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Evaluation of Disposal Concepts for Used Solvents at DOD Bases

February 1983

Prepared for
DEFENSE PROPERTY DISPOSAL SERVICE
DEFENSE LOGISTICS AGENCY
Battle Creek, Michigan 49016

through
SPACE DIVISION
AIR FORCE SYSTEMS COMMAND
Los Angeles, California

Prepared by
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Washington, D.C. 20024

Contract No. F04701-82-C-0083

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The information in a Technical Operating Report (TOR) is developed for a particular program and is therefore not necessarily of broader technical applicability.

FOREWORD

This report presents the results and conclusions of a study performed for the Defense Property Disposal Service (DPDS) by The Aerospace Corporation from July 1982 through February 1983. The objective of the study was to evaluate alternative disposal concepts for used solvent materials at Department of Defense (DOD) installations. Aerospace performed the study by developing a data base on solvent use and disposal practices through visits to a number of DOD bases and commercial facilities using solvent materials and disposal operations. Both federal and state regulatory requirements relating to the use, storage, and disposition of hazardous solvent materials were examined. The characteristics of the alternative methods of solvent use and disposal at the facilities were identified, and a method for determining potential cost savings through the use of alternative solvent disposal techniques was applied. This Final Report presents a number of recommended recycle and reuse improvements for the storage and disposal of used solvents at military installations that are more cost effective than incineration or other destructive disposal practices. This information may be of value to the future disposal management of hazardous solvent wastes at military facilities.

ACKNOWLEDGMENTS

The Aerospace project team acknowledges the assistance and cooperation of a number of organizations and individuals in support of this study.

Invaluable information and substantial assistance were provided by agencies and commands of the Department of Defense and the industrial companies and the trade association involved in waste solvents as follows: the Defense Property Disposal Service, Battle Creek, Michigan, for initiation and sponsorship of the project (Col. R.A. Hamblin, USAF, Col. J.T. Cuccaro, USA, and Mr. George Jonas as well as Mr. Larry Bailey and Mr. J. Gerard Payer, Project Monitors, for their guidance and contributing assistance); the military services and base commanders for their cooperation in allowing us to inspect their solvent use and disposal operations and to interview their personnel (i.e., key personnel in Appendix A); the many industrial solvent user companies, solvent process and recycling equipment manufacturers, new solvent suppliers, and the used solvent recyclers and transporters who willingly shared their knowledge and experiences (see Section II for organizations); and to the Environmental Protection Agency for interpretation and information on current and projected hazardous waste regulations and incinerator and landfill disposal methods.

EXECUTIVE SUMMARY

BACKGROUND

This report presents the results, conclusions, and recommendations of a study performed by The Aerospace Corporation to evaluate alternative disposal concepts for used solvents at Department of Defense (DOD) bases. This study was conducted at the request and under the sponsorship of the Defense Property Disposal Service of the Defense Logistics Agency located in Battle Creek, Michigan.

A data base of information was developed relating to used solvent disposal practices by conducting a series of site survey visits to selected military bases and several commercial facilities involved in solvent usage and disposal activities. The bases are representative of the diversity in size, location, and function found throughout the complete family of military facilities. In addition, telephone contacts were made with many other commercial organizations involved in some phase of solvent usage or disposition.

SOLVENT MATERIAL USE PRACTICES

During the base visits, five solvent process use categories were identified to account for the bulk of used solvents generated at military facilities. These include vapor degreasing, cold cleaning baths, paint stripping and carbon removing, paint thinning and equipment clean up, and metal preparation and precision cleaning. These categories provide a useful framework for identifying the solvent use patterns and quantifying the used solvent generation at military installations. The types and major quantities of used solvent materials in each of the five categories were identified with respect to their rate of generation and physical characteristics as they were removed from the various processes. Most of the used solvents identified are hazardous wastes under current Environmental Protection Agency (EPA) regulations. The use categories and solvents identified are listed below.

Process Use Categories	Classes and Types
Vapor Degreasing	Chlorinated 1,1,1-Trichloroethane Tetrachloroethylene Trichloroethylene
Cleaning Baths	Mineral Spirits Stoddard Solvent Varsol PD-680
Paint Stripping and Carbon Removing	Chlorinated Methylene Chloride with Additives
Paint Thinners	Oxygenated Methyl Ethyl Ketone Toluene Xylene
Metal Preparation and Precision Cleaning	Alcohols and Freon

DISPOSAL ALTERNATIVES

At the conclusion of site visits to both military and industrial installations, four alternatives were identified for the disposition of used solvent material.

Destructive Disposal--the disposition of the used solvent through the common disposal techniques of incineration or landfill. With this option, there is no opportunity for reuse of the material. The exercise of this option typically results from a decision process in which the used material is determined to have no salvage value or reclamation potential. Most of the installations visited were using this option to some degree.

Sale--defined as a transaction in which a used solvent removed from a process is either transferred or sold for reuse. The generating facility will realize some revenue if the used solvent material can be sold to a commercial recycling organization. Included in this category is an arrangement known as manufacturer take-back. In this case, the supplier of the solvent agrees to take back the used solvent from the DOD installation allowing either some credit against the purchase of new material or, in some cases, charging the installation a nominal fee for transportation of the material to the manufacturer's facility. This material is typically reclaimed in the process of manufacturing new material.

Off-Base Recycle by Distillation--involves recycling of used solvent material by a service contractor at a facility located off the user installation. The solvent user makes arrangements with the commercial recycling organization to remove the used solvent from the base and reprocess the material to a condition suitable for reuse. The material is then returned to the installation for reuse.

On-Base Recycle by Distillation--involves the operation of an on-base recycling facility, typically staffed by base personnel. The recycle facility collects the used solvent materials from processes in operation at the base and recycles them to a condition suitable for continued use in the solvent process at the base.

It was noted that sale and recycle alternatives require the effective segregation of used solvent materials so that reclamation processing can be feasibly and efficiently conducted. Distillation equipment used for recycling cannot efficiently separate mixed or unsegregated solvents.

TECHNICAL AND OPERATIONAL FEASIBILITY

The technical and operational feasibility of each of the disposal alternatives was investigated. A review of both federal and state

environmental and safety regulations having an impact on the implementation of these alternatives at military installations was conducted. The objective was to identify any constraining factors on the application of these alternatives at military installations. Detailed information on successful used solvent recycling at both military and industrial facilities located throughout the country was collected and analyzed.

Several issues concerning the implementation of solvent recycling activities for DOD facilities were identified. These issues included the acceptability of recycled material, manpower and training requirements, capital and operating costs, and reclamation process waste disposal; they were examined to identify possible constraints. After examining the records and reviewing the recycling experiences at some DOD bases, a sound basis for recycling used solvents was demonstrated.

The experiences of the bases and commercial facilities conducting solvent recycling demonstrated that these operations do not require personnel of high technical skill levels. State-of-the-art distillation equipment for solvent reclamation is highly automated and does not require full-time operator attention. Thus, personnel dedicated to equipment operation is not a requirement.

The capital cost of solvent reclamation equipment for on-base operation is relatively modest. Reclamation equipment for bases with large used solvent amounts will cost about $75,000; suitable reclamation facilities for bases with small amounts will cost under $50,000. For the majority of solvent use profiles observed at military installations and the potential cost savings resulting from recycle, payback of the initial capital investment can be achieved in less than 1 year.

When reclamation activities are performed on-base, a waste stream comprising the nonrecoverable contaminates or still bottoms will

be generated. This waste stream represents less than 10 percent of the original volume of used solvents processed in the reclamation activity and can be turned over to the local Defense Property Disposal Office (DPDO) for destructive disposal.

Practical reclamation of used solvent materials requires effective and dependable segregation of these materials after they are removed from the generating processes. While it is technically possible to separate various solvents in a mix, it is not economically practical to do so with waste streams that have been commingled. Information gathered during the facility surveys indicates that good cooperation of base personnel at all levels is important for the successful operation of solvent reclamation activities. Personnel must appreciate the importance of and practice good segregation of waste solvents materials in the reclamation operation.

None of the issues identified (e.g., suitability of used material, manpower and training requirements, capital cost, and still bottom disposal) were judged to be constraining factors in the application of sale or recycling alternatives of used solvents at military facilities. This assessment is based primarily on the observed successful operation of these alternatives at military and commercial facilities visited. Installations conducting sale and recycling activities consistently reported significant economic benefits resulting from these activities. A major reduction in materials requiring environmentally acceptable destructive disposal was also noted.

ECONOMIC ANALYSIS

Once the sale and recycling options were found technically feasible, and an economic analysis of the disposal alternatives was conducted, a list of approximately 500 DOD installations serviced by the Defense Property Disposal Service (DPDS) was screened and two

representative base size and solvent use characteristic profiles were chosen. These profiles were based on information gathered during on-site visits and discussions with DPDS personnel.

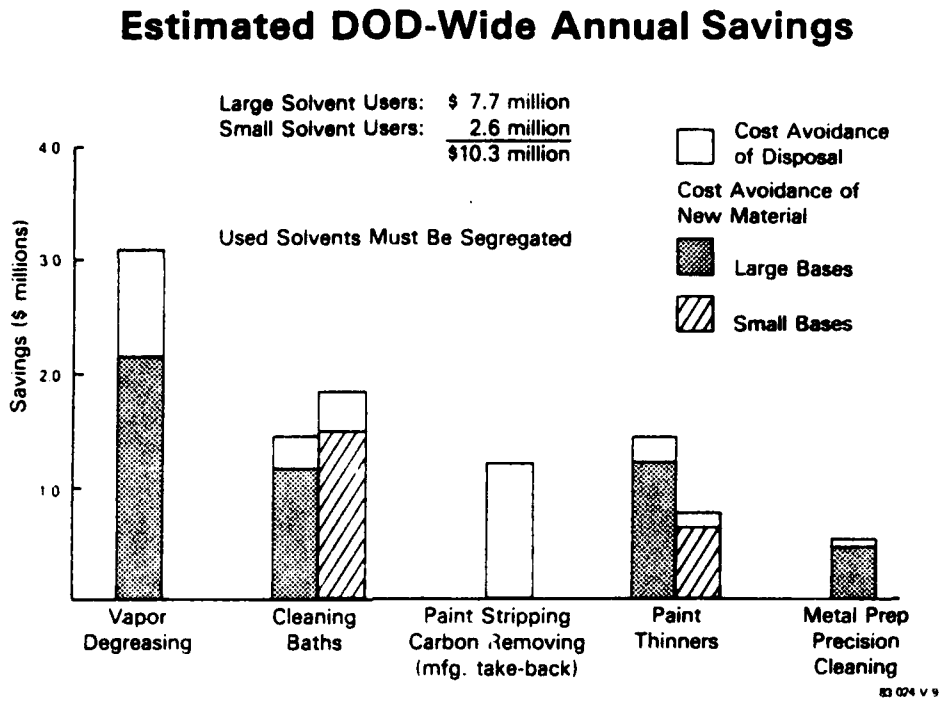
The large base-large solvent user category is typified by installations such as air logistic centers, shipyards, and large army depots. Twenty-nine installations were selected for inclusion in this class. All five solvent process use categories were assumed to be operating at these facilities. Small base-small solvent users were typified by tactical and operating facilities with specialized maintenance functions; 124 installations were selected in this class. Only two solvent process categories were assumed to be in use at these smaller bases.

Costs used in the analysis were based on information gathered at military installations and through discussions with industrial facilities and organizations providing used solvent disposal services. Cost estimates were developed for all four waste solvent disposal alternatives and the five solvent use categories. Costs were calculated, and the annual cost savings were compared. Ranking of the disposal alternatives was based primarily on potential economic benefit with consideration of the environmental acceptability and operational feasibility of the alternative.

ECONOMIC BENEFITS

Recycle of used solvents ranked highest for all solvent process use categories except one. That category was paint stripping and carbon removing at large bases for which manufacturer take-back or sale was judged the most feasible alternative.

The annual DOD cost saving for recycling at the 29 large and 124 small bases is shown in the following figure and includes the potential cost savings for the five process use categories. The



potential annual savings for the large and small solvent user bases were $7.7 million and $2.6 million, respectively, for a total of $10.3 million. Again, used solvents must be segregated after use for these savings to be achieved.

CONCLUSIONS

A wide variety of solvent use and disposal practices was observed during the DOD facility visits. The predominant mode of used solvent disposition caused primarily by poor segregation was destructive disposal involving either incineration or landfill. DOD is now paying to dispose of significant quantities of these unsegregated or poorly identified used solvent materials. Disposal of used solvents is the worst alternative to DOD, in terms of economics, for two reasons: (1) it requires purchase of replacement solvents by the base and (2) it incurs a disposal cost to DPDS. Only a few DOD facilities are actively engaged in recycle or reuse of used solvent materials.

Disposal alternatives exist that have been shown to be both technically feasible and economically attractive for the disposal of used solvents. The adoption of these cost savings alternatives would not entirely eliminate the use of destructive disposal methods; however, such alternatives would greatly reduce the amount of material requiring destructive disposal. The implementation of sale or recycling of used solvents can result in direct economic and environmental benefits to DOD through avoidance of new solvent purchase costs and disposal costs, while reducing the potential for improper release of these hazardous waste solvents into the environment.

RECOMMENDATIONS

Based on the evaluation of the used solvent situation at DOD bases, it is recommended (1) that DOD firm up their requirements for sale and recycle of used solvents with policies that require bases to segregate and recycle used solvents unless the bases can show it to be not feasible and (2) that DOD develop methods for base and DPDS cooperation and training to improve segregation, storage, and reuse of used solvents.

An approach to accomplish this would be to (1) establish and implement action plans at the base level to achieve the requirement, (2) activate plans and authorize procurement of needed distillation equipment or contracts with off-base recyclers, (3) establish a schedule and reporting system to measure progress, and (4) update procurement specifications for distillation and solvent process use equipment to the industrial sector state-of-the-art.

It is suggested that those bases and personnel now successfully selling or recycling used solvents be used as sources of knowledge to help expand the application of their techniques throughout DOD.

ACRONYMS AND ABBREVIATIONS

A&D	abandonment and destruction
DLA	Defense Logistics Agency
DOD	Department of Defense
DOT	Department of Transportation
DPDO	Defense Property Disposal Offices
DPDS	Defense Property Disposal Service
EPA	Environmental Protection Agency
OSHA	Occupational Safety and Health Act
POL	petroleum, oil, and lubricants
RCRA	Resource Conservation and Recovery Act (of 1976)
RTD	reuse, transfer, and donation

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I. INTRODUCTION

Large volumes of used solvent materials are generated on a continuing basis as a result of operations at Department of Defense (DOD) installations. The final disposition of this used solvent material requires proper consideration of the environmental consequences, the economics, and the viability of the disposition method. These factors have always been integral parts of the disposition decision process; however, the environmental factors have assumed an increasing importance as a result of the federal environmental regulations of hazardous waste materials under the Resource Conservation and Recovery Act (RCRA) of 1976.* These regulations are designed to define responsibility for the environmentally acceptable disposition of a wide range of hazardous waste. The DOD waste solvents classified as hazardous wastes by the Environmental Protection Agency (EPA) encompass most of the solvent materials found in common use at DOD facilities at this time. The purpose of the regulations is to establish a shared liability originating with the waste generator and extending through the final disposal of hazardous waste (i.e., from cradle to grave).

DOD compliance with these as well as other environmental regulations is mandated by Executive Order 12088, Federal Compliance with Pollution Control Standards. The military is achieving compliance with the regulations now in place and with the regulatory structure as it evolves. Much of this effort centers on the identification and management of hazardous wastes, particularly at the installation level. The costs of handling and disposal of these wastes will be of increasing concern as hazardous waste regulations are promulgated.

* P.L. 94-580, October 21, 1976, as amended by P.L. 95-609, November 8, 1978.

Until recently, the responsibility for disposal of hazardous waste, including waste solvent material, has been largely assumed by the individual service facilities generating the waste. While under current DOD policy (DEQPPM 80-8), the installation commander continues to have the overall responsibility for securing and maintaining compliance with environmental regulations, DOD has established, under the Defense Logistics Agency (DLA), the Defense Property Disposal Service (DPDS) as a focal point for hazardous waste disposal activities. To centralize the disposal management function and ensure DOD compliance with federal and local regulations, DOD assigned responsibility for storage and disposal of hazardous materials to DPDS. The formal assignment of this responsibility was accomplished in Defense Environmental Quality Program Policy Memorandum 80-5. This memorandum defines the types of materials for which DPDS is responsible.

In addition to its normal cycle for disposition of excess, surplus, and waste material, DPDS has been directed to use private contracts to accomplish the disposal of hazardous material turned in by the various DOD facilities. Under these service contracts, DPDS typically pays the low bid contractor to remove and properly dispose of waste material that has been turned in to DPDS by the generating military installation.

As DPDS gradually assumed responsibility for the storage and disposal of hazardous waste turned in by military installations, the need for a systematic analysis of alternative approaches for acceptable disposal techniques became increasingly apparent. DPDS requested that The Aerospace Corporation perform a feasibility study of alternative methods for storage and disposal of used solvent materials currently generated at DOD facilities. Solvent materials represent one of the major hazardous material groups with respect to both environmental concerns and amounts generated. The study examined the full range of options for the performance of the disposal

function, and general recommendations were made for the selection and implementation of disposal alternatives at DOD facilities. While initial guidance for the study primarily centered on the examination of bulk storage and disposal techniques, there was flexibility in considering other approaches that would lead to the environmentally acceptable disposition of used solvents and that might prove economically beneficial to DOD.

The approach chosen for the study involved visits by a survey team to selected military bases to collect information on current solvent usage and disposal practices. Emphasis was placed on obtaining much of this information at the working level to gain an appreciation of the attitudes and concerns surrounding the solvent use and disposal functions. Also visited were commercial facilities engaged in solvent use activities similar to those of DOD. During these visits, information on the methods used in the private sector for dealing with the disposal of waste solvents was collected. Analysis was performed to determine if the approaches used in the commercial sector might be successfully implemented at DOD installations.

This report presents the results and conclusions of the Aerospace study. Data are presented on the types of solvent materials found in common use at the DOD facilities visited. Used solvent material from DOD process operations and reported to the Defense Property Disposal Offices (DPDOs) for disposal are also quantified and characterized. Recent experiences of the selected installations and of their DPDOs in disposing of waste solvent material are summarized and analyzed. A summary of the current private industry practices is presented. Based on these data, a number of disposal alternatives are developed and analyzed for each used solvent material category and disposal alternative available with respect to their environmental and technical acceptability and their potential economic benefit to DOD. The report contains discussions on equipment that could be used in the implementation of some of the disposal alternatives.

II. STUDY METHODOLOGY AND APPROACH

The study of alternative methods of used solvent storage and disposal was conducted in a series of steps that allowed the elements of the study to evolve from and be guided by the preceding steps:

- Develop data base and visit military bases,
- Visit commercial facilities to identify alternatives,
- Investigate regulatory requirements,
- Consider disposal alternatives,
- Analyze alternative applications,
- Analyze economic costs and benefits, and
- Develop conclusions and recommendations.

This approach allowed concentration of study resources on those courses of action having the maximum benefit to the DOD organizations involved. While the basic study tasks were defined at the outset of the study, the specific details of each step were dependent on the findings of the preceding steps. The resulting conclusions of the study are thus based on the information and analysis that evolved with the study.

A. MILITARY FACILITY SURVEY VISITS

The first step in the study was to develop a data base of existing solvent usage practices at military installations. This included identifying the major solvent materials in common use, the processes in which these materials were being used, the characteristics and quantities of the used solvent materials as they were removed from the processes, and the recent experience of the individual bases and DPDOs in disposing of used solvent materials. The body of data was developed by visiting a representative group of military bases located within the United States.

The wide range of missions and functions performed in connection with the operation and support of modern U.S. military forces results in an equally diverse set of facilities at which these functions are performed. Military facilities use significant amounts of solvent materials. The installations range in size from large industrial complexes such as Air Force logistics centers, Army depots, and Navy shipyards to small installations performing specialized functions. Functions range from the complete maintenance of large military equipment such as aircraft, mechanized equipment, and ships to specialized component maintenance and overhaul of navigational and avionics units. This diversity of mission gives rise to a wide variety of solvent cleaning, degreasing, and stripping operations and materials.

The selection of candidate installations at which to conduct solvent usage and disposal surveys had as its prime objective obtaining a broad data base representative of the storage and disposal problems facing DOD installations. Facility selection was made from the more than 400 facilities served by DPDS. Input to this selection process was solicited by DPDS from the services and branch organizations involved. Aid in coordinating the survey visits was also provided by the individual services. The final selection of military bases surveyed was made by the DPDS and is presented in Table 1. The key personnel contacted during the base visits are identified in Appendix A.

During the facility visits, survey teams identified the major types and amounts of solvent materials in use at each installation, the nature of the processes, and the characteristics of the used solvent material as it is removed from a process. This information was used to develop the disposal options available to military facilities for disposing of used solvents. Detailed waste generation, storage, and disposal information collected during facility visits is presented in Appendix B.

Table 1. DOD Installations Visited

Army	Navy	Air Force
Seneca Depot	Jacksonville NAS	Kelly AFB
Tooele Depot	Norfolk NARF	Hill AFB
Corpus Christi Depot	Norfolk PWC	Robins AFB
		MacDill AFB
		Tyndall AFB
Marine Corps	**Defense Logistics Agency**	Davis-Monthan AFB
El Toro MCAS	Columbus	Bergstrom AFB
	Tracy	McClellan AFB

B. COMMERCIAL FACILITY SURVEYS, VISITS, AND CONTACTS

During the second phase of the study, visits to commercial facilities performing functions similar to those at the military facilities were made to identify additional alternatives for used solvent disposal that might be adopted. The selection of and site visits to these facilities were arranged by the study team. In addition to actual commercial site visits, several commercial organizations were surveyed by telephone concerning their solvent usage and disposal practices. A listing of those visited and contacted is presented in Table 2. These commercial facilities are representative of the various activities using modern solvent cleaning, degreasing, and stripping operations.

In addition to contacts with commercial solvent user facilities, the study team contacted a wide variety of commercial organizations involved in solvent process equipment manufacturing, new solvent material supply, solvent reclamation equipment manufacturing, solvent recycling, and waste solvent transportation and disposal. A list of those contacted is presented in Table 3.

Table 2. Commercial Facilities Visited and Contacted by Telephone

Delta Airlines
Pan American Airlines
United Airlines
Avial (Aircraft Maintenance)
Pratt & Whitney (UTI)
Caterpillar Tractor
Greyhound Bus
District of Columbia Transit Authority
National Machine Tool Builders Association

The total combination of military and commercial contacts provided a broad body of information on solvent usage practices and alternative methods for disposal of used solvent materials.

C. REGULATORY REQUIREMENTS

For the third step in the study, regulatory requirement impacts on the various disposal alternatives were investigated. The major motivation for the DPDS assigned responsibility and the conduct of this study is to support DOD environmental compliance efforts. To ensure that solvent disposal techniques are in compliance with current and expected environmental regulations, the body of regulations pertaining to the use, handling, transport, and disposal of solvent materials were reviewed. The bulk of these regulations is governed by the Resource Conservation and Recovery Act passed in 1976, but certain Occupational Safety and Health Act (OSHA) and Department of Transportation (DOT) regulations also impact the selection of viable

Table 3. Commercial Facilities Contacted

Solvent Process Equipment Manufacturers

Detrex Chemical Industries, Inc., Detroit, Michigan
Baron-Blakeslee, Melrose Park, Illinois
Corbane Industries, Inc., Louisville, Kentucky
Vapor Engineering Inc., Pensacola, Florida
Phillips Manufacturing Co., Chicago, Illinois

New Solvent Suppliers

Exxon Corporation, Baltimore, Maryland
PPG Industries, Pittsburgh, Pennsylvania
ReTep Corporation, Salt Lake City, Utah
Circle Prosco, Inc., Bloomington, Illinois
Dow Chemical, Midland, Michigan
The Prillaman Co., Martinsville, Virginia
Eldorado Chemical Co., Fort Worth, Texas

Used Solvent Recyclers and Transporters

National Association of Solvent Recyclers, Dayton, Ohio
The Prillaman Co., Martinsville, Virginia
U.S. Pollution Control, Oklahoma City, Oklahoma
Chemical Recovery Systems, Romulus, Michigan
Custom Organics, Inc., Chicago, Illinois
M&J Solvents Co., Atlanta, Georgia
Oil & Solvent Process Co., Azusa, California
Romic Chemical Corp., Palo Alto, California
Golden Eagle Oil Refinery, Inc., Salt Lake City, Utah
McKesson Envirosystems, Fort Wayne, Indiana

Solvent Reclamation Equipment

Finish Engineering Company, Inc., Erie, Pennsylvania
DCI Corporation, Indianapolis, Indiana
Gardner Machinery Corporation, Charlotte, North Carolina
Chem-San International, Inc., Fairfield, New Jersey
Baron-Blakeslee, Melrose Park, Illinois
Detrex Chemical Industries, Inc., Detroit, Michigan
Vapor Engineering Inc., Pensacola, Florida
Brighton Corporation, Cincinnati, Ohio
Artisan Industries, Inc., Waltham, Massachusetts

storage and disposal alternatives. The EPA policy on RCRA is designed to shift responsibility for regulation to the state level as each state regulatory plan is approved. Some states have already assumed portions of this responsibility. The current status of state primacy in RCRA regulations is presented in Appendix C. The waste regulations of these states were reviewed to determine what, if any, impacts on alternative disposal options, result from variations in regulations.

D. IDENTIFICATION AND ANALYSIS OF ALTERNATIVES

The fourth step in the study involved consideration of disposal alternatives identified during the military base and commercial facility visits and contacts.

Using the information collected during the base visits and commercial contacts, technically viable and environmentally acceptable alternative practices and procedures for the storage and disposition of used solvent materials at DOD bases were identified. The investigation included the identification of resources and facilities required to place the alternative solvent disposal practices into operation at a military facility. The availability of necessary equipment and services were investigated along with their performance records. Some of this information had been previously collected during the base and facility visits, but much of the detail in this step was developed through additional contacts with the individual equipment suppliers and recycling service contractors. This information provided the basis to judge the overall feasibility of the various alternatives and the potential constraints to their application.

E. STUDY OF DISPOSITION ALTERNATIVES AT MILITARY FACILITIES

The fifth step in the study involved an analysis of the potential application of each of the identified alternatives to an actual

situation at a military installation. This allowed for the development of the necessary procedures, equipment, and capital requirements to implement solvent disposal alternatives under a set of realistic conditions. The facilities selected for this analysis were the large Naval installations in the Norfolk, Virginia, area, including the Naval Air Rework facility, the Naval shipyard, and the Public Works Center. Scheduling conflicts did not permit visits to the Norfolk Naval Shipyard facilities. Arrangements were made to tour these facilities and to survey solvent usage and disposal practices accompanied by representatives of commercial companies. The companies selected purchase used solvents outright, provide used solvent recycling services in Virginia, or supply equipment for solvent reclamation suitable for on-base solvent recycling installations at the Naval facilities in the Norfolk area. The survey was intended to develop complete details of application or installation of the alternatives including economics so other bases faced with similar requirements could use the information as guidance in selecting and implementing their own programs.

F. ECONOMIC ANALYSIS

The sixth step in the study involved the projection of overall economic data for the alternatives in order to estimate the potential economic benefit to DOD that would result from the implementation of one or more of the disposal options. Based on the observed solvent use characteristics at the bases visited, a solvent usage and used solvent generation profile for two representative base sizes was developed. The two profiles characterize a large base-large solvent user, such as an air logistic center, a Naval shipyard, or a major Army depot, and a small base-small solvent user such as a tactical Air Force base, Naval base, or specialized Army maintenance facility.

By examining a listing of all military installations and their functions, 29 military installations that fulfill the large base-large

solvent user profile and 124 installations that represent the small base-small solvent user profile were selected for study. Next, the economic details of the application of the solvent disposal options and the solvent process use categories were developed to determine whether any economic benefits would accrue to DOD as a result of the application of the alternative at the bases. The alternatives were then compared on the basis of overall economics. The comparison considered cost of implementation and potential cost savings for each approach. The next step in the study projected the potential cost savings resulting from the adoption of alternative solvent disposal techniques at the 29 large and 124 small facilities. Names of the facilities in each category are listed in Appendix D.

III. SOLVENT CHARACTERIZATION

The first step in the study process identified and classified the types and characteristics of the solvent materials and the process use categories in operation at military installations. At the outset, characterization of the types of solvents used at military installations was developed from DPDS records of types of materials turned into DPDOs for disposal. Initial examination of these records indicated a fairly large number of individual solvent types. As additional information was gathered during installation visits and data on the rates of waste generation of the individual streams were examined, solvent characterization became clear and allowed for systematic classification.

Although it was found that several types of solvents in a particular generic classification are turned in at a DPDO, generally only one or two specific solvents come from a single facility. It was determined that solvents in use at military installations could be classified in terms of their process applications rather than by types. The framework of major process use and solvent classes with specific types was developed and is presented in Table 4.

