hot spots" and result in solvent decomposition and element burnout. Immersion heating coils are preferred. More frequent cleanouts and lower soil concentrations will increase heater life.

When operating this equipment, the solvent liquid level should be maintained above the heating elements. If the heating elements become exposed, the heating surfaces will sharply increase in temperature and degrade the solvent, causing an "acid" condition. Dow recommends installing a "low-liquid-level" switch which shuts off the heating element before this condition can occur.

| Table II — Recommended Steam Pressure for Steam-Heated Solvent Systems |
|---------------------------------|-----------------|
| DOW Methylene Chloride          | <2              |
| Vycor Degreasing Grade          |                 |
| Chlorothene SVM                  |                 |
| 1,1-Dichloroethane              | 1-6             |
| New-Tri methylacetylene         | 10-15           |
| DOW Perchlorothene SVG           | 45-60           |
Gas - Gas also is used to heat degreasers. The burners are generally atmospheric types. Immersion coils are preferable to line burners under the liquid sump. Direct heating of the degreaser bottom has the disadvantage of poor heat exchange caused by the settling of metal fines on this surface. Again, as in the electrically heated equipment, soil accumulation on the heating surfaces can cause "hot spots" and degrade the solvent. As with electric heaters, this problem can be avoided by maintaining the solvent level above the heating elements. The stack should vent to the outside atmosphere, should be of an acid-resistant material or have an acid-resistant lining, and should be equipped with a back-draft eliminator.

Gas burners should have safety pilot protection that shuts off the gas flow within 45 seconds after pilot failure. Continuous pilot systems are inadvisable since they may be left on when solvent is low or when the degreaser is being cleaned. Pilots should be turned off during cleanout to avoid contact of solvent vapor with open flame.

It is recommended that the burners be enclosed in a housing designed to provide inlet combustion air that is free from solvent vapors. This is more significant when a degreaser is installed in a pit. If it is installed in a room with a negative pressure, air should be supplied from the outside.

Heat Safety Controls
No matter what type of heat is used, it is recommended that shutoff safety controls be installed in the supply line, such as valves in the steam or gas supply lines and a switch in the electrical power supply. These controls may be operated by:

- Vapor safety thermostats, located above the condenser coils, to interrupt the heat supply when the condensation is inadequate and the vapor rises to contact the thermostats.
- Bottom safety thermostats which interrupt the heat supply when the solvent-oil temperature exceeds the limit set in the thermostat.
- Float switches to turn off the heat when the solvent level is dangerously low.
- Flow switches in the water supply line to assure that condenser water is flowing before the heat can be turned on.

All shutoff controls should require manual resetting so the cause may be investigated and remedied before restarting.

Freeboard
Freeboard is the distance from the top of the vapor line to the top of the confining sidewall at the top of the tank. The freeboard zone reduces vapor disturbance caused by air motion in the work area. The freeboard zone also permits drainage of the work being removed, evaporation of residual solvent and drying of the part with minimum of solvent loss as well as reduced solvent emissions into the air.

The height of the freeboard is generally 1/4 of the open width of the tank, or a minimum of 12 inches. In degreasers of extreme length, the height of the freeboard is increased. Generally speaking, the higher the freeboard the lower the solvent consumption.

TABLE III - Recommended Thermostat Settings

<table>
<thead>
<tr>
<th>Vapor Safety Thermostat °F</th>
<th>Sump Thermostat °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dow Methylene Chloride</td>
<td>120</td>
</tr>
<tr>
<td>Vapal Degreasing Grade</td>
<td>(see comments)</td>
</tr>
<tr>
<td>Chloroformine SM</td>
<td>130</td>
</tr>
<tr>
<td>Tri Chloroformine</td>
<td>122</td>
</tr>
<tr>
<td>Neutra</td>
<td>133</td>
</tr>
<tr>
<td>Tri Chloroformine</td>
<td>122</td>
</tr>
<tr>
<td>Dow Perchloroformine SVC</td>
<td>120</td>
</tr>
</tbody>
</table>

The recommended thermostat setting for methylene chloride is ambient temperature + 10°, but ≤ 100° F in other words. If the ambient temperature is 75° the setting will be 85° F. However, if the ambient temperature is 95°, the maximum setting will be 100° F.
NOTE: Minimum freeboard height may be stipulated by existing or proposed federal, state and local air pollution regulations. A minimum freeboard height of 0.75 of the width is required by Air Pollution regulations on certain regulated solvents.

Vapor Control
The basis of effective vapor degreaser design is control of the vapor level. This control is best done by use of condensing coils. Condensing coils are located within the degreaser tank at a height above the boiling solvent equal to the work height plus allowances for clearance below the work and a 3-9 inch vapor layer above the work. The usual design of a degreaser provides for the normal vapor level to be at the midpoint of the vertical span of these coils. Thus, the positioning of the condensing coils also establishes the freeboard height in a given tank.

To prevent excessive condensation of atmospheric moisture on the coil surfaces above the vapor line, the temperature of the water leaving the coils should be above the dew-point of the ambient air. To help accomplish this, the water should flow into the lowest coil and out the top coil.

Freeboard Cooler or Water Jacket
This is a small-channeled perimeter cooler around the outside of the tank at the vapor level. Its primary function is to prevent the conduction of heat from the walls in contact with the vapor and boiling solvent to the freeboard area.

As with the condenser coils, the temperature of the water flowing through this cooler should be above the dew point of the ambient air. Frequently, the water supply for this cooler is the exhaust water from the condenser coils.

Refrigerated Freeboard Chiller
This system is designed to reduce solvent emissions at the solvent vapor-air interface by placing a cool, dry layer of air above the vapor zone. This cool air blanket assists in confining the solvent vapors.

The refrigerated freeboard chiller consists of a coil placed on the inside perimeter of the unit, immediately above the primary condensing coils. An external refrigeration unit supplies the coils with the necessary cooling.

The chiller unit will condense, and in some cases freeze, atmospheric moisture onto the coils. The additional water from these coils should be handled by placing a separate trough under the coils, draining to its own water separator or a holding tank. If an additional trough is not placed on the equipment, the coils should drip into the solvent condensate trough; but a larger water separator would then be considered for effectively separating the water from the solvent. Additional water in the solvent may cause corrosion and shorten equipment life.

Water Separator
Water enters a degreaser from several sources:
- Condensation of atmospheric moisture on the condenser coils.
- Moisture on work being cleaned.
- Steam or cooling-water leaks.
- Water-soluble cutting oils.
- Water can form a boiling mixture with the solvent that is vaporized, causing equipment corrosion, decreased solvent life, and increased vapor losses. All degreasers should be equipped with a proper-sized water separator.

In water separation, the condensed solvent-water mixture drops into a trough below the condenser coils and flows by gravity to the separator (see Figure 4). The mixture enters the separator below the solvent level. The water, because of its lower specific gravity and insolubility, rises to the top and is discharged through a water drain. Relatively moisture-free
The solvent is then discharged through the solvent return line to the degreaser or storage tank. This separation requires time. Since five minutes is a practical minimum, the separation chamber should have a capacity of at least 1/12 the hourly solvent condensing rate.

A deep separator is more efficient to operate than a shallow one of equal volume, the reason being that the solvent-water interface area is less in the deeper design.

The cooler the solvent, the less water it will carry. Cooling can be accomplished by:
- Locating the water separator away from the degreaser sidewall to establish an air insulating space of 3 to 5 inches.
- Installing cooling coils within the separation chamber of the water separator.
- Utilizing a heat exchanger through which the hot solvent-water mixture flows before entering the water separator.

Since the temperature of the water should be colder than that used in the condensing coils, it is recommended that the heat exchanger or solvent cooling coils have a water source independent of the condenser coils. Typically, cooling water is piped through the water separator before it enters the condensing coils.

The flooding valve reduces corrosion by periodically purging the free water layer from the separator. When this valve is closed, the solvent level in the separator rises and allows the free water to overflow through the drain. The overflow should continue until solvent flows from this drain, at which time the flooding valve is opened and normal levels are established.

The flooding valve should be of the ball, gate, or butterfly type.

Ideally, the opening mechanism should be spring-loaded so it will close only when held by the operator and will return to the open position when released.

Periodic cleaning and maintenance of the water separator should be scheduled to prolong the life of the solvent and minimize corrosion of the equipment.

Storage Tank

Storage tanks, usually vented, may be built in as a part of the degreaser or provided as auxiliary units. These tanks are receptacles for clean solvent when the degreaser is used as a self-distilling unit before cleanout. They may also be used as spray pump reservoirs.

Provisions for Cleanout

Danger to life may exist in any degreaser with any solvent. Safety precautions must be observed.

Degreaser units should have openings of sufficient size to be convenient for cleanout procedures. If possible, they should be designed so that cleaning does not require human entry. Very large units should have access doors in major compartments to minimize escape travel distance in case of emergency.

Drain lines from all compartments should start from a recessed portion of each compartment bottom. This facilitates complete drainage of solvent, reduces ventilation time required for removal of residual solvent, and lowers the hazard to entering personnel.

NOTE: Completely draining the solvent, however, does not eliminate the vapors, which are heavier than air and thus remain in the tank, constituting a hazard to life if inhaled in excessive concentrations.

Materials of Construction

Stainless steel is the recommended construction material for degreaser units since it exhibits superior corrosion resistance to all solvents. Mild steel is satisfactory if suitably protected against corrosion by an organic coating such as Heresite (Heresite-Saerkaphen, Inc.).

NOTE: Aluminum alloys should not be used as materials of construction for degreasing units, pumps, valves, lines, tanks, nozzles or associated equipment. However, chlorinated solvents have been used safely and effectively for many years for cleaning aluminum parts.
Materials Handling

Manual or Open-Top Units
In manually operated units, the work is usually processed through various cleaning cycles in metal baskets or on racks or hooks and is transferred either manually or by electric or air-driven hoists.

Use of Hoists — The handling of heavy, bulky work is done by electric or air-driven hoists. A maximum vertical travel speed of 11 feet per minute (1 ft per 5½ sec) is recommended for entry and removal of work. Metal chains should be used for suspending the work. Link-type hoist chains require the least maintenance, although roller chains are acceptable.

Work Baskets and Racks — Baskets and racks should be constructed of open-mesh, nonporous material as light in weight as possible (see Figure 5), since basket and rack weights increase the heat requirement of the degreaser and add to process costs. Oversized baskets act as pistons, disturbing the vapor level and forcing vapors out of the unit. Generally, basket or work size should provide a minimum of four inches of clearance on each side. However, applicable governmental regulations should be checked to assure compliance of your system, since some states prescribe basket size in their regulations for implementing the Clean Air Act.

Conveyorized Units
Conveyorized degreasers are generally large, automatic units designed to handle a large volume of work in either a straight-through process or a return-type process (where work enters and leaves from the same end). Conveyorized equipment, when it can be used economically, has the advantage of minimizing the human element and producing consistently good cleaning with a minimum of solvent loss.

Monorail Conveyorized Type — A monorail conveyor (see Figure 6) is ideal when production rates are high. It facilitates the cleaning of such parts as cabinets, panels, and castings which can be suspended on hooks or hangers. Horizontal conveyor speeds depend upon the size of the work face pushing through the solvent vapors. Vertical speeds should be limited to 11 feet per minute. The monorail trolleys should travel above the vapor level; if this is not possible, the trolleys should be automatically regreased as soon as they emerge from the unit.

Cross-Rod Conveyorized Type — This type is generally used for processing small parts placed either in baskets or drum-shaped mesh cylinders. The cylinders are used when rotation is required to drain solvent from parts of irregular shape. If there is any danger that the surface finish of the work may be damaged during rotation with other parts, the work can be immobilized within the cylinder.
Gyro or Ferris Wheel Type — A gyro or Ferris Wheel conveyor permits the operator to load and unload a basket at the same station. Between loading and unloading, the freely suspended baskets pass through solvent vapor and liquid.

