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NSRP 0378

# THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

## **Solvent Recycling for Shipyards**

U.S. DEPARTMENT OF THE NAVY  
CARDEROCK DIVISION, NAVAL SURFACE  
WARFARE CENTER

in cooperation with  
Peterson Builders, Inc.

## Report Documentation Page

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National Shipbuilding Research Program  
SNAME Panel SP-3  
Surface Preparation and Coatings

# **Solvent Recycling for Shipyards**

**May, 1993**

prepared by

**National Steel and Shipbuilding Co.**  
San Diego, California

for

**PETERSON BUILDERS, INC.**  
Sturgeon Bay, Wisconsin

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## FOREWORD

This research project was produced for the National Shipbuilding Research Program (NSRP) as a cooperative cost-shared effort between the U.S. Navy and Peterson Builders, Inc. (PBI) of Sturgeon Bay, WI. The Surface Preparation and Coatings Panel (SP-3) of SNAME'S Ship Production Committee sponsored the project under the technical direction of James Rogness of PBI, NSRP Program Manager.

The research was conducted and the report prepared by National Steel and Shipbuilding Co. (NASSCO) of San Diego, CA. NASSCO participants included Jerry Keener as Project Manager and Indelacio Parra as Project Engineer. Les Hansen acted as an engineering consultant and authored the final report.

The project team acknowledges Al Hamilton, NASSCO Paint Department Manager, and other members of the Paint Department, as well as other departments, who supported the start up of NASSCO'S pilot solvent recycling program. Thanks also go out to the representatives of the shipyards and other companies that took the time and effort to participate in the project surveys and provide valuable feedback.

## 1. INTRODUCTION

Large volumes of chemical solvents are used annually for various purposes in shipyards, primarily for paint thinning and equipment cleaning. A majority of the solvents used for cleaning are used once or twice and discarded. This practice is impractical from two perspectives. First, the cost of virgin solvent is high and appears to be headed upward. Therefore, minimizing the purchase and use of virgin solvents would yield immediate cost benefits. Also, solvents are considered hazardous materials by the Environmental Protection Agency (EPA), and once used they become hazardous waste and must be disposed of as such. The cost of hazardous waste disposal is currently high and continues to increase as stricter state and local environmental laws are implemented. Disposal costs can nearly equal the per-gallon purchase cost of virgin solvents.

One of the simplest and most cost effective methods to reduce both the volume of virgin solvent purchased and the volume of solvent waste is recycling. Due to low initial equipment and maintenance costs, on-site solvent recycling has proven feasible from a cost/benefit standpoint, particularly for reasonably high volume operations. Where volume of solvent used does not justify an on-site program, off-site recycling would be a more practical alternative to disposal.

The goal of recycling is to recover from the waste solvent, a solvent of similar purity to that of the virgin solvent for eventual reuse in the same operation;

or of a sufficient purity to be used in another application. Recycling can also include the direct use of a solvent waste from one waste stream in another operation. The most common technique used for solvent recovery is distillation. With this method, the waste solvent is heated to its boiling point and the resulting purified vapor is withdrawn, condensed and collected for reuse.

While on-site solvent recycling is generally feasible for high volume users from a cost standpoint, successful implementation of a shipyard solvent recycling program can prove to be a challenge. Some of the obstacles to overcome include:

- Establishment and implementation of new work methods and procedures
- Need for operator and worker training
- Risks involved with misuse of reclaimed solvents
- Liabilities for worker health, fires, explosions, leaks and spills
- Risks resulting from improper equipment operation

## 2. PROJECT OVERVIEW

The principal objective of this project is to define the requirements and procedures necessary to implement an effective shipyard solvent reclamation program. Most large shipyards can easily cost justify the purchase of an on-site recycling system. However, difficulties often arise with setting up and maintaining a comprehensive program for the use of equipment and reclaimed solvents.

While this report emphasizes program **implementation**, economics are discussed to an extent necessary to assist a shipyard that has not yet purchased a solvent reclamation system. Although several methods exist for small-scale reclamation of solvent waste, the scope of this project has been limited to the distillation process, since this is the most commonly used method. For completeness, other recycling techniques are briefly described. Also, to best serve the intended audience, the project focuses on solvents used in painting operations.

The report begins with a summary discussion of the economic and environmental benefits of solvent recycling, along with alternatives to recycling. Since the environmental and regulatory aspects of solvent use and solvent recycling are becoming more important each year, a full section of the report is dedicated to these issues. Survey data from shipyard and industry users of recycling equipment and equipment manufacturers is also included. The process undertaken by NASSCO to justify, purchase and start

a pilot program for solvent recycling is then discussed, primarily to provide perspective to a shipyard that may be facing this process in the future. The report concludes with a proposal for the implementation of a generic, comprehensive shipyard solvent recycling program, based on NAS-SCO's experience, survey data and other project research.

This project was accomplished in several phases or tasks as summarized below

- Interview current shipyard and industry users of recycling equipment to assess applicability to the shipbuilding environment. (Survey results are included in Section 5)
- Survey manufacturers and compile information on available equipment and features. (Data is summarized in Section 6)
- Investigate and outline environmental, health and safety issues relative to solvent recycling.
- Develop recommended procedures for an effective shipyard solvent recovery program.
- Implement procedures through an on-site pilot program and monitor results.
- Summarize findings in a final report.

The primary benefit expected from the implementation of this project is a reduction in shipyard costs through the establishment of an on-site solvent recycling program. Potential savings in solvent raw material purchases and solvent waste disposal costs for a yard that generates at least 300 gallons of waste solvents monthly are in the range of \$30-50,000 annually (after initial investment payback). Ship yards that currently own recycling equipment would also be expected to benefit in the form of improved operations resulting from the information and recommendations contained in this report.

### 3. BENEFITS OF SOLVENT RECYCLING

#### 3.1. Economic Benefits

One of the main reasons to begin a shipyard solvent recycling program is cost savings. The results of cost analyses from several industries that use solvents, including shipbuilding, show that recycling will save money, provided the volume of solvents used is large enough. Most shipyards generate sufficient solvent waste in their painting operations to cost justify solvent recycling, either on site (in yard) or off site. The economic benefits of on-site recycling include:

- I Reduced cost to purchase virgin solvent
- I Lower waste disposal costs
- I Reduced off-site transportation and treatment costs
- I Potential income from sale of reclaimed solvents (subject to environmental regulation)
- I Quality control of reclaimed solvent purity

The decision to procure, install and operate an on-site recovery system must be based on a complete analysis of the technical and economic feasibility of the system under consideration. The analysis must also consider operational issues such as ease and safety of operation. This "cost/benefit" analysis is used to determine the payback period and return-on-investment (R.O.I) for the solvent recovery system.

For example, the results of an economic analysis performed by the University of California, Davis in 1986 (Ref.1) showed that for a small distillation system (1 -2 gal. per hr.), the cost to produce reclaimed solvent was \$0.30 - 0.50 per gallon. This compares to a cost of about \$5-7 per gallon for virgin solvents. The R.O.I. for this small system was 81% per annum, which equates to a payback period of just over a year. The economic benefits were proportionally greater for larger capacity recycling systems.

NASSCO's experience during the first six months of a pilot recycling program (See Section 7) indicate similar savings and a short payback period — 6 to 9 months. Section 7.1. outlines the economic analysis undertaken by NASSCO to justify the purchase of an on-site solvent distillation system. The format used by NASSCO can be followed by any shipyard to develop a cost/benefit analysis.

For shipyards that generate volumes of waste solvent too small to justify on-site recycling, economic benefits are possible through off-site recycling. Privately owned commercial recycling facilities offer a variety of services such as operating a waste treatment or recycling facility on the generator's property or accepting and recycling batches of solvent waste at their own facility. Reclaimed solvents can be purchased from commercial recyclers at 10 - 20% of the cost of virgin solvents. However, the quality and purity of these solvents should be

verified. They are usually suitable only for surface and equipment cleaning — not for paint thinning.

### 3.2. Environmental Benefits

As federal, state and local environmental regulations relative to handling and disposal of hazardous materials become more stringent, the need for solvent recycling increases. There are several direct environmental benefits to be derived from an on-site solvent recycling program, such as:

- Reduced liability for transporting hazardous waste off site
- Simplification of regulatory compliance requirements (recordkeeping, reporting, tracking, etc.)
- Compliance with the hazardous waste minimization declaration of the Resource Conservation and Recovery Act (RCRA)

If solvents are not recycled on site, large quantities of solvent waste must be transported away from the shipyard for either disposal or off-site recycling. Once the solvent waste leaves the shipyard, several environmental laws are triggered governing the transportation, handling and disposal of the waste. Ultimate liability for any violation of these laws rests with the waste generator (the shipyard). As part of this process, the waste generator is required to fill out a written report (manifest) describing the details of the transaction, along with a waste minimization declaration. This declaration states that the generator has a program in place to reduce toxic

waste to an economically practicable extent. A manifest is required for all off-site shipments, whether for disposal or recycling. Since solvent recycling can greatly reduce the volume of waste solvent, recycling can significantly reduce hazardous waste liability and paperwork.

Another advantage to be gained from on-site solvent recycling is the avoidance or reduction of what can be a burdensome paperwork process. On-site recycling equipment or operations do not require a Federal permit, provided the reclaimed solvents are used within the shipyard. In some areas of the country, permits may be required by local Air Pollution Control Agencies. If reclaimed solvents are sold to an outside entity for reuse or to be burned as fuel, the full reporting and permitting process would be triggered. Also, the sale of solvents may trigger additional environmental regulations, such as the Toxic Substances Control Act (TSCA). See Section 4 for a comprehensive discussion of the regulatory issues relative to shipyard solvent recycling.

### 3.3. Alternatives to Recycling

Although this project is intended to address solvent recycling, other options exist for solvent use and disposal that should be mentioned. The primary alternatives to recycling are source reduction and treatment. Source reduction may be more desirable, at least from an environmental and safety perspective.

Source reduction focuses on process changes that can be made to either reduce or eliminate the use of solvents

and subsequent generation of solvent wastes. Source reduction would be the first priority from an environmental, health, and possibly from an economic standpoint, since the goal of source reduction is to limit the use and disposal of toxic (and expensive) solvents, which also reduces worker exposure. A source reduction program may consist of several components, including:

Product Reformulation - Attempting to reformulate the currently used solvent with less toxic or non-toxic ingredients.

Product Substitution - The use of a different, non-hazardous (and less expensive) material in place of the solvent, such as the use of water-based coatings.

Process Modification - Changing to a less toxic or less waste-intensive process, such as the use of powder coating in place of solvent-based coatings; or equipment changes, such as the use of airless or HVLP systems to reduce paint consumption and overspray.

Procedure Alteration - Changes in operating practices or organizational politics that result in reduced waste, such as improved employee training, proper scheduling and increased use of preventative maintenance.

Obviously, the most effective method of source reduction would be to find ways to completely eliminate the use of solvents wherever possible. The first step in achieving this objective would involve an analysis of all areas of the shipyard where solvents are currently used. Each case would then be examined to determine whether

solvent elimination was feasible. Some examples are:

- Substituting water-based coatings for solvent-based coatings
- Substituting water and citric acid-based cleaners and strippers for chemical cleaners
- Using mechanical cleaning methods instead of solvent cleaning
- Change from conventional painting to solventless processes such as thermal spray or powder coatings.

Treatment (or pretreatment) refers to processes or techniques that destroy the waste and yield waste streams that pose little or no environmental risk. Treatment or pretreatment of solvent waste should be considered only after exhausting all available source reduction and recycling options, since treatment does not necessarily reduce the volume of solvents used or the amount of waste generated. There are several options available for solvent waste treatment, including air or steam stripping and incineration.

Shipyards generally would not generate large enough volumes of solvent waste to justify on-site treatment, particularly where recycling is practiced. There are, however, companies around the country that market transportable incineration systems that may prove cost-effective (Ref. 2). Off-site treatment can often be justified in the case of small-volume waste generation. Incineration currently is the most common form of off-site treatment. There are a few



locations, primarily in California, that are permitted to burn hazardous waste, although more are expected to be available in the near future.

Another option to recycling, which is gaining in popularity, is the waste exchange program. Under this system, two or more facilities exchange recyclable waste. Recipient companies either use the waste untreated or subject it to a minimal amount of treatment before reuse. This exchange concept is successful as long as each facility is able to recycle the other's waste stream more efficiently than their own. Waste exchange services are available through private or government-funded organizations to facilitate recycling transactions by identifying the supply and demand for various wastes.

## 4. ENVIRONMENTAL, HEALTH AND SAFETY ISSUES

This section presents an overview of the environmental issues and regulations, as well as the health and safety concerns related to solvent use and disposal. Several types of regulations and statutes govern the management of solvents and solvent waste. These include hazardous waste, air pollution, water pollution, occupational health, and transportation regulations. The specific requirements for a shipyard handling hazardous waste depend on the location of the shipyard and the type and amount of emissions.