This categorization accounts for the major quantities (>500 gallon per year installation) of used solvents generated at the installations surveyed in connection with this study. The five process use designations in Table 4 reflect those processes or activities that generate the predominant amount of the used solvent or waste stream containing that particular solvent at the installations surveyed. This classification has been confirmed through discussions with commercial solvent users and solvent suppliers and provides a useful aid in understanding problems and factors that relate to the storage and disposal of used solvent materials.

A description of the major solvent classes is presented with some of their applications and hazardous characteristics. Most of these

Table 4. Solvent Applications on DOD Bases

Process Use Categories	Classes and Types
Vapor Degreasing	Chlorinated 1,1,1-Trichloroethane Tetrachloroethylene Trichloroethylene
Cleaning Baths	Mineral Spirits Stoddard Solvent Varsol PD-680
Paint Stripping and Carbon Removing	Chlorinated Methylene Chloride with Additives
Paint Thinners	Oxygenated Methyl Ethyl Ketone Toluene Xylene
Metal Preparation and Precision Cleaning	Alcohols and Freon

solvents fall into the EPA hazardous waste generic groups F001 through F005* because they are known toxic or ignitable wastes.

* Ref. 40 CFR 261 Subpart D, "Lists of Hazardous Wastes," revised as of July 1, 1982.

Halogenated Solvents: Halogenated compound solvents are composed of hydrogen, carbon, and a halogen (e.g., chlorine or fluorine). The major types of halogenated solvents encountered in the study are:

- Chlorinated solvents: 1,1,1-trichloroethane, tetrachloroethylene, trichloroethylene, and methylene chloride.

- Fluorinated solvents: trichlorofluoromethane (Freons)

Hydrocarbon Solvents: Hydrogen and carbon compound are solvents that generally are derived from petroleum or coal tar products. Typical solvents observed in this group are:

- Aromatics: toluene and xylene.

- Aliphatics: heptane and mineral spirits.

Mineral spirits, representing a broad group of solvents, are known by varous trade or functional names, including dry cleaning solvent, Stoddard solvent, Varsol (Exxon), and PD-680.

Oxygenated Solvents: These solvents are composed of hydrogen, carbon, and oxygen. Examples of the various types are:

- Alcohols: methanol and ethanol.

- Ketones: methyl ethyl ketone (MEK) and methyl isobutyl ketone (MIBK).

Miscellaneous: The solvents listed above are often mixed with each other and other components (e.g., emulsifiers) and are typically used as paint strippers, paint or lacquer thinners, carbon removers, and metal cleaners.

The major characteristics and applications of these solvents are summarized in Table 5. Additional information compiled by the U.S. Coast Guard covering hazardous solvent characteristics is presented in Appendix E.

Five different solvent applications were found to require relatively large quantities of solvents based on the service activities surveyed. These include vapor degreasing, cleaning baths, paint stripping and carbon removing, paint thinning, and metal preparation and precision cleaning. A summary of the major solvent applications and the solvents used in each application is given below. This process use categorization is the framework for the analysis of solvent disposition alternatives.

Vapor Degreasing: Chlorinated solvents are used for vapor degreasing of fabricated metal parts at large installations. Because of its lower toxicity, 1,1,1-trichloroethane primarily is used rather than trichloroethylene or tetrachloroethylene. About 400 waste drums of used chlorinated solvents from vapor degreasing units are collected annually from a large installation engaged in major military maintenance.

Cleaning Baths: Mineral spirits or the military equivalent solvent PD-680 are used in parts and equipment cleaning processes as sprays or dips. Its ability to remove oils and greases from metal and its low evaporation rate make the solvent a versatile, widely used material in different shop activities at all installations. About 150 and 500 waste drums of PD-680 are generated annually from small and large bases, respectively.

Paint Strippers and Carbon Removers: Many industrial solvents are available for paint stripping and carbon removing processes. The solvent type will depend on the specific application. A common solvent component observed is methylene chloride, a chlorinated

Table 5. Solvent Class Characteristics

Solvent Class	Examples	Application	Characteristics
Halogenated	1,1,1-trichloroethane Tetrachloroethylene Trichloroethylene	Vapor degreasing	High solvent power Low flammability High volatility Rapid evaporation Low residue properties
	Methylene chloride (with additives)	Stripper carbon remover	Good metal cleaning, paint stripping, and surface coating agent
	Freons	Highly specific cleaning (e.g., avionics)	High solvency High purity Rapid evaporation Low residue properties
Hydrocarbon	Toluene Xylene	Cleaning and thinning	High solvent power Highly volatile Rapid evaporation High purity
	Mineral Spirits	Oil and grease remover from parts, limited thinning applications	Broad distillation and good solvent power Slow evaporation Moderately volatile Mixed hydrocarbon composition High flash point
Oxygenated	Alcohols Ketones	Thinners	High mixing and diluting ability

methane industrial solvent. Methylene chloride is usually blended with other chemical components to maximize its effectiveness against specific coatings. These additives include alcohols, acids, amines or ammonium hydroxide, detergents, and paraffin wax. The solvent can be applied as a dip or in aerosol mixtures. Larger installations can generate about 500 drums of this waste material per year from dip tank processes.

Paint Thinners: Painting and the application of similar coatings were found to be major functions at all the installations surveyed. It was noted that several different kinds of solvents were used in connection with these operations. These include toluene, xylene, methyl ethyl ketone, and alcohols. These materials are used in three general functions: (1) to thin paint and coatings prior to application, (2) to clean surfaces prior to painting in wipe-on applications, and (3) to clean paint and coating application equipment after painting or coating operations. The first two functions can generally be considered as consumptive with respect to solvents and do not generate any direct waste stream. The third function, equipment cleanup, is responsible for the generation of the major waste stream for these materials. While most of these solvents are supplied to the facility as pure material, they are also frequently purchased as a blend or are mixed in the paint shop prior to clean-up applications. Leftover paint in the equipment also becomes part of the clean-up solvent waste stream. None of the facilities surveyed were making any attempt to segregate solvent wastes resulting from equipment clean-up, and it does not appear that absolute segregation is possible in view of the materials and functional applications. About 400 drums of paint thinner solvent waste are generated annually at large installations while small installations generate about 50 drums annually.

Metal Preparation and Precision Cleaning: Alcohols, along with ketones, esters, and cresylic acids, are the typical solvents used for

cleaning surfaces prior to application of a paint or anticorrosion coating. Usual applications are in small quantities such as for wipe-on, and solvents are usually consumed in the process.

In processes where very specific cleaning requirements must be met, only certain solvent compounds are suitable. For example, Freons are used to clean certain electrical parts and instruments. The cleaning process requires compounds of high solvency, high purity, and rapid evaporation rates. About 75 drums of waste Freon could be generated annually at an installation having this activity.

IV. USED SOLVENT DISPOSITION PRACTICES

A. MILITARY INSTALLATION DISPOSITION PRACTICES

After identifying and classifying solvent materials, the second step of the installation surveys developed an information base pertaining to current experiences and practices for the disposition of used solvents at DOD installations. The installations surveyed represent a wide variety of activities and base sizes. The visits resulted in the identification of an equally broad range of current practices and experiences in the area of used solvent disposition. This section presents the general approaches to waste solvent disposition observed in practice. While the exact details for the use of a particular approach may vary from base to base, the general approaches were found consistent.

The disposal practices observed at the various installations include storage and segregation, disposal, sale, off-base recycling, and on-base recycling. The disposal practices for the installations visited are listed in Table 6. The selection of a particular approach or mix of approaches to waste disposition was found to be and can be expected to remain a base-specific decision. This decision depends on various factors, some of which change with time, and may include installation functions and size, solvent types and quantities used, geographic location, state regulatory requirements, or installation operating policies.

1. Storage and Segregation

One of the original objectives of the study was to evaluate current and future storage alternatives for used solvents. Based on on-site visits and discussions with military and industrial representatives involved in hazardous waste management, it became apparent that the scope of the study should encompass not only storage

Table 6. Current Disposal Practices

Installation	Storage and Segregation Program*	Disposal Practices			
		Disposal	Sale	Off-Base Recycling	On-Base Recycling
Seneca Army Depot	Good	¶			
Tooele Army Depot	Fair	¶	¶		
Corpus Christi Army Depot	Good				¶
Kelly AFB	Fair	¶	¶	§	
Hill AFB	Good		¶	¶	
Robins AFB	Good				¶
MacDill AFB	Fair	§			
Tyndall AFB	Fair	¶			¶
Davis-Monthan AFB	Good		¶		
Bergstrom AFB	Fair		¶		
McClellan AFB	Good			§	¶
Jacksonville NAS	Poor	¶			
Navy, Norfolk, VA	Fair	¶			§
El Toro MCAS	Poor	§			
DLA, Columbus, OH	Fair	¶	¶		
DLA, Tracy, CA	Fair	§			

*Good = Achieves segregation
Fair = Achieves partial segregation
Poor = Achieves minimal segregation (uses one or more common waste storage tanks)
¶In Place
§Pending

options but disposal alternatives available to the military as well. Regardless of the management and disposal alternative selected by an installation, there is still a storage requirement for hazardous material. Even with installations practicing segregation and recycling, temporary storage facilities will be necessary.

Storage containers for hazardous materials removed from process areas consist of either drum or bulk tank systems. These container and storage systems are used for all solvents as well as for other hazardous materials for short-term storage away from process areas. Drum containers (typically 55-gallon capacity) are the most prevalent system employed. Use of drums allows for collection and handling of small volumes of materials and reduces the potential problem of accidental mixing or commingling of used solvents. Waste materials can be placed in drums at the process unit area, often in the same drums in which the virgin material was delivered. The use of new burnable drums to contain materials destined for incineration can also be considered to reduce used drum disposal problems.

Bulk container storage provides for the collection of larger volumes of waste material. Volumes can range from 500 to over 30,000 gallons. Bulk container storage of used solvents reduces collection and handling times because of the larger quantities of waste materials that can be stored. However, the concept has the potential problem of commingling different wastes. For example, the mixing of a small volume of a used chlorinated solvent into a bulk container of PD-680 significantly reduces the potential for PD-680 recycling and may greatly increase the cost for PD-680 disposal. Indeed, most of the bulk tanks used at bulk storage facilities are previously used tanks (e.g., for petroleum, oil, and lubricant (POL)) and are often stored underground. Commingling of waste materials is a common practice when bulk containers are used.

Currently, there are no regulations to prohibit underground storage of hazardous waste. However, aboveground containment is

preferable because long-term storage increases the potential for leakage. An alternative to the bulk storage concept is portable storage tanks. These tanks or bowsers are aboveground, sized to the appropriate specific waste volume generated, located near or convenient to process areas, and can be transported easily to recycle or disposal facilities.

The storage facilities at the bases vary in compliance for conforming storage. A conforming storage compound should at a minimum have an impervious pad to hold hazardous materials in the event of spills and a suitable cover to protect against the elements. The wastes should be segregated within the compound (e.g., acids, caustics, solvents, waste paints). The facility should be sized to accommodate the expected level of waste generation over a given period of time. There are current DOD actions to improve or construct new conforming storage facilities at military installations. Such facilities are still required even if an effective recycle program is initiated, but the size of the facilities may be significantly reduced.

For military operations, drum storage is acceptable provided the containers used are in a safe-to-handle and transport condition for used solvents. The use of plastic drum covers to protect drums that must be stored in areas exposed to the elements will help to keep the drums in better condition. It must be stressed that drum storage, or any other containers used for waste material, is only a temporary storage option. Drum storage would be acceptable for all disposal options and would involve minimal disruption or adjustment to current process operations. Where feasible, bulk containerization and storage would reduce handling and transportation efforts. Caution must be exercised to avoid commingling materials in bulk tanks.

Storage facilities are an integral part of any installation hazardous waste management system. It is important that a facility conform to accepted requirements for proper storage and that the term of storage be reduced as much as is practical. In addition, base

operating personnel, their management, and the DPDOs must be aware of and involved in the containerization, collection, handling, storage, and disposal operations at the base.

The concept of good material segregation is of singular importance in implementing any of the disposal alternatives for used solvents. Most processes at DOD bases use only one type of solvent material at a time. That is, they are not routinely mixed for use in cleaning processes. There are many functional disadvantages to mixing solvent materials including increased and sometimes unpredictable reactions with components to be processed or cleaned in the process, decreased chemical stability of the solvent materials leading to generation of harmful contaminates, and in some cases, decreased solvent power. For these reasons, essentially only a single solvent material is placed or replenished in a process unit. Similarly, if two different types of solvent materials are mixed for any reason, it is difficult and in most cases economically impractical to attempt to separate the two materials in any solvent reclamation activity. Therefore, the single solvent material found in most solvent processes will usually contain only nonsolvent contaminates when the solvent is removed from a process as a used material. Solvent reclamation equipment is most capable of separating the single used solvent from contaminates in an effective manner.

Steps should be taken, therefore, to avoid mixing different used solvent materials as they are removed from process use or as they are temporarily stored awaiting final disposition. While not as critical, good segregation of solvent materials can simplify the processing of used solvent materials for destructive disposal and in most cases minimize the cost of that disposal. Without proper segregation of used solvent materials, the effectiveness of solvent reclamation processes is greatly reduced or in many cases eliminated.

2. Disposal

For purposes of this study, "disposal" is defined as a DOD purchased service for destructive disposal of the used solvent material resulting from the designation of the material as having no sale or reclamation value. Disposal of waste solvents is the most common alternative exercised by bases in the past and continues to be the most prevalant method employed by the bases surveyed. The wastes are collected from the process areas and disposed of either directly by the base or through the DPDO. Waste solvents for disposal were usually found to be containerized in 55-gallon drums, although several large bulk tanks were also found in use. Most installations using disposal did not place emphasis on segregation of the used solvent materials. The lack of dependable material characterization and segregation was observed to complicate disposal and increase the disposal costs.

Disposal methods vary among the installations visited. In cases where a private contract disposer was used, waste solvents were either landfilled or incinerated. It should be noted that any destructive disposal option as used by the military is not a low cost option. Typically, disposal costs for landfill or incineration may well exceed $100 per drum and, depending on the requirements for pretreatment and transportation, could reach $200 per drum. Recent hazardous waste regulations will increase future handling costs for hazardous waste materials, as already evidenced by requirements for installation waste generators to adequately characterize their wastes for proper disposal.

Destructive disposal techniques can achieve environmentally acceptable disposition of used solvent materials; however, the associated costs for this approach do not make it economically attractive as an end objective.

3. Sale

"Sale" is defined as a disposition transaction in which DOD either reuses, transfers, or donates the material to eligible organizations or receives some revenue through the sale of the used solvent material. In general, when a used solvent is determined to be excess or surplus, the material is turned in to DPDS by the generating facility for disposition through the DPDS sales cycle.

Solvent material turned in to a DPDO is screened according to the normal DPDS system of (1) reuse, transfer, and donation (RTD), (2) sales, and (3) abandonment and destruction (A&D). The RTD cycle involves government agencies and entails no monetary transaction. Very little solvent material is disposed of during this portion of the cycle. However, Brookhaven National Laboratory is using selected used material in the solvent category in an alternative energy source program. Material in the sales portion of the cycle has the potential to generate revenue for DPDS and the installation. The A&D portion of the cycle results from a total lack of interest in the used material as offered in the other portions of the DPDS disposition cycle. Material designated for A&D action effectively reverts to the "disposal" option. DPDS will typically negotiate a service contract in which they pay for the disposal of these materials.

Sales exposure is made by a national monthly sales catalog and by local auction to determine possible market potential. Salability of any solvent material depends on the solvent type, quantity, and degree of contamination. Sales revenue ranges from $0.10 to over $1.00 per gallon. Regardless of the revenue generated, the sale of any material avoids the potential cost of disposal resulting from designation of the material for A&D. Thus, sale is a more economically desirable option than disposal.

Another variation of the sale option is an arrangement referred to as manufacturer or supplier take-back. In this situation, the

original material manufacturer or supplier agrees to "take back" used materials from the user. The waste material is usually then reprocessed in the manufacturing facility. The user may either receive a credit or pay a nominal fee for this disposition service. The fee is typically much less than the corresponding cost of destructive disposal. Paint stripper waste, for example, at Hill Air Force Base, is disposed of in this manner. Under the current agreement with the material supplier, the cost to the base is $0.10 per gallon to have the supplier remove the spent material from the stripper tanks and transport the material back to their facility for disposal or reprocessing. The $0.10 per gallon charge is essentially a transportation fee.

The sale option can accomplish environmentally acceptable disposition of used solvent materials when qualified manufacturers or their representatives receive the used material and use proper practices in its reprocessing or end use. Some bases have had recent experience in which unqualified individuals have purchased the material and improperly released it to the environment. When properly conducted, the sales option can have a potential economic benefit for DOD that the disposal option does not have. To realize this economic potential, used solvent materials must be segregated at the point of generator and maintained in this condition throughout the sales cycle.

Most used solvents investigated that have been successfully sold through the DPDS sales cycle have been containerized in 55-gallon drums. Only two facilities visited had bulk storage facilities in which solvents are stored in a segregated manner for later sale for recycle or reuse. Several facilities reported that mineral spirit solvent material (PD-680) was routinely placed in the waste oil stream. In most cases, this stream was being sold for as much as $0.40 per gallon, but the end use was generally as fuel in operations like those of asphalt plants. No attempt was being made to recover the solvent from the stream for recycling.

4. Off-Base Recycling

For this discussion, "off-base recycling" defines an arrangement in which the installation (solvent user) arranges for the used solvent to be taken off-base to a commercial recycling facility. There the recycler processes the used solvent to a reusable condition, and the solvent is returned to the military facility for reuse. The facility pays for this recycling service and receives the reclaimed solvent for use in processes at a cost much lower than the original purchase price of new solvent.

An installation can contract with a private recycler to pick up contaminated solvents, transport them to a private recycling facility, process the solvents, return the reclaimed solvents to the installation, and dispose of the unsalvageable residue. Specifications for loading and unloading, addition of neutralizers or inhibitors (where applicable), quality control of reclaimed solvents, and other operational factors can be incorporated into the contract statement of work.

Most segregated used solvents at military installations can be practically and economically recycled, including the chlorinated vapor degreasing solvents, PD-680 or Stoddard solvents, Freon, and heptane. Paint thinning solvents (i.e., toluene, MEK, and xylene) also can be reclaimed as pure solvents from paint residue if they were not intentionally blended when used to thin the material or if they have not been commingled as a result of use. Because this is not typical, paint thinning solvents are generally reclaimed as blends to be reused as equipment cleanup solvents where high purity or exact blend composition is not critical. It is not economically practical to separate the mixed materials by distillation in reclamation processes.

Volatile solvent fractions in other mixtures such as paint strippers can be separated by distillation, but here again there is little opportunity to reuse this reclaimed solvent in its original

application because reuse would involve the reformulation of proprietary mixtures to achieve the original paint stripper material.

Storage and handling of both used and reclaimed solvents can be efficiently accomplished in either 55-gallon drums or in large bulk storage tanks. Similar to sale of the used materials, good material segregation must be established and maintained before recycling. Segregation may be easier to establish and control if 55-gallon drums are used because this approach represents the continuation of current practice for handling new and used solvents in the work place. As a system for recycling develops or when process equipment in the work place is replaced or rehabilitated, the installation of suitable segregated bulk storage facilities integrated with new process equipment can be considered.

Off-base recycling costs vary depending on the type of solvent being recycled and the degree of contamination of the solvent. Hydrocarbon solvent, such as PD-680 and Stoddard solvent, reclamation costs range from $0.50 to $0.80 per gallon; chlorinated solvents like 1,1,1-trichloroethane cost about $1.50 per gallon to reprocess. These two groups represent the range of costs associated with off-base recycling services.

Off-base recycling of used solvents presents an environmentally acceptable alternative to disposal of used solvents with minimal base personnel disruption, and there are economic benefits to be realized through the implementation of this approach. The key factors in the success of this approach are seen as the development of a supportive attitude on the part of command, supervisory, and operating personnel; the establishment of good handling and segregation practices for the used material; and the availability of a commercial organization that can perform the reclamation service for the base. The transportation distance to the reclamation facility may vary greatly depending on the geographical location of the recycler. Recyclers in the West may

collect material for recycling from user facilities several hundred miles from their location; Midwest and East Coast recyclers tend to limit the area served.

5. On-Base Recycling

For this discussion, "on-base recycling" is defined as a capability on the base to perform the used solvent reclamation function and to routinely collect the waste solvent material from the work area for reclamation. The reclaimed solvent is returned to the appropriate process unit for reuse. The reclamation processing equipment is typically operated and maintained by base personnel, but this step could be obtained on a contract basis. The small waste stream of nonrecoverable contaminants removed in the reclamation process requires conventional disposal. This disposal function is the responsibility of the cognizant DPDO. It involves, however, a much smaller stream (typically, 10 percent) of the initial used solvent stream, as shown in Figure 1.

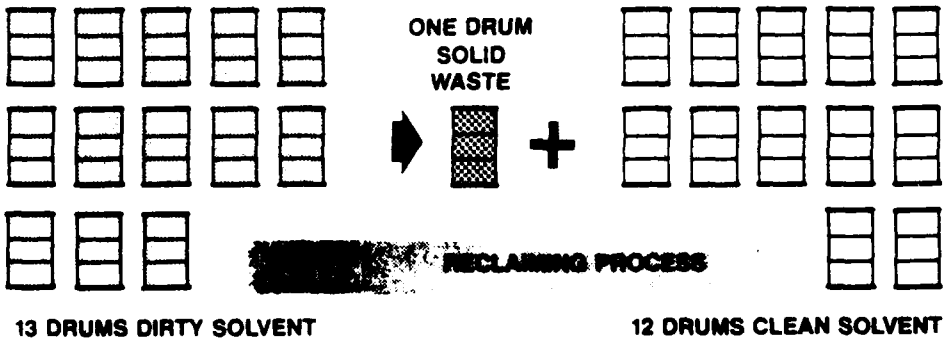

Figure 1. Solvent Reclaiming Yield

Equipment is readily available to implement appropriately sized reclamation facilities at military installations. Several types of distillation equipment were identified during the course of the study. These have a demonstrated ability to perform the reclamation function for a broad range of used solvent materials. Several facilities surveyed have solvent reclamation equipment installed and operating and several others have had equipment in the past, but for one reason or another the equipment is now inoperative. Reclamation facilities at some of the installations visited have been in successful routine operation for several years and are operated by base personnel. No base that currently operates reclamation equipment identified any persistent technical or operational difficulties with the equipment, and all expressed satisfaction with the reclaimed solvent materials.

Most solvents found in the major waste streams can be processed for reclamation by on-base recycling. The most frequently reclaimed solvent classes observed were the chlorinated solvents used in vapor degreasing, the Stoddard solvents used in cold cleaning bath applications, and Freon used in precision cleaning applications. Heptane, used as a calibration fluid, is now undergoing preliminary testing at one reclamation operation, and the reclamation of mixed paint thinners from waste paint material is being actively considered by two installations.

Quality control tests of the recycled materials have confirmed the ability of on-base reclamation equipment to produce reclaimed solvent material suitable for reuse in the original solvent processes.

B. COMMERCIAL FACILITY DISPOSITION PRACTICES

Site visits and discussions with commercial facilities produced a set of used solvent disposal alternatives similar to those found at

military bases. The primary difference, however, was that commercial facilities have been able to minimize the use of destructive disposal and increase reuse, recovery, or recycling of used solvents. Discussions indicated that the primary motivation for those choices is economics. They generally indicated that environmental compliance is necessary no matter which option is selected, and cost is the primary factor when selecting an option.

Destructive disposal tends to be practiced by smaller facilities where either the volume of the used solvent generated is small (less than 10 barrels per year) or the overall facilities are older and have little modern processing and support equipment. Most small facilities are limited in their solvent usage, relying primarily on mineral spirits for most cleaning applications. Used mineral spirits present minimal disposal problems and can generally be included in the waste oil stream for disposal or potential sale.

Larger facilities that use a full range of solvent materials successfully segregate and sell their used solvent materials for recycle or reuse. This was particularly true of the chlorinated materials and Freon. Many large facilities indicated that in-plant recycling of some materials is being considered in light of changing environmental regulations. Recycler services were used by the medium and larger companies. No technical objections to recycled solvent material were identified, but concern was expressed by some companies with their ability to control the flow of material in a reclamation activity involving an outside contractor.

Most of the large organizations contacted were operating some form of solvent reclamation equipment on a routine basis at one or more of their facilities. Most of these facilities have been operating for some time, and all companies having recycling facilities expressed satisfaction with their operation. They identified the economic incentives of the operation as the prime factor in this

satisfaction. All organizations stressed the importance of proper handling and storage of used solvents to maintain material segregation for effective recycling. They described the measures taken to help ensure proper segregation, including systems of containers that made it difficult to accidentally mix materials in the handling process, location and availability of containers that made it simpler to maintain segregation than to carelessly mix materials, and training of personnel to make employees aware of the economic incentives of segregation and the economic penalties if segregation is not maintained.

V. RECLAMATION POTENTIAL

The majority of solvent materials encountered in significant quantities in waste streams at military installations potentially can be reclaimed or recycled. Reclamation of these solvents can be accomplished through sale of the used material to commercial reuse or recycling operators or by using off-base or on-base recycling facilities. The solvents most frequently found in the process use categories are discussed below. Considerations that influence the choice of solvents to recycle and how to reclaim them include volume of the waste solvent stream, costs for disposal, the equipment necessary for reclamation, the value of the reclaimed solvent, and potential for environmental impact through improper release of the waste material to the environment. The environmental assessment is based on the general characteristics of the materials as presented in Appendix E and the reported effects of the material when it is improperly released in the environment.*

A. CHLORINATED VAPOR DEGREASING SOLVENTS

The chlorinated solvents used in vapor degreasing processes have the highest overall potential for reclamation. At the large maintenance facilities visited, vapor degreasing equipment was in wide usage. Although older vapor degreasing equipment allows much of the solvent feed material to be lost through evaporation during operation, a significant chlorinated solvent waste stream was observed at these

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* "Resource Conservation and Recovery Act," House Report 94-1491, U.S. Congress, House of Representatives, 94th Congress, 2nd Session, 1976, pp. 17-23.
"Management of Hazardous Industrial Wastes: Research and Development Needs," Report of the Committee on Disposal of Hazardous Industrial Wastes, Publication NMAB-398, National Academy Press, Washington, D.C., February 1983.
"Technologies and Management Strategies for Hazardous Waste Control," Office of Technology Assessments, Congress of the United States, March 1983.

facilities. Because there is little opportunity for this material to be commingled with other solvents during normal process operation, effective material segregation can be accomplished. As vapor degreasing equipment is modernized and loss through evaporation is reduced through the use of vapor recovery equipment such as carbon filters and refrigerated condensing units, the ability to frequently clean and reuse the solvent will increase the attractiveness of solvent reclamation and reuse. This is because a clean process with freshly reclaimed solvent will demonstrate greater cleaning efficiency.

As a class, chlorinated solvents have one of the highest disposal costs for destructive disposal. The high chloride potential makes incineration expensive, and liquid landfilling is either not allowed or is expensive. The presence of chlorinated solvents in a mixture of solvents destined for disposal significantly increases the costs of disposal.

Equipment necessary for reclamation of the chlorinated solvents is typically the simplest type of distillation equipment available. Chlorinated solvents are routinely distilled by commercial manufacturing facilities in connection with production line vapor degreasing equipment. Equipment to accomplish distillation is widely available from vapor degreasing equipment manufacturers and general distillation equipment manufacturers.

The value of reclaimed chlorinated solvent is high. Current prices for new material are generally in the range of $3.50 to $4.50 per gallon. A substantial economical benefit can be realized when reclaimed material costing between $0.50 and $1.50 per gallon is used to replace new material.

The potential for environmental impact resulting from improper release of chlorinated solvents to the environment is high. These

materials have a high persistence in the environment because they do not readily biodegrade. This characteristic can lead to groundwater pollution--a major impact.

B. MINERAL SPIRIT SOLVENTS FOR VAT CLEANING

Mineral spirits used in cold cleaning bath applications are those solvents used in the largest volumes on the bases visited. The government material specification designated as PD-680 provides a technical description of this solvent found in common use at military installations. At some bases, this material is known by its generic name, Stoddard solvent.

Large quantities of PD-680 are used for general parts and equipment cleaning applications. While some installations use large (greater than 200 gallons) dip tanks of mineral spirits, they also typically use small quantities in buckets and in small cleaning tanks scattered throughout the facility. Collection of waste solvent materials from the scattered usage locations is being accomplished by most bases and results in a significant waste stream.

The cost for disposing of mineral spirits through incineration should be minimal because of the potential heating value (Btu content); however, DOD is currently paying for disposal at several of the bases visited. Because of the volume of this material, disposal costs can be large. It appears that PD-680 may be routinely disposed of in the used oil waste stream at many installations. This practice avoids the disposal cost (oil reclaimers typically pay the facility for their waste oils), but it eliminates the potential for recycle of this solvent.

Mineral spirits or Stoddard solvents are routinely reclaimed by several military installations visited and commercial manufacturing and maintenance facilities contacted. Equipment is readily available

to accomplish distillation of this waste stream. At several of the installations currently recycling this material, the same reclamation equipment has been in routine and satisfactory operation for many years.