Vibra Type — In this patented process, the work is dipped into solvent, rises on a vibrating spiral elevator trough through a counter-flowing rinse of clean solvent distillate and vapor and, finally, a drying section (see Figure 8). Cleaning is done by the combination of vibration and solvent action. Controlled feeding and unloading permits removal of excess chips and contaminants such as oil and cutting solutions. A vibratory drive draws up and releases a spiral track. These pulsations move the work at uniform speeds upward along the track. As the work is vibrated up the spiral, it passes through and is cleaned by solvent condensate flowing down the track. Unusually hard-to-remove particles are dislodged and washed away. Vibra degreasers are especially effective for cleaning small objects, such as nails, nuts, bolts, rivets, fasteners, small stampings, screw machine parts, and small die castings. Hourly cleaning capacity is measured in the thousands of pounds, depending on the size of the unit. This equipment has proven practical in cleaning metal chips in preparation for remelting.

FIGURE 7 — Cross-Rod Conveyorized Degreaser

FIGURE 8 — Vibra Degreaser
Degreaser Installation

Equipment manufacturers provide qualified representatives to supervise the installation of vapor degreasers. The representative should check the location, wiring, piping, service connection, regulators, thermostats and setting of controls. Additional help with installation and initial operation can be obtained by contacting the nearest Dow sales office.

Location

Vapor degreasing equipment should be integrated into the production flow in a manufacturing process, a factor which usually predetermines location.

Space Requirements

Since the cleaning and drying process ordinarily takes only one to three minutes, space requirements for equipment are minimal. When a low ceiling imposes restrictions, equipment can be installed in a pit. Length restrictions are often overcome by utilizing wider units that route workloads through a U-shaped path. Adequate space should be provided to service and maintain all parts of the equipment.

Room Size

In a large room, dragout vapors are readily dissipated. Many factors should be considered when determining proper room size, such as room ventilation, vapor degreaser size, work load, etc., to assure maintenance of a healthful environment. Exhaust ventilation is commonly used in situations where solvent vapor concentrations need to be lowered.

Pits

Safety Rail — A railing around any uncovered portion of the degreaser pit at a height of 42 inches above the work-floor level is required by the Occupational Safety and Health Administration (OSHA) for protection of the operator.

Clearance — Sufficient clearance should be provided around the tank in the pit area to permit easy access to all degreaser doors, controls, and connections and for the removal of cleanout ports. Access and clearance for the removal and maintenance of heating elements must be provided.

Subway gratings or other flooring should be installed as a safety measure over the open area of the pit surrounding the degreaser.

Exhaust — Provision should be made for an exhaust system capable of clearing the pit area of heavy solvent vapors at a rate per minute at least twice the volume of air in the pit. Intake of the exhaust system should be at the bottom of the pit and near the cleanout door. Pit exhausts are used primarily to eliminate vapors that would result if solvent accumulated in the pit. An additional exhaust intake at the top of the degreaser may be required to handle vapor losses.

Drainage — The pit should be provided with a drain to a holding tank or with a sump pump to avoid accumulation of solvent, rinse water, or sludge in the bottom of the pit.

Location of Gas-Heated Degreasers

These must not be located in a room where mechanical exhaust produces a negative pressure unless complete exhaust of combustion products is provided by an exhaust fan.

Avoidance of Heat and Flames

Degreasers should not be installed in areas where the solvent vapors can come in contact with open flames, excessively hot metal surfaces, or welding operations. (See p. 28.) If plant layout necessitates placement of the degreaser near such heat sources, exhaust intakes must be provided near the equipment to minimize contact of solvent vapor with flames or excessively hot surfaces and to remove the decomposition products that result from such exposure.

Avoidance of Drafts

To minimize solvent loss induced by air turbulence over the vapor zone, degreasers should be placed away from excessive air currents, open windows or doors, heating and ventilating equipment, or any device causing rapid, uncontrolled air displacement. Normal air circulation is sufficient to dilute small quantities of vapor that normally escape from the degreaser. When the degreaser must be placed in an unfavorable location, two- to three-foot baffles on the windward side will divert drafts and protect the vapor level.

Heat Information

Steam — Locate unions so as to minimize the length of external piping which must be removed when servicing steam coils and plates. Leave sufficient room for easy removal of the door.

The steam condensate outlet should be located lower than the inlet to insure complete drainage of the coil.

Gas Hookup — Local codes or Article 2, Chimneys and Flues, National Board of Fire Underwriters, should be observed to insure proper installation of the stack venting.
the combustion chamber or heating tube. The following construction practices should be followed:

- Flues must exhaust combustion products outside the building to prevent corrosion and toxicity hazards. Flue gas should not be exhausted near fresh-air intakes.
- Flues must be insulated to a height above the top of the tank sufficient to provide protection to the operator.
- There must not be a back draft down the stack; this would release flue gases into the room.
- The flue should be constructed of acid-resistant material, such as asbestos-cement, since acid decomposition products may mix with condensing moisture, producing a corrosive mixture.
- To avoid severe corrosion, a means should be provided to minimize entry of rain or other atmospheric moisture into the flue.
- Electrical Grounding — Electrical degreasers must be properly grounded and provided with fuses.

Water Piping Requirements

One water valve should open and shut off the cooling water supply. A control valve on each water inlet to the degreaser is used for regulating the flow rate. Water outlets from condenser jackets or from cooling coils should not flow directly into sewer lines but should drain into an open sight funnel where water flow and temperature can be checked. Water flow should be controlled to maintain a water outlet temperature of 100°F to 120°F (39°C to 49°C). Because of its low boiling point, methylene chloride may require refrigeration coils. Where direct piping to sewers is preferred, flow meters and thermometers can be installed in the water lines for control purposes. A thermostatically controlled valve is preferred to avoid the need for operator adjustments.

Warning: Nothing should be welded on the body of the degreaser or storage tank when solvent or solvent vapors are present, since thermal decomposition will occur and form toxic products. Many degreasers are internally coated with organic or inorganic protective films which can be damaged by the high temperatures involved in welding. Consequently, welding on such units should be avoided.
Degreaser Operation

Starting Procedure

1) Start air exhaust equipment.
2) Turn on condensing water. Check condenser water discharge point to insure proper flow.
3) Check to see that solvent drain valves are closed.
4) Add solvent to all compartments and water separators to recommended operating levels. Add solvent in such a way that free fall of solvent stream and splashing are minimized. Addition of solvent by transfer pump is preferred.
5) Turn on heat supply. For steam heat, adjust to settings recommended for specific solvent.
6) Allow degreaser to reach operating temperature as evidenced by solvent condensing on water coils.
7) Check temperature of immersion rinse bath or spray pump reservoir. Adjust heat controls at these points if required.
8) Start spray pump and conveyor, if applicable.
9) Check to insure solvent condensate flow to water separator, and solvent return to proper compartments of degreaser.
10) If necessary, recheck and adjust solvent levels in all compartments.
11) When vapor level reaches condensing coils, check auxiliary vapor level control by turning off water supply and allowing vapors to operate safety thermostat and cut off heat supply. Adjust setting as necessary.
12) Restore water supply to condensers.
13) Actuate maximum solvent temperature control in cleaning compartments to insure proper operation.
14) Check all thermometers and gauges to insure operation in proper range for system.
15) Start work load through unit.
16) Check condenser water discharge temperature and adjust to 100-120°F (38-49°C) for all solvents except methylene chloride. This will minimize the likelihood of atmospheric moisture condensing on the cooling coils. Because of methylene chloride's low boiling point (104°F/40°C), condensing water for that solvent should be held in the 60-70°F (16-21°C) range.

Cleaning the Work

Size of Work Load

Machines are designed with sufficient heat capacity to generate the solvent vapor necessary to clean specified load-pounds per hour. Vapor drop should not exceed 3 to 4 inches upon entry of work. Work loads exceeding the prescribed maximum result in vapor-level fluctuations which cause poor cleaning and increase solvent consumption.

Proper Positioning of Work

The work should be placed in baskets or suspended from hooks so that maximum solvent or vapor contacts the work during the entire cleaning cycle and maximum solvent drains from recesses or pockets.

Rate of Entry and Removal

Recommended vertical rate of entry and removal of work is 11 fpm (1 ft per 5½ sec) to minimize disturbance of vapors. It may be necessary to reduce this rate when the work load approximates the size of the degreaser opening and produces a piston effect. After cleaning, the work remains in the freeboard zone until it is completely dry.

Vapor Contact Time

The work should remain in the vapor zone long enough to raise the temperature of the work until all condensation on the parts ceases. Too short a time in vapor results in poor cleaning; work withdrawn when wet causes unnecessary loss of solvent.

Transfer of Work

When work is transferred from one compartment to another, the work should be kept within the vapor zone.

Spraying

Work should be sprayed as low as possible within the vapor zone to minimize vapor disturbance from the high velocity of either a lance or header spray. Solvent supply should be clean or only lightly contaminated and maintained at a temperature below that of the vaporized solvent.

Solvent Level in Heating Chamber

The solvent level should be 2 to 4 inches above the heating coils and should never be allowed to drop below 1½ inches above the uppermost part of the heating element. Failure to keep the solvent level above the heating coils can result in solvent decomposition and acid formation. A low-level indicator device can be installed to shut
Solvent Contamination

High contamination in the boiling compartment of a unit results in decreased cleaning efficiency, poor vapor generation, sludge formation, and coking of the heating element. As the concentration of contaminants increases, the boiling temperature of the solvent-oil mixture gradually rises to a point where the efficiency of the operation is impaired. Maximum recommended boiling points are:

- Methylene Chloride: 107°F
- CHLOROTHENE SM Solvent: 174°F
- NEU-TRI Solvent: 194°F
- Perchloroethylene: 257°F

When the solvent boils at these higher temperatures, the soil concentration is about 30%. The solvent then must be reclaimed. This can be accomplished by draining the degreaser and using external stills, sending the solvent to a reclaimer, or utilizing the degreaser as a still. When the degreaser is used as a still, the solvent condensate should be routed to an external storage tank or a 55-gallon drum. Boil-down should be continued until:

- No more condensate is going to the storage tank or drum.
- The solvent level approaches the top of the heating coils.

It is then mandatory that the remaining sludges, oils, and contaminants be removed from the degreaser. No further cleaning will be necessary.

Screen Placement Over Work Rest

For longer solvent life, less frequent cleanouts, and better cleaning, a screen may be placed over the work rest to collect excessive metal fines and nonsolubles. The screen will require occasional removal and cleaning. This is good preventive maintenance.

**Shut-Down Procedure**

1. Stop work throughput.
2. Shut off heat supply.
3. Allow vapor level to drop below condenser coils.
4. Shut off water.
5. Shut off exhaust fans.
6. Place cover over open-top degreasers, especially overnight and on weekends.
7. Turn on water supply to still condenser.
8. Open solvent lines from degreaser boiling sump to still transfer pump.
9. Be sure the drain valve is closed. Start solvent transfer pump to fill still to operating level. (On stills operating continuously, pump will cut off automatically when predetermined level is reached.) Open steam inlet valve and adjust steam pressure to level prescribed for solvent involved. In the event of foaming, steam pressure should be reduced to eliminate possible entrainment of contaminants into distillate compartment.
10. Increase steam pressure gradually to maintain constant distillate flow. This is necessary as contaminants collect and raise the boiling point of solvent-oil mixture. The flow of distillate will normally cease for the respective solvents when the oil-solvent temperatures reach the ranges listed in Table IV.

**Operation Of External Still**

At the previous points, optimum solvent recovery will have been achieved for CHLOROTHENE SM and CHLOROTHENE SM and methylene chloride. For NEU-Tri and perchloroethylene, continue solvent recovery will have been achieved for CHLOROTHENE SM and methylene chloride. For NEU-Tri and perchloroethylene, move on to Step 7 (steps 7 & 8 for NEU-Tri and perchloroethylene only, not for CHLOROTHENE SM or methylene chloride). Close steam coil inlet valve and carefully open steam injector valve, taking care to prevent foaming of the concentrated solvent-oil mixture.