An in-depth discussion of environmental regulatory issues would be beyond the scope of this report. Appropriate shipyard personnel involved in the handling and disposal of solvents are encouraged to work with their Environmental Affairs Department to become knowledgeable of the relevant regulations and statutes. This is particularly important in light of the rapidly changing environmental landscape.

### 4.1. Federal Regulations

The most comprehensive federal law related to hazardous waste is the Resource Conservation and Recovery Act (RCRA), originally adopted in 1976. In 1984, Congress passed a sweeping set of amendments to RCRA known as the Hazardous and Solid Waste Amendments (HSWA). Together these laws have significant implications for waste minimization. RCRA, in effect, mandates “cradle-to-

grave” responsibility for hazardous waste generators, covering the full spectrum of generation, treatment, storage, handling and disposal of waste. At the federal level, RCRA and HSWA are administered by the Environmental Protection Agency (EPA).

HSWA requires all hazardous waste generators to establish waste minimization programs. Since September 1985, generators have been required to sign a certification on manifests for off-site shipment stating that they have a program in place to reduce the volume or quantity and toxicity of the waste generated, and that the waste management method minimizes the threat to human health and the environment. Generators are also required to submit biannual reports (Form R) describing waste minimization efforts and actual reductions in waste volume and toxicity. Hazardous waste treatment, storage, and disposal (TSD) permits require that the permittee annually certify that a waste minimization program is in place. EPA has affirmed that participation in waste exchange programs and recycling in general qualifies as waste minimization. Generators disposing of “recyclable wastes” may be asked to provide justification for not recycling.

HSWA also created a comprehensive national land disposal restriction program that affects solvent waste disposal. As of May, 1990, most solvents and paint wastes (still bottoms) are prohibited from landfill

disposal, unless EPA established treatment standards are met. Incineration is the most common treatment method for solvent wastes. Certain wastes are entirely prohibited from land disposal, even with treatment.

Two additional federal regulations can ultimately have an impact on solvent waste disposal. The 1980 Comprehensive Environmental Response Compensation and Liability Act (CERCLA), also known as "SUPERFUND," provides funding and enforcement authority for mitigation of hazardous substance spills or cleanup of past waste sites. The Superfund Amendments and Reauthorization Act of 1986 (SARA) strengthened and expanded on the mandates under CERCLA. Often, even small generators of hazardous waste can be held financially liable for the clean up of improperly disposed waste.

In addition to hazardous waste regulations, solvent recycling may be governed by federal air quality regulations mandated by the Clean Air Act (CAA) or the 1990 Amendments to the CAA. The CAA establishes health-based ambient air quality standards for major air pollutants. Volatile organic compounds (VOCs), which produce ozone (smog), are one of the regulated pollutants under the CAA. Since most solvents emit large doses of VOCs, solvent recycling equipment may be subject to air quality regulations. See Section 4.4 for a discussion of permitting requirements.

The disposal of solvent waste may also be impacted by the federal water quality guidelines established by the Clean Water Act and the Safe Drinking

Water Act, both administered by EPA. These laws regulate wastewater disposed to surface waters, municipal sewers, and injection wells. Limits are placed on the concentrations of solvents being discharged into these water systems, and pretreatment is required for wastewaters contaminated with solvents.

#### 4.2. State (California) Regulations

This discussion of state regulations related to solvents will focus on current California regulations, since California has traditionally set the environmental tone for the country. California has its own hazardous waste laws and regulations, which add detail to, and often extend, the federal requirements. In general, California and other states administer the federal laws and regulations in cooperation with the EPA. The current trend is for EPA to transfer increasing responsibility for program development and enforcement to the states.

In 1981, California became the first state to establish a hazardous waste land disposal restriction program. Wastes that have been restricted from land disposal in California include halogenated solvents at concentrations above 1000 parts per million (ppm). Land disposal includes landfills, surface impoundments, and land treatment. Also, beginning in 1990, California enacted a requirement that wastes containing specified percentage of volatile organic compounds (VOCs) must be incinerated or treated.

California's hazardous waste regulations require that a generator of

wastestreams determined by the state to be recyclable must attempt to recycle those wastes. All types of solvents are included in this recyclable list. California's Environmental Protection Agency (Cal EPA) routinely checks shipment manifests to determine if any of the specified wastes are being disposed of on land. If so, the Agency contacts the generator and inquires why the wastes are not being recycled. The regulations stipulate that the generator must respond in 30 days or less. The generator's justification must include a summary of efforts made to find a use for the waste, and technological and economic reasons for not having recycled the waste. As a result of this program, solvent (and other hazardous waste) recycling is on the increase in California.

California has also set air quality standards for major air pollutants. Some of these standards are more stringent than the national standards. For a proposed facility or process to receive an air quality permit in California, the applicant must show that the project will not interfere with achieving or maintaining the state and national ambient air quality standards.

New facility projects must also comply with California's toxic air contaminant program. Under this program, the state identifies toxic air contaminants to be subsequently controlled. Many of the solvents used in painting and cleaning have been identified as contaminants, subject to strict controls. Nearly every state currently has an air toxics program in place. The programs may differ somewhat from state to state, but most programs will include regulation of organic solvents.

California has incorporated the federal water quality guidelines into its own legislation to control waste discharges into surface water and municipal sewer systems. California's Water Quality Control Boards have determined "water quality goals" for various potential ground and surface water pollutants. These goals or standards represent the maximum contaminant levels (MCLs), expressed as concentrations, that are permitted in the water source. For example, the current MCL for xylene, a commonly used paint solvent, is 20 micrograms per liter (ug/l) or .000020 grams/liter. These stringent standards preclude the disposal of untreated solvent waste into any water source. Even with treatment, solvents may not be able to meet the MCLs.

#### 4.3. Health and Safety Concerns

In addition to the state and federal environmental laws and regulations, there exist the regulations imposed by the State and Federal Occupational Safety and Health Administration (OSHA). Many of the OSHA regulations complement the environmental regulations. The federal and California OSHA regulations pertain to administrative responsibilities including standards-setting, recordkeeping, activities of advisory committees, access to employee medical records, duties of employers, enforcement actions, accreditation of testing laboratories, on-site consultations, and examination and copying of documents.

Under the Occupational Safety and Health Act of 1970, employers are required to maintain accurate records

of employee exposures to potentially toxic materials or harmful physical agents, and to promptly advise employees of any excessive exposure and of the corrective action being undertaken. In general, OSHA requires that worker exposure standards to specific toxic substances be established. Associated with these standards are requirements for recordkeeping.

Those employers in industries that use hazardous materials such as solvents must identify the hazards of the materials. The information must be recorded on a Material Safety Data Sheet, OSHA Form No. 20, or a similar form. The Data Sheet can be useful as a fact sheet on the properties and potential hazards of a chemical. The pertinent information required includes:

- Chemical name of the material
- Physical data
- Fire and explosion hazard data
- Reactivity data
- Spill, leak, and clean-up procedures
- Special protective equipment
- Handling information

The Federal Right-to-Know Regulation of 1986 requires that employees be trained in the safe use of potentially hazardous substances. The regulation also requires that all hazardous substances be properly labelled and a Data Sheet on that substance be available to each employee. Standards

for toxic and hazardous substances are implemented on an air contaminant basis as well as a handling basis.

Handling standards are procedures that companies must follow for a specific chemical. These procedures include appropriate protective equipment, respirators, personal monitoring, environmental monitoring, and appropriate signs, information and training. OSHA handling standards are in effect for many of the solvents commonly used in shipyards. Personnel involved in solvent use or recycling should be fully aware of these standards and requirements.

The extent of personnel protective equipment (PPE) needed when working around solvents depends on the type and toxicity level of the particular solvent. As a minimum, the following PPE would normally be used by anyone loading or cleaning a solvent distillation unit:

- Respirator
- Disposable rubber gloves
- Plastic face shield and safety glasses
- Coveralls or adequate protective outer clothing
- Protective boots

The shipyard's Industrial Hygienist can provide additional information regarding protective equipment requirements and handling standards.

One of the key safety concerns relative to solvent recycling operations is proper bonding and grounding of containers. The action of transferring a liquid from one container to another may produce voltage potentials that can result in static electrical sparks

capable of igniting flammable vapors. Therefore, dispensing and receiving containers must be bonded together with a suitable conductive strap before pouring. Also, drums must be connected to an adequate electrical ground when they are used as a dispensing or receiving vessel.

When selecting a solvent distillation system, attention should be placed on safety features. Important safety features include explosion-proof electricals and grounding protection, overpressure relief valves, and auto shut-off for excessive temperature or cooling failure. Further information on health and safety issues can be obtained from the state OSHA enforcement unit.

#### 4.4. Permitting Requirements

The Resource Conservation and Recovery Act (RCRA) includes a permit requirement for anyone involved in the treatment, storage or disposal of hazardous wastes. Recycling would be included under the general definition of treatment. However, as mentioned in Section 3.3, the establishment of a shipyard solvent recycling program would not trigger federal permitting requirements under RCRA, since on-site recycling activities are exempted. Some state permitting requirements may be more stringent than the federal requirements, and in some cases permits may be required.

If solvents are sent to an off-site facility for recycling, no special permit is required by the shipyard. The recycling facility, however, must have a permit as discussed in Section 4.5. Also, storage of waste solvents on site

for longer than 90 days prior to recycling would trigger a RCRA permitting requirement. Procedures should be set up to ensure solvents are processed within this time constraint.

Local air quality regulations in certain states may mandate a permitting requirement for the operation of solvent distillation equipment. This requirement results from the possibility of toxic air emissions, in the form of volatile organic compounds (VOCs), being released during the distillation operation. Solvent recycling equipment is usually designed to include a vapor recovery system to contain solvent fumes, so VOC emissions, if any, are minimal. If required, the expense for equipment capable of completely capturing VOCs would be prohibitive, particularly for a small solvent reclamation system (Ref. 3).

Most permits limit the amount of VOCs, in pounds, that can be emitted from the system on a daily basis. In addition to regulating air emissions, the issuance of an air quality permit allows the local air regulatory agency to ensure that the equipment being purchased and operated at the shipyard meets necessary health and safety requirements. Also, the permit usually includes a record-keeping requirement. The agency requests daily records of the input and output volume of the recycling unit, as well as the amount of waste produced per batch. These records must be maintained for a minimum of three years.

The local air permitting requirement is normally based on equipment capacity. For example, Southern California Air

Pollution Control Districts require a permit for distillation units larger than five gallons. Since this capacity limit may vary by state or locality, each shipyard should obtain permitting information from their local air regulatory agency. Also, initial permit costs may be substantial, and these costs should be included in the economic analysis.

#### 4.5. Waste Disposal

In years past, solvent waste was commonly disposed of either in landfills or into the local sewer system. As discussed in Sections 4.1 and 4.2, current federal and state environmental regulations have virtually eliminated these disposal methods. Defined as hazardous materials, solvents are subject to the strict disposal guidelines of RCRA.

The same properties that make organic solvents useful create a threat to human health and the environment when solvents occur in industrial wastes. Solvent volatility can result in emissions from the waste. When the waste is land disposed, the emissions can cause air pollution and fire hazards at the disposal site. Because a solvent is chemically inert, it resists natural degradation in a land disposal site. This persistence allows the solvent to retain its hazardous properties long after disposal.

Solvents have low viscosity and low surface tension, that aid in penetration and destruction of the liner that is intended to seal the bottom of a land disposal site. A solvent can dissolve a polymer plastic liner, or extract water from a clay liner, resulting in liner

leakage. The threat is compounded by the ability of solvents to dissolve and transport other hazardous materials in the disposal site.

There are limited options for the proper disposal of waste solvents. If used cleaning solvents are not recycled on site, large volumes of liquid solvent waste are generated requiring disposal. This waste solvent is normally accumulated in 55 gallon drums in the work area, and then moved to the shipyard's central hazardous material processing area for disposal. If solvents are being recycled in the shipyard, the volume of solvent waste is much less, since the used solvents have been reclaimed and put back in use. Also, the waste resulting from a solvent distillation process is very concentrated. "Still bottoms" consist of paint residue and other impurities removed from the solvent during distillation. These still bottoms represent only a fraction of the volume of the original liquid solvent put into the still.

Shipyards may have the option of treating their solvent waste on site, provided this practice can be economically justified. (See Sect. 3.3). In most cases however, these wastes will need to be disposed off site. As mandated by RCRA, solvent wastes, either in a liquid or sludge form, must be shipped to a state-certified treatment, storage and disposal facility (TSDF). Liquid wastes of low purity are typically incinerated for fuel in industrial operations such as cement kilns. Higher purity waste solvents can be refined or distilled for resale. Paint and solvent waste solids can also be incinerated. However, if toxic components can be removed, solids

have potential for alternative uses in products such as undercoating and water sealer.

Before committing to do business with a particular TSDf, the shipyard should be certain that the facility is reputable and has all required state and local permits. In addition, the TSDf should not have a history of violations or be under investigation for improper practices. A facility audit can be performed by the shipyard if necessary. Using a reputable facility is important since the shipyard remains responsible for the hazardous waste throughout the transportation, treatment, and disposal process.