As a class, mineral spirits generally have the lowest purchase cost per gallon of all the solvents in common use. The typical cost of new material is $1.50 to $2.50 per gallon in comparison to the $0.50 to $0.80 per gallon cost for reclamation. The volume of this material and the large resulting waste stream make this material economically attractive for recycling.

Harm to the environment can result from improper disposal of mineral spirits, but the impacts are generally self-correcting through natural dispersion and breakdown of the material. The release can usually be treated as would an oil or gasoline spill and does not normally represent a major concern with respect to potential long-term environmental effects.

C. PAINT STRIPPING AND CARBON-REMOVING SOLVENT MATERIALS

The process use category of paint stripping and carbon removing can involve a large number of solvent materials; however, the solvent most frequently identified as a major constituent of these processed materials was methylene chloride. Methylene chloride was frequently found in formulations including phenols, mild acids, and caustics as well as smaller amounts of other solvents. Some solvent compounds include heavy metals such as chromium in their formulation.

Major quantities of these solvents are used at the larger maintenance facilities in a variety of stripping and cleaning operations. They appear as waste in two distinct streams. The first waste stream occurs when emptying large dip tanks. The resulting waste stream has a substantial volume but may have minimal solvent

because much of the original solvent content (methylene chloride) may be lost through evaporation at the tanks. The remaining material is typically placed in drums or large bulk storage tanks awaiting disposal. The second waste stream involves the direct application of the stripper material to large structures such as aircraft or machinery. After the stripper material has been allowed to act, it is usually removed from the structure by washing the structure with water. The resulting dilute waste stream is typically routed to an industrial waste treatment plant for disposal. In a few instances, the dilute material was collected and containerized for final disposal.

Costs for disposal of waste strippers are substantial even though the chlorinated solvent content of the waste may be low. Disposal is complicated by the presence of other materials such as the heavy metals and phenols along with paint sludge constituents. An industrial waste treatment plant at a facility that can properly treat the waste material resulting from direct application appears to represent the most cost effective method of disposing of this stream. This is being done successfully at a number of the installations contacted.

Although simple distillation equipment can be employed to separate solvent material from the balance of the stripper components and the other contaminants in the material removed from dip tanks, there would be a large residual waste stream (still bottoms) requiring disposal. This waste stream is composed primarily of sludge containing the paint solids and the other stripper components. This waste can be difficult to incinerate, and disposal costs can be high.

One installation visited removes a portion of the stripper material containing primarily sludge from the bottom of its large dip tanks, filters it to remove the paint material, and returns the filtered material to the tank. This filtration process is expected to more than double the life of the stripper material. No other installations were processing or reclaiming the materials on base.

Off-base solvent recyclers can and do process stripper materials to recover the remaining solvent content, but there must be a substantial amount of the solvent remaining to make this approach economically viable. However, manufacturers of the original stripper material formulation frequently have the capability to reprocess the waste material and use the constitutents in the formulation of new materials. An arrangement in which a manufacturer agrees to take back the used stripper material (manufacturers take-back) is being used at two of the military installations visited and with several commercial facilities.

While the solvent material recovered from this waste stream is valuable, it has minimal functional value to the military because material reformulation will be required to use the reclaimed solvent as a stripper. The reclaimed material can, however, be sold by a solvent recycler or, as previously mentioned, be reprocessed by the original stripper manufacturer. The value of the waste will vary depending on the solvent remaining in the waste, the nature of other contaminants, and the potential for selling or using the recycled material. For manufacturer take-back, the observed costs were $0.15 per gallon credit and $0.10 per gallon transportation charge.

There is substantial potential for environmental impact resulting from improper disposal of stripper material because of the chlorinated solvents present in the waste. The sludge content can also have an impact if it contains soluble pollutants, including heavy metals. These waste sludge materials may also be difficult to incinerate. The residual waste stream resulting from reclamation of this material presents similar environmental concerns. The potential environmental impact of this waste stream is thus a major factor in the decision on what recycle or disposal alternatives should be selected.

D. PAINT THINNING SOLVENTS

Several types of solvents are used as thinners in the application of paint and other coatings and in equipment cleanup. These include

hydrocarbons such as toluene and xylene, ketones such as methyl ethyl ketone and acetone, and some mineral spirits. When used to thin paints, the majority of this solvent is lost through evaporation during application, and it is not available for reclamation. Most of the paint thinner waste stream results from the use of solvents to clean mixing and application equipment after usage. While pure single solvents are sometimes used in thinning, premixed blends of several solvents are also commonly used. When used as thinners for paint application, these blends must be tightly controlled, but use in the equipment cleanup function does not normally require tight formulation specifications.

Large quantities of waste mixed paint thinning solvents were identified at large maintenance installations, and substantial amounts of this type of mixed waste material were observed at military activities having aircraft or equipment painting operations. Waste generation rates vary as a function of work load at most installations. In general, no attempt was being made to separate waste paint from paint containing waste solvents in collection or disposal containers.

Mixed paint thinning solvents have relatively low disposal costs when handled by incineration because they have a high energy content and can be easily fed to most incineration equipment. Industries using equipment such as cement kilns requiring high energy fuels frequently buy mixed paint thinning solvent waste materials for use as process fuel. Large quantities of this type of waste are turned in to the DPDOs for routine disposal. Frequently, this results in relatively high costs for disposal of these waste solvents. In some instances, the contract disposal costs are in excess of $1.00 per gallon.

Because of the general use of paint thinning solvents (i.e., equipment cleanup) and because they are frequently blends when they are received, the waste stream cannot be expected to be segregated by

solvent type. Distillation technology is capable of separating the various components of the mixed waste stream, but separation is not economically feasible for these materials. Simple single-stage distillation equipment of the type suitable for most on-base reclamation operations would require the stream to be passed through the unit several times to achieve good separation. It is relatively simple, however, to separate the mixed volatile solvent fractions from the paint residue to yield a clean mixed solvent stream. Simple single-stage distillation of the type used for the reclamation of other solvents can be used to process this material.

The resulting mixed solvent stream is frequently used directly in commercial facilities for equipment cleanup or waste solvent. It is also economically practical to adjust the resulting mixture to some general blend specification by the addition of one or more virgin solvent materials. This is frequently done when the material is processed for resale by a solvent recycler. Pure virgin paint thinning solvents (toluene, xylene, MEK, and acetone) cost between $2.00 and $3.50 per gallon. The blended reclaimed material can replace these pure solvents in equipment cleanup applications at a cost from $0.50 to $1.00 per gallon.

The materials in this group are generally quite volatile and dissipate rapidly when a spill occurs. However, most of these materials are toxic, and toxicity is increased by the constituents of the paint and other contaminants in the waste stream. Paint thinners can enter a groundwater supply and potentially contaminate the water, a major environmental concern. Much of this solvent material is biodegradable, which helps to minimize the long range environmental impacts of an improper release.

E. METAL PREPARATION AND PRECISION CLEANING SOLVENT MATERIALS

Specialized cleaning operations at some installations require low residue, rapidly evaporating solvents. These applications generally

involve the maintenance of delicate, sensitive navigational equipment or electronics equipment. The solvents are used to clean the components or circuit boards prior to reassembly or packaging for storage. Some alcohols are used for this function (primarily methanol); however, little of this solvent material was identified in the facility waste streams. Specialized operations at some bases (not visited) do generate significant waste streams of this material. Freon is the solvent most frequently encountered in waste streams of this class. Several installations use large quantities of these solvents in both specialized and general cleaning operations because of their high solvent power, low residual, and low toxic properties.

Relatively large volumes of these solvents are used in specialized cleaning processes, but only small amounts appear in most facility waste streams. This is because current usage allows the majority of the solvent to be lost through evaporation. In spite of this, several installations that use these materials in large quantities do have substantial waste streams available for reclamation. When a reclamation facility can be located near the process units using the solvent, the desirability of reclamation for these materials is increased. The loss of the material to evaporation can be reduced through modernization of process equipment. The volume in the waste stream at a base of 10 to 100 barrels per year is both technically and economically viable for recycle because virgin Freon costs more than $8.00 per gallon.

The current cost associated with disposal of alcohols and Freon is not high. In most instances, these solvents can be sold for a nominal salvage value to commercial solvent recycling facilities. If the solvent is highly contaminated or if it is commingled with other solvents, disposal by incineration may be necessary. The disposal of methanol by incineration is relatively inexpensive because of its energy content. Freon is not flammable, however, and has a substantial chlorine content. Disposal, when necessary, is thus relatively costly.

While methanol is a relatively inexpensive solvent, $1.50 to $2.00 per gallon, Freon is the most expensive solvent found in general use at the facilities visited. Depending on the specific type and purity, new Freon costs between $8.00 and $12.00 per gallon. Freon can be reclaimed for between $0.50 and $1.50 per gallon.

In discussions with personnel involved in on-base recycling of Freon, it was learned that the recycled material is typically only used as replacement for Type 2 Freon. This material is used in applications where the ultra-pure specifications of Type 1 Freon are not required. Thus, the effective value of the reclaimed Freon is at the lower end of the new material cost range.

There are only minimal impacts associated with the accidental release of methanol and Freon to the land and water environments. Both materials, especially Freon, are highly volatile and evaporate quickly. Freon is not toxic to aquatic life and does not pose a significant hazard as a water pollutant. Methanol is toxic to aquatic life in medium concentration (250 ppm) but dissipates rather rapidly.

F. CONCLUSIONS

All of the solvents identified in major waste streams at the installations visited have some potential for reclamation and reuse. The major candidates for reclamation are

- Chlorinated Vapor Degreasing Solvents: significant volume, high in value, easily reclaimed, major environmental concern (toxic materials).

- Mineral Spirits: high volume, easily reclaimed, significant value.

- Freon: high in value, easily reclaimed, significant volume at certain facilities.

- Paint Thinners: high volume, easily reclaimed, significant value, potential environmental impacts.

It has been demonstrated that these materials can be reclaimed at on-base facilities or off-base solvent reclamation centers when the waste solvent material is properly segregated. There is a potential sales value when proper segregation of the material is maintained.

Although used paint stripper materials can be reclaimed, it appears that they are best handled by the original material manufacturer. The formulations are proprietary, and the original manufacturers are in the best position to carry out the reclamation processing.

VI. RECYCLING

A. ON-BASE RECYCLING

While developing the data base, the study team learned of several facilities, both military and commercial, conducting successful on-base or in-house waste solvent reclamation operations. Table 7 lists the military installations visited and several commercial facilities currently conducting reclamation operations. In discussions with personnel at these facilities, the study team established the technical feasibility and the economic and environmental compliance incentives that influenced the decision to initiate and continue these activities. This section presents the application of on-base reclamation operations and the equipment necessary for the disposition of used solvents at military bases.

1. On-Base Solvent Reclamation Equipment

Simple solvent reclamation processing techniques can feasibly be applied to most of the waste solvent materials found in large volumes at DOD facilities. Simple small scale (less than 500 gallons per hour) solvent reclamation processes use the principle of distillation to separate the volatile solvent materials from the much less volatile contaminants. Contaminants in the waste streams of interest typically include oils, greases, hydraulic fluids, water, paint pigments and chips, and "dirt."

Table 8 lists the physical characteristics of the majority of solvent materials of interest for recycling. To achieve separation, the distillation process depends on the difference in boiling points of the solvent and the contaminants in the solvent. The primary physical characteristic in solvent reclamation is the boiling point. Where the atmospheric boiling point of the solvent is low (below 200°F), the material can be effectively separated from contaminants in

Table 7. Locations of Solvent Reclamation

DOD Facilities		Commercial Facilities	
McClellan AFB	PD-680	Delta Airlines	Chlorinated solvents Stoddard solvent
Corpus Christi Army Depot	1,1,1-trichloroethane PD-680	United Airlines	Chlorinated solvents Stoddard solvent
Robins AFB	1,1,1-trichloroethane Freon	Pratt & Whitney	Chlorinated solvents Stoddard solvent
Norfolk NARF	PD-680 Heptane	Caterpillar Tractor	Chlorinated solvents

Table 8. Solvent Data Sheet*

Solvent	Atmos. Boiling Pt(°F)	Azeo. Boiling Pt(°F)	Density (lb/gal)
Aliphatic Hydrocarbon			
Hexane	157	142.9	5.51
Heptane	209	174.8	5.70
Stoddard	308-316	204	6.47
Aromatic Hydrocarbon			
Benzene	176	157	7.32
Toluene	232	185	7.20
Xylene	261-318	202.1	7.17
Chlorinated Hydrocarbon			
Trichloroethylene	189	163.8	12.2
PERC	249	189.7	13.5
1,1,1-trichloroethane	166	149	11.0
Methylene Chloride	104	101.2	11.07
Fluorocarbon			
Freon TF	117.6	112	13.06
Freon 112	199	166	13.69
Acetone	133	133	6.59
M E K	175	164.1	6.71
MIBK	241	190.2	6.67

*Figures are calculated on a flow rate of 100 gal/h.
Source: DCI Corp., Indianapolis, Indiana

the stream in a simple atmospheric distillation unit. In such a unit, the contaminated solvent material is heated to the boiling point of the solvent of interest. The pure vapor is then condensed, and the clean distilled solvent is collected. Such equipment represents the simplest in distillation technology and is in widespread use.

When the boiling point of the solvent of interest is above 200°F (such as Stoddard solvent (PD-680)), the distillation process must be augmented in some manner to allow efficient vaporization of the solvent material of interest. One method of accomplishing this is to lower the boiling point of the solvent by reducing the pressure in the distillation unit or by applying a vacuum to the distillation system. The temperature and the total energy necessary to vaporize the solvent are thus reduced to a much lower level. Simple vacuum distillation units of this type are in widespread use in many commercial applications. Such units can generally be used for both the higher and lower boiling point solvents by adjusting the heating and vacuum controls.

An alternative to vacuum distillation for high boiling point solvents is steam injection distillation. In this system, live steam is injected directly into the solvent distillation chamber and mixed with the waste solvent. The combination of solvent and water in the form of steam produces an azeotropic mixture that has a much lower boiling point than that of the solvent of interest. Examples are shown in Table 8. The azeotropic mixture containing the solvent and water vapor can thus be separated from the contaminants in the mixture, oil, grease, solids, and paint pigment, because they do not form part of the azeotropic mixture. The water and solvent vapor can then be condensed in a normal fashion because water is relatively insoluble in the pure solvent. The water fraction of the mixture can be effectively separated by gravity to yield the clean processed solvent. The condensed water can be reused in the boiler to create more steam for process operation.

While it is technically possible to separate mixed solvents by the distillation process, it is not operationally or economically practical to attempt such separation with simple solvent distillation equipment. The equipment described above is intended primarily for the separation of single or unmixed solvent from typical contaminants in used solvent streams. The efficient operation of the distillation process equipment discussed above depends on good waste stream segregation to achieve optimal reclaimed product quality and economic benefit.

2. Solvent Materials for On-Base Reclamation

The majority of the solvents identified in large volume waste streams at military installations can be reclaimed for reuse using on-base reclamation equipment. The major solvents in each process use category are discussed below.

All of the chlorinated vapor degreasing solvents found in use at military bases can be reclaimed in simple on-base distillation equipment. These materials include trichloroethylene, perchloroethylene, and 1,1,1-trichloroethane. Their relatively low boiling points and low flammability make it possible to process these materials in an atmospheric still to yield suitable reclaimed materials. Stabilizing additives can be added after distillation if necessary. The requirement for such additives will be discussed in more detail later in this section.

Mineral spirits (Stoddard solvent or PD-680) as a class of materials has a higher boiling point (approximately 300° to 320°F). These solvents cannot be feasibly processed in an atmospheric distillation unit. However, this class can easily be processed in a simple vacuum distillation unit or a steam stripping distillation unit. Both approaches produce solvents suitable for reuse without further processing. While vapor from this material is relatively flammable, it can be distilled safely in simple on-base equipment that

has been in routine use for many years at several military and industrial facilities contacted.

Although the chlorinated solvent contained in paint stripping and carbon removing material can be reclaimed in simple distillation equipment, on-base reclamation of this material is not considered as an attractive endeavor because of the difficulties encountered in reuse of the reclaimed material. Exceptions may exist at specific facilities, but sale or manufacturer take-back appears to be the most practical option for dealing with this waste stream.

The wide range of boiling points for the types of solvents typically found in the paint thinning waste stream generally requires that the mixed material be processed in a vacuum distillation or steam stripping unit. Essentially the same mixture proportions present in the initial waste stream feed material can be expected in the reclaimed materials. As mentioned, it is not feasible to attempt separation of these mixed solvents in an on-base reclamation facility. Most of these solvents are flammable, and care must be taken in handling them during the on-base distillation process.

Freon can be easily distilled in simple on-base atmospheric distillation units. The Freon materials have a relatively low boiling point and are not flammable. Equipment for processing these materials has been in common use for many years at several of the military installations visited. While no on-base installations now processing methanol were identified, there is no technical obstacle to processing this material in simple atmospheric distillation units. The material has a relatively low boiling point and although it is flammable, it should be possible to safely process this material in simple on-base distillation units.

Most other waste solvents that have been identified or that might be found at military bases can also be satisfactorily processed in simple on-base distillation equipment. These include heptane, carbon

tetrachloride, ethylene dichloride, methyl acetate, butyl acetate, and methyl isobutyl ketone. Many of the distillation units identified for on-base use are capable of processing most or all of these solvent materials by simple adjustment of their operating controls.

3. General Economics of On-Base Reclamation Facilities

The relative simplicity and physical size of distillation equipment for on-base reclamation of used solvent materials minimizes both the capital and operating costs of these facilities. While the installation and operation of each reclamation facility should be matched to the situation on a particular base, the cost data provide a guideline in developing facility capital and operating requirements. Capacities and costs of commercial solvent distillation equipment are shown in Table 9.

Solvent distillation units range in size from small self-contained units capable of processing 0.5 gallon of waste per hour (Figure 2) to large units capable of 100 gallons per hour or more (Figure 3). The small units are available in both atmospheric and vacuum distillation configurations. Such units handle a variety of solvents and can be considered for use at smaller bases having low waste solvent generation rates. These systems are generally self-contained and can be delivered from off-the-shelf stock and placed in operation by simple electrical and condensing water supply connections. The condensing water is not contaminated in any way because it does not come in contact with the process stream. Therefore, it can be discharged directly to the normal sewage system. Such units are generally intended to be housed and operated in a closed or indoor environment. Purchase costs of a self-contained unit of this type fall between $4000 and $6000 for the complete system.

A number of solvent distillation units are designed to process about 50 gallons per hour of waste solvent material. Such units are larger physically and require more extensive support facilities such

Table 9. Commercial Solvent Distillation Equipment

Small	Medium	Large
15 gal/h	Up to 50 gal/h	50 to 125 gal/h
Batch	Batch or Continuous	Continuous
Paint Thinners and Chlorinated	All Solvents	All Solvents
Automated Shutdown at End of Batch	Automated, Requires Operator Attention at Batch Change	Automated With Occasional Operator Checks
Equipment Cost:		
$3,000-$5,000	$30,000-$60,000	$60,000-$100,000

as a steam supply or a separate boiler to produce steam for system operation. The units are typically modular in nature and can be readily adapted to a wide range of shelter facilities. Such units were observed operating in both an indoor closed environment and simple outdoor roofed shelters. The systems can be easily modified to match the desired operating environment. A steam-heated unit having its own dedicated boiler unit provides the maximum degree of flexibility for the facility. These units are generally capable of handling the full range of solvents of interest by simple heating and vacuum adjustments. The units require a water supply for operation of the condensing system. This water is not contaminated because it does not come in contact with the process stream. Thus, it can be discharged directly to the sewer system. The purchase cost of units in this size range is between $30,000 and $60,000 for atmospheric distillation units requiring a separate steam supply and full capability vacuum or steam injection units including a dedicated steam boiler, respectively. Installation costs will vary from site to site,

Figure 2 Small Batch Solvent Recovery Still

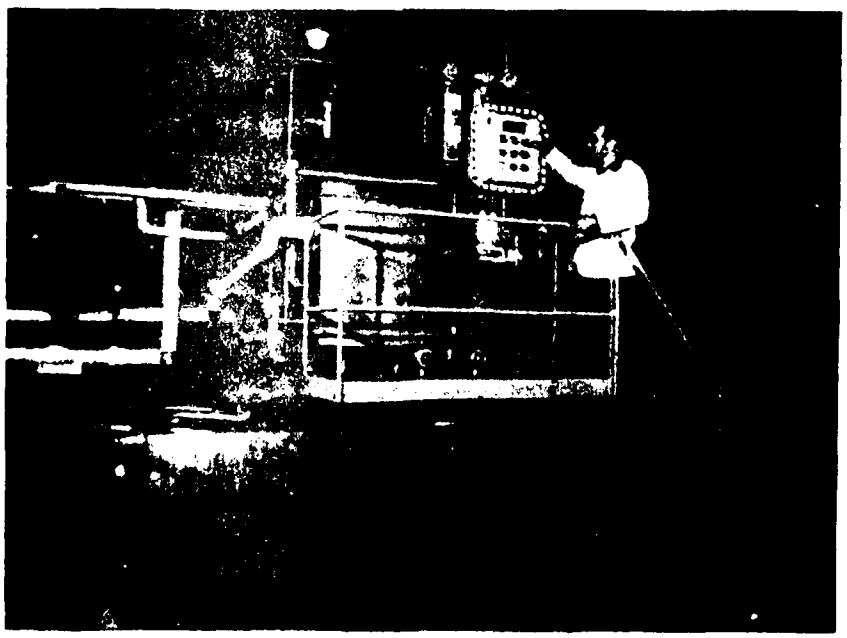

Figure 3 Large Continuous Process Solvent Recovery Still

but a figure of 20 percent of the equipment cost can be used for estimating purposes.

Larger distillation capacities are available through either the use of multiple smaller units or the installation of a single larger unit. The largest single unit that appears practical for on-base recycling operations at the military bases visited is judged to be 100 gallons per hour. These units have costs in the range from $90,000 to $120,000 associated with their purchase and installation. The larger installations are more sensitive to specific site conditions but have the same general support requirements as do the smaller 50-gallon-per-hour units.

The capital cost of on-base distillation equipment is small, and simple linear amortization over the expected lifetime can be used to calculate this element of facility costs. It is difficult to accurately predict the useful life of this equipment in terms of either years or material throughput because expected use will be rather irregular. However, in base visits and discussions with facility operating personnel, several units were identified that have been in operation more than 10 years. The general consensus among equipment manufacturers is that these units should be capable of operating over a 20-year period if properly cared for and maintained. While this lifetime estimate is not believed to be particularly sensitive to equipment capacity, it is felt that higher capacity units can be expected to have longer useful lifetimes. This is because of their more rugged construction and higher expected use factor.

Using this period as representative of the useful life of the equipment, the total lifetime throughput of the unit in gallons can be estimated. The number of gallons processed per year was selected using typical solvent generation rates observed on the larger military bases visited. The equipment selected for such base requirements was a 50-gallon-per-hour vacuum distillation unit having a dedicated

boiler. The installed cost of the unit was assumed to be $60,000. Assuming 350 barrels (19,250 gallons) of solvent could be reclaimed using this facility in a 1-year period, the amoritized capital costs ver the expected equipment lifetime of 20 years could be estimated at 15.5 cents per gallon of recovered material. While this estimate is sensitive to the assumptions of equipment useful life and yearly throughput, the most pessimistic assumptions should add less than 50 percent to this value.

The operating costs for a solvent reclamation facility are made up of three major components: labor, utilities, and maintenance material. Labor is the most significant of these. During discussions with base management and equipment manufacturers representatives, several important facts about the equipment and the necessary operating personnel characteristics were identified. First, modern solvent distillation equipment is highly automated. The equipment can be adjusted to process a specific type of solvent at the outset of a day's operation or a batch of material. The equipment can generally monitor its own operation and automatically maintain process control within the desired limits. If process equipment malfunctions occur (e.g., if a material feed pump were to fail), the control system could shut the system down in an orderly fashion and alert operating personnel to the situation. Thus, the full time attention of an operator is not generally required for the proper operation of this equipment.

Based on the experience of the operating reclamation facilities, the proper operation and necessary understanding of the equipment does not require a high level of expertise on the part of operating personnel. We were told that average maintenance personnel could successfully be trained in the adjustment and operation of the equipment in a matter of a few weeks. Because the types of solvents processed are relatively constant, setup adjustment and operation of the equipment should become routine.

Based on the discussions conducted during base visits and contacts with commercial reclamation facilities, a labor cost level of $12.50 per hour was selected for the operator of the distillation equipment. While it is believed that handling the used solvent material between the using process and the reclamation facility will not increase the current handling requirements, operator time for supervision and coordination of this effort has been included in the labor costs estimates. It is also believed that routine equipment maintenance should be included in the operational cost estimate.

Using the cost assumptions, the cost of operator labor per gallon of reclaimed solvent material was calculated based on equipment operating time. A throughput of 50 gallons per hour was assumed. The labor cost per gallon can thus be calculated by dividing the $12.50-per-hour labor rate by 50-gallons-per-hour throughput. The resulting cost of operation is $0.25 per gallon of reclaimed solvent material. Higher equipment throughput (i.e., 100 gallons per hour) would not increase the operator labor requirement and would thus reduce the labor costs on a per gallon basis if such an installation were selected.

The balance of operating costs is made up of utilities and maintenance material. Utilities include the cost of electricity and cooling water. The energy requirement varies by solvent type and the degree of contamination in the used material stream. Cooling water, however, should show only minor variations from material to material. The upper end of the reported operating range of these costs or $0.05 per gallon was selected for use in this estimate. The cost of maintenance material is also difficult to estimate for a unit that may not operate on a regular basis. However, a value of $0.01 per gallon was selected as a conservative estimate of this cost based on the experiences of equipment manufacturers and equipment operators. The total for utilities and maintenance material is thus $0.06 per gallon.

Therefore, a representative estimate of overall distillation costs can be developed as follows:

Capital amortization:	15.5¢/gal
Labor costs:	25.0
Utilities and maintenance material:	6.0
Total operating costs:	46.5¢/gal

It is believed that this represents a conservative estimate of costs. Actual experience can easily prove this estimate to be high.

4. Operating Practices for On-Base Solvent Reclamation Facilities

All of the solvent recycling facilities on military installations were separated from the process or processes they serve. The used solvent was generally collected by the facility maintenance personnel and taken to the reclamation facility for processing. Pickup and return of the material was accomplished in both 55-gallon drums as well as bulk containers such as small mobile tanks or bowsers and small tank trucks. Many facilities indicated that plans have been made to install bulk tanks at the processing facility to hold both the used material prior to processing it in one continuous batch as well as to hold the reclaimed material while it is awaiting reuse. However, the use of 55-gallon drums was not believed to place any major constraints on the current operation of the reclamation facilities.

At all the facilities visited, there was a working relationship between all the individuals involved with the solvent use and reclamation process. This included individuals involved with replenishing as well as removing used solvents from process units, those involved in transporting and handling the new and used solvent material on base, and those operating the recycling facility

equipment. While at some bases there are relatively direct benefits from effectively accomplishing the recycling function (e.g., money set aside for personnel living quarter improvements), all personnel contacted seem to share a common sense of purpose and feeling of responsibility for supporting the recycling activity. When a problem arises, there is a willingness and ability to identify the source and deal with the problem effectively. We also noted that in most instances, the base commander gives direct support to the solvent reclamation operations and often is the motivating force in their establishment. Without this type of cooperation at all personnel levels, it will be difficult to accomplish effective and efficient reuse or recycle of used solvent materials.

The ability of a base to reclaim used solvent through on-base user controlled facilities gives that base a large measure of independence from sources of supply for new solvent materials. We were told of several instances in which the recycling facility kept the maintenance facility in operation when normal solvent supply sources were not able to supply needed solvent materials to the base. This then becomes a major motivating factor and a frequently quoted justification for the initiation and maintenance of solvent reclamation facilities at a base.

B. OFF-BASE RECYCLING

An alternative to on-base solvent reclamation facilities is the use of off-base contractor reclamation services. Requirements for using such services with a number of organizations was discussed. The study team worked with the National Association of Solvent Recyclers, a trade organization representing solvent recyclers, to develop information on off-base recycling. Information was also obtained from military facilities now using or contemplating use of off-base recycling facilities.

Solvent recycling services have been available for many years. They have been commonly applied to dry cleaning solvents and

industrial solvents used in coating manufacturing and application, printing, food processing, cosmetics, and equipment manufacturing. Frequently, recycling is offered by a supplier of new solvents as an added service to its customers. Most solvents processed in recycling facilities are returned to the customer source after processing, but used solvents are also bought outright for reprocessing and sale. Solvent recyclers are selective, however, in the purchase of used materials and are not interested in poorly segregated materials or materials having low solvent contents.

1. Industry Makeup and Structure

The recycling industry is composed of a number of independent businesses. They range in size from small operators with only a few employees serving local metropolitan industrial areas and processing a few thousands of gallons of solvent material a month to larger multiple-office businesses operating in a geographical area covering several states and processing several hundred thousand gallons of used solvents per month. The National Association of Solvent Recyclers represents a number of these organizations. The current membership of this association is listed in Table 10. The location of the membership is shown on Figure 4 along with the location of 29 of the larger military installations. While the organization represents a little over half the companies offering solvent reclamation services on a routine basis, it is believed that the membership companies represent over 70 percent of the processing capacity in the recycling industry. Contact was established with this organization early in the study, and much information on the industry was obtained from discussions with the association officials and members. It is believed that the association membership represents a valid cross-section of the total solvent recycling industry.