<table>
<thead>
<tr>
<th>Table IV - Oil-Solvent Temperature Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solvent</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Methylene Chloride</td>
</tr>
<tr>
<td>CHLOROTHENE SM Solvent</td>
</tr>
<tr>
<td>NEU-TRI Solvent</td>
</tr>
<tr>
<td>Perchloroethylene</td>
</tr>
</tbody>
</table>

At the previous points, optimum solvent recovery will have been achieved for CHLOROTHENE SM and methylene chloride. For NEU-Tri and perchloroethylene, continue solvent recovery will have been achieved for CHLOROTHENE SM and methylene chloride. For NEU-Tri and perchloroethylene, move on to Step 7 (steps 7 & 8 for NEU-Tri and perchloroethylene only, not for CHLOROTHENE SM or methylene chloride). Close steam coil inlet valve and carefully open steam injector valve, taking care to prevent foaming of the concentrated solvent-oil mixture.

**Operation Of External Still**

At the previous points, optimum solvent recovery will have been achieved for CHLOROTHENE SM and methylene chloride. For NEU-Tri and perchloroethylene, continue solvent recovery will have been achieved for CHLOROTHENE SM and methylene chloride. For NEU-Tri and perchloroethylene, move on to Step 7 (steps 7 & 8 for NEU-Tri and perchloroethylene only, not for CHLOROTHENE SM or methylene chloride). Close steam coil inlet valve and carefully open steam injector valve, taking care to prevent foaming of the concentrated solvent-oil mixture.
8) Continue steam injection until nearly all solvent is recovered; this occurs when distillate return stops, as evidenced in sight glasses or at discharge end of solvent line from the water separator. Close steam injector valve.

9) When distillation is complete, close cold water valve.

10) Allow residue to cool. Drain and discard in accordance with acceptable disposal practices.

Common Degreaser Problems

It is beyond the scope of this bulletin to discuss in detail all the problems that occur with inefficient, improper, and unsafe degreasing practices. Most of these problems can be avoided by a better understanding of the theory of solvent degreasing, and by following the equipment manufacturer’s instructions in the operation of the degreaser. A few of the most common problems that result in health hazards, excessive operating costs and unsatisfactorily degreased work are discussed here.

Pronounced Vapor Odors

Continuing strong or objectionable solvent odor can prove serious. It indicates high vapor concentrations that may endanger the health of the operator and others working in the vicinity of the degreaser. This condition must be investigated at once and immediate steps taken to remedy it, both as a safety precaution and as an economy measure.

Causes and Remedies

Following are common causes and suggested remedies for excessive vapor concentration.

Failure to Turn on Cooling Water to the Condenser—Water flow to the cooling coils should always be started before applying heat to the solvent. An auxiliary thermostatic control is recommended to turn off the heat supply in case of failure or interruption of the flow of water.

Excessive Heat Applied to the Boiling Solvent Chamber—Proper controls should be provided and periodically checked to control the heat supplied to the solvent.

Excessive Rate of Immersion or Withdrawal of Work from Unit—The work should not be immersed or withdrawn from the unit faster than 11 fpm (1 ft per 5½ sec).

Drafts Across Open Area of Unit—Avoid open windows, fans, etc., near a degreaser, to minimize disturbance of vapor level.

Improper Racking of Parts—Rack parts to provide maximum drainage and to avoid solvent dragout.

Spraying Above Vapor Level in Solvent Flush Units—Spray below the vapor level to avoid excessive disturbance of vapor.

Excessive Moisture in Unit—Various factors may cause this undesirable condition. Excessive moisture is easily recognized by the presence of white, cloud-like (ghost) vapors that float lightly around the cooling coils. Leaks in cooling coils, atmospheric condensation on coils caused by excessive flow of cold water, and entrainment of moisture in the degreaser by water-soluble or dispersible cutting compounds are the most common causes of excessive moisture. Moisture in solvent lowers the vapor density, causing excessive solvent loss. Water separators of efficient design will continuously eliminate water that gets into the system.

Work Baskets Too Large for Unit—The dimensions of the work basket should allow for enough clearance from the walls of the degreaser to avoid pistonlike action that expels solvent vapor during immersion or withdrawal of the work.

Overloading the Unit—Overloading the unit causes excessive drop in vapor level. Air displaced and replaced in the degreaser is subsequently expelled with a mixture of solvent vapors as the vapor level recovers to operating height.

Cleaning Cycle Too Short—Too short a cleaning cycle may result in poorly cleaned work but, more importantly, the work will probably not attain vapor temperature. Consequently the work will be wet with solvent upon removal from the degreaser.

Leaks in Solvent Compartments or Lines—All leaks should be repaired immediately and all solvent line connections, access doors, and solvent transfer pumps checked periodically.
Excessive Solvent Consumption

The economical operation of a metal degreaser is of paramount importance to all those concerned with plant production costs. Solvent consumption varies with the volume, type, physical dimensions and design of parts cleaned. It is also dependent on the nature and amount of contaminants removed, as well as many other factors. No overall figure can be established for solvent consumption, although strict observance of the equipment manufacturer's operating instructions will result in more efficient degreasing at minimum cost.

Causes

Pronounced vapor odors and excessive solvent losses are related. Any vapors that can be smelled have, of course, left the machine. The elimination or reduction of vapor escape from the degreaser reduces solvent consumption. Other factors contributing to excessive solvent consumption are:

- Fluctuating vapor level due to faulty thermostat control or to heavy work loads.
- Failure to cover open top of unit during shutdown periods.
- Dumping insufficiently distilled sludge during cleanout of unit.
- Cleaning of garments, leather goods and other solvent-absorbing materials in a degreaser.
- Use of wood or absorbent materials in basket construction or as parts separators to prevent scratching of the work.

- Open-top water separators. These should have covers. Vapor vent lines can be installed, running from separator and emptying into degreaser at the top cooling coil.
- Water contamination of the degreasing solvent.

Remedies

The remedies outlined for correcting pronounced odors will substantially reduce solvent consumption. Proper maintenance and inspection, frequent cleaning, and strict observance of instructions will result in rapid, efficient and economical metal degreasing. Use of a cold trap or carbon adsorption may be of assistance.

Corrosion

Corrosion, if not immediately arrested, can result in serious damage to the equipment and may eventually cause complete deterioration. Generally, corrosion first becomes apparent at the vapor-atmosphere interface when rust appears on the walls of the unit around the cooling coils and condensate trough.

Causes

The most common cause of corrosion is water contamination. Corrosion within a metal degreaser can result from the thermal decomposition of solvent and the formation of acid. This decomposition results from localized overheating caused by high surface temperatures of the heater or elevation of the solvent boiling point because of excessive oil content. Poor housekeeping, which allows excessive accumulation of contaminants that might catalyze decomposition, may be responsible for acid formation.
Solvent vapors that escape the degreasing equipment can result in a corrosion problem as well as present a toxicity hazard. Vapor that contacts hot metal surfaces or open flame — such as uninsulated heat treating ovens, gas vent stacks, welding arcs, or cutting torches — can decompose to form hydrochloric acid. The acid vapors can corrode both cleaned and uncleaned production articles as well as surrounding equipment and structural metals.

NOTE: Highly clean metal surfaces are more susceptible to atmospheric moisture corrosion and should be protected for storage.

Remedies

- Avoid high surface temperatures of the heaters by frequent inspection of all temperature controls.
- Avoid excessive accumulation of contaminants with good housekeeping and frequent distillation of the solvent and cleaning of the unit.
- Make periodic additions of fresh solvent to maintain stabilizer concentration and to avoid exposing the heating coils.
- Be sure water separator is of adequate size. Open drain valve frequently to eliminate accumulated water.
- Controls can fail despite inspection; visually check and make sure heating elements are properly covered with solvent.
- To combat corrosion of cleaned or uncleared inventory stock, structural metals or surrounding equipment, don’t locate degreasers near high-temperature equipment in welding or cutting areas. If such location is necessary, high-temperature equipment should be insulated or ventilation of vapors provided.

Stained Work

Staining generally occurs in the cleaning of heavily contaminated light-gauge metals, which may reach vapor temperature before sufficient condensing action has taken place to dissolve and rinse away the soils. The temperature involved may change the physical and chemical properties of these soils and possibly render them insoluble and difficult to remove by further recycling.

This condition may be corrected by changing the cleaning cycle — i.e., rapidly immersing the work in warm liquid solvent or spraying to dissolve most of the contaminants before completing the cleaning action in the pure vapor phase. Another corrective measure is the use of a higher-boiling solvent, such as perchloroethylene, to prolong the vapor condensing action before the parts attain vapor temperature.

Staining is also caused by overloading, which produces a prolonged drop in vapor level, thereby lessening the amount of washing action normally realized by condensing vapor. Work degreased in a unit containing excess moisture may emerge with a film of surface rust. This can occur when the work is withdrawn through a solvent-moisture mixture (ghost vapors). The solvent is readily evaporated, leaving minute water droplets, which accelerate corrosion, on the surface.

One cause of this problem is condensation of moisture in the air onto the cooling coils. It can be reduced by controlling the rate of cooling-water flow to keep the temperature of the exhaust water above the dew point. Leaks in condensers and steam coils are other sources of moisture in solvent.
Degreaser Maintenance

Cleanliness is essential for safety, operating economy and process efficiency. Factors determining frequency of cleaning include:

- Volume of work
- Nature and amount of soil
- Boiling temperature of solvent-oil mixtures.

Cleaning Procedures

Routine

The accumulation of metal chips, turnings, or fines and oils (particularly buffing compounds) invokes solvent decomposition. Therefore, routine cleaning is essential. The presence of aluminum metals requires even stricter attention to preventing accumulation.

1. Turn off heat supply to all compartments except vapor generating chamber.
2. Close solvent distillate return lines to degreaser.
3. Route condensate return from water separator to a clean storage tank or a suitable clean container.
4. Continue distillation in boiling chamber until solvent reaches the recommended minimum level of 1 1/2 inches above the heating surface, or until vapors fail to reach condenser. At no time should the heating elements be exposed. Deterioration of solvent, destruction of heater, and, if low-flash oils are involved, a flash fire might result.
5. Turn off heat supply to boiling chamber and allow residue to cool before draining.
6. If residues must be drained prior to cooling, wear approved respiratory equipment and provide adequate ventilation.
7. Metallic fines and chips or other insolubles should be removed with a hoe or similar tool. Particular attention should be given the area under the heating coil.
8. Replace plug in drain line or close drain valve. Open solvent return line to the degreaser and adjust liquid level in all compartments with distilled solvent, using additional fresh solvent as necessary.
9. Disposal of the residue should comply with local regulations governing the disposal of waste products. Residues should not be emptied into municipal sewers.

CAUTION: Do not store solvent-sludge mixtures in tightly closed drums. Occasionally, some mixtures of metal fines (aluminum, brass, iron, zinc, etc.), oils and solvent can undergo reaction, with generation of sufficient gases and pressure to burst standard steel drums.

Comprehensive

Comprehensive cleaning should be performed periodically. This necessitates the removal of all solvent from the degreaser and still. It also requires the services of competent maintenance personnel thoroughly familiar with metal degreasing and with the hazards associated with the process. The procedure is as follows:

1. Transfer all solvent from the degreaser to storage tanks or suitable containers and blank off lines. It is preferable to distill all dirty solvent prior to cleaning. Observe minimum solvent levels as prescribed to prevent exposure of heating elements.
2. Turn off heat and allow unit to cool; drain residual solvent and sludge from all compartments.
3. Thoroughly aerate the unit by forced ventilation from a fan, compressed air or blower to expel the solvent-laden air outside the building by means of a suitable exhaust system.
4. Remove or protect indicating thermometers, controls, etc., to avoid damage.
5. Disconnect heat supply and remove steam or gas coils or electric heaters.
6. Remove cleanout ports, taking care not to damage the gaskets.
7. Remove all dirt, sludge and metal chips from the bottom of each compartment with a scraper or hoe. It may be necessary for maintenance personnel to enter some units. Such entry should be permitted only when the degreaser is thoroughly ventilated and maintenance personnel suitably protected.