The cost to dispose of solvent and paint waste through a TSDf varies from location to location, but in all cases the cost is high. For example, the 1992 cost in southern California to have 55 gallon drums of paint waste solids removed by a TSDf hauler was \$300-400 per drum or approximately \$6-7 per gallon. The cost to dispose of liquid solvent waste may be lower by \$1-2 per gallon, depending on purity, since this type of waste has potential value for industrial incineration. In some states, hazardous waste brokers or haulers may reduce disposal fees when there are established markets for solvent or paint wastes.



## 5. SUMMARY OF INDUSTRY USERS SURVEY

This section presents a summary of the information gathered from surveying various industry users of solvents and solvent recycling equipment. East, West and Gulf Coast shipyards were the main participants in the survey. A local San Diego paint manufacturer and a turbine manufacturing company were also included in the survey. A contact sheet (See Figure 5-1) was circulated at the first SP-3 Panel meeting of 1992 to encourage panel participation and identify potential shipyard survey respondents.

The surveys were initially conducted during the second and third quarters of 1992, with telephone follow-up during the fourth quarter. Eleven of the fourteen companies included in the survey responded, either initially or during the follow-up phase. Table 5-A lists the shipyards and other companies that were surveyed. Figure A-1 in Appendix A shows a sample of the survey form that was mailed or faxed to participants. Figure A-2 shows the form used for the follow-up telephone survey. A summary of the survey responses from shipyards or other companies involved in recycling is presented in Table 5-B.

### 5.1. Survey Results

A synopsis of the responses to the industry survey indicates the following

- 5 of the 10 shipyards responding are currently recycling solvents or are in the process of

evaluating recycling equipment. The other yards may consider recycling in the future.

- All respondents with recycling systems are utilizing the distillation method, either with or without vacuum assistance.
- Still capacities range from 15 to 65 gallons, and the average capacity is 35 gallons.
- The average production efficiency, or recovery rate, for the distillation units is about 70%. That is, for every 10 gallons of liquid solvent waste put in, 7 gallons are recovered as reusable solvent. Manufacturers typically advertise (ideal) recovery rates over 90%.
- Most of the respondents are processing one primary solvent type through their systems. This procedure ensures a more useable end product.
- In all cases, recycled solvents are used on-site and not sold to outside sources.
- In every case but one, recycled solvents are used for equipment or surface cleaning — not paint thinning. The exception was a paint manufacturer, who sometimes uses high quality recovered solvents in paint formulation.
- About half of the recycling units

**SOLVENT RECYCLING FOR SHIPYARDS  
TASK 3-90-4**

SHIPYARD SOLVENT RECYCLING CONTACT SHEET

ATTENZMEE	SHIPYARD	CONTACT	TELEPHONE	F A X
J. Keener	NASSCO	J. Keener	619-544-3492	619-544-3543
J.D. Neeson	Bath Iron Works	J.D. Neeson	207-442-2095	207-442-1842
W.R. Ellis	Mare Island Naval Shipyard	J. Ceballos	707-646-4529	707-646-4300
E.P. Johns	Charleston Naval Shipyard	Al Orrutia	803-743-5519	---
John Kern	Norfolk Naval Shipyard	John Kern	804-396-4704	804-396-2726
Gary Szymanski	Peterson Builders	Gary Szymanski	414-743-5534 ext. 457	---
Ernie Miguez	Avondale	L. Townsend	504-436-5559	---
John Coil	Atlantic Marine	John Coll	205-690-7117	205-690-7200
Don Rowen	Atlantic Drydock	Don Rowen	904-251-3111	904-251-3500
Bill Naunton	Beth Ship	Walt Farson	410-388-4640	---
Chuck Nugent	North Florida Shipyard	John Shiffert	904-353-1775	904-353-2665
Kay Freeman	Ingalls	Kay Freeman	601-935-3919	601-935-2952

**Figure 5-1 Panel Meeting Contact Sheet**

SHIPYARDS SURVEYED	RESPONDED TO SURVEY	CURRENTLY RECYCLING SOLVENTS	EVALUATING RECYCLING
Atlantic Drydock			
Atlantic Marine	✓		
Avondale	✓		
Bath Iron Works	✓	✓	
Beth Ship	✓		
Charleston Naval			
Ingalls	✓		✓
Mare Island Naval	✓	✓	
NASSCO	✓	✓	
Norfolk Naval			
North Florida	✓		
Peterson Builders, Inc.	✓		✓
Southwest Marine	✓	✓	
Proline Paint Mfr.	✓	✓	
Solar Turbines	✓	✓	

Table 5-A Survey Participants

SHIPYARD/ COMPANY	STILL MANUFACTURER	STILL CAPACITY (gal)	AVERAGE RECOVERY RATE	TANK LINING TYPE	VACUUM OPTION	Nr/TYPE SOLVENT(S) RECYCLED	USE FOR RECLAIMED SOLVENTS	SELL RECYCLED SOLVENTS?
Bath Iron Works	Progressive Recovery Inc.	45	50	Stainless Steel	Yes	Mineral Spirits	Equipment & Surface Cleaning	No
Ingalls	Finish Thompson Inc.	3-5	Unknown	Disposable Bag	Yes	N/A	---	---
Mare Island Naval	Finish Co. Inc.	55	N/A	Disposable Bag	Yes	Various	Equipment & Surface Cleaning	No
NASSCO	Recycling Systems of America	17.5	65-75	Teflon Coating	Yes	Zylene	Equipment & Surface Cleaning	No
Southwest Marine	Progressive Recovery Inc.	65	75	Stainless Steel	No	One	N/A	N/A
Proline Paints	SIVA Int'l. Inc.	15	70	Disposable Bag	No	Various	Equipment & Surface Cleaning	No
Solar Turbines	Finish Thompson Inc.	15	70	Disposable Bag	No	One	Equipment Cleaning	No

Table 5-B Survey Response Summary

N/A = Information not available

utilize a disposable bag to collect waste residue. These bags may offer convenience, but their substantial cost (\$10 -50 each) must be included in the unit's operational cost. Also, bags have the potential to break or leak.

Additional comments from survey respondents are as follows:

- One shipyard attempted to evaluate a small (3 - 5 gallon) distillation unit manufactured by Finish Thompson, Inc. (Model LS-Jr.). The test proved unsuccessful due to the inability of the unit to generate sufficient heat (with a vacuum attachment) to complete the distillation process.
- Another shipyard reported problems with the initial start-up of their unit (Progressive Recovery, Inc., Model SCR-150) due to complicated installation and operating procedures. This yard also experienced problems with excess water mixed with the solvent during distillation. Also, the use of a vacuum attachment was recommended to increase the unit's heat output, resulting in more efficient operation.
- Concern was expressed by a shipyard over the start-up costs associated with a recycling program. While recycling clearly "looks good on paper," manpower, administrative, permitting, training and other factors must be carefully evaluated to ensure effective program start-up.

## 5.2. Shipyard Applicability

Solvent recycling, both on-site and off-site, has been ongoing in several types of industries for many years. These industries include:

- Manufacturing (All types)
- Aerospace
- Printing
- Metal Finishing
- Electronics
- Maintenance

The primary use for solvents in these operations is parts and equipment cleaning. Some of these industries generate such large volumes of waste solvents that recycling must be designed into production processes to ensure cost effectiveness. For example, large manufacturing operations can generate in excess of 100,000 gallons of mixed waste solvents per month. These solvent-intensive industries utilize a broad spectrum of recycling methods and extensive equipment to meet their needs.

Shipyards use solvents mainly in painting operations, which are only a part of the overall manufacturing process. Therefore, most shipyards tend to generate relatively small amounts of solvent waste as compared to other industries. However, due to the availability of inexpensive, small packaged distillation equipment, on-site solvent recycling is quite feasible for shipyard applications.

The survey results indicate that all respondents, both shipyards and non-shipyards, were using the distillation method to reclaim solvents. This data, together with information from

equipment suppliers, confirms that distillation systems are most applicable for the shipyard environment. While other methods and equipment are available for solvent recycling, as described in Section 6.1, distillation appears to offer the most flexible and cost effective means to recover shipyard solvent waste.

## 6. SUMMARY OF EQUIPMENT SURVEY

As part of the project research, various manufacturers and distributors of solvent recycling equipment around the country were contacted to obtain information on available equipment. This section provides a summary overview of the equipment, features and options, and a cost range for each manufacturer's systems. Appendix B contains more detailed equipment data from manufacturer-supplied literature and a contact list including vendors' names, addresses and phone numbers. Although this project focuses on the distillation method for recycling solvents, brief general descriptions of other recycling methods are provided in Section 6.1 for information.

### 6.1. Recycling Methods

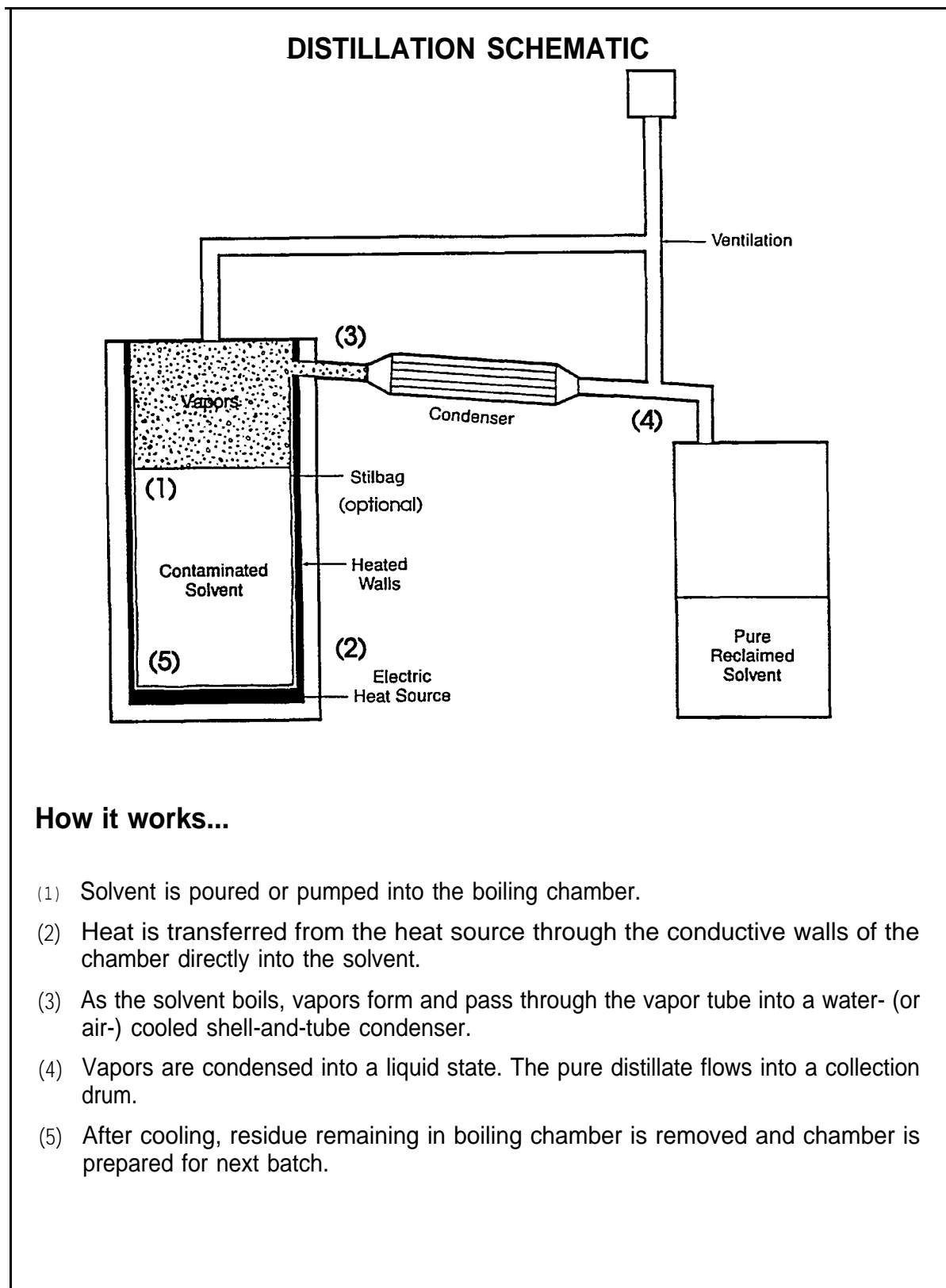
A variety of methods and related equipment are available for recycling solvents. The method used by a particular industry or operation will depend on the amount, type and concentration of waste solvents generated, as well as the economic feasibility of the method and equipment. Following is a brief description of commonly utilized techniques for recovering concentrated solvent waste.

Distillation Distillation is the oldest and most popular technique utilized for solvent recovery. It relies on the principle that the solvent has a lower boiling point than the contaminants. Batch and continuous distillation are the most common procedures.