The majority of the organizations in the association offer both reclamation of a customer's used solvent with return of the reclaimed solvent to the originator and outright purchase of the used solvent

Table 10. Membership Roster-National

Association of Solvent Recyclers

Eastern Region		Southern Region	Midwestern Region		Western Region
Anachemia Solvents Ltd. Mississauga, ON Canada 416/279-5122	Liberty Solvents & Chemical Co. Twinsburg, OH 216/425-4484	All-Worth, Inc. Birmingham, AL 205/841-1707	Acme Solvent Reclaiming Rockford, IL 815/397-0298	Hydrite Chemical Co. Cottage Grv., WI 608/257-5892	Chemical Processors Inc Seattle, WA 206/767-0350
Berkley Products Co. Akron, PA 717/859-1104	Marisol Inc. Middlesex, NJ 201/469-5100	Arivec Chemical Inc. Douglasville, GA 404/942-4332	Baron-Blakeslee Division of Purex Melrose Pk., IL 312/450-3900	The Milsolv Co. Butler, WI 414/252-3550	McClary Columbia Corp. Washougal, WA 206/835-5159
Envir Processing Svcs. Dayton, OH 513/222-1062	Pride Solvents & Chemical Co W. Babylon, NY 516/643-4800	KDM Co. San Antonio, TX 512/333-4011	Chemical Recovery Systems Romulus, MI 313/326-3100	Safety Kleen Corp. Elgin, IL 312/697-8460	Oil & Solvent Process Co. Azuzu, CA 213/334-5117
GM Gannon Co. Inc. Warwick, RI 401/738-2200	Solvents Recovery Services Linden, NJ 201/925-8600	M&J Solvents Co. Atlanta, GA 404/355-8240	Clayton Chemical Co. Sauget, IL 618/271-0467	Spartan Chemical Co. Wyoming, MI 616/534-4921	Rho-Chem Corp. Inglewood, CA 213/776-6233
General Chemical Framingham, MA 617/872-1202	Solvent Resource Recovery West Carrollton, OH 513/859-6101	The Prillaman Co. Martinsville, VA 703/638-8829	Custom Organics, Inc. Chicago, IL 312/247-2828	US Chemical Co. Roseville, MI 313/778-1414	Romic Chemical Corp. Palo Alto, CA 415/324-1638
Hampden Color & Chemical Co. Springfield, MA 413/732-2112	Spectron Inc. Elkton, MD 301/398-1736	Ramsey Chemical Valdosta, GA 912/247-7797	Enviro-Chem Corp. Zionsville, IN 317/769-6153	Waste Research & Reclamation Eau Claire, WI 715/834-9624	Solvent Service, Inc. San Jose, CA 408/286-6446
Hukill Chemical Corp Bedford, OH 216/232-9400	Techtronics, Inc. Brooklyn, NY 212/624-5240	US Pollution Control Oklahoma City, OK 405/528-8371	Fisher-Calo Chem. & Solv. Chicago, IL 312/254-5222		Omega Chemical Corp. Whittier, CA 213/698-0991
Industrial Solvents & Chemical Co. Emigsville, PA 717/938-4621					

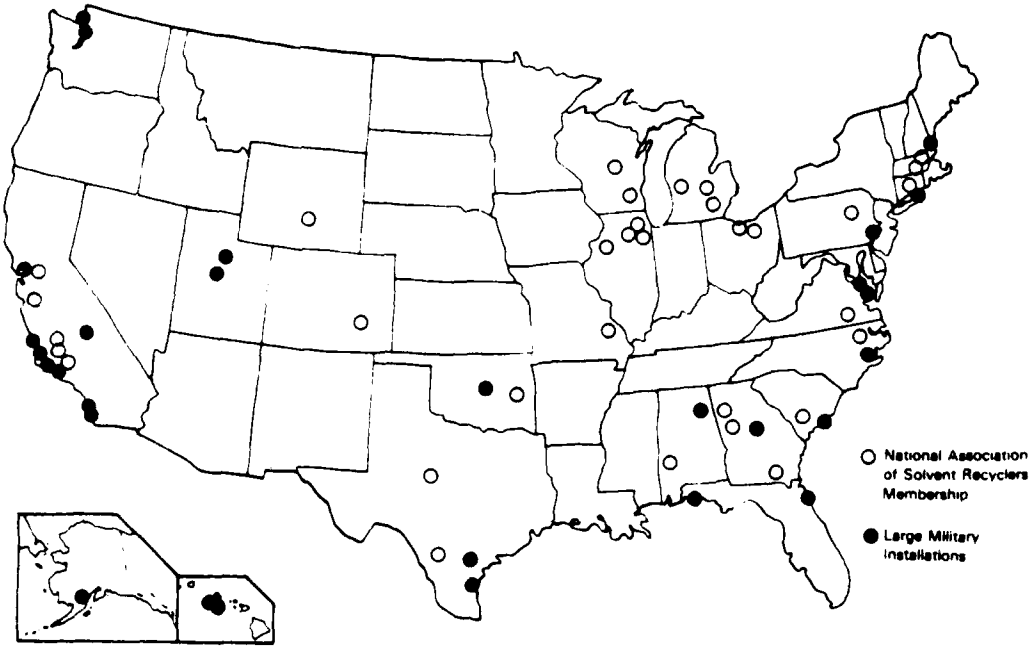

Figure 4. National Association of Solvent Recyclers and Large Military Installations

with the expectation of selling the reclaimed solvent to other customers. The issue of used solvent segregation is very important to both recycling and outright purchase of used materials. While operators expressed interest in the outright purchase of used solvents, they stated that poorly segregated solvent material is of little interest because the risks and costs of processing these materials generally outweigh the potential profit from their processing and resale.

Many hazardous waste disposal contractors are accepting DOD-generated used solvents for destructive disposal; some of these used solvents that are adequately segregated are then actually being sold by the disposal contractors to the solvent recycling industry. In this situation, DOD pays for solvent disposal on a disposal contract, and the disposal contractor sells selected solvents to recyclers for an additional profit. The recycler, by buying from the disposal contractor, avoids the necessity of accepting unsegregated or unrecoverable materials because the determination of the suitability of used materials is generally the responsibility of the disposal contractor. Several of the recycling organizations contacted believe that purchases from the disposal contractor are more desirable than attempting to purchase the used solvents directly from the government because the military does not reliably identify used materials. Other recyclers contacted simply were not aware of the availability of the used solvents from military installations.

While a simple approximation of the probable contaminants in used solvents is sufficient when the solvents are not mixed or highly contaminated, the information about used solvents originating in government facilities has a poor reputation for accuracy and reliability. Thus, there is a general lack of interest on the part of the recycling operator in buying used material directly from the government generator.

When a recycler accepts material for processing and return to the customer, the customer is held responsible for determining the suitability of the used material for recycle. While the recycler will provide the necessary tests of the used material, the customer will be required to pay for these tests. The costs of such testing will then be included in the overall charge for reclamation services. The results of the test will also provide a basis for determining the overall solvent reclamation costs. Recyclers indicate that their requirement for such costly testing could be greatly reduced as their confidence in the customer's identification of the used material and

potential contaminants in the material increases. The requirement for additional testing of used solvent material from regular commercial customers is minimal after a good working relationship has been developed.

Recyclers will generally accept material for reclamation in either 55-gallon barrels or from a bulk storage tank at a generator facility. They will transport the material to their facility, process it, and return it to the customer in either 55-gallon barrels or in bulk form if the customer desires. Reclaimed materials will undergo routine quality control checks, but additional checks can be conducted at customer request to ensure the desired quality of returned product. Materials normally can be handled to ensure that the customer receives, in return, the reprocessed material originally supplied.

Recyclers contacted generally are willing to supply reclamation services on a long-term contract basis or a one-time basis for each individual lot of used solvent material. The latter arrangement generally involves slightly higher cost for similar solvent processing. There also exist contractual arrangements covering several types of solvents. In general, the independent solvent recycling facility is able to offer a high degree of flexibility to suit the requirements of the used solvent generator. Recyclers should be able to tailor their services to the requirements of the military installation served.

2. Off-Base Recycling Technology

The technology used in most commercial recycling operations is similar in nature to the equipment used for on-base solvent recycling. Facilities generally employ some form of distillation or evaporation equipment to separate volatile solvents from unwanted contaminants. While larger facilities frequently use thin film evaporation equipment to process used solvent material at a higher

rate, some form of atmospheric vacuum, or steam injection distillation, is still the most commonly used technology in these facilities.

The equipment is usually operated in a continuous manner with multiple holding tanks to allow segregation of materials and customer batches. The throughput of plant equipment is generally greater than 200 gallons per hour and will exceed 1000 gallons per hour in some larger operations. Although the equipment is highly automated, continuous operator surveillance is normally provided in most large volume recycling operations. Recycling facilities typically include laboratory testing facilities where analysis of the used and reclaimed materials can quickly be accomplished. Test equipment for rough quantitative analysis as well as precise quantitative analysis is normally available. Satisfactory operation of all technology identified in routine operation at solvent recycling facilities has been proven through extensive operating experience in the industry.

3. Economics of Off-Base Recycling

The cost of providing off-base solvent reclamation service to a customer has several components, including transportation of the material to and from the off-base recycling facility, necessary testing of both the used and reclaimed material, processing of the used material, and disposal of the residual contaminants removed from the material. The recycler will typically negotiate a price with a potential customer considering all of these components. The cost of each component will vary depending on the situation and the characteristics of the material to be recycled.

Most recyclers operate their own trucks to collect and deliver solvents. A few recyclers use the services of contract trucking companies for pick up and delivery. The method of determining transportation costs varies from operator to operator. Several of the operators determine transportation costs on a truck-mile basis no

matter what the load size. This method is more common to operators restricting their pickups to a small geographical area. A current typical rate for this type of service is $1.00 per mile round trip, but the costs can range from $0.50 to $3.00 per mile when large trailers or tank trucks are used.

A customer usually holds the used solvents until a sizable quantity has been accumulated. Large trucks can carry up to 80 drums (4400 gallons) of material while tank trucks can carry 3000 gallons (55 barrels) or more in a typical load.

Some of the recycling operators and most of the contract trucking operators providing service for solvent pickup and delivery charge for these transportation services on a weight and distance basis. A typical cost for service on this basis ranges from $0.10 to $0.30 a ton mile depending on the type of equipment used and the nature of the load.

Several of the recyclers contacted had regular pickup routes covering a geographic area. These operators do not typically break out the transportation costs from the overall costs of the recycling service. They are generally geared to serving smaller volume customers on a regular and frequent basis in a restricted area.

An ancillary cost associated with transportation is any necessary repacking or transfer of the used material at the time of pickup from the customer. Several instances were identified in which used solvents from military facilities were offered for transport in 55-gallon drums that were in very poor physical condition. Many of the drums were leaking or under substantial pressure as indicated by bulging ends. Some drums were badly rusted or dented to the extent that additional leaks appeared imminent. A conscientious transporter cannot accept drums in this condition for over-the-road transport. The alternatives available to deal with this situation involve either

transfer of the material to barrels in suitable condition for transport or placing the damaged barrels in salvage containers or "overpacks." Both of these alternatives add costs to material recycling or detract from the potential value as a reclaimable material in a direct sale situation. Also, if suitable barrels are not provided with the used material, the reprocessor will be required to use either reconditioned or new barrels to contain the reclaimed material when it is redelivered to the customer, adding additional cost to the recycling service.

If usage and generation rates are high enough, bulk storage tanks for specific used and reclaimed materials can reduce the problems associated with barrels. Typical recyclers have tank trucks equipped with pumps to properly transfer the material from on-base storage tanks. Minimal costs are associated with this activity when it is performed in connection with recycling services. These tank trucks may also be used to collect properly segregated solvent from generator facilities if the material is stored in 55-gallon drums. Collection in the tank truck may be used in the case of damaged drums to avoid the necessity for repackaging in 55-gallon drums or placing the damaged barrels in overpacks. Similarly, the solvent reprocessor can deliver the reprocessed material to the user facility in a tank truck to be placed in bulk storage tanks at the user facility. These bulk storage tanks for recycled materials can be filled either by gravity drain from the tank trucks or by operating the pumps on the tank truck to fill elevated tanks.

In order to accept the used solvent for shipment and processing, the recycler must have sufficient and reliable information concerning the makeup of the material. Without this information, the recycler is at substantial risk in legally transporting the material and safely and economically processing it for reclamation. Sufficient information on composition can generally be provided based on the generator's knowledge of the initial solvent used in the process, the general history of process operation, the typical characteristics of

contaminants expected, and the knowledge that used materials have not been commingled after removal from service in the process. With this information, the recycler can provide an accurate quote of cost per gallon of reclaimed solvent. If this information is not available from the generator or if the recycler has reason to doubt the accuracy of the information provided, testing of the used material may be required.

Testing cost can range from $5.00 per sample for a simple qualitative test to confirm user supplied data to as much as $25.00 or more to determine the constituents of a complex mixture. For example, a check for PCB content may be necessary if this material is suspected in a group of drums of used solvent to be accepted for shipment and processing. If such mixing has occurred, potential for practical reclamation of this solvent is minimal, and the waste generator will probably have to pay disposal costs.

The demand for the costly testing now being conducted in connection with used solvent disposition could be greatly reduced if military facilities could improve their reputation in the area of dependable solvent segregation and proper and dependable labeling of the containerized materials. Recyclers do not generally encounter these problems in their dealings with private industry.

Testing for quality control of the reclaimed material can be accomplished to the level desired by the customer. Because the material is typically processed in large batches and later transferred to drums for delivery to the customer, only one test of the total batch will usually be necessary to confirm product acceptability. Product testing conducted on a spot check or exception basis is also found to be satisfactory by most commercial recycling customers.

The negotiated price for the actual solvent processing will depend on the types of solvents being processed, the degree of contamination, the nature of the contaminants, and the specifications placed on the

reclaimed solvent material by the customer. Solvents with high boiling points require more energy to process. Stoddard solvent is an example of a high boiling solvent at 308° to 316°F. Similarly, additional cooling is needed to condense the material during distillation. The type of solvent also determines the risks involved in processing the material. Highly flammable materials may have slightly higher processing costs than nonflammable materials, although this was not found to be a major cost factor.

The type and level of contaminants are a significant factor in the determination of reclamation costs. If sludge contaminants are a factor in solvent handling (e.g., large amounts of sludge make handling difficult), processing costs will be higher. If contaminants have boiling points near that of the solvent material of interest, multiple passes of the reclaimed material through the distillation process may be necessary to achieve the desired product purity. If the contaminant is a major portion of the used solvent (i.e., greater than 30 percent), more total material will require processing to yield a like amount of reclaimed solvent. Thus, the cost of solvent reclaimed on a per gallon basis will be increased. Higher levels of contaminants will also mean larger amounts of residual materials that will require disposal after processing. This will influence the processing price, especially if the contaminants present special problems for disposal (e.g., sludges containing soluble heavy metals). Waste paint strippers and carbon removers as well as paint thinning solvents might contain such materials in the distillation residuals.

Although recycled solvents are generally acceptable as functionally equivalent replacements for most solvent process applications, it cannot be said that they are equal to virgin solvents in all respects. Most contaminants in reclaimed solvents of concern can be effectively removed in the distillation process, but trace quantities of certain contaminants may remain after reclamation processing has been completed. The acceptable levels of such

contaminants may be established in specifications prior to the material processing. The levels of most contaminants remaining in the processed material can be reduced by multiple passes of the material through the distillation process. If this is deemed necessary, it will increase recycling costs.

Some solvent materials contain additives to enhance the chemical stability of the principal solvent. For example, new 1,1,1-trichloroethane solvent contains an additive, typically a polyacrylamide, to inhibit the formation of acid when the solvent is heated in vapor degreasing equipment. A major portion of this additive remains in the used solvent and will be passed over to the reclaimed solvent in the distillation process. The additive level will, however, be below that found in the new material. The additive level normally achieved in the reclaimed solvent is usually acceptable when the recycled material is used in conjunction with virgin solvent makeup in a process unit. If it is desired by the customer, the higher additive level can be reestablished by addition of stablizing material during the reclamation process. This will increase the cost of the reclaimed material by $0.10 to $0.25 per gallon. Specifications placed on the reclaimed material can thus ensure that a product acceptable to the user results from the reclamation operations.

VII. ECONOMIC ANALYSIS OF ALTERNATIVE DISPOSAL APPROACHES

Upon identifying the alternative disposal technologies and observing several successful recycling and reuse operations at the bases visited, the potential economic benefits that could accrue from the application of these disposal technologies were analyzed. The cost estimate methodology and projections are based on information gathered from on-site installation visits and discussions with DPDS personnel and representatives from the solvent recycling and disposal industry. The cost estimate methodology is described, followed by the results of the analysis.

A. DESCRIPTION OF METHODOLOGY

1. Characteristic Profiles

Observations made during on-site base visits produced two characteristic base size profiles--large base and small base. These representative installations employ all or some of the five solvent processes and four disposal technologies observed. Note that profiling installations into two size categories is for the cost estimate analysis only. In reality, the size range for military installations in DOD is quite wide. This characteristic, along with mission type, geographic location, and other factors, makes each installation different in its use and disposal of solvents.

The large base category is typically a large volume solvent user. Representative annual used solvent volumes generated at a large base are 1,1,1-trichloroethane (400 drums), PD-680 (500 drums), paint strippers and carbon remover (500 drums), paint thinners (400 drums), and Freon (75 drums). Examples of large base types include air logistics centers, shipyards, air rework facilities, and large Army depots. All five solvent process use categories are generally used at

these bases. Twenty-nine installations were selected to represent this large base profile.

The small base category is a small volume solvent user. Representative annual used solvent volumes are PD-680 (150 drums) and paint thinners (50 drums). Tactical air wings and small or specialized maintenance facilities are some examples of a small base. The cleaning bath and paint thinning process use categories were assumed to be in use at a small base. There were 124 installations selected to represent this small base profile.

2. Base Cost Projections

The cost projection system for the representative bases is developed from data collected during military and commercial facility visits and through discussions with DPDS personnel and industrial organizations providing solvent recycling, disposal services, or both. Cost projections were calculated for the four waste solvent disposal alternatives (Table 6) and the five solvent process use categories (Table 4) and are based on 1982 dollars. The base savings were determined from the difference between the destructive disposal cost (highest) and each of the other three disposal alternatives. This difference represents the potential cost avoidance for a base when it elects to either sell, recycle off-base, or recycle on-base its used solvents rather than destructively dispose of them.

The base savings calculated for each option were used to rank the various options. The primary basis used in the ranking was the maximum economic benefit derived from exercising that option as compared to the cost of the destructive disposal option. In addition, the environmental acceptability and operational feasibility of each alternative were considered. For example, recycling of used material is more desirable from an environmental standpoint than destructive disposal; however, due to the current operational configuration at an

installation, recycling may not be feasible. In these cases, the sale option may be a more desirable alternative to destructive disposal.

The savings were determined from the cost avoidance of buying new material and the cost avoidance of the DPDS disposal cost. The savings to the installation were developed for each solvent. For large bases, the total base savings for each of the five solvent categories were multiplied by 29. For small bases, the total savings for the two solvent categories was multiplied by 124.

B. COST SAVINGS ANALYSIS

The cost projection analysis produced annual savings estimates for representative large and small base cases by solvent process use categories and disposal alternatives. From this projection, DOD-wide annual savings estimates were estimated. For illustrative purposes, the application of the cost projection methodology for a vapor degreasing solvent at a single large base is described.

The specific vapor degreasing solvent used in the anlaysis was 1,1,1,-trichloroethane. Table II presents the annual savings for a large base in disposing of used 1,1,1-trichloroethane. A derivation of the cost estimates and the supporting assumptions used in the calculations are presented in Appendix F.

The destructive disposal alternative is used as the reference case to compare with the other three alternatives. The total DOD cost represents the cost to the installation to purchase new, recycled, or makeup material ($93,500) plus the cost (or credit in the sale option) to DPDS to dispose of the used material. The DOD savings or cost avoidance is determined from the DOD cost for the disposal option minus the DOD cost for each of the other three alternatives. For example, the DOD savings when the on-base recycle alternative is employed is $110,250 ($133,500 minus $23,250) per large base. The

Table 11. Annual Savings for Representative Large Base
(for disposal of 1,1,1-trichloroethane)

Disposal Alternative	Storage Time (days)	Base Cost ($)	DPDS Cost ($)	DOD Cost ($)	DOD Savings ($) (cost avoidance)
Disposal	10 to 410	93,500 (new)	40,000	133,500	0
Sale	10 to 90	93,500 (new)	22,000 (credit)	71,500	62,000
Recycle Off-Base	5 to 10	37,000 (recycle, plus makeup)	0	37,000	96,500
Recycle On-Base*	2 to 5	19,250 (recycle makeup, and amoritized still costs)	4,000	23,250	110,250

Assumptions: 400 bbl/yr
Storage costs not included
Solvent use process evaporation not included
10% nonsolvent in waste stream
$75,000 capital cost for on-base recycling facility

* The annual DOD savings of $110,250 exceeds the $75,000 capital cost for recycling facility and illustrates the less than 1-yr payback period. (See discussion in Section 3, page 6-6.)

estimates include the additional cost for makeup material for the recycle options but do not include storage costs or process evaporation costs.

The savings estimates for the disposal alternatives clearly show the potential economic advantages of implementing recycling and reuse. In order of highest overall savings to a base, the ranking is (1) recycle on-base, (2) recycle off-base, (3) sale, and (4) disposal. Lack of segregation forces the maximum total cost to DOD for the disposal case. The base has to buy new solvent for makeup and the DPDS has to pay the highest price for disposal of the unsegregated used solvent. This destruction disposal reference case represents the worst alternative to DOD in terms of economics.

The total DOD-wide annual savings for all solvents and disposal options for the 29 large and 124 small bases is displayed in Figure 5. Each bar represents the potential cost savings resulting from the purchase avoidance of new material (bottom section) and the potential cost savings resulting from the cost avoidance for disposal of used solvent (top section). Note that the small bases are analyzed for cleaning bath and paint-thinning solvents only, while the large bases are analyzed for all five solvent categories. For vapor degreasing, the total DOD-wide annual savings are estimated at $3.2 million as shown in Figure 5. For the 29 selected large bases, expenditures of $2.2 million could be avoided in new material purchase, and $1.0 million could be avoided in DPDS annual disposal cost. The paint strippers and carbon remover category is a manufacturer take-back example, and the cost savings represent only the cost avoidance for disposal. Total annual savings for large solvent users are estimated to be $7.7 million, while potential annual savings for small solvent users are estimated to be $2.6 million a year. Implementation of selected recycle options at all bases in the two groups of military installations could achieve an estimated total DOD-wide dollar savings of up to $10.3 million annually.

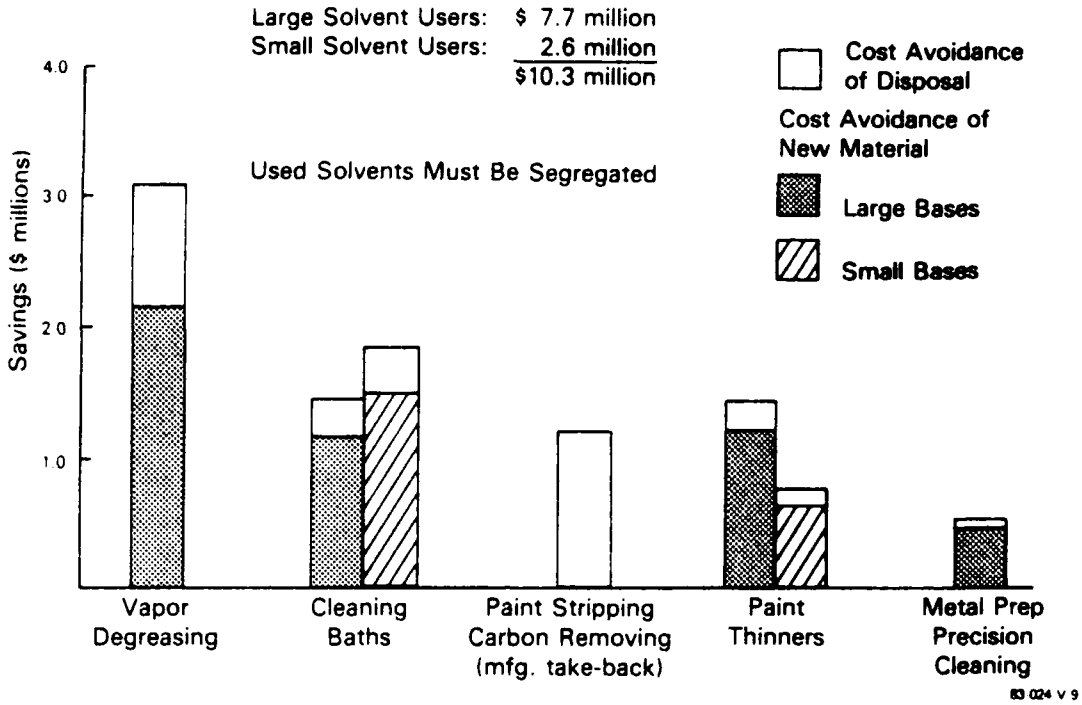

Figure 5. Estimated DOD-Wide Annual Savings

A summary of the potential annual cost savings for large and small bases is shown in Table 12. The order of highest to lowest DOD-wide potential annual savings for large bases is vapor degreasing ($3.2 million), cleaning bath ($1.4 million), paint thinners ($1.4 million), paint stripper and carbon remover ($1.2 million), and metal preparation and precision cleaning ($0.5 million). Solvents for paint stripping and carbon removal applications use a manufacturer take-back arrangement, while the other four solvent categories use the recycle on-base option. It should be noted that the analysis considered Freon under the metal preparation and precision cleaning category, because it is used at 15 bases for avionics and electronic cleaning operations. For small bases, the cleaning bath solvent application could provide about $1.9 million annual savings and $0.7 million annual savings for paint thinners for a total savings of $2.6 million. Both solvent types are processed by on-base recycling.

Table 12. Annual Cost Savings for Large and Small Bases*

Solvent Application/Type	Optimum Disposal Option	Cost Avoidance For New Material 1 Base	Cost Avoidance For Disposal 1 Base	Base Savings 1 Base	Total Savings for All Bases
LARGE BASES (29 total)					
Vapor Degreasing (1,1,1-trichloroethane)	Recycle On-Base	$74,250	$36,000	$110,250§	$3.2 million§
Cleaning Bath (PD-680)	Recycle On-Base	39,600	9,900	49,500	1.4 million
Paint Stripper/ Carbon Remover	Manufacturer Take-Back	0	40,425	40,425	1.2 million
Paint Thinners	Recycle On-Base	41,940	7,555	49,495	1.4 million
Metal Prep/ Precision Cleaning (Freon)	Recycle On-Base	28,512	3,037	31,549	0.5 million
Total for Large Bases		$184,302	$96,957	$281,219	$7.7 million
SMALL BASES (124 total)					
Cleaning Bath (PD-680)	Recycle On-Base	$11,880	$3000	$14,880¶	$1.9 million¶
Paint Thinners	Recycle On-Base	5,130	1000	6,130	0.7 million
Total for Small Bases		$17,010	$4000	$21,010	$2.6 million

* Includes disposal avoidance and sales credit.
§ Example: $110,250 x 29 bases = $3.2 million
¶ Example: $14,880 x 124 bases = $1.9 million

The cost estimates demonstrate that there are significant economic savings to be realized DOD-wide in the implementation of recycling and reuse of waste solvents by military installations. There are also additional unquantified savings to be realized from the prevention of improper release of hazardous used solvents into the environment.

Successful implementation of recycling and reuse alternatives at an installation does require some fundamental concepts to be employed in each facility's operations. Segregation of used solvents to the maximum practical extent is required, and it is essential that even used solvents of similar types also should be segregated. For example, PD-680, Type I, has a low flash point and should not be mixed with PD-680, Type II. Proper containerization of used solvents must be practiced to facilitate material handling of used solvents from the process areas to staging sites. Proper segregation and containerization will greatly improve any disposal option. These two requirements must involve the active participation of the base command, industrial process division management, shop personnel, and the DPDO. At bases now successfully recycling waste solvents, a willingness to cooperate and participate exists among base personnel and with the DPDO. (See Appendix G for examples of successful solvent practices.)

Bases considering on-base distillation and reclamation will find that state-of-the-art equipment is highly automated and readily available. The capital cost of solvent reclamation equipment for on-base recycling is relatively modest (e.g., in the large solvent use category, stills typically cost less than $75,000, and for small bases, still costs are under $50,000). Based on the majority of solvent use profiles observed at installations and the potential cost savings resulting from recycling and reuse, the pay-back of the initial capital investment in most cases can be achieved in less than 1 year (see Table 11).