8. When the degreaser is thoroughly ventilated, a maintenance worker, wearing a harness and lifeline and equipped with approved respiratory protection, may enter the degreaser (under the constant observation of a second person in attendance outside the degreaser; see Figure 11) and proceed with the following steps.

9. Scrape thoroughly the removed steam coils or electric elements to remove caked sludge that may interfere with heat transfer and disrupt the heat balance of the unit.

10. Clean condensate line from collecting trough to water separator by blowing out with compressed air or cleaning with a wire brush.

11. For proper cleaning of the water separator, remove if necessary.

12. The various controls, indicators and regulators should be cleaned and checked before reassembly.

13. All strainers, filters, liquid level glasses, etc., should be cleaned and checked before reassembly and replaced if necessary.

14. With the cleaning operation completed, the various components should be reassembled and all joints and connections made leakproof.

15. Before reinstalling cleanout ports, the machined surfaces should be coated with litharge-glycerol or ethylene glycol. The gaskets should be examined for breaks or blistering and replaced if necessary.

16. When the unit is reassembled, the various compartments should be filled to their normal operating levels with clean solvent and the unit started.

17. All controls and regulators should be checked and reset if necessary. The degreaser is then ready for operation.

**Restoration of Acid Degreasers**

A degreaser becomes acid when its solvent loses the stabilizers added to protect it against acid buildup due to the natural chemical reaction to heat, metals, water, oils, etc., encountered in the degreasing process. To deacidify:

1. Remove the solvent from the degreaser.

2. If entry into the degreaser or pit is required, the unit must first be thoroughly aerated by forced ventilation from a fan, compressed air or blower to expel all solvent vapor to the outside of the building. When the degreaser is thoroughly ventilated, a maintenance person, wearing harness and lifeline and equipped with approved respiratory protection, may enter the degreaser under the constant observation of a second person in attendance outside the degreaser (also with proper breathing apparatus; see Figure 11) and proceed with the following steps.

3. Scrape carefully or brush off residues on the equipment, including water separators. Do not damage coating.

4. Flush off the equipment with a solution of sodium carbonate (Na₂CO₃), 8 ounces per gallon water. Be sure to flush solvent lines and pumps. (Replacement of piping is often more economical.)

**Note:** Sodium hydroxide (NaOH) or other strong alkalis should never be used.

5. Remove all water and dry the equipment, lines and pumps before recharging with fresh solvent.

6. After going through normal startup procedures, run an acid-acceptance test at least once daily until it is obvious that the system has reached safe operating equilibrium. If acid acceptance drops to 0.08 within the first day or so, draw off 25-50% of the solvent charge and replace with new solvent. Dow provides a free Acid Acceptance Test Kit that can be used to determine the acid condition of Dow vapor degreasing solvents.

**Note:** Solvents do not become acid without cause. Determine the reason and eliminate it to prevent further difficulty. Send Dow a sample of solvent removed from the degreaser for complete chemical analysis and recommendation from our unique Solvent Analysis Service regarding its reclaimability and reuse.
Solvent Reclamation

Degreaser Boil-Down

Solvent can be reclaimed and soil concentrated in the degreaser itself by taking the degreaser out of production and boiling down the residues and diverting the distillate to a storage tank or other container. The minimum operational level of liquid in the boiling sump of two inches above the heating element must also be maintained during this process. The degreaser should therefore be turned off when the solvent reaches this level. The solvent-soil mixture should then be removed from the sump and stored until the next boil-down operation, when it may be added back into the degreaser for further distillation. (See page 22, "Instructions for Boil-Down.")

It is important that metal fines (aluminum, brass, iron, zinc, etc.) be removed from the solvent-soil mixture before storing to avoid potentially dangerous chemical reactions.

In-House Distillation

This operation becomes necessary under the following conditions: when production volume is high; when contaminants are heavy; when a minimum of interruption to production cleaning is desired; or when additional solvent distillate is required.

Continuous—Solvent is pumped directly from the boiling sump, which is the most contaminated compartment of the degreaser, to the still for purification. There it is boiled to produce pure solvent vapor which is then condensed. Distillate, after passing through a water-cooled separator, is returned directly to the degreaser or to a storage reservoir common to the still and the degreaser. Solvent level in the still is maintained by an automatic leveling device actuating a transfer pump. Use of a remote still affords maximum cleaning efficiency in the degreaser and enables continuous production with infrequent shutdowns for cleaning the degreaser.

Periodic concentration and removal of residues is required in a continuous still, the increase in boiling point of the solvent normally determining the frequency. Depending on the nature of the residues, it may be necessary to remove heating coils or cleanout ports for eliminating solids from the still. Residues should be handled in accordance with plant and municipal regulations and should not be dumped into city sewage systems. Ventilation should be provided at cleanout ports when residues are being removed.

Batch—Batch reclaiming stills are operated in manner similar to that used for continuous stills, except that the solvent supplied to the unit is generally concentrated to some extent in the degreaser and then transferred to a reclaiming still for final solvent recovery.

Commercial Recycling

It is sometimes advantageous to send the used solvent to a commercial reclaimer. The recycled solvent can be returned to the generator or utilized elsewhere by the reclaimer, depending upon the terms of the transaction. Generally, the used solvent has more value to the reclaimer prior to its concentration by boil-down or distillation.

The use of any reclaimed solvent, whether in-house or commercial, should be approached with appropriate caution, because of possible stabilizer depletion and the potential for contamination by compounds not indigenous to the original generator’s system. Some effects of these factors could be shortened solvent life, reduced margin of safety before an acid condition can develop, reduced protection from corrosion development, chemical incompatibilities which can be reactive leading to acid formation, excess water content and even the possibility of a flammable mixture. We strongly recommend that reclaimed solvent be fully analyzed for stabilizers and contaminants before it is reused. Dow solvent customers can utilize the solvent analysis service for this purpose.

We also recommend that users of a recycled chlorinated solvent should deal with a reclaimer who has received federal, state and local operating approvals and applicable permits. Users should receive complete documentation from the reclaimer, including a MSDS.
proper label and a product analysis. The user should set specifications for reclaimed solvent according to the performance and safety requirements of the particular use for the product.

**Instructions for Boil-Down**

When heating chlorinated solvents for boil-down, observe the temperature of the contaminated solvent in the boiling sump of the still. TABLE V shows approximate boiling points for solvents contaminated with 25-30% oil:

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Boiling Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylene Chloride</td>
<td>107°F</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>174°F</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>192°F</td>
</tr>
<tr>
<td>Perachloroethylene</td>
<td>257°F</td>
</tr>
</tbody>
</table>

When the contaminated solvent reaches its boiling point, you should concentrate the sludge in the still. To do this, first turn off the transfer pump and close the gate valve in the dirty solvent line; then continue distillation until the liquid level has dropped to the recommended level of two inches above the heating elements.

Before draining, turn off the heat in the boiling sump, allow the solvent sludge to cool to 30-100°F, and drain the sludge into one or more 55-gallon drums. At this time, parts, chips, metallic fines, and oiled sludge should be removed from the still or the degreaser.

In removing solids, pay particular attention to the area under the heating elements; this area is accessible through the cleanout port.

Refill the sump of the still from the degreaser by closing the drain valve, opening the gate valve in the solvent line from the degreaser boiling sump, and turning on the transfer pump.

Be careful not to let the heating elements or heating surfaces in the degreaser become exposed. When the liquid level reaches two inches above the heating element or elements, turn on the heat. Add enough virgin solvent to the clean dip of the degreaser to maintain proper liquid levels in all chambers of the degreaser or still.

Accumulated sludge can be reclaimed either in-house or by a commercial reclaimer until its oil concentration reaches 60-70%. When the oil concentration reaches that limit, it should be discarded in compliance with federal, state, and local regulations governing the disposal of hazardous waste products.
Solvent Recovery with Activated Carbon

The solvent recovery/air cleansing system takes vapor-laden air from degreasing or cleaning operations and passes it through a specially prepared activated carbon bed to remove the solvent which would otherwise be lost. At predetermined intervals, steam is passed through the carbon bed to carry the vapors to a condenser. A water separator removes the water from the solvent, which is then recovered and returned to storage tanks.

The carbon-adsorption vapor-recovery system is designed to permit high air flows for better ventilation.

Carbon adsorption tends to remove significant portions of the solvent stabilizers while adding water contamination. Your nearest Dow sales office should be contacted for information to assure trouble-free operation.

The activated carbon system can recover some chlorinated or fluorinated hydrocarbons, including trichloroethylene and perchloroethylene. Recovery of CHLOROTHENE brand solvents, however, requires special considerations. Before attempting this recovery technique with the CHLOROTHENE solvents, your nearest Dow sales office should be contacted for information (see back cover for addresses).
Toxicity, Handling Precautions, First Aid

For toxicity information, please consult form no. 100-6170-86. For handling precautions and first aid measures, please consult the Dow publication entitled “Safety, Health, Environmental Aspects and Bulk Handling of Dow Chlorinated Solvents,” form no. 100-6171-86.

How to Select a Vapor Degreasing Solvent

A step-by-step approach...
1. Identify any special performance requirements or special applications.
2. Check the economics.
3. Give prime consideration to worker safety.
4. Satisfy all environmental requirements.

Then, on the basis of these factors, choose the best solvent for the job.

Solvent Performance

In vapor degreasing, one key to solvent performance is the volume of work that can be processed — that is, the work capacity of a degreaser. Machine capacity establishes the upper limit of productivity but, in actual practice, the rate of production for any given degreaser depends largely on the boiling point of the solvent. All other things being equal, the lower the boiling point of the solvent, the greater the work throughput. (See Table VIII.)

TABLE VIII — Boiling Temperatures of Dow Solvents

<table>
<thead>
<tr>
<th>SOLVENT</th>
<th>BOILING TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylene Chloride</td>
<td>194°F</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>158°F</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>189°F</td>
</tr>
<tr>
<td>Perchloroethylene</td>
<td>230°F</td>
</tr>
</tbody>
</table>
On the basis of boiling point, then, methylene chloride, with a boiling temperature of 104°F, has the highest work throughput of the four solvents. By contrast, perchloroethylene, with a boiling temperature of 250°F, has the lowest work throughput.

Figure 12 shows the energy efficiency of the four solvents expressed in terms of pounds of steel cleaned per 25kwh of heat input. The energy efficiency is highest when methylene chloride is used, provided the degreaser is equipped with the chilling or refrigerating equipment required to condense an adequate volume of solvent.

(The comparisons in Figure 12 exclude energy used to provide cooling in degreaser operation. For comparisons based on overall energy requirements, see Figure 26, page 36.)

The vapor pressures of typical cutting and lubricating oils removed by degreasing, although low, are high enough to allow measurable concentrations of these oils in the vapor zone above the boiling sump of the degreaser. In most vapor degreasing applications the presence of small amounts of oil in the degreasing vapor can be tolerated. However, depending on the particular oil and solvent being used, the concentration of oil in the vapor zone can become high enough to require attention in critical cleaning operations.

As an aid to selecting the proper solvent, Figure 13 shows typical concentrations of representative oils in the vapor zone. In each case, the concentration derived assumed a boiling solution of the oil and solvent. The actual values were in the range of 1-3 ppm (by volume) for methylene chloride, 1-59 ppm for 1,1,1-trichloroethane, 2-111 ppm for trichloroethylene, and 14-800 ppm for perchloroethylene — all for oil concentrations of 5-30% by volume in the liquid. Three oils were evaluated: a mineral-lard oil, a sulfochlorinated-lard oil, and sulfurized-lard oil.
A prime requirement for any vapor degreasing solvent is the ability to dissolve all greases, fats, oils, waxes, resins, gums and rosin fluxes generally used in metalworking operations. Besides this, the solvent also must clean the parts without corroding, oxidizing, staining, etching, pitting, or dulling them or the degreaser itself.

Solvent cleaning power is expressed in terms of the Kauri Butanol value (TABLE IX). The higher the value, the greater the cleaning power.

