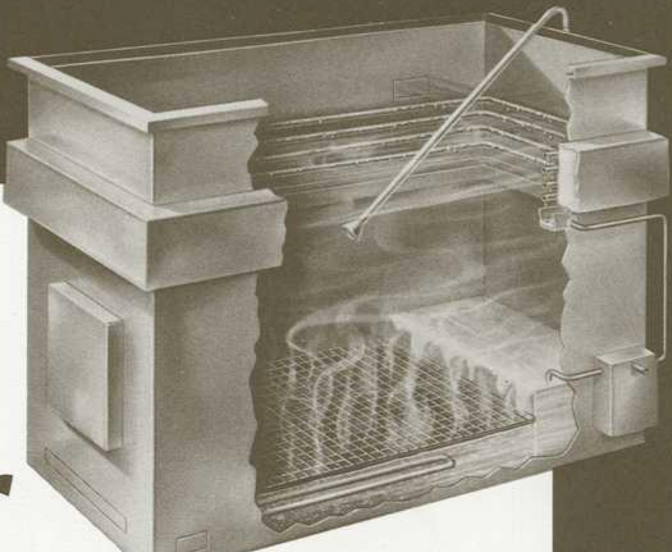
Manual on Vapor Degreasing



Third Edition

Manual on Vapor Degreasing
3rd Edition

Compiled by
ASTM SUBCOMMITTEE D26.02
ON VAPOR DEGREASING

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Foreword

This manual is a users' guide on the vapor degreasing process. Its contents have been developed by Subcommittee D26.02 on Vapor Degreasing and represents the Subcommittee's best technical knowledge. A complete list of the ASTM Committee D-26 full consensus standards appears in Table 1.

The procedures described herein may involve hazardous materials, operations, and equipment. This manual does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this manual to establish appropriate safety and health practices and determine the applicability of regulatory limitations before use.

This manual is the 3rd edition and was previously published as STP 310A. It is now designated as MNL 2. It has been updated to reflect advances in environmental and regulatory requirements.

TABLE 1. ASTM Standards on halogenated organic solvents.

Number	*Title*
	TEST METHODS FOR
D 2106	Acid Acceptance, Amine, of Halogenated Organic Solvents
D 2942	Acid Acceptance, Total, of Halogenated Organic Solvents (Nonreflux Methods)
D 3444	Acid Number, Total of Trichlorotrifluoroethane
D 2989	Acidity-Alkalinity of Halogenated Organic Solvents and Their Admixtures
D 2943	Aluminum Scratch Test for 1,1,1-Trichloroethane
D 3741	Appearance of Admixtures Containing Halogenated Organic Solvents
D 3443	Chloride in Trichlorotrifluoroethane
D 2108	Color of Halogenated Organic Solvents and Their Admixtures (Platinum-Colbalt Scale)
D 2251	Metal Corrosion by Halogenated Organic Solvents and Their Admixtures
D 2109	Nonvolatile Matter in Halogenated Organic Solvents and Their Admixtures
D 3445	Nonvolatile Matter in Trichlorotrifluoroethane
D 3742	1,1,-Trichloroethane Content
D 3979	Particulate Matter in Trichlorotrifluoroethane
D 2110	pH of Water Extractions of Halogenated Solvents and Their Admixtures
D 3447	Purity of Trichlorotrifluoroethane
D 1901	Relative Evaporation Time of Halogenated Organic Solvents and Their Admixtures
D 4494	Residual Odor in Drycleaning Grade Perchloroethylene Detecting

TABLE 1. ASTM Standards on halogenated organic solvents.

Number	*Title*
D 3448	Specific Aqueous Conductance of Trichlorotrifluoroethane
D 2111	Specific Gravity of Halogenated Organic Solvents and Their Admixtures
D 3316	Stability of Perchloroethylene with Copper
D 3446	Water Content of Trichlorotrifluoroethane with Karl Fischer Reagent
D 3401	Water in Halogenated Organic Solvents and Their Admixtures
D 2988	Water-Soluble Halide Ion in Halogenated Organic Solvents and Their Admixtures
	GUIDE FOR
D 3640	Emission Control in Solvent Metal-Cleaning Systems
	PRACTICES FOR
D 4276	Confined Area Entry
D 4579	Handling an Acid Degreaser or Still
D 3844	Labeling Halogenated Hydrocarbon Solvent Containers
D 3698	Solvent Vapor Degreasing Operations
	SPECIFICATIONS FOR
D 4081	Drycleaning Grade Perchloroethylene
D 4126	Vapor-Degreasing Grade and General Solvent Grade 1,1,1-Trichloroethane
D 4079	Vapor-Degreasing Grade Methylene Chloride
D 4376	Vapor-Degreasing Grade Perchloroethylene
D 4080	Vapor-Degreasing Grade Trichloroethylene

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INTRODUCTION

This *Manual on Vapor Degreasing* is presented as a guide to consumers who desire the essential information on the vapor degreasing process. The information contained should help to determine if the vapor degreasing process is best suited for the particular cleaning requirements. Consumers who are currently operating vapor degreasing equipment will benefit by the following procedures recommended. The benefits will be reflected in better cleaning, lower cost, and greater safety. The manufacturers of vapor degreasing equipment and degreasing solvents maintain trained technical staffs who should be consulted for advice on specific applications and problems.

Existing and proposed state and federal regulations require specific operating procedures and equipment. The information in this manual is presented in good faith, but users should rely on their own legal advisors to assure compliance with these regulations.

The manual is sponsored by ASTM Committee D-26 on Halogenated Organic Solvents.

PROCESS DESCRIPTION

Vapor degreasing is a physical method of removing solvent soluble soils and other entrapped soils from metal, glass, and other essentially nonporous objects. By bringing the soiled articles at room temperature into contact with hot solvent vapor, the vapor condenses to a liquid on them. Sufficient liquid solvent is formed to carry the soluble and insoluble soils away as the solvent drains by gravity.

Solvents used in this process are methylene chloride, perchloroethylene, 1,1,1-trichloroethane, trichloroethylene, and trichlorotrifluoroethane.

In its simplest form (as shown in Fig. 1*a*), a solvent vapor degreaser is a tank with a heat source to boil the solvent and a cool surface to condense the vapor in the upper section. The soiled articles are suspended in this air-free zone of solvent vapor. The hot vapor condenses onto the cool parts, dissolving oils and greases providing continuous rinse in clean solvent.

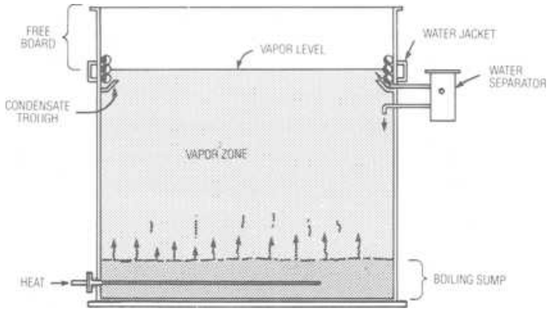


FIG. 1*a*—Vapor only degreaser.

As the condensed solvent drains from the part, it carries off the soils and returns to the boiling liquid reservoir. This vapor treatment is often augmented by mechanical action such as liquid immersion (Fig. 1*b*), ultrasonic agitation (Fig. 1*c*), or spraying the work (Fig. 1*d*) with liquid solvent beneath the vapor level. The work is held in the vapor zone for final rinsing until the parts reach vapor temperature, at which time the condensation stops. The articles dry immediately within the machine as they are withdrawn from the vapor. The process is a safe, rapid, economical procedure for preparing clean, dry articles for subsequent finishing or fabricating, usually without further treatment.

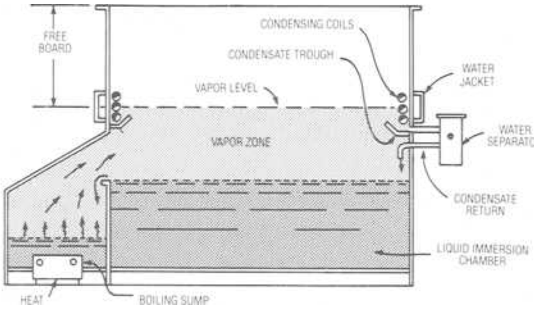


FIG. 1*b*—Liquid-vapor degreaser.

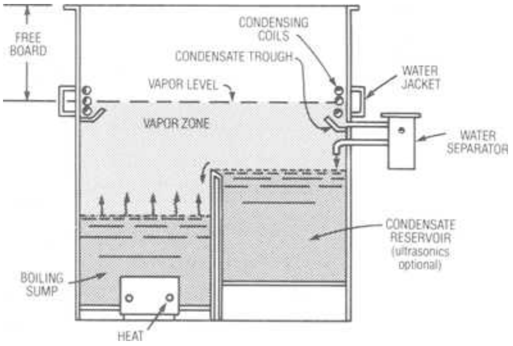


FIG. 1*c*—Liquid-liquid-vapor degreaser.

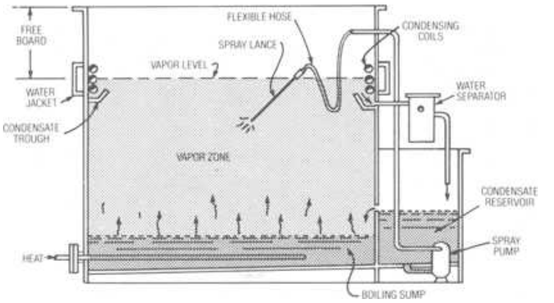


FIG. 1*d*—Perimeter condensing vapor-spray-vapor degreaser.

APPLICATIONS

Material to be Cleaned

The vapor degreasing process is applicable to cleaning all of the common industrial metals: malleable, ductile, and gray cast iron; carbon and alloy steel, stainless steel; copper; brass; bronze; zinc; aluminum; magnesium; tin; lead; nickel; and titanium. Because the process cleans by solvent action rather than by chemical reaction, with proper solvent maintenance, there is no danger of etching or other chemical attack on highly polished or delicate metal surfaces. It is also used to clean articles and workloads containing parts of different metals and assemblies. In addition to removing contaminants from metal, vapor degreasing has been employed for cleaning glass, ceramics, plastics, elastomers, coated items, and combinations thereof, that are not affected by the solvent.

Shape, Form, and Size of Work to be Cleaned

The vapor degreasing process is adaptable to parts of a wide range of sizes and shapes through the choice of cleaning cycle and proper work handling. The process is used to clean parts ranging from the size of minute transistor components to large aircraft sections, diesel engine traction motors, or 100-ft (30.5-m) tube lengths. Because of the short cleaning-and-drying cycle, the process is used also to clean metal strip and wire at high speeds.

Successful application of vapor degreasing for various sizes and shapes depends principally on the choice of the proper cleaning cycle, whether it be vapor only, spray-vapor, or liquid immersion-vapor cycle. Extremely small parts can be readily handled in laboratory-size units or, where the volume warrants, in standard manual or conveyorized equipment. Because the process requires only a single tank large enough to accommodate the load, massive parts can be cleaned, rinsed, and dried with a minimum amount of floor-space requirement.

Because the solvent and solvent vapor penetrate rapidly, the process is particularly adaptable to parts containing recesses, blind holes, perforations, crevices, and welded seams. For parts of complicated design or small parts that tend to nest, provisions are made, either through racking or basket rotation (see Fig. 6) to make the load essentially free-draining to avoid dragout of the liquid solvent. In some complicated assemblies, the process is often supplemented by ultrasonic cleaning in the rinse chamber to aid in removing troublesome soils from critical surfaces.

Types and Amount of Soils to be Removed

The lubricants used in metal fabrication are usually soluble in the solvents commonly used in the vapor degreasing process. Dissolving of the soil by the solvent is a physical action. At the boiling temperature of the solvent, these contaminants are rapidly dissolved and are effectively flushed away with any adhering dirt or insoluble soil. Where necessary, this flushing action is augmented by immersion in vigorously boiling solvent or by sprays with clean, warm solvent or with ultrasonic agitation. With the right cycle, the process is used to remove stamping oils, machining oils, polishing and buffing compounds, drawing compounds, quenching oils, water, and so forth. With the buffing and polishing compounds that oxidize during storage before cleaning, a predip in solvent is sometimes employed to wet and loosen the buffing compound before going through the degreasing cycle.

Vapor degreasing, as a cleaning process, is used frequently in maintenance operations. The soil removed in these operations varies even more widely, for example: tar, lubricating greases, motor oil, varnish from oxidized oil, carbon, sand, and road salts. The last three soils are insoluble but are often removed partially by dissolving the soluble soils. Even when insolubles are not removed fully, subsequent cleaning steps, such as bead blasting or alkaline washing, are made more efficient by the absence of oil and grease.

Solid particles, such as metal dust or chips, held on the surface along with inorganic salts, are removed effectively following the washing action of the solvent as it dissolves the oil or grease.

Process Limitations

The process may be ineffective in removing contaminants that are insoluble in the solvent or do not contain sufficient solvent-soluble material to be effectively loosened and flushed away with the boiling solvent or solvent spray. This would include metallic salts; metallic oxides; sand; forging, heat treatment, and welding scale; certain carbonaceous deposits; and many of the inorganic soldering, brazing, and welding fluxes.

Halogenated solvents should not be used to remove contaminants, such as strong alkalies and acids, that would react with the solvent.

Degree of Cleanliness Required

Of the many factors in choosing a metal cleaning method, the degree of cleanliness required is perhaps the prime consideration. By selection of the proper solvent and cleaning equipment best suited to the shape of the work and the contaminants involved, the desired degree of cleanliness can usually be attained with the degreasing process. Solvent-soluble soils can be completely removed, and the insoluble soils flushed off. Because the final cycle in the process is a rinse in pure solvent vapors, no soluble residues will remain on the part nor will soil be redeposited.

A dry surface, free from organic contamination, is produced by this process. As a result, the vapor-degreased part is suitable for many subsequent finishing operations without further treatment. A grease-free surface is ideal for enameling, painting, lacquering, and phosphatizing to give proper binding of the primer paint or other finish to be applied. Before electroplating, the removal of oil and grease prevents organic contamination of the plating tanks. In this application, it is followed frequently by mild electrolytic cleaning or an acid dip. Other applications are cleaning before heat treating, assembly, inspection, and testing.

The proper cycle to obtain the desired cleaning results can be determined by small-scale experiments. Where the mechanical action of the boiling solvent or warm liquid sprays will not give the required cleanliness, the use of ultrasonic energy can supplement cleaning.

Cleaning Limitations

The limits of the degree of cleanliness attainable by the process are as follows:

1. For some applications, it may get the parts "too clean" because of its thorough removal of oil and grease. Thus, after degreasing, mild steel parts have no protective film remaining. If a period of storage is contemplated after cleaning, a suitable rust preventative may be required.

2. The process does not produce a surface that will pass the "water-break" test (see *Note*). Thus, for cleaning requirements that necessitate essentially complete freedom from water-soluble, solvent-soluble, and chemically combined contaminants, vapor degreasing may be followed by water rinsing to remove traces of water-soluble soils and oxidation and reduction steps to remove any oxides or sulfides, and so forth, from the surface.

Note—The "water-break" is used to detect the presence of organic contaminants on a metal surface. This test indicates a hydrophillic surface rather than cleanliness. The surface is immersed in a beaker of overflowing deionized water (or tap water free of contaminants), removed vertically, and the draining water film observed. On a surface with organic (hydrophobic) matter, the water film will tend to break up and withdraw into wetted areas and expose areas not wetted.

If the surface is free of hydrophobic materials, the water film drains as a thin, uniform layer. The presence of wetting agents in the water or on the surface will give erroneous results.