VIII. CONCLUSIONS

The evaluation of used solvent disposal concepts at DOD bases developed information on the current used solvent management practices at DOD and commercial facilities and analyzed the alternatives and the potential for improvement of these practices. While current DOD practice appears aimed at or at least results in destructive disposal of most used solvents, several economically attractive and environmentally sound alternatives have been identified as feasible for most DOD installations.

After completing the 16 assigned base visits and conducting discussions with personnel at a number of additional military bases, the study team has concluded that there are wide variations in the approach, practices, and attitudes for handling and disposition of used solvent materials. Attitudes ranged from total dependence on destructive disposal for all solvents to an intense coordinated base-wide effort to recycle as much as possible. While improvements are possible for packaging, storage, and handling, other factors such as material segregation and proper identification are necessary keys to improving the existing situation. After improvements in these areas are made, a group of economically attractive and environmentally sound alternatives to destructive disposal of used solvents become available to DOD bases. Many of the problems of packaging, storage, and handling will be minimized or resolved as a result of resolution of the key issues, material segregation, and proper identification. This assessment is supported by the experiences of the few military bases now successfully managing their used solvents through effective recycle and reuse practices.

Current DOD practices for the disposition of used solvents are dominated by the use of destructive disposal. While this approach can achieve an environmentally acceptable disposition of these materials, it is contrary to stated DOD policies related to the conservation and

reuse of resources. Major costs for continuing with this disposal option are incurred on a recurring basis. Costs for destructive disposal are extremely difficult to forecast because of highly variable disposal industry pricing policies and the difficulty in determining the nature of the waste prior to the negotiation of a disposal (service) contract. It is reasonable, however, to expect current disposal costs to rise based on the evolving RCRA regulations pertaining to hazardous wastes.

Several alternatives to destructive disposal of used solvents on DOD bases exist that are both technically viable, operationally feasible, and economically attractive for immediate implementation. This conclusion is based upon the reported experiences of DOD bases successfully exercising these alternatives and the observed and reported practices of private industry. The alternatives to destructive disposal represent significant cost-saving improvements to current practice. The economics and the spirit of current DOD regulations favor the options of on-base or off-base recycling for the disposition and reuse of used solvents at DOD bases. The study shows that minimal capital outlay is required to implement one or more of these alternatives. The payback period for the projected outlay is relatively short, generally less than 1 year, with an expected facility operating life of greater than 15 years.

Investigations of the characteristics of reclaimed solvents indicate that both on-base and off-base solvent recycling operations are capable of providing reclaimed solvents suitable for reuse in the majority of processes and applications found at DOD installations. Specific exceptions include special processes requiring high purity solvent which can best be supplied with new high purity material. Reclaimed solvents from these processes can be reused in less critical applications. If on-base recycling is selected, operation of the recycling facility requires few personnel with minimal skill levels. Operation of these facilities on a smaller base can generally be

handled on a part-time basis by a single individual. The necessary hardware for the larger bases with high solvent usage can be procured and installed for less than $100,000. Process waste from reclamation activities must still be handled by destructive disposal, but the costs will be significantly less (approximately 90 percent less) than the current cost incurred in disposal of the total used solvent stream. The potential for environmental impact is reduced as the total volume requiring destructive disposal has been reduced to less than 10 percent of the original waste stream.

Although the options for reuse or recycle of used solvents are both technically and economically viable, they depend heavily on achieving improvements in the handling and segregation of used solvents in the work place and in the necessary storage facilities. Segregation requires the participation and cooperation of trained operating personnel and the support of facility management and base command personnel. It was noted that good material segregation and overall base personnel cooperation are two essential areas requiring improvement at many of the facilities visited.

The information obtained relating to the experience of the bases engaged in used solvent recycle or reuse demonstrates the direct economic benefit to be realized. The economic analysis described in this report projects an estimation of this economic benefit. While it is not possible to directly estimate the cost impact to DOD from improper releases of used solvents in the environment, some indication of these costs can be inferred from recent DOD experiences. It is expected that the frequency and the impacts of such releases can and will be reduced through reuse and recycle of used solvent materials.

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APPENDIX A

KEY PERSONNEL CONTACTED AT DOD INSTALLATIONS

Installation	Contact
Seneca Army Depot (Romulus, NY)	Thomas Battaglia, Environmental Engineer
Tooele Army Depot (Tooele, UT)	David Woodworth, Environmental Engineer Jim Kinsinger, DPDO Chief Jim Demetropolis, Maintenance Division Lt. Bill Bradshaw, Maintenance Division
Corpus Christi Army Depot (Corpus Christi, TX)	Wen Kao, Environmental Coordinator Mario Lopez, Chief, Environmental Engineering Hector DeLeon, Maintenance
Kelly Air Force Base (San Antonio, TX)	John Hallden, Environmental Engineer Robert Martin, Special Assistant to Deputy Base Commander for Hazardous Waste Matters Ruth Iron Necklace, DPDO Chief
Hill Air Force Base (Ogden, UT)	Keith Davis, Environmental Engineer Hal Gorringe and Clyde Gowers, Physical-Chemical Lab, Maintenance Division Dave Andrews, DPDO
Robins Air Force Base (Warner-Robins, GA)	O.H. Carstarphen, Maintenance Division Charles Gibbs, Physical-Chemical Lab, Maintenance Division
MacDill Air Force Base (Tampa, FL)	Brandon Blonshine, Environmental Coordinator Sam Shiver, DPDO Chief
Tyndall Air Force Base (Panama City, FL)	Bernie Lindenberg and Capt. Doug Downey, Environmental Services Center

Installation	Contact
Tyndall Air Force Base (Panama City, FL) (continued)	Maj. Steve Termatt and Capt. Glenn Tapio, Environics Auturo McDonald, Environmental Coordinator
Davis-Monthan Air Force Base (Tucson, AZ)	Col. Rowif Nymo, Deputy Base Commander Curtis Lueck, Base Environmental Engineer H.K. Poole, Environmental Coordinator Don Gutschall, DPDO Chief
Bergstrom Air Force Base (Austin, TX)	Col. Mary Turner, Deputy Base Commander James Wueste, Environmental Coordinator Capt. Patric Nassaux, Bioenvironmental Engineer
McClellan Air Force Base (Sacramento, CA)	Dale Schulze, Paul Brunner, and Kirk Schmultz; Environmental Planning Rick Meisman, Bill Whitfield, Phyllis Woodring, and John Cucarro; Maintenance Division James Hand and Dean Easten, DPDO
Jacksonville Naval Air Station (Jacksonville, FL)	Bill Roche, Environmental Coordinator Stan Garrison, Mark Dolan, and Jim Dixson; NARF R.D. Rogers, DPDO Chief
Navy, Norfolk Complex (Norfolk, VA)	Stephen Olson, LANTDIV Harold W. Miller, PWC Mike Shane, NARF Robert Kennedy, DPDO
El Toro Marine Corps Air Station (Tustin, CA)	Lt. David Kirkman, Jeff Simko, and Harry Metcalf; Environmental Planning

Installation	Contact
Defense Logistics Agency (Columbus, OH)	Lt. J. Coleman, EV Officer, DPDS Region Dan Lindsay, EV Coordinator, DCSC Lt. Col. De Sapri, Commander of DPDS Region, Columbus Jim Walton, DPDO Chief Thomas Charlton, Chief of Sales, DPDS Region Crate Spears, EV and Sales
Defense Logistics Agency, Tracy and Rough and Ready Island (Tracy, CA)	Jack Haines and Wes Harris, Environmental Engineering Dick Wessels, DPDO/Stockton
DPDR - Ogden Office	Robert Paquette, John Ryan, and Tom Migdalski; Environmental Protection Dan Fisher, Sales Ernie Bertagnolli, Contracts

APPENDIX B

SPENT SOLVENTS OBSERVED AT FACILITIES

This appendix presents a tabular summary of the information developed through site visits to the 16 military facilities listed in the table. This information includes the volumes identified of waste solvents generated in each of five process use categories that currently require some type of disposal action. A second table presents a brief summary of the facilities at each installation for the storage of used solvents and a summary of the base associated Defense Property Disposal Office (DPDO) experience in carrying out the disposal function.

Observed Generation Rated for Major Used Solvents
(55-gallon drums per year)

Base	Vapor Degreasers	Cleaning Baths	Paint Strippers Carbon Removers	Paint Thinners	Metal Prep
Seneca Army Depot	15	140	15	10	None
Kelly AFB	700*	152	60-120 Bal to IWTP§	100	62
Tooele Army Depot	75-115	¶	1,600*	¶	None
Hill AFB	545	455	1200	60*	10
Robins AFB	700	¶	To IWTP§	100	70
MacDill AFB	None	10*	6	15	None
Tyndall AFB	None	50	8	12-60	None
Jacksonville NAS	460	60	872	780	113
Davis-Monthan AFB	3	190	14	20	None
Bergstrom AFB	None	170	39	34	None
Corpus Christi Army Depot	275	750	¶	¶	¶

*Estimated by study team
§Industrial Waste Treatment Plant
¶Not Available

Observed Generation Rated for Major Used Solvents (continued)
(55-gallon drums per year)

Base	Vapor Degreasers	Cleaning Baths	Paint Strippers Carbon Removers	Paint Thinners	Metal Prep
McClellan AFB	150	90	None	620	75
El Toro MCAS	None	¶	None	620	None
Tracy and Rough and Ready Island DLA	5	120	None	None	None
Norfolk NARF/ PWC	100	540	44	400	¶

*Estimated by study team
§Industrial Waste Treatment Plant
¶Not Available

Observed Handling and Disposal Practices

Base	Transport and Storage	Sales Disposal
Seneca Army Depot	Shops to storage in drums by fork lift. Base has conforming storage facility.	DPDS not involved; base has contract for disposal of all materials. Pickup approximately every 3 months or as required.
Kelly AFB	Shops to temporary storage in drums by truck 1000- to 10,000-gal bulk tank for perchloroethylene. No conforming drum storage on base; DPDO remote.	Some solvent disposed of directly by base. 1200 drums in DPDO backlog with approx. 800 waiting for turn-in. Some sales expected, but most of backlog expected to go on disposal service contract.
Tooele Army Depot	Shops to storage in drums by forklift and truck. Base has conforming storage facility.	Some sales have been made and some service contracts have been let. Sale of 1,1,1 and methylene chloride may go to term contract.
Hill AFB	Shops to temporary storage in drums and bulk tank truck for Stoddard and 1,1,1. Some bulk storage for Stoddard.	Very little of material has sold to date. Disposal contract let for 178 drums at approximately $160/drum.
Robins AFB	Transport in drums by truck, looking at 500-gal transport cart for 1,1,1. DPDO has conforming storage.	2077 drums of hazardous waste to DPDO in last 20 months for sale/disposal. Only hydraulic and oil consistently salable.
MacDill AFB	Transported in drums by forklift and truck. Small conforming storage facility now stored in DPDO lot.	Last sale sold 20 drums at $8/drum. Some new material, some PD-680. Oil with PD-680 included sells for 40¢/gal.
Tyndall AFB	Transported in drums to Eglin DPDO. Base contract for hauling; no information on Eglin DPDO facilities.	No information on Eglin DPDO experience.

Observed Handling and Disposal Practices (continued)

Base	Transport and Storage	Sales/Disposal
Jacksonville NAS	Carried by drum and dumpster to central 27,000-gal tank. On-base tank considered conforming storage. Remote DPDO has location problem for conforming storage.	Pumped from tank for disposal on term contract. DPDO not now involved except for waste oil and PCBs. Last disposal contract cost was $1.30/gal.
Davis-Monthan AFB	Segregation at shops into drums for truck transport to DPDO. Base has conforming storage facility.	Sale by DPDO.
Bergstrom AFB	Eighty percent of PD-680 to oil/water separator in drain system; balance plus some other solvents to large holding tank.	Base pays contractor to skim oil and solvents, transport to POL tank (for sale at approx. 34¢/gal), and dispose of remainder.
	No conforming storage at DPDO branch.	Procedure for acceptance by Kelly DPDO under discussion.
Corpus Christi Army Depot	Segregation of trichlor and PD-680 at shops using drums and bowsers. Collection by onsite recyclers.	Small amount of material (still bottoms) to Naval Air Station for disposal. Disposal by service contract through Naval Air Station.
McClellan AFB	Shops temporarily store used solvents; drummed solvents to DPDO; DPDO has conforming storage facility.	DPDO responsible for sales/disposal; emergency service contract issued (October 1982); disposed of 2000 drum backlog. Base considering recycling contract.

Observed Handling and Disposal Practices (continued)

Base	Transport and Storage	Sales/Disposal
El Toro MCAS	Used solvents mixed with waste oils and and lubricants; base to build hazardous waste collection facilities. No conforming storage at DPDO.	El Toro used some waste solvent as boiler fuel. DPDO sells excess. Some burned for crash-crew exercises.
Tracy and Rough and Ready Island DLA	Used and excess solvents stored at Tracy's Storage Facility; new facility being built. Rough and Ready Island materials stored at DPDO.	Awaiting recurring disposal contract.
Norfolk NARF/PWC	Used solvents handled in 55-gal drums. Material collected in nonconforming holding yard at NARF and removed from there by disposal contractor. PWC has conforming storage.	PWC now has service contract for disposal of all hazardous wastes. Very little used solvent material has been sold.

APPENDIX C

STATUS OF STATE PRIMACY FOR RCRA REGULATIONS
(as of March 28, 1983)

State	Approval Phase*
Alabama	1
Alaska	none
Arizona	1
Arkansas	1, 2A, 2B
California	1, 2A
Colorado	none
Connecticut	1
Delaware	1
District of Columbia	none
Florida	1
Georgia	1, 2A, 2B
Hawaii	none
Idaho	none
Illinois	1
Indiana	1, 2A, 2B
Iowa	1
Kansas	1
Kentucky	1, 2A, 2B
Louisiana	1
Maine	1
Maryland	1
Massachusetts	1
Michigan	none
Minnesota	none
Mississippi	1, 2A, 2B
Missouri	none
Montana	1
Nebraska	1
Nevada	none
New Hampshire	1
New Jersey	1
New Mexico	none
New York	none
North Carolina	1, 2A, 2B
North Dakota	1
Ohio	none
Oklahoma	1, 2A, 2B
Oregon	1
Pennsylvania	1
Rhode Island	1

STATUS OF STATE PRIMACY FOR RCRA REGULATIONS (continued)
(as of March 28, 1983)

State	Approval Phase*
South Carolina	1, 2A, 2B
South Dakota	none
Tennessee	1
Texas	1, 2A, 2B
Utah	1
Vermont	1
Virginia	1
Washington	none
West Virginia	none
Wisconsin	1
Wyoming	none

* Phase 1 allows states to administer a hazardous waste program in lieu of and corresponding to that portion of the federal program that covers identification and listing of hazardous waste (40 CFR Part 261), generators (40 CRF 262), and transporters (40 CRF Part 263) of hazardous wastes, and establishes preliminary (interim status) standards for hazardous waste treatment, storage and disposal facilities.

Phase 2 allows states to administer a permit program for hazardous waste treatment, storage, a disposal facilities in lieu of and corresponding to the federal hazardous waste permit program (40 CFR Parts 122, 124, and 264).

APPENDIX D

LARGE AND SMALL MILITARY BASES CONSIDERED IN ECONOMIC ANALYSIS

Large Bases	State
Anniston Army Depot	Alabama
Elmendorf Air Force Base	Alaska
Alameda Naval Air Station	California
Long Beach Naval Shipyard	California
North Island Naval Air Station	California
Mare Island Naval Shipyard	California
Marine Corps Logistics Base	California
McClellan Air Force Base	California
Port Hueneme Navy Complex	California
San Diego Navy Complex	California
Naval Submarine Base, New London	Connecticut
Jacksonville Naval Air Station	Florida
Pensacola Naval Air Station	Florida
Robins Air Force Base	Georgia
Hickam Air Force Station	Hawaii
Pearl Harbor Navy Complex	Hawaii
Portsmouth Naval Shipyard	New Hampshire
Cherry Point Marine Corps Air Station	North Carolina
Tinker Air Force Base	Oklahoma
Philadelphia Naval Shipyard	Pennsylvania
Charleston Navy Complex	South Carolina
Corpus Christi Naval Air Station	Texas
Kelly Air Force Base	Texas
Hill Air Force Base	Utah
Tooele Army Depot	Utah
Norfolk Naval Air Station	Virginia
Norfolk Navy Complex	Virginia
Naval Submarine Base	Washington
Puget Sound Naval Shipyard	Washington

LARGE AND SMALL MILITARY BASES CONSIDERED IN ECONOMIC ANALYSIS (continued)

Small Bases	State
Redstone Arsenal	Alabama
Adak Naval Station	Alaska
Fort Richardson	Alaska
Fort Wainwright	Alaska
Shemya Air Force Base	Alaska
Davis Monthan Air Force Base	Arizona
Luke Air Force Base	Arizona
Williams Air Force Base	Arizona
Yuma Marine Corps Air Station	Arizona
Little Rock Air Force Base	Arkansas
Camp Pendleton Marine Corps Base	California
Castle Air Force Base	California
China Lake Naval Weapons Center	California
El Centro Naval Air Facility	California
El Toro Marine Corps Air Station	California
Fort Ord	California
George Air Force Base	California
Hunters Point Naval Shipyard	California
LeMoore Naval Air Station	California
March Air Force Base	California
Mather Air Force Base	California
Miramar Naval Air Station	California
Moffett Field Naval Air Station	California
Naval Amphibious Base	California
Norton Air Force Base	California
Sacramento Army Depot	California
Sierra Army Depot	California
Travis Air Force Base	California
Twentynine Palms Marine Corps Base	California
Fort Carson	Colorado
Dover Air Force Base	Delaware
Cecil Field Naval Air Station	Florida
Eglin Air Force Base	Florida
Homestead Air Force Base	Florida

LARGE AND SMALL MILITARY BASES CONSIDERED IN ECONOMIC ANALYSIS (continued)

Small Bases	State
MacDill Air Force Base	Florida
Orlando Naval Training Center	Florida
Tyndall Air Force Base	Florida
Whiting Field Naval Air Station	Florida
Dobbins Air Force Base	Georgia
Fort Benning	Georgia
Fort Stewart	Georgia
Moody Air Force Base	Georgia
Barbers Point Naval Air Station	Hawaii
Kaneohe Bay Marine Corps Air Station	Hawaii
Schofield Barracks Military Reserve	Hawaii
Wheeler Air Force Base	Hawaii
Mountain Home Air Force Base	Idaho
Scott Air Force Base	Idaho
Grissom Air Force Base	Indiana
Fort Riley	Kansas
McConnell Air Force Base	Kansas
Fort Campbell	Kentucky
Barksdale Air Force Base	Louisiana
England Air Force Base	Louisiana
Fort Polk	Louisiana
New Orleans Naval Support Activity	Louisiana
Loring Air Force Base	Maine
Aberdeen Proving Ground	Maryland
Andrews Air Force Base	Maryland
Pax River Naval Air Test Center	Maryland
K.I. Sawyer Air Force Base	Michigan
Wurtsmith Air Force Base	Michigan
Columbus Air Force Base	Mississippi
Gulfport Naval Construction Bn Center	Mississippi

LARGE AND SMALL MILITARY BASES CONSIDERED IN ECONOMIC ANALYSIS (continued)

Small Bases	State
Keesler Air Force Base	Mississippi
Meridian Naval Air Station	Mississippi
Fort Leonard Wood	Missouri
Richards-Gebaur Air Force Base	Missouri
Whiteman Air Force Base	Missouri
Malmstrom Air Force Base	Montana
Offutt Air Force Base	Nebraska
Fallon Naval Air Station	Nevada
Nellis Air Force Base	Nevada
Pease Air Force Base	New Hampshire
Fort Dix	New Jersey
Fort Monmouth	New Jersey
McGuire Air Force Base	New Jersey
Cannon Air Force Base	New Mexico
Holloman Air Force Base	New Mexico
Kirtland Air Force Base	New Mexico
White Sands Missile Range	New Mexico
Brooklyn Naval Support Activity	New York
Plattsburgh Air Force Base	New York
Seneca Army Depot	New York
Griffiss Air Force Base	New York
Camp LeJeune Marine Corps Base	North Carolina
Fort Bragg	North Carolina
Pope Air Force Base	North Carolina
Seymour Johnson Air Force Base	North Carolina
Grand Forks Air Force Base	North Dakota
Minot Air Force Base	North Dakota
Rickenbacker Air Force Base	Ohio
Wright-Patterson Air Force Base	Ohio
Altus Air Force Base	Oklahoma
Fort Sill	Oklahoma

LARGE AND SMALL MILITARY BASES CONSIDERED IN ECONOMIC ANALYSIS (continued)

Small Bases	State
Letterkenny Army Depot	Pennsylvania
New Cumberland Army Depot	Pennsylvania
Tobyhanna Army Depot	Pennsylvania
Beaufort Marine Corps Air Station	South Carolina
Charleston Air Force Base	South Carolina
Myrtle Beach Air Force Base	South Carolina
Parris Island Marine Corps Recruit Depot	South Carolina
Shaw Air Force Base	South Carolina
Ellsworth Air Force Base	South Dakota
Bergstrom Air Force Base	Texas
Carswell Air Force Base	Texas
Chase Field Naval Air Station	Texas
Dyess Air Force Base	Texas
Fort Hood	Texas
Kingsville Naval Air Station	Texas
Laughlin Air Force Base	Texas
Randolph Air Force Base	Texas
Red River Army Depot	Texas
Reese Air Force Base	Texas
Sheppard Air Force Base	Texas
Fort Belvoir	Virginia
Fort Eustis	Virginia
Langley Air Force Base	Virginia
Little Creek Naval Amphibious Base	Virginia
Oceana Naval Air Station	Virginia
Fort Lewis	Washington
McChord Air Force Base	Washington
Whidbey Island Naval Air Station	Washington
Francis E. Warren Air Force Base	Wyoming

APPENDIX E

HAZARD INFORMATION ON COMMON SOLVENTS

Information on the most common solvents used by the militay services is attached in tabular form. The tables provide pertinent health and safety hazards information and some physical and chemical properties. The tables have been reproduced directly from the Chemical Hazard Response Information System (CHRIS) report.*

---

* CHRIS - Hazardous Chemical Data, Department of Transportation, U.S. Coast Guard (GPO 050-012-00147-2), October 1978.

DCM	DICHLOROMETHANE

Common Synonyms
Methylene chloride
Methylene dichloride

Watery liquid — Colorless — Sweet, pleasant odor

Stable in water. Irritating vapor is produced

Stop discharge if possible
Avoid contact with liquid and vapor
Isolate and remove discharged material
Notify local health and pollution control agencies

Fire

Not flammable
POISONOUS GASES ARE PRODUCED WHEN HEATED.
Wear goggles and self-contained breathing apparatus
Cool exposed containers with water

Exposure

CALL FOR MEDICAL AID

VAPOR
Irritating to eyes, nose and throat
If inhaled, will cause nausea and dizziness.
Move to fresh air
If breathing has stopped, give artificial respiration
If breathing is difficult, give oxygen

LIQUID
Irritating to skin and eyes.
Harmful if swallowed.
Remove contaminated clothing and shoes
Flush affected areas with plenty of water
IF IN EYES, hold eyelids open and flush with plenty of water
IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk

Water Pollution

Effect of low concentrations on aquatic life is unknown.
May be dangerous if it enters water intakes.
Notify local health and pollution control officials
Notify operators of nearby water intakes

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook, CG 446-4)

Disperse and flush

2. LABELS

No hazard label required by Code of Federal Regulations

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:**
Methylene chloride
Methylene dichloride

3.2 **Coast Guard Compatibility Classification:** Halogenated hydrocarbon

3.3 **Chemical Formula:** CH_2Cl_2

3.4 **NBCO/United Nations Numerical Designation:** 9 0/1593

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid

4.2 **Color:** Colorless

4.3 **Odor:** Pleasant aromatic, like chloroform, sweet, ethereal

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Organic vapor canister mask, safety gloves, protective clothing

5.2 **Symptoms Following Exposure:** INHALATION: anesthetic effects, nausea and drunkenness. CONTACT WITH SKIN AND EYES: skin irritation, irritation of eyes and nose

5.3 **Treatment for Exposure:** INHALATION: remove from exposure, give oxygen if needed. INGESTION: no specific antidote. CONTACT WITH SKIN AND EYES: remove contaminated clothing, wash skin or eyes if affected

5.4 **Toxicity by Inhalation (Threshold Limit Value):** 500 ppm

5.5 **Short-Term Inhalation Limits:** 1000 ppm for 60 min

5.6 **Toxicity by Ingestion:** Grade 2, LD_{50} 0.5 to 5 g/kg

5.7 **Late Toxicity:** None

5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause moderate irritation such that personnel will find high concentrations unpleasant. The effect is temporary

5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin

5.10 **Odor Threshold:** 204-307 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** Not flammable under conditions likely to be encountered

6.2 **Flammable Limits in Air:** 12% - 19%

6.3 **Fire Extinguishing Agents:** Not pertinent

6.4 **Fire Extinguishing Agents Not to be Used:** Not pertinent

6.5 **Special Hazards of Combustion Products:** Dissociation products generated in a fire may be irritating or toxic

6.6 **Behavior in Fire:** Not pertinent

6.7 **Ignition Temperature:** 1184°F

6.8 **Electrical Hazard:** Not pertinent

6.9 **Burning Rate:** Not pertinent

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** No reaction

7.2 **Reactivity with Common Materials:** No reaction

7.3 **Stability During Transport:** Stable

7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent

7.5 **Polymerization:** Not pertinent

7.6 **Inhibitor of Polymerization:** Not pertinent

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** Not pertinent

8.2 **Waterfowl Toxicity:** Not pertinent

8.3 **Biological Oxygen Demand (BOD):** Not pertinent

8.4 **Food Chain Concentration Potential:** None

9. SELECTED MANUFACTURERS

1. Ancon Chemical Corp
   Westlake, La 70669
2. Dow Chemical Co
   Midland, Mich 48640
3. Ethyl Corp
   Industrial Chemicals Division
   451 Florida St
   Baton Rouge, La 70801

10. SHIPPING INFORMATION

10.1 **Grades or Purity:** Aerosol grade, technical grade

10.2 **Storage Temperature:** Data not available

10.3 **Inert Atmosphere:** Inerted

10.4 **Venting:** Data not available

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook, CG 446-3)

A-P-X

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:** ORM - A

12.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	1
Health	
Vapor Irritant	2
Liquid or Solid Irritant	1
Poison	2
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	2
Aesthetic Effect	2
Reactivity	
Other Chemicals	1
Water	0
Self-Reaction	0

12.3 **NFPA Hazard Classification:**

Category	Classification
Health Hazard (Blue)	2
Flammability (Red)	1
Reactivity (Yellow)	0

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 **Physical State at 18°C and 1 atm:** Liquid

13.2 **Molecular Weight:** 84.93

13.3 **Boiling Point at 1 atm:** 104°F = 39.8°C = 313.0°K

13.4 **Freezing Point:** −142°F = −96.7°C = 176.5°K

13.5 **Critical Temperature:** 473°F = 245°C = 518°K

13.6 **Critical Pressure:** 895 psia = 60.9 atm = 6.17 MN/m²

13.7 **Specific Gravity:** 1.322 at 20°C (liquid)

13.8 **Liquid Surface Tension:** Not pertinent

13.9 **Liquid-Water Interfacial Tension:** Not pertinent

13.10 **Vapor (Gas) Specific Gravity:** 2.9

13.11 **Ratio of Specific Heats of Vapor (Gas):** 1.199

13.12 **Latent Heat of Vaporization:** 142 Btu/lb = 78.7 cal/g = 1.30 × 10⁵ J/kg

13.13 **Heat of Combustion:** Not pertinent

13.14 **Heat of Decomposition:** Not pertinent

13.15 **Heat of Solution:** Not pertinent

13.16 **Heat of Polymerization:** Not pertinent

(Continued on page 1 of 4)

NOTES

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KRS	KEROSENE

Common Synonyms			
Illuminating oil Kerosine Range oil Fuel oil No. 1 Jet Fuel JP-1	Watery liquid Floats on water.	Colorless	Fuel oil odor

Stop discharge if possible
Call fire department
Avoid contact with liquid
Isolate and remove discharged material
Notify local health and pollution control agencies.

Fire

Combustible
Extinguish with dry chemical, foam, or carbon dioxide
Water may be ineffective on fire
Cool exposed containers with water

Exposure

CALL FOR MEDICAL AID

LIQUID
Irritating to skin and eyes
Harmful if swallowed

Remove contaminated clothing and shoes.
Flush affected areas with plenty of water.
IF IN EYES, hold eyelids open and flush with plenty of water.
IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk.
DO NOT INDUCE VOMITING

Water Pollution

Dangerous to aquatic life in high concentrations
Floating on shoreline
May be dangerous if it enters water intakes.
Notify local health and wildlife officials.
Notify operators of nearby water intakes

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook, CG 440-4)

Mechanical containment
Should be recovered
Chemical and physical treatment

2. LABELS

No hazard label required by Code of Federal Regulations

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:** No. 1 Fuel oil, Kerosine, Illuminating oil, Range oil, JP-1

3.2 **Coast Guard Compatibility Classification:** Miscellaneous hydrocarbon mixtures

3.3 **Chemical Formula:** C_nH_{2n+2}

3.4 **IMCO/United Nations Numerical Designation:** 3.3/1223

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid

4.2 **Color:** Colorless to light brown

4.3 **Odor:** Characteristic, like fuel oil

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Protective gloves, goggles or face shield

5.2 **Symptoms Following Exposure:** Vapor causes slight irritation of eyes and nose. Liquid irritates stomach, if taken into lungs, causes coughing, distress, and rapidly developing pulmonary edema

5.3 **Treatment for Exposure:** ASPIRATION: enforce bed rest, administer oxygen, call a doctor. INGESTION: do NOT induce vomiting, call a doctor. EYES: wash with plenty of water. SKIN: wipe off and wash with soap and water

5.4 **Toxicity by Inhalation (Threshold Limit Value):** 200 ppm

5.5 **Short-Term Inhalation Limits:** 2000 mg/m³ for 60 min.