**TABLE IX — Kauri Butanol Values**

<table>
<thead>
<tr>
<th>SOLVENT</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trichloroethylene</td>
<td>50</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>32</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>39</td>
</tr>
<tr>
<td>Methylene Chloride</td>
<td>35</td>
</tr>
</tbody>
</table>

Except for the lower cleaning power of perchloroethylene, the four solvents have practically the same cleaning power for normal industrial soils, but each has advantages in special applications. Here are examples:

- Trichloroethylene is used in specialty applications to strip semicured varnish or paint films, heavy rosins and buffing compounds.
- Perchloroethylene is excellent for removing high-melt waxes and for cleaning wet parts and light-gauge metal parts.
- 1,1,1-Trichloroethane and blends of 1,1,1-trichloroethane excel for cleaning printed circuit boards, electronic components, electric motors, and other items that might be damaged by trichloroethylene or perchloroethylene. It has a gentler cleaning action than trichloroethylene, and — with its relatively low boiling point — avoids the problem of plastic warping and melting associated with the higher-boiling perchloroethylene.
- Methylene chloride, with the lowest boiling point of the four solvents, is well suited to cleaning thermal switches, thermometers, and other temperature-sensitive parts. It also has the highest solvent power, and will remove tough paint residues and hard-to-dissolve resins effectively.

Most vapor degreasing operations can be performed with any of the four solvents, so the choice is often based on other performance characteristics, safety, environmental considerations, or cost.

**Properties of Vapor Degreasing Solvents**

**General Properties**

Properties required and desirable in an industrial degreasing solvent are summarized first, followed by an individual evaluation of the advantages and disadvantages of each of the four Dow solvents. This is followed by the general specifications for each solvent.

To provide thorough, safe, economical and rapid metal degreasing, the ideal solvent must have the properties described below. The industrial chlorinated solvents possess these properties and therefore are widely accepted by industry for metal degreasing applications. However, different solvents don’t possess all of these properties to the same extent. Choice should depend on various considerations relative to the specific cleaning operation.

**High Solvent Power**

A prime requirement is the ability to dissolve all greases, fats, oils, waxes, resins, gums and rosin fluxes generally encountered in any metalworking operation.

**Inertness To Metals And Plastics**

The solvent must clean the parts without corroding, oxidizing, staining, etching, pitting, or dulling the work or the degreaser itself.

**Nonflammability**

The elevated temperatures involved in vapor degreasing exclude the use of flammable solvents. The chlorinated solvents are relatively nonflammable, exhibiting no flashpoints by standard laboratory test methods.

Under normal conditions, the likelihood of flammability problems with these solvents is extremely remote. TABLE X shows the flammability limits of the four solvents at 25°C. For additional information on solvent flammability, contact your nearest Dow sales office.

**Warning:** Drums that contain or have contained chlorinated solvents must not be welded or cut with a cutting torch because of decomposition and explosion hazards.

**Low Toxicity**

The safety and health of operating personnel must be assured at all times. It is essential that the solvent used be sufficiently low in toxicity that the exposure likely to occur when the material is properly used will not impair the health of the operator.
TABLE X — Flammable Limits in Air

<table>
<thead>
<tr>
<th>% OF SOLVENT IN AIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOWER LIMIT</td>
</tr>
<tr>
<td>Methanol</td>
</tr>
<tr>
<td>Nitrobenzene</td>
</tr>
<tr>
<td>Trichloroethylene</td>
</tr>
<tr>
<td>Perchloroethylene</td>
</tr>
</tbody>
</table>

*Technical Grades: see Material Safety Data Sheet for each product.

Low Latent Heat
This property provides more pounds of vapor per unit of heat input, thereby reducing the cost of vaporizing the solvent.

High Density Vapor
This property assures ease of solvent vapor recovery and provides effective control of the solvent vapor level by means of condensing coils or thermostats. High density vapor reduces the amount of solvent lost through work transfer and air disturbance of the vapor blanket — factors that can be controlled but not entirely eliminated.

Chemical Stability
The solvent should remain stable and effective in both the liquid and vapor phases after continuous and repeated operating practices. Degreasing solvents must be properly stabilized to provide adequate protection against reactive metal chips and fines, acidic heat, air, moisture, and other metalworking contaminants.

Boiling Point
The boiling point should be low enough for the solvent to separate easily from the higher boiling cutting oils, greases, and other contaminants by simple distillation. At the same time, the boiling point should be high enough that the degreaser condensation coils can function efficiently with plant water.

All of the Dow solvents discussed in the following pages meet these demanding requirements.

Vapor Pressure
The volatility and evaporation rates of solvents are related to their vapor pressure. The exact vapor pressure of a solvent at a specific temperature can be calculated from the Antoine equation:

\[
\log_{10} P = A - \left[ \frac{B}{T + C} \right]
\]

where \( P \) is the vapor pressure in mm Hg, \( T \) is the temperature in degrees Celsius (°C) and \( A, B, \) and \( C \) are the Antoine constants for the particular solvent. The Antoine constants for 1,1,1-trichloroethane are:

\[ A = 6.89126, \quad B = 1204.66, \quad C = 226.71 \]

The evaporation rates of chlorinated solvents vary, but generally one or more of them will provide an optimum rate.

TABLE XI — Relative Evaporation Rates of Some Common Solvents

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Relative Evaporation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone Chloride</td>
<td>1.0</td>
</tr>
<tr>
<td>Methylene Chloride</td>
<td>6.5</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>0.63</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>0.26</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>0.05</td>
</tr>
<tr>
<td>Methylene Chloride</td>
<td>0.34</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>1.39</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>0.97</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>0.40</td>
</tr>
<tr>
<td>Perchloroethylene</td>
<td>0.09</td>
</tr>
</tbody>
</table>

The rates in the above table were determined by evaporating the solvents from equal surface areas on an analytical balance for five minutes. The values are compared using the 1,1,1-Trichloroethane value as one. Higher values indicate faster evaporation rates.
CHLOROTHENE SM Solvent

CHLOROTHENE SM solvent is vapor-degreasing-grade inhibited 1,1,1-trichloroethane (C₂H₃Cl₃). It is a clear, colorless liquid with a characteristic odor and incorporates a special stabilizer system. It is an excellent vapor degreasing solvent which has had wide acceptance.

Advantages

Extra Safety — The 8-hour time-weighted average (TWA) concentration accepted by the Occupational Safety and Health Administration (OSHA) for 1,1,1-trichloroethane is 350 ppm by volume in air, compared to 100 ppm for trichloroethylene and perchloroethylene. Many laboratory studies on animals and humans have documented the low toxicity of inhibited 1,1,1-trichloroethane.

Lower Solvent Consumption — Because of its lower boiling point and lower weight per gallon, as much as 40% lower solvent consumption has been reported with CHLOROTHENE SM solvent than with trichloroethylene.

Conversion Ease — CHLOROTHENE SM solvent can be used in existing trichloroethylene degreasers with minor modifications. These include reducing the heat input, readjusting the thermostats, and installing a properly sized water separator.

Versatility — CHLOROTHENE SM solvent is an excellent solvent for cold cleaning as well as vapor degreasing and is commonly used for both. Plants can reduce inventory and purchasing costs by using just this one solvent. When used in wipe, dip, spray or flush operations, the solvent can also be economically reclaimed in a vapor degreasing or reclamation still.

Reduced Utilities Cost — Because of the low boiling point of CHLOROTHENE SM solvent (24°F below that of trichloroethylene), less heat and water are required to clean a given work load and to provide for condensation. Cleaned parts are cooler, permitting more rapid handling and processing, while reduced heat radiation means further heat savings.

Greater Operator Comfort — The reduced sidewall radiation loss results in a cooler working area, and the lower parts temperature adds to operator comfort.

Selective Solvent Power — The special solvent characteristics of CHLOROTHENE SM solvent permit it to dissolve and clean metalworking soils without attacking certain sensitive materials such as many plastics and resins. It is the chosen solvent for degreasing hermetic stators and printed circuit boards where other solvents may damage insulation, remove identification, or cause heat warping.

Distillation Ease — The lower boiling point of CHLOROTHENE SM solvent allows it to be efficiently distilled without steam stripping. Thus, added energy costs and water contamination are avoided.

Disadvantages

Not Recoverable by Carbon Adsorption — This process depletes the stabilizers in CHLOROTHENE SM solvent below acceptable levels and is not recommended for vapor recovery of this solvent.

Won’t Tolerate Excessive Water — Degreasing operations having gross water contamination should not employ CHLOROTHENE SM solvent. Moderate or intermittent water contamination is effectively handled by an adequately sized and designed water separator. CHLOROTHENE SM should not be used in equipment constructed of aluminum.
TABLE XII — Typical Properties of CHLOROTHENE SM Solvent Brand of 1,1,1-Trichloroethane

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling point, 760 mm Hg</td>
<td>180°F (74°C)</td>
</tr>
<tr>
<td>Freezing point</td>
<td>-34.4°F (-36.9°C)</td>
</tr>
<tr>
<td>Specific gravity, 25/25°C</td>
<td>1.320</td>
</tr>
<tr>
<td>Specific heat, cal/g°C</td>
<td>0.25</td>
</tr>
<tr>
<td>Heat of vaporization, cal/g</td>
<td>58.7</td>
</tr>
<tr>
<td>Brn/pint</td>
<td>102</td>
</tr>
<tr>
<td>Refractive index at 25°C</td>
<td>1.434</td>
</tr>
<tr>
<td>Viscosity at 25°C, centipoise</td>
<td>0.79</td>
</tr>
<tr>
<td>Pounds per gallon at 25°C</td>
<td>10.57</td>
</tr>
<tr>
<td>Flash point (fag open cup, ASTM Method D1310)</td>
<td>None</td>
</tr>
<tr>
<td>Fire point (tag open cup, ASTM Method D1310)</td>
<td>None</td>
</tr>
<tr>
<td>Vapor density (air = 1.00)</td>
<td>4.50</td>
</tr>
<tr>
<td>Kauri butanol value</td>
<td>1.24</td>
</tr>
<tr>
<td>Solvent-water azeotropic boiling point</td>
<td>444°F (229°C)</td>
</tr>
</tbody>
</table>

NOTE: These properties are laboratory values typical of the product but should not be confused with, or regarded as specifications.

FIGURE 14 — Boiling Point of Mixtures of CHLOROTHENE SM and Oil

FIGURE 15 — Specific Gravity of Mixtures of CHLOROTHENE SM and Oil

FIGURE 16 — Vapor Pressure of CHLOROTHENE SM Brand of 1,1,1-Trichloroethane
**NEU-TRI Solvent**

This chlorinated solvent, stabilized trichloroethylene (C₂HCl₃), satisfies the basic requirements for a metal degreasing solvent. It is a clear, colorless liquid with a characteristic odor.

**Advantages**

**High Solvent Power**—NEU-TRI brand of trichloroethylene has a high solvency for oils, greases, waxes, tars, lubricants and coolants generally found in the metal processing industries. It is effective and economical. Its aggressive solvent action is often chosen for removing difficult soils, such as semicured varnish or paint films, heavy resins, buffing compounds, etc.

**No Conversion Costs**—Most industrial degreasing equipment was originally designed for trichloroethylene and can therefore be used to full advantage and without modification with NEU-TRI solvent.

**Recoverable by Carbon Adsorption**—Carbon adsorption recovery of NEU-TRI solvent is widely and successfully practiced. This recovery process does stress the stabilizer system, and monitoring the system when this solvent is first installed is recommended to assure efficient performance.

**Disadvantages**

**Not Recommended for Cold Cleaning**—The use of NEU-TRI solvent is not generally recommended for wipe, spray, dip, and flush operations. Its evaporation rate is not significantly different from that of 1,1,1-trichloroethane; however, its toxicity is less favorable for these applications.

**Attacks Some Plastics**—In operations involving printed-circuit boards, plastics, and electric motors, CHLOROTHENE SM is preferable to NEU-TRI which, having strong properties, will remove printed-circuit board markings, swell or dissolve plastics, and attack electric motor insulations.