The batch process consists of placing a fixed amount of solvent waste into a heated chamber. Heat is applied to raise the temperature to the solvent boiling point and the resulting vapor is withdrawn and condensed. The process is terminated when the impurity level in the distillate becomes prohibitive. Batch distillation most commonly uses a single equilibrium stage. Single stage batch distillation can usually produce a purity of greater than 95% if the process is carried out slowly and the vapor pressures of the components differ greatly. Figure 6-1 shows a schematic diagram and summary description of the batch distillation process.

Continuous multistage distillation is commonly applied when a high degree of distillate purity is required, the volatility differences of the solvent and contaminants is small, and the amount to be distilled is large. This method of distillation is carried out in a column equipped with trays to produce maximum contact between liquid and vapor phases. Feed is introduced continuously into the column and condensed liquid is withdrawn in a continuous or semi-continuous fashion.

Many different distillation units (stills) are commercially available. Capacities range from 0.8 to 1000 gallons per cycle and clean solvent output rates from one to 120 gallons per hour. The output rates vary depending on the heat of vaporization of the solvent, the type and concentration of the contaminant present, and power input.



**Figure 6-1 Schematic of Distillation Process**



Evaporation Evaporation is a procedure usually used for solvent sludge, still bottoms, or other solvent waste with a very high concentration of contaminants. In a turbulent film evaporator, also called a wipe-film evaporator, a set of blades spreads the waste in a thin film against the heated wall of a cylindrical vat. A high degree of heat transfer is maintained as the heavy sludge makes its way to the bottom of the vat and is collected for disposal. The solvent vapors are collected and condensed. Film evaporation is best suited for low-boiling solvents without abrasive solids.

Another evaporation method involves the use of a dryer. In this operation, the waste is fed between two heated drums that are counter-rotated. The solvent evaporates off, leaving the non-volatile components in the form of a dry film, which is scraped off and collected for disposal. This process can handle pumpable sludge that contains up to 90% solids and can recover nearly all the solvent for reuse.

Sedimentation Sedimentation, also called gravitation, is a technique in which the particles suspended in the liquid are settled out by gravity. The contaminated solvent is put into settling tanks, and after a sufficient period of time the separated liquid is drawn off from the solids that have settled to the bottom. Sedimentation is often used to remove solids from organic solvents as a preliminary purification or pre-filtration stage. This method can be particularly useful to recover cleaning solvents from painting operations.

Capital and maintenance costs are very low due to the simplicity of the equipment and low energy and expertise requirements. A disadvantage of this procedure is that finely dispersed colloidal particles tend to stay suspended in the solvent solution and cause the separation efficiency to be low. Settling times for small particles may be quite long, and large volumes or several tanks may be required to furnish a quantity through-put. To avoid loss of solvent by evaporation into the air, settling containers must have proper covers.

Decantation Decantation is a gravity separation technique used to separate liquids of different densities. A mixture of immiscible liquids is fed into a decant tank where it continuously separates. As the various liquids are separated into their respective layers, they are coalesced and with drawn. Since dirt particles can interfere with the process, they are sometimes filtered out before decantation.

Decantation is often used to remove insoluble oils from spent solvents in the dry cleaning and petroleum refining industries. Because the nonaqueous layer removed by decantation is often saturated with water, further processing to dry the recovered liquid is often necessary. An advantage to decantation is that decant tanks are simple in design and relatively compact.

Centrifugation Centrifugation is used to separate liquids and solids from the solvent through the application of centrifugal force. In sedimentation-type centrifugation, a waste stream is added into a spinning centrifuge. The

slightly denser contaminants are forced against the inner wall of the unit. Solids are removed by the continuous displacement of entering fluid or by a screw conveyor.

In filtration-type centrifugation, the inner wall of the unit is a filter. Solvent is forced through the filter and the solids are retained inside to be mechanically removed by blades that scrape the filter as the unit rotates. Like filtration gravity separation, centrifugation is used a preliminary purification step before other recycling operations.

Filtration Filtration separates suspended particles from a liquid by using a porous filter medium. Many different types of filtration can be used. The basic operational steps of each encompasses forcing a mixture of fluid and solids through a filter using gravity or other pressure. The solids are trapped by the filter and cleaned off later or disposed of with the filter.

Some of the factors for selecting filtration equipment include particle size distribution, viscosity, production throughput, process condition, performance requirements, and materials of construction. The cost of filtration equipment may vary greatly due to the wide array of equipment available.

Solvent Extraction With solvent extraction, the separation of components is achieved by mixing the waste stream with a liquid that acts as a solvent to one component but is immiscible with the other component. A basic operation consists of mixing the waste solvent and the addition

solvent and then allowing the mixture to separate into phases in a holding tank. Separation of the added solvent from the recovered solvent usually requires distillation.

## 6.2. Systems Overview

Table 6-A summarizes information collected from several solvent distillation equipment suppliers and manufacturers. The table contains a description of the systems available from each manufacturer, including a size or capacity range in gallons (most manufacturers offer a variety of sizes), a range of nominal distillation rates in gallons per hour, methods used for heating systems, required power consumption, types of solvents that can be recovered with each system, and a price range corresponding to the available size range. The table also shows the types of options and features available for the various systems. The data in Table 6-A represents only a sampling of the recycling suppliers and equipment currently on the market around the Country.

This systems summary indicates that a wide range of distillation systems with various options are available for shipyard applications. The options most likely to benefit shipyards are the vacuum attachment, which permits distillation of solvents with higher boiling points, and the water separator, since water is often present in waste solvents. Additional features can add from 10 to 30% to the base price of a typical unit, but they usually pay for themselves quickly through increased efficiency.

MANUFACTURERS	EQUIPMENT DESCRIPTION						AVAILABLE OPTIONS								
	CAPACITY RANGE (GAL)	NOMINAL DISTILLATION RATE (GPH)	TYPE OF HEATING	POWER RATING (kw)	TYPE OF SOLVENTS RECOVERED	PRICE RANGE (\$)	VACUUM ASSIST <sup>(1)</sup>	AIR COOLED	WATER COOLED	PORTABLE	HEAT RESISTANT BAG	TEFLON LINED	TRANSFER PUMP	WATER SEPARATOR	INSPECTION WINDOW
Branson Ultrasonics Corp. Danbury, CT	22-77	11-54	Electric Immersion 230V/18-60A	4-20	All	5115-10,420			✓				✓	✓	
Finish Thompson, Inc. Erie, PA	3-55	0.5-14	Electric Element 120-240V	0.8-7.8	All to 320°F	4000-28,900	✓		✓	✓	✓				✓
Hoyt Corp. Westport, MA	5-15 (others avail.)	2-5	Electric Plate 120V/11.6A- 220V/21A	1.4-4.4	All to 330°F	3815-6625	✓		✓			✓	✓		
Progressive Recovery, Inc. Columbia, IL	5-120	1-40	Thermal Oil 10,000-140,000 BTU	1.2-36	All	5000-37,000	✓		✓						
Pure-Flo Distillers, Inc. Ramona, CA	20	8-10	Thermal Oil	4.5	All	Call for Quote			✓	✓	✓				
Recycling Systems of America, Inc. Greenland, NH	3-17.5	3 Max	Electric Element 240V/12.5A	3.0	All to 500°	3500-8500	✓	✓				✓			
Recyclene Products, Inc. San Francisco, CA	15-55	10-20	Thermal Oil	1.5-9	All to 320°	10,000-35,000	✓		✓		✓			✓	
Solvent Recovery Systems, Inc. Houston, TX	5-50	1-6	Thermal Oil	1-4.5	All to 425°	4000-20,000			✓	✓	✓		✓		
Solvent Kleene, Inc. Peabody, MA	8-55	1-10	Thermal Oil	2-8	All to 400°	3300-14,250	✓		✓	✓	✓				

Table 6-A Systems Overview Summary

<sup>(1)</sup> Vacuum attachments permit higher temperature operation — usually to 500°F

Most of the systems are “off-the-shelf” and can be delivered in less than a month. Prices (1992) range from about \$3000.00 for a 3-5 gallon capacity portable unit to nearly \$37,000.00 for a 120 gallon unit. Therefore, any shipyard should be able to find a solvent recycling system on the market to meet their particular processing requirements or budget constraints.

## 7. SOLVENT RECYCLING PROGRAM AT NASSCO

This section describes the steps taken at National Steel and Shipbuilding Co. (NASSCO) to implement a program to recycle solvents used around the shipyard. The section opens with a brief description of the methods and procedures for handling solvents and managing solvent wastes that were practiced prior to the start-up of the solvent recycling program. Next is a discussion of the cost analysis performed by NASSCO to justify the purchase of a solvent distillation unit. An overview of NASSCO's pilot recycling program is then presented. The section concludes with a discussion of the results and lessons learned from the implementation of the program.

### 7.1. Previous Methods

Prior to attempting to implement any new or improved work methods, regardless of the obvious benefit, an examination and analysis of current methods is necessary. This analysis provides a baseline of comparison and validation for the changes and improvements to come. The procedures used by NASSCO to handle and process solvents and solvent wastes prior to starting a recycling program were probably not unlike those of other shipyards and industries where painting is a significant operation.

The Paint Department was assumed to be the largest solvent user in the shipyard. A solvent usage survey was conducted for all areas of the shipyard

to verify this assumption. (The form used for the analysis is shown in Figure 8-3.) Results of this survey indicate that although solvents are used in a few other areas, notably the Machine Shop, the Paint Department uses about 95% of the total volume of purchased solvents. NASSCO's past (and current) practices for handling solvents in the Paint Department are summarized in the following paragraphs.

Virgin (new) solvents are issued from stock as needed by paint personnel at various locations around the shipyard. Solvents are used in various applications such as paint reducing or thinning, surface preparation prior to painting, and equipment and hose cleaning. The amount of solvents used for the various purposes are recorded by the foremen on the form shown in Figure 7-1. This form serves as a usage record and an inventory control tool. These procedures for dispensing solvents currently remain unchanged.

The procedures for processing used solvents have been affected most by the addition of solvent recycling. Fifty-five gallon drums are used to collect and temporarily store recovered waste solvents. Solvents are recovered primarily from equipment cleaning operations, since most of the solvents used for surface cleaning volatilize and are not recoverable. Cleaning rags soaked in solvents must be collected in drums for disposal as hazardous waste. Empty drums are stored in the yard's central paint storage area and are delivered by forklift as requested.



Full drums are sent to the Reclamation Department to be processed for proper hazardous waste disposal.

In the past, there was little or no segregation of the various types of paint and solvent waste. Used cleaning solvents could have been mixed with paint solids or sludge. Also, all types of paint equipment cleaning wastes were mixed together in the same drum, including water-based, oil-based and solvent-based wastes. An attempt was made, although not always successfully, to separate solid waste, liquid waste, and solvent contaminated cleaning materials such as rags. The need for careful segregation of paint and solvent wastes would prove to be a most important element in the success of NASSCO's solvent recycling program. Sections 7.3 and 7.4 cover this issue in detail.

## 7.2. Cost and Benefit Analysis

An analysis of the projected costs and expected benefits to be derived from a solvent recycling program is probably the most critical step in starting the program. This analysis will be used as a basis for shipyard management's decision whether or not to spend the necessary capital for equipment or other start-up costs. The cost analysis is usually performed by an industrial engineer or department staff engineer, but it can be done by any qualified staff or administrative support person. There are several formats and approaches that can be followed in performing the analysis, and there is no, one "right" format. The key is to pick one that is simple, easy to follow and covers all important factors. This section describes the cost analysis

format used by NASSCO to justify the purchase of a solvent distillation unit.

Information and data collection is a prerequisite to the cost/benefit analysis. Also, certain assumptions may need to be made where hard data cannot be obtained. Background information needed for the analysis includes:

- Type and chemical composition of most commonly used cleaning solvents — information can be obtained from Manufacturer's Safety Data Sheets (MSDS) or directly from suppliers
- Past average annual (or monthly) cleaning solvent usage and projection of future use — can be obtained from Paint Department historical records and future work projection for 1-2 years
- Past and projected annual (or monthly) volume of solvent waste disposed of — available from person or department responsible for hazardous waste disposal
- Current cost per gallon to dispose of liquid and solid solvent and paint wastes — from shipyard Hazardous Materials Department or Environmental Affairs Department
- Preliminary information on specifications and purchase and operating costs for various models of solvent distillation units — obtain directly from

equipment manufacturers and suppliers (See Section 6 for equipment overview)

your Environmental Affairs Department or local agencies.

- Status of current federal, state and local environmental regulations pertaining to solvent recycling — contact

Once background data has been collected, the cost analysis can be completed. Following is a step-by-step breakdown of the analysis process used by NASSCO for this project.

**STEP 1: Determine Material Cost Savings from Reduced Need to Purchase New Solvents.**

- Average amount of cleaning solvent used per month (from records) = 375 gal/mo.
- Projected cleaning solvent usage for next year (based on work projections) = 300 gal/mo.
- Recoverable solvent (based on still operating efficiency of 80%\* and 10% loss factor) = 215 gal/mo.
- Current cost of virgin cleaning solvent = \$7.00/gal
- Monthly material cost savings = 215 gal. x \$7 = \$1505/mo.