5.6 **Toxicity by Ingestion:** Grade 1, LD_{50} 5 to 15 g/kg

5.7 **Lethal Toxicity:** Data not available

5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary.

5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin

5.10 **Odor Threshold:** 1 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** 100°F (min.) (C.C.)

6.2 **Flammable Limits in Air:** 0.7% - 5%

6.3 **Fire Extinguishing Agents:** Foam, dry chemical, or carbon dioxide

6.4 **Fire Extinguishing Agents Not to Be Used:** Water may be ineffective

6.5 **Special Hazards of Combustion Products:** Not pertinent

6.6 **Behavior in Fire:** Not pertinent

6.7 **Ignition Temperature:** 444°F

6.8 **Electrical Hazard:** Not pertinent

6.9 **Burning Rate:** 4 mm/min

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** No reaction

7.2 **Reactivity with Common Materials:** No reaction

7.3 **Stability During Transport:** Stable

7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent

7.5 **Polymerization:** Not pertinent

7.6 **Inhibitor of Polymerization:** Not pertinent

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** 2990 ppm/24 hr/bluegill/TL_m/fresh water

8.2 **Waterfowl Toxicity:** Data not available

8.3 **Biological Oxygen Demand (BOD):** 53%, 5 days

8.4 **Food Chain Concentration Potential:** None

9. SELECTED MANUFACTURERS

1. Atlantic Richfield Co
   717 Fifth Ave
   New York, N.Y. 10022
2. Shell Oil Co
   1 Shell Plaza
   Houston, Tex. 77001
3. Sun Oil Co
   240 Radnor Rd
   St. Davids, Pa. 19087

10. SHIPPING INFORMATION

10.1 **Grades or Purity:** Light hydrocarbon distillate 100%

10.2 **Storage Temperature:** Ambient

10.3 **Inert Atmosphere:** No requirement

10.4 **Venting:** Open (flame arrester)

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook, CG 446-3)

A-T-U

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:** Combustible Liquid

12.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	2
Health	
Vapor Irritant	1
Liquid or Solid Irritant	1
Poisons	1
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	1
Aesthetic Effect	3
Reactivity	
Other Chemicals	0
Water	0
Self-Reaction	0

12.3 **NFPA Hazard Classifications:**

Category	Classification
Health Hazard (Blue)	0
Flammability (Red)	2
Reactivity (Yellow)	0

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 **Physical State at 15°C and 1 atm:** Liquid

13.2 **Molecular Weight:** Not pertinent

13.3 **Boiling Point at 1 atm:** 392-500°F = 200-260°C = 473-533°K

13.4 **Freezing Point:** −50°F = −45.6°C = 227.6°K

13.5 **Critical Temperature:** Not pertinent

13.6 **Critical Pressure:** Not pertinent

13.7 **Specific Gravity:** 0.80 at 15°C (liquid)

13.8 **Liquid Surface Tension:** 23-32 dynes/cm = 0.023-0.032 N/m at 20°C

13.9 **Liquid-Water Interfacial Tension:** 47-49 dynes/cm = 0.047-0.049 N/m at 20°C

13.10 **Vapor (Gas) Specific Gravity:** Not pertinent

13.11 **Ratio of Specific Heats of Vapor (Gas):** Not pertinent

13.12 **Latent Heat of Vaporization:** 110 Btu/lb = 60 cal/g = 2.5 × 10⁵ J/kg

13.13 **Heat of Combustion:** −18,540 Btu/lb = −10,300 cal/g = −431.24 × 10³ J/kg

13.14 **Heat of Decomposition:** Not pertinent

13.15 **Heat of Solution:** Not pertinent

13.16 **Heat of Polymerization:** Not pertinent

(Continued on page 3 and 4)

NOTES

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MAL — METHYL ALCOHOL

Common Synonyms
Methanol
Wood alcohol
Wood naphtha
Wood spirit
Pyroxylic spirit

Watery liquid | Colorless | Alcohol odor

Floats and mixes with water. Flammable, irritating vapor is produced.

Stop discharge if possible. Keep people away
Shut off ignition sources and call fire department
Stay upwind and use water spray to "knock down" vapor
Avoid contact with liquid and vapor
Isolate and remove discharged material
Notify local health and pollution control agencies

Fire

FLAMMABLE
Vapor may explode if ignited in an enclosed area.
Flashback along vapor trail may occur
Extinguish with dry chemical, alcohol foam, or carbon dioxide.
Water may be ineffective on fire
Cool exposed containers with water

Exposure

CALL FOR MEDICAL AID

VAPOR
Irritating to eyes, nose and throat
If inhaled, will cause dizziness, headache, difficult breathing, or loss of consciousness.
Move to fresh air
If breathing has stopped give artificial respiration.
If breathing is difficult give oxygen

LIQUID
POISONOUS IF SWALLOWED
Irritating to skin and eyes.
Remove contaminated clothing and shoes.
Flush affected areas with plenty of water
IF IN EYES hold eyelids open and flush with plenty of water
IF SWALLOWED and victim is CONSCIOUS have victim drink water or milk and have victim induce vomiting.
IF SWALLOWED and victim is UNCONSCIOUS OR HAVING CONVULSIONS do nothing except keep victim warm

Water Pollution

Dangerous to aquatic life in high concentrations.
May be dangerous if it enters water intakes.
Notify local health and wildlife officials
Notify operators of nearby water intakes.

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook, CG 446-4)

Issue warning: high flammability
Restrict access
Evacuate area
Disperse and flush

2. LABEL

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:** Colonial spirit, Columbian spirit, Methanol, Wood alcohol, Wood naphtha, Wood spirit
3.2 **Coast Guard Compatibility Classifications:** Alcohol
3.3 **Chemical Formula:** CH_3OH
3.4 **IMCO/United Nations Numerical Designation:** 3.2/1230

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** Faint alcohol, like ethyl alcohol, faintly sweet, characteristic pungent

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Approved canister mask for high vapor concentrations; safety goggles, rubber gloves
5.2 **Symptoms Following Exposure:** Exposure to excessive vapor causes eye irritation, headache, fatigue and drowsiness. High concentrations can produce central nervous system depression and optic nerve damage. 50,000 ppm will probably cause death in 1 to 2 hrs. Can be absorbed through skin. Swallowing may cause death or eye damage.
5.3 **Treatment for Exposure:** *Remove victim from exposure and apply artificial respiration if breathing has ceased.* INGESTION: induce vomiting, then give 2 teaspoons of baking soda in glass of water, call a physician. SKIN OR EYES: flush with water for 15 min
5.4 **Toxicity by Inhalation (Threshold Limit Value):** 200 ppm
5.5 **Short-Term Inhalation Limits:** 260 mg/m³ for 60 min.
5.6 **Toxicity by Ingestion:** Grade 1, 5 to 15 g/kg (rat)
5.7 **Late Toxicity:** None
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. *The effect is temporary.*
5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin
5.10 **Odor Threshold:** 100 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** 54°F C.C., 61°F O.C.
6.2 **Flammable Limits in Air:** 6.0% – 36.5%
6.3 **Fire Extinguishing Agents:** Alcohol foam, dry chemical, or carbon dioxide
6.4 **Fire Extinguishing Agents Not to Be Used:** Water may be ineffective.
6.5 **Special Hazards of Combustion Products:** Not pertinent
6.6 **Behavior in Fire:** Containers may explode
6.7 **Ignition Temperature:** 867°F
6.8 **Electrical Hazard:** Class I, Group D
6.9 **Burning Rate:** 1.7 mm/min

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** No reaction
7.2 **Reactivity with Common Materials:** No reaction
7.3 **Stability During Transport:** Stable
7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent
7.5 **Polymerization:** Not pertinent
7.6 **Inhibitor of Polymerization:** Not pertinent

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** 250 ppm/11 hr/goldfish/dead/fresh water
8.2 **Waterfowl Toxicity:** Data not available
8.3 **Biological Oxygen Demand (BOD):** 0.6 to 1.12 lb/lb in 5 days
8.4 **Food Chain Concentration Potential:** None

9. SELECTED MANUFACTURERS

1. Borden Inc
   Borden Chemical Division
   Gonzales, La 70734
2. Celanese Corp
   Celanese Chemical Co. Division
   245 Park Ave
   New York, N.Y. 10017
3. E. I. du Pont de Nemours & Co., Inc
   Industrial and Biochemical Dept.
   Wilmington, Del 19898

10. SHIPPING INFORMATION

10.1 **Grades or Purity:** CP, Crude, ACS all 99.9%
10.2 **Storage Temperature:** Ambient
10.3 **Inert Atmosphere:** No requirement
10.4 **Venting:** Open (flame arrester) or pressure-vacuum

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook, CG 446-5)

A-P-Q-R-S

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:** Flammable liquid
12.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	3
Health	
Vapor Irritant	1
Liquid or Solid Irritant	1
Poisons	2
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	1
Aesthetic Effect	1
Reactivity	
Other Chemicals	2
Water	0
Self-Reaction	0

12.3 **NFPA Hazard Classifications:**

Category	Classification
Health Hazard (Blue)	1
Flammability (Red)	3
Reactivity (Yellow)	0

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 **Physical State at 18°C and 1 atm:** Liquid
13.2 **Molecular Weight:** 32.04
13.3 **Boiling Point at 1 atm:** 148.1°F = 64.5°C = 337.7°K
13.4 **Freezing Point:** −144.0°F = −97.8°C = 175.4°K
13.5 **Critical Temperature:** 464°F = 240°C = 513°K
13.6 **Critical Pressure:** 1142.0 psia = 77.7 atm = 7.87 MN/m²
13.7 **Specific Gravity:** 0.792 at 20°C (liquid)
13.8 **Liquid Surface Tension:** Not pertinent
13.9 **Liquid-Water Interfacial Tension:** Not pertinent
13.10 **Vapor (Gas) Specific Gravity:** 1.1
13.11 **Ratio of Specific Heats of Vapor (Gas):** 1.254
13.12 **Latent Heat of Vaporization:** 473.0 Btu/lb = 262.8 cal/g = 11.00 × 10³ J/kg
13.13 **Heat of Combustion:** −9619 Btu/lb = −5677 cal/g = −195.8 × 10³ J/kg
13.14 **Heat of Decomposition:** Not pertinent
13.15 **Heat of Solution:** (est.) −9 Btu/lb = −5 cal/g = −0.2 × 10³ J/kg
13.16 **Heat of Polymerization:** Not pertinent

(Continued on page 3 and 4)

NOTES

REVISED 1976

MEK — METHYL ETHYL KETONE

Common Synonyms
MEK
2-Butanone
Ethyl methyl ketone

Liquid | Colorless | Sweet odor

Floats and mixes with water. Flammable, irritating vapor is produced.

Stop discharge if possible. Keep people away.
Shut off ignition sources and call fire department.
Stay upwind and use water spray to "knock down" vapor.
Avoid contact with liquid and vapor.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

FLAMMABLE.
Flashback along vapor trail may occur.
Vapor may explode if ignited in an enclosed area.
Extinguish with dry chemical, alcohol foam, or carbon dioxide.
Water may be ineffective on fire.
Cool exposed containers with water.

Exposure

CALL FOR MEDICAL AID

VAPOR
Irritating to eyes, nose and throat.
If inhaled, will cause nausea, vomiting, headache, dizziness, difficult breathing, or loss of consciousness.
Move to fresh air.
If breathing has stopped, give artificial respiration.
If breathing is difficult, give oxygen.

LIQUID
Will burn eyes.
Harmful if swallowed.
Remove contaminated clothing and shoes.
Flush affected areas with plenty of water.
IF INJURED, hold eyelids open and flush with plenty of water.
IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk.

Water Pollution

Dangerous to aquatic life in high concentrations.
May be dangerous if it enters water intakes.
Notify local health and wildlife officials.
Notify operators of nearby water intakes.

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook, CG 446-6)

Issue warning: high flammability.
Disperse and flush.

2. LABEL

3. CHEMICAL DESIGNATIONS

3.1 Synonyms: 2-Butanone; Ethyl methyl ketone; MEK
3.2 Coast Guard Compatibility Classification: Ketone
3.3 Chemical Formula: $CH_3COCH_2CH_3$
3.4 IMCO/United Nations Numerical Designation: 3.2/1193

4. OBSERVABLE CHARACTERISTICS

4.1 Physical State (as shipped): Liquid
4.2 Color: Colorless
4.3 Odor: Like acetone; pleasant, pungent

5. HEALTH HAZARDS

5.1 Personal Protective Equipment: Organic canister or air pack; plastic gloves, goggles or face shield
5.2 Symptoms Following Exposure: Liquid causes eye burn. Vapor irritates eyes, nose, and throat, can cause headache, dizziness, nausea, weakness, and loss of consciousness.
5.3 Treatment for Exposure: INHALATION: remove victim to fresh air; if breathing is irregular or has stopped, start resuscitation and administer oxygen. EYES: wash with plenty of water for at least 15 min and call physician.
5.4 Toxicity by Inhalation (Threshold Limit Value): 200 ppm
5.5 Short-Term Inhalation Limits: 300 mg/m³ for 60 min.
5.6 Toxicity by Ingestion: Grade 2; 0.5 to 5 g/kg (rat)
5.7 Lethe Toxicity: None
5.8 Vapor (Gas) Irritant Characteristics: Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary.
5.9 Liquid or Solid Irritant Characteristics: Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.
5.10 Odor Threshold: 10 ppm

6. FIRE HAZARDS

6.1 Flash Point: 20°F C.C., 22°F O.C.
6.2 Flammable Limits in Air: 1.8% - 11.5%
6.3 Fire Extinguishing Agents: Alcohol foam, dry chemical, or carbon dioxide
6.4 Fire Extinguishing Agents Not to be Used: Water may be ineffective
6.5 Special Hazards of Combustion Products: Not pertinent
6.6 Behavior in Fire: Not pertinent
6.7 Ignition Temperature: 961°F
6.8 Electrical Hazard: Class I, Group D
6.9 Burning Rate: 4 - mm/min

7. CHEMICAL REACTIVITY

7.1 Reactivity with Water: No reaction
7.2 Reactivity with Common Materials: No reaction
7.3 Stability During Transport: Stable
7.4 Neutralizing Agents for Acids and Caustics: Not pertinent
7.5 Polymerization: Not pertinent
7.6 Inhibitor of Polymerization: Not pertinent

8. WATER POLLUTION

8.1 Aquatic Toxicity: 5640 mg/l 48 hr bluegill; 11 m/fresh water
8.2 Waterfowl Toxicity: Data not available
8.3 Biological Oxygen Demand (BOD): 214% 5 days
8.4 Food Chain Concentration Potential: None

9. SELECTED MANUFACTURERS

1. Celanese Corp
   Celanese Chemical Co. Division
   245 Park Ave
   New York, N.Y. 10017
2. Exxon Chemical Co
   Houston, Tex. 77001
3. Shell Chemical Co
   Industrial Chemicals Division
   Houston, Tex. 77001

10. SHIPPING INFORMATION

10.1 Grades or Purity: 99.5+%
10.2 Storage Temperature: Ambient
10.3 Inert Atmosphere: No requirement
10.4 Venting: Open (flame arrester) or pressure-vacuum

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook, CG 446-3)

A-P-Q-R-S

12. HAZARD CLASSIFICATIONS

12.1 Code of Federal Regulations: Flammable liquid
12.2 NAS Hazard Rating for Bulk Water Transportation:

Category	Rating
Fire	3
Health	
Vapor Irritant	1
Liquid or Solid Irritant	1
Poisons	2
Water Pollution	
Human Toxicity	2
Aquatic Toxicity	1
Aesthetic Effect	1
Reactivity	
Other Chemicals	2
Water	0
Self-Reactive	0

12.3 NFPA Hazard Classifications:

Category	Classification
Health Hazard (Blue)	1
Flammability (Red)	3
Reactivity (Yellow)	0

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 Physical State at 18°C and 1 atm: Liquid
13.2 Molecular Weight: 72.11
13.3 Boiling Point at 1 atm: 175.3°F = 79.6°C = 352.8°K
13.4 Freezing Point: −123.3°F = −86.3°C = 186.9°K
13.5 Critical Temperature: 504.5°F = 262.5°C = 535.7°K
13.6 Critical Pressure: 603 psia = 41.0 atm = 4.15 MN/m²
13.7 Specific Gravity: 0.806 at 20°C (liquid)
13.8 Liquid Surface Tension: Not pertinent
13.9 Liquid-Water Interfacial Tension: Not pertinent
13.10 Vapor (Gas) Specific Gravity: 2.5
13.11 Ratio of Specific Heats of Vapor (Gas): 1.075
13.12 Latent Heat of Vaporization: 191 Btu/lb = 106 cal/g = 4.44 × 10⁵ J/kg
13.13 Heat of Combustion: −13,400 Btu/lb = −7491 cal/g = −313.6 × 10⁵ J/kg
13.14 Heat of Decomposition: Not pertinent
13.15 Heat of Solution: (est.) −9 Btu/lb = −5 cal/g = −0.2 × 10⁵ J/kg
13.16 Heat of Polymerization: Not pertinent

(Continued on page 5 back)

NOTES

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MIK	METHYL ISOBUTYL KETONE

[illegible] 4-Methyl-2-pentanone Isobutyl methyl ketone MIBK	Watery liquid — Colorless — Mild pleasant odor Floats and mixes slowly with water. Flammable, irritating vapor is produced.
	Stop discharge if possible. Keep people away Shut off ignition sources and call fire department Stay upwind and use water spray to "knock down" vapor Avoid contact with liquid and vapor Isolate and remove discharged material Notify local health and pollution control agencies
Fire	**FLAMMABLE** Flashback along vapor trail may occur. Vapor may explode if ignited in an enclosed area. Wear goggles and self-contained breathing apparatus Extinguish with dry chemical, alcohol foam, or carbon dioxide Water may be ineffective on fire Cool exposed containers with water
Exposure	CALL FOR MEDICAL AID **VAPOR** Irritating to eyes, nose and throat. If inhaled, will cause dizziness or loss of consciousness. Move to fresh air If breathing has stopped, give artificial respiration If breathing is difficult, give oxygen **LIQUID** Irritating to skin and eyes. Harmful if swallowed. Remove contaminated clothing and shoes Flush affected areas with plenty of water IF IN EYES, hold eyelids open and flush with plenty of water IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk
Water Pollution	Effect of low concentrations on aquatic life is unknown Fouling to shoreline May be dangerous if it enters water intakes. Notify local health and wildlife officials Notify operators of nearby water intakes

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook, CG 446-4)

Issue warning — high flammability
Evacuate area
Disperse and flush

2. LABEL

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:** Hexone, Isobutyl methyl ketone, Isopropylacetone, 4-Methyl-2-pentanone, MIBK, MIK

3.2 **Coast Guard Compatibility Classification:** Ketone

3.3 **Chemical Formula:** $(CH_3)_2CHCH_2COCH_3$

3.4 **NIOSH/United Nations Numerical Designation:** UN 1245

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid

4.2 **Odor:** Colorless

4.3 **Odor:** Pleasant, mild, characteristic; sharp; non-residual; ketone

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Organic canister or air pack; rubber gloves, goggles or face shield.

5.2 **Symptoms Following Exposure:** Vapor causes irritation of eyes and nose, high concentrations cause dizziness and depression. Liquid dries out skin and may cause dermatitis; irritates eyes but does not injure them.

5.3 **Treatment for Exposure:** INHALATION: remove to fresh air, give artificial respiration if needed; call a doctor. SKIN OR EYES: wash eyes thoroughly with water; wash skin with water until irritation stops.

5.4 **Toxicity by Inhalation (Threshold Limit Value):** 100 ppm

5.5 **Short-Term Inhalation Limits:** 100 ppm for 60 min.

5.6 **Toxicity by Ingestion:** Grade 2, LD_{50} 0.5 to 5 g/kg (rat)

5.7 **Late Toxicity:** None

5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present at high concentrations. The effect is temporary.

5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.

5.10 **Odor Threshold:** 0.47 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** 73°F C.C.; 75°F O.C.

6.2 **Flammable Limits in Air:** 1.4%—7.5%

6.3 **Fire Extinguishing Agents:** Alcohol foam, dry chemical, or carbon dioxide

6.4 **Fire Extinguishing Agents Not to be Used:** Water may be ineffective

6.5 **Special Hazards of Combustion Products:** Irritating vapors are generated when heated.

6.6 **Behavior in Fire:** Vapors may travel a considerable distance and ignite.

6.7 **Ignition Temperature:** 854°F

6.8 **Electrical Hazard:** Class I, Group D

6.9 **Burning Rate:** Data not available

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** No reaction

7.2 **Reactivity with Common Materials:** No reaction

7.3 **Stability During Transport:** Stable

7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent

7.5 **Polymerization:** Not pertinent

7.6 **Inhibitor of Polymerization:** Not pertinent

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** Data not available

8.2 **Waterfowl Toxicity:** Data not available

8.3 **Biological Oxygen Demand (BOD):** (Theor.) 1.9%, 0.5 day, (Theor.) 12%, 5 days

8.4 **Food Chain Concentration Potential:** None

9. SELECTED MANUFACTURERS

1. Exxon Chemical Co.
   Houston, Tex. 77001
2. Shell Chemical Co.
   Industrial Chemicals Division
   Houston, Tex. 77001
3. Union Carbide Corp.
   Chemicals & Plastics Division
   270 Park Ave.
   New York, N. Y. 10017

10. SHIPPING INFORMATION

10.1 **Grades of Purity:** 99+%

10.2 **Storage Temperature:** Ambient

10.3 **Inert Atmosphere:** No requirement

10.4 **Venting:** Open (flame arrester) or pressure-vacuum

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook, CG 446-3)

A-P-Q-T-U

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:** Flammable liquid

12.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	3
Health	
Vapor Irritant	1
Liquid or Solid Irritant	1
Poisons	1
Water Pollution	
Human Toxicity	2
Aquatic Toxicity	1
Aesthetic Effect	2
Reactivity	
Other Chemicals	2
Water	0
Self-Reaction	0

12.3 **NFPA Hazard Classifications:**

Category	Classification
Health Hazard (Blue)	2
Flammability (Red)	3
Reactivity (Yellow)	0

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 **Physical State at 15°C and 1 atm:** Liquid

13.2 **Molecular Weight:** 100.16

13.3 **Boiling Point at 1 atm:** 241.2°F = 116.2 = 389.4°K

13.4 **Freezing Point:** −119°F = −84°C = 189°K

13.5 **Critical Temperature:** 565.9°F = 298.3°C = 571.5°K

13.6 **Critical Pressure:** 475 psia = 32.3 atm = 3.27 MN/m²

13.7 **Specific Gravity:** 0.802 at 20°C (liquid)

13.8 **Liquid Surface Tension:** 23.6 dyne/cm = 0.0236 N/m at 20°C

13.9 **Liquid-Water Interfacial Tension:** 13.7 dyne/cm = 0.0137 N/m at 20.7°C

13.10 **Vapor (Gas) Specific Gravity:** Not pertinent

13.11 **Ratio of Specific Heats of Vapor (Gas):** 1.081

13.12 **Latent Heat of Vaporization:** 149 Btu/lb = 82.5 cal/g = 3.45 × 10⁵ J/kg

13.13 **Heat of Combustion:** (est.) −16,400 Btu/lb = −9,100 cal/g = −382 × 10⁵ J/kg

13.14 **Heat of Decomposition:** Not pertinent

13.15 **Heat of Solution:** (est.) −9 Btu/lb = −5 cal/g = −0.2 × 10⁵ J/kg

13.16 **Heat of Polymerization:** Not pertinent

(Continued on page [illegible])

NOTES

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MNS	MINERAL SPIRITS

Common Synonyms Petroleum spirits Naphtha	Watery liquid Colorless Gasoline-like odor Floats on water.

Stop discharge if possible
Call fire department
Avoid contact with liquid
Isolate and remove discharged material
Notify local health and pollution control agencies

Fire	Combustible Extinguish with water, dry chemical, foam, or carbon dioxide Cool exposed containers with water
Exposure	CALL FOR MEDICAL AID LIQUID Irritating to skin and eyes. Harmful if swallowed. Remove contaminated clothing and shoes Flush affected areas with plenty of water IF IN EYES: Hold eyelids open and flush with plenty of water IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk DO NOT INDUCE VOMITING
Water Pollution	Effect of low concentrations on aquatic life is unknown Floating to shoreline May be dangerous if it enters water intakes Notify local health and wildlife officials Notify operators of nearby water intakes

1. RESPONSE TO DISCHARGE

(See Pertinent Methods Handbook CG-446-2)

Mechanical containment
Should be removed
Chemical and physical treatment

2. LABELS

No hazard label required by
Code of Federal Regulations

3. CHEMICAL DESIGNATIONS

3.1 Synonyms: Naphtha
Petroleum spirits
3.2 Coast Guard Compatibility Classifications: Miscellaneous hydrocarbon mixtures
3.3 Chemical Formula: Not applicable
3.4 NIOSH/United Nations Numerical Designations: 3 3/1300

4. OBSERVABLE CHARACTERISTICS

4.1 Physical State (as shipped): Liquid
4.2 Color: Colorless
4.3 Odor: Like gasoline

5. HEALTH HAZARDS

5.1 Personal Protective Equipment: Plastic gloves, goggles or face shield (as for gasoline)
5.2 Symptoms Following Exposure: INHALATION: mild irritation of respiratory tract. ASPIRATION: severe lung irritation and rapidly developing pulmonary edema, central nervous system excitement followed by depression. INGESTION: irritation of stomach
5.3 Treatment for Exposure: INHALATION: remove victim to fresh air. ASPIRATION: enforce bed rest, give oxygen; call a doctor. INGESTION: do NOT induce vomiting; guard against aspiration into lungs. EYES: wash with copious amounts of water. SKIN: wipe off and wash with soap and water
5.4 Toxicity by Inhalation (Threshold Limit Value): 300 ppm
5.5 Short-Term Inhalation Limits: 4000 - 7000 ppm for 60 min.
5.6 Toxicity by Ingestion: Grade 2, LD_{50} 0.5 to 5 g/kg
5.7 Late Toxicity: Data not available
5.8 Vapor (Gas) Irritant Characteristics: Vapors are noncircumvating to the eyes and throat.
5.9 Liquid or Solid Irritant Characteristics: Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.
5.10 Odor Threshold: Data not available

6. FIRE HAZARDS

6.1 Flash Point: 105-140°F C.C., depending on grade
6.2 Flammable Limits in Air: 0.9% - 5.0%
6.3 Fire Extinguishing Agents: Foam, carbon dioxide, dry chemical
6.4 Fire Extinguishing Agents Not to be Used: Do not use straight hose water stream
6.5 Special Hazards of Combustion Products: Not pertinent
6.6 Behavior in Fire: Not pertinent
6.7 Ignition Temperature: 540°F
6.8 Electrical Hazard: Not pertinent
6.9 Burning Rate: 4 mm/min

7. CHEMICAL REACTIVITY

7.1 Reactivity with Water: No reaction
7.2 Reactivity with Common Materials: No reaction
7.3 Stability During Transport: Stable
7.4 Neutralizing Agents for Acids and Caustics: Not pertinent
7.5 Polymerization: Not pertinent
7.6 Inhibitor of Polymerization: Not pertinent

8. WATER POLLUTION

8.1 Aquatic Toxicity: Data not available
8.2 Waterfowl Toxicity: Data not available
8.3 Biological Oxygen Demand (BOD): 0%, 5 days
8.4 Food Chain Concentration Potential: None

9. SELECTED MANUFACTURERS

1. Atlantic Richfield Co
717 Fifth Ave
New York, N.Y. 10022
2. Phillips Petroleum
Bartlesville, Okla. 74004
3. Shell Oil Co
1 Shell Plaza
Houston, Tex. 77001

10. SHIPPING INFORMATION

10.1 Grades or Purity: Various grades available. 70-100% of the materials are derived from petroleum and 0-30% are aromatic hydrocarbons like benzene and toluene. Flash points vary with the exact composition but are usually above 100°F
10.2 Storage Temperature: Ambient
10.3 Inert Atmosphere: No requirement
10.4 Venting: Open (flame arrester)

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook CG-446-3)

A-T-U

12. HAZARD CLASSIFICATIONS

12.1 Code of Federal Regulations: Combustible liquid
12.2 NAS Hazard Rating for Bulk Water Transportation: Not listed
12.3 NFPA Hazard Classifications:

Category	Classification
Health Hazard (Blue)	0
Flammability (Red)	2
Reactivity (Yellow)	0

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 Physical State at 16°C and 1 atm: Liquid
13.2 Molecular Weight: Not pertinent
13.3 Boiling Point at 1 atm: 110 - 395°F = 154 - 202°C = 428 - 475°K
13.4 Freezing Point: Not pertinent
13.5 Critical Temperature: Not pertinent
13.6 Critical Pressure: Not pertinent
13.7 Specific Gravity: 0.76 at 20°C (liquid)
13.8 Liquid Surface Tension: Data not available
13.9 Liquid-Water Interfacial Tension: Data not available
13.10 Vapor (Gas) Specific Gravity: Not pertinent
13.11 Ratio of Specific Heats of Vapor (Gas): (at 1:1.030)
13.12 Latent Heat of Vaporization: Data not available
13.13 Heat of Combustion: Data not available
13.14 Heat of Decomposition: Not pertinent
13.15 Heat of Solution: Not pertinent
13.16 Heat of Polymerization: Not pertinent

(Continued on page 3 and 4)

NOTES

REVISED 1976

MTC	METHYL CHLORIDE

Common Synonyms Chloromethane	Liquefied compressed gas Colorless Odorless or sweet odor Floats and boils on water. Flammable, visible vapor cloud is formed.