**Degrades in Ultraviolet Light**—NEU-TRI degrades in ultraviolet light producing phosgene, which does not contain enough HCl to provide a warning before phosgene overexposure occurs.

**Steam Stripping**—Steam stripping is commonly practiced with trichloroethylene to recover the solvent effectively without causing thermal degradation. This practice, however, does result in undesirable water contamination and requires manual control and operator attention.

**Reactive with Caustic Soda (NaOH)**—NEU-TRI solvent reacts with caustic soda to form the toxic and spontaneously combustible product, dichloroacetylene.

For additional information about NEU-TRI solvent, request bulletin 100-5548, available from your nearest Dow sales office.
TABLE XIII — Typical Properties of NEU-TRI Solvent Brand of Trichloroethylene

180°F (82°C) c = 0.22
180°F (82°C) c = 0.46
180°F (82°C) c = 0.69
180°F (82°C) c = 0.94
0°F (-18°C) c = 9.7
0°F (-18°C) c = 12.1
0°F (-18°C) c = 14.4
0°F (-18°C) c = 16.7
0°F (-18°C) c = 19.1
0°F (-18°C) c = 21.1
0°F (-18°C) c = 23.4
0°F (-18°C) c = 25.7
0°F (-18°C) c = 28.0
0°F (-18°C) c = 30.3

NOTE: These properties are laboratory values typical of the product but should not be confused with, or regarded as specifications.

FIGURE 17 — Boiling Point of Mixtures of NEU-TRI and Oil

FIGURE 18 — Specific Gravity of Mixtures of NEU-TRI and Oil

FIGURE 19 — Vapor Pressure of NEU-TRI Brand of Trichloroethylene
DOW
Perchloroethylene
SVG
This chlorinated solvent, suitably stabilized with a tough corrosion inhibitor, fulfills the requirements for many types of metal degreasing. In certain applications, it is preferred. Perchloroethylene (C₂Cl₄) is a clear liquid with a characteristic odor.

Advantages
Effective with Wet Metals—The high boiling point of this solvent (121°C/250°F) permits complete and thorough drying of the work by vaporizing moisture entrapped in porous metals, deeply recessed parts, and blind holes. This property is particularly advantageous where the presence of moisture may prove detrimental to the finish of the work.

Reduced Staining—Light-gauge metals may rapidly attain the vapor temperature of the lower boiling solvents before sufficient condensing action takes place to dissolve all the oil and rinse away the contaminants. The higher boiling point of perchloroethylene permits a longer and more thorough rinsing action and may reduce staining in cleaning operations employing vapor exposure only.

Removes Stubborn Soils—With its high boiling point, perchloroethylene is especially effective for removing high-melting pitches and waxes and for cleaning grossly contaminated parts.

Stability — Perchloroethylene shows little tendency to hydrolyze (degrade with water), but can decompose in the presence of strong ultraviolet light (e.g., from arc welding), releasing phosgene.

Decreased Corrosion—DOW Perchloroethylene SVG contains an inhibitor system that provides extra corrosion protection for cleaned parts and the degreaser.

Vapor Recoverable by Carbon Adsorption—Perchloroethylene has had the longest and most successful experience with carbon adsorption recovery of all degreasing solvents.

Disadvantages
High Heat Required—The high boiling point of perchloroethylene (250°F) necessitates added heat to bring work up to the solvent vapor temperature. Thus, utility costs are higher. Steam-heated units require a pressure of 45 to 60 psig, which is not always available in small plants.

Longer Cooling Time—Because of the high temperature of parts emerging from the degreaser, more time must be allowed for the work to cool before it can be handled.

Higher Solvent Consumption—The higher boiling point of perchloroethylene raises the temperature of the air next to the degreaser wall, causing air turbulence. This, combined with its higher liquid density, yields greater weight loss with equal volume, resulting in higher solvent losses than are experienced with CHLOROTHENE SM or NEU-TRI solvents.

Steam Stripping—Steam stripping is commonly practiced with perchloroethylene to recover the solvent effectively without causing thermal degradation. This practice, however, does result in undesirable water contamination and requires manual control and operator attention.

Heat Effects—Certain aircraft aluminum alloys are subject to structural change at temperatures near 250°F, the boiling point of perchloroethylene. Also, printed circuit boards and plastic materials may warp or melt.

Not Recommended for Cold Cleaning — While the slow evaporation rate of perchloroethylene makes it useful as a cold cleaning solvent, the special inhibitor used in DOW Perchloroethylene SVG can cause sensitization in some people, and skin contact should be minimized.

For additional information about DOW Perchloroethylene SVG, request the bulletin on this solvent available from your nearest Dow sales office.
TABLE XIV - Typical Properties of DOW Perchloroethylene

NOTE: These properties are minimum values. Vertical of the product but should not be confused with or interpreted as specifications.

FIGURE 20 - Boiling Point of Mixtures of Perchloroethylene and Oil

FIGURE 21 - Specific Gravity of Mixtures of Perchloroethylene and Oil

FIGURE 22 - Vapor Pressure of Perchloroethylene
**DOW Methylene Chloride, Vapor Degreasing Grade**

Methylene Chloride \((\text{CH}_2\text{Cl}_2)\) is an inherently stable solvent, clear and colorless, with characteristic odor. DOW Methylene Chloride, Vapor Degreasing Grade, formulated with a special inhibitor, provides better corrosion protection than technical-grade material.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Solvent Power</strong>—Methylene Chloride is the strongest of the common vapor degreasing solvents. This solvent power enables it to perform effectively in such diverse tasks as paint-mask cleaning and removing excess impregnating resin from castings.</td>
<td><strong>Low Vapor Density</strong>—This property makes methylene chloride vapors more susceptible to losses from air movement around the equipment. Specialized equipment design, with a higher freeboard, is recommended for efficient use.</td>
</tr>
<tr>
<td><strong>Good for Temperature-Sensitive Parts</strong>—Often, the boiling point ((40^\circ\text{C}; 104^\circ\text{F})) of methylene chloride makes possible the degreasing of thermal switches, thermometers, etc., which would be damaged by high temperatures. This solvent is chosen when parts must be near room temperature after cleaning, such as for immediate handling or air gauging.</td>
<td><strong>Rapid Evaporation Rate</strong>—Methylene chloride evaporates more rapidly than other vapor degreasing solvents. Covering the degreaser during non-operating periods is imperative to prevent excessive solvent losses.</td>
</tr>
<tr>
<td><strong>Low Cost</strong>—DOW Methylene Chloride, Vapor Degreasing Grade, is low in cost compared to alternative low-temperature solvents used for similar applications.</td>
<td>For additional information on DOW Methylene Chloride, Vapor Degreasing Grade, request the bulletin by that name, available from your nearest Dow sales office.</td>
</tr>
</tbody>
</table>
TABLE XV — Typical Properties of DOW Methylene Chloride Vapor Degreasing Grade

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling point</td>
<td>104°F (39.5°C)</td>
</tr>
<tr>
<td>Flash point</td>
<td>142°F (-9.4°C)</td>
</tr>
<tr>
<td>Density @ 60°F</td>
<td>1.320</td>
</tr>
<tr>
<td>Viscosity @ 60°F</td>
<td>2.28</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>76.2</td>
</tr>
<tr>
<td>Flash point @ 25°C</td>
<td>141.7</td>
</tr>
<tr>
<td>Density @ 25°C</td>
<td>1.421</td>
</tr>
<tr>
<td>Viscosity @ 25°C</td>
<td>1.320</td>
</tr>
<tr>
<td>Boiling point (open cup, ASTM Method D1310)</td>
<td>None</td>
</tr>
<tr>
<td>Flash point (open cup, ASTM Method D1310)</td>
<td>None</td>
</tr>
<tr>
<td>Density (oil = 1.00)</td>
<td>2.93</td>
</tr>
<tr>
<td>Viscosity (oil)</td>
<td>156</td>
</tr>
<tr>
<td>Boiling point (specific gravity boiling point)</td>
<td>100.6°F (38.4°C)</td>
</tr>
</tbody>
</table>

NOTE: These properties are laboratory values typical of the product but should not be confused with as specifications.

FIGURE 23 — Boiling Point of Mixture of Methylene Chloride and Oil

FIGURE 24 — Specific Gravity of Mixtures of Methylene Chloride and Oil

FIGURE 25 — Vapor Pressure of Methylene Chloride
Economics of Dow Chlorinated Solvents

Solvent consumption and energy requirements, as well as the price of the solvent, are the major economic considerations. Consumption rates for the four solvents are affected by such factors as cleaning cycle, work load and type of materials being cleaned. Vapor loss also varies from solvent to solvent because of differences in their physical properties.

Vapor loss occurs when solvent diffuses from the dense solvent vapor blanket into the overhead air mass. The actual rate of diffusion depends on the vapor density and boiling point of the solvent being used. The comparison of solvent consumption shown in Figure 26 is based on tests in an idling open-top degreaser having a 24" X 58" opening.

<table>
<thead>
<tr>
<th>TABLE XVI</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOLVENT</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
</tr>
<tr>
<td>Trichloroethylene</td>
</tr>
<tr>
<td>Methylene Chloride</td>
</tr>
<tr>
<td>Perchloroethylene</td>
</tr>
</tbody>
</table>

The test values for solvent consumption (that is, vapor loss from an idling open-top degreaser per square foot of open-top area per hour) were 0.142 lb for 1,1,1-trichloroethane, 0.201 lb for trichloroethylene, 0.260 lb for methylene chloride and 0.293 lb for perchloroethylene.

Energy requirements (see Figure 27) include not only the heat needed to bring the solvent to its boiling point but also, in the case of methylene chloride, the energy required to provide extra cooling capacity for adequate vapor condensation. Heat loss by radiation from the degreaser, which is dependent upon the solvent boiling point, is also taken into account in this comparison. The higher kwh values are for an uninsulated degreaser; the lower values (in parentheses) are for a degreaser with two inches of insulation. The degreasers used cleaned five loads of steel (100 lb each) and provided 20 gallons of solvent spray per hour.

The values for the comparison of hourly energy requirements were 14.0 kwh (9.1 kwh) for 1,1,1-trichloroethane, 16.3 kwh (10.1 kwh) for trichloroethylene, 20.8 kwh (11.5 kwh) for perchloroethylene, and 21.47 kwh (20.12 kwh) for methylene chloride.

Because of its lower boiling point and equal vapor density, up to 40% lower solvent consumption can be realized with 1,1,1-trichloroethane compared to trichloroethylene or perchloroethylene. The lower solvent consumption rate and energy requirements of 1,1,1-trichloroethane are major advantages of this product.
Which Solvent to Choose?

Which chlorinated vapor degreasing solvent is right for your particular operation? This bulletin has described some of the advantages and disadvantages of the major chlorinated solvents. Table XVII provides an overall summary of these points.