\*NOTE: Efficiency will vary with equipment

**STEP 2: Determine Savings from Reduced Waste Disposal**

- Average amount of liquid solvent waste disposed of = 350 gal/mo
- Amount of waste from cleaning solvent = 350 x 0.8(80%) = 280 gal/mo  
(assume 20% waste from other sources)
- Current cost to dispose of liquid solvent waste = \$4.00/gal
- Monthly liquid disposal cost savings = 280 gal x \$4 = \$1120/mo.
- Amount of sludge (still bottoms) generated by still @ 80% efficiency = 280 X 0.2(20%) = 56 gal/mo.
- Current cost to dispose of still bottoms = \$6.00/gal
- Net monthly disposal cost savings = \$1120- (56 x \$6) = \$784/mo.

**STEP 3: Calculate Total Projected Cost Savings (with Solvent Recycling)**

- Add material and waste disposal savings = \$1505 + \$784 = \$2289/mo.

**STEP 4 Determine Total Cost of Proposed New Recycling System**

- Purchase price of 17.5 gal. distillation unit (including shipping) = \$8745
- Staff start-up costs (incl. Paint Dept. staff time for analysis, procedures, training and testing, and Environmental Dept. support) = \$5000



- San Diego APCD permit fee (one time) = \$1500
- Installation cost (labor and material) = \$420
- Estimated operating costs = \$0.10/gal x 215 gal/me. = \$22/me.  
(from manufacturer)

STEP 5: Calculate Investment Payback Period

- Total start-up cost = \$8745 + \$5000 + \$1500 + \$420 = \$15,665
- Net monthly savings incl. operating costs = \$2289-22 = \$2267/me.
- Divide system cost by monthly savings = \$15,665/2267 = 6.9
- Payback period = 6.9 mos.

As seen from the above analysis, NASSCO'S solvent recycling system would pay for itself in about seven months, if all assumptions were correct. Stated another way, the annual return-on-investment (ROI) for this expenditure would be about 171%. This short payback time is highly favorable from an investment standpoint and makes for an easy management decision to approve funding. Usually, payback of a capital investment in less than two years would justify the expenditure.

However, there are several factors and variables involved in the analysis, and changes in any of them can have a significant effect on the results. For example, if NASSCO'S projected solvent usage were to go down by 50% (to 150 gal/me), the payback period would double to about fourteen months. A change in the cost of solvents or hazardous waste disposal, or a decision to purchase a larger or more expensive still would change the payback period. Equipment efficiency will also impact the results of the analysis.

Other economic factors, which for simplicity were not included in the above analysis, should not be

overlooked. A detailed investment analysis would take into account the effects of state and federal income taxes, including any tax credits or incentives. Allowable depreciation expense on the newly purchased equipment would also have potential economic impact. In addition, NASSCO'S analysis includes the cost of a permit required by the local Air Pollution Control District. In many states or localities, permitting may not be required for a solvent still, so this cost would not be included. Finally, it is important to remember that NASSCO'S cost/benefit analysis is provided only as a guide, and the numbers used will not necessarily reflect the situation at any other shipyard. Any yard desiring to start up a new solvent recycling program should carefully collect and analyze their unique data.

### 7.3. NASSCO'S Pilot Program

At the onset of this project, NASSCO did not have a solvent recycling program in place, although there had been discussion and limited research on the subject for several years prior. The decision to purchase a solvent distillation unit, based on the cost

analysis described in the previous section, was made shortly before the award of this National Shipbuilding Research Program (NSRP) project. Therefore, a solvent recycling program would have been initiated regardless of NASSCO's NSRP project involvement. (Project funds were not used to purchase the distillation unit.) The timing of the project award supported a clear project approach, which was to set up a pilot recycling program at NASSCO and share the process and results with the shipbuilding industry through the NSRP.

As part of the analysis and decision making process, NASSCO surveyed and interviewed a nearby shipyard — Southwest Marine Inc. (SWM) — that had previously purchased a solvent distillation unit and established a solvent recycling program. Upon beginning this NSRP project, NASSCO also surveyed and interviewed other shipyards around the country, as well as related industries that use solvents, such as a local paint manufacturer — Proline, Inc. The information gathered in these interviews and surveys proved valuable in selecting a solvent still and in developing NASSCO'S solvent recycling program. A summary of survey results is included in Section 5.

Another early step in the process of selecting the "right" piece of equipment was in-yard production testing of candidate units. Based on data from the Paint Department's monthly use of cleaning solvents (95% of total shipyard use), a unit with capacity to process 15-20 gallons of solvent per (8 hr.) shift would adequately meet demand. Several manufacturers and distributors of solvent reclamation units were

contacted regarding the use or lease of their equipment for NASSCO'S evaluation testing. Most manufacturers did not have demonstration units available for loan, but one company was able to provide NASSCO with a 15 gallon capacity unit to use for one month of testing. This unit proved to be somewhat difficult to operate and maintain and had other undesirable features. The unit was returned after the trial period. After discussions with equipment vendors and recommendations from other users, NASSCO decided to purchase a 17.5 gallon unit from Recycling Systems of America.

The Paint Department primarily utilizes one type of solvent for paint equipment and surface cleaning. This solvent, composed mainly of the chemical xylene, amounts to about 99% of the total solvent usage. Other solvents have been phased out for economic and environmental reasons.

Standardizing the type of solvent being recycled has several advantages. The distillation system operates more efficiently than with a mixture of solvents with different boiling points. A smaller, less complex unit can usually be used to handle a single solvent type. Probably the greatest advantage to standardizing solvents for recycling is increased quality of the reclaimed product. When different solvent types are recycled in the same batch, purity of the resultant product is sacrificed. Therefore, the end product is much more useable when the solvent being recycled is standardized.

The decision of which piece of solvent reclamation equipment to buy is only the beginning of implementing a

successful shipyard solvent recycling program. In most cases the Paint Department, being the biggest solvent user, will take the lead in program start-up. Other shipyard departments must be brought into the process early to ensure cooperation and support. Careful consideration should be given as to which departments or personnel will be active participants in the program and which will just need to be kept informed. This participation may vary depending on the yard's internal organization and structure. The key departments in NASSCO'S program, other than the Paint Department, are:

- Safety
- Environmental Affairs
- Reclamation (Waste Disposal)
- Transportation
- Personnel Programs (Training)

These departments are vital to program success and must be actively involved in all phases of development and implementation. Other departments and key management personnel are kept apprised of program policies and activities through presentations and memos.

Following the purchase of a solvent still, and prior to full production operation, the development of a detailed equipment operating procedure is essential. Although any purchased piece of equipment comes with operating instructions, there is usually a need to expand and tailor these instructions to the user. In many cases the operating instructions are vague or incomplete and need to be rewritten for clarity. Even when clarity is not an issue, the instructions should be edited or modified as

necessary to meet the needs of the individual shipyard. For best results when rewriting instructions, it may be necessary to work with the equipment manufacturer. Operating procedures should also be developed in the shipyard's accepted format and widely posted or distributed to ensure all workers involved with equipment operation are informed. An example of the operating procedures for NASSCO'S solvent system is shown in Figure 7-2. Equipment operators must be trained in the proper operation of the system, including a thorough understanding of the procedures. Training is further discussed in Section 8.6.

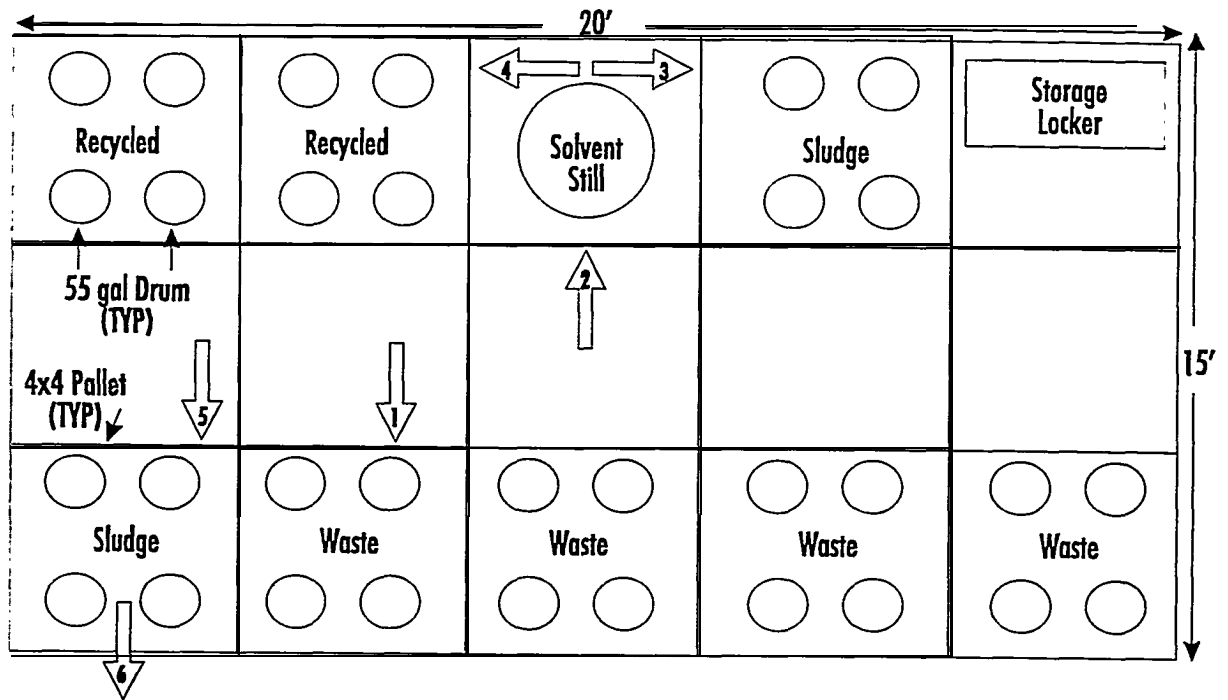
A facility layout and flow analysis is also necessary to determine the optimum location for the recycling equipment and storage drums. As part of this analysis, material movement into and out of the recycling area is studied. The most efficient locations are then designated for temporary storage of both solvent waste and recycled material, based on a projected processing volume. Figure 7-3 illustrates NASSCO'S recycling area layout and flow.

NASSCO realized from the start that one of the most important elements in a shipyard solvent recycling program is an effective yard-wide procedure for recycling. The development and implementation of this overall procedure lies at the heart of this project. This phase of the project was therefore given a significant amount of effort and attention. To be effective, the overall procedure must be comprehensive and include such areas as:

SOLVENT RECOVERY SYSTEM - SRS 8500  
OPERATING PROCEDURE

- (1) Fill out the distillation process form in full.
- (2) Follow all safety procedures when filling or emptying still.
- (3) First make sure output hose is hooked up to recovery barrel and grounded.
- (4) Make sure there is water in the water trap bucket and the hose is one half inch below the water at all times.
- (5) Make sure recovery barrel is sealed from all other openings.
- (6) Make sure condenser unit output hose is higher than barrel dumping into.
- (7) Attach ground lead to thinner waste barrel.
- (8) To fill still with waste thinner, screw regulator to smaller opening on drum. Make sure valve to regulator is off, then hook up air supply. Place safety pins on yellow hose fillings and turn on air.
- (9) Insert fitting and black syphon hose in other opening of drum. Make sure syphon hose is 2" above sludge level to avoid plugging, then insert other end in still drum. Now open valve and turn pressure to two (2) PSI and fill still.
- (10) Fill with 17 1/2 gallons maximum or to four inches from top rim of still drum.
- (11) Put syphoning equipment away.
- (12) To close, place lid with warning sign facing still, and in front of positioning pins. Turn knobs one quarter turn counter clockwise to lock in place.
- (13) Turn power switch clockwise to ON position and ensure fan turns on.
- (14) Now turn on cycle switch clockwise to ON position and ensure the yellow light is on.
- (15) If fan or light does not turn on, contact supervisor for assistance.
- (16) Distillation starts within 20 to 40 minutes and continues at a rate of 20 minutes per gallon.
- (17) After unit has been turned on, check one to two hours later for leaks in unit.
- (18) If leaks are present, correct leaks or contact supervisor for assistance.
- (19) When cycle light turns off, the still operation has been completed. Turn off cycle switch only.
- (20) Wait one half hour to allow still to cool before opening lid.
- (21) Be sure to follow the safety procedures when emptying sludge from still drum.
- (22) Open sludge disposal drum and hook up ground cable to drum.
- (23) To open lid on still, turn knobs one quarter turn clockwise and remove lid. Turn off power switch.
- (24) Place lid in a safe place in the upright position to avoid any damage to gasket.
- (25) When cleaning still, be sure to use a plastic scoop to empty sludge into sludge waste barrel. Never use any type of sharp instruments to avoid damaging teflon lining.
- (26) Clean thoroughly. (No residue should remain in still drum.)