Avoid contact with liquid and vapor. Keep people away
Wear goggles and self-contained breathing apparatus
Stop discharge if possible
Shut off ignition sources and call fire department
Stay upwind and use water sprays to "knock down" vapor
Isolate and remove discharged material
Notify local health and pollution control agencies

Fire	FLAMMABLE POISONOUS GASES ARE PRODUCED IN FIRE Flashback along vapor trail may occur Vapor may explode if ignited in an enclosed area Wear goggles and self-contained breathing apparatus Stop discharge if possible Cool exposed containers and protect men effecting shutoff with water Let fire burn
Exposure	CALL FOR MEDICAL AID VAPOR Not irritating to eyes, nose or throat If inhaled, will cause nausea, vomiting, headache, difficult breathing, or loss of consciousness. Move to fresh air If breathing has stopped, give artificial respiration If breathing is difficult, give oxygen LIQUID Will cause frostbite Flush affected areas with plenty of water DO NOT RUB AFFECTED AREAS
Water Pollution	Not harmful to aquatic life

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook, CG-446-4)

Issue warning: high flammability, air contaminant
Restrict access
Evacuate area

2. LABEL

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:** Artic
Chloromethane

3.2 **Coast Guard Compatibility Classifications:** Halogenated hydrocarbon

3.3 **Chemical Formula:** CH_3Cl

3.4 **IMCO/United Nations Numerical Designation:** 2.0/1063

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquefied gas

4.2 **Color:** Colorless

4.3 **Odor:** Faint, sweet, non-irritating, faint ether-like

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Approved canister mask, leather or vinyl gloves, goggles or face shield

5.2 **Symptoms Following Exposure:** Inhalation causes nausea, vomiting, weakness, headache, emotional disturbances, high concentrations cause mental confusion, eye disturbances, muscular tremors, cyanosis, convulsions. Contact of liquid with skin may cause frostbite.

5.3 **Treatment for Exposure:** Remove to fresh air. Call a doctor and have patient hospitalized for observation of slowly developing symptoms.

5.4 **Toxicity by Inhalation (Threshold Limit Value):** 100 ppm

5.5 **Short-Term Inhalation Limits:** 100 ppm for 5 min

5.6 **Toxicity by Ingestion:** Not pertinent

5.7 **Late Toxicity:** None

5.8 **Vapor (Gas) Irritant Characteristics:** Vapors are nonirritating to the eyes and throat.

5.9 **Liquid or Solid Irritant Characteristics:** No appreciable hazard. Practically harmless to the skin because it evaporates quickly. May cause frostbite.

5.10 **Odor Threshold:** Does not available

6. FIRE HAZARDS

6.1 **Flash Point:** < 32°F C.C.

6.2 **Flammable Limits in Air:** 8.1% - 17.2%

6.3 **Fire Extinguishing Agents:** Dry chemical or carbon dioxide. Stop flow of gas.

6.4 **Fire Extinguishing Agents Not to be Used:** Not pertinent

6.5 **Special Hazards of Combustion Products:** Toxic and irritating gases are generated in fires

6.6 **Behavior in Fire:** Containers may explode

6.7 **Ignition Temperature:** 1170°F

6.8 **Electrical Hazard:** Not pertinent

6.9 **Burning Rate:** 2.2 mm/min

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** No reaction

7.2 **Reactivity with Common Materials:** Reacts with zinc, aluminum, magnesium, and their alloys, reaction is not violent.

7.3 **Stability During Transport:** Stable

7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent

7.5 **Polymerization:** Not pertinent

7.6 **Inhibitor of Polymerization:** Not pertinent

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** None

8.2 **Waterfowl Toxicity:** None

8.3 **Biological Oxygen Demand (BOD):** None

8.4 **Food Chain Concentration Potential:** None

9. SELECTED MANUFACTURERS

1. Ascon Chemical Corp
   Westlake, La. 70669
2. Dow Chemical Co
   Midland, Mich. 48640
3. Ethyl Corp
   Industrial Chemicals Division
   451 Florida St
   Baton Rouge, La. 70801

10. SHIPPING INFORMATION

10.1 **Grades or Purity:** Technical grade, "Artic" refrigerant grade

10.2 **Storage Temperature:** Ambient

10.3 **Inert Atmosphere:** No requirement

10.4 **Venting:** Safety relief

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook, CG-446-5)

A-B-C-D-E-F-G

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:** Flammable compressed gas

12.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	4
Health	
Vapor Irritant	0
Liquid or Solid Irritant	0
Poisons	2
Water Pollution	
Human Toxicity	0
Aquatic Toxicity	1
Aesthetic Effect	0
Reactivity	
Other Chemicals	1
Water	0
Self-Reaction	0

12.3 **NFPA Hazard Classifications:**

Category	Classification
Health Hazard (Blue)	2
Flammability (Red)	4
Reactivity (Yellow)	0

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 **Physical State at 15°C and 1 atm:** Gas

13.2 **Molecular Weight:** 50.49

13.3 **Boiling Point at 1 atm:** −11.6°F = −24.2°C = 249°K

13.4 **Freezing Point:** −143.9°F = −97.7°C = 175.5°K

13.5 **Critical Temperature:** 290.5°F = 143.6°C = 416.8°K

13.6 **Critical Pressure:** 968 psia = 65.9 atm = 6.68 MN/m²

13.7 **Specific Gravity:** 0.997 at −24°C (liquid)

13.8 **Liquid Surface Tension:** 16.2 dynes/cm = 0.0162 N/m at 20°C

13.9 **Liquid-Water Interfacial Tension:** (est.) 30 dynes/cm = 0.03 N/m at −24°C

13.10 **Vapor (Gas) Specific Gravity:** 1.7

13.11 **Ratio of Specific Heats of Vapor (Gas):** 1.259

13.12 **Latent Heat of Vaporization:** 143.3 Btu/lb = 101.3 cal/g = 4.241 × 10⁵ J/kg

13.13 **Heat of Combustion:** −5200 Btu/lb = −2070 cal/g = −123.1 × 10⁵ J/kg

13.14 **Heat of Decomposition:** Not pertinent

13.15 **Heat of Solution:** Not pertinent

13.16 **Heat of Polymerization:** Not pertinent

(Continued on page 5 and 6)

NOTES

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TCE	TRICHLOROETHANE

Common Synonyms
1,1,1-Trichloroethane
Methylchloroform

Heavy liquid — Colorless — Sweet odor

Sinks in water. Immersing vapor is produced.

Stop discharge if possible. Keep people away.
Avoid contact with liquid and vapor.
Call fire department.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

Combustible
POISONOUS GASES ARE PRODUCED IN FIRE.

Wear goggles and self-contained breathing apparatus.
Extinguish with dry chemical, carbon dioxide, or foam.

Exposure

CALL FOR MEDICAL AID
VAPOR
Irritating to eyes, nose and throat.
If inhaled, will cause dizziness or difficult breathing.

Move to fresh air.
If breathing has stopped, give artificial respiration.
If breathing is difficult, give oxygen.

LIQUID
Irritating to skin and eyes.
If swallowed, may produce vomit.

Remove contaminated clothing and shoes.
Flush affected areas with plenty of water.
IN EYES, lift upper and lower lids and flush with plenty of water.
IF SWALLOWED, DO NOT INDUCE VOMITING. Have victim drink water.
[illegible]
IF SWALLOWED and victim is CONSCIOUS and SUFFICIENT [illegible]
[illegible] water, victim warm.

Water Pollution

Effect of low concentrations on aquatic life is unknown.
May be dangerous if enters water intakes.

Notify health and wildlife officials.
Notify operators of nearby water intakes.

1. RESPONSE TO DISCHARGE

See Response Methods Handbook, CG-446-2.

Shield water intakes.
Notify local health and wildlife officials.

2. LABELS

No hazard label required by Code of Federal Regulations.

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:** Methyl chloroform; Chloroform; Methyl chloroform; 1,1,1-Trichloroethane
3.2 **Coast Guard Compatibility Classification:** Halogenated hydrocarbon
3.3 **Chemical Formula:** CH_3CCl_3
3.4 **NRCU United Nations Numerical Designation:** Not listed

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** Chloroform-like, sweetish

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Organic vapor-acid gas canister, self-contained breathing apparatus for emergencies; neoprene or polyvinyl alcohol-type gloves, chemical safety goggles and face shield, neoprene safety shoes (or leather safety shoes plus neoprene footwear); neoprene or polyvinyl alcohol suit or apron for splash protection.

5.2 **Symptoms Following Exposure:** INHALATION symptoms range from loss of equilibrium and incoordination to loss of consciousness. High concentration can be fatal due to simple asphyxiation combined with loss of consciousness. INGESTION produces effects similar to inhalation and may cause some feeling of nausea. EYES: slightly irritating and lachrymatory. SKIN: defatting action may cause dermatitis.

5.3 **Treatment for Exposure:** Get medical attention for all eye exposures and any other serious overexposures. Do NOT administer adrenalin or epinephrine, otherwise, treatment is symptomatic. INHALATION: remove victim to fresh air, if necessary, apply artificial respiration and/or administer oxygen. INGESTION: have victim drink water and induce vomiting. EYES: flush thoroughly with water. SKIN: remove contaminated clothing and wash exposed area thoroughly with soap and warm water.

5.4 **Toxicity by Inhalation (Threshold Limit Value):** 350 ppm
5.5 **Short-Term Inhalation Limits:** 1000 ppm for 60 min. in man
5.6 **Toxicity by Ingestion:** Grade 1. LD_{50} 5 to 15 g/kg (rat, mouse, rabbit, guinea pig)
5.7 **Late Toxicity:** Data not available
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary.

(Continued on page 4)

6. FIRE HAZARDS

6.1 **Flash Point:** Data not available
6.2 **Flammable Limits in Air:** 7% - 16%
6.3 **Fire Extinguishing Agents:** Dry chemical, foam, or carbon dioxide
6.4 **Fire Extinguishing Agents Not to be Used:** Not pertinent
6.5 **Special Hazards of Combustion Products:** Toxic and irritating gases are generated in fires.
6.6 **Behavior in Fire:** Not pertinent
6.7 **Ignition Temperature:** 632°F
6.8 **Electrical Hazard:** Not pertinent
6.9 **Burning Rate:** (est.) 2.9 mm/min

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** Reacts slowly, releasing corrosive hydrochloric acid
7.2 **Reactivity with Common Materials:** Corrodes aluminum, but reaction is not hazardous.
7.3 **Stability During Transport:** Stable
7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent
7.5 **Polymerization:** Not pertinent
7.6 **Inhibitor of Polymerization:** Not pertinent

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** 75 - 150 ppm/96 hr. TLm fresh water
*Time period not specified
8.2 **Waterfowl Toxicity:** Data not available
8.3 **Biological Oxygen Demand (BOD):** Data not available
8.4 **Food Chain Concentration Potential:** None

9. SELECTED MANUFACTURERS

1. Dow Chemical Co.
Midland, Mich. 48640
2. PPG Industries, Inc.
Industrial Chemicals Division
Gateway Center
Pittsburgh, Pa. 15222
3. Vulcan Materials Co.
Chemical Division
Wichita, Kan. 67201

10. SHIPPING INFORMATION

10.1 **Grades or Purity:** Uninhibited, inhibited, industrial, shipping, reagent, room cold cleaning
10.2 **Storage Temperature:** Ambient
10.3 **Inert Atmosphere:** No requirement
10.4 **Venting:** Pressure-vacuum

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook, CG-446-3)

A X Y

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:** Not listed
12.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	1
Health	
Vapor Irritant	1
Liquid or Solid Irritant	1
Poisons	2
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	3
Aesthetic Effect	2
Reactivity	
Other Chemicals	1
Water	0
Self-Reaction	0

12.3 **NFPA Hazard Classifications:** Not listed

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 **Physical State at 15°C and 1 atm:** Liquid
13.2 **Molecular Weight:** 133.41
13.3 **Boiling Point at 1 atm:** 165°F = 74°C = 347°K
13.4 **Freezing Point:** < −38°F = < −39°C = < 234°K
13.5 **Critical Temperature:** Not pertinent
13.6 **Critical Pressure:** Not pertinent
13.7 **Specific Gravity:** 1.33 at 20°C (liquid)
13.8 **Liquid Surface Tension:** 25.4 dynes/cm = 0.0254 N/m at 20°C
13.9 **Liquid-Water Interfacial Tension:** (est.) 45 dynes/cm = 0.045 N/m at 20°C
13.10 **Vapor (Gas) Specific Gravity:** 4.6
13.11 **Ratio of Specific Heats of Vapor (Gas):** 1.104
13.12 **Latent Heat of Vaporization:** 100 Btu/lb = 55 cal/g = 2.4 × 10⁵ J/kg
13.13 **Heat of Combustion:** (est.) 4700 Btu/lb = 2600 cal/g = 110 × 10⁶ J/kg
13.14 **Heat of Decomposition:** Not pertinent
13.15 **Heat of Solution:** Not pertinent
13.16 **Heat of Polymerization:** Not pertinent

(Continued on pages 3 and 4)

5. HEALTH HAZARDS (Cont'd.)

5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.
5.10 **Odor Threshold:** 100 ppm

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TCF	TRICHLOROFLUOROMETHANE

Common Synonyms	Liquid	Colorless	Odorless
F 11 Freon 11 Genetron 11	Sinks in water. Harmful vapor is produced. Boiling point is 75° F		

Stop discharge if possible. Keep people away.
Avoid contact with liquid.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

Not flammable
POISONOUS GASES MAY BE PRODUCED IN FIRE
Wear goggles and self-contained breathing apparatus

Exposure

CALL FOR MEDICAL AID
VAPOR
If inhaled, will cause dizziness or difficult breathing
Move to fresh air.
If breathing has stopped, give artificial respiration.
If breathing is difficult, give oxygen.
LIQUID
Not harmful

Water Pollution

Not harmful to aquatic life
May be dangerous if it enters water intakes.
Notify local health and wildlife officials.
Notify operators of nearby water intakes.

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook, CG 446-4)

Should be removed.
Chemical and physical treatment.

2. LABELS

No hazard label required by Code of Federal Regulations.

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:** Arctic 11, Freon 11, Isotron 11, Eskimon 11, Frigen 11, Isotron 11, F 11, Genetron 11, Leon 11
3.2 **Coast Guard Compatibility Classification:** Halogenated hydrocarbon
3.3 **Chemical Formula:** $CFCl_3$
3.4 **IMCO United Nations Numerical Designation:** Not listed

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** Odorless, weak chlorinated solvent

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Airline respirator, rubber gloves, monogoggles
5.2 **Symptoms Following Exposure:** Breathing concentrations approaching 10% in air will cause dizziness and drowsiness. Contact with tissues may cause frostbite.
5.3 **Treatment for Exposure:** INHALATION: remove victim to non-contaminated area and apply artificial respiration if breathing has stopped, call a physician immediately; oxygen inhalation may be utilized. SKIN: if frostbite has occurred, flush areas with warm water.
5.4 **Toxicity by Inhalation (Threshold Limit Value):** 1000 ppm
5.5 **Short-Term Inhalation Limits:** Data not available
5.6 **Toxicity by Ingestion:** Data not available
5.7 **Late Toxicity:** Data not available
5.8 **Vapor (Gas) Irritant Characteristics:** Not irritating
5.9 **Liquid or Solid Irritant Characteristics:** May cause frostbite
5.10 **Odor Threshold:** Data not available

6. FIRE HAZARDS

6.1 **Flash Point:** Not flammable
6.2 **Flammable Limits in Air:** Not flammable
6.3 **Fire Extinguishing Agents:** Not pertinent
6.4 **Fire Extinguishing Agents Not to be Used:** Not pertinent
6.5 **Special Hazards of Combustion Products:** Produces irritating and toxic products when heated to decomposition temperatures
6.6 **Behavior in Fire:** Not pertinent
6.7 **Ignition Temperature:** Not flammable
6.8 **Electrical Hazard:** Not pertinent
6.9 **Burning Rate:** Not flammable

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** No reaction
7.2 **Reactivity with Common Materials:** No reaction
7.3 **Stability During Transport:** Stable
7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent
7.5 **Polymerization:** Not pertinent
7.6 **Inhibitor of Polymerization:** Not pertinent

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** None
8.2 **Waterfowl Toxicity:** None
8.3 **Biological Oxygen Demand (BOD):** None
8.4 **Food Chain Concentration Potential:** None

9. SELECTED MANUFACTURERS

1. E. I. duPont de Nemours & Co., Inc.
   Freon Products Division
   Wilmington, Del. 19898
2. Pennwalt Corp.
   Chemical Division
   3 Penn Center
   Philadelphia, Pa. 19102
3. Union Carbide Corp.
   Chemicals and Plastics Division
   270 Park Ave.
   New York, N.Y. 10017

10. SHIPPING INFORMATION

10.1 **Grades or Purity:** Technical
10.2 **Storage Temperature:** Ambient
10.3 **Inert Atmosphere:** No requirement
10.4 **Venting:** Safety relief

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook, CG 446-3)

A-C-I-J

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:** Not listed
12.2 **NAS Hazard Rating for Bulk Water Transportation:** Not listed
12.3 **NFPA Hazard Classifications:** Not listed

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 **Physical State at 15°C and 1 atm:** Liquid
13.2 **Molecular Weight:** 137.4
13.3 **Boiling Point at 1 atm:** 74.8°F = 23.8°C = 297.0°K
13.4 **Freezing Point:** −168°F = −111°C = 162°K
13.5 **Critical Temperature:** 388°F = 198°C = 471°K
13.6 **Critical Pressure:** 639.4 psia = 43.5 atm = 4.41 MN/m²
13.7 **Specific Gravity:** 1.49 at 20°C (liquid)
13.8 **Liquid Surface Tension:** 23 dynes/cm = 0.023 N/m at 20°C
13.9 **Liquid-Water Interfacial Tension:** Not pertinent
13.10 **Vapor (Gas) Specific Gravity:** 4.7
13.11 **Ratio of Specific Heats of Vapor (Gas):** (est.) 1.128
13.12 **Latent Heat of Vaporization:** 78.3 Btu/lb = 43 Cal/g = 1.82 × 10⁵ J/kg
13.13 **Heat of Combustion:** Not pertinent
13.14 **Heat of Decomposition:** Not pertinent
13.15 **Heat of Solution:** Not pertinent
13.16 **Heat of Polymerization:** Not pertinent

(Continued on page 5 and 6)

NOTES

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TCL	TRICHLOROETHYLENE

Common Synonyms
Trichloroethene
Trichlor

Watery liquid **Colorless** **Sweet odor**

Sinks in water. Irritating vapor is produced.

Stop discharge if possible. Keep people away.
Avoid contact with liquid and vapor.
Call fire department.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

Combustible
POISONOUS GASES ARE PRODUCED IN FIRE
Fire fighting procedures: Use self-contained breathing apparatus.
Extinguish with dry chemical, carbon dioxide, or foam.

Exposure

CALL FOR MEDICAL AID
VAPOR
Irritating to eyes, nose and throat.
If inhaled, will cause nausea, vomiting, difficult breathing, or loss of consciousness.
Water rinse.
If victim has stopped, give artificial respiration.
Give oxygen if breathing difficult.
LIQUID
Irritating to skin and eyes.
If swallowed, will cause nausea, vomiting, difficult breathing, or loss of consciousness.
Remove contaminated clothing and shoes.
Flush skin with water.
Flush eyes with water.
DRINK LARGE QUANTITIES OF WATER and induce vomiting.
Do not have victim drink alcohol.
Do not induce vomiting if victim is unconscious or convulsing.
Keep victim warm.

Water Pollution

Effect of low concentration on aquatic life is unknown.
May be dangerous if it enters water intakes.
Notify municipal and industrial officials.
Stop operations upstream of water intakes.

1. RESPONSE TO DISCHARGE

See Polluting Substances Handbook, CG-446-3.

Should be [illegible]
Chemical and physical treatment [illegible]

2. LABELS

No hazard labeling required by Code of Federal Regulations.

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:** Algylen, Chlorylen, Chemalgene, Threthylene, Trichlorethylene, Trichloran, Trichloroethene, Trichlor, Trichlorethylene, Trichloryl, Trichloroethylene
3.2 **Coast Guard Compatibility Classification:** Halogenated hydrocarbon
3.3 **Chemical Formula:** $CHCl=CCl_2$
3.4 **IMCO United Nations Numerical Designation:** 1710

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** Chloroform like, ethereal

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Organic vapor acid gas canister, self-contained breathing apparatus for emergencies, neoprene or rubber gloves, chemical safety goggles, face shield, neoprene safety shoes, neoprene suit or apron for splash protection.
5.2 **Symptoms Following Exposure:** INHALATION: symptoms range from irritation of the nose and throat to nausea, an attitude of irresponsibility, blurred vision, and finally disturbance of central nervous system resulting in cardiac failure. Chronic exposure may cause organic injury. INGESTION: symptoms similar to inhalation. SKIN: defatting action can cause dermatitis. EYES: slightly irritating sensation and lachrymation.
5.3 **Treatment for Exposure:** Do NOT administer adrenalin or epinephrine; get medical attention for all cases of overexposure. INHALATION: remove victim to fresh air, if necessary, apply artificial respiration and/or administer oxygen. INGESTION: have victim drink water and induce vomiting; repeat three times, then give 1 tablespoon epsom salts in water. EYES: flush thoroughly with water. SKIN: wash thoroughly with soap and warm water.
5.4 **Toxicity by Inhalation (Threshold Limit Value):** 100 ppm
5.5 **Short-Term Inhalation Limits:** 200 ppm for 30 min
5.6 **Toxicity by Ingestion:** Grade 1. LD_{50} 50 to 500 mg/kg
5.7 **Late Toxicity:** Data not available
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary.
5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.
5.10 **Odor Threshold:** 50 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** 90°F C.C. (practically nonflammable)
6.2 **Flammable Limits in Air:** [illegible]
6.3 **Fire Extinguishing Agents:** Water fog.
6.4 **Fire Extinguishing Agents Not to be Used:** Not pertinent.
6.5 **Special Hazards of Combustion Products:** Toxic and corrosive gases are produced in combustion.
6.6 **Behavior in Fire:** Not pertinent.
6.7 **Ignition Temperature:** [illegible]
6.8 **Electrical Hazard:** Not pertinent.
6.9 **Burning Rate:** Not pertinent.

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** Not reactive.
7.2 **Reactivity with Common Materials:** Not reactive.
7.3 **Stability During Transport:** Stable.
7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent.
7.5 **Polymerization:** Not pertinent.
7.6 **Inhibitor of Polymerization:** Not pertinent.

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** [illegible] daphnia in fresh water
8.2 **Waterfowl Toxicity:** Data not available
8.3 **Biological Oxygen Demand (BOD):** Data not available
8.4 **Food Chain Concentration Potential:** None

9. SELECTED MANUFACTURERS

Dow Chemical
Midland, Michigan
E. I. duPont de Nemours & Co., Inc.
Explosives Department
Wilmington, Delaware
PPG Industries, Inc.
Industrial Chemicals Division
Lake Charles, Louisiana

10. SHIPPING INFORMATION

10.1 **Grades or Purity:** Technical, cleaning, degreasing, extraction
10.2 **Storage Temperature:** Ambient
10.3 **Inert Atmosphere:** No requirement
10.4 **Venting:** Pressure vacuum

11. HAZARD ASSESSMENT CODE

See Hazard Assessment Handbook, CG-446-3.

A-X-Y

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:** ORM-A
12.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	
Health	
Vapor (irritant)	[illegible]
Liquid or Solid (irritant)	[illegible]
Poison	[illegible]
Water Pollution	
Human Toxicity	
Aquatic Toxicity	[illegible]
Aesthetic Effect	[illegible]
Reactivity	
Other Chemicals	
Water	0
Self Reaction	[illegible]

12.3 **NFPA Hazard Classifications:** Not listed

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 **Physical State at 18°C and 1 atm:** Liquid
13.2 **Molecular Weight:** 131.39
13.3 **Boiling Point at 1 atm:** 187°F = 87°C = 360°K
13.4 **Freezing Point:** −123.8°F = −86.4°C = 186.8°K
13.5 **Critical Temperature:** Not pertinent.
13.6 **Critical Pressure:** Not pertinent.
13.7 **Specific Gravity:** 1.46 at 20°C (liquid)
13.8 **Liquid Surface Tension:** 29 dynes/cm = 0.029 N/m at 20°C
13.9 **Liquid-Water Interfacial Tension:** 34.5 dynes/cm = 0.0345 N/m at 24°C
13.10 **Vapor (Gas) Specific Gravity:** 4.5
13.11 **Ratio of Specific Heats of Vapor (Gas):** [illegible]
13.12 **Latent Heat of Vaporization:** 103 Btu/lb = 57 cal/g = 2.4 × 10⁵ J/kg
13.13 **Heat of Combustion:** Not pertinent.
13.14 **Heat of Decomposition:** Not pertinent.
13.15 **Heat of Solution:** Not pertinent.
13.16 **Heat of Polymerization:** Not pertinent.

(Continued on pages 7 and 8)

NOTES

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TEC	TETRACHLOROETHANE

Common Synonyms			
1,1,2,2-Tetrachloroethane Acetylene tetrachloride	Liquid	Colorless to pale yellow	Sweet odor
	Sinks in water		

AVOID CONTACT WITH LIQUID AND VAPOR. KEEP PEOPLE AWAY
Wear rubber overclothing (including gloves)
Stop discharge if possible
Isolate and remove discharged material
Notify local health and pollution control agencies

Fire

Not flammable
Poisonous gases may be produced when heated

Exposure

CALL FOR MEDICAL AID

VAPOR
Irritating to eyes, nose and throat.
Harmful if inhaled

If in eyes, hold eyelids open and flush with plenty of water
If breathing has stopped, give artificial respiration
If breathing is difficult, give oxygen

LIQUID
POISONOUS IF SWALLOWED OR IF SKIN IS EXPOSED.
Irritating to skin and eyes.
If swallowed will cause nausea and vomiting.

Remove contaminated clothing and shoes
Flush affected areas with plenty of water
IF IN EYES, hold eyelids open and flush with plenty of water
IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk and have victim induce vomiting
IF SWALLOWED and victim is UNCONSCIOUS OR HAVING CONVULSIONS, do nothing except keep victim warm

Water Pollution

Effect of low concentrations on aquatic life is unknown
May be dangerous if it enters water intakes.

Notify local health and wildlife officials
Notify operators of nearby water intakes

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook, CG 446-4)

Issue warning - poison air contaminant
Restrict access
Should be removed
Chemical and physical treatment

2. LABELS

No hazard label required by Code of Federal Regulations

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:** Acetylene tetrachloride, 1,1,2,2-Tetrachloroethane

3.2 **Coast Guard Compatibility Classification:** Halogenated hydrocarbon

3.3 **Chemical Formula:** $Cl_2CHCHCl_2$

3.4 **NRCO/United Nations Numerical Designation:** Not listed

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid

4.2 **Color:** Colorless, slightly yellow; light yellowish green

4.3 **Odor:** Chloroform-like, pleasant; like carbon tetrachloride; mild, sweetish, similar to several other chlorinated hydrocarbons

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Chemical safety goggles; plastic face shield; air- or oxygen-supplied mask, safety hat with brim; solvent-proof apron, synthetic rubber gloves

5.2 **Symptoms Following Exposure:** Compound is a powerful narcotic and liver poison; may also cause changes in blood composition and neurological disturbances. Repeated exposure by inhalation can be fatal. Ingestion causes vomiting, diarrhea, severe mucosal injury, liver necrosis, cyanosis, unconsciousness, loss of reflexes, and death. Contact with eyes causes irritation and lachrymation. Can be absorbed through the skin and may produce severe skin lesions.