Space Requirements

The equipment is compact and requires a minimum of building space. Because the process requires that the workload be lowered completely below the vapor level, vertical-dimension requirements will be in excess of twice the vertical dimension of the workload. In areas of low ceiling heights, the degreaser usually is installed in a pit. Generally, this process is particularly adaptable where floor space is limited, such as in adding cleaning steps to an existing production line or in expanding plants or in new plants where the building area proves costly.

Adaptability to Conventional Conveying and Work-Handling Methods

The process is adaptable to most conventional conveying and work-handling methods. In manual operations, control of workload speed usually is accomplished by hoists that limit the vertical speed to 11 ft/min (3.3 m/min).All of the vapor degreasing cycle combinations can be reproduced on a continuous basis, and because cleaning is achieved by physical rather than chemical means, consistent cleaning can be obtained with a minimum of operator attention.

In conveyorized crossrod degreasers, work containers can be transferred automatically from a roller conveyor. Often the use of rotary fixtures allows small parts to be cleaned in their work containers without the necessity of transferring before and after the cleaning process. Large parts can be handled on a monorail conveyor (Fig. 2); where floor space is limited, a U-bend construction may be used, allowing parts to enter and exit the same end.

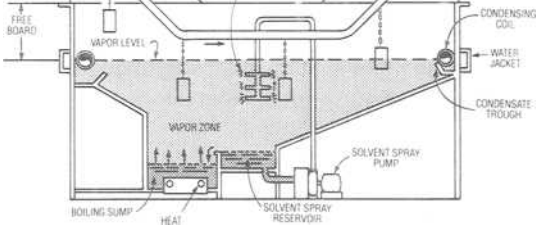


FIG. 2—Vapor-spray-vapor monorail degreaser.

Total Cost to Attain Desired Cleaning Results

The overall objective in selecting a metal cleaning process is to choose one that will give the desired cleaning results consistently and safely at a minimum cost. To determine overall cost, comparison of a specific cleaning method with other cleaning processes requires consideration of all of the factors involved that contribute to the total cost. In addition to the costs of chemicals or solvent, other operating costs, including utilities, labor, maintenance, investment carrying costs, and building space must be considered. In many instances, vapor degreasing is the most economical cleaning method.

Summarizing, the cost factors favoring vapor degreasing are as follows: low energy requirements, low equipment investment, low floor space requirements, no drying equipment required, and consistent cleaning quality attainable with a minimum of control. This process eliminates the cost of wastewater treatment, and with solvent distillation, reduces waste disposal to a minimum.

Typical Uses for Vapor Degreasing

Before Applying Protective Coatings

It is used extensively before the application of protective or decorative finishes, or both.

1. Before painting, enameling, or lacquering, clean surfaces give good adhesion of finishes. Since vapor degreasing leaves the metal dry, it is particularly suitable for preparing surfaces for many finishes.

2. Before electroplating, degreasing is used for removing large amounts of mineral oil contamination prior to electrocleaning and subsequent electroplating.

Before Inspection

Inspections may be numerous, making speed and ease of handling very important. Inspection profits from the visually clean surface provided by vapor degreasing without extensive rinsing or drying.

Before Assembly

Assembly requires that parts be free from inorganic contamination as well as from grease and oil. The vapor process leaves the parts clean and dry, ready for assembly and subsequent finishing.

Before Further Metal Work or Treatment

In many cases, parts must be prepared for a subsequent operation such as welding, heat treatment, or further machining. Vapor degreasing between steps allows the operator to start each new step with clean, dry parts. Before heat treatment, all traces of processing oils should be removed from surfaces; their presence can cause smoking and nonuniform hardening.

Before and After Machining

By starting a machining operation with a clean metal surface, the chances of carrying imperfect parts through to other operations are minimized. Cutting oils give best results when used on clean surfaces. After machining, oil and grease can be readily removed by degreasing, which also facilitates chip removal.

Before Packaging

Final cleaning in a degreaser prepares parts for packing and shipping. Nonferrous metals, such as copper and aluminum, and decorative plated surfaces of chromium, zinc, and silver, are left clean, bright, and shiny.

SELECTION OF A VAPOR DEGREASING SOLVENT

Appropriate characteristics for solvents to be used in the vapor degreasing process are as follows:

1. Solvency for the removal of oils, greases, and other contaminants commonly encountered. The contaminants must dissolve rapidly and completely in the solvent at or near its boiling point.

2. Nonflammable under normal operating conditions and as determined by ASTM test methods for flash point.

3. A low latent heat of vaporization and a low specific heat. These properties permit the maximum amount of solvent to condense on a given weight of metal and to keep the heat requirements to a minimum. In addition to heating the workload up to the temperature of the vapor, a large part of the heat is used to distill the solvent continuously to provide clean solvent for spraying or rinsing.

4. A vapor density greater than air. When the vapors are heavier than air, they can be maintained in the degreaser with minimum of loss.

5. Chemical stability under conditions of use. The degreasing solvent must be able to withstand all of the stresses encountered in vapor degreasing. This includes exposure to heat, light, air, metal chips and fines, acidic salts, mildly alkaline and acidic metalworking lubricants, and moisture that may be brought in with the work or from atmospheric condensation. Resistance to these stresses can either be part of the inherent properties of a solvent or be accomplished through the addition of suitable stabilizers.

6. Compatible with all of the matarials being cleaned and those used in the degreaser construction even after continuous use and redistillation.

7. A boiling point low enough to permit the solvent to be easily separated from oil, grease, or other contaminants by simple distillation. A low boiling point also serves to keep the temperature of the degreased work at a reasonable level for subsequent handling.

8. The boiling point should be high enough so that sufficient vapors will be condensed and the vapor level controlled with the available cooling means.

9. Solvent supply should be readily available.

10. Environmentally controllable under normal operating conditions of the vapor degreasing process. With proper operation and properly designed equipment, solvent vapor concentration in the working atmosphere at the degreaser should be able to be maintained within the recommended Occupational Safety and Health Administration (OSHA) standards. The solvent of choice must be used in compliance with all federal, state, and local regulations, and industry recommendations for proper use and handling.

All of the factors just listed and the

properties listed in Table 1 should be considered in conjunction with the solvent or equipment supplier in making final choice of solvent.

VAPOR DEGREASING EQUIPMENT

There is a variety of cleaning cycles that can be used in vapor degreasing. To select the proper cycle for a specific cleaning application, consideration should be given to the nature and number of parts, type of soil, the method of handling the parts, and any physical limitations such as floor space, ceiling height, and so forth. Following is a discussion of the advantages and limitations of the most commonly used cycles. It is to be noted that in all cases, the cycles are arranged so that a final vapor distillate rinse is obtained. Usually, the choice of cleaning cycle can be confirmed by test cleaning in a supplier's laboratory.

Straight Vapor Degreasing

In the straight vapor cycle, all cleaning results from the condensation of the solvent vapors on exposed surfaces of the parts. Condensation continues until the part is heated to the vapor temperature. The condensed solvent dissolves the contamination and, as it drips from the part, carries away the soil.

As lighter gage metals heat more rapidly, a limited flow of condensate is obtained on such work. This cycle is usually satisfactory for the removal of oils and greases that are completely, or nearly completely, soluble in the degreasing solvent. The mass of the part, gage of the metal, and its specific heat must be given due consideration and checked to be sure that sufficient distillate will be condensed to provide adequate cleaning. Only that amount of solvent that condenses on a part is available for cleaning. Therefore, parts must be definitely separated and so arranged that the condensation from one part does not drain or drip over other parts.

Vapor-Distillate Spray-Vapor Degreasing

When insoluble soils, such as shop dirt, chips, and partially soluble contaminants, such as polishing, buffing, and pigmented drawing compounds are present on the surface of the work to be cleaned, additional cleaning can be obtained by augmenting the vapor cycle with a spray of clean solvent over the work surface. In this simple form of vapor-distillate spray-vapor

TABLE 1. Physical properties of vapor degreasing solvents.

Property	Methylene Chloride	Perchloroethylene	1,1,1-Trichloroethane	Trichloroethylene	Trichlorotrifluoroethane (CFC-113)[a]
Boiling point, °F (°C)	104 (40)	250 (121)	165 (74)	188 (87)	118 (48)
Latent heat of vaporization (boiling point), Btu/lb (kJ/kg)	142 (330)	90 (209)	102 (237)	103 (240)	63 (147)
Specific heat (liquid)					
Btu/lb, °F (kJ/kg °C)	0.28 (1.2)	0.21 (0.88)	0.25 (1.0)	0.23 (0.96)	0.21 (0.88)
Specific gravity					
vapor (air = 1.00)	2.93	5.73	4.55	4.54	6.47
liquid (water = 1.00)	1.33	1.62	1.33	1.46	1.57
Liquid density, lb/gal (g/cm^3) at 77°F (25°C)	11.0 (1.32)	13.5 (1.62)	11.0 (1.32)	12.1 (1.45)	13.2 (1.58)
Vapor density at boiling lb/ft^3 (g/L)	0.206 (3.30)	0.320 (5.13)	0.291 (4.67)	0.278 (4.45)	0.462 (7.40)
Freezing point, °F (°C)	−142 (−97)	−8 (−22)	−34 (−37)	−123 (−86)	−31 (−35)
Coefficient of cubical expansion avg: per °C liquid	0.00137	0.00102	0.00125	0.00117	0.00160
Applicable range, °C	0 to 40	0 to 25	0 to 30	0 to 40	0 to 40

[a] Azeotropes of CFC-113 are also available. Other constant boiling mixtures are also used.

cleaning, exceptional results are accomplished by the spraying of comparatively small quantities of distillate over the work (see Figs. 1*d* and 3). It must be noted that normally 1 or 2 gal/min (4 or 8 L/min) of distillate is available for spraying. Therefore, the size of the parts and rate of production are very limited.

This cycle is accomplished usually in hand-operated equipment and occasionally on limited production of reasonably small parts in conveyorized units. This cycle also has the advantage that no recontamination can take place as only pure condensate is used for cleaning.

Vapor-Immersion-Vapor Degreasing

If the amount of oils and greases is heavy in proportion to the condensing capacity of the work being cleaned, or if the contour of the parts is intricate, immersion in an adequate volume of solvent usually is required to produce intimate solvent contact with the work. This method of cleaning is also preferred when the work is of the type that can be handled in bulk containers or baskets, resulting in most pieces being closely nested in the container. Figure 1*b* illustrates this cycle. The basic cycle used is immersion in boiling solvent, immersion in a cool, relatively clean rinse, followed by a final vapor rinse, and drying.

In some instances, it is desirable to eliminate the immersion in the contaminated boiling solvent.

Vapor-Spray-Vapor Degreasing

Some soils are only partially soluble in the solvents, such as polishing, buffing, and drawing compounds. Vapor degreasing alone may remove the lubricant but leave the insoluble compounds on the work part surface. Vapor-spray-vapor degreasing is the preferable cleaning cycle for such soils or for parts too large to immerse. In this cycle, the relatively large quantities of solvent required for the spray are supplied by the use of a separate sump circulating relatively clean solvent. Figure 2 illustrates this cleaning cycle.

The work should be sprayed with an adequate volume of solvent as soon as it is immersed in the vapor to obtain satisfactory cleaning. This is particularly important where the insoluble compounds or soil may set up or bake on the item being cleaned.

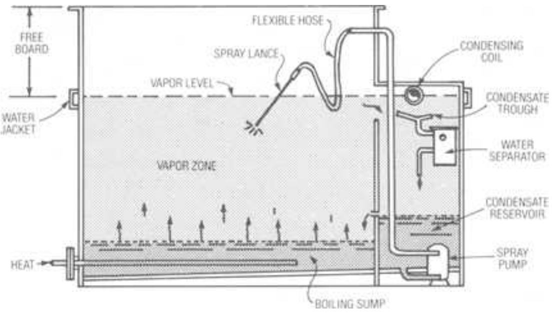


FIG. 3—Offset condenser vapor-spray-vapor degreaser.

This cycle is applied to almost all high-volume production cleaning requirements of metal objects as well as castings and large weldments where all of the significant surfaces can be reached with the sprayed solvent. The large-volume, forceful spray removes soluble and insoluble soils readily. Nozzles can be arranged to break air pockets, and this provides both spray and vapor cleaning in enclosed cavities.

Ultrasonics

Ultrasonic energy exists in a liquid as alternate rarefactions and compressions of the liquid. During rarefaction, small vacuum cavities are formed that collapse, or implode, during compression. This continuing rapid process, called cavitation, is responsible for the scrubbing effect that produces ultrasonic cleaning.

The ultrasonic energy is created within a liquid by means of transducers that convert electrical energy into acoustic energy. These transducers are similar in function to a radio speaker except they function at ultrasonic frequencies and transmit acoustic energy to a liquid rather than to air. The transducers are usually bonded to the underside of the tanks containing the cleaning liquid or are encased in stainless steel for immersion within a liquid. The transducers are energized by an electronic generator. The generator transforms the electrical current for efficiently energizing the transducers at the desired frequencies.

All ultrasonic cleaning systems consist of the four fundamental components of transducer, generator, container for liquid, and cleaning liquid. The overall effectiveness of the cleaning is dependent upon the size or quantity of the parts being cleaned. The number of transducers and generators is determined by the tank size. The choice of cleaning liquid depends on the parts being cleaned and contaminant to be removed.

Frequency affects cleaning efficiency by determining the cavity size. Low frequencies generate large but relatively few cavities with high cleaning power. High frequencies generate a great number of small cavities with good penetrating capability. The selection of the correct frequency is difficult for it varies with each cleaning application and should, therefore, be selected on the basis of tests.

Ultrasonic cleaning should be considered for accelerated cleaning or when the degree of cleanliness required is beyond that which is normally obtained from any of the foregoing degreasing cycles. Usually, it is used when it is required to remove very finely divided insolubles or to accelerate the cleaning process.

Ultrasonic energy, at the proper frequency, produces an energy form that is able to attack and remove strongly adherent soils on remote surfaces and in blind holes.

Other Cleaning Cycles

Combinations of these basic cleaning steps can be incorporated to fit any cleaning requirement. The safest means of determining the proper cleaning cycle for any cleaning requirement is by demonstration and test. If degreasing equipment of various design is not available for testing, the assistance of experienced equipment or solvent manufacturers should be solicited so that proper tests can be made.

Specialized Equipment and Methods of Handling

Common work-handling methods are applicable to most of the degreasing cycles. This includes the following:

(1) manual or automatic hoist, or both,
(2) monorail (Fig. 2),
(3) crossrod (Fig. 5),
(4) ferris wheel (Fig. 6),
(5) vibra (Fig. 7), and
(6) elevator.

In addition, specialized equipment has been developed that has specific application to vapor degreasing. When work is of the type or configuration that cannot be placed so that it will be cleaned or drained, or both, it should be rotated in immersion-type degreasing equipment. If the surface finish is such that it would be damaged by bulk handling, the work can be placed in trays holding each piece individually and these trays inserted into fixtures that would revolve the tray and the work.

Complicated and intricately cored castings can be handled in rotating fixtures to provide excellent cleaning results and complete drainage in any of the immersion cleaning cycles.

Wire mesh belt conveyors can be used to clean miscellaneous small parts in equipment employing the vapor, vapor-spray-vapor, or immersion cycles.

Manual spray equipment is applied usually where the total volume of work to be cleaned is small or the workloads are intermittent. Conveyorized equipment is preferred whenever it can be economically justified. The elimination of human error results in consistent cleaning results and maximum economy.

Degreasers are installed easily in continuous production lines and can be readily automated because of the variety of handling means that can be incorporated into specially designed degreasers, eliminating all direct labor and handling.

Method of Heating

After the proper cleaning cycle and type of machine have been selected, the utilities available for heating the solvent must be considered.