*Figure 7-2 Sample Still Operating Procedure*



### SOLVENT RECYCLING AREA LAYOUT & FLOW

#### FLOW ARROW DEFINITIONS:

- 1 Waste Solvent (before processing)
- 2 Solvents Enter Still
- 3 Still Bottom/Sludge Collection
- 4 Recycled Solvent Collection
- 5 Sludge Storage
- 6 To Reclamation

#### NOTES:

- Projected Volume: 16 drums a month
- Maximum Processing Rate: 1 drum a day or 20 drums a month
- Waste Storage Capacity: 16-55 gallon drums

*Figure 7-3 Recycling Area Flow Diagram*

- Equipment operating procedures,
- In-process handling instructions,
- Actions required by all support departments,
- Health and safety issues,
- Environmental regulations,
- Waste disposal requirements, and
- Allowable (and unallowable) uses for recycled solvents

In effect, this procedure covers all aspects of solvent use and recycling, from original generation of waste to the final disposal of recycling by-products (still bottoms). The yard-wide procedure developed by NASSCO, included as Figure 7-4, is provided as a sample. NASSCO'S procedure is intended only as guidance to another shipyard in developing their own procedure. Each yard's procedures should be developed to address their individual circumstances.

#### 7.4. Implementation Results

The only aspect of a solvent recycling program that could be considered more important than the development of the overall procedure is the successful implementation of that procedure. Simply stated, implementation involves taking a well-developed written plan or procedure and making it work in an actual production setting. A written procedure that can't be executed is of little value. Successful implementation of a new program often proves to be the most difficult aspect. The reasons

for this difficulty are many and varied. One of the most common reasons is resistance to change and doubt on the part of the production supervision and workers who must follow the new procedures. They may be skeptical of the need for a new program or would simply like to maintain the "status quo." Therefore, in many cases the participants must be sold on the program and convinced that it is necessary and beneficial.

Another pitfall to successful implementation occurs when a program or procedure looks good on paper, but cannot work in the field due to some unforeseen obstacle. For this reason, it is important for the new program to contain a trial implementation period to "work out the bugs." During this phase, solutions can be developed for any problems encountered and the procedures modified or improved as necessary. NASSCO'S solvent recycling program included this all-important trial implementation phase.

One of the surest ways to overcome potential implementation pitfalls is through communication and teamwork. By bringing in the key players from around the shipyard early in the program, NASSCO was able to get a good start on implementation. Based on results from the first six months of the program, it appears that the selected still is working well and will meet future recycling goals. An average of almost 200 gallons per month have been reclaimed at a recovery rate of over 60%. This level of solvent recovery equates to an investment payback period of just under eight months, which is only one

**NASSCO YARD-WIDE PROCEDURE  
"SOLVENT RECYCLING FOR SHIPYARDS"**

1. Hazardous waste coordinator orders empty drum from paint storage.
2. Hazardous waste coordinator specifies whether drum is for waste water or thinner.  
DO NOT MIX WATER WITH SOLVENT.
3. Paint storage personnel will then place a hazardous waste label and color code drum for appropriate use. They will also call Transportation Department to deliver drum as requested.
4. The hazardous waste area coordinator will set up drum on a containment pallet and fill out label. He will also place a MSDS label on drum. (Solid topped pallets may not be used to store liquids.)
5. Coordinator will then attach a ground wire to drum.
6. All drums will remain in location until they are filled.
7. When drum is filled, the coordinator will call the Transportation Department to have drum delivered to the distillation area. (No liquid waste solvent drums shall be sent to the Reclamation Department for disposal.)
8. The still operator will then mark arrival date on drum.
9. Drums have 30 days from date of arrival at distillation area to be processed. Objective is to prioritize waste solvent and reclaim prior to 30 day limit. If 30 days will be exceeded, contact supervisor in charge and he will sign release to Reclamation Department.
10. Within the 30 day limit the solvent recovery system SRS-8500 operating procedures "will be administered.
11. The waste solvent will then be distilled and the results recorded on a process log form.
12. All sludge remaining in waste solvent drum and sludge from still bottom will be sent to Reclamation Department for proper disposal.
13. Call paint storage for issue of tinted recycled solvent. The tinted solvent will be issued in a five gallon can painted white to distinguish from other solvents issued in the department.
14. Tinted solvent will be used only for paint equipment cleaning or surface cleaning (SP-1 ), for paint reducing.
15. After using recycled solvent, it will be reclaimed through the same procedure.
16. Reclamation Department shall not dispose of any solvent drums until a yellow NASSCO Material Reclamation ticket has been filled out and signed by G. Nugent or L Parra.

***Figure 7-4 Sample Yard-Wide Recycling Procedure***

month longer than projected in the economic analysis described in Section 7.2. As procedures are fine-tuned and still operation becomes more efficient, the recovery rate is expected to approach 80%. Figure 8-1 in Section 8 shows NASSCO'S break-even analysis using an 8070 recovery rate.

Table 7-A shows the process log form used by NASSCO to record and track solvent consumption before and after recycling. The last section of this log is used to track the solvents processed through the distillation unit. The actual recovery rate or efficiency of the system can be calculated by dividing the amount of solvent reclaimed (Column 16) by the amount processed (column 15). For example, if 300 gallons of waste solvents had been processed in a month, resulting in 225 gallons of reusable solvent, the recovery rate would be 75%. The remaining 75 gallons of dry sludge (still bottoms) would be disposed of as hazardous waste. The log format also allows the shipyard to determine the quantity and percentage of solvent being used for different purposes: paint reducing (Col. 10), equipment cleaning (Col. 12), and surface cleaning (Col. 13). The use of a solvent process log such as NASSCO'S is recommended for any shipyard involved in solvent recycling.

Hopefully, sharing the lessons learned from the trial implementation phase will benefit another shipyard contemplating a similar program. The results and lessons learned from the start-up of NASSCO'S program are summarized as follows:

- There is a natural tendency to resist change. New procedures should be explained and "sold" to all involved.
- Make sure that the right people — those actually doing the job — are informed of and understand the new procedures.
- Water contamination of waste solvents will seriously reduce efficiency of the solvent still. Also, water contamination will cause some solvents to become acidic and no longer recyclable. Water and latex paint waste must be kept out of waste solvent containers and they should be protected from the weather.
- Recovery rate is a function of the concentration of solids in the solvent waste. Most stills work best with low-solids waste.
- Proper identification of drums used for recycling is important to keep waste streams separated. Clearly mark separate drums for each type of solvent waste, water-based paint waste, sludge, rags and clean recycled solvent.
- Environmental regulations limit the time that waste solvents can be stored prior to recycling to 90 days. (Longer storage would trigger the requirement for a RCRA permit or necessitate disposal.)





Program procedures must adequately address this time constraint to ensure that all solvent can be recycled. (NASSCO has set an internal storage limit of 30 days prior to recycling.)

- For a successful program, reclaimed solvents must be fully utilized. Workers and foremen need to know (1) that reclaimed solvents are available and should be used, (2) the appropriate uses for reclaimed solvents (cleaning vs. thinning), and (3) how to request and obtain reclaimed solvents from stock.
- Monitor the program frequently to ensure that procedures continue to be followed. Over time, new workers may enter the picture and they need to be educated.

## 8. PROPOSED SHIPYARD SOLVENT RECYCLING PROGRAM

As previously stated, the primary objective of this project is to define the requirements necessary to implement an effective shipyard solvent recycling program. This section summarizes the elements necessary for such a program. Although largely based on NASSCO'S experience, the proposal is intended to be generic and easily adaptable to another shipyard's needs. Information gained through interviews and surveys of shipyards and related industries was also used to develop the proposed program.

The section begins with a discussion of the economic and environmental factors that should be considered when planning a solvent recycling program. Next are recommendations for starting a yard-wide solvent recycling program. A discussion of equipment selection criteria is then presented. Recommended uses for reclaimed solvents are described next. The section concludes with a discussion of the importance of education and training to a successful program.

### 8.1. Economic Considerations

As discussed in Section 3.1., there are economic benefits to be gained from a solvent recycling program. These cost savings are the primary motivator for most shipyards to begin recycling solvents on site. The degree of savings is dependent mainly on the volume of waste solvents generated — large solvent volume means large savings. The volume of waste solvent generated will also dictate whether on-site or off-

site recycling is the better economic option.

If an investment in on-site recycling equipment cannot be cost justified due to insufficient volume, off-site recycling may be preferable. Some commercial recycling facilities charge a minimal fee or accept waste solvents at no charge based on the type and volume of waste received. The value of a solvent waste to a commercial recycler depends on the type, market value, purity (quality), and quantity of waste generated. Other factors include how often the waste is produced and the distance between the generating facility and the recycling facility.

A commonly practiced arrangement between generator and recycler is batch tolling. In a batch tolling arrangement, the commercial recycler accepts solvent waste from a generator, distills or otherwise reclaims the solvent, and resells the recovered product to the original generator for reuse. Batch tolling is attractive if the price of reclaimed solvent is less than the equivalent grade of virgin solvent.

Section 7.2 presented a sample cost analysis format for evaluating the economic feasibility of on-site solvent recycling. This analysis is used to calculate the potential payback period and the annual return-on-investment for a recycling system. As can be seen, the cost of a particular distillation unit is the primary factor in determining the length of the payback period. Although purchasing a less expensive unit would result in a shorter payback,

consideration should be given to spending a bit more up front to get a better quality unit. The long term advantages of this decision should outweigh the short term reduction in savings.

Another type of cost analysis useful for determining the feasibility of starting an on-site recycling program is a "break-even" analysis. This analysis is a fairly simple method to calculate the monthly volume of waste solvents that would be needed to justify the cost of a particular solvent recycling system. The break-even method is basically a graphic version of the cost/benefit analysis, and uses the same background data. In some cases, this method may be easier to understand, particularly in a presentation format. Figure 8-1 shows a break-even analysis using the data from NASSCO'S sample cost/benefit analysis in Section 7.2.

## 8.2. Environmental Considerations

Environmental factors go hand-in-hand with economic factors in making a decision to implement a shipyard solvent recycling program. A solvent recycling program can form the cornerstone of an overall shipyard hazardous waste minimization program. Usually solvents are the most wide-spread and most frequently used toxic substances in the shipyard. Solvents are also highly regulated by federal and most state environmental agencies. Therefore, from an environmental perspective, the evaluation of solvent recycling as an alternative to disposal should receive top priority. Section 3.2 highlighted the environmental benefits of solvent recycling and Section 4 discussed

many of the related environmental issues and regulations. Section 3.3 also discussed some viable environmental alternatives to solvent recycling.

Recycling solvents is unquestionably an environmentally sound practice once waste solvents have been generated. However, the clear first choice in the environmental hierarchy of hazardous waste minimization is source reduction. Reducing solvent use will naturally reduce solvent waste and the need for disposal. It is important to recognize that if a shipyard decides to invest in a solvent recycling system, and later begins an aggressive source reduction program, the annual cost savings derived from recycling will be diminished. As solvent use is reduced, so is the amount of solvent waste available for recycling. Since the cost benefit from recycling is dependent on the volume of solvent recycled, a reduced economic benefit would result.

In an extreme case, the near elimination of the use of recyclable cleaning solvents would render the solvent recycling system obsolete. For most shipyards, however, the probability of completely eliminating the use of cleaning solvents in the near future is slim. Recycling can be seen as an interim measure until alternatives are found. Therefore, a combination of recycling and solvent source reduction where possible appears to be the most practical environmental approach — at least for the near future.