5.3 **Treatment for Exposure:** INHALATION: remove victim from exposure; begin artificial respiration if breathing has ceased. INGESTION: induce vomiting, call a physician. EYES: irrigate with water for 15 min. SKIN: remove clothing, wash skin thoroughly with warm water and soap

5.4 **Toxicity by Inhalation (Threshold Limit Value):** 5 ppm

5.5 **Short-Term Inhalation Limits:** 10 ppm, 30 min

5.6 **Toxicity by Ingestion:** Grade 3, oral LD_{50} = 200 mg/kg (rat)

5.7 **Late Toxicity:** Liver poisoning, nervous disorders

5.8 **Vapor (Gas) Irritant Characteristics:** Vapor is moderately irritating such that personnel will not usually tolerate moderate or high vapor concentrations.

5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin

5.10 **Odor Threshold:** 0.5 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** Not flammable

6.2 **Flammable Limits in Air:** Not flammable

6.3 **Fire Extinguishing Agents:** Not pertinent

6.4 **Fire Extinguishing Agents Not to be Used:** Not pertinent

6.5 **Special Hazards of Combustion Products:** Irritating hydrogen chloride vapor may form in fire

6.6 **Behavior in Fire:**

6.7 **Ignition Temperature:** Not pertinent

6.8 **Electrical Hazard:** Not pertinent

6.9 **Burning Rate:** Not pertinent

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** No reaction

7.2 **Reactivity with Common Materials:** May attack some forms of plastics

7.3 **Stability During Transport:** Stable

7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent

7.5 **Polymerization:** Not pertinent

7.6 **Inhibitor of Polymerization:** Not pertinent

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** Data not available

8.2 **Waterfowl Toxicity:** Data not available

8.3 **Biological Oxygen Demand (BOD):** Data not available

8.4 **Food Chain Concentration Potential:** Data not available

9. SELECTED MANUFACTURERS

1 Hooker Chemical Corp
Industrial Chemicals Div
Niagara Falls, N. Y. 14302

2 Aldrich Chemical Co
940 W. Saint Paul Ave
Milwaukee, Wis. 53233

3 Eastman Organic Chemicals
Rochester, N. Y. 14650

10. SHIPPING INFORMATION

10.1 **Grades or Purity:** Technical, 98%

10.2 **Storage Temperature:** Ambient

10.3 **Inert Atmosphere:** No requirement

10.4 **Venting:** Open

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook, CG 446-3)

A-X

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:** ORM-A

12.2 **NAS Hazard Rating for Bulk Water Transportation:** Not listed

12.3 **NFPA Hazard Classifications:** Not listed

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 **Physical State at 15°C and 1 atm:** Liquid

13.2 **Molecular Weight:** 167.85

13.3 **Boiling Point at 1 atm:** 295.3°F = 146.3°C = 419.5°K

13.4 **Freezing Point:** −46.8°F = −43.8°C = 229.4°K

13.5 **Critical Temperature:** Data not available

13.6 **Critical Pressure:** Data not available

13.7 **Specific Gravity:** 1.595 at 20°C (liquid)

13.8 **Liquid Surface Tension:** 37.85 dynes/cm = 0.03785 N/m at 20°C

13.9 **Liquid-Water Interfacial Tension:** Data not available

13.10 **Vapor (Gas) Specific Gravity:** 5.79

13.11 **Ratio of Specific Heats of Vapor (Gas):** 1.090 at 25°C

13.12 **Latent Heat of Vaporization:** 99.2 Btu/lb = 55.1 cal/g = 2.30 × 10⁵ J/kg

13.13 **Heat of Combustion:** Not pertinent

13.14 **Heat of Decomposition:** Not pertinent

13.15 **Heat of Solution:** Not pertinent

13.16 **Heat of Polymerization:** Not pertinent

(Continued on page 1 and 6)

NOTES

TOL	TOLUENE

Common Synonyms
Toluol
Methylbenzene
Methylbenzol

Watery liquid — Colorless — Pleasant odor

Floats on water. Flammable, irritating vapor is produced

Stop discharge if possible. Keep people away
Shut off ignition sources and call fire department
Stay upwind and use water spray to knock down vapor
Avoid contact with liquid and vapor
Isolate and remove discharged material
Notify local health and pollution control agencies

Fire

FLAMMABLE
Flashback along vapor trail may occur
Vapor may explode if ignited in an enclosed area

Wear goggles and self-contained breathing apparatus
Extinguish with dry chemical, foam, or carbon dioxide
Water may be ineffective on fire
Cool exposed containers with water

Exposure

CALL FOR MEDICAL AID

VAPOR
Irritating to eyes, nose and throat
If inhaled, will cause nausea, vomiting, headache, dizziness, difficult breathing, or loss of consciousness.

Move to fresh air
If breathing has stopped, give artificial respiration
If breathing difficult, give oxygen

LIQUID
Irritating to skin and eyes.
If swallowed, will cause nausea, vomiting or loss of consciousness.

Remove contaminated clothing and shoes
Flush affected areas with plenty of water
IF IN EYES, hold eyelids open and flush with plenty of water
IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk
DO NOT INDUCE VOMITING

Water Pollution

Dangerous to aquatic life in high concentrations
Fouling to shoreline
May be dangerous if it enters water intakes

Notify local health and wildlife officials
Notify operators of nearby water intakes

1. RESPONSE TO DISCHARGE

See Response Methods Handbook, CG 446-4

Isolate water intake if contaminated
Evacuate area

2. LABEL

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:** Methylbenzene
Methylbenzol
Toluol

3.2 **Coast Guard Compatibility Classification:** Aromatic hydrocarbon

3.3 **Chemical Formula:** $C_6H_5CH_3$

3.4 **IMCO United Nations Numerical Designation:** 3.2 1294

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid

4.2 **Color:** Colorless

4.3 **Odor:** Pungent, aromatic, benzene-like, distinct, pleasant

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Air-supplied mask, goggles or face shield, plastic gloves

5.2 **Symptoms Following Exposure:** Vapors irritate eyes and upper respiratory tract, cause dizziness, headache, anesthesia, respiratory arrest. Liquid irritates eyes and causes drying of skin. If aspirated, causes coughing, gagging, distress, and rapidly developing pulmonary edema. If ingested causes vomiting, griping, diarrhea, depressed respiration

5.3 **Treatment for Exposure:** INHALATION: remove to fresh air, give artificial respiration and oxygen if needed, call a doctor. INGESTION: do NOT induce vomiting, call a doctor. EYES: flush with water for at least 15 min. SKIN: wipe off, wash with soap and water.

5.4 **Toxicity by Inhalation (Threshold Limit Value):** 100 ppm

5.5 **Short-Term Inhalation Limits:** 600 ppm for 30 min

5.6 **Toxicity by Ingestion:** Grade 2. LD_{50} 0.5 to 5 g/kg

5.7 **Late Toxicity:** Kidney and liver damage may follow ingestion

5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary

5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin

5.10 **Odor Threshold:** 0.17 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** 40°F (C.C.) 55°F (O.C.)

6.2 **Flammable Limits in Air:** 1.27% - 7%

6.3 **Fire Extinguishing Agents:** Carbon dioxide or dry chemical for small fires, ordinary foam for large fires

6.4 **Fire Extinguishing Agents Not to be Used:** Water may be ineffective

6.5 **Special Hazards of Combustion Products:** Not pertinent

6.6 **Behavior in Fire:** Vapor is heavier than air and may travel a considerable distance to a source of ignition and flash back

6.7 **Ignition Temperature:** 997°F

6.8 **Electrical Hazard:** Class I, Group D

6.9 **Burning Rate:** [illegible] mm/min

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** No reaction

7.2 **Reactivity with Common Materials:** No reaction

7.3 **Stability During Transport:** Stable

7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent

7.5 **Polymerization:** Not pertinent

7.6 **Inhibitor of Polymerization:** Not pertinent

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** 1180 mg/l 96 hr sunfish TL_m (fresh water)

8.2 **Waterfowl Toxicity:** Data not available

8.3 **Biological Oxygen Demand (BOD):** 0% 5 days, 1% other 5 days

8.4 **Food Chain Concentration Potential:** None

9. SELECTED MANUFACTURERS

1. Exxon Chemical Co
Houston, Tex 77001
2. Shell Chemical Co
Petrochemicals Division
Houston, Tex 77001
3. Sun Oil Co
St. Davids, Pa 19087

10. SHIPPING INFORMATION

10.1 **Grades or Purity:** Research, reagent, nitration, all 99.8+; industrial contains 94+, with 5% xylene and small amounts of benzene and nonaromatic hydrocarbons; 90, 120 less pure than industrial

10.2 **Storage Temperature:** Ambient

10.3 **Inert Atmosphere:** No requirement

10.4 **Venting:** Open (flame arrester) or pressure-vacuum

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook, CG 446-3)

A-T-U

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:** Flammable liquid

12.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	3
Health	
Vapor Irritant	1
Liquid or Solid Irritant	1
Poisons	2
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	3
Aesthetic Effect	2
Reactivity	
Other Chemicals	1
Water	0
Self-Reaction	0

12.3 **NFPA Hazard Classifications:**

Category	Classification
Health Hazard (Blue)	2
Flammability (Red)	3
Reactivity (Yellow)	0

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 **Physical State at 18°C and 1 atm:** Liquid

13.2 **Molecular Weight:** 92.14

13.3 **Boiling Point at 1 atm:** 231.1°F = 110.6°C = 383.6°K

13.4 **Freezing Point:** −139°F = −95.0°C = 178.2°K

13.5 **Critical Temperature:** 605.4°F = 318.6°C = 591.8°K

13.6 **Critical Pressure:** 596.1 psia = 40.55 atm = 4.108 MN/m²

13.7 **Specific Gravity:** 0.867 at 20°C (liquid)

13.8 **Liquid Surface Tension:** 29.0 dynes/cm = 0.0290 N/m at 20°C

13.9 **Liquid-Water Interfacial Tension:** 36.1 dynes/cm = 0.0361 N/m at 25°C

13.10 **Vapor (Gas) Specific Gravity:** Not pertinent

13.11 **Ratio of Specific Heats of Vapor (Gas):** 1.089

13.12 **Latent Heat of Vaporization:** 155 Btu/lb = 86 cal/g = 3.61 × 10⁵ J/kg

13.13 **Heat of Combustion:** −17,430 Btu/lb = −9686 cal/g = −405.5 × 10³ J/kg

13.14 **Heat of Decomposition:** Not pertinent

13.15 **Heat of Solution:** Not pertinent

13.16 **Heat of Polymerization:** Not pertinent

(Continued on pages 3 and 6)

NOTES

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TTE	TETRACHLOROETHYLENE

Common Synonyms Tetrasol Perclene Perchloroethylene	Watery liquid Colorless Sweet odor Sinks in water. Irritating vapor is produced.
Stop discharge if possible Avoid contact with liquid and vapor Isolate and remove discharged material Notify local health and pollution control agencies	
Fire	Not flammable Poisonous gases are produced when heated.
Exposure	CALL FOR MEDICAL AID **VAPOR** **Irritating to eyes, nose, and throat.** **If inhaled, will cause difficult breathing, or loss of consciousness.** Move to fresh air If breathing has stopped, give artificial respiration. If breathing is difficult, give oxygen **LIQUID** **Irritating to skin and eyes.** **Harmful if swallowed.** Remove contaminated clothing and shoes Flush affected areas with plenty of water IF IN EYES hold eyelids open and flush with plenty of water IF SWALLOWED and victim is CONSCIOUS have victim drink water or milk
Water Pollution	Effect of low concentrations on aquatic life is unknown. May be dangerous if it enters water intakes. Notify local health and wildlife officials Notify operators of nearby water intakes

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook CG 446-4)

Should be removed

Chemical and physical treatment

2. LABELS

No hazard label required by Code of Federal Regulations

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:** Perchloroethylene
Perclene
Perk

3.2 **Coast Guard Compatibility Classification:** Halogenated hydrocarbon

3.3 **Chemical Formula:** C_2Cl_4 ($Cl_2C=CCl_2$)

3.4 **IMCO/United Nations Numerical Designation:** 9 07/1897

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid

4.2 **Color:** Colorless

4.3 **Odor:** Ethereal, like chloroform, mildly sweet

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** For high vapor concentrations use approved canister or air-supplied mask, chemical goggles or face shield, plastic gloves

5.2 **Symptoms Following Exposure:** Vapor can affect central nervous system and cause anesthesia. Liquid may irritate skin after prolonged contact. May irritate eyes but causes no injury.

5.3 **Treatment for Exposure:** INHALATION: if illness occurs, remove patient to fresh air, keep him warm and quiet, and get medical attention. INGESTION: induce vomiting only on physician's recommendation. EYES AND SKIN: flush with plenty of water and get medical attention if irritation or injury occurs.

5.4 **Toxicity by Inhalation (Threshold Limit Value):** 100 ppm

5.5 **Short-Term Inhalation Limits:** 400 ppm for 60 min.

5.6 **Toxicity by Ingestion:** Grade 2. LD50: 5 to 5 g/kg

5.7 **Late Toxicity:** None

5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or throat if present in high concentrations. The effect is temporary.

5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.

5.10 **Odor Threshold:** 5 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** Not flammable

6.2 **Flammable Limits in Air:** Not flammable

6.3 **Fire Extinguishing Agents:** Not pertinent

6.4 **Fire Extinguishing Agents Not to be Used:** Not pertinent

6.5 **Special Hazards of Combustion Products:** Toxic, irritating gases may be generated in fires

6.6 **Behavior in Fire:** Not pertinent

6.7 **Ignition Temperature:** Not flammable

6.8 **Electrical Hazard:** Not pertinent

6.9 **Burning Rate:** Not flammable

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** No reaction

7.2 **Reactivity with Common Materials:** No reaction

7.3 **Stability During Transport:** Stable

7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent

7.5 **Polymerization:** Not pertinent

7.6 **Inhibitor of Polymerization:** Not pertinent

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** Data not available

8.2 **Waterfowl Toxicity:** Data not available

8.3 **Biological Oxygen Demand (BOD):** None

8.4 **Food Chain Concentration Potential:** None

9. SELECTED MANUFACTURERS

1. Dow Chemical Co
   Midland, Mich 48640
2. PPG Industries Inc
   Industrial Chemical Division
   Barberton, Ohio 44203
3. Vulcan Materials Co
   Chemicals Division
   Wichita, Kan 67201

10. SHIPPING INFORMATION

10.1 **Grades or Purity:** Dry cleaning and industrial grades, 99+%

10.2 **Storage Temperature:** Ambient

10.3 **Inert Atmosphere:** No requirement

10.4 **Venting:** Pressure-vacuum

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook CG 446-2)

A-X

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:** ORM-A

12.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	0
Health	
Vapor Irritant	1
Liquid or Solid Irritant	1
Poison	2
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	3
Aesthetic Effect	2
Reactivity	
Other Chemicals	1
Water	0
Self-Reaction	1

12.3 **NFPA Hazard Classification:** Not listed

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 **Physical State at 18°C and 1 atm:** Liquid

13.2 **Molecular Weight:** 165.83

13.3 **Boiling Point at 1 atm:** 250°F = 121°C = 394°K

13.4 **Freezing Point:** −8.3°F = −22.4°C = 250.8°K

13.5 **Critical Temperature:** 657°F = 347°C = 620°K

13.6 **Critical Pressure:** Not pertinent

13.7 **Specific Gravity:** 1.63 at 20°C (liquid)

13.8 **Liquid Surface Tension:** 31.1 dynes/cm = 0.0311 N/m at 20°C

13.9 **Liquid-Water Interfacial Tension:** 44.4 dynes/cm = 0.0444 N/m at 23°C

13.10 **Vapor (Gas) Specific Gravity:** Not pertinent

13.11 **Ratio of Specific Heats of Vapor (Gas):** 1.116

13.12 **Latent Heat of Vaporization:** 90.2 Btu/lb = 50.1 cal/g = 2.10 × 10⁵ J/kg

13.13 **Heat of Combustion:** Not pertinent

13.14 **Heat of Decomposition:** Not pertinent

13.15 **Heat of Solution:** Not pertinent

13.16 **Heat of Polymerization:** Not pertinent

(Continued on page 5 and 6)

NOTES

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XLO	o-XYLENE

Common Synonyms
1, 2 Dimethylbenzene
Xylol

Watery liquid — Colorless — Sweet odor

Floats on water. Flammable, irritating vapor is produced

Stop discharge if possible. Keep people away
Call fire department
Avoid contact with liquid and vapor
Isolate and remove discharged material
Notify local health and pollution control agencies

Fire

FLAMMABLE
Flashback along vapor trail may occur
Vapor may explode if ignited in an enclosed area
Wear self-contained breathing apparatus
Extinguish with foam, dry chemical, or carbon dioxide
Water may be ineffective on fire
Cool exposed containers with water

Exposure

CALL FOR MEDICAL AID

VAPOR
Irritating to eyes, nose and throat
If inhaled, will cause headache, difficult breathing, or loss of consciousness
Move to fresh air
If breathing has stopped, give artificial respiration
If breathing is difficult, give oxygen

LIQUID
Irritating to skin and eyes
If swallowed, will cause nausea, vomiting, or loss of consciousness
Remove contaminated clothing and shoes
Flush affected area with plenty of water
IF IN EYES, hold eyelids open and flush with plenty of water
IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk
DO NOT INDUCE VOMITING.

Water Pollution

Dangerous to aquatic life in high concentrations
Floating to shoreline
May be dangerous if in excess water intake
Notify local health and wildlife officials
Notify operators of nearby water intakes

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook, CG-446-4)

Issue warning — high flammability
Evacuate area
Should be removed
Chemical and physical treatment

2. LABEL

3. CHEMICAL DESIGNATIONS

3.1 **Synonyms:** 1,2 Dimethylbenzene
3.2 **Coast Guard Compatibility Classification:** Aromatic hydrocarbon
3.3 **Chemical Formula:** o-$C_6H_4(CH_3)_2$
3.4 **NIMCO/United Nations Numerical Designation:** 3.2/1307

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** Benzene-like, characteristic aromatic

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Approved canister or air-supplied mask, goggles or face shield, plastic gloves and boots
5.2 **Symptoms Following Exposure:** Vapors cause headache and dizziness. Liquid irritates eyes and skin. If taken into lungs, causes severe coughing, distress, and rapidly developing pulmonary edema. If ingested, causes nausea, vomiting, cramps, headache, and coma. Can be fatal. Kidney and liver damage can occur
5.3 **Treatment for Exposure:** INHALATION: remove to fresh air, administer artificial respiration and oxygen if required, call a doctor. INGESTION: do NOT induce vomiting, call a doctor. EYES: flush with water for at least 15 min. SKIN: wipe off, wash with soap and water
5.4 **Toxicity by Inhalation (Threshold Limit Value):** 100 ppm
5.5 **Short-Term Inhalation Limits:** 300 ppm for 30 min
5.6 **Toxicity by Ingestion:** Grade 3, LD_{50} to 500 mg/kg
5.7 **Late Toxicity:** Kidney and liver damage
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary
5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin
5.10 **Odor Threshold:** 0.05 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** 63°F (C.C.) — 75°F (O.C.)
6.2 **Flammable Limits in Air:** 1.1% — 7.0%
6.3 **Fire Extinguishing Agents:** Foam, dry chemical, or carbon dioxide
6.4 **Fire Extinguishing Agents Not to be Used:** Water may be ineffective
6.5 **Special Hazards of Combustion Products:** Not pertinent
6.6 **Behavior in Fire:** Vapor is heavier than air and may travel considerable distance to a source of ignition and flash back
6.7 **Ignition Temperature:** 867°F
6.8 **Electrical Hazard:** Class I, Group D
6.9 **Burning Rate:** 5.8 mm/min

7. CHEMICAL REACTIVITY

7.1 **Reactivity with Water:** No reaction
7.2 **Reactivity with Common Materials:** No reaction
7.3 **Stability During Transport:** Stable
7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent
7.5 **Polymerization:** Not pertinent
7.6 **Inhibitor of Polymerization:** Not pertinent

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** 9.1 (48 hr) [illegible] mg/liter [illegible] in fresh water
8.2 **Waterfowl Toxicity:** Data not available
8.3 **Biological Oxygen Demand (BOD):** [illegible] in 5 days, 25°C
8.4 **Food Chain Concentration Potential:** Data not available

9. SELECTED MANUFACTURERS

1. Atlantic Richfield Co.
ARCO Chemical Co. Division
260 South Broad St.
Philadelphia, Pa. 19101
2. Exxon Services Co., Inc.
Petrochemicals Division
60 Wall St.
New York, N.Y. 10005
3. Shell Chemical Co.
Petrochemicals Division
Houston, Tex. 77001

10. SHIPPING INFORMATION

10.1 **Grades or Purity:** Research 99.9%
Pure 99.75%, Commercial 95%
10.2 **Storage Temperature:** Ambient
10.3 **Inert Atmosphere:** No requirement
10.4 **Venting:** Open (flame arrester) or pressure vacuum

11. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook, CG-446-2)

A-T-L

12. HAZARD CLASSIFICATIONS

12.1 **Code of Federal Regulations:** Flammable liquid
12.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	1
Health	
Vapor Irritant	1
Liquid or Solid Irritant	1
Poisons	2
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	3
Aesthetic Effect	2
Reactivity	
Other Chemicals	1
Water	0
Self Reaction	0

12.3 **NFPA Hazard Classifications:**

Category	Classification
Health Hazard (Blue)	2
Flammability (Red)	3
Reactivity (Yellow)	0

13. PHYSICAL AND CHEMICAL PROPERTIES

13.1 **Physical State at 15°C and 1 atm:** Liquid
13.2 **Molecular Weight:** 106.16
13.3 **Boiling Point at 1 atm:** 291.9°F = 144.4°C = 417.6°K
13.4 **Freezing Point:** −13.3°F = −25.2°C = 248.0°K
13.5 **Critical Temperature:** 674.8°F = 357.1°C = 630.3°K
13.6 **Critical Pressure:** 541.5 atm = 36.84 psia = 3.732 MN/m²
13.7 **Specific Gravity:** 0.880 at 20°C (liquid)
13.8 **Liquid Surface Tension:** [illegible] dynes/cm = 0.01053 N/m at [illegible]
13.9 **Liquid-Water Interfacial Tension:** [illegible] dynes/cm = 0.0360 N/m at 20°C
13.10 **Vapor (Gas) Specific Gravity:** Not pertinent
13.11 **Ratio of Specific Heats of Vapor (Gas):** 1.094
13.12 **Latent Heat of Vaporization:** 149 Btu/lb = 82.9 cal/g = 3.47 × 10⁵ J/kg
13.13 **Heat of Combustion:** −17,548 Btu/lb = −9754.7 cal/g = −408.41 × 10⁵ J/kg
13.14 **Heat of Decomposition:** Not pertinent
13.15 **Heat of Solution:** Not pertinent
13.16 **Heat of Polymerization:** Not pertinent

(Continued on page 1 of 4)

NOTES

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APPENDIX F

COST DERIVATIONS FOR WASTE DISPOSAL ALTERNATIVES

This appendix presents a table comparing the cost savings of the sale and recycling alternatives with the reference case, destructive disposal by incineration. The assumptions for this table are itemized and the derivation of individual costs are given.

Annual Costs Savings for Sale and Recycling Alternatives
(400 barrels of 1,1,1-trichloroethane)

Cost	Sale	Off-Base Recycling	On-Base Recycling
Disposal Cost*	$133,540	$133,540	$ 133,540
DOD Costs			
Base Cost	93,500§	29,700§	9,900¶
Base Makeup		+ 7,480	+9,350§
DPDS Disposal	-22,000**		+4,004§§
Total DOD Cost	71,500	37,180	23,250
Savings (through cost avoidance)	$ 62,040	$ 96,360	$ 110,290

*Reference Case: Destructive Disposal by Incineration

Base Cost	$ 93,500(new solvent)
DPDS Disposal Cost	+40,040
Total DOD Destructive Disposal Costs	$133,540

§New solvent
¶Recycled solvent
**Sale credit
§§Disposal still bottoms

DERIVATION OF COSTS

Disposal (reference case)

$93,500	400 drums of new solvent	@	$233.75/drum ($4.25/gal)*
$40,040	Disposal of 400 drums	@	$100.13/drum

Transportation: 300 miles roundtrip at $2.50/mile¶ and 80 drums/load — $9.38/drum

Disposal Cost — 90.75/drum

$100.13/drum

Where disposal costs are:

$0.15/lb x 11 lb/gal = $1.65/gal

$1.65/gal x 55 gal/drum = $90.75/drum

Based on $0.15/lb charged by the MSD Cincinnati Incinerator**

- Base rate (~6 x 10^6 lb/year):	4.5¢/lb
- Heating value surcharge (@ 4700 Btu/lb):	1.2¢/lb
- Residue surcharge:	1.3¢/lb
- Neutralization surcharge:	8.0¢/lb
	15.0¢/lb

Sale

$22,000 Sale credit of 400 barrels of waste solvent:

$1.00/gal¶¶ x 55 gal/drum x 400 drums = $22,000

* Cost of new 1,1,1-trichloroethane from manufacturers

¶ Average cost from three disposal companies

** From S.D. Celson, Metropolitan Sewer District of Greater Cincinnati, October 4, 1982

¶¶ Estimated cost based on DPDS records and discussions with recyclers

On-Base Recycling

$9,900 Processing used solvent:

$0.50/gal* x 55 gal/drum = $27.50/drum

$27.50/drum x 360 drums = $9,900

$9,350 Makeup with new solvent:

$4.25/gal¶ x 55 gal/drum = $233.75/drum x 40 drums

$233.75/drum x 40 drums = $9,350

$4,004 Disposal of still bottoms:

$100.13/drum x 40 drums = $4,004

Off-Base Recycling

$29,700 Recyclers transport and processing fees:

$1.50/gal** x 55 gal/drum = $82.50/drum

$82.50/drum x 360 drums = $29,700

360 drums = 400 drums - 40 drums of still bottoms

$7,480 Recycled makeup solvent from recyclers:

$3.40/gal¶¶ x 55 gal/drum = $187/drum

$187/drum x 40 drums = $7,480

* Estimated cost from still manufacturers and base operating experience
¶ Estimated cost from solvent recyclers
** Estimated cost for recycled makeup from recyclers
¶¶ Estimated cost for recycled solvent from recyclers

APPENDIX G

EXAMPLES OF SUCCESSFUL SOLVENT PRACTICES

At each of the bases visited where some form of used solvent segregation, disposal, and reuse by sale or recycling was in progress, operational information was gathered. The following cases are examples of base operations.

CORPUS CHRISTI ARMY DEPOT - ON-BASE RECYCLING

For a number of years, the Corpus Christi Army Depot has successfully recycled PD-680 and 1,1,1-trichloroethane. Current volume is about 55,000 gallons per year.

The depot developed its recycling capability by using surplus equipment and existing base personnel, without any large investment. As the recycling needs increased, the expansion was deliberate and restrained.

The key to the success at Corpus Christi appears to be that all concerned parties understand the value of recycling and want it to be a success. The depot commander recognizes the cost savings and advantages of internal solvent sources as not vulnerable to new solvent supply shortages; the shop personnel appreciate the ready availability of clean solvents; and the recycling personnel know they have turned potential wastes into a valuable resource.

ROBINS AIR FORCE BASE - ON-BASE RECYCLING

About 1-1/2 years ago, Robins AFB had accumulated several hundred drums of used solvent material that the base expected to eventually dispose of through a service contract. A request for bids on the service contract indicated that the cost for disposal of the material would be approximately $34,000. An engineer associated with flight line operations convinced base management they should purchase a distillation unit costing approximately $40,000 to recycle the used

material rather than continually paying to have the material disposed of. In August 1982, the distillation unit was placed in operation and to date has successfully recycled much of the backlog of used chlorinated vapor degreasing solvents. It has been estimated by the base operating personnel that the distillation unit will pay for itself in cost avoidance of purchasing new chlorinated solvents in less than 1 year. In addition, base personnel plan to use the unit to recycle other solvent and petroleum material otherwise the base would pay for disposal. There are good base management and operating personnel cooperation in the recycling effort, and the demonstrated results have increased the potential for growth of the operation.

HILL AIR FORCE BASE - OFF-BASE RECYCLING

Several years ago, an on-base facility for the reclamation of used chlorinated vapor degreasing solvents was in regular operation at Hill AFB. During recent construction activities, portions of the facility had to be dismantled, and normal access to the facility was blocked by new equipment and structures. Because of the age and condition of the reclamation equipment, a decision was made not to continue the operation of the solvent reclamation facility. In examining the requirements for this function, it was decided that there was potential for reclamation of a wider variety of materials than just the chlorinated solvents. It was decided that an attempt should be made to locate a commercial organization in the area that could perform a wide variety of solvent material reclamation processing at off-base facilities. An organization was located in nearby Salt Lake City, and a contract was negotiated to pick up, process, and return four solvent materials. These included 1,1,1-trichloroethane, Stoddard solvent (PD-680), Freon, and isopropyl alcohol. Because recycling had previously been in use at the base, both the procedures and necessary cooperation were present at the outset of the off-base program. To date, several batches of used solvent material have been successfully processed by the contractor, and plans are underway to continue and expand this program in the future.