If steam is available as a plant utility or can be economically generated, it is preferable to install a steam-heated degreaser. If steam is not available on a year-round basis, equipment can also be heated by electricity, gas, or circulating hot water.

Heat pump systems, requiring electricity as the only utility, are also available for use with low boiling point solvents.

EQUIPMEMT DESIGN REQUIREMENTS

Both state and federal regulations specify design parameters and associated equipment for solvent emission control and safety. The recommendations offered in this section are based on good engineering and experience, but do not guarantee compliance with national or local regulations, or both.

Equipment design follows the selection of a cleaning cycle and work handling method. Important design considerations to achieve effective, economical, and safe operation are summarized below.

Size of Equipment

The size of the tank is determined by the dimension of the largest workload that will be suspended from the hoist or conveyor. Open tanks require at least 50% greater vapor or working area than that required for the size of the largest part. Otherwise, the work going in and out will act as a piston to displace solvent vapors out of the machine.

Freeboard for Open Top Vapor Degreaser

Freeboard is the distance from the top of the vapor level to the top of the degreasing tank. Industry-wide tests, as well as emission control tests sponsored by the U.S. Environmental Protection Agency (EPA), show that for open top degreasers, solvent losses decrease as the freeboard height-to-width ratio increases. Federal and state regulatory agencies are now requiring at least a 0.75 ratio in their proposed regulations. Most degreaser manufacturers are using the 0.75 ratio as a minimum. In certain cases, where a very large, square degreaser is required, it is impossible and impractical to follow this formula. Unless regulations prohibit it, a maximum freeboard height of 4 ft (122 cm) is reasonable. Equipment should not be modified so as to decrease the designed freeboard ratio.

Minimum Evaporative Area

Air-vapor interface area must be kept to a minimum consistent with the warning about piston effect if the tank is too small. Various devices for reducing the area can be designed into conveyorized equipment.

Heat Input

The amount of heat required depends on the weight and specific heat of the work to be cleaned, radiation losses of the tank, amount of heat desired for the distillation rate or for the sprays, and the solvent selected for use.

Work Heat

The hourly solvent heat requirements in British thermal units (Btu's) is calculated by multiplying the pounds of work to be cleaned per hour by the specific heat of the metal and the temperature rise from room temperature to the boiling point of the solvent in degrees Fahrenheit. Normally, a 50% safety factor is added to this figure. For large workloads, two sets of heating coils can be provided: one to maintain a constant vapor level, the second to compensate for the work "shock loads."

Every effort must be made to maintain a constant vapor level to avoid pumping action resulting in solvent-laden air being expelled from the tank. Sufficient heat input capacity should be provided so that the top of the work will be covered with vapors as quickly as possible for efficient vapor condensation and degreasing.

Radiation Losses

Heat input requirements should consider radiation losses from bare tank walls at boiling solvent temperatures into a 70°F (21°C) room temperature. These losses can be minimized by insulating the degreaser.

Heat for Distillate

The cleanliness of the sump in which the work is dipped or from which the sprayed solvent is obtained depends on the amount of distillate solvent flowing into them. The solvent from such sumps overflows to a vapor generating or boiling sump. The concentrated oil/solvent mixture from boiling sump is often pumped to a still, and the distillate from such still is returned to the sump requiring the cleanest solvent. The gallonage of clean solvent distillate entering the cleanest sump is set, and the heat required for this gallonage is added to total heat input requirement.

Types of Heat Input

Steam Heat

Heat is applied to the solvent by means of immersion steam coils, plate coils, or steam jackets forming the bottom of the tank. Pressures required for various solvents are shown in Table 2. As the concentration of oil in the solvent increases, the boiling temperature increases; thus, the steam pressure required increases. Therefore, as the contamination level of the solvent increases, it is necessary to increase the steam pressure to achieve the same distillation rate.

Gas Heat

Gas heating is accomplished with immersion gas coils in the solvent. The burner should be equipped with automatic pilot protection to provide for shutdown of all gas within 45 s after pilot failure. Gas burning capacity generally is double for that calculated for steam to allow for combustion inefficiency and flue stack losses. With a gas-fired unit, hot spots must be avoided, flue stacks must be insulated, and some means of preventing back draft must be incorporated.

Electric Heat

Electric heat is usually accomplished by means of immersion heaters in the solvent. Small units, requiring low heat input may be heated by strip heaters fastened to the underside of the tank. *Caution*: immersion-type heaters are of a type to give low watt density (20 W/in.^{2} or 3.1 W/cm^2). The equipment must be designed to maintain sufficient solvent liquid level to minimize danger of electric heater elements being exposed above the liquid. Exposed elements will cause heater failure and solvent decomposition, which produces toxic and corrosive products.

Hot Water Heat

Pressurized hot water pumped through immersion coils is also a satisfactory method of heating degreaser equipment. Temperatures and pressures recommended are shown in Table 3.

Heat Pump

Heat recovery vapor degreaser systems based on heat pump technology are available for use with low boiling point solvents. The system employs a refrigeration system for condensing, and uses the recovered heat from the coolant and from the compressor to boil the solvent. The only utility required is electricity. Some low boiling point solvents used in heat pump degreasers are trichlorotrifluoroethane, methylene chloride, and their azeotropes, and blends with alcohols, ketones, and esters. These offer a broad range of cleaning capabilities for specific applications. The cleaning of heat-sensitive parts and difficult cleaning jobs requiring polar solvents are typical examples. In all cases, where heat pumps are used, it is important to have enough available energy to maintain a constant distillation rate, even at 50 wt% contamination of the solvent.

Vapor Control

The control of the degreaser is essentially the control of the solvent vapor. The control of vapors at the desired vapor level is

TABLE 2. Pressures required for various solvents.

	Boiling Point		Steam Pressure	
Solvent	°F	°C	psig	kPa
Methylene chloride	104	40	1–3	7–21
Perchloroethylene	250	121	40–60	276–414
1,1,1-Trichloroethane	165	74	1–6	7–41
Trichloroethylene	188	87	5–15	34–103
Trichlorotrifluoroethane	118	48	1–3	7–21

TABLE 3. Temperatures and pressures recommended for hot water heat.

Solvent	Water Temperature °F	Water Temperature °C	Pressure psig	Pressure kPa
Methylene chloride	200	93	atmospheric	
Perchloroethylene	300–325	149–163	70–105	483–724
1,1,1-Trichloroethane	230–270	110–132	20–50	138–345
Trichloroethylene	250–300	121–149	25–70	172–483
Trichlorotrifluoroethane	200	93	atmospheric	

accomplished by the flow of water or other coolant through coils and a jacket around the walls. See Page 15 for recommended thermostat settings.

Water Jacket

A welded jacket is sometimes used around the tank perimeter at the vapor level. The prime function of the jacket is to keep the wall of the freeboard zone cool to prevent vapors from rising because of convection.

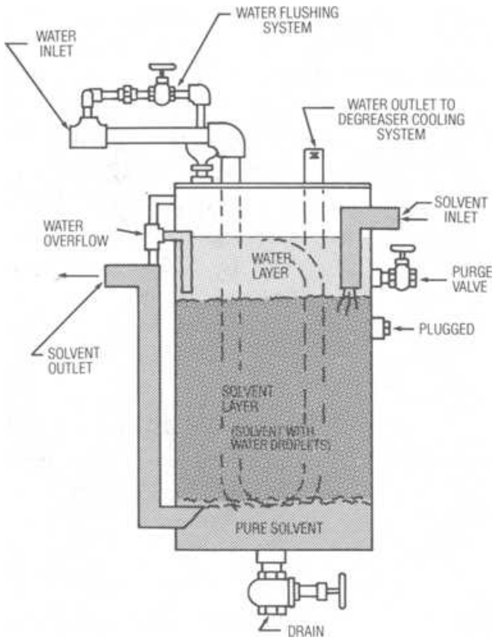
Cooling Coils

Coolant flows through closely spaced turns of pipe positioned to control the vapor level of the degreaser. These can consist of either a helical coil positioned in an offset compartment leaving a clear sidewall within the degreaser body or multiple passes can be provided around the inside perimeter of the tank.

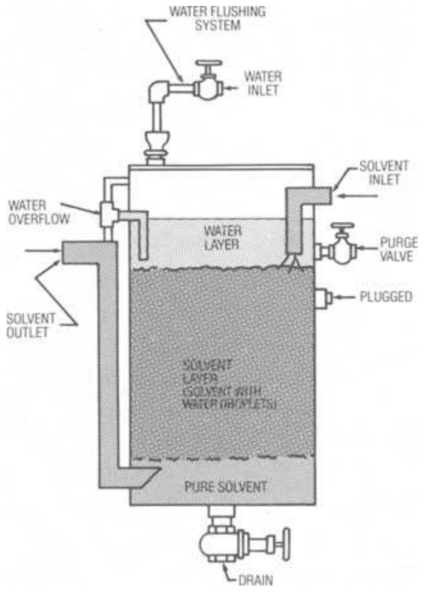
Moisture Removal

A properly designed water separator (see Fig. 4) on the distillate line keeps the moisture content at a low level. It is important that sufficient depth and volume be provided so that there is adequate residence time for gravity separation of the water. This moisture control can be improved further by lowering the temperature of the distillate with suitable cooling. Cooled condensate encourages better separation of water in the separator.

When operating a vapor degreaser or still equipped with a conventional water separator, conditions exist where some of the active ingredients of fluorocarbon admixtures can be extracted by condensing water vapors. This may render the product ineffective. Therefore, it is advisable to re-



WATER SEPARATOR WITH COOLING COIL.



WATER SEPARATOR LESS COOLING COIL.

FIG. 4—Water separator.

place the water separator with a molecular sieve solvent dryer when fluorocarbon admixtures containing water-extractable components, such as aliphatic alcohols, are being used. For equipment already in place in the field, it is often possible to either add a molecular sieve dryer or to convert the water separator into one.

Conveyor Systems

Monorail Degreaser

A number of different types of monorail systems are in use (Fig. 2). Design speeds usually are for a maximum of 11-ft/min (3.3-m/min) vertical travel. Design should attempt to keep the conveyor above the vapor level in passing through the degreasing equipment. If this is not possible, provisions should be made for automatic lubrication.

Crossrod Degreaser

A crossrod conveying system consists of two parallel strands of chain connected at intervals by rods from which workloads are suspended (Fig. 5). These are designed generally for a given number of pounds per basket or per crossrod and a given number of crossrods per hour. Rotating baskets or fixtures can be mounted on these crossrods.

Ferris Wheel Degreasers

The degreasing tank and conveyor are enclosed with the exception of an opening only large enough to permit manual loading and unloading of the work basket (Fig. 6). This opening, depending on the specific design, can be closed by use of a door, and opened only during loading and unloading of the basket. The conveyor is similar to a ferris wheel and can contain a limited number of baskets. Thus, it has a smaller production capacity than the crossrod type. Either immersion or spray can be incorporated in the cleaning cycle, along with the vapor rinse and dry stages. Some types are designed to rotate in the baskets to enhance cleaning and drying.

Vibra Degreaser

This type of system is especially adapted for bulk handling of small parts, particularly in the fastener industry (Fig. 7). Special designs are available for cleaning chips, shavings, and grindings of valuable metals. Parts to be cleaned are fed at a controlled rate to a load chute, which directs the parts down into a spiral trough elevator. The spiral elevator vibrates by means of a dual motor vibrator drive and conveys the parts upward through solvent and vapors to the unload chute from which they exit the degreaser clean and dry. Small sizes of this unit lend themselves to in-line

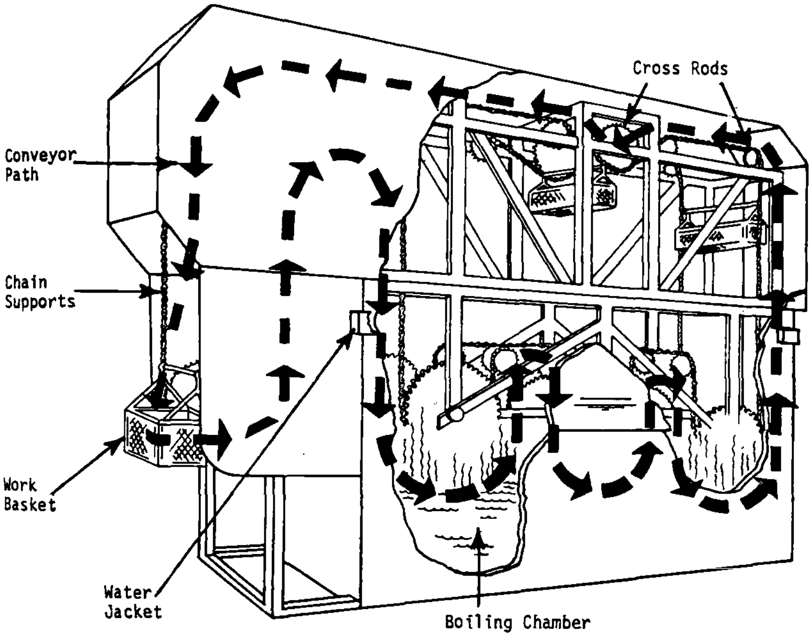


FIG. 5—Liquid-liquid-vapor crossrod degreaser.

cleaning systems for high production items.

Elevator Degreaser

A platform design is used to lower and raise parts. Open rollers usually are provided in the elevator and are used in conjunction with gravity roller conveyors for conveying the work to and from the degreaser elevator. Elevator structure must be designed to prevent solvent entrapment. Tanks should be designed so there is ample vapor space clearance between the elevator and the tank walls so that pumping or piston action of the vapor does not take place. Frequently, a cover is controlled by the elevator mechanism and closes the degreaser even while parts are in the cleaning cycle, providing an enclosed design.

Operating and Safety Controls

Steam-Heated Degreasers

A steam pressure reducer or regulator, or both, is required and should be designed for the degreasing solvent used. A pressure gage and relief valve should be installed on the low-pressure side. An automatic shutoff valve should be provided in the steam line to shut off the steam in case of insufficient cooling water flow. This is preferably done by a control sensor located above the operating vapor level so that, should the vapor level rise above the cooling coils for any reason, this sensor will respond to the vapor temperature and shut off the steam. Such a device should be of the manual reset type requiring investigation and manual resetting. Steam traps should be arranged to receive condensate from the steam coils by gravity and then return the condensate to a condensate receiver or boiler with a minimum amount of back pressure.

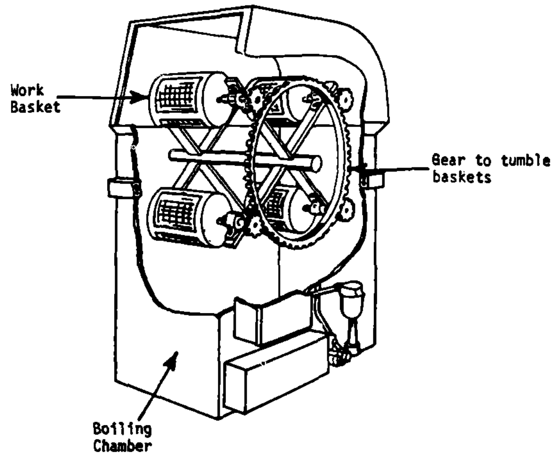


FIG. 6—Ferris wheel degreaser.