## SOLVENT RECYCLING BREAK EVEN ANALYSIS

GALLONS RECYCLED PER MONTH @ 80% RECOVERY  
BREAK EVEN IN FIRST YEAR AT \$15,665 IN MONTH 7

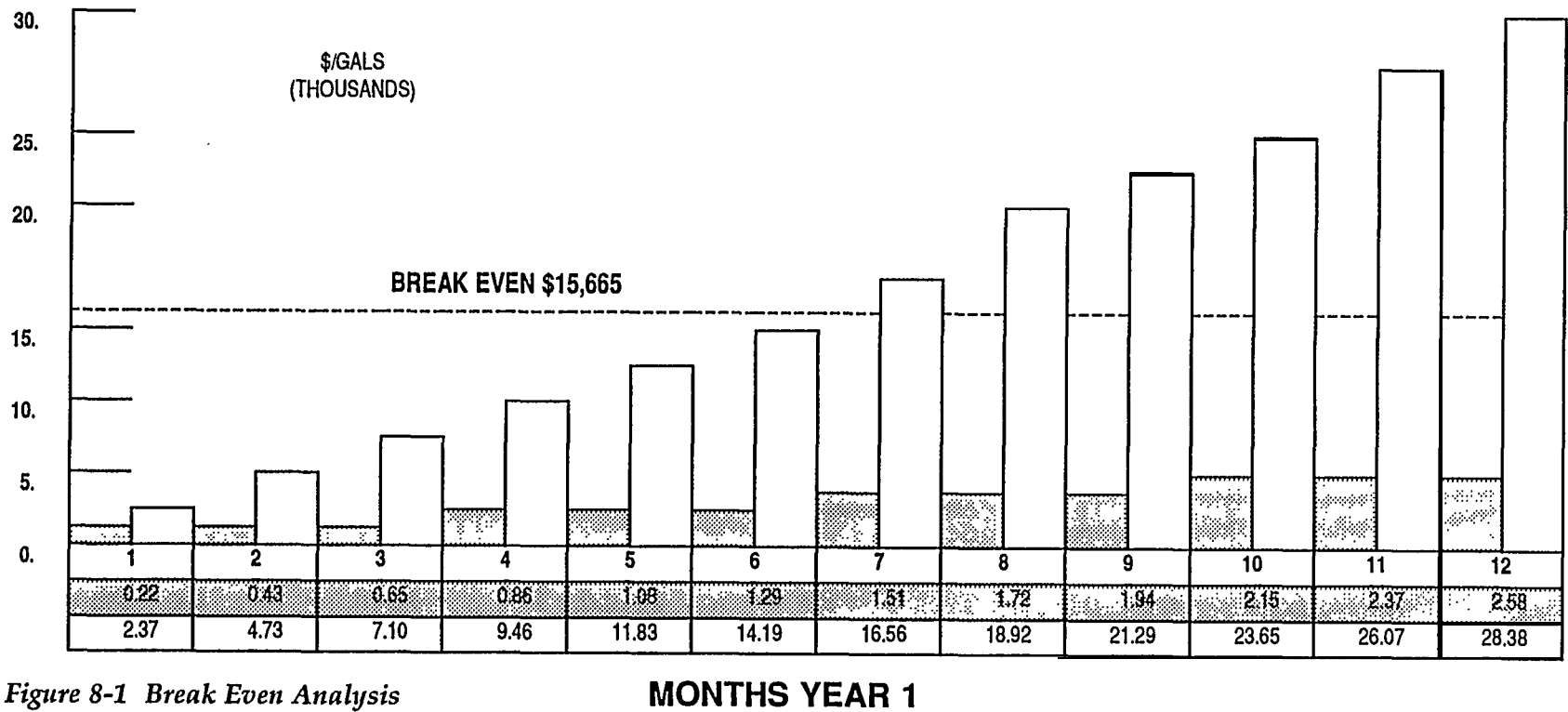


Figure 8-1 Break Even Analysis

**GALLONS CUM**

### NOTES:

SAVINGS/GALLON: \$7.00 NEW SOLVENT + \$4.00 DISPOSAL SAVINGS = \$11.00/GALLON.  
ANALYSIS ASSUMES 215 GALS RECOVERED/MO.  
TOTAL START-UP COSTS: \$15,665

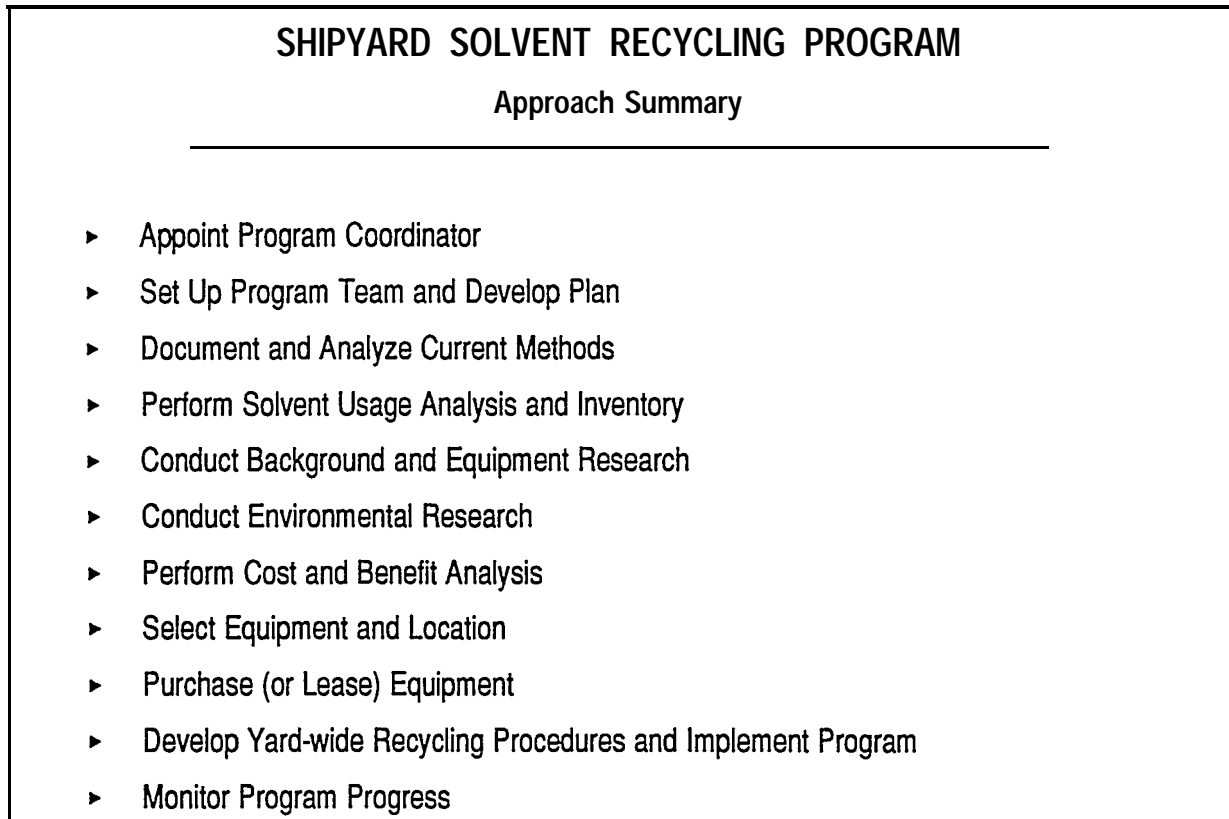
### 8.3. Setting Up the Program

This section outlines and summarizes a recommended approach to setting up a shipyard solvent recycling program. This approach is based on NASSCO'S experience as discussed in Section 7, as well as input obtained from surveys of other shipyards. The format is intended to be generic and easily adaptable to any shipyard's operations. The approach steps are listed in recommended priority order and each is followed by a brief discussion. A summary of the approach is included as Figure 8-2.

1. Selection of a program or project coordinator. In some cases, upper management may mandate the investigation of solvent recycling and

request a department or an individual to head the project. In other situations, the primary user department (typically the Paint Department) will take the initiative to begin recycling and recruit a staff engineer or other individual within the department to coordinate. In either case, the selected coordinator should have proven project management skills.

2. Development of the program plan and schedule. In this step, the program coordinator will form a project team by identifying other key departments and participants necessary to the success of the program. The team then agrees upon a preliminary working plan and time schedule to set up the program. This phase also includes a determination of who in the



**Figure 8-2 Approach to Solvent Recycling**

organization should be kept informed of program activities.

**3. Solvent usage survey and inventory.**

An important early step in the program is a quantitative analysis of solvent use throughout the shipyard. A survey is conducted to determine the types, quantities and locations of all solvents currently in use, as well as waste handling procedures. Survey results can be recorded on a form similar to NASSCO'S as shown in Figure 8-3. This data also forms the basis for the cost analysis described in Step 7.

**4. Documentation of current methods.**

Following the inventory, an examination of current work methods relative to solvent use is necessary before starting a recycling program. A study of current methods can reveal problem areas and help determine the best course of action for the new program.

**5. Background research.** To be effective, the project team must become knowledgeable regarding the solvent recycling process, as well as the basics and operation of available recycling systems. This information can best be obtained through phone contacts, surveys or visits from equipment vendors, manufacturer's representatives or systems engineers. Vendors will sometimes loan their equipment for a trial demonstration period.

**6. Environmental research.** Information is needed on all environmental aspects of solvent recycling. This includes waste minimization options; potential safe alternatives to solvents; federal, state and local regulations relative to solvent recycling; and permitting requirements and fees. The company's Environmental Department

and local regulatory agencies are good sources of information.

**7. Cost and benefit analysis.** The economic analysis to determine projected costs and expected benefits from solvent recycling is a critical step in the program. The results of this process are used to justify the capital expenditure required for an on-site recycling program. If on-site recycling cannot be economically justified, off-site recycling is the next best option. A sample analysis is provided in Section 7.2.

**8. Equipment and site selection.** Following the economic justification of on-site recycling, the appropriate recycling equipment must be selected. Also, thought should be given to the optimum location for the equipment with respect to facilities and material flow. Equipment selection is further discussed in the next section.

**9. System purchase and installation.** In some cases, leasing a solvent recycling system may be more advantageous than purchasing, particularly if an evaluation period is necessary. Once the system is installed, a permit should be obtained, if required. Detailed equipment operating procedures should be developed and published, and operators fully trained, prior to production start up.

**10. Development of yard-wide procedures and program implementation.**

The key element in a successful shipyard solvent recycling program is the development of comprehensive, yard-wide procedures for recycling. These procedures serve as a working reference document for the ongoing program. Procedures must obviously be tailored to each shipyard's needs.





The project team can then implement the program by encouraging the up-front involvement of shipyard personnel in the education and training process.

11. Monitoring program progress. Once program implementation has begun, monitoring progress is important to continued program success. The project team or program coordinator should periodically check to ensure that procedures are working as intended and the program is on-track. If problem areas are found, procedural or other program modifications may be required. Also, feedback to workers on the ongoing economic success of the program will strengthen participation.

#### 8.4. Equipment Selection

Selection of the "right" piece of equipment for solvent recycling is obviously important to the success of a shipyard program. As shown in Section 6, a wide variety of solvent distillation equipment is available from various vendors around the country. The choices include a range of sizes as well as operating features and options.

Proper equipment selection must be based on an analysis of the present and future needs of an individual shipyard. Factors to be considered in the analysis include:

What is the shipyard's current level of cleaning solvent usage?

Are there any anticipated changes to solvent usages in the future?

What type or types of solvents will be recycled?

Will the unit be utilized by more than one department or area?

Which operating features are truly necessary, rather than nice to have?

How important is full or partial automation?

Does the shipyard plan to initiate an aggressive source reduction program?

Answering questions like these will assist the yard in determining the best unit size and options for their needs.

Not all shipyards have the same solvents and solvent flows. Equipment selection must be based on a yard's particular solvent usage patterns. Also, solvent usage in all areas of the shipyard should be considered when selecting recycling equipment. Usually, the Paint Department is the primary user of solvents, but the Machine Shop or other shops may also use significant quantities of cleaning solvents:

Painting operations in some yards may be decentralized and spread out in various areas around the yard. In these cases, a determination must be made whether centralized or decentralized solvent recycling is more cost effective. With centralized recycling, used solvents are transported from different areas of the yard to a central location for processing with one distillation unit. If decentralization is chosen, two or more smaller recycling systems would be set up close to the

areas of high solvent use. This approach may prove more efficient for recycling several different types of solvents, since each system could process a specific solvent type.

Discussions with recycling equipment manufacturers and vendors can provide valuable input to proper equipment selection. Manufacturers representatives will gladly provide data, literature and recommendations for the models they sell. However, any information from manufacturers should be taken with the understanding that they are obviously trying to push their own equipment. Distributors that handle a wide range of manufacturer's products would be more likely to give objective and unbiased recommendations.

Some vendors will provide demonstration units for a short evaluation period with the hope that the unit will then be purchased. The shipyard will usually need to cover this transaction with a demo (no cost) purchase order, and a certificate of insurance may be required from the vendor. Leasing with an option to buy should also be considered. If cost effective, this method permits a trial evaluation without a commitment. Another good potential source of information is other shipyards and businesses that have set up solvent recycling systems.

Section 6 presents an overview and summary of features for various types of solvent recycling systems on the market. Once the required unit size and desired options are determined, the data in Section 6 can be used to help select a unit to meet the shipyard's needs. While this list may

not be all-inclusive, it certainly provides a good starting point. An equipment vendor contact list is also included in Appendix B.

#### 8.5. Uses for Reclaimed Solvents

Recycled solvents have several potential uses, depending primarily on the quality and purity of the solvent. Solvent use and recycling procedures in the shipyard will usually determine the ultimate quality of the recycled product. For example, blending different types of waste solvents (having similar boiling points) prior to distillation will result in a recycled solvent of questionable purity. If, on the other hand, the shipyard has a policy of using a standard solvent type for all paint applications, purity of the recycled solvent will be much higher.

In certain cases, high quality reclaimed solvents may be suitable for use as a paint thinner or reducing agent. However, paint manufacturers are understandably reluctant to approve the use of reclaimed solvents in their paints, since even the purest reclaimed solvents will contain a certain amount of contamination. Using reclaimed solvents as thinners without approval of the paint manufacturer could void the coating warranty. If a shipyard wishes to use reclaimed solvents for paint thinning, purity testing should be performed by an independent laboratory. The test results should then be sent to the paint manufacturer for approval. This is the only viable procedure for using reclaimed solvents as thinners. Due to the complex process and potential risks, this method of use for reclaimed solvents is not recommended.

When complete solvent standardization is not feasible, the next best approach is waste segregation. Segregating solvent wastes is important in improving the recyclability of the solvent. If several types of solvents are used in the shipyard, solvent waste should be segregated to the maximum extent possible. The individual solvent types can then be distilled in separate batches to maintain maximum purity. Where large enough quantities of waste solvents are generated, more than one distillation unit may be justified to process the different solvents. Maintaining the highest solvent quality possible when recycling is critical since low quality solvent may become unusable, requiring disposal as a hazardous waste.