**TABLE XVII: Comparison of Solvents Used in Vapor Degreasing**

<table>
<thead>
<tr>
<th>Solvent Type</th>
<th>Trichloroethylene</th>
<th>1,1,1-Trichloroethane</th>
<th>Perchloroethylene</th>
<th>Methylene Chloride</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air pollution controls (in most states)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of compliance, OSHA limit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degreaser heat input</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work capacity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling capacity needed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solvent consumption (hot)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remove high-melting waxes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Standard or lowest performance
- Best or preferred performance

**TABLE XVIII: Typical Properties of Dow Brand Chlorinated Vapor Degreasing Solvents**

<table>
<thead>
<tr>
<th>Property</th>
<th>CHLOROTHENE SM Inhibited 1,1,1-Trichloroethane Solvent</th>
<th>NEU-TRI® Stabilized Trichloroethylene Solvent</th>
<th>DOW Perchloroethylene SVG Specially Stabilized</th>
<th>DOW Methylene Chloride, Vapor Degreasing Grade, Specially Stabilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling point</td>
<td>230 °F (110 °C)</td>
<td>245 °F (118 °C)</td>
<td>260 °F (121 °C)</td>
<td>104 °F (39.6 °C)</td>
</tr>
<tr>
<td>Freezing point, approx.</td>
<td>34 °F (-1 °C)</td>
<td>24 °F (-40 °C)</td>
<td>97 °F (36.6 °C)</td>
<td>142 °F (61.7 °C)</td>
</tr>
<tr>
<td>Specific gravity, 25/25 °F</td>
<td>0.920</td>
<td>1.458</td>
<td>1.619</td>
<td>1.020</td>
</tr>
<tr>
<td>Specific heat, Btu/lb °F</td>
<td>0.40</td>
<td>0.22</td>
<td>0.21</td>
<td>0.28</td>
</tr>
<tr>
<td>Heat of vaporization</td>
<td>702</td>
<td>401</td>
<td>902</td>
<td>1417</td>
</tr>
<tr>
<td>Flash point</td>
<td>145 °F (63 °C)</td>
<td>147 °F (64 °C)</td>
<td>150 °F (66 °C)</td>
<td>169 °F (76 °C)</td>
</tr>
<tr>
<td>Vapor density</td>
<td>1.55</td>
<td>1.53</td>
<td>1.76</td>
<td>2.93</td>
</tr>
<tr>
<td>Vapour B.T.U. per cu ft</td>
<td>224</td>
<td>199</td>
<td>90</td>
<td>136</td>
</tr>
<tr>
<td>Solvent-water azeotropic temperature,</td>
<td>145 °F (62.8 °C)</td>
<td>162 °F (72.2 °C)</td>
<td>190 °F (87.6 °C)</td>
<td>100.6 °F (38.1 °C)</td>
</tr>
<tr>
<td>zing point</td>
<td>4.3 °F (45.6 °C)</td>
<td>5.4 °F (11.9 °C)</td>
<td>15.8 °F (9.8 °C)</td>
<td>15.8 °F (9.8 °C)</td>
</tr>
</tbody>
</table>

*Trademark of The Dow Chemical Company*
*These are typical properties of the products and should not be confused with nor regarded as specifications.*
Technical Assistance

Technical assistance in evaluating, selecting and using vapor degreasing solvents is offered to customers through Dow's Technical Service & Development group. These services are the most extensive in the industry. For example, whichever solvent you choose, Dow provides the following important services to enable its customers to guard against solvent breakdown and head off trouble before it starts. Both services are provided without charge to the customer. They are:

1) Dow laboratory analysis of Dow solvents in customer use.
2) Acid acceptance test kits for customer use on their site.

Exclusive Solvent Analysis Service — Periodically, you can send us a sample of the Dow solvent you're using. We'll give it a complete chemical analysis, and report back to you on its condition for effective vapor degreasing. If any unusual conditions are detected, we'll recommend methods for changes in your operation to make optimum use of our product.

Acid Acceptance Test Kit — Dow provides a free Acid Acceptance Test Kit (see Figure 28) which you can use to guard against solvent breakdown. Dow vapor degreasing solvents are stabilized with neutral, acid-accepting stabilizers, and the concentration of these stabilizers at any time is an excellent indicator of solvent condition. Dow's easy-to-use kit enables you to check stabilizer concentration "on the spot" and keep the solvent from becoming acidic.

Your nearest Dow Sales Office (see list on back cover) will tell you how to obtain these two valuable Dow services.

We're Ready To Help

Dow maintains the largest, most experienced solvents technical service and development department in the industry — more than 20 trained specialists capable of assisting you with any technical problems involving our products.

If you have a new cleaning/degreasing application or a problem with an old one, why not place a call to Dow's experts? Our specialists will very likely have a ready answer; or they may decide that an on-site evaluation of your operation, equipment, and requirements is appropriate. In any case, the service is at Dow's expense, because helping your operation run smoothly means business for Dow.

Also, Dow TS&D solvent specialists are available to assist customers in complying with federal and state regulations on solvents operations, and can provide information on OSHA, CAA and RCA requirements.

For further information on technical assistance, contact the nearest Dow sales office.

For help in handling emergencies involving chemicals in general, telephone:

CHEMTREC Emergency Response
(800) 424-9300

For additional information, contact your local Dow Sales Representative.
Equipment Suppliers
for Chlorinated Solvents Users

The following is a representative list of manufacturers and suppliers of equipment which may be used in the design and construction of vapor degreasing systems and in the bulk handling and storage of chlorinated solvents. Specific questions about the specifications or suitability of any of the products offered by these firms should be addressed to the firm in question. The Dow Chemical Company neither endorses the products offered nor guarantees their performance. (Note: The names, addresses, zip codes, telephone numbers, etc., listed here are believed to be accurate as of the date of publication. For current information, consult Thomas Register, Standard and Poor's, or the Dun & Bradstreet Reference Book of Manufacturers.)

Air Sampling
Instruments
Anatole J. Spin Co.
505 8th Avenue
New York, NY 10018
(212) 695-5766

Bendix Corp.
Environmental & Process
Instruments Division
1400 Taylor Avenue
Baltimore, MD 21204
(301) 321-5200

Enmet Corporation
P.O. Box 979
2308 S. Industrial Highway
Ann Arbor, MI 48106-0979
(313) 761-1270

Faxboro Corporation
P.O. Box 5449
2308 S. Industrial Highway
Ann Arbor, MI 48106-0979
(313) 761-1270

Spectrex
3594 Haven Ave.
Indiana, PA 15701
(213) 875-3810

Bulk Delivery Pumps
Abex Corporation
Manufactured Products
Waukesha Foundry Division
1300 Lincoln Avenue
Waukesha, WI 53186
(412) 542-0741

Blackmer Pump Company
1809 Century Avenue, S.W.
Grand Rapids, MI 49509
(616) 241-1611

Roper Pump Company
P.O. Box 269
Commerce, CA 90029
(800) 335-5551

Viking Pump-Houdaille
406 State Street
Cedar Falls, IA 50613
(319) 266-1741

Centrifugal Pumps
Allis Chalmers
Industrial Pump Division
1150 Tennessee Avenue
Cincinnati, OH 45229
(513) 482-2500

Ingersoll Rand Co.
3 Century Drive
Parappry, NJ 07054
(201) 267-0476

ITT Morton
445 Godwin Avenue
Midland Park, NJ 07432
(201) 344-6900

Distillation Equipment
Acro Electric Corporation
3801 N. 25th Avenue
Schiller Park, IL 60176
(312) 678-8870

Artisan Industries, Inc.
73 Pond Street
Wattham, MA 02254
(617) 893-6800

Baron-Blakeslee
2001 N. Janice Avenue
Melrose Park, IL 60160
(312) 450-3900

Branson Cleaning Equipment Company
P.O. Box 766
1 Parret Drive
Shelton, CT 06484
(203) 929-7301

Brighton Corporation
11861 Mosteller Road
Cincinnati, OH 45241
(513) 771-2300

Crest Ultrasonic Corp.
P.O. Box 7266
Scotch Road
Marcel County Airport
Trenton, NJ 08628
(609) 883-4000

Detrex Corporation
Industrial Equipment Division
4930 Town Center
Southfield, MI 48075
(313) 358-5800

Eaton Corporation
Process Control Components Division
1199 South Chillicothe Road
Aurora, OH 44202
(216) 562-9111

Phillips Manufacturing Co.
7334 N. Clark Street
Chicago, IL 60626
(312) 336-6200

Remo Equipment Corp.
32-34 Montgomery Street
Hillside, NJ 07205
(201) 687-6700

Exhaust Blowers
Buffalo Forge Co.
P.O. Box 985
490 Broadway
Buffalo, NY 14240
(716) 847-5121

Chicag Blower Corp.
1675 Glen Ellyn Road
Glendale Heights, IL 60139
(630) 858-2600

Garden City Fan
P.O. Box 760
1701 Terminal Road
Niles, MI 49120
(616) 693-1150

Fillers
Cuno, Inc.
400 Research Parkway
Meriden, CT 06450
(203) 237-5541

Millipore Corp.
Division of Service
Filtration Corp.
1234 Depot Street
Glencoe, IL 60025
(312) 798-9300

Sefarco
Division of Service
Filtration Corp.
1234 Depot Street
Glencoe, IL 60025
(312) 798-9300

John Crane-Houdaille
6400 Oakton Street
Morron Grove, IL 60053
(312) 967-2430

Federal-Mogul Corp.
Rubber and Plastics Group
P.O. Box 9966
Detroit, MI 48236
(313) 354-7700

Gatlock, Inc.
1250 Midtown Tower
Rochester, NY 14604
(716) 232-1400

Manville Corp.
P.O. Box 5108
12999 Deer Creek
Canyon Road
Denver, CO 80217
(303) 978-4900

RM Engineered Products Co., Inc.
P.O. Box 5205
4854 East O’Hear Avenue
North Charleston, SC 29406
(803) 744-6261

Hand Pumps
Baldwin Staats, Inc.
5254 Jackman Road
Toldeo, OH 43613
(419) 476-6546

Binks Manufacturing Co.
9201 W. Bermon Avenue
Franklin Park, IL 60131
(312) 571-3000

Blackmer Pump Co.
1809 Century Avenue, S.W.
Grand Rapids, MI 49509
(616) 241-1611

Graco, Inc.
P.O. Box 1441
Minneapolis, MN 55440
(612) 623-6000

Holpin Supply Co.
3804 S. Broadway Place
Los Angeles, CA 90037
(213) 252-3311

Sefarco
Division of Service
Filtration Corp.
1234 Depot Street
Glencoe, IL 60025
(312) 985-9300