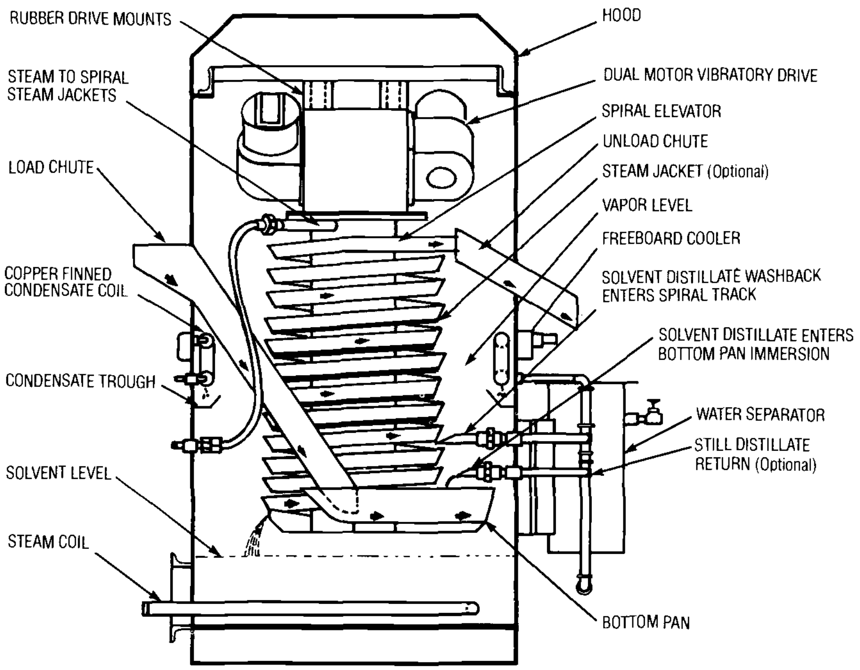


FIG. 7—Vibra degreaser.

Gas-Heated Degreasers

Gas burners should be provided with safety pilot protection to provide for shutdown of all gas within 45 s after pilot failure. When the solvent level is too low or the machine is being cleaned out, all gas, including the pilot, should be shut off. A thermostatic device should be provided to shut off all gas if the boiling temperature of the liquid gets beyond a preset temperature or the liquid level threatens to expose the immersion gas coil. The high temperatures, possible with gas, make control mandatory, and it should require manual resetting. Oil and grease dissolved in the solvent raises the boiling point, and this temperature rise should be limited. In normal operation, the degreasers should be cleaned out before becoming heavily contaminated, as discussed later under "Degreaser Operation." An automatic valve or device should be installed in the gas supply line for shutting off the gas in case of excessively high vapor level, as previously described. This should be of the manual reset type calling for investigation of the cause of high vapor level and require manual resetting of the valve.

Electrically Heated Degreasers

It is especially important to provide a low liquid level device on all electrically heated degreasers to prevent solvent decomposition when heating elements are exposed. A low liquid level device can be thermostatic or the mechanical float type. Again, a vapor thermostat is essential to prevent excessive vapor rise if the condenser system fails.

Vapor Thermostat Setting

A thermostatic control is required to shut off the heat if excessively high vapor level occurs. The vapor thermostat settings shown in Table 4 are recommended for the various degreasing solvents.

Water Flow Switch

Pending federal regulations and many existing state regulations require a coolant flow switch and temperature control that will shut off the heat source if the coolant becomes too warm or is not flowing adequately.

Safety Precautions[1]

1. Means for cleaning out the degreasing equipment without anyone having to enter should be incorporated in the design insofar as possible.

2. Amply-sized cleanout door plates strategically located, removable cleanout plates with mounted steam coils, and removable plates near spray zone, in the case of spray unit, are essential.

3. A permanent caution sign describing conditions required before entry is permissible and should be affixed to or near all such openings.[2]

4. Covers should be provided for all open tanks so that the equipment is covered completely when not in use.

5. Degreasers should be equipped with a thermostat immersed in the boiling liquid to shut off the heat source should the temperature exceed the recommended setting (Table 5).

6. Safe handling procedures are covered in detail in the section on "Safe Handling of Vapor Degreasing Solvents (p. 23)."

Location of Solvent Degreasing Equipment

The sequence of work flow through the plant is usually the prime factor in determining the location of solvent degreasing equipment; however, alternate locations should be considered for the following reasons.

Ventilation

The degreaser should be located in an area where vapor cannot stagnate and there is sufficient ventilation in the working area to maintain vapor concentrations in air below the acceptable time-weighted average (OSHA or ACGIH values, whichever is lower).

Clearance

Adequate clearance should be provided around the degreaser to permit access to

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[1] OSHA regulations require the following: (1) location of degreasers to prevent solvent vapors from entering welding areas, (2) ventilation of degreaser and pits, and (3) guardrails where needed. Local electrical and plumbing codes should also apply.

[2] Refer to ASTM Practice for Confined Area Entry (D 4276).

TABLE 4. Vapor thermostat setting.

Solvent	Recommended Vapor Thermostat Setting	
	°F	°C
Methylene chloride	95	35
Perchloroethylene	180	82
1,1,1-Trichloroethane	130	54
Trichloroethylene	160	71
Trichlorotrifluoroethane	105	41

NOTE 1: These same vapor thermostat settings are also recommended for solvent recovery stills.

NOTE 2: Modify setting for admixture products.

TABLE 5. Boil sump thermostat setting.

Solvent	Recommended Liquid Thermostat Setting	
	°F	°C
Methylene chloride	110	43
Perchloroethylene	260	127
1,1,1-Trichloroethane	175	79
Trichloroethylene	195	91
Trichlorotrifluoroethane	125	52

NOTE 1—Manufacturers' recommendations should be followed for boil sump thermostat settings cn solvent recovery stills.

all cleanout doors and allow complete removal of the heating elements.

Drafts

A degreaser should be installed so that it is not affected by drafts caused by windows, doors, fans, unit heaters, ventilators, or adjacent spray booths. Normal air circulation (at velocities not exceeding 50 ft/min [15 m/min]) is desirable and should not be confused with direct drafts such as just outlined. Drafts may be diverted from the top of the degreaser by the use of baffles located on the windward side of the degreaser.

Ovens

No degreaser should be installed adjacent to open flames of a gas-heated oven. If the plant layout requires that the degreaser be installed near a direct-heat gas-fired paint baking oven, for instance, fresh air intakes from outside of the building to the oven burner should be considered. This will avoid the possibility of wrinkling or fouling of the paint surface from exposure to solvent combustion products.

Open Flames or Hot Surfaces

No degreaser should be installed near open flames or near high-temperature surfaces (above 750°F [399°C]). Welding and heat treatment operations and space heaters should not be located in proximity to solvent degreasing equipment. When these operations are in the same general area as solvent degreasing equipment, precautions should be taken, such as enclosures and local ventilation to ensure that no traces of solvent vapors enter these areas.

Gas-Heated Degreasers

Do not locate gas-heated degreasers (usually provided with natural draft ventilation on combustion chamber in tank) in a room where the general mechanical exhaust system produces a slight negative pressure, unless powered exhaust is provided for the products of combustion.

INSTALLATION

The installation of each degreasing machine should be supervised by a qualified representative of the equipment manufacturer to ensure the checking of location, installation of pipe and wiring, and proper setting of controls.

The elevation of the top of a manually operated, open-top degreaser should be approximately 42 in. (1.07 m) above either the floor level or the operating platform. This elevation is considered sufficient to provide protection against a person falling into a degreaser and is an approved elevation with reference to the operator's breathing zone. (If lower, a railing or other protective device should be provided at approximately the 42-in. [1.07-m] level.)

DEGREASER OPERATION

Every degreaser is provided with specific operating instructions for safe, economical, and efficient operation of the unit. Since these instructions vary with design, type, and work cycle of the unit, it is essential that the operator be familiar with specific instructions pertaining to his unit. Operating instructions should be posted in a conspicuous place on the degreaser. All degreasers are designed to process a maximum load rated in pounds per hour based on a specific heat input to vaporize sufficient solvent. If the work capacity of the unit is exceeded, vapor level fluctuations will be encountered. These fluctuations increase solvent consumption and may also cause poor cleaning and longer cleaning cycles.

Operating the Degreaser[3]

Equipment manufacturers and producers of vapor degreasing solvents generally agree that the following procedures and practices will permit optimum cleaning performance and safety of operation:

1. Turn on condenser coolant system and check to ensure that it is operating properly.

2. Start emission control and ventilation equipment where provided.

3. Actuate all control devices on equipment, as follows: automatic heat shutoff thermostat located above condensing zone; maximum surface temperature controls on heating elements; and maximum solvent temperature control in cleaning compartments. Check all controls periodically to make sure they are working.

4. Check and adjust solvent levels in all compartments and adjust as necessary.

5. Check that all degreaser covers are in place during heat-up as well as cooldown.

6. Turn on the heat supply and adjust the settings as necessary. Adjust the heat balance in the degreaser so that the level of the vapor remains constant at the design level or midpoint of the condenser coils. A proper balance is achieved if solvent vapors are generated at the same rate they are condensed by work entering the vapor zone and by the condensers.

7. Once the vapor level reaches the condensing coils, check the flow of condensed solvent through the water separator and its return to proper degreaser compartments.

8. Check operation of solvent spray pump (when provided).

9. Check all thermometers and gages to ensure operation in proper range for system.

10. Start workload through system.

11. Check condenser coolant flow or temperature, or both. Adjust as necessary to ensure that the vapor level does not rise above the design or operating level and to minimize condensation of moisture from room air on the condenser coils. Check that all coolant and heating lines are free of leaks and the water separator is functioning properly to prevent contamination in the degreaser.

Proper Positioning of Work

Parts being cleaned in vapor degreasers, whether contained in baskets or suspended from hooks or racks, should be positioned to permit maximum drainage. Retention of solvent in pockets, recesses, and so forth, will result in excessive solvent dragout, increased process costs, and atmospheric

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[3] ASTM Practice for Solvent Vapor Degreasing Operations (D 3698).

contamination. Parts should also be positioned in a manner that will permit intimate contact of all work surfaces with the cleaning solvent in all phases of the cleaning cycle-immersion, spraying, and final vapor rinse.

Rate of Entry and Removal

The maximum vertical rate of entry and removal of work is 11 ft/min (3.3 m/min). Higher throughput rates will cause vapor disturbances, resulting in high solvent losses and unnecessary contamination of the atmosphere.

Duration of Contact Time with Solvent Vapors

The workload should be retained in the vapor zone for its final vapor condensate rinse until condensation ceases to facilitate drying. Work withdrawn earlier may emerge wet with solvent condensate. Insufficient contact time is encountered most frequently in hand-operated, open-top machines.

Solvent Contamination Levels

The effectiveness of a vapor degreasing operation is dependent on the ability of the machine to produce a constant supply of clean solvent vapor for cleaning. To accomplish this, the contamination level in the solvent should be maintained as low as practical. This is particularly true in the case where a rinse immersion is employed. Unnecessarily high contamination in any compartment of a unit can result in lower cleaning efficiency.

Contamination levels in vapor-generating sumps in excess of the recommended maximum of 25% (Table 5) can result in added difficulties such as solvent breakdown, insufficient vapor generation, and heat-element sludging. Auxiliary stills are employed frequently in conjunction with degreasers to maintain low contamination levels in the degreaser compartments.

Spraying of Parts

Spraying should be done within the vapor zone to avoid excessive vapor disturbance. Pending federal and many state regulations may require spray control switches that shut off the pump if the vapor level drops in excess of 4 in. (10 cm). Refer to the Appendix, Federal EPA Guidelines for Open Top and Conveyorized Degreasers. The spray should be distillate or, at most, very lightly contaminated, and the solvent temperature should be below its boiling point. The solvent spray will lower the temperature of the work and cause condensation of pure vapors on the work during the final stage of the cleaning cycle.

Water Contamination

Water within the degreaser often is the cause of corrosion of the equipment, spotting of processed work, and increased solvent consumption. The corrosion problem stems from the corrosive nature of the water itself and the combined action of the solvent and water. Therefore, introduction of water into a unit should be minimized. Sources of water entry include condensation of atmospheric moisture, leaking condensers or steam lines, and wet processed work. Work contaminated with water-compounded process oils are likely to introduce large amounts of water. Water that enters the machine is removed to a great degree by water separators.

For effective functioning of the water separator, the temperature of the condensate should be the below values shown in Table 6.

Solvent Handling

Addition of solvent to the vapor degreaser should be done with care to minimize disturbance of the vapor level. Preferably, the solvent should be pumped into the degreaser, rather than poured directly from drums or by buckets. The makeup solvent should be added to the clean rinse compartments or the condensate tank of the degreaser. When added directly to an operating portion of the machine, the solvent should be discharged within the vapor zone.

Solvent Distilling and Operation of Stills

A solvent recovery still is a covered tank with a heat source to boil the solvent, a condenser to condense the vapor and a water separator.

Solvent recovery stills are designed to reclaim vapor degreasing solvents by removing contaminants such as grease, oil, rosin solder/flux, and pitch. The reclamation process is accomplished by boiling the solvent/contaminant mixture, condensing

TABLE 6. Recommended solvent condensate temperature for the water separator.

Solvent	Recommended Solvent Condensate Temperature °F	°C
Methylene chloride	100	38
Perchloroethylene	190	88
1,1,1-Trichloroethane	149	65
Trichloroethylene	164	73
Trichlorotrifluoroethane	112	44

the resultant contaminant-free vapor, and finally passing the distillate through a water separator.

The same operating conditions observed with degreasing equipment should be followed with stills. Proper operation of devices controlling vapor levels, liquid temperature, and the condenser coolant system should be ensured (refer to Table 4 for recommended vapor thermostat settings).

Users of solvent recovery stills (Fig. 8) realize substantial operating cost savings by reclaiming solvents rather than disposing of them. Further significant cost savings result from the increased efficiency of production and reduced maintenance of degreasing operations made possible by the connection of a solvent recovery still to a degreaser. The still not only permits a degreaser to operate for longer periods without cleanout downtime, but also improves cleaning by keeping the degreasing solvent relatively free of contaminants at all times. This insures maximum solvent action, reduced operating temperatures, and greater overall workload capacity. Additionally, the still provides an in-house source of clean solvent and fewer disposal problems.

In many operations, reclamation of the solvent is conducted easily by distilling the solvent within the degreaser's boiling sump and diverting the distillate to a separate tank or drums. Care should be taken, regardless of the amount of solvent contamination, to keep the solvent level at 1 in. (3.8 cm) above the uppermost heating elements. This mode of solvent recovery has definite limitations; the degreaser must be taken out of service for a number of hours, and the bottoms, after concentration, often contain over 50% solvent.

In a large, single installation, handling a heavy contamination load, or in plants with a number of degreasing units, separate distillation facilities usually are warranted. The still may be coupled directly to a large unit and operate on an essentially continuous basis, or the contaminated solvent may be collected regularly from a number of units and reclaimed in a batch process. Stills specifically designed for solvent recovery are more efficient than degreasers. Stills equipped with steam injection lines are capable of almost total solvent recovery.

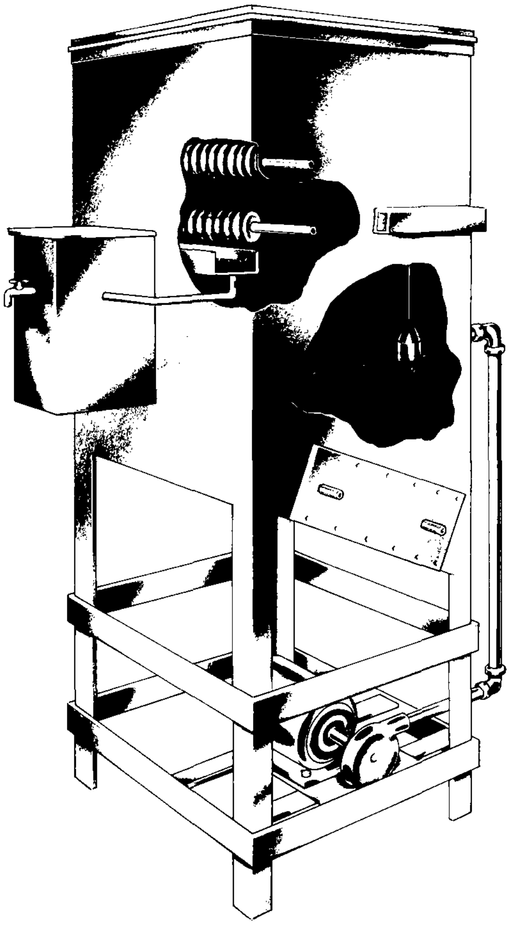

FIG. 8—Recovery still.