The most common uses for reclaimed solvents of varying or unknown purity are in paint equipment cleaning and surface preparation prior to painting. The only requirement for solvent used for these purposes is that it be effective for the job. Solvent surface cleaning (SP-1) removes oil, grease, smoke or other contaminants from hull sections or fabricated parts prior to painting. However, the practice of surface cleaning with solvents is being phased out in many shipyards where possible to reduce air pollution caused by solvent VOC emissions. Also, solvent-soaked rags are considered hazardous waste, and must be disposed of accordingly. Non-toxic surface cleaners are available as alternatives to solvent cleaning.

Typical equipment types that can be effectively cleaned with recycled solvents include

brushes  
rollers

spray guns  
paint hoses  
pumps and pots

Any paint tools or equipment that was previously cleaned with virgin solvents can be cleaned with recycled solvents.

In general, a relatively pure reclaimed solvent can be recycled many times before it would be rendered ineffective for equipment cleaning. Paint personnel familiar with equipment cleaning will know when a reclaimed solvent has lost its effectiveness. Solvents no longer useable for cleaning are discarded as hazardous waste. As previously mentioned, maintaining recycled solvent purity by waste segregation will ensure maximum reuse potential. Also, to avoid contamination, water-based and solvent-based paint equipment should be kept separated.

As part of the project research, NASSCO decided to test the effectiveness of reclaimed solvents for surface and equipment cleaning in actual production use. The test was set up as a "blind" comparison of reclaimed and virgin solvents. To conduct the test, batches of new and reclaimed solvents were dyed separate colors using food coloring. Both batches were sent out into the field to be used for general surface cleaning and paint equipment cleaning. Workers using the solvents were asked to compare and evaluate the cleaning effectiveness of the two unidentified samples. Each sample was rated on a scale of 1 to 5, with 1 indicating poor performance and 5 excellent performance. A sample evaluation form used to record the test results is shown in Figure 8-4.

## RECYCLED SOLVENT EVALUATION FORM

Area: \_\_\_\_\_ Batch: \_\_\_\_\_ Test: \_\_\_\_\_

By: \_\_\_\_\_ Delivered Date: \_\_\_\_\_

Complete Date: \_\_\_\_\_

TYPE APPLICATION	SAMPLE 1	SAMPLE 2	SAMPLE 3
<b>SP-1 (Surface Preparation)</b>			
A. Oil			
B. Grease			
C. Smoke			
D. Other			
<b>Equipment Cleaning</b>			
A. Brushes			
B. Paint Hoses			
C. Pumps & Pots			
D. Spray Guns			
E. Other			
Rating 1-5 1 = Poor 5 = Excellent Comments: _____ _____ _____ _____ _____			

*Figure 8-4 Recycled Solvent Evaluation Form*

The results of this test, although somewhat arbitrary, indicate that the recycled solvents were equal in cleaning effectiveness to new solvents. This result was to be expected, since NASSCO has virtually standardized the type of cleaning solvent being used. The recycled solvent is nearly equal in chemical composition to the virgin material and should be nearly equal in performance. Had NASSCO's policy been to mix various waste solvent types prior to recycling, the test results might have been different.

Probably the most significant aspect of this test was to eliminate possible worker prejudice against using reclaimed solvents. Had the test never been run, some workers might have doubted the effectiveness of reclaimed solvents. This doubt would have resulted in resistance to their use. However, since the workers participated in the test and witnessed the positive results, they are now staunch supporters of solvent recycling.

## 8.6. Education and Training

For a shipyard solvent recycling program to succeed, up-front involvement and participation of key personnel is essential. This involvement will provide the basis for a strong education and training element. This all-important aspect of any new program is sometimes overlooked or not fully emphasized. Although a new recycling program can usually be sold initially on the basis of economic advantages, education and training must be included to ensure the long term success of the program. Shipyard management and other

departments important to the program must be educated and informed, while personnel directly involved in equipment operation and program procedures must be properly trained.

The education process begins at the very early stages of the program. The person or department responsible for coordinating the program must first become informed as necessary regarding the various aspects of solvent waste handling and solvent recycling. The coordinator must then take the lead to educate and encourage participation from other members of the project team.

As the initial research and cost analysis progresses, shipyard management must be informed and educated as to program status and the results of the analyses. This information will be used by management to make a decision on whether to approve the capital expenditure required for an on-site recycling system. Other departments key to the recycling effort should also be educated regarding recycling in general, as well as the shipyard procedures developed by the program team to implement solvent recycling.

Following the selection and purchase of a solvent recycling system, the program coordinator or project team will need to develop a comprehensive training program for the recycling equipment operators. This training should include specialized written or verbal instruction as well as hands-on training. The extent of training required will depend on size and features of the equipment selected.

In most cases the equipment vendor will, upon request, provide a representative to conduct or assist with operator training. Basic equipment maintenance and repair is a necessary element of the training program. Also the training should include some type of operator assessment to ensure proficiency prior to full production operation.

Early participation and training are also important for shipyard personnel that will be directly involved in implementing the yard-wide recycling procedures. Since these procedures include the transportation, storage and handling of solvents before and after recycling, participants must be knowledgeable of the shipyard's environmental and safety policies for handling hazardous material and hazardous waste, as well as the overall recycling procedures. The need for formal training sessions will in large part depend on how involved the key players have been in the program formation.

When formal training is required, a recommended method is to set up a classroom-style training session led by the program coordinator or a qualified training instructor. The session would include an overview of the new recycling program and the specific requirements of each department. Yard-wide procedures and responsibilities would be discussed and any questions addressed. The length of the session would depend on the complexity of the individual yard's program and procedures, but sessions shorter than four hours are usually most effective. This type of training and communication session will go a long way in assuring the success of the new recycling program.

## 9. SUMMARY AND CONCLUSIONS

The shipbuilding industry utilizes significant volumes of various types of solvents in day-to-day operations, especially in surface preparation and coating activities. This solvent usage results in the generation of large volumes of hazardous solvent waste. Problems associated with the use and disposal of solvents include:

High initial purchase cost for virgin solvents

Increasing costs for hazardous waste disposal

Health and safety issues relative to handling hazardous materials

Environmental regulatory and liability issues

Environmental considerations, as well as economic benefits, will be a driving force in the decision to recycle solvents. Solvents are usually the most frequently used toxic and hazardous substances in the shipyard. Solvents are also highly regulated by the Environmental Protection Agency and most state agencies. Hazardous waste minimization and "cradle-to-grave" generator liability for waste are mandated under the Resource Conservation and Recovery Act and the Hazardous and Solid Waste Amendments. An on-site solvent recycling program can reduce generator liability and simplify regulatory compliance requirements.

Solvent recycling has proven to be a simple and cost effective method to reduce the requirement to purchase new solvents, as well as reduce the volume of waste solvents for disposal. Recycling equipment utilizing the distillation technique to recover spent solvents is readily available around the country, relatively inexpensive to purchase and maintain, and in use by many industries. On-site solvent recycling can be cost justified for shipyards that generate as little as 200 gallons of waste solvents monthly. When on-site recycling is not economically feasible, off-site solvent recycling is usually available as an alternative to disposal.

Project research included surveys of shipyards and other industries that use solvents and solvent recycling equipment. Of the ten shipyards that responded to the survey, five were recycling solvents or evaluating recycling equipment. Small capacity (less than 55 gallon) distillation units (stills) were typically used. All yards use reclaimed solvents internally for equipment and surface preparation cleaning (SP-1). The survey results verify shipyard applicability for solvent recycling by the distillation method.

Equipment manufacturers and distributors were also surveyed to determine the types and costs of typical systems on the market. This survey confirmed that a broad selection of distillation equipment is available to meet shipyard needs.

Various sizes and features are available, and costs range from about \$3000 for a 5 gallon capacity unit to \$37,000 for a 120 gallon unit.

Starting a pilot solvent recycling program at NASSCO was an important phase of this project. The information and lessons learned from NASSCO'S experience formed the basis for a proposed generic shipyard recycling program. NASSCO'S program, coordinated by the Paint Department, began with preliminary planning and data gathering. Next, a cost and benefit analysis was performed to establish the economic feasibility of the program. A solvent distillation system was then selected and purchased. Finally, yard-wide procedures for solvent handling and recycling were developed and implemented. The new procedures were monitored closely over a period of months to ensure successful implementation.

Through teamwork, communication and persistence, NASSCO'S program has been successful. The payback period for the initial start-up investment is projected to be less than eight months and virgin solvent purchases have been significantly reduced. Also, there has been a nearly 60% reduction in the volume of hazardous solvent waste disposal. After recouping start-up costs, NASSCO expects to save at least \$40,000.00 annually with the recycling program.

This project has focused on the requirements and procedures necessary to successfully implement a shipyard solvent recycling program. Implementation of any new shipyard program, and solvent recycling is no exception,

often proves to be a challenge. The key elements for an effective program can be summarized as follows:

Follow the approach outlined in Section 8 to set up the program.

Keep any formalized procedures simple and easy to follow.

Continually communicate with all personnel and departments involved in the program.

Standardize or segregate solvents whenever possible.

Work with equipment suppliers to select the 'right' system for your shipyard.

Monitor program progress and modify procedures as required.



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APPENDIX A  
INDUSTRY SURVEY FORMS



TANK \_\_\_\_\_ Bag                      \_\_\_\_\_ Teflon Lined                      \_\_\_\_\_ S t a i n l e s s  
                         \_\_\_\_\_ A l u m i n i u m                      \_\_\_\_\_ Other

Physical Dimensions: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(3) General Comments:

a. Ease of cleaning: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

b. \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(4) Problems: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Figure A-1 Sample Suroey Form**

## TELEPHONE FOLLOW-UP SURVEY

Project:	Date:
Contact Data:	
Name	Title:
Company:	Time:
Telephone:	Fax:
Subject: _____ _____	

**QUESTION 1:** Do you use multiple solvents in the still at the same time?

**RESPONSE 1:** \_\_\_\_\_

**QUESTION 2:** Do you separate by type of paint?

**RESPONSE 2:** A . E p o x y      B. Enamel \_\_\_\_\_ C. Latex \_\_\_\_\_ D . N O

**QUESTION 3:** Have you found a minimum break even value? If so, what is it?

**RESPONSE 3:** \_\_\_\_\_  
\_\_\_\_\_

**QUESTION 4:** What is your disposal cost for sludge?

**RESPONSE 4:** \_\_\_\_\_

**QUESTION 5:** Do you re-use solvent or sell distilled product?

**RESPONSE 5:** \_\_\_\_\_

**QUESTION 6:** For which of these operations do you use reclaimed solvents:

**RESPONSE 6:** S P - 1      Equipment Cleaning Paint Reducing N o n e

**QUESTION 7:** Are reclaimed solvents used anywhere else in the yard? If so, what other tasks are they used for?

**RESPONSE7:** \_\_\_\_\_  
\_\_\_\_\_

**QUESTION 8:** Do you have a set recycling procedure that I could review for the NSRP project?

**RESPONSE 8:** \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Figure A-2 *Sample Follow-Up Form*

## APPENDIX B

### EQUIPMENT MANUFACTURERS CONTACT LIST

NAME	ADDRESS	PHONE/FAX
Baron-Blakeslee, Inc.	2001 N. Janice Ave. Melrose Park, IL 60160	(708)338-0571
Branson Ultrasonics Corp.	41 Eagle Rd. P.O. Box 1961 Danbury, CT 06813-1961	(203)796-0400/ (203)796-0320
Finish Thompson, Inc.	921 Greengarden Rd. Erie, PA 16501-1591	(814)455-4478/ (814)455-8518
Hoyt Corporation	Forge Road Westport, MA 02790-0217	(800)343-9411/ (508)636-2088
Progressive Recovery, Inc.	1020 N. Main St. Columbia, IL 62236	(618)281-7196/ (618)281-7930
Pure-Flo Distillers, Int.	16619 Wikiup Rd. P.O. Box 1470 Ramona, CA 92065	(619)788-0248/ (619)788-0351
Recycling Systems of America, Inc.	#9 Autumn Pond Ind. Park P.O. Box 358 Greenland, NH 03840	(603)430-9343/ (603)427-2045

Recyclene Products, Inc.	405 Eccles Ave. So. San Francisco, CA 94080	(800)451-0075
Solvent Recovery Systems, Inc.	14335 W. Interdrive "A" Houston, TX 77032	(800)367-5773/ (713)449-8872
Solvent Kleene, Inc.	131 Lynnfield St. Peabody, MA 01980	(508)531-2279/ (508)532-9304
Unique industries, Inc.	11544 Sheldon St. Sun Valley, CA 91353	(818)767-5229

#### **OTHER CONTACTS**

National Association of Recycling industries	330 Madison Ave. New York, NY 10017	(212)867-7330
National Association of Solvent Recyclers	1406 Third National Bldg. Dayton, OH 45402	(513)223-0419

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