Gaskets
Anchor Packag Co.
110 Keystone Drive
Montgomeryville, PA 18936
(215) 842-8700
<table>
<thead>
<tr>
<th>Company</th>
<th>Address and Phone Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solvent Resistant Grease Lubricants</td>
<td></td>
</tr>
<tr>
<td>Tower Oil &amp; Technology Company</td>
<td>205 W. Randolph Street, Chicago, IL 60656 (312) 346-0852</td>
</tr>
<tr>
<td>Spray Equipment</td>
<td></td>
</tr>
<tr>
<td>Binks Manufacturing Co.</td>
<td>9201 W. Belmont Avenue, Franklin Park, IL 60131 (312) 671-3000</td>
</tr>
<tr>
<td>Steam Condensate Return Pumps</td>
<td></td>
</tr>
<tr>
<td>American-March-Pumps, Inc.</td>
<td>722 Porter, Lansing, MI 48906 (517) 484-2100</td>
</tr>
<tr>
<td>Steam Controls, Pressure-Reducing Valves</td>
<td></td>
</tr>
<tr>
<td>A.W. Cash Valve Mfg. Co.</td>
<td>666 E. Wabash Avenue, Decatur, IL 62525 (217) 422-8574</td>
</tr>
<tr>
<td>Steam Traps</td>
<td></td>
</tr>
<tr>
<td>Armstrong Machine Works</td>
<td>816 Maple Street, Three Rivers, MI 49093 (616) 273-1415</td>
</tr>
<tr>
<td>Vent Driers for Bulk Tanks</td>
<td></td>
</tr>
<tr>
<td>Sentry Tank Accessories</td>
<td>3800 N. Cornad Street, Franklin Park, IL 60131 (312) 865-0575</td>
</tr>
<tr>
<td>Safety Containers</td>
<td></td>
</tr>
<tr>
<td>Eagle Manufacturing Co.</td>
<td>24th &amp; Charles Street, Weatsburg, WV 26070 (304) 737-3171</td>
</tr>
<tr>
<td>Leak-Proof Can Company</td>
<td>155 W. 84th Street, Chicago, IL 60620 (312) 224-4230</td>
</tr>
<tr>
<td>Justrite Manufacturing Company</td>
<td>2454 Dempster Street, Des Plaines, IL 60016 (312) 298-9290</td>
</tr>
<tr>
<td>Safety Thermostats</td>
<td></td>
</tr>
<tr>
<td>Honeywell, Inc.</td>
<td></td>
</tr>
<tr>
<td>Honeywell Plaza Minneapolis, MN 55408</td>
<td>(612) 870-5200</td>
</tr>
<tr>
<td>Johnson Controls</td>
<td>1250 E. Diehl</td>
</tr>
<tr>
<td>National Controls, Inc.</td>
<td>1460 Van Houten Avenue, Clifton, NJ 07015 (201) 471-3400</td>
</tr>
<tr>
<td>Toledo Scale Company</td>
<td>350 W. Wilson Bridge Road, Worthington, OH 43085 (614) 438-4511</td>
</tr>
<tr>
<td>Velasco Scale Company</td>
<td>P.O. Box 2230</td>
</tr>
<tr>
<td>Solenoid Valves</td>
<td>122 South Avenue A, Freeport, TX 77541 (409) 233-5461</td>
</tr>
<tr>
<td>Automatic Switch Company</td>
<td>50-60 Hanover Road, Norham Park, NJ 07932 (201) 966-2000</td>
</tr>
<tr>
<td>Magnatrol Valve Corp.</td>
<td>P.O. Box 17</td>
</tr>
<tr>
<td>Safety Valve Corp.</td>
<td>67 Fifth Avenue, Hawthorne, NJ 07507 (201) 427-4341</td>
</tr>
<tr>
<td>Strainers</td>
<td></td>
</tr>
<tr>
<td>Kaydon Corp.</td>
<td>P.O. Box 250, Greenville, TN 37744 (615) 638-8156</td>
</tr>
<tr>
<td>Neptune Measurement Co.</td>
<td>P.O. Box 792, Greenwood, SC 29648 (803) 223-1212</td>
</tr>
<tr>
<td>Rockwell International</td>
<td>400 N. Lexington Ave., Pittsburgh, PA 15208 (412) 247-3000</td>
</tr>
<tr>
<td>Vapor Degreasers Equipment</td>
<td></td>
</tr>
<tr>
<td>Baron-Blakeslee</td>
<td>2001 N. Janice Avenue, Melrose Park, IL 60160 (312) 450-3900</td>
</tr>
<tr>
<td>Branson Cleaning Equipment Company</td>
<td>P.O. Box 768, 1 Parret Drive, Shelton, CT 06484 (203) 929-7301</td>
</tr>
<tr>
<td>Branson Cleaning Equipment Co.</td>
<td></td>
</tr>
<tr>
<td>Bladeletone Ultrasonics, Inc.</td>
<td>1111 Allen Street, Jamestown, NY 14701 (716) 665-2620</td>
</tr>
<tr>
<td>Crest Ultrasonic Corp.</td>
<td></td>
</tr>
<tr>
<td>Detrex Corporation</td>
<td>Industrial Equipment Division 4000 Town Center Southfield, MI 48075 (313) 386-5600</td>
</tr>
<tr>
<td>Lewis Corporation</td>
<td>324 Christian Street, Oxford, CT 06483 (203) 264-3100</td>
</tr>
<tr>
<td>Phillips Manufacturing Co.</td>
<td>7334 N. Clark Street, Chicago, IL 60626 (312) 338-6200</td>
</tr>
<tr>
<td>Ramco Equipment Corp.</td>
<td>32-34 Montgomery Street, Hillside, NJ 07205 (201) 687-6700</td>
</tr>
<tr>
<td>S&amp;W Enterprises</td>
<td>P.O. Box 383</td>
</tr>
<tr>
<td>Talley Degreaser</td>
<td>P.O. Box 1208</td>
</tr>
<tr>
<td>Taylor Industries</td>
<td>P.O. Box 1278</td>
</tr>
<tr>
<td>Unique Industries</td>
<td>11544 Sheldon Street, Sun Valley, CA 91452 (213) 875-3810</td>
</tr>
<tr>
<td>Water Control Valve</td>
<td></td>
</tr>
<tr>
<td>Johnson Controls</td>
<td>1250 E. Diehl</td>
</tr>
<tr>
<td>National Controls, Inc.</td>
<td>1460 Van Houten Avenue, Clifton, NJ 07015 (201) 471-3400</td>
</tr>
<tr>
<td>National Controls</td>
<td>P.O. Box 150</td>
</tr>
<tr>
<td>National Controls, Inc.</td>
<td>9150 W. Wilson Bridge Road, Worthington, OH 43085 (614) 438-4511</td>
</tr>
<tr>
<td>Toledo Scale Company</td>
<td>P.O. Box 2230</td>
</tr>
<tr>
<td>Velasco Scale Company</td>
<td>122 South Avenue A, Freeport, TX 77541 (409) 233-5461</td>
</tr>
<tr>
<td>Solenoid Valves</td>
<td>50-60 Hanover Road, Norham Park, NJ 07932 (201) 966-2000</td>
</tr>
<tr>
<td>Automatic Switch Company</td>
<td>P.O. Box 17</td>
</tr>
<tr>
<td>Magnatrol Valve Corp.</td>
<td>67 Fifth Avenue, Hawthorne, NJ 07507 (201) 427-4341</td>
</tr>
<tr>
<td>Safety Valve Corp.</td>
<td>P.O. Box 17</td>
</tr>
<tr>
<td>Safety Valve Corp.</td>
<td>67 Fifth Avenue, Hawthorne, NJ 07507 (201) 427-4341</td>
</tr>
<tr>
<td>Strainers</td>
<td></td>
</tr>
<tr>
<td>Kaydon Corp.</td>
<td>P.O. Box 250, Greenville, TN 37744 (615) 638-8156</td>
</tr>
<tr>
<td>Neptune Measurement Co.</td>
<td>P.O. Box 792, Greenwood, SC 29648 (803) 223-1212</td>
</tr>
<tr>
<td>Rockwell International</td>
<td>400 N. Lexington Ave., Pittsburgh, PA 15208 (412) 247-3000</td>
</tr>
<tr>
<td>Vapor Degreasers Equipment</td>
<td></td>
</tr>
<tr>
<td>Baron-Blakeslee</td>
<td>2001 N. Janice Avenue, Melrose Park, IL 60160 (312) 450-3900</td>
</tr>
<tr>
<td>Branson Cleaning Equipment Co.</td>
<td>P.O. Box 768, 1 Parret Drive, Shelton, CT 06484 (203) 929-7301</td>
</tr>
<tr>
<td>Branson Cleaning Equipment Co.</td>
<td></td>
</tr>
<tr>
<td>Bladeletone Ultrasonics, Inc.</td>
<td>1111 Allen Street, Jamestown, NY 14701 (716) 665-2620</td>
</tr>
<tr>
<td>Crest Ultrasonic Corp.</td>
<td></td>
</tr>
<tr>
<td>Detrex Corporation</td>
<td>Industrial Equipment Division 4000 Town Center Southfield, MI 48075 (313) 386-5600</td>
</tr>
<tr>
<td>Lewis Corporation</td>
<td>324 Christian Street, Oxford, CT 06483 (203) 264-3100</td>
</tr>
<tr>
<td>Phillips Manufacturing Co.</td>
<td>7334 N. Clark Street, Chicago, IL 60626 (312) 338-6200</td>
</tr>
<tr>
<td>Ramco Equipment Corp.</td>
<td>32-34 Montgomery Street, Hillside, NJ 07205 (201) 687-6700</td>
</tr>
<tr>
<td>S&amp;W Enterprises</td>
<td>P.O. Box 383</td>
</tr>
<tr>
<td>Talley Degreaser</td>
<td>P.O. Box 1208</td>
</tr>
<tr>
<td>Taylor Industries</td>
<td>P.O. Box 1278</td>
</tr>
<tr>
<td>Unique Industries</td>
<td>11544 Sheldon Street, Sun Valley, CA 91452 (213) 875-3810</td>
</tr>
</tbody>
</table>
Economical and Efficient Vapor Degreasing with Chlorinated Solvents from Dow

DOW CHEMICAL U.S.A.
AN OPERATING UNIT OF THE DOW CHEMICAL COMPANY

AREA HEADQUARTERS OF THE DOW CHEMICAL COMPANY
DOW CHEMICAL U.S.A. .................................................. MIDLAND, Michigan 48674
DOW CHEMICAL LATIN AMERICA: ........................................... CORAL GABLES, Florida 33134
DOW CHEMICAL EUROPE, S.A. ................................................. 8810 HORGEN, Switzerland
DOW CHEMICAL PACIFIC LIMITED ........................................... P.O. Box 711, HONG KONG
DOW CHEMICAL CANADA INC. ............................................. SARNIA, Ontario, Canada N7T 7K7
DOW QUIMICA, S.A. .......................................................... SAO PAULO, Brazil

SALES OFFICES OF DOW CHEMICAL U.S.A.
ATLANTA .............................................................. Suite 2005, 20 Perimeter Center East, Atlanta, GA 30346
BATON ROUGE ......................................................... Suite 400, 2900 West Fork Drive, Baton Rouge, LA 70827
BOSTON ............................................................... Westborough Office Park, 1600 West Park Drive, Westborough, MA 01581
CHARLOTTE .......................................................... Suite 200, 5727 Westpark Drive, Charlotte, NC 28210
CHICAGO ............................................................. Suite 800, 10 Gould Center, 2850 Golf Road, Rolling Meadows, IL 60008
CINCINNATI ......................................................... Northmark Business Center, 10123 Alliance Road, Cincinnati, OH 45242
CLEVELAND ........................................................ 14955 Sprague Road, Strongsville, OH 44136
DALLAS .............................................................. Suite 1025—Lock Box 18, One Galleria Tower, 13355 Noel Road, Dallas, TX 75240
DENVER ............................................................... Suite 310, 6025 South Quebec Street, Englewood, CO 80111
DETROIT ............................................................... Suite 415, Travelers Tower, 26555 Evergreen Road, Southfield, MI 48076
GRAND RAPIDS .................................................. Suite 301, 2100 Raybrook S.E., Grand Rapids, MI 49506
HOUSTON ............................................................. Suite 300, 6050 Newcastle Road, Houston, TX 77042
INDIANAPOLIS .................................................. 9550 N. Zionsville Road, Indianapolis, IN 46258
KANSAS CITY ..................................................... Corporate Woods, Suite 160, 10890 Benson Drive, Shawnee Mission, KS 66210
LOS ANGELES ..................................................... Suite 110, 17870 Castleton St., City of Industry, CA 91747
MEMPHIS ............................................................. Suite 330, 6050 Primacy Parkway, Memphis, TN 38119
MINNEAPOLIS ..................................................... 11100 Bren Road West, Minnetonka, MN 55343
NEW YORK .......................................................... 500 West 57th Street, New York, NY 10019
PHILADELPHIA .................................................... Suite 100, 500 S. Lenola Road, Moorestown, NJ 08057
PITTSBURGH .................................................... Suite 1313, Four Gateway Center, Pittsburgh, PA 15221
RICHMOND ........................................................ 409202 Discovery Dr., Richmond, VA 23238
ROCHESTER ........................................................ 400 Perinton Hills Office Park, Fairport, NY 14450
ST. LOUIS .......................................................... 450 University Club Tower, 1034 S. Brentwood Blvd., St. Louis, MO 63117
SAN FRANCISCO ................................................ 2800 Mitchell Drive, Walnut Creek, CA 94598
SEATTLE .............................................................. Suite 522, 600-108th N.E., Bellevue, WA 98004
TAMPA ................................................................. Suite 450, 5100 W. Kennedy Boulevard, Tampa, FL 33609

NOTICE: Dow believes the information and recommendations herein to be accurate and reliable as of January, 1987. However, since any assistance furnished by Dow with reference to the proper use and disposal of its products is provided without charge, and since use conditions and disposal are not within its control, Dow assumes no obligation or liability for such assistance and does not guarantee results from use of such products or other information herein; no warranty, express or implied, is given nor is freedom from any patent owned by Dow or others to be inferred. Information herein concerning laws and regulations is based on U.S. federal laws and regulations except where specific reference is made to those of other jurisdictions. Since use conditions and governmental regulations may differ from one location to another and may change with time, it is the Buyer's responsibility to determine whether Dow's products are appropriate for Buyer's use, and to assure Buyer's workplace and disposal practices are in compliance with laws, regulations, ordinances, and other governmental enactments applicable in the jurisdiction(s) having authority over Buyer's operations.