In the case of continuously operating auxiliary stills, the solvent is pumped directly from the most contaminated compartment of the degreaser, and the solvent distillate is returned directly to the degreaser rinse compartment or to a storage reservoir common to the still and the degreaser. The solvent level in the still is maintained by automatic level controls, which actuate a transfer pump that feeds the still. This type of operation affords maximum cleaning efficiency and enables continuous production with only infrequent shutdown for cleaning of the degreaser.

Since the continuous still receives contaminants from the degreaser, it is necessary to shut off the solvent supply periodically to concentrate and dispose of contaminants in the still. The frequency with which the still contaminants require concentration and dumping is dependent upon a variety of factors. The best results are obtained usually by establishing a fixed schedule based on the rate of buildup of both soluble and insoluble soils. In the concentrating operation, the contaminants may be concentrated to a point where 10% or less of the solvent remains. Many stills are provided with steam injection to recover all but the very last traces of the remaining solvent. Steam stripping is not generally recommended for use with 1,1,1-trichloroethane. Additionally, steam stripping must be controlled carefully to avoid solvent foaming and subsequent boilover of dirty solvent into the distillate receiver. Depending on the nature of the residues, it may be necessary to remove heating coils or cleanout ports to remove solids from the still. The residue concentrations in either degreaser sumps or separate stills may present a fire or health hazard and should be handled and disposed of in accordance with proper safety procedures and also in compliance with local and state regulations involving hazardous wastes. Allowing residues to cool to room temperature is preferred. If the residues must be removed from the still while hot, ventilation must be provided to minimize atmospheric contamination and attendant toxicity hazards to the personnel. Still residues, while still hot, may offer the additional hazard of flammability.

Shutting Down the Degreaser

Degreasers are usually shut off during nonproduction periods. The shutdown procedure is essentially the reverse of the startup operation and is given in the following steps:

1. Stop processing work and clear the machine of all work.
2. Shut off heat supply.
3. Allow vapor level to drop well below the condenser area.
4. Shut down condenser coolant supply system.
5. Shut off exhaust fans and close cover on degreasers.
6. Auxiliary equipment and control devices should be shut down in accordance with manufacturer's recommendations for cleaning and maintenance of the degreasing equipment.

Cleaning and Maintenance of the Degreasing Equipment

The importance of good housekeeping cannot be stressed too strongly. Cleanliness is essential for the safety of the operator, the economy of operation, and the effectiveness of the process. There is no set rule to govern the frequency of cleaning. This is determined by the volume of work being processed and the nature and amount of soil to be removed. As a guide, degreasers should be boiled down and drained when the contamination level reaches a maximum of 25%. When the contamination is oil, this can be determined by the boiling point of the solvent-oil mixture (Table 7).

Procedure for General Cleaning of Degreaser and Still

Cleaning necessitates the removal of all solvent from the degreaser and still. It also requires the services of competent maintenance men thoroughly familiar with metal degreasing and the associated hazards. The procedure involves the following steps:

1. Distill or remove all solvent from the degreaser to storage tanks or suitable containers.
2. Turn off heat supply.
3. Allow to cool.
4. Shut down condenser coolant supply.

TABLE 7. Recommended maximum boiling temperature.

Solvent	Recommended Maximum Boiling Temperature °F	°C
Methylene chloride	110	43
Perchloroethylene	260	127
1,1,1-Trichloroethane	175	79
Trichloroethylene	195	91
Trichlorotrifluoroethane	125	52

5. Drain residues (if still hot or warm, provide additional ventilation).

6. Ventilate equipment thoroughly to remove residual solvent (liquid and vapor) as completely as possible.

7. Carefully remove thermometers and safety devices to avoid damage.

8. Disconnect heat-supply service connections.

9. Remove cleanout ports and heating elements.

10. Remove all dirt, sludge, and metal chips possible from the bottom of each compartment without entering the machine.

11. Lock off all power to conveyor and pumps, and disconnect or lock closed solvent lines from storage.

12. When the unit is aerated thoroughly by forced ventilation (fan, compressed air, or blower exhausting outside the building), maintenance personnel may enter the unit (ASTM D 4276)[2] to complete the cleaning. The man entering the unit must wear a harness and lifeline in addition to approved respiratory protection, such as a hose mask operating from a remote source of compressed air or a self-contained breathing apparatus. A second person must be in attendance outside the degreaser at all times with supplied air breathing apparatus as an added safety precaution. Continue ventilation of the unit while maintenance personnel clean the unit interior. They shall, as follows:

(a) Brush out the condensate trough and check to make sure there are no obstructions to condensate flow. Use non-ferrous materials such as nylon, brass or equivalent. Do not brush stainless steel equipment with steel wire brushes.

(b) Brush condensing coils, walls, overhead, and compartment floors to remove all accumulated residue, scale, and so forth.Take care to avoid damaging corrosion-resistant finishes. Brush down rusted areas, inspect and lubricate conveyor system or internal drive system, as required.

13. Scrape and brush heating elements free of all caked sludge to ensure efficient heat transfer. Inspect and replace faulty elements. Chemical cleaning with aqueous, hot alkaline solutions, or with formulated organic solvent carbon remover is often practiced. These aggressive chemicals should be flushed out immediately after use. These liquids should be disposed of in accordance with federal, state, and local regulations. (See section on "Chemical Hazards, Effects of Alkalies").

14. Clean out condensate lines from the collecting trough outlet to water separator and from water separator to discharge point in the degreaser. These lines can be blown out with compressed air; short runs may be brushed out.

15. Clean out the water separator, removing any sludge that may have accumulated on the bottom.

16. Clean and check controls, indicators, and regulators before reassembly.

17. Clean strainers, filters, sight glasses, porthole glasses, and so forth before reassembly.

18. With the cleaning operation completed, carefully reassemble the various components and make all joints and connections leak-proof. Most common pipe dopes will affect adequate seal at pipe fittings, but Teflon® tape is preferred. Do

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®Trademark of E. I. DuPont de Nemours & Company not use excessive quantities of pipe dope on fittings. The joining surfaces of cleanout ports should be clean and dry. Replace worn and torn gaskets. Lead, polytetrafluoroethylene (PTFE-TEFLON), and plant fiber compressed sheet are effective gasketing materials, particularly where flanges are rough and thicker gaskets are required. In all instances, as thin a gasket as possible should be used. Where compressed cork or paper gaskets are used, a coating of graphite and glycerin or ethylene glycol will do much to prevent gasket bonding to the metal surface. Such bonding usually results in breaking the gasket during teardown and often necessitates scraping to remove adhering gasket material.

19. After assembly is complete, turn on coolant supply to condensers and heat exchangers to inspect for leaks. Where steam heat is used, apply steam pressure to the heating coils and check for leaks (turn off steam and allow to cool before adding the solvent).

20. Fill all compartments to normal operating level and start unit in prescribed manner.

21. Check all solvent lines, valves, fittings, gasketed closures, and pumps for leaks and adjust as necessary. Refer to start up procedure when degreaser is ready to be put back into operation.

Routine Maintenance

The following points are recommended in the routine maintenance of the equipment:

1. Keep all compartments of the equipment filled to the prescribed operating levels.

2. In starting the equipment each day, observe whether excessive time is required for vapors to rise and hold steady at the midpoint of the condenser coils. Also observe whether the vapor level drops abnormally when work is put through. If either of the above occurs, the unit may require cleaning, whether normally recommended cleanout temperatures have been reached or not.

3. Keep liquid level sight glasses and porthole glasses clean.

4. Check solvent pumps, gasketed closures, transfer lines, and so forth daily for leaks. Repair of leaks at an early stage will result in solvent savings and safety.

5. Frequently check the temperature of discharging condenser coolant. Maintain the condenser coolant flow so maximum outlet temperature is in the range of 100 to 120°F (38 to 49°C) for perchloroethylene, 1,1,1-trichloroethane and trichloroethylene, and less than 75°F (24°C) for methylene chloride and trichlorotrifluoroethane.

6. If the water drain outlet on the water separator is valved, open the valve frequently and allow accumulated water to drain out.

7. Periodically check solvent flow returning to the degreaser from the water separator. Diminished solvent flow through the separator may indicate the following:

(a) partial block in the distillate line from the collecting trough,
(b) reduced rate of vapor generated due to sludging of heating elements,
(c) excessive contamination, or
(d) reduced heat input.

8. Inspect the condensate collecting trough frequently. If the trough is overflowing, a block may have developed in the distillate line between the condensate trough outlet and the water separator.

9. When steam is used for heating, check the steam pressure gages frequently to ensure continued operation within the recommended pressure range. Also check steam traps frequently.

10. Keep the conveyor mechanism well lubricated at all times.

11. Check the temperature of the boiling solvent in the degreaser regularly to determine the contamination level and, thus, when to clean the degreaser.

Acid Degreasers

An "acid degreaser" is the result of decomposition of the degreasing solvent to acid products. An acid degreaser may be recognized by the presence of a variety of symptoms including a strong acid odor, dense white acrid smoke in the vapor zone, pitting and rusting on parts after degreasing, and loss of acid acceptance.

If a degreaser is determined to have

"gone acid," the following steps should be taken immediately:

Immediate Action for Handling an Acid Degreaser/Still

1. TURN OFF HEAT SOURCE TO THE DEGREASER. Do not turn off the condenser water or the ventilation fan.

2. SEND ALL UNNECESSARY PERSONNEL AWAY FROM THE AFFECTED AREA. Those required to clean the unit must be properly trained and equipped for such exposure.

3. INTRODUCE ENOUGH WATER INTO THE UNIT TO COVER ALL SOLVENT to a depth of 2 to 4 in. (5 to 10 cm). Add a water solution of soda ash (sodium carbonate) at a concentration of about 1/4 to 1/2 lb/gal (30 to 60 kg/m^3) of water. This will help neutralize the acid decomposition and will facilitate cleaning the machine. DO NOT USE CAUSTIC SODA (sodium hydroxide) OR CAUSTIC POTASH (potassium hydroxide) because an explosive product may result.

Once the immediate steps have been taken, the degreaser should be thoroughly cleaned out and neutralized. A complete recommended procedure for this cleanout may be found in ASTM Practice for Handling an Acid Degreaser or Still (D 4579).

Economics of Degreaser Operation

A number of factors enter the overall picture of vapor degreasing economics such as initial equipment cost and depreciation, plant floor space requirement, heat, water, electricity, solvent, maintenance, operating labor, and waste disposal.

Solvent Cost

Aside from the labor to operate manual machines, the largest continuing expenditure in vapor degreasing operations is for the solvent. It is lost from degreasing equipment by way of dragout on parts, diffusion of solvent vapor into the air, and through leaks. Solvent may also be lost through poor solvent handling techniques while draining the equipment and adding makeup solvent. These solvent loss routes point out the necessity of carefully selecting the proper equipment for a given job; of properly locating the equipment in draft-free areas within the plant; and of practicing good operating, solvent handling, and preventative maintenance techniques.

Experience has indicated that free-draining work may be cleaned for as little as 1/2 gal (2 L) of solvent per ton when handled in covered, conveyorized equipment. The same workload will require at least 20% more solvent per ton when processed through manually operated, open-top units. This increase is due to greater loss of solvent vapor by diffusion into the air and by nonuniformity of work throughput.

Small parts processed at high volume rates through conveyorized, covered units may use 1 to 2 gal (4 to 8 L) of solvent per ton. At equivalent feed rates through manual open-top equipment, solvent consumption again will be increased by at least 20%.

Each cleanout of the degreaser results in loss of solvent when solvent-laden oil is discarded. Reclaiming stills will minimize such losses substantially since they are designed specifically to effect almost total recovery of solvent from oil-solvent mixtures (see Page 17, Solvent Distilling). Solvent consumption can be reduced by the installation of covers, extended freeboard, refrigerated freeboard coils, or vapor recovery equipment utilizing carbon adsorption. The economics of these systems will depend on the balance between solvent savings and investment required.

Maintenance and Direct Labor Costs

Maintenance and direct labor costs will vary considerably depending on variations in hourly wage rates, unit size, cleanout frequency, and so forth. Equipment manufacturers can supply an estimate of the manpower requirement for direct and maintenance labor for a given piece of equipment.

Utilities Costs

Costs of gas, steam, and electric heating vary considerably. Thus, the source of heat should be considered carefully where a choice is available. Aside from cost, steam heating is preferred to avoid the risk of thermally decomposing the solvent. In distillation equipment, steam heating is even more important because of the high boiling temperatures experienced when the solvent becomes more concentrated with contaminants.

Process water from most lakes, rivers, or wells is suitable for equipment condensers and is usually much cheaper than municipal water. In areas where water cost is high or conservation is required, condenser water may be recycled through water cooling towers or refrigeration chillers. Condenser water cost may be reduced also by re-using condenser effluent water as follows, in (1) plating operations, (2) spray paint water curtain systems, (3) heat treating quench towers, and (4) numerous other industrial secondary uses.

SAFE HANDLING OF VAPOR DEGREASING SOLVENTS

The vapor degreasing solvents that are discussed in this publication (methylene chloride, perchloroethylene, 1,1,1-trichloroethane, trichloroethylene, and trichlorotrifluoroethane) have all been used industrially for many years. Their toxic properties and the methods for handling them safely have become known through extensive experimentation and human experience. The facts that are presented in this section are drawn largely from several readily available published sources. They are as follows: (1) Hygienic Guide Series of the American Industrial Hygiene Association, 66 South Miller Road, Akron, OH 44313; (2) American National Standards Acceptable Concentrations of Toxic Dusts and Gases, published by American National Standards Institute, 1430 Broadway, New York, NY 11018; (3) Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes, published by the American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Cincinnati, OH 45211; (4) F. A. Patty, Industrial Hygiene and Toxicology, 3rd Revised Edition, Vol. 2A, Interscience Publishers, New York, 1981; and (5) Occupational Safety and Health Standards, as published by the United States Department of Labor.

Employee Education

Employee Selection

Only reliable, dependable, and thoroughly trained employees should be given the responsibility of operating and maintaining a degreaser. They should be thoroughly familiar with the hazards involved with these solvents and the safeguards necessary for safe solvent handling and degreaser operation, maintenance, and cleanout.

Preemployment

A preassigned medical physical examination should be required.

Reporting Leaks

Each employee should be impressed with his responsibility to report promptly any suspected leaks or equipment failures. This responsibility should be stressed. All leaks and equipment failures should be promptly corrected.

HAZARDS

The primary hazards related most closely to vapor degreasing can be categorized as health, fire, and chemical reactivity hazards.

Health Hazards

The principal hazards to be avoided in safe handling and use of vapor degreasing solvents are excessive inhalation of vapor and excessive skin contact (Tables 8, 9, and 10). Smoking, eating and drinking should be avoided in the vicinity of all vapor degreasing operations.

Contact with halogenated solvents in the workplace can result from one or more of the following routes of exposure:

(1) inhalation,
(2) skin contact,
(3) ingestion (swallowing), and
(4) eye contact.

Inhalation

Each of the vapor degreasing solvents exerts an appreciable vapor pressure at room temperature and above (Table 9). Thus, high concentrations of solvent vapors are

TABLE 8. Standards related to control of health hazards.

Industrial Health Standards	Methylene Chloride	Perchloro-ethylene	1,1,1-Tri-chloroethane	Trichloro-ethylene	Trichloro-trifluoro-ethane (CFC-113)
ACGIH[a]-TLV's TLV[b]-TWA (ppm)	50	50	350	50	1000
TLV-STEL[c] (short-term exposure limit)		200	450	200	1250
OSHA—permissible exposure limits					
PEL-TWA[d] (ppm)	500	25[f]	350	50[f]	1000
Acceptable ceiling[e] concentration, ppm	1000	. . .	450[f]	200	. . .
Acceptable maximum peak above the acceptable ceiling concentration for an 8-h shift[e], ppm	2000	. . .	. . .	. . .	. . .

NOTE: Refer to current OSHA Occupational Exposure Standards (29 CFR, Part 1910.1000).

[a] ACGIH—American Conference of Governmental Industrial Hygienists, "Threshold Limit Values . . . 88–89," 6500 Glenway Avenue, Cincinnati, OH 45411.

[b] Threshold Limit Value—Refers to a time-weighted concentration for a normal 8-h workday and a 40-h workweek. Current OSHA standards should be reviewed.

[c] STEL—15-min time-weighted average, which should not be exceeded, even though the 8-h average is within the TLV. STEL exposures should not exceed 15 min and should not be repeated more than four times a day.

[d] Eight-hour time-weighted average—an employee's exposure to any material listed in OSHA Table Z-2 in any 8-h work shift of a 40-h workweek shall not exceed the 8-h time-weighted average limit for that material in the table.

[e] An employee's exposure to material listed in OSHA Table Z-2 shall not exceed at any time during an 8-h shift the acceptable ceiling concentration limit given for the material in the table, except for a time period, and up to a concentration not exceeding the maximum duration and concentration allowed in the column under "Acceptable Maximum Peak Above the Acceptable Ceiling Concentration for an Eight-Hour Shift."

[f] OSHA amended its Air Contaminants standard January 19, 1989, lowering the PEL of perchloroethylene to 25 ppm with no STEL and lowering the PEL of trichloroethylene to 50 ppm with a STEL of 200 ppm.

possible as a result of spills, equipment malfunctions, or improper operation. Breathing an excessive concentration of the vapor can produce symptoms or irritation and narcosis. The anesthetic effect is generally not considered serious because it is reversible, and if persons so affected are removed to fresh air, the recovery is rapid and complete. The most serious hazard rests in the situation where the person is overcome and is unable to remove himself from the contaminated area, in which case death may occur. Excessive exposures are most likely to be encountered during the following situations: (1) degreaser cleanout, (2) improper tank entry and, (3) when vapors are allowed to rise above the cooling coils because of control failures, and poor maintenance. Accidental overexposure to the vapors during operation of a properly designed and functioning vapor degreaser is unlikely. Breathing an excessive concentration of solvent vapors for an extended period of time can produce advanced symptoms of narcosis, cardiac arrhythmias, unconsciousness, and even death. Note the vapors of halogenated solvents are heavier than air and can settle, under certain circumstances, in low areas such as pits or tanks. They can displace oxygen, under such conditions, making entry into these areas very hazardous. Verify that these areas are safe to work in before entering. Certain chlorinated hydrocarbon solvents can damage the liver if overexposure occurs over a long period of time (inhalation, ingestion, and skin absorption). The individual members of this group of solvents vary widely in this respect. Drinking alcoholic beverages may increase the possibility for the development of toxic effects resulting from exposure to these products.

Skin Contact

While inhalation of vapor is the primary hazard of solvents, contact of the liquid with the skin can also be hazardous because it can result in dermatitis. Some solvents may be absorbed through intact skin into the circulatory system and largely eliminated via the lungs or through urine elimination.

Solvents can cause dermatitis in a number of ways: first, they dissolve and remove the natural body oils from the skin, which then dries and cracks; second, chlorinated solvents actually attack the outer layer and may cause red blotches and blisters if kept in contact with the skin. Employees using solvents must be informed of the hazards resulting from skin contact. Solvents should not be used as skin cleaners. No worker with a skin irritation should be employed in a process involving exposure to organic solvents.

Ingestion (Swallowing)

It is possible to swallow enough solvents intentionally to cause serious injury, even death. During normal handling, the possibility of ingestion is unlikely. Solvents should not be sampled or stored in mislabeled containers such as beverage containers.

Eye Contact

Solvents at or near room temperature would be expected to produce pain and transient irritation when splashed into the eye and promptly flushed with water. Hot solvent, particularly perchloroethylene

TABLE 9. Properties related to control of health hazards.

Property	Methylene Chloride	Perchloroethylene	1,1,1-Trichloroethane	Trichloroethylene	Trichlorotrifluoroethane
Molecular weight	85	166	133	131	187
Vapor pressure at 77°F (25°C) (mm Hg)	440	18	132	80	334
Saturated vapor concentration in air at 77°F (25°C) (ppm)	578 000	24 300	173 700	105 000	421 000
Liquid volume (mL) which, if evaporated in static air in an enclosure of 1000 ft^3 would give a vapor concentration equal to PEL	37.0	3	40.2	5.2	137
Volume of air (ft^3) necessary to dilute vapor from one pound to concentration equal to PEL	9 410	94 000	8 600	60 500	2 100

(boiling point 250°F [121°C]) can cause burns of a more serious nature. Medical attention is recommended for further treatment. Generally, these solvents at normal temperature are of little significance from the eye contact standpoint, although irritation and pain may occur.

First Aid

Inhalation

Anyone suffering from the symptoms of overexposure of the vapor of the halogenated solvents should be removed to fresh air and kept at rest in a well-ventilated room. Solvent-wet clothing, including shoes, should be removed. If necessary, chilling can be avoided by wrapping the patient in a blanket. Call a physician immediately. If breathing has stopped, administer artificial respiration at once. If breathing appears difficult, oxygen should be administered. Never give anything by mouth to an unconscious patient.

Note to Physician

Treatment is nonspecific and should be directed to promote recovery from an anesthetic agent. In treating persons suffering toxic effects caused by exposure to halogenated solvents, the use of epinephrine (adrenalin) and similar drugs must be avoided because they may produce cardiac arrhythmias, including ventricular fibrillation.

Skin Contact

Soaked clothing should be immediately removed and not worn again until thoroughly cleaned and dried. Contaminated shoes should be discarded. Contaminated areas of the skin that were exposed to solvent should be thoroughly washed with soap and water followed by the application of lanolin or cold cream. Cases of severe drying or cracking of the skin or dermatitis should be treated by a physician.

Ingestion

DO NOT INDUCE VOMITING. Call a physician promptly or seek assistance at the emergency room of the nearest hospital. NEVER GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON.

Eye Contact

Splashes of the liquid in the eye should be treated with continuous washing with large amounts of water for at least 15 min. Hold the eyelids apart to ensure thorough washing, then obtain medical attention.

Fire Hazard

Generally speaking, the halogenated hydrocarbons do not present a significant fire hazard (Table 10). Halogenated solvents commonly used in vapor degreasing, including trichloroethylene, perchloroethylene, 1,1,1-trichloroethane, trichlorotrifluoroethane, and methylene chloride, do not have a flash point by ASTM flashpoint test methods. They have been shown to be essentially nonflammable under prescribed use conditions.

Under certain other conditions where high vapor concentrations in air can develop, the vapors of some of these solvents are flammable in the presence of an ignition source. Additionally, these solvents may autoignite above 880°F (470°C) and will degrade, forming toxic and corrosion products.

Because of vapor flammability, operations that generate or create high temperatures or sources of radiant energy, such as those encountered in open flames, unshielded (unventilated) resistance heating, arc welding or cutting, and high intensity ultraviolet light, should not be located in areas where vapors or solvent are present.

Further, welding should never be done on equipment containing solvent liquid or vapors. Also, lights in degreasers should be protected against breakage by a shield or bull's-eye.

Degreaser Sludge

Degreaser residue or sludge, whether or not stripped of solvent, may be flammable. It should be cooled to ambient temperature before removal.

Decomposition Products

Vapors of halogenated solvents can be decomposed to form toxic and corrosive products when exposed to sources of high temperature, such as:

(1) open flames,

TABLE 10. Flammability properties of halogenated solvents.

Property	Methylene Chloride	Perchloro-ethylene	1,1,1-Tri-chloroethane	Trichloro-ethylene	Trichloro-trifluoro-ethane (CFC-113)
Flash Point, °C (°F)[a]	none	none	none	none	none
Autoignition temperature, °C (°F)	556 (1032)[c]	none[d,e]	458 (856)[c]	416 (780)[c]	none >7650 (1200)[f]
Flammability limits in air at atmospheric pressure, volume %[b]					
at 25°C (77°F)	none[c,d] 14.8 to 22.0[h]	none[d,e]	6.8 to 10.5[c] 10.0 to 15.5[g] 7.5 to 15.0[h]	8.0 to 10.5[d,e]	none[f]
at 100°C (212°F)	15.9 to 19.1[c]	none[d,e]	6.3 to 13.0[c]	10.5 to 41[c] 11.0 to 38[f]	none[f]

[a] ASTM Test Method for Flash Point for Tag Closed Tester (D 56).

[b] ASTM Test Method for Limits of Flammability of Chemicals (E 681).

[c] Kuchta, M. M., Furno, A. L., Bartkowiak, A., and Martindill, G. H., *Journal of Chemical and Engineering Data*, Vol. 13, No. 3, July 1968, pp. 421–428.

[d] Archer, W. L. and Stevens, V. L., *Ind. Eng. Chem., Prod. Res. Dev.*, Vol. 16, No. 4, Dec. 1977, pp. 319–325.

[e] Wray, H. A., *Journal of Coatings Technology*, Vol. 56, No. 717, Oct. 1984, pp. 37–43.

[f] Scott, G. S., Perlee, H. E., Martindill, G. H., and Zabetakis, M. G., Technical Document Report ASDTR-61-278, Supplement No. 1, Oct. 1962 and Quarterly Progress Report No. 3, 1 July to 30 Sept. 1964 (to correct erroneous data for trichlorotrifluoroethane), Bureau of Mines Reports for Air Force Systems Command, Wright-Patterson Air Force Base, OH.

[g] Torkelson, T. R., et al., *Journal of the Industrial Hygiene Association*, Vol. 19, No. 5, Oct. 1958, pp. 353–362.

[h] Material Safety Data Sheet, Dow Chemical U.S.A., 1985.

(2) heat treat ovens,
(3) paint baking ovens,
(4) gas and electric space heaters,
(5) arc welding,
(6) gas welding, and
(7) cigarette smoking.

If such operations must be located near a degreaser, solvent vapors must be vented out of the building. Outside air should be provided for combustion devices. Ultraviolet radiation, such as from a welding arc, can cause similar decomposition. Smoking should be prohibited in the vicinity of degreasing operations.

Stabilized Grades

Improperly stabilized methylene chloride, perchloroethylene, 1,1,1-trichloroethane, and trichloroethylene are subject to decomposition under vapor degreasing conditions to form corrosive acid by-products. For this reason, only solvent grades suitably stabilized for vapor degreasing applications should be used.

Effects of Alkalies

Strong alkalies, such as caustic soda (sodium hydroxide), may react with halogenated solvents; therefore, they should not be mixed.

Chemical Reactivity

Reactive Metals

Halogenated solvents may react violently with reactive metals of the alkali series such as lithium, sodium, and potassium. The alkaline earths, such as calcium, strontium, and barium, may also react vigorously with halogenated solvents. Finely divided metals are much more reactive than bulk metals so that even moderately reactive metals, such as magnesium and aluminum, can become a problem under certain conditions. Use of vapor degreasing with active metals should be preceded by a thorough investigation of the possible hazards resulting from the use of the various solvents.

Aluminum should not be used as a material of construction for pumps, tanks, pipelines, valves, spray equipment and other handling equipment used for chlorinated solvents. Properly stabilized halogenated solvents are however commonly used in cleaning aluminum and other sensitive metals.

PREVENTION OF EXPOSURE TO SOLVENTS

Safe Working Practices

Maintaining Steady Vapor Level

The high vapor densities of the halogenated solvents make it possible to maintain a definite vapor level in the degreaser, keeping solvent vapor concentrations in the operator's breathing zone below the maximum recommended time-weighted average (TWA) concentration with both manual and automatic degreasers. Items to check to ensure a steady vapor line are the following:

1. Freedom from drafts across the degreaser (from fans, open windows, unit heaters, excessive room ventilation, traffic, and so forth.
2. Sufficient heat input to maintain a steady vapor level at the center of the condenser when no work is going through the degreaser.
3. Adequate supply of coolant for degreasers.
4. The workload should be sized to the heat input capacity of the degreaser. When the workload is lowered into the degreaser, the vapor drop should be kept to a minimum. It is preferable that the vapor level does not drop a distance greater than 4 in. (10 cm). However, for certain large single-item loads, such as found in maintenance applications, the vapor drop limitation cannot be achieved.
5. All spraying must be accomplished below the vapor level.
6. Vertical speed of the work must be kept at or below 11 ft/min (3.3 m/min) to avoid disturbing the vapor level excessively.
7. Parts should be racked to be free-draining to avoid dragout of liquid solvent.
8. The industry standard for freeboard heights is 75% of the width, where practical.
9. The workload cross-sectional area should not exceed 50% of the degreaser tank cross-sectional area at the vapor line.
10. Do not vapor degrease absorbent materials such as wood, paper, leather, and clothing.
11. Solvent vapor concentrations at the operator's breathing zone can be maintained at satisfactorily low levels with normal room ventilation, provided that the precautions for maintaining vapor level just given are followed. However, when the degreaser is located in a small room or where laws require it, an exhaust is used around the lip of the degreaser to withdraw vapor-laden air that normally would be lost in the room atmosphere.

A downdraft exhaust table can be used where load configuration traps solvent liquid or vapor upon removal from the degreaser. The installation of either lip ventilation at the degreaser or a downdraft exhaust table may not give satisfactory control of vapor resulting from an improperly constructed or operated machine. Mechanical ventilation requirements are established to control vapor concentrations below the vapor inhalation standard (TWA, ceiling, and so forth).

In many instances, an acceptable alternate to exhaust ventilation is the use of refrigerated freeboard device described under the section on Solvent Conservation Devices and Procedures.

Equipment Maintenance

Whenever possible, any maintenance of equipment should be accomplished from the outside using the access or cleanout doors. If the equipment must be entered, the tank or container must first be thoroughly checked to ensure that all solvent has been removed from the equipment and the solvent vapors have been eliminated. No person should enter a degreaser without proper safety equipment and attended by another person, similarly equipped, outside the degreaser. FAILURE TO OBSERVE THESE ELEMENTARY RULES HAS BEEN THE DIRECT CAUSE OF MOST OF THE INDUSTRIAL ACCIDENTS INVOLVING THESE SOLVENTS. See ASTM Practices for Confined Area Entry (D 4276).

Solvent Transfer

The most efficient method of transferring these solvents from the drum to the equipment in which it is to be used is by pumping the solvent through a pipe connected directly to the bung opening of the drum. Transferring by hand, using open buckets, is not recommended because of the possibility of overexposure to vapor and the unnecessary loss of solvent.

Spills

Spilled solvent should be cleaned up immediately by employees wearing adequate personal protective equipment. Other personnel should be evacuated. Compressed air or fans should not be used to dry up spills because they will increase air contamination. Mops and rags should be used to soak up the solvent and should be placed immediately in closed containers out-of-doors where they can be dried safely. Large spills can be controlled by flooding with water. A floating water layer retards evaporation and reduces the formation of high vapor concentrations. DO NOT FLUSH SPILLED SOLVENT INTO PLANT SEWERS OR DRAINS. Spill reporting may be required by federal, state, or local regulations.

Contaminated Clothing

Clothing splashed with solvent should be removed immediately and not used again until it has been dried and freed of the odor of the solvent. The clothes should be dried outdoors or in a well-ventilated area, and then washed to remove any residue. Contaminated shoes should be discarded.

Personal Protective Equipment

Employees must be instructed thoroughly in toxicity, hazards, first aid, and proper handling of solvents. They should know the location and purpose of personal protective equipment and should be thoroughly trained and periodically retrained in its use and maintenance. The OSHA Hazard Communications Standard requires training, written safety program, labeling, and availability of material safety data sheets. However, personal protective equipment should not be used as a substitute for good, safe working conditions.

Solvent-resistant gloves and aprons fabricated from or impregnated with polyvinyl alcohol, polyvinylidene chloride, or neoprene polymers should be worn if skin contact is likely.

Natural rubber is affected by halogenated hydrocarbon solvents and should not be used.

Note—Protective creams alone cannot be relied upon to afford adequate protection. Chemical safety goggles should be worn where there is danger of splashing.

Respiratory Protection

To assess the safety of any particular operation, measurement of the solvent vapor exposure to workers in the area is recommended. If it is determined that the concentration in air is less than the recommended TWA for the solvent, no injury would be expected to workmen. If changes are made in the operation, which may result in an increase in concentration, duration, or frequency of exposure, measurements should be repeated. The degree of hazard can be minimized by containing the cleaning operation in an enclosed area, such as a hood, by ventilation that removes the vapors from the workroom air away from workers. The use of personal protective devices, such as gas masks, respirators, and self-contained or remote breathing apparatus, are not recommended for continuous use but can be effective for handling spills or similar upsets.

The type of respiratory protection required is dependent upon the concentration of the vapor to be expected in the workplace, which in turn can be determined by measurement of the vapor concentration. If the concentrations are no more than 2% by volume, the canister type of gas mask will offer adequate control for short periods. With most halogenated hydrocarbons, breakthrough of the canister is noted by the detection of the odor of the halogenated material. However, odor alone is not a totally reliable indicator of canister exhaustion.[4] The cartridge type respirator is less effective because it has a smaller canister, and, therefore, contains less absorbent material. These cartridge types are usually useful only up to vapor concentrations of 1000 ppm. The self-contained

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[4] All respirators must be approved by either the National Institute for Occupational Safety and Health (NIOSH) or Mine Safety & Health Administration.

breathing apparatus will be necessary if the concentration of the vapors rises above 2%, the capacity of the canister mask, or if the use is in an area where oxygen deficiency may be a factor. Generally, *cartridge and canister masks are recommended for escape only.*

METHODS OF EVALUATING EXPOSURES IN THE WORKPLACE

Obtaining factual information on the concentration of vapor in the air must be obtained by chemical or physical measurement only. Relying on subjective evaluation, such as odor, may be misleading.

Sampling should be conducted with care to ensure that the samples represent a true picture of the actual conditions. If they are to be taken to determine employee exposure, they should be collected at the breathing zone. The samples should also be taken under actual working conditions, particularly if the operation or exposure is intermittent. It is the obligation of the employer to be sure operational exposures are within OSHA limits. It is recommended, however, that the ACGIH guidelines be met.

A variety of means are available for the measurement of halogenated hydrocarbons in air.

Detector Tubes

Tubes for chlorinated hydrocarbons are simple to use and, in comparison with some other methods, less costly. Tubes and a pump for sampling air are available in kit form. To increase their reliability, it is suggested that recalibration of the tubes be accomplished using random tubes from boxes with the same lot numbers.

Universal Carbon Tubes

These tubes have the advantage of collecting simultaneously a variety of hydrocarbons that might be in the air. A sampling pump is used to draw the vapor through the activated charcoal, which adsorbs the vapors. Analysis is accomplished by desorbing the charcoal with carbon disulfide and analyzing by gas chromatography.

Halide Meter

The principle is based on the fact that, in the presence of a halocarbon, the ultraviolet spectral content of an electrical spark is increased and the degree of increase is related to the concentration of the halocarbon. Its advantages lie in its capacity to define total exposure, its reliability in determining peak exposures, and its capability to be hooked up to a recorder for long-term studies, providing a written log for future reference. This instrument should be used with the chlorocarbons only.

Flame Ionization, Organic Vapor Detector

The portable Foxboro unit is available to measure[5] the vapor concentrations in air of all of the solvents. It is specifically used for trichlorotrifluoroethane since the above detectors cannot be used with this solvent.

Infrared, Organic Vapor Analyzer

The portable infrared analyzer[6] is also available for detection of trichlorotrifluoroethane. It is also useful with other solvents.

LABELING

All containers should have labels as required by OSHA to identify the product and carry a warning statement. Appropriate warning statements should be placed in prominent positions on the degreasing equipment itself. Labeling should also satisfy RCRA, DOT, and Clean Air Act requirements (ASTM Practice for Labeling Halogenated Hydrocarbon Solvent Containers [D 3844]).

Handling and Storage

These recommendations and local, state, and federal regulations should be followed for solvent storage and handling.

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[5] Analytical Century OVA-108, or equivalent

[6] Foxboro Analytical MIRAN 103, or equivalent

Storage

The storage and handling of nonflammable halogenated hydrocarbon solvents, while not usually considered hazardous, still require an approach of prudence and caution. Caution must be exercized to ensure that containers of these solvents do not leak liquid or vapor into adjacent areas creating health hazards. Drums of degreasing solvents should be kept closed to avoid evaporation; they should not be exposed to extreme heat. Preferably, these drums should be stored in an area sheltered from rain to avoid external drum rusting and possible solvent contamination by water. A room containing solvent stored in containers should be well-ventilated and cool. The containers should be fitted with closures. It is not good practice to store solvents in basements where escaping dense solvent vapor can concentrate.

Solvents are shipped in the following types of containers:

(1) drums,
(2) tank trucks, and
(3) tank cars.

Drums

Drums should be fitted with both 3/4- and 2-in. (2- and 5-cm) flanges, threaded to accept iron pipe size (IPS) plugs. The solvent should not be poured into open pails or buckets; it should be pumped from the drum to the machine by means of a hand- or motor-driven pump. Solvent handling in open containers increases the potential hazard of spilling, skin contact, unnecessary exposure to vapor, and encourages the dangerous practice of dumping the cold solvent into the boiling compartment of a heated degreaser. Solvent drums should be stored in a cool place with the bungs up.

Tank Trucks

Solvent is unloaded either by gravity or by pump to the customer's storage tanks. For intraplant distribution, small mobile tank trucks are commonly used. There are several manufacturers of this equipment. The type chosen should be fitted with a solvent-resistant plastic hose, a level indicator, and either a hand- or motor-driven pump. A 275-gal (1040-L) domestic fuel oil tank, mounted on wheels and fitted with equivalent accessories, makes a suitable substitute.

Tank Cars

Solvents are also shipped in railroad tank cars. On arrival at the customer's plant siding, they can be unloaded into the customer's storage facilities by gravity, pumping, or using dry air pressure. Standard safety features, such as leveling the cars, blocking wheels, and hanging "caution" signs, should be followed. If the tank car is to be unloaded by either gravity or pumping, pipe connections are made at the liquid outlet of the tank car. This outlet may be at the bottom of the tank or in the dome. In the case of gravity unloading, the delivery end of the pipe is connected to the customer's storage tank. If it is necessary to pump the solvent, the connection is made to the suction side of the pump. Loss of solvent vapors to the air of the low boiling solvents, methylene chloride, and trichlorotrifluoroethane, can be minimized by connecting the vapor phases of the tank car to the tank with appropriate piping. Make sure that adequate pressure and vacuum protection is provided for both the tank and the tank car. The dome on the tank car must be opened so that the discharge valve can be opened. Care should be taken during inclement weather to prevent moisture from entering the tank car. When the car is empty, all valves should be closed and the dome cover secured.

A less preferred way of unloading railroad cars is with the use of air pressure. This is considered appropriate for perchloroethylene, 1,1,1-trichloroethane, and trichloroethylene as long as not more than 20 psig (138 kPa) of pressure is applied and the car is equipped with a 25-psi (172-kPa) pressure relief valve in accordance with the Department of Transportation (DOT) regulations. When using air, the following steps should be followed:

1. Connect discharge piping to tank car outlet.

2. Open liquid outlet and inner discharge valve of tank car.

3. Replace dome cover and bolt securely.

4. Apply compressed air not in excess of 20 psig (138 kPa) to the dome. When tank car is empty, the compressed air will blow out the piping, and the pressure in the tank car will drop. The bottom outlet is then closed and the air supply connection removed. Vent carefully to relieve pressure. Open the dome and turn off inner discharge valve.

5. Replace the dome cover.

Storage Tanks

Storage vessels should be constructed and tested in accordance with the applicable American Society of Mechanical Engineers (ASME) or American Petroleum Institute (API). Allowances should be made for snow and wind load.

New regulations governing multiple tank storage areas are planned for many parts of the country. All applicable regulations should be investigated thoroughly to ensure that the proposed installation is in complete compliance.

Mild steel tanks are generally recommended, but for certain processes, Type 304 or 316 stainless steel may be desirable. For some services, mild steel tanks with solvent-resistance linings, such as phenolic-epoxy copolymers, may even be preferred.

Any of the common materials of construction, except aluminum or its alloys, may be used in the fabrication of a storage tank for chlorinated solvents. Although fully stabilized solvents are perfectly compatible with and recommended for use with all metals, including aluminum, prolonged storage of large quantities of the solvents in aluminum tanks is definitely not recommended.

Design load can be based on a weight of 14 lb/gal (1677 kg/m^3). For example, a vertical tank constructed of ¼-in. (6.4-mm) steel plate will be satisfactory for up to 15 000 gal (56 781 L) of solvent.

Tanks may be installed inside or outside a building or underground. Aboveground installations are generally preferred since these often permit the elimination of a pump. Also, leaks are easier to detect and repairs are easier to make. A vertical tank is less expensive and requires less space. However, either a vertical or horizontal configuration is quite satisfactory.

As part of the hazardous waste amendments passed in late 1984, Congress included a set of far-reaching provisions directing the U.S. Environmental Protection Agency (EPA) to begin regulation of most types of underground storage tanks. Under these provisions, EPA issued regulations requiring owners of underground tanks to notify state agencies by 8 May 1986 of the existence of these tanks. EPA is setting new standards for the types of underground tanks that can be used in the future and must ultimately set regulations on leak detection for tanks.

Above-ground tanks should be installed on reinforced concrete footings. A 1-in. (2.54-cm) layer of asphalt mastic should be applied between the tank bottom and the concrete pad to prevent corrosion and rusting of the tank bottom.

Containing Spills or Leaks

An accidental spill or leak is always possible. One of the simplest ways to contain the spill is to build a dike around the storage tank. This will help prevent ground-water contamination. The volume of the dike should be equal to or greater than the storage tank volume. This will guard against the worst case situation of spilling the entire contents of the tank. Also, local, federal, and state regulations may require dikes for storage tanks.

To comply with EPA regulations, all tanks of 2500 gal (9462-L) capacity or larger must be equipped with a permanently submerged fill pipe that extends to within 6 in. (15 cm) of the bottom. Most fabricators have standardized on a 2-in. (5.1-cm) diameter inlet line to match the size of the outlet line from tank cars and trucks. An equivalent size vent or "breather" line must be provided.

In addition to the inlet and vent nozzles, the tank should have a 22-in. (56-cm) minimum (24-in. [61-cm] preferably) manway on the roof and another on the shell to facilitate inspection, ventilation, and cleanout of the tank; a pump suction nozzle located 3 to 4 in. (8 to 10 cm) above the floor plate for complete drainage of the tank; and a nozzle for a level gage (the size of this nozzle will be dictated by the gage type selected). A pressure-vacuum relief system is also desirable.

As a general safety precaution, tanks should be grounded to discharge any static electricity.

Before initial quantities of chlorinated solvents are put into a storage area, the tank and auxiliary equipment, including piping, must be thoroughly cleaned to remove dirt, mill scale, and other contaminants that would degrade or discolor the product. This may require sand blasting, vapor generation degreasing, or just wiping to obtain the clean surface required.

State regulations provide for a variety of methods to prevent or limit the escape of vapor from storage tanks to the atmosphere. Depending upon the material stored, as well as the size of the storage tank and the locality of the tank, regulations may require a refrigerated vent, a conservation vent, or a floating roof. These regulations must be consulted before designing storage facilities.

Vents

A breather vent line must be provided on the tank to protect against bursting or collapse of the tank as it is being filled or as product is withdrawn. It also provides for normal expansion and contraction of solvents caused by changes in air temperature.

An air dryer installed in the vent line is quite important. Its purpose is to minimize the entry of moist air, which can cause rusting and subsequent weakening of the steel tank and contamination and discoloring of solvent.

Solvents are not corrosive, but their highly efficient degreasing ability quickly removes any protective oil film from the interior metal surface of the tank and leaves it vulnerable to rust-forming action.

Level Gage

All storage vessel should be equipped with some means of gaging the contents. Simple gages are preferable. Among the many types that can be used, the simplest are the following: rod types, float gage, sight glass, pressure gage at bottom of tank, and air-pressure-balance gage or manometer.

Pumps

A centrifugal type pump is most commonly used. This should be located so that a positive head is maintained on the suction side of the pump. Many positive displacements are also satisfactory. They allow more flexibility in their location but may need more maintenance because of their precision tolerances. A bypass valve must be provided on any positive displacement pump.

Pumps may be constructed of iron, steel, bronze, or brass, but not aluminum. Mechanical seals are preferable to packing glands.

Piping and Hosing

Ordinary steel pipe is suitable for handling solvents. Underground piping should be welded. Surface piping may be screwed, flanged or welded. Compressed-cork gaskets are suitable for pipe flanges.

Flexible metal hose of bronze or stainless steel should be used for connecting a tank car or tank truck to the main unloading line. This will prevent breaking or bending of stationary pipe as the springs raise the tank car or truck during unloading. (Most trucks have or can have their own hoses.) A flexible hose lined with polyvinyl alcohol resin, polyvinylidene chloride, or polytetrachloroethylene plastic is also suitable for such use. The polyvinyl alcohol, however, must be protected from moisture, which readily attacks it.

Positive locking quick connections of the Kamlok type should be used on the hose. Brass, bronze, or stainless steel are satisfactory. Aluminum piping and fittings are not recommended for halogenated solvent service.

Unions

Ground joint unions of metal-to-metal seats have been found superior to gasket-type unions.

Valves

Globe or stainless steel ball valves with Teflon trim are recommended where throttling is desired. Gate valves are suitable only in locations where the valve operations are either fully open or fully closed. Valves should have all-metal seats and disks. The use of aluminum is not recommended.

Although trichlorotrifluoroethane and methylene chloride may be safely stored in atmospheric tanks, it is preferable to use a pressure vessel for these solvents. This has the advantage of eliminating solvent losses through a breather connection.

Entering and Cleaning Tanks

Extreme care should be taken to see that all foremen and crews selected to undertake cleaning and repairs are familiar with possible hazards. There must be another person watching from the outside. No tank should be entered unless the precautions previously specified are followed (see ASTM D 4276). Ventilation through special vent openings in the bottom should be continued during cleaning and inspection. Under no circumstances should internal or external welding be performed until it has been determined that there is no solvent or solvent vapors in the tank.

Waste Disposal

Degreaser sludge is classified as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) and, as such, must be handled in compliance with federal, state, and local regulations. Your local agency for Management of Solid and Hazardous Wastes, or EPA Regional Solid Wastes Office, should be consulted to determine what alternatives are available for disposal of degreaser wastes.

SOLVENT CONSERVATION DEVICES AND PROCEDURES

Conservation of degreasing solvents has always been desirable from the standpoint of cost reduction. Today, it is vitally important because of the added concern for air pollution, industrial hygiene, energy conservation, and raw material conservation.

Conservation Devices

Many of the following procedures are also required by national, state, and local regulations.

Degreasing machines that are well designed, properly maintained and operated will function with minimum loss of solvent. Degreaser freeboard design and degreaser covers can play a major role in the control of solvent losses. Additionally, refrigerated freeboard devices and carbon adsorbers are available as auxiliary conservation equipment. Various of these conservation means are required individually or optionally by regulations. In the discussion that follows, each of these subjects will be reviewed in order of increasing capital cost. Each of these methods is capable of reducing solvent losses by 40% or more when properly selected, designed, and operated.

Covers

Flexible or rigid covers, either manually operated or powered, are used on open top degreasers. The design of the cover should be such that the vapor line is not disturbed during operation. The operator should be able to operate the cover with little effort.

If the degreaser is supplied with a lip exhaust, the air intake (slot) must be above the cover. It is preferable not to run the exhaust blower when the cover is closed.

The cover should be open only when work is being processed in the degreaser. For large degreasers where large loads are processed with a single strand hoist, covers are available that can close while the load is in the degreaser.

Freeboard Design

The freeboard (or distance from the top of the vapor zone to the top of the degreaser) protects the vapor zone from wind disturbances. In the past, freeboards were constructed to be roughly equal to 50 to 60% of the width of the degreaser. Recently, the industry standard has been increased to 75% of the degreaser width, as described on Page 9. This design standard is an option in complying with some regulations.

On existing equipment with shorter freeboard dimensions, the freeboard can be increased by adding the necessary sheet metal. The extension need not be welded to the existing freeboard because it will be well above the vapor zone. Consequently, the cost of this equipment modification is minimal. The extension should be designed to accept the existing or a new cover. Although simple, this method has been very effective in limiting solvent losses.

Refrigerated Freeboard Device

A refrigerated freeboard device is a control system that utilizes refrigerated coils above the standard condensing coils. These coils create a cold air inversion blanket that suppresses solvent losses. It can be added to existing degreasers or be integrated into new equipment. Degreasers using the refrigerated freeboard must be equipped with functioning water separators since some water can be expected to condense or freeze on the coils.

Carbon Adsorber

With carbon adsorption, solvent vapors escaping from a degreaser are captured by a lip exhaust, filtered and blown through a bed of activated carbon pellets, granules or fibers. The carbon traps the solvent but allows the air to pass through. The solvent is recovered by steaming the bed and condensing the solvent and steam. Obviously, solvent vapors that are not collected by the exhaust cannot be recovered. Automated systems are common, but manually operated units are available.

The use of steam to recover the solvent from the carbon results in exposing the solvents to large amounts of steam condensate. Many of the stabilizers for degreasing solvents are extracted by the water. Azeotropic cosolvents, such as alcohols, are also extracted from trichlorotrifluoroethane blends. Solvent manufacturers should be consulted for solvent compatibility with this recovery system, solvent stabilizer analysis, and restabilization information.

Conservation Procedures

The increase in solvent consumption is often unnoticed because it is gradual and usually tied in with production volume. Operating cost and ecology problems can be minimized with reasonable attention to operation and maintenance procedures as follows:

1. One of the most serious causes of excess loss is draft. Any air movement in the degreaser vicinity creates vapor turbulence. Look for open windows and doors, ventilation fans and space heaters, air conditioners, even drafts created by paint spray booths or roof exhaust. Overventilation through the slot exhaust of the degreaser is a common problem.

2. Dragout of solvent or withdrawal of work. Care should be exercised to rack parts for proper drainage from blind holes and recesses. Also, work should remain in the vapors long enough to ensure total heating of the work. Vertical hoists are not to exceed a vertical speed of 11 ft/min (3 m/min); bulky loads, even slower.

3. Extremely large workloads may cause the vapor line to drop significantly. When this occurs, air is drawn into the degreaser and mixes with the vapor. As the vapor line rises, this air-solvent mixture will be lost through displacement.

4. Loads and baskets must not fit too closely within the tank walls or they will create a piston action when loading or unloading. Instead of the vapors being condensed by the work, they will be forced out of the degreaser.

5. Manual spraying of the work must be done well below the vapor level. Spraying from above the vapors will cause turbulence and will result in excessive fumes in the work area. Spray force should do no more than flush the work. High pressure sprays are definitely to be avoided.

6. Heavy loads with large surface areas should not dwell in the freeboard area longer than necessary to allow good drainage. Thermal updrafts from the hot work may draw vapors from below and expel them.

7. Water separators should have covers. All separators should be equipped with means for cooling the solvent to below the boiling temperature of the solvent-water azeotrope. Consult your solvent supplier for guidance. Make sure that the flow of the solvent condensate from the water-cooled condenser coils to the separator is unobstructed.

8. Check periodically for leaks from sources such as pump packings, valves, gasketed covers, sight glasses, pipe joints, and so forth.

9. Maintain proper heat balance by keeping clean and descaled all of the heat exchanger surfaces, both internal and external.

10. Open top degreasers should be covered at all times when not in use to realize maximum solvent conservation.

11. Solvent recovery stills should be used when possible. Spent solvent is valuable and should not be discarded. Reclamation services are available in most locations. If in-house distillation is not available, arrange for pick up of spent solvent for reclamation.

12. Bulk solvent storage tanks should be equipped with pressure-vacuum vent devices that reduce vapor losses because of tank "breathing" caused by temperature changes.

GLOSSARY

Azeotrope—A specific composition of two or more substances which has a constant boiling point and does not change in composition during distillation.

Azeotropic Boiling Point—The boiling temperature of an azeotrope is often lower than the boiling point of each of the substances forming the mixture. For example, perchloroethylene-water azeotrope boils at 190°F (88°C).

Azeotropic Degreasing Solvent—A specific composition of two or more solvents, which does not change in the liquid and vapor phases; therefore, it behaves like a single solvent in a vapor degreaser and has a constant boiling point.

Carbon Adsorption—A recovery process that captures solvent vapors from air on activated carbon. The solvent is recovered (by desorption) from the carbon by injection of steam into the carbon bed and condensing the resultant solvent and water vapor.

Condensate—Liquid solvent resulting from cooling solvent vapors. It is the clean solvent that condenses on the cooling coils of a vapor degreaser or still.

Desiccant Dryer—A means of removing water from a solvent by adsorption with desiccant, such as a silica gel or molecular sieve.

Desorption—The process of regenerating a carbon adsorption unit by treating the carbon with steam to remove the adsorbed solvent.

Distillation—A process of purifying a solvent by boiling, condensing the vapor, and collecting the condensate.

Dragout—Solvent that is carried out of a vapor degreasing operation as a liquid trapped in or on the parts being processed.

Ecology—The relation between living organisms and their environment.

Freeboard—Distance from the top of the vapor level to the top of the degreasing tank.

Halogenated Solvents—Liquid substances that contain carbon and halogen or carbon, hydrogen, and halogen (such as fluorine or chlorine) atoms. In this text, the term refers to the commercial solvents; methylene chloride, perchloroethylene, 1,1,1-trichloro-ethane, trichloroethylene, and Tichlorotrifluoroethane.

Nonflammable—A term used to describe those halogenated solvents that have no fire or flash point when tested by standard test methods. The Department of Transportation specifies ASTM Test Method for Flash Point by Tag Closed Tester (D 56) or ASTM Test Methods for Flash Point of Liquids by Setaflash-Closed-Cup Apparatus (D 3278) as acceptable test methods for determining flash points of liquids. Under unusual conditions, certain nonflammable solvents may exhibit some ability to burn.

Refrigerated Freeboard Device—A low-temperature heat exchange coil located in the degreaser freeboard zone, immediately above the water-cooled condensers. The device maintains a dense, cold-air mass above the solvent vapor, which reduces the loss of vapors from the unit.

Shock Load—A large part or load of parts, which cause the solvent vapor level to drop substantially below the normal operating level.

Steam Distillation—The practice of injecting steam directly into the still after normal distillation has ceased to recover more solvent from the residue.

Still—A unit employed to purify solvent by distillation.

Vapor Line—The line or level of the solvent vapor-air interface in the vapor degreasing unit.

Vapor Safety Thermostat—A device that senses the temperature of the solvent vapors and shuts off the heat supply by actuating a solenoid, spring-loaded valve or a switch if the hot solvent vapors rise too high in the degreaser.

Water Separator—A device designed to remove water from the solvent by flotation.

Work Capacity—The load a degreaser is designed to process efficiently while maintaining a steady vapor level.

SOLVENT NOMENCLATURE (ALTERNATE CHEMICAL NAMES)

- Methylene Chloride
  - Dichloromethane
  - Methylene Dichloride
  - MeC
  - DCM

- Perchloroethylene
  - Perchlorethylene
  - Tetrachloroethylene
  - Per or Perc
  - PCE

- Trichloroethylene
  - Trichlorethylene
  - Tri
  - TCE

- 1,1,1-Trichloroethane
  - Methyl Chloroform
  - TCA

- Trichlorotrifluoroethane
  - Fluorocarbon 113
  - CFC-113
  - R-113

ABBREVIATIONS

General

ft	foot
ft/min	feet per minute
g	gram
g/cm^3	grams per cubic centimeter
gal	gallon
h	hour
in.	inch
kPa	kiloPascals
lb	pound
mg/m^3	milligrams per cubic meter
min	minute
mL	millilitres
mm HG	millimetres of mercury
m	meter
ppm	parts per million
psig	pounds per square inch gage
s	second
W/in.^{2}	Watts per square inch
W/cm^2	Watts per square centimetre

Regulatory

ACGIH	American Conference of Governmental Industrial Hygienists
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980, commonly known as "Superfund"
CFSC	Consumer Product Safety Commission
CTG	Control Technology Guideline
DOT	Department of Transportation
EPA	Environmental Protection Agency
MSHA	Mine Safety & Health Administration
NAAQS	National Ambient Air Quality Standards
NFPA	National Fire Protection Association
NIOSH	National Institute of Safety & Health
NSPS	New Source Performance Standard
OAQPS	Office of Air Quality Planning and Standards
OSHA	Occupational Safety and Health Act and Administration
PEL	Permissible Exposure Level
RACT	Reasonably Available Control Technology
RCRA	Resource Conservation and Recovery Act
SIP	State Implementation Plan
Superfund	*see* CERCLA
TLV	Threshold Limit Value
TSCA	Toxic Substances Control Act
TWA	Time Weighted Average
VOC	Volatile Organic Compound

APPENDIX

Federal EPA Guidelines* (RACT Document) (See Attached)

The U.S. EPA published guidelines for control of solvent metal cleaning operations to assist state and local regulatory agencies in the preparation of acceptable State Implementation Plans for the attainment of the National Ambient Air Quality Standard for Ozone. However, state and local agencies were not obligated to adopt these guidelines exactly and in detail. Thus, some variations occur in different state and local regulations, and these should be reviewed specifically to assure compliance.

Federal EPA Guidelines (RACT Document)

Complete Control Systems for Open Top Vapor Degreasers

Control System A

Control Equipment:

1. Cover that can be opened and closed easily without disturbing the vapor zone.

Operating Requirement:

1. Keep cover closed at all times except when processing workloads through the degreaser.

2. Minimize solvent carryout by the following measures:

(a) Rack parts to allow full drainage.

(b) Move parts in and out of the degreaser at less than 3.3 m/min (11 ft/min).

(c) Degrease the workload in the vapor zone at least 30 s or until condensation ceases.

(d) Tip out any pools of solvent on the cleaned parts before removal.

(e) Allow parts to dry within the degreaser for at least 15 s or until visually dry.

3. Do not degrease porous or absorbent materials, such as cloth, leather, wood or rope.

4. Workloads should not occupy more than half of the degreaser's open top area.

5. The vapor level should not drop more than 10 cm (4 in.) when the workload enters the vapor zone. (Rescinded by Federal EPA)

6. Never spray above the vapor level.

7. Repair solvent leaks immediately, or shut down the degreaser.

8. Do not dispose of waste solvent or transfer it to another party if more than 20% of the waste (by weight) can evaporate into the atmosphere. Store waste solvent only in closed containers.

9. Exhaust ventilation should not exceed 20 m^3/min per m^2 (65 cfm per ft^2) of degreaser open area, unless necessary to meet OSHA requirements. Ventilation fans should not be used near the degreaser opening.

10. Water should not be visually detectable in solvent exiting the water separator.

Control System B

Control Equipment:

1. Cover (same as in System A).
2. Safety switches:

(a) Condenser flow switch and thermostat (shuts off sump heat if condenser coolant is either not circulating or too warm).

(b) Spray safety switch—shuts off spray pump if the vapor level drops excessively, about 10 cm (4 inches).

3. Major control device:

Either:

(a) freeboard ratio greater than or equal to 0.75 and if the degreaser opening is >1 m^2 (10 ft^2), the cover must be powered;

(b) refrigerated chiller (freeboard);

(c) enclosed design (cover or door opens only when the dry part is actually entering or exiting the degreaser);

(d) Carbon adsorption system, with ventilation ≥ 15 cm/m^2 (50 cfm/ft^2) of air/vapor area (when cover is open), and

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*Control of Volatile Organic Emissions from Solvent Metal Cleaning, EPA, 450/2-77-022, Nov. 1977.

exhausting <25 ppm solvent averaged over one complete adsorption cycle; or

(e) control system, demonstrated to have control efficiency, equivalent to or better than any of the above.

4. Permanent, conspicuous label, summarizing operating Procedures 1 to 6.

Operating requirement is the same as in System A.

Federal EPA Guidelines (RACT Document)

Control System for Conveyorized Dereasers

Control System A

Control Equipment: none.

Operating Requirements:

1. Exhaust ventilation should not exceed 20 m^3/min per m^2 (65 cfm per ft^2) of degreaser opening, unless necessary to meet OSHA requirement. Work place fans should not be used near the degreaser opening.

2. Minimize carry-out emissions by

(a) racking parts for best drainage or

(b) maintaining vertical conveyor speed at <3.3 m/min (11 ft/min).

3. Do not dispose of waste solvent or transfer it to another party if more than 20% of the waste (by weight) can evaporate into the atmosphere. Store waste solvent only in covered containers.

4. Repair solvent leaks immediately, or shut down the degreaser.

5. Water should not be visibly detectable in the solvent exiting the water separator.

Control System B

Control Equipment:

1. Major control devices: The degreaser must be controlled by either:

(a) refrigerated chiller (freeboard);

(b) carbon adsorption system, with ventilation ≥ 15 m^3/min per m^2 (50 cfm/ft^2) of air/vapor area (when downtime covers are open), and exhausting <25 ppm of solvent by volume, averaged over a complete adsorption cycle; or

(c) system demonstrated to have control efficiency equivalent to or better than either of the above.

2. Either a drying tunnel, or another means such as rotating (tumbling) basket, sufficient to prevent cleaned parts from carrying out solvent liquid or vapor.

3. Safety switches:

(a) Condenser flow switch and thermostat—shuts off sump heat if coolant is either not circulating or too warm.

(b) Spray safety switch—shuts off spray pump or conveyor if the vapor level drops excessively, for example, >10 cm (4 in.).

(c) Vapor level control thermostat—shuts off sump heat when vapor level rises too high.

4. Minimized openings: entrances and exits should silhouette workloads so that the average clearance between part and the edge of the degreaser opening is either <10 cm (4 in.) or $<10\%$ of the width of the opening.

5. Downtime covers: Covers should be provided for closing off the entrance and exit during shutdown hours.

Operating Requirements: 1 to 5, same as for System A.

6. Downtime cover must be placed over entrances and exits of conveyorized degreasers immediately after the conveyor and exhaust are shut down and removed just before they are started up